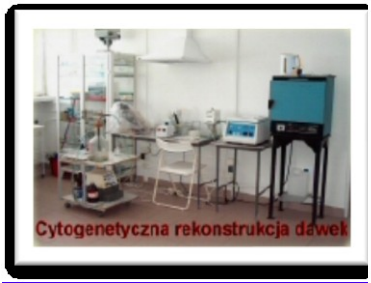
CENTRAL LABORATORY FOR RADIOLOGICAL PROTECTION

CLOR REPORT
RESEARCH AND OPERATIONAL ACTIVITIES

2004-2005



WARSAW KONWALIOWA 7

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A short description of CLOR

Creation

Central Laboratory for Radiological Protection (CLOR) was created in 1957 by a decree of Prime Minister with functions concerning the protection of state from radiation hazards. Until 2001 CLOR was under the authority of the National Atomic Energy Agency, and from August 2001 is under the authority of the Ministry of Economy.

Status

We are research center with altmost 50 years tradition and our statutory responsibility 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.

Fields of activity

Our duties comprise of:

- monitoring of radioactive contamination in foodstuffs and environmental components,
- around-the-clock radiological emergency service assistance,
- support the countermeasures against illegal trafficking in nuclear and radioactive materials,
- monitoring of personal radiation doses,
- calibration and attestation of radiation measurement instruments,
- research on matters dealing with radiation, radiation protection, radiobiology and radioecology,
- professional training in radiation protection.

Expertise and research

CLOR offers high quality services which are based on its expertise in radiological protection and which are backed up by continual research and development. Our customers include major corporations, industrial organizations, hospitals, universities and local authorities. Our staffs have a wide range of practical experiences in the measurements of radiation both in the workplace and environment.

Main lines of development

- Optimizing support missions for public authorities.
- Reworking its research process in consultation with its main partners.
- Opening up its expertise to take the expectations of society into account.
- Developing the European and international dimension.

2004 budget

Receipts of 254 M€, expenditure of 276 M€,
of which 16 M€ went into investments.

Staff

CLOR employs about 40 specialists –
engineers, researchers, physicians, and technicians, experts competent in radiation protection and 18 management, assist and administrative personnel.

SCIENTIFIC COUNCIL

Chairman

Prof. Dr hab. Zbigniew Jaworowski

Vice Chairmen

Prof. Dr hab. Barbara Gwiazdowska
Mgr Wojciech Muszyński

Members

Dr Wojciech Bulski
Prof. dr hab. Stanisław Chibowski
Mgr inż. Hanna Dzikiewicz-Sapiecha
Mgr inż. Krzysztof Isajenko
Prof. dr hab. Marek Janiak
Dr Maria Kowalska
Dr Ludwika Kownacka
Prof. dr hab. Stefan Kozłowski
Dr Paweł Krajewski
Prof. dr hab. Kazimierz Lebecki
Dr Melania Pogorzelska
Dr Lidia Rosiak
Prof. dr hab. Sławomir Sterliński

Secretary
Mgr Małgorzata Bogusz

SPECIAL LABORATORY FACILITIES

CLOR undertakes wide activity of maintenance of high quality service in a frame of calibration of radiometric devices, standardization and control and possess unique laboratory equipment to test measurement devices.

Moreover CLOR radiochemical units is developing and implementing new metedology for determining low level natural occurring radioizotopes in environmental samples.

SECONDARY STANDARD DOSIMETRY LABORATORY FOR RADIATION PROTECTION

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 - organized and documented teamwork. The reference radiation qualities in SSDL comply with the PN-ISO 4037-1 Standard. In addition preliminary work has been done to prepare production of few high air-kerma spectra as a new tool for the laboratory.

THE RADON CALIBRATION CHAMBER

CLOR operates a walk-in radon/aerosol chamber with ante-room (shown on the left) 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.12.37m3 and the surface-to-volume ratio of ca. 2.6 m-1. Climatic condition: temperature and relative humidity may be controlled manually or automatically.

AEROSOL SAMPLING STATIONS ASS-500

ASS-500 is designed for ultra-sensitive monitoring of radioactive air contamination both in normal and emergency situations. Sampling can be performed in various atmospheric conditions: temperature, pressure, humidity as well as dust air. Low limit of detection for Cs-137 is about 0.5 µBq/m3

CYTOGENETIC BIODOSIMETRY LABORATORY

In the years 2002-2003, 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. 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.

RADIOACTIVE IODINE LABORATORY

In 1997, Central Laboratory for Radiological Protection set up a programme "The Laboratory for monitoring of radioiodine in thyroid for population in emergency situation". It has been mainly foreseen for fast screening population in radiological emergency situation, or for monitoring occupationally exposed people far away from Laboratory. 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.

LABORATORY OF PERSONAL DOSES AND ENVIRONMENTAL DOSES

Since 45 years the Laboratory of Personal Doses and Environmental Doses in CLOR has been carried out monitoring 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. The detectors enable the dose range of 0,1 mSv do 2 Sv for personal effective doses Hp(10) and Hp(0,07). Monitoring of fast neutrons was performed by means of the Kodak NTA nuclear emulsion. The detection limit of monitoring system was 0,4 mSv

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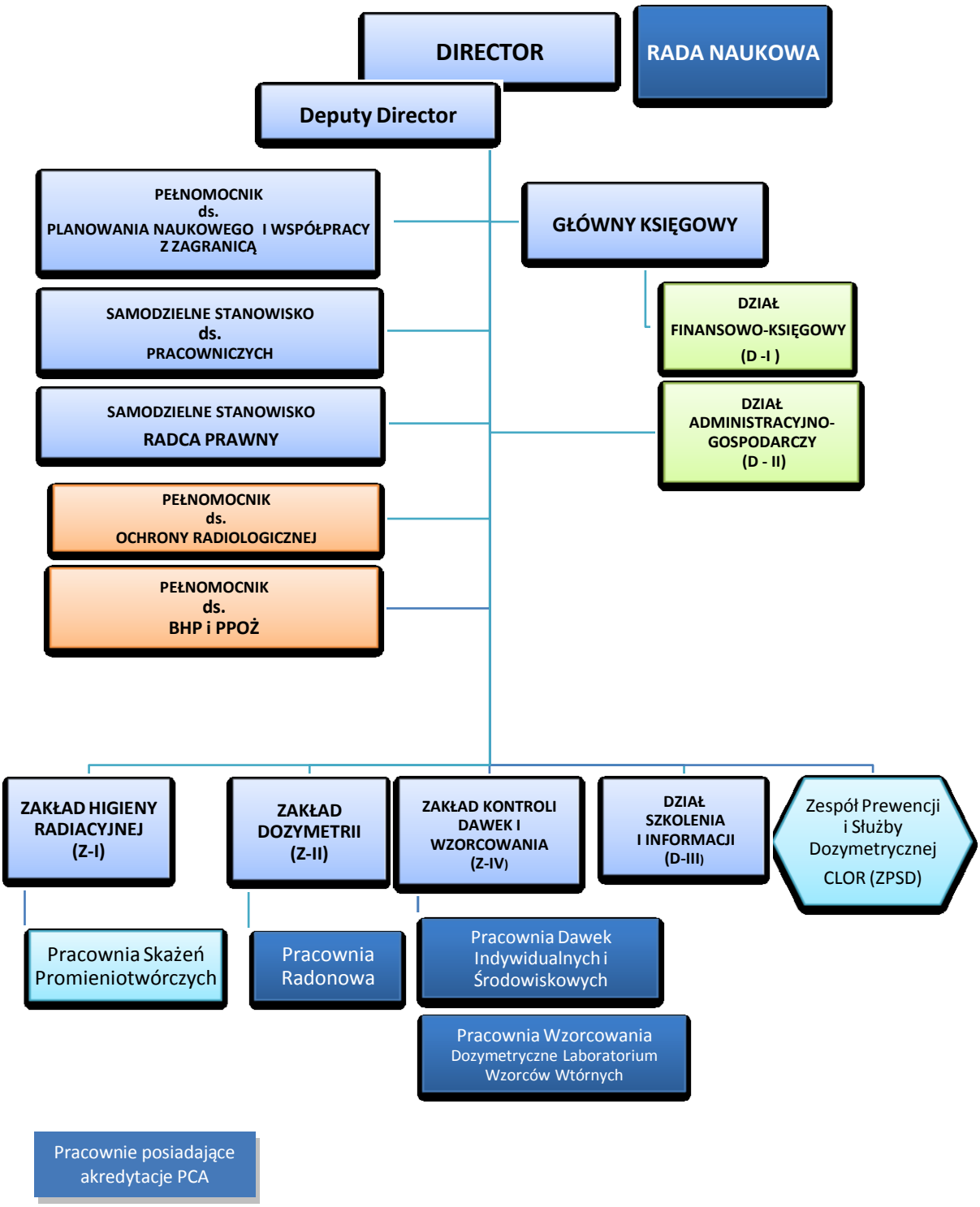
As in the former years, in 2002 and 2003 the efforts of CLOR were concentrated on operational and preventive actions, aimed to ensure the radiation safety of the country. These activities, covering several public services, engaged about 70 percent of human and financial resources of CLOR. The operational 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”.

ORGANIZATION CHART



1 RESEARCH ACTIVITIES

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

M. Suplińska, Z. Pietrzak-Flis

DEPARTAMENT OF RADIATION HYGIENE

Iodine-129 in the environment originates from natural and man-made sources which include: nuclear weapon tests, discharges from reprocessing facilities and from the damaged nuclear reactor at Chernobyl, and normal operation of nuclear reactors. According to the estimation by Hou et al. [1] more than 95% of ^{129}I in the Baltic Sea waters originates from European reprocessing facilities, whereas the contribution from the Chernobyl accident is less than 1% in the south Baltic and less than 4% in the north Baltic At present the concentration of ^{129}I in the Baltic Sea waters ranges from 1-3x10^{-13} g/l in the north Baltic to 6x10^{-13} g/l in the south Baltic. The ratio of ^{129}I/^{127}I in the south Baltic, equal to 5 x 10^{-8}, is four orders of magnitude higher than the pre-nuclear era level and two orders of magnitude higher than the fallout level from global nuclear weapons testing. Large share of radioactive substances, including ^{129}I, entering the sea is finally deposited in sediments. The study on ^{129}I in bottom sediments, limited only to the Kattegat area [2], indicated that ^{129}I originated mainly from the reprocessing plants at La Hague and Sellafield and that the ratio of ^{129}I/^{127}I in the surface 12-cm layer ranged from 5.0x10^{-9} to 3.0x10^{-8}.

The objective of this study was to determine the geographical and vertical distribution of ^{129}I in the bottom sediments in the south Baltic area. Simultaneously with ^{129}I, ^{127}I was determined. It allowed to calculate ^{129}I/^{127}I ratio and to estimate sources of ^{129}I in the studied area.

Sediment core samples were collected at three locations of the south Baltic Sea: Bornholm Deep (P5), open sea area (P140) and Gdansk Deep (P1). The present report also includes the results of the previous study for Gulf of Gdansk (P110), Gdansk Deep (P1) and Bornholm Basin (P39) [3]. Each core was divided into 4 depth layers: 0-2; 2-5; 5-7; 7-9 cm. The locations are shown in Fig. 1.

The ^{129}I and ^{127}I were determined by radiochemical neutron activation analysis (RNAA) method described by Muramatsu and Yoshida [4], with some modifications by Z.Pietrzak-Flis et al. [5]. The procedure consists of pre-irradiation chemistry (sample decomposition, iodine extraction and back-extraction cycle, freeze drying), irradiation and post-irradiation chemistry (separation of iodine and measurements of ^{130}I and ^{126}I). ^{125}I was used as yield tracer.

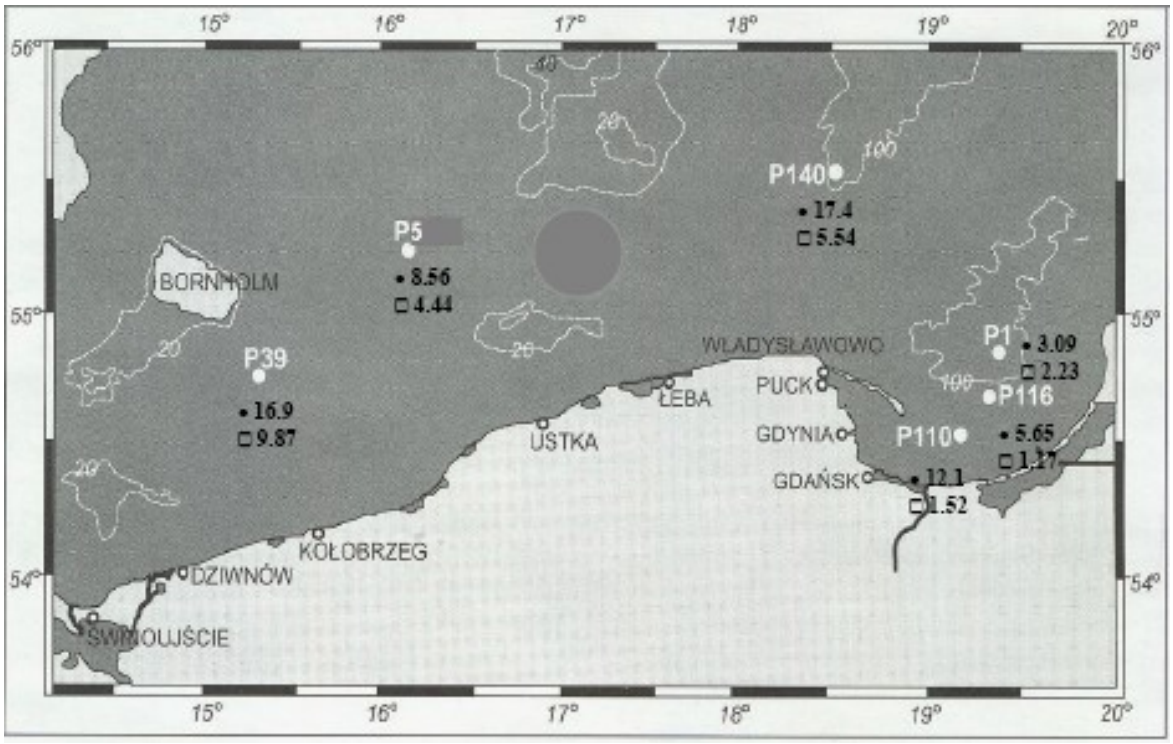


Figure 1. Locations of sampling stations and deposition of ^{129}I (• x 10-9g m-2) and ^{127}I (μ g m^{-2}) evaluated for 9-cm layer of Baltic Sea bottom sediment

In Table 1 there are given concentrations of ^{129}I and ^{127}I in the core samples and the atom ratios of 129I/127I. The concentrations of ^{129}I were the highest in the 0-2 cm layer of the sediments. They decreased exponentially with depth (Fig. 2). The concentrations of ^{129}I in the surface layers were the highest in the Bornholm Basin (P39) – 11.2 x 10^{12} at/kg and in eastern part of the southern Baltic Sea (P140) – 10.2 x 10^{12} at/kg. Taking into account that the sedimentation rate in the open Baltic Sea equals to about 0.5 mm per year it could be estimated that the 2-cm layer has been formed in the last 40 years. Evidently, this high level of ^{129}I is due to the marine discharges from reprocessing plants at La Hague and Sellafield which rose strongly from the beginning of the seventies of the last century [1, 2]. At the sampling station P5 in the Bornholm Deep, concentration of ^{129}I in the upper layer was only about half of that at stations P39 and P140. At present, no explanation of this observation can be proposed.

In the Gdansk Basin (P1, P110, P116) the concentrations of ^{129}I in the upper layer were lower than in the open sea. In this Basin the sedimentation rate is about four times higher than in the open Baltic Sea area (~ 2 mm y^{-1}), hence the layer of 2 cm was formed in the past 10 years. The obtained results suggest that the marine discharges of ^{129}I from the European reprocessing plants reach the Gdansk Basin in a smaller degree than the open Baltic Sea.

The ^{127}I concentrations were similar along the profiles, however, differences between sub-regions were considerable. Mean concentrations of ^{127}I were the highest in P39 sampling station - 413±20 mg/kg and they decreased in the following sequence: P5 - 208±12 mg/kg, P140 - 202±5 mg/kg, P1 -113±11 mg/kg, P116 - 77±7 mg/kg and P110 - 57±13 mg/kg.

Table 1. Concentrations of ^{129}I and ^{127}I in Baltic Sea bottom sediment and the ratios of $^{129}I/^{127}I$

Sampling station	Sampling date Depth (m)	*Layer* (cm)	^{129}I (mBq/kg)	^{129}I (g/kg) x 10^{-10}	^{129}I (at/kg) x 10^{12}	^{127}I (g/kg) x 10^{-3}	^{127}I (at/kg) x 10^{20}	$^{129}I/^{127}I$ ratio (at/at) x10^{-9}
P-39 54°44,0'N 15°08,0'E	June 2000 (63)	0-2	15.4	24.05	11.23	409	19.43	5.78
		2-5	4.70	7.35	3.43	388	18.38	1.87
		5-7	0.62	0.97	0.45	420	29.96	0.23
		7-9	0.77	1.20	0.56	431	20.63	0.27
P-5 55°14,0'N 15°59,0'E	June 2003 (90)	0-2	6.68	10.44	4.88	196	9.27	6.52
		2-5	2.69	4.21	1.97	206	9.75	2.01
		5-7	1,33	2.09	0.97	206	9.78	1.00
		7-9	1,17	1.83	0.85	224	10.60	0.80
P-140 55°33,3'N 18°23,0'E	June 2002 (88)	0-2	13.9	21.79	10.18	208	9.88	10.30
		2-5	4.01	6.26	2.93	203	9.62	3.04
		5-7	1.64	2.56	1.20	202	9.60	1.24
		7-9	0.62	1.03	0.48	196	9.28	0.52
P-1 54°50,0'N 19°19,0'E	June 2005 (107)	0-2	4.54	7.10	3.32	103	4.88	6.78
		2-5	0.64	1.00	0.47	113	5.35	0.88
		5-7	0.39	0.62	0.29	128	6.09	0.47
		7-9	0.33	0.51	0.24	109	5.18	0.46
P-110 54°30,0'N 19°06,8'E	June 1999 (70)	0-2	7.46	11.66	5.45	67.2	3.19	17.10
		2-5	2.01	3.15	1.47	69.6	3.30	4.45
		5-7	1.11	1.73	0.81	48.1	2.28	3.54
		7-9	0.33	0.52	0.24	44.7	2.12	1.15
P-116 54°39,1'N 19°17,6'E	June 2001 (88)	0-2	4.76	7.44	3.48	82.9	3.93	8.84
		2-5	2.50	3.90	1.82	67.7	3.21	5.68
		5-7	0.89	1.40	0.65	79.8	3.60	1.81
		7-9	0.41	0.65	0.30	76.6	3.63	0.83

Deposition of ^{129}I and ^{127}I, calculated on the basis of analyzed four layers up to 9 cm, are given in Fig. 2. It can be seen, that deposition of ^{129}I was almost the same in P39 and P140, whereas the deposition of ^{127}I was about two times higher in P39 comparing to P140. In the Bornholm Deep (P5), deposition of ^{129}I and ^{127}I was about two times lower than in P39. In the Gdansk Basin, deposition of ^{129}I was much more differentiated; it was the highest at P110 and it decreased with the distance from the Vistula river mouth. It seems that higher deposition of ^{129}I at P110 might result from discharge of ^{129}I from the Vistula river, which according to [6] is equal to 8.6 x10^{21} atoms y^{-1}.

Atomic ratios of ^{129}I to ^{127}I are presented in Fig. 3. In the upper 0-2 cm layers it ranged from 1.7x10^{-8} to 5.80x10^{-9} and decreased along the profiles down to 10^{-10}.The ratios 10^{-8} - 10^{-9} are by one to two orders of magnitude higher than those observed after the nuclear weapons tests and by three to four orders of magnitude higher than those in the pre-nuclear era. This indicates that ^{129}I in the upper layer of sediments originated from the reprocessing facilities. Concentrations of stable iodine in bottom sediments in the open Sea were from about 200 mg/kg to about 400 mg/kg, while in the Gdansk Basin these concentrations were much lower, being from about 57 mg/kg to 113 mg/kg. In consequence $^{129}I/^{127}I$ ratio was higher in Gdansk Basin than in the open Sea, despite of higher concentrations of ^{129}I in sediments collected in the open Sea region.

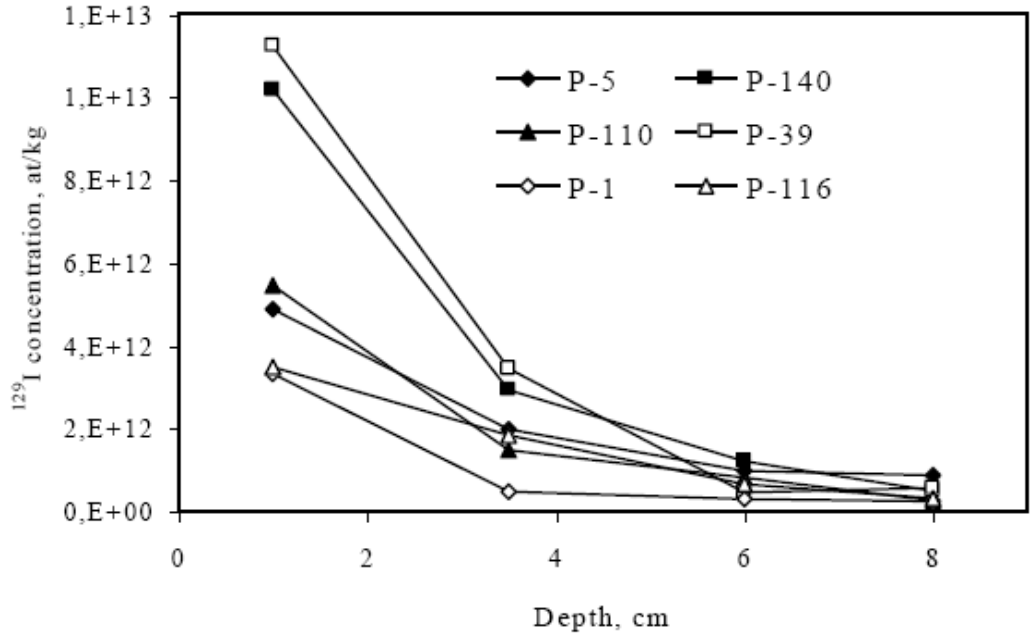


Figure 2. Depth profiles of the ^{129}I concentration in the sediment cores from the South Baltic Sea

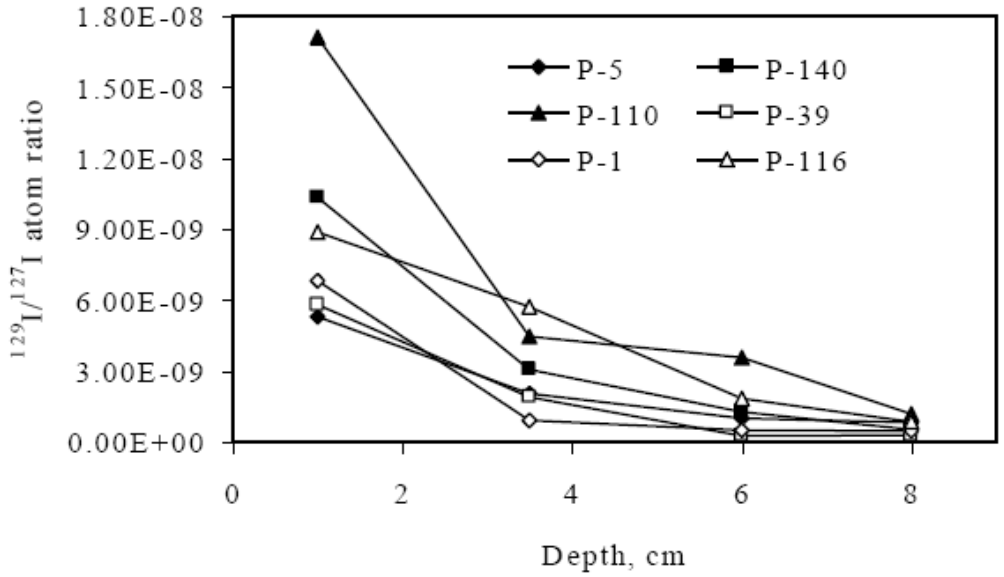


Figure 3. $^{129}I/^{127}I$ atom ratio in the sediment cores

Acknowledgements

The authors express sincere thanks to Mr. A. Adamczyk and Mr. E. Chrzanowski for technical assistance.

References:

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5. Pietrzak–Flis, Z., Krajewski, P., Radwan, I. Muramatsu, Y, Retrospective evaluation of 131I deposition density and thyroid dose in Poland after Chernobyl accident, Health Phys., 84 pp.698-708 (2003).
6. Aldahan, A.,Kekli, A.,Possnert,G. Distribution and sources of 129I in rivers of the Baltic region, J. Environ. Radioactivity 88:49-73 (2006).

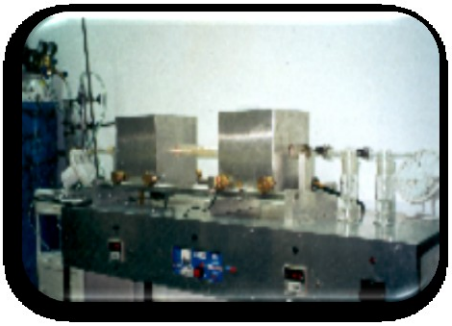
The work supported by Ministry of Science and Higher Education.

1.2 IODINE–129 IN THYROIDS OF DEERS IN EASTERN POLAND

Z. Pietrzak-Flis, E. Chrzanowski

DEPARTAMENT OF RADIATION HYGIENE

Iodine-129 occurs naturally due to spontaneous fission of uranium and to the interaction of cosmic rays with xenon in the upper atmosphere. Large amounts of this isotope have been released to the environment as a result of human activity. Main sources of anthropogenic ^{129}I include nuclear weapon tests, releases from nuclear fuel reprocessing plants and normal operation of nuclear reactors. An additional source of the anthropogenic ^{129}I are nuclear accidents.



The discharged ^{129}I is a permanent contaminant in the biosphere owing to its long half-life (1.57×10^7 years). In consequence, it will accumulate in the biosphere and it will become distributed similarly as ^{127}I. Till now, the anthropogenic ^{129}I has not caused a significant radiation exposure of man, however, it becomes a concern due to its increasing amounts in the environment. It is of importance as a sensitive tracer of releases from reprocessing plants and waste repositories, and also as an indicator of the short-lived iodine-131 ($T_{1/2}$ = 8.2 days) released after the nuclear reactor accident in Chernobyl.

Concentration of ^{129}I in the environment is usually expressed in relation to the concentration of stable ^{127}I, as the $^{129}I/^{127}I$ ratio.
Iodine accumulates in the thyroid of man and animals, hence this gland is considered to be the most sensitive indicator of ^{129}I in the environment.

^{129}I concentrations were extensively measured in thyroids and other environmental materials in the US and Europe [1–3]. The results indicate that the $^{129}I/^{127}I$ ratio in thyroids of humans increased from its pre-nuclear value of 4×10^{-11} and 2.5×10^{-9} (USA, 1947-1949) [1] to 2.1×10^{-9} – 4.7×10^{-8} (Germany, 1979–1984) [2]. In countries of the European Community in the period before the Chernobyl accident (1978–1981), in the bovine thyroid mean $^{129}I/^{127}I$ ratio was 1.9×10^{-8} (range of 2.1×10^{-9} – 7.9×10^{-7}) [2] .

In the present work the activity concentration of ^{129}I and the $^{129}I/^{127}I$ ratios were determined in thyroids of deers in northern and southern regions of eastern Poland. The aim of this work was to evaluate the contamination of these regions with ^{129}I after the Chernobyl accident. The results obtained will constitute the reference level of ^{129}I in the environment which is needed to determine effects of possible emissions from the nuclear facilities of radioactive iodine in future. Also they allow to get more information on the long-term ecological behavior of this radionuclide.

Thyroids of deers were collected in the Forest Inspectorates in Rudnik (Voivodship Podkarpackie) in November 2004, and of Supraśl (Voivodship Podlaskie) in December 2004.
Content of ^{129}I and ^{127}I was determined using radiochemical neutron activation analysis (RNAA), which allows to determine simultaneously both isotopes. Preparatory treatment and separation of iodine from thyroids were performed according to the procedure described in [4]; post activation analysis was adopted from Muramatsu [5] with modification [6]. Samples were activated in a research reactor MARIA at Świerk at the flux density of 1.5×10^{13} n cm^{-2} s^{-1} for 7.5 h. By neutron irradiation, ^{130}I and ^{126}I are produced from $^{129}I$and ^{127}I, respectively. The gamma rays of 536 keV and 388.5 keV of ^{130}I and ^{126}I, respectively, were counted using HpGe detector. The contents of ^{129}I and ^{127}I were calculated by comparing with the standards. Chemical yield was controlled with the use of ^{125}I as a tracer.

Concentrations of ^{129}I (mBq/g dw, mg/g dw), ^{127}I (mg/g dw) and atomic ratio of $^{129}I/^{127}I$ for thyroids of deers from forest inspectorates in Rudnik and Supraśl are presented in Table 1 and 2, respectively. In Rudnik concentrations of ^{129}I were in the range from 1.51×10^{-7} mg/g dw to 6.18×10^{-7} mg/g dw and the mean concentration was equal to $4.62 \pm 2.95 \times 10^{-7}$ mg/g dw. Mean concentration of ^{127}I was 2.24 ± 1.14 mg/g dw (range.0.88 – 4.78 mg/g dw), mean $^{129}I/^{127}I$ atomic ratio was $1.93 \pm 0.26 \times 10^{-7}$. Animals were 1 to 6 year-old, both males and females. The data obtained do not indicate on any dependence of iodine concentrations on age or sex of the animals.

Concentrations of iodine in thyroids from Supraśl were higher than those in Rudnik. Especially high was the concentration of ^{127}I (above two-fold of that in Rudnik), giving in consequence lower $^{129}I/^{127}I$ ratio ($1.37 \pm 0.61 \times 10^{-7}$).
Atom concentrations and atom ratios in thyroids from Rudnik and from Supraśl are presented in Figs. 1 and 2. In Rudnik, the range of the $^{129}I/^{127}I$ ratio was small (1.62×10^{-7} –

2.38 x 10^{-7}) and this indicates that ^{129}I was distributed in the environment in a similar way as stable iodine. In Supraśl, the range of this ratio was much larger (0.54 x 10^{-7} – 2.10 x 10^{-7}). This means that the distribution of ^{129}I differed from the distribution of stable iodine to a larger extent than in Rudnik. It can be supposed that in Supraśl ^{129}I was not fully mixed with ^{127}I and thus these isotopes were not in equilibrium.

In Rudnik, the relationship between ^{129}I and ^{127}I in thyroid is linear, with the high correlation coefficient of 0.99. With the rise of ^{127}I concentration, concentration of ^{129}I increased. Such a relationship did not occur in thyroids from Supraśl. At high concentrations of ^{127}I, concentrations of ^{129}I were lower compared to other thyroid samples (Fig. 4.).

These data were obtained for thyroids collected 18 years after the Chernobyl accident. Present results suggest that in this time ^{129}I became distributed in the forest ecosystem in Rudnik similarly as stable iodine, indicating the achievement of equilibrium between these two iodine isotopes. Unlike in Rudnik, in the forest ecosystem in Supraśl such an equilibrium was not yet achieved. Evidently, the process of mixing of ^{129}I and ^{127}I in the forest of Supraśl was slower than that in Rudnik.

The ^{129}I/^{127}I ratios in the thyroids of deers were higher than those reported in literature for the pre-Chernobyl times [2] or later in countries not affected by this accident (1.4 x 10^{-8} in Chiba, Japan,1995) [7]. Evidently, the increased values observed in the regions of eastern Poland can be attributed to the deposition of iodine isotopes following the Chernobyl accident. ^{129}I can be a measure of the contamination with ^{131}I after the accident, therefore, further examinations are needed to evaluate the contamination of other regions.

Table 1. Iodine-129 and iodine-127 concentrations in thyroids of deers from forest inspectorate Rudnik in south-eastern Poland

Sample No	Age years	Sex	^{129}I mBq/g dw[a)]	^{129}I 10^{-7} mg/g dw	^{127}I mg/g dw	^{129}I/^{127}I 10^{-7}at/at
1	1	f	3.88	6.06	2.78	2.13
2	1	f	1.91	2.98	1.77	1.66
3	1	f	2.45	3.83	2.07	1.82
4	1	f	7.40	11.6	4.78	2.38
5	3	f	3.96	6.18	2.99	2.04
6	3	m	1.88	2.94	1.55	1.86
7	3	f	0.97	1.52	0.92	1.62
8	5	f	0.96	1.51	0.88	1.68
9	6	f	3.27	5.11	2.23	2.25
10	6	m	2.91	4.54	2.45	1.82
Mean ± SD			2.96 ± 1.89	4.62 ± 2.95	2.24 ± 1.14	1.93 ± 0.26

[a)] dry weight

Table 2. Iodine-129 and iodine-127 concentrations in thyroids of deers from forest inspectorate Supraśl in north-eastern region of Poland

Sample No	Age years	Sex	^{129}I mBq/g dw	^{129}I 10^{-7} mg/g dw	^{127}I mg/g dw	^{129}I/^{127}I 10^{-7}at/at
1	2	m	2.75	4.30	7.83	0.54
2	2	m	4.86	7.60	4.75	1.58
3	2-3	f	2.51	3.93	6.25	0.62
4	2-3	f	6.30	9.83	4.61	2.10
5	2-3	f	5.73	8.95	5.31	1.66
6	2-3	f	5.82	9.09	5.15	1.74
Mean ± SD			4.73 ± 1.73	7.28 ± 2.56	5.70 ± 1.17	1.37 ± 0.61

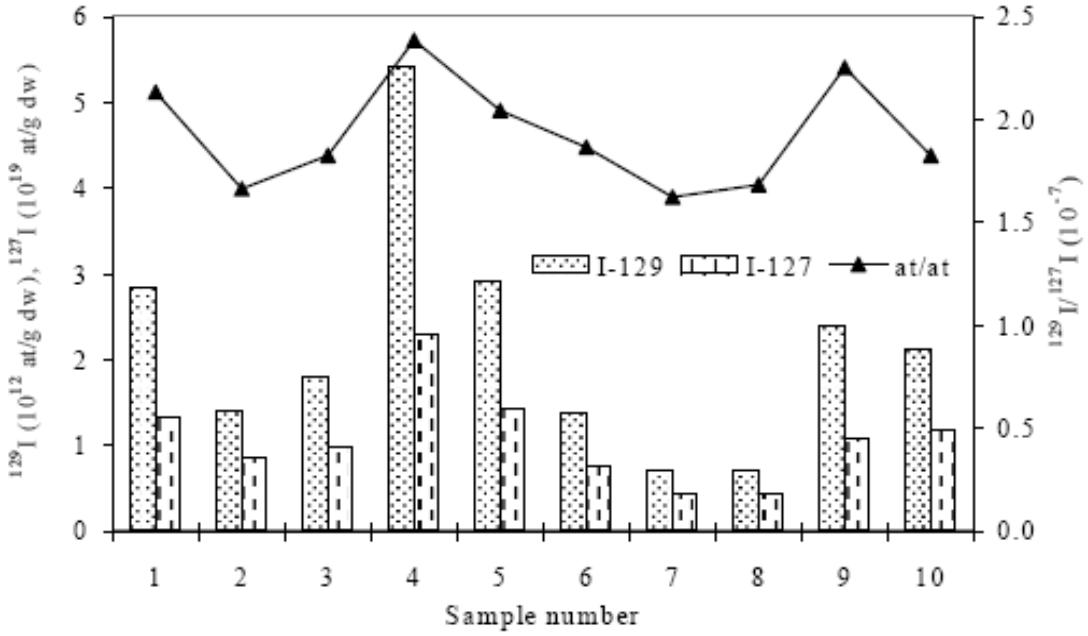


Figure 1. Concentration of ^{129}I and ^{127}I and their ratios in thyroid samples 1 – 10 of deers in Rudnik

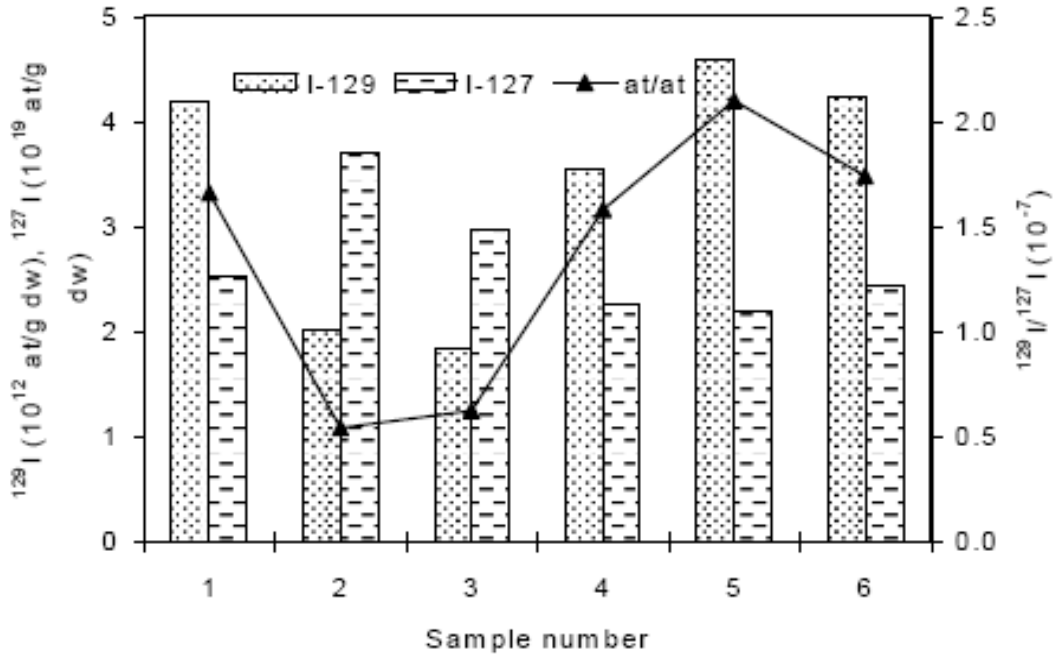


Fig. 2. Concentration of ^{129}I and ^{127}I and their ratios in thyroid samples 1 – 6 of deers in Supraśl

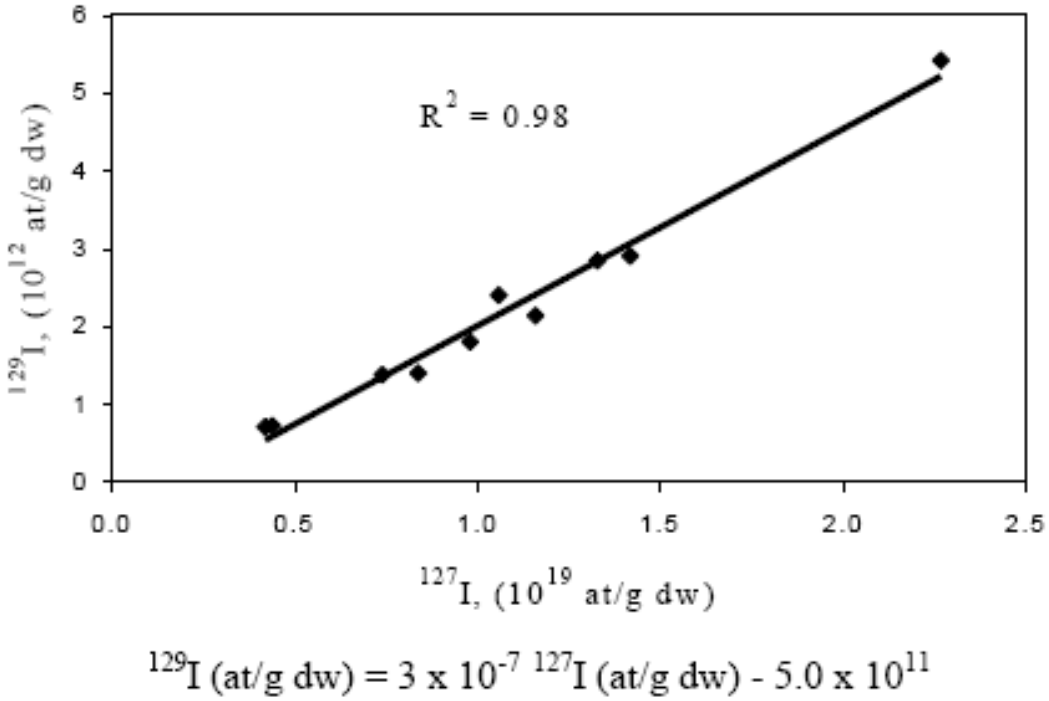


Fig. 3. Relationship between ^{129}I and ^{127}I concentrations in thyroids of deers from Rudnik

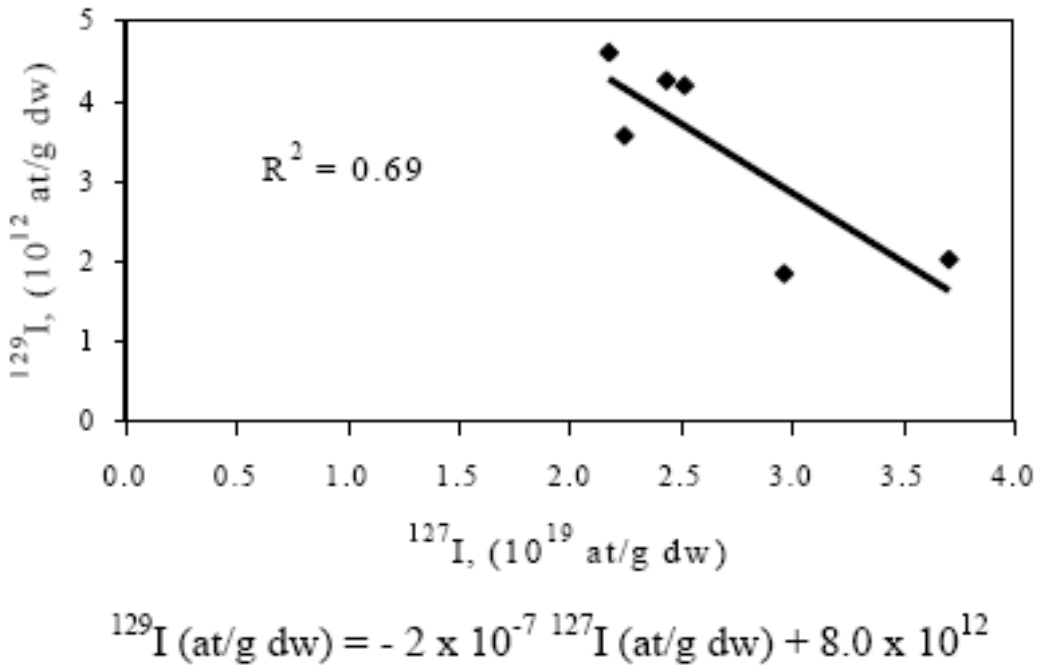


Figure 4. Relationship between ^{129}I and ^{127}I concentrations in thyroids of deers from Supraśl

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Acknowledgements

The authors express sincere thanks to the Directorate General of National Forests and to the Regional Directorates of National Forests in Lublin and Białystok for the assistance in the collection of thyroid samples. Thanks are also due to Mrs. I. Komarnicka and to Mr. A. Adamczyk for technical assistance.

The work supported by Ministry of Science and Higher Education.

1.3 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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DEPARTMENT OF RADIATION HYGIENE

Abstract

Zwierzęta i Rośliny Standardowe wg. ICRP
Reference Animals and Plants

- **gryzoń *(a rodent)***
- **kaczka *(a duck)***
- **żaba *(a frog)***
- **ryba słodkowodna *(a freshwater fish)***
- **flądra *(a marine flatfish)***
- **pszczoła *(a bee)***
- **krab *(a crab)***
- **ślimak morski *(a marine snail)***
- **dżdżownica *(a earthworm)***
- **sosna *(a pine tree)***
- **trawa *(a grass)***
- **wodorosty *(a seaweed)***

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.

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.

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

[13]. Monitoring data on 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) ^{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 137Cs (bomb-tests-fallout & Chernobyl origin), 226Ra (natural radionuclide) and 239,240Pu (bomb-tests-fallout) concentrations in biota, bottom sediment and water is presented in Table 1. The concentrations of 137Cs measured in the most contaminated region in Poland (Stare Olesno 380 Bq·kg-1 d.w.) and the concentrations of 226Ra 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].

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.

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The work supported by Ministry of Science and Higher Education.

2 PUBLIC SERVICE MISSIONS - RADIATION SAFETY AND PERMANENT MONITORING

2.1 PERMANENT MONITORING STATIONS (PMS) NETWORK IN POLAND

K. A. Isajenko, P. Lipiński

DOSIMETRY DEPARTMENT

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.

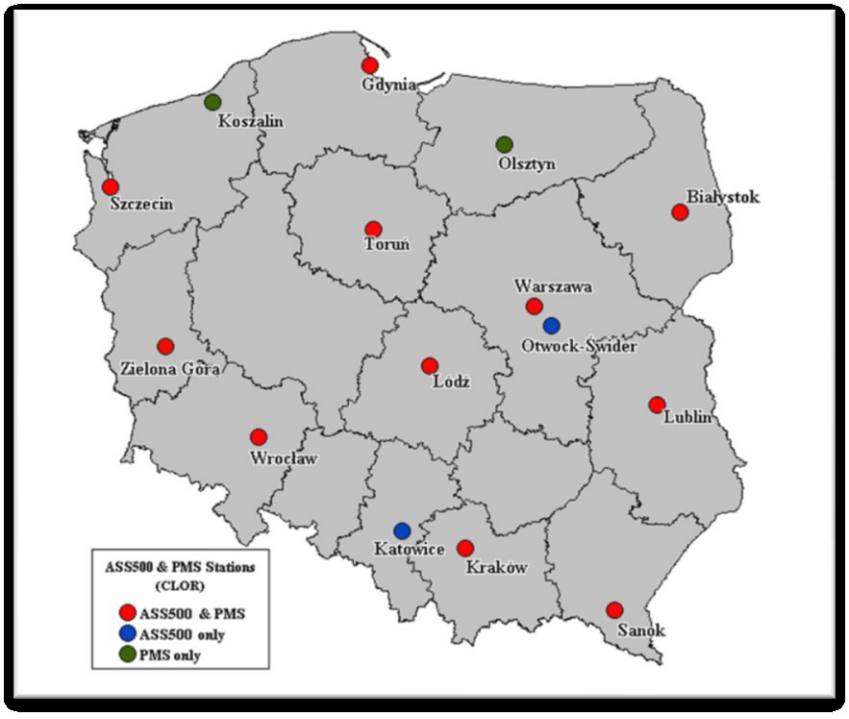

Figure 1. The location of the PMS and ASS-500 stations in Poland.

These stations were located in Białystok, Gdynia, Koszalin, Kraków, Lublin, Łódź, Olsztyn, Sanok, Szczecin, Toruń, Warszawa, Wrocław and Zielona Góra. At the sometime a central system managing the measurement network was installed at CLOR in Warszawa. 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 Environmental, and by the end of 2004 it used to be integrated with the network of the ASS-500 stations into one coherent system, in which the data collected from particular stations were transferred to the central server in CLOR. At the end of 2004 Polish National Atomic Energy Agency issued a tender for the supervision and service of the PMS stations for the yaer 2005. As the result of the tender the PMS stations were withdrawn from CLOR's supervision. Since the beginning of 2005 the disconnecting of the two systems (ASS-500 and PMS) is underway.

Description of the PMS system

The PMS stations continuously monitored 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 remainings; 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 used to be connected to PMS system. The block diagram of the PMS station is presented in Figure 2.

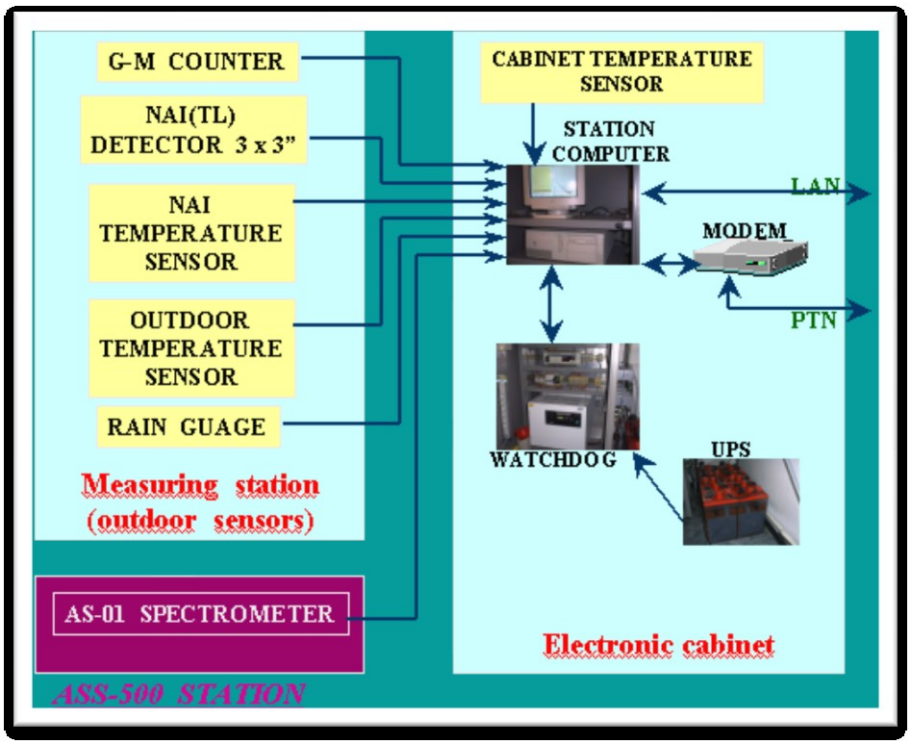

Figure 2. PMS station block diagram.

The data collected by the station computer used to be transmitted to the central system which was located in Dosimetry Department of CLOR in Warsaw. The central system consisted of two computers: one controlling the transmission and second having the MS SQL Server 2000 (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 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 was generated on the central computer. In normal situation the station data were averaged hourly, but in emergency there was 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.

Figure 3. PMS server graphical user interface.

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

The monitoring results of the PMS station network

Every month the Dosimetry Department of CLOR used to prepare the report of the PMS station network status for the Polish National Atomic Energy Agency. It contained 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. More detailed reports were prepared quarterly. The excerpt from a report (dose rate curves for all stations) of the fourth quarter of 2004 is presented in Figure 5.

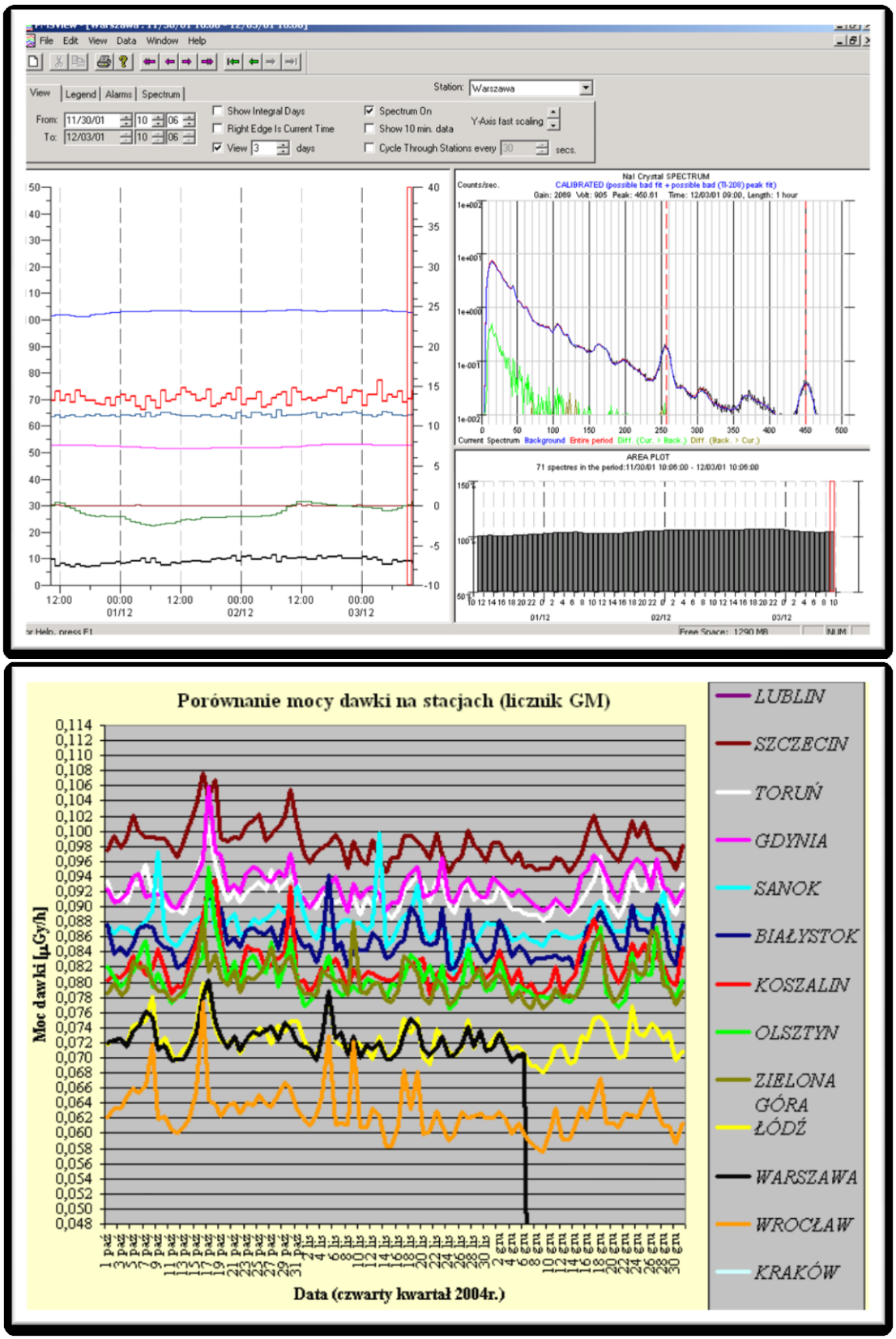

Figure 5. Comparison of the total gamma dose rate on seven PMS stations in the fourth quarter of 2004.

Table 1. Monthly report (September 2004).

Station Name	Number in PMS network	Dose rate measured by GM-counter [μGy/h] AVG	MIN	MAX	Dose rate from Th component (NaI(Tl) detector) [μGy/h] AVG	MIN	MAX
Gdynia	5	0.092	0.089	0.095	0.084	0.083	0.084
Lublin	6	-*)	-*)	-*)	0.103	0.100	0.108
Białystok	7	0.086	0.082	0.089	0.082	0.080	0.082
Warszawa	8	0.072	0.070	0.076	0.068	0.067	0.068
Kraków	9	-*)	-*)	-*)	0.103	0.101	0.106
Szczecin	20	0.100	0.097	0.102	0.081	0.079	0.083
Wrocław	21	0.064	0.061	0.068	-*)	-*)	-*)
Sanok	22	0.088	0.085	0.094	-*)	-*)	-*)
Zielona Góra	40	0.080	0.078	0.083	0.076	0.075	0.077
Koszalin	41	0.082	0.079	0.086	0.078	0.077	0.080
Olsztyn	42	0.082	0.077	0.086	0.076	0.073	0.078
Łódź	50	0.074	0.071	0.079	0.063	0.061	0.069
Toruń	51	0.092	0.090	0.096	0.090	0.088	0.092
TOTAL		0.083			0.082		

*) *– No data – NaI(Tl) or GM detectors malfuction.*

The lowest dose rate was observed at Wroclaw in January 2004 (56 nGy/h), and the highest - at Krakow station (in January 2004 also), at Sanok (in November 2004) and at Szczecin (in June 2006) - 100 nGy/h - the result of heavy rainfall and, thus, radon washout. The average dose rate value for Poland in 2004 was 83 nGy/h. Table 2 shows the averages, minima and maxima of the dose rate measured by PMS stations in Poland in 2004.

Table 2. Gamma dose rate in 2004 – average, minimum and maximum for all PMS stations.

Station	Gamma dose rate in 2004 [nGy/h] Average	MIN	MAX
BIAŁYSTOK	84	67	136
GDYNIA	92	80	126
KOSZALIN	82	69	122
KRAKÓW	59*)	43*)	118
LUBLIN	106	55	156
ŁÓDŹ	72	61	119
OLSZTYN	80	66	136
SANOK	87	68	132
SZCZECIN	98	85	134
TORUŃ	91	81	128
WARSZAWA	71	55	123
WROCŁAW	62	49	111
ZIELONA GÓRA	80	67	141

*) *– GM probe malfuction.*

Data collected by the PMS system were 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.

2.2 RADIOACTIVITY OF GROUND-LEVEL AIR IN POLAND IN 2004 AND 2005: RESULTS FROM AEROSOL SAMPLING STATIONS TYPE ASS-500.

K. Isajenko, I. Kwiatkowska, M. Biernacka, P. Lipiński

DOSIMETRY DEPARTMENT

In 2004 the ASS-500 aerosol sampling stations were located in Warsaw, Świder, Białystok, Katowice, Kraków, Lublin, Gdynia, Wrocław, Szczecin, Sanok, Toruń and Łódź. In May 2004 the network was enlarged by the station located in Zielona Góra. Ten of the 13 stations in 2005 are equipped with NaI(Tl) detectors placed above the filter. The gamma spectra and other parameters, eg. the air flow rate through the filter, were transmitted to the station computer and sent to CLOR. Filters from three stations: in Szczecin, Toruń and Zielona Góra are measured in Dosimetry Department in CLOR. The network of ASS-500 stations belongs to the Polish Early Warning System.

The station in Zielona Góra has been included in the network in the week 21 of 2004. The other stations were working without longer breaks. This resulted in collecting of 666 weekly aerosol samples in 2004 and 674 in 2005. Filters with the deposited aerosol, i.e. the total dust, were kept for at least 2 days in room temperature, then pressed into tablets 50 mm in diameter, and measured with HPGe detectors and multichannel analizers. The effectivities of the detectors were in the range from several to 40%. The thickness of the tablets was in the range of 2.9-7.3 mm. In 2004 two radioactivity standards of 4.1 and 6.1 mm thick were used for calibration of the gamma spectrometers. Since the fourth quarter of 2004 the new radioactivity standard was used for calibration of the spectrometers. In emergency situations the filters are to be measured immediately after collecting the aerosols.

In 2004 the average mass of the weekly sampled total dust was 3.0 g with a range of 0.7-7.9 g. The average volume of filtered air was 72563 m^3, ranging 22583-116202 m^3. In 2005 the average mass of the total dust samples was 3.2 g, ranging 0.7-10.2 g. The average volume of the filtered air was 70901 m^3, ranging 19026-132583 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.

Arithmetic means, and general weekly trends, for air and total dust in 2004 and 2005 are presented in Table 1 and Table 2.

It can be seen from the tables, that the maxima of ^{131}I concentrations in dust and in air have occurred in 2004 at Białystok in the week 49 (29.11–6.12), in 2005 in air at Wrocław in the week 49 (5.12–12.12) and in dust at Warsaw in the week 9 (7.03-14.03). The sources of the maximum concentrations in 2004 and in 2005 have not been identified.
In 2004 the maxima for ^{137}Cs concentrations in air and dust were observed at Białystok, in the week 2 (5.01-12.01).In 2005 the maxima for ^{137}Cs concentrations in air and dust were observed also at Białystok but not at the same time: in air in the week 44 (31.10-7.11), in dust in the week 6 (7.02-14.02).
The measurements carried out in 2004-2005 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.
At the end of 2005 the station in Warszawa discovered the presence of tin ^{113}Sn having the concentration 5.3 Bq/m^3 (week 49: 5-12.12.2005) and in the week 50 (12-19.12.2005) the presence of technetium ^{99m}Tc with the activity of 2 mBq/m^3. The information about the presence of those two radionuclides in the ground-level atmosphere was passed to the Radiation Emergency Centre (CEZAR).

ACKNOWLEDGEMENTS

This work was sponsored by National Atomic Energy Agency.

2.3 SUPPORT TO COMBAT ILLICIT TRAFFICKING IN NUCLEAR AND RADIOACTIVE MATERIALS

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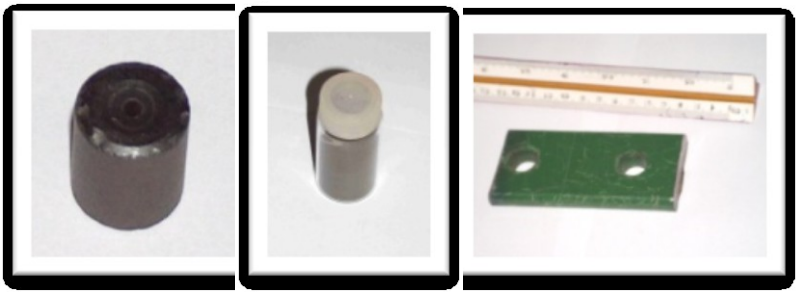
In 2004 CLOR continued its activity of providing assistance to the law enforcement services in detection of nuclear and radioactive materials of unknown origin and response to illicit trafficking cases involving such materials. Being a recipient and executor of the European PECO project on combating illicit trafficking of nuclear materials launched by the Institute for Transuranium Elements (ITU), CLOR has contributed to the implementation of an

improved response system to illicit cases resulting *inter alia* in better response procedures in force and enhanced cooperation between competent authorities and services involved in the response actions in Poland. Although the PECO project was focused on the third line of defense i.e. material categorization and identification, and on improving capabilities of the Polish nominated radio-analytical laboratory, i.e. CLOR, for analysis of seized nuclear and radioactive materials, the outcome of the project has been profitable to the all authorities and services responsible for combating illicit nuclear traffic in Poland.

Of a crucial importance for the response system to illicit cases in Poland were:

- the handbook for the Response to Illicit Trafficking or inadvertent movement of NUclear and radioactive Materials (RITNUM), elaborated, according to the International Technical Working Group (ITWG) model action plan, by CLOR with contribution of the all identified entities involved in this issue in Poland;
- the hands-on workshop "Bobrowniki2004" on response to illicit trafficking of nuclear and radioactive materials held on 28 September 2004 in the Podlasie Province[1] to validate the national RITNUM handbook and to prove competence of and cooperation between the exercising entities.

In addition, an active involvement in the Bobrowniki exercise of the two expert groups from CLOR, which were the National Emergency Response Service and specialists in categorization of seized radioactive and nuclear materials, was for the practising services a tutorial on the observance of basic rules of safety and radiological protection as well as on detection and evaluation of hazard. Response actions carried out at the two scene sites of the exercise, the border crossing and the abandoned buildings, were continued at the CLOR premises to provide, upon laboratory analysis of the seized radioactive items and collected environmental samples, a nuclear forensic expertise for the relevant Polish authorities, including criminal investigation bodies.



The in-field exercise and the further laboratory investigations had been carried out with the use of two low enriched uranium (LEU) pellets, depleted uranium (DU) powder and two metal objects

[1] For information on the exercise see: Hands-on workshop "BOBROWNIKI 2004" : Response to Illicit Trafficking of Nuclear and Radioactive Materials in Poland.

contaminated with cobalt-60, all taken over in the past in emergency incidents. Two pellets with isotopic abundance about 2 % of U-235 were chosen out of 50 pellets (0.85 kg) seized in March 1995 at the Polish - Czech border crossing point in Cieszyn in a car trying to leave Poland. Powder of depleted uranium (DU) was seized (0.49 kg) together with a shielding container of depleted uranium (18 kg) in a private apartment in Gdynia by the police in March 1993. Two metal pieces contaminated with cobalt-60 (Co-60) were a fraction of agriculture equipment made of contaminated steal, likely transferred from the Czech Republic to Poland in 1995-1997. At that time CLOR determined an isotopic abundance in the seized items by means of infinite thickness method and high–resolution gamma spectrometry, the methods applied in the 1990-ties at CLOR to categorize nuclear and radioactive materials of illicit origin.
Assistance provided to CLOR, under the above mentioned project, in the form of training, delivery of a dedicated equipment for non-destructive assay of seized radioactive material and joint analysis at the ITU of uranium pellets and powder used in the demonstration exercise, contributed to the progress in technical capabilities and nuclear forensic expertise of the CLOR for analysis of nuclear and radioactive materials of illicit trafficking origin. The equipment delivered by the ITU, a high–resolution low-energy germanium detector with the proper electronics and software - MGA and MGAU codes for determination of enrichment in plutonium and uranium respectively, was used for analysis of uranium pellets and powder at the CLOR premises after the Bobrowniki2004 exercise.

The use of a hand-held instrument equipped with NaI detector in the demonstration exercise resulted in a preliminary categorization of the seized items and needed further investigations and confirmation in-situ at the CLOR premises to deal with the threat posed by the incidents to environment and to proliferation concerns.

The second incident site, where was a suspicion of environmental contamination and a presence of other hidden or abandoned radioactive sources, was checked with a Mobile Spectrometric Laboratory by CLOR specialists. No other sources or the presence of contamination were detected there. Nevertheless, environmental samples had been collected to measure them at the CLOR laboratories in order to evaluate contamination inside and around the building, where a hiding place with radioactive materials was located.

One sample of grain collected at the hiding place and two samples of soil collected near the building were measured by gamma spectrometry and radiochemistry methods at CLOR to determine Cs, U and Pu. The results of laboratory tests of the environmental samples were used to release the incident site, when it was determined that the content of measured isotopes was in the range of contamination level typical for the Podlasie District.

To address proliferation concerns and to support the law enforcement bodies in criminal investigations further analysis of the seized nuclear and radioactive materials were carried out at the CLOR laboratories. Report on measurements of the seized substances was delivered within 48 hours to the President of the National Atomic Energy Agency (PAA) and to the Governor of the Podlasie Province. Information contained in the report included *inter alia* physical characterization (weight, dimensions, density, photo) of the seized items and the abundance of isotopes in each item. The tools applied at CLOR were High Resolution Gamma Spectrometry and GENIE 2000 software combined with high purity germanium (HPGe) detectors:
coaxial type (from 10 to 1800 keV) to measure two metal plates contaminated with Co-60;
planar type (low-energy germanium, from 3 to 1200 keV) and MGAU (Multi-Group Analysis for Uranium) code to measure isotopic composition of uranium in two pellets and powder.

The validation of the RITNUM handbook procedures was continued and in March 2005 two CLOR specialists participated in a joint analysis of uranium pellets and powder sent to the ITU after measurements carried out at CLOR. The goal of nuclear forensic investigations at ITU of uranium pellets and powder was to:

- compare the results of non-destructive measurements between the two laboratories, CLOR and ITU,
- improve CLOR experience in analytical techniques for material characterization and in interpretation of the findings,
- determine *inter alia* the producer, method and time of production.

The overview of analytical scheme performed at ITU, its results, and comparison with the categorization results achieved at CLOR presents the ITU technical report “Analysis of uranium pellets and powder seized in Poland” prepared with contribution of the CLOR specialists, who participated in the joint analyses, and issued in August 2005. The report confirms a close convergence of the results obtained with the use of high resolution gamma spectrometry in the both collaborating institutions, ITU and CLOR.

Basing on the ITU results the following main conclusions have been drawn:

- analysis of uranium pellets confirmed the 2,0% enrichment of U-235 obtained earlier at CLOR;
- uranium content in the pellet corresponds to uranium dioxide (UO_2);
- low abundance (0,006%) of U-236 in pellets suggests that the material was produced from natural uranium and has never been used in the nuclear reactor;
- the LEU pellets were produced in the end of 1990 by the MZ Electrostal in the Russian Federation and were to be used at Ignalina NPP in Lithuania;

- analysis of uranium powder indicates, that it was depleted uranium with 0,2% content of U-235 and uranium concentration in powder corresponded to U_3O_8;
- information about production and application this kind of powder was not found.

In May 2005 CLOR issued the latest version No.07 of the "Handbook for the response to illicit trafficking or inadvertent movement of nuclear and radioactive materials in Poland", which was disseminated amongst all authorities and services involved in this issue in Poland.

In September 2005 CLOR issued in English and Polish language the Final Report of the EU PECO Project on Combating Illicit Trafficking of Nuclear Materials in Poland presenting its contribution to the project implementation to support relevant services in combating illicit nuclear traffic in Poland. Benefiting from the cooperation with the ITU CLOR is going to develop and execute ISO17025 accreditation procedure in the scope of gamma spectrometry for nuclear forensics.

The effect of a joint work with participation and contribution of the all identified entities involved in this issue in Poland need further cooperation between radio-analytical laboratories, both domestically and internationally. Close cooperation between national nuclear and traditional forensic laboratories to share knowledge and experience has already resulted in the good outcome of the demonstration exercise in Bobrowniki. This can be maintained and expanded by other nuclear forensic laboratories in Poland to establish a national forensic laboratory network with CLOR as a coordinator. CLOR intends to participate in the international interlaboratory forensics exercise, to be organized by the Exercise Task Group within the ITWG, to test its current capability profile and to become a member of the International Nuclear Forensic Laboratory Network.

2.4 HANDS-ON WORKSHOP "BOBROWNIKI 2004" : RESPONSE TO ILLICIT TRAFFICKING OF NUCLEAR AND RADIOACTIVE MATERIALS IN POLAND

G. Smagala, S. Sterlinski, P. Lipinski, R. Tanczyk, I. Kaminska, D. Grabowski, K. Isajenko, M. Suplinska

Introduction

A demonstration exercise "Bobrowniki 2004" of the response to illicit trafficking in nuclear and radioactive materials was held on 28th September 2004 in the Podlasie Province in Poland. Services *inter alia* of the Border Guards, Customs, Police, Sanitary Epidemiological Station and the Central Laboratory for Radiological Protection (CLOR) demonstrated their competence and collaboration in the exercise. Support for a potential fire, explosion, or any

other hazard to health, life, or property was provided by medical and fire brigade teams. An approved scenario of the exercise assumed two related incidents in two places:

- at the border crossing in Bobrowniki;
- in an abandoned building beyond the borderland zone.

Practical carrying out of the two episodes of the hands-on workshop was compliant with the scenario, developed earlier at CLOR in co-operation with the practising entities. Respectively to the predetermined place of the emergency incidents, the Governor of Podlasie was the host of the event and services of the Podlasie Province the main exercising entities. The key players, upon request, received support from CLOR, which participated in a double role as the 24h National Radiation Emergency Service and the expert institution in radioactive contamination measurements and categorization of the seized nuclear and radioactive materials.

The exercise was organised by CLOR in cooperation with the National Atomic Energy Agency (PAA) and the Podlasie Province Office. The origin of the exercise was the European PECO project on combating illicit trafficking of nuclear materials and the resultant national handbook for the Response to Illicit Trafficking of NUclear and radioactive Materials (RITNUM), developed in line with international standards by CLOR, the nominated Polish executor of the project. According to an agreement of the PECO project signed in 2001 by President of PAA and Director of the Institute for Transuranium Elements (ITU) from the Joint Research Centre of the European Commission (EC), the handbook should be subject to verification by conducting a demonstration exercise in the field.

More than 100 persons representing 31 national institutions, 6 international organisations or foreign countries as well as local mass media watched the in-field exercise and participated in the discussion on summing up the hands-on workshop afterwards. The exercise observers, both national and foreign (from the EC, including ITU, from the IAEA, EUROPOL, International Technical Working Group on nuclear smuggling, Belarus and USA) were provided not only with details of the hands-on workshop on duties foreseen for participating services, authorities, observers, analytical and forensic laboratories (classic and nuclear forensics), but also with live reports delivered at the scene sites by representatives of the practising entities.

"Bobrowniki 2004" exercise was conducted with the use of real nuclear and radioactive material samples, seized in the past in similar incidents, and the options of combining radioactive material with explosives or explosive devices as well as with so-called "blocking of the object" by a group of criminals were included. The quantity and

activity of the nuclear and radioactive materials were selected in such a manner that they did not provide ionising radiation that would be dangerous to participants in the exercise or observers. Safety conditions planned by CLOR were formally approved by PAA in the form of an administrative decision authorising the use of such materials in the exercise.

To shorten the action from over ten hours in operational time to a few hours in real time and to make it visible to observers a few simplifications were introduced in carrying out of the scenario e.g. :

- all services arrived before starting the exercise and awaited in vicinity until called;
- the abandoned building was located a few hundred metres instead of 30 km from the border crossing in Bobrowniki;
- the time to carry out some procedures was shorted to a minimum, with just a presentation of selected elements, especially when collecting forensic evidence, swipes or environmental samples;
- distances of location of the external police ring were shortened in the second incident so that it could be visible to the observers and which should not be visible in reality;
- distances of location of some equipment were shortened so that the time of operation could be shortened, inter alia of a pyrotechnic barrel.

The in-field exercise was a starting point out of the three phase test to validate the national RITNUM handbook. The first stage was subject to ad hoc summary and analysis carried out by the observers and the practising services just after completion of the exercise in the field. The next two stages were carried out in the stationary laboratories and included laboratory investigations at:

- CLOR – analysis of the seized nuclear and radioactive materials as well as collected environmental samples and swabs;
- ITU – with participation of the CLOR experts, further special analysis of uranium samples used in the exercise and examined at CLOR.

The results of the laboratory investigations were progressively reported by CLOR to the relevant authorities to support them in decision taking process on prosecution and release of the incident site.

Border crossing scene

Border Guard officers of the Border Control Station in Bobrowniki were the chief exercising entity and carrying out the actions of the response system at the border crossing scene. To conduct some activities the Border Guards requested support from other services of the Podlasie Province, in particular from the Customs and the Provincial Sanitary Epidemiological Station (WSSE) as well as from special services, in the frame of the state assistance, which were the 24h National Radiation Emergency Service and CLOR specialists.

The incident occurred at 05:00 hours in operational time on 28th September 2004 at the Border Control Station in Bobrowniki at crossing the border from Poland to Belarus. An officer of Border Guards, when his personal radiation-signalling device was activated, stopped a vehicle suspected of transporting radioactive materials or of radioactive contamination.

The vehicle was isolated, measurements of the radiation dose of the vehicle and driver were made and a control zone was set up. To maintain correct legal procedures, a Customs officer participated in removing customs locks. The vehicle and its load were checked with the use of a dog with a guide and with a special electronic device to detect explosive material. Additionally, a mobile X-ray device was used to look for hidden objects. The examination did not confirm any presence of explosive material or device.

The procedure at the scene site was run in compliance with the evaluation of the hazard carried out both by the Border Guard staff as well as by the supporting services. Waiting for the arrival of the state assistance, the Provincial Sanitary Station from Bialystok was requested to evaluate the hazard to people and the environment.
The National Radiation Emergency Service was involved in a search and recovery of radioactive objects as well as in other radiation related activities like measurement of

radioactive contamination, assessment of hazard, collection of radiological evidence, transport arrangements of a seizure. In effect of a search of the vehicle, a metal object emitting ionising radiation was found and two metal pellets with increased level of radiation were detected hidden in a pallet of transported goods. All the performed activities were recorded for legal reasons by a forensic technician of Border Guards.

The seized items were subject to a preliminary categorization performed by the CLOR specialists. The presence of isotope cobalt-60 was detected in the metal object and of isotope uranium-235 and uranium-238 in two metal pellets. Complete categorization of the seized items was performed at the CLOR premises after the exercise in the field.

Simultaneously to the above action an operational activity had been carried out and during an interrogation the driver disclosed that the material had been collected at abandoned warehouse buildings about 30 km from the border crossing in Bobrowniki from persons who were armed and probably stored there more such materials as well as explosives.

A decision was taken to detain the driver and transform the response action of the incident from a local one to regional becoming the subject of interest of many provincial services. The information was passed on to the all services in the Podlasie Province.

Abandoned buildings scene

The Police, including a Storm Group, Antiterrorist Squad and Forensic Team, of the Podlasie Province were the key provincial entity on the stage in the abandoned buildings scene. Upon an observation of the Border Guard patrols, which were sent to the abandoned place to watch it until the Police arrive, it was settled that the incident site is located in an undeveloped area with probably two armed persons in one of the buildings.

At the Provincial Centre of Crisis Management in Bialystok actions were undertaken compliant with the provincial emergency plan. The Governor of Podlasie ordered to convene the provincial team of emergency response to evaluate the situation and undertake action. Simultaneously, the Governor of Podlasie requested the President of PAA, via the National Radiation Emergency Service, for support with respect to dosimetric surveillance, evaluation of radioactive contamination, reduction of hazard to people and the environment, categorisation of materials which may be seized in the abandoned buildings and transportation of the materials.

In consequence, both the National Emergency team and CLOR specialists participating in the border crossing scene were included in the action in the abandoned buildings. Additionally, a transportation team from the Radioactive Waste Management Plant was sent to make available transport of a seized radioactive material from the both incident sites.

After arrival to the site of the incident, the Action Commander has set up a staff composed of representatives of: Police, National Radiation Emergency Service, Fire Brigades, ambulance service and Chief of the local commune. Having evaluated the forces and means, the Action Commander ordered the Police commander to use the support of the National Emergency Service and CLOR specialists to unblock the building, determine the type of radiation and categorise the seized materials.

Unblocking of the building was done by force by a Police Antiterrorist Squad. Before force was applied, an assumption was made that the conducted mediations did not produce a peaceful solution. The Police Storm Group detained two persons holding firearms and located a suspicious charge. The participants in the action were provided with individual dosimetric devices, which were controlled by the National Emergency Service and CLOR specialists. No hazard was registered.

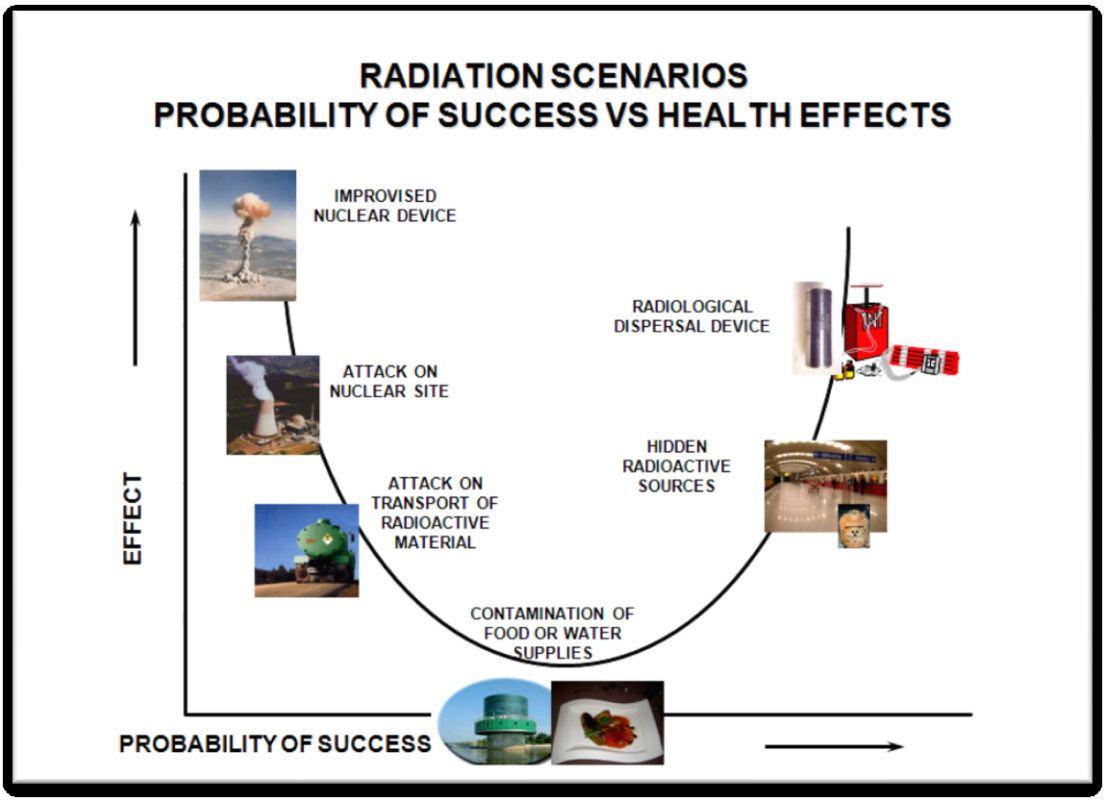
The located charge, which could have proven to be explosive device, was removed by a miner-pyrotechnical team with a robot device having attached a radiation measuring instrument. The charge was placed in a special barrel to be taken for neutralisation at a special site. In addition, the Police used a pyrotechnician with a dog to check the site for the presence of explosives. No explosives were detected, however a hiding place with radioactive materials was detected due to the activation of a radiation-signalling device, held by the pyrotechnician.
The National Emergency Service team, protected itself against potential contamination with protective clothing (overalls, helmets, rubber shoes, rubber gloves and gas masks), checked external contamination of the participants after each action and assessed working conditions before actions. The team was also subject to contamination control carried out by the CLOR specialists. Minimising hazard was the basic rule of the operation. For that reason, the Police Forensic Team action was preceded by the hazard and working conditions evaluation and controlled during the whole operation.

The Police Forensic Team marked hot places, identified and collected traces of classic forensic evidence. The National Emergency Service collected swipes for radiological evidence. To avoid contamination of the evidence or its damage the two services worked together. The material found in the hiding place was a metal object and gray powder in a glass container. The presence of isotope cobalt-60 was detected in the metal object and of isotope uranium-235 and uranium-238 in the powder.
CLOR specialists performed a preliminary categorisation of the seized items on the scene site. Measurements were continued at the CLOR premises to perform categorization with the use of more advanced nuclear forensic tools than those installed at the Mobile Spectrometric Laboratory being at the disposal of the CLOR experts.
In order to evaluate contamination inside and around the building CLOR specialists collected environmental samples, which included a grain sample and two samples of soil. The area was checked with a Mobile Spectrometric Laboratory for the presence of contamination and other hidden or abandoned radioactive sources. No other sources or the presence of contamination or external contamination of participants in the action were detected.

Summary of the exercise

The demonstration exercise was a great experience for the host of the event, the organisers, the authorities of Podlasie, the observers, media, protecting services and first of all for the

services who were the main players of the exercise. The course of the exercise was analysed and conclusions drawn to improve the procedures in force by the authorities and services of Podlasie as well as of the country.
The exercise revealed matters that require analysis and better solutions so that similar situations can be avoided in the future, e.g. better personal protection for persons participating in the response system to incidents of illicit trafficking in radioactive materials or adjusting emergency plans of specific services in relation to their own potential.
The exercise was continued at the CLOR premises and included laboratory investigations of the seized radioactive materials and collected environmental samples and swabs. The results of the performed analyses were submitted by CLOR to the President of PAA in time-frame prescribed in the RITNUM handbook, that is, within the period of 48 hours and one month.
Further analysis of nuclear materials used in the exercise, which were the low enriched uranium pellets and depleted uranium powder, were held at ITU jointly with CLOR scientists in March 2005. A joint analysis of nuclear materials contributed to determine the producer of pellets and allowed to learn about a practical dispatch of nuclear materials for tests in a laboratory abroad and the procedure of preparing expertise for criminal investigation bodies.
The experience gathered from the exercise was used to introduce amendments to the "Handbook for the response to illicit trafficking or inadvertent movement of nuclear and radioactive materials in Poland", which the latest version No.07 was issued in May 2005 by CLOR.



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

M. Suplińska, A. Adamczyk

DEPARTMENT OF RADIATION HYGIENE

Studies on the distribution of ^{137}Cs, $^{239,240}Pu$, and ^{238}Pu in bottom sediments from the Southern Baltic Sea are performed by CLOR in the frame of Monitoring Program of Radioactive Substances in the Baltic Sea, coordinated by Helsinki Commission. In last two years, studies on distribution of ^{90}Sr in bottom sediments have been included to the monitoring program.

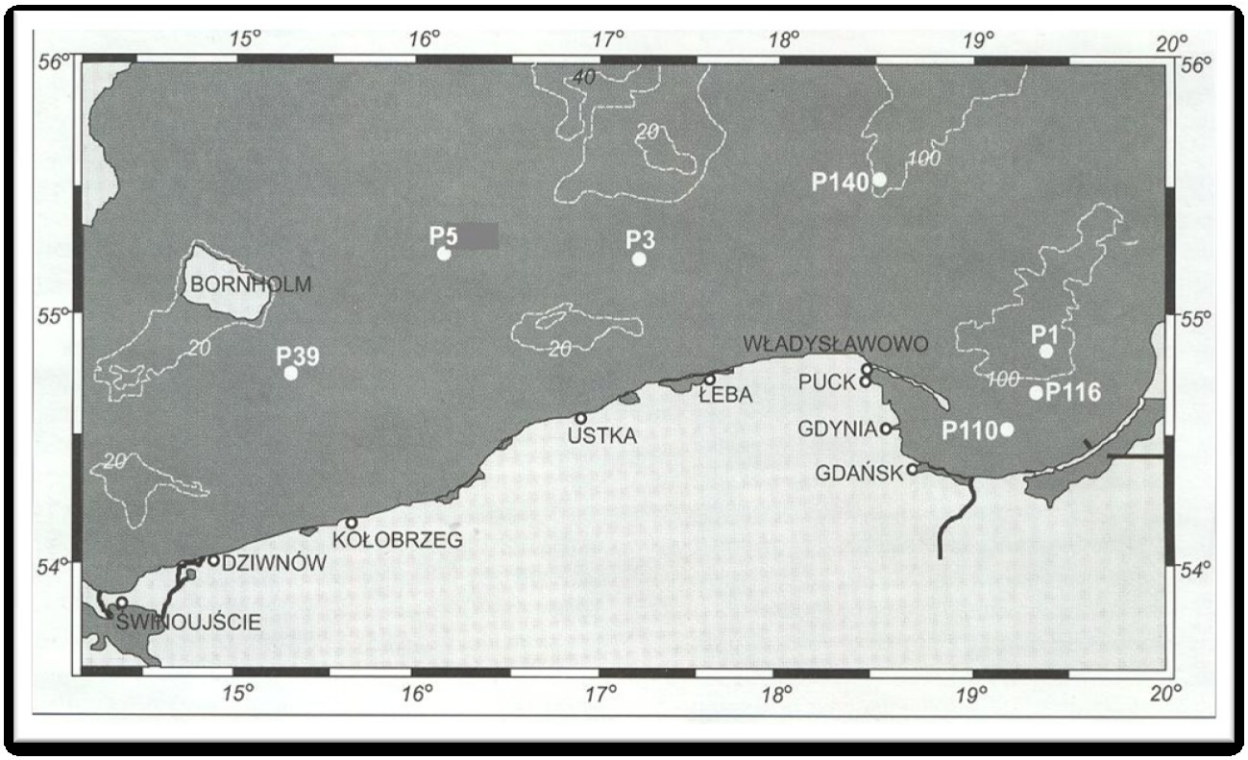


Figure 1. Sediment sampling stations in HELCOM MORS program.

The sources of radioactive contaminations in the Baltic Sea are as follow: direct atmospheric fallout from nuclear weapons tests and from the Chernobyl accident, run-off from the land into sea via rivers, hydrodynamic transport from western European nuclear reprocessing plants direct discharges into the sea and from nuclear installation in the Baltic Sea region [1]. Bottom sediment core samples were collected from six locations of southern part of the Baltic Sea, once a year in June (Fig. 1).

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 its short-lived daughter nuclide ^{90}Y preceded 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, Risø National Laboratory and National Atomic Energy Agency, Warsaw.
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 2004 and 2005 ranged from 185 Bq kg$^{-1}_{dw}$ to 291 Bq kg$^{-1}_{dw}$ (Fig. 2). In the sediments from Bornholm Basin, the ^{137}Cs concentrations were evidently lower (67-94 Bq kg$^{-1}_{dw}$).

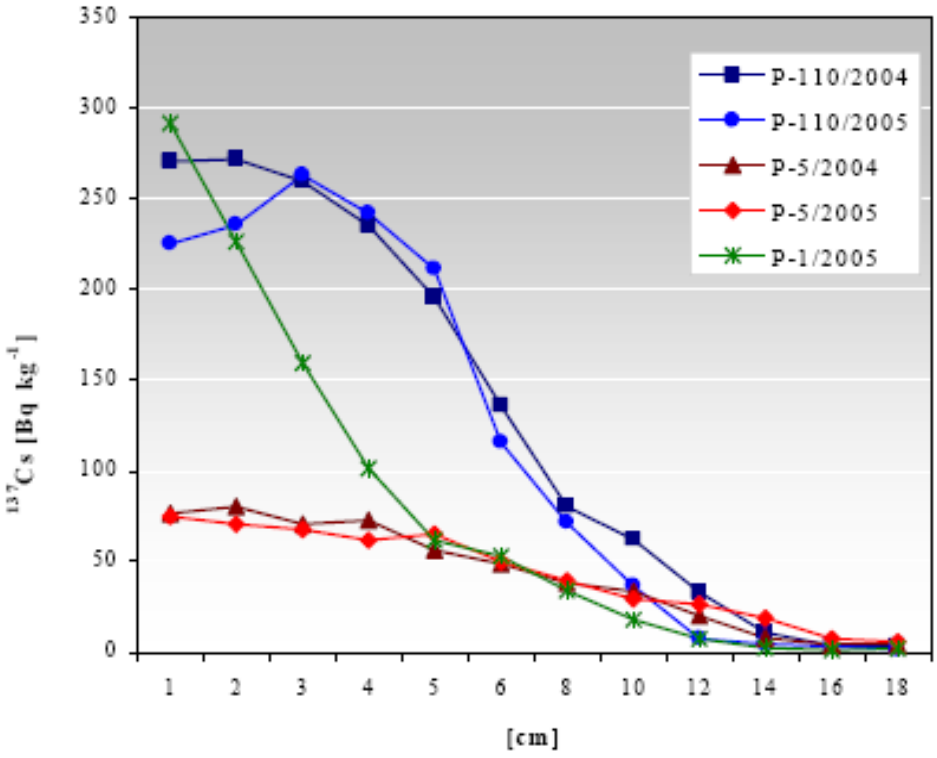


Figure 2. Vertical distribution of ^{137}Cs in bottom sediments from Gulf of Gdansk (P-110), Gdansk Deep (P-1) and Bornholm Deep (P-5), 2004 and 2005.

In the location P-110 (Gulf of Gdansk) patterns of ^{137}Cs vertical distribution show the maximum of ^{137}Cs concentration in the layer from 2 to 3 cm in 2005. In this region ^{137}Cs vertical distribution from several locations indicate that the maximum of its concentration observed earlier in the layer of 0-1 cm, was moved to the deeper ones. Similar process was also found in Gulf of Finland [3].
The average deposition of ^{137}Cs, ranged from 1.40 kBq m^{-2} in Bornholm Deep to 4.93Bq m^{-2} in Gulf of Gdansk (Fig.3).

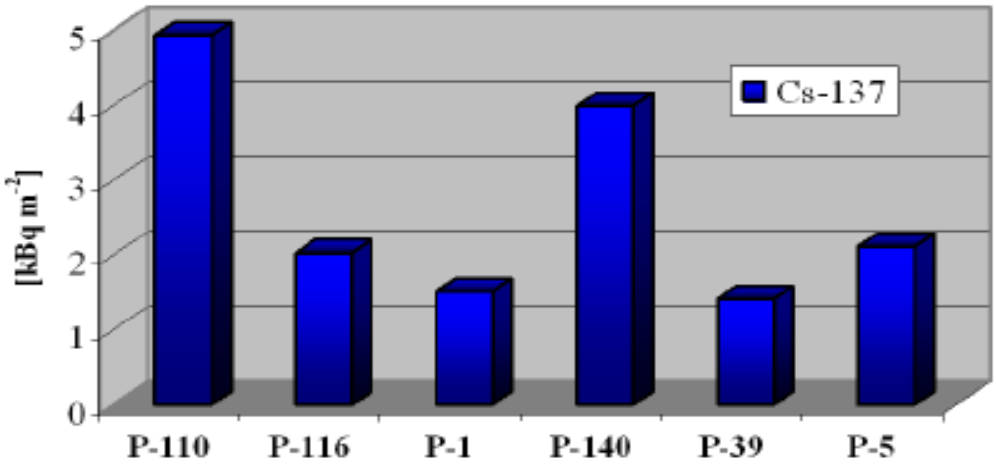


Figure 3. Deposition of ^{137}Cs in Southern Baltic Sea bottom sediments, 2004 and 2005

Similarly as for ^{137}Cs the highest concentrations of plutonium in bottom sediments (Fig. 4) were found in Gulf of Gdansk, however, the maxima of ^{238}Pu and ^{239,240}Pu were found always in deeper layers. In core samples from station P-110, taken in 2004 and 2005 maxima of ^{239,240}Pu concentrations: 10.4±0.36 Bq kg^{-1}_{dw} and 10.5±0.48 Bq kg^{-1}_{dw}, respectively were observed in the depth of 8-10 cm. In the same layer there were also observed the highest concentrations of ^{238}Pu (0.34±0,03 Bq kg^{-1}_{dw} 0.41±0,06 Bq kg^{-1}_{dw}). In P-5 (Bornholm Deep) and P-1 (Gdansk Deep) to the depth of 8 cm the concentrations of plutonium were almost uniform along the profile. In P-5 the average concentrations of ^{239,240}Pu and ^{238}Pu were 1.02±0.17 Bq kg^{-1}_{dw} and 0.035±0.008 Bq kg^{-1}_{dw}, respectively. In P-1 these concentrations were 2.57±0.33 Bq kg^{-1}_{dw} and 0.051±0.019 Bq kg^{-1}_{dw}.

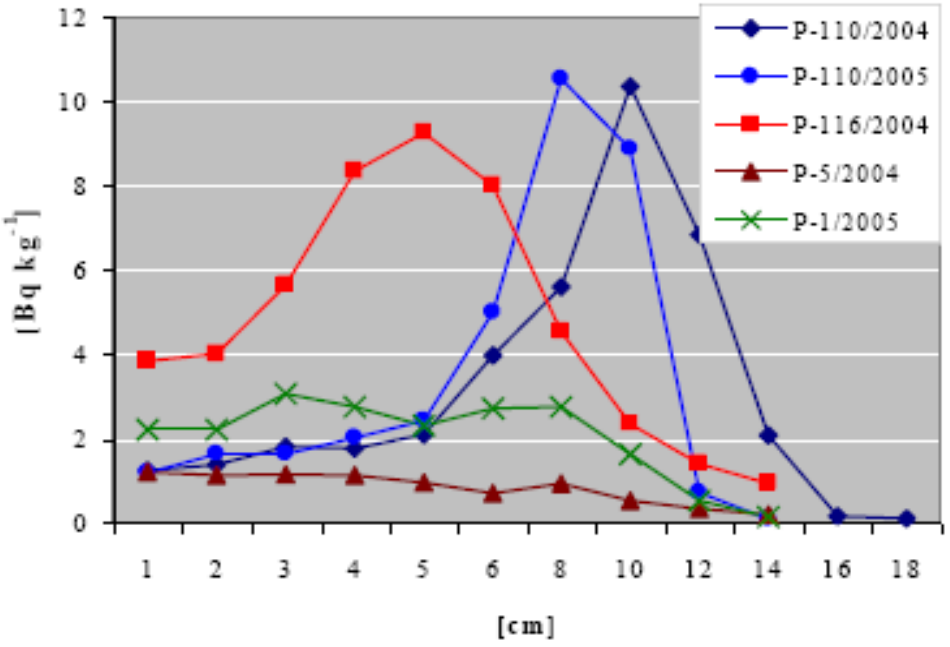


Figure 4. Vertical distribution of ^{239,240}Pu in bottom sediment from Gulf of Gdansk (P-110 and P-116) Gdansk Deep (P-1) and Bornholm Deep (P-5), 2004 and 2005

The highest concentrations of plutonium observed in deeper layers of the sediment cores indicate global fallout as the main source of plutonium in Southern Baltic Sea. The ratios of ^{238}Pu to ^{239,240}Pu in majority of samples ranged from 0.03 to 0.05, being similar to the ratios found for the cumulative deposit from global fallout after the nuclear weapons tests [4].
Deposition of ^{239,240}Pu ranged from 0.021 kBq m^{-2} in Bornholm Basin (P-5) to 0.265 kBq m^{-2} in Gulf of Gdansk (P-110) – Fig. 5. Similar values were found in previous years [5].

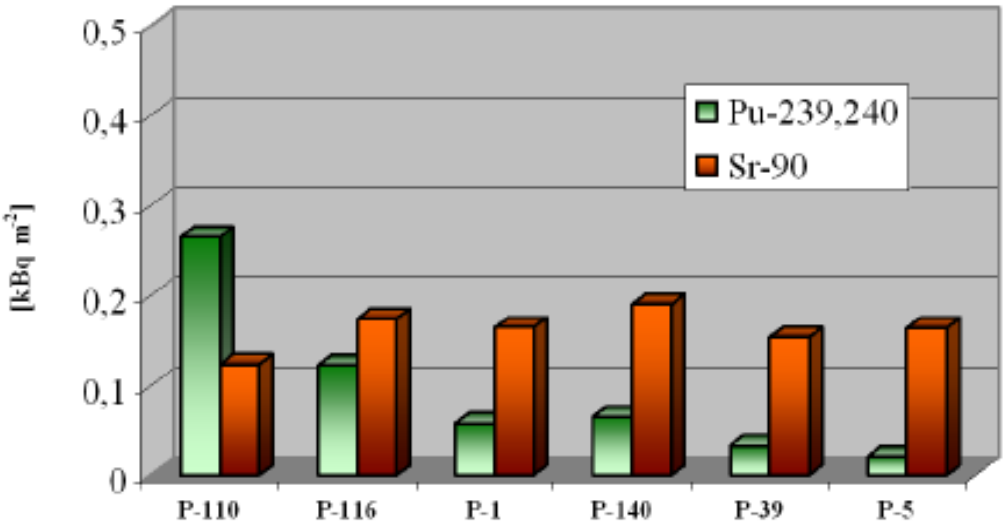


Figure 5. Deposition of ^{239,240}Pu and ^{90}Sr in the Southern Baltic Sea, 2002 and 2005

In 2004 and 2005 determinations of ^{90}Sr were performed in the open sea area. Deposition of ^{90}Sr, ranged from 0,14 kBq m^{-2} to 0,19 kBq m^{-2} and was similar in whole Southern Baltic Sea (Fig. 5). Concentrations of ^{90}Sr in bottom sediments in four examined sub-regions of open sea area were uniform along the profiles and ranged from 2.85 Bq kg^{-1} to 4.48 Bq kg^{-1}. However, strontium-90 distribution in Gulf of Gdansk indicates two marked sources of contamination: fallout from the Chernobyl accident and long-term fallout from nuclear weapon tests [6].
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 - 26.8±0.59 Bq kg$^{-1}_{dw}$, was found in Gulf of Gdansk and the highest - 49.5±3.35 Bq kg$^{-1}_{dw}$ in the Bornholm Deep.

Conclusions

1. 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 indicate that ^{137}Cs is still present in new-formed layers of the bottom sediments.
2. Deposition of ^{90}Sr, similar in whole Southern Baltic Sea, is 20-50 times lower comparing with deposition of ^{137}Cs.
3. 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.

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2.6 MONITORING ^{137}Cs CONCENTRATION IN SOIL, 2004-2006

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DOSIMETRY DEPARTMENT

The investigations of radioactive contaminations of soil are performed in the frame of Polish National Environmental Monitoring System. The soil sampling is carried out at the premises of the network of meteorological stations of the Institute of Meteorology and Water Management.

The results of the measurements of soil samples 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 sampling points as circle cartodiagrams or extrapolates results of the point measurements to the whole area of Poland.
In the 254 points soil samples were collected to determine concentration of the caesium isotopes and natural radionuclides by means of the spectrometric analysis.

In each point the samples of soil were taken in October 2004 with a knife-edge pipe of 7 cm 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 value of ^{137}Cs deposition density in Poland is 2.54 kBq·m^{-2}, ranging from 0.11 to 23.68 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 2004.

The mean values of concentrations of natural radionuclides in soil in Poland are: for ^{226}Ra - 25.0, for ^{228}Ac - 23.4 and for ^{40}K – 408 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: 116.0 Bq·kg^{-1} of ^{226}Ra and 82.3 Bq·kg^{-1} of ^{228}Ac.

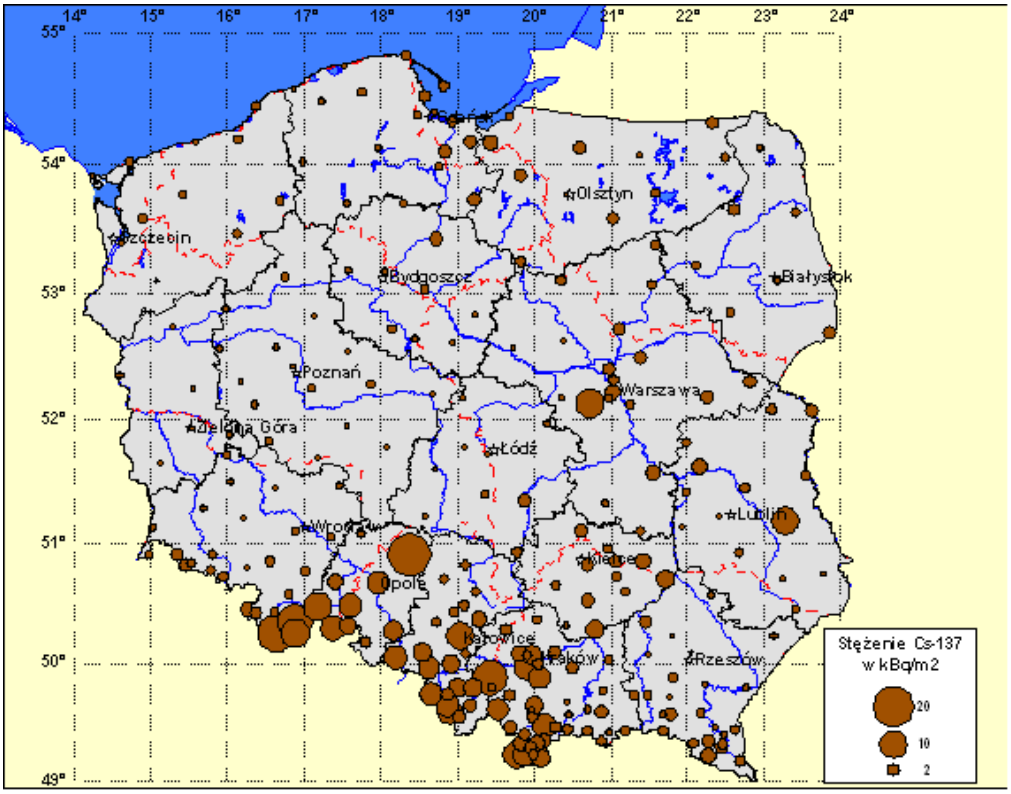

Figure 1. ^{137}Cs deposition in the 10 cm surface layer of soil in Poland, in October 2004

References:

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ACKNOWLEDGEMENT

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

2.7 CAESIUM-137 RADIUM-226 AND POTASIUM-40 IN THE SOUTHERN BALTIC SEA FISH FLESH*)

M. Suplińska, A. Adamczyk

RADIATION HYGIENE DEPARTMENT

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. Fish samples were collected from Southern Baltic Sea in the years 2004 and 2005. 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.

Activity concentrations of ^{137}Cs in fish flesh ranged from 5.04 Bq kg$^{-1}_{ww}$ to 10.0 Bq kg$^{-1}_{ww}$. Concentration of ^{137}Cs in fish flesh, similar in sub-regions of Southern Baltic Sea differs a little with fish species. The highest activity concentrations of ^{137}Cs were found in flesh of cod. In other species concentrations of ^{137}Cs was about 15% lower. The average concentrations of ^{40}K, ^{137}Cs and ^{226}Ra in fish flesh, depending on species, in years 2004 and 2005 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 lenght [cm]	^{137}Cs [Bq kg$^{-1}_{ww}$]	^{226}Ra [Bq kg$^{-1}_{ww}$]	^{40}K [Bq kg$^{-1}_{ww}$]
Herring	2004	15-25	7.13±0.42	0.023±0.001	121±7.73
	2005	16-25	6.40±0.79	0.030±0.003	122±4.19
Sprat**	2004	9-14	6.23±0.56	0.068±0.004	109±7.19
	2005	8-13	6.39±0.45	0.075±0.007	104±4.55
Plaice	2004	19-32	6.13±0.53	0.036±0.006	93.6±3.92
	2005	23-30	6.69±1.20	0.052±0.008	96.4±5.93
Cod	2004	20-37	7.59±1.27	0.064±0.023	122±7.62
	2005	28-55	7.69±0.78	0.068±0.010	117±4.78

** whole fish

The average concentrations of ^{137}Cs determined in particular species in years 2004 and 2005 were very similar. The highest average concentration of ^{137}Cs, was found in cod samples - 7.64 Bq kg$^{-1}_{ww}$ and in remaining fish species this concentration was equal to 6.50±0.36 Bq kg$^{-1}_{ww}$. The activity concentrations of ^{226}Ra in cod samples (0.064-0.068 Bq kg$^{-1}_{ww}$) were about two times higher than in herring and plaice (0.023-0.030 Bq kg$^{-1}_{ww}$). Activity concentration of ^{40}K in four fish species ranged from 93.65 Bq kg$^{-1}_{ww}$ to 122 Bq kg$^{-1}_{ww}$.

In the region of Southern Baltic Sea, maximum concentration of ^{137}Cs in fish flesh (14.4±2.9 Bq kg$^{-1}_{ww}$) [1] was observed in 1989-1991 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 2004-2005. The average value for all species (6.78±0.61 kg$^{-1}_{ww}$) was 53% 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 45.1 Bq m^{-3} in 2004 [3].

Temporal changes of radiocaesium concentrations in fish observed in the period of 1985-2005 were presented in Fig. 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 about 16.4 years.

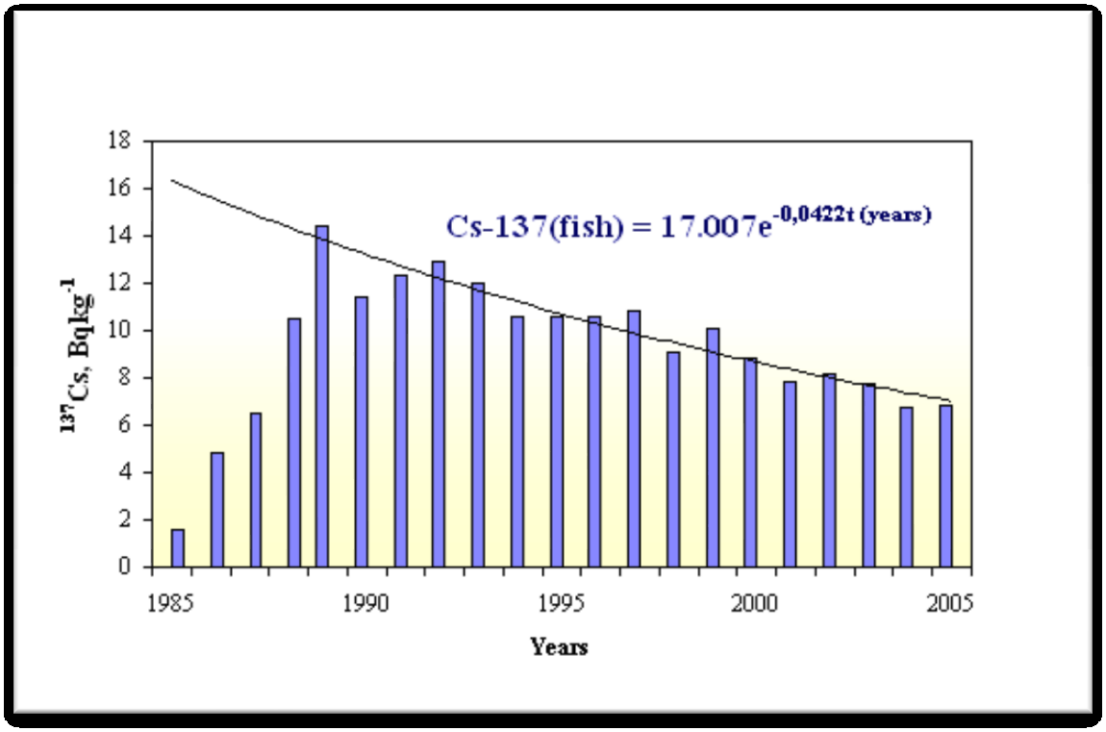

Figure 1. Temporal changes of 137Cs concentrations in Southern Baltic Sea fish flesh

Taking into account average ^{137}Cs activity concentrations obtained in 2004-2005, the average committed effective dose due to yearly intake from fish consumption (4.8 kg) was calculated as 0.42 µSv $year^{-1}$. In the same time, the average ^{40}K concentration in fish from the Baltic Sea (111 Bq kg^{-1}_{ww}) corresponds to a dose of 3.20 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 natural ^{40}K

Table 2. Average committed effective dose due to yearly intake from fish consumption in Poland, 2004-2005

	^{40}K	^{137}Cs	^{226}Ra
Activity concentration [Bq kg^{-1}_{ww}]	111	6.80	0.052
Dose coefficient [µSv Bq^{-1}]	0.006	0.013	0.28
Dose [µSv/year]	3.20	0.42	0.07

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ACKNOWLEDGEMENT

**)* *This work was performed in frame of Helsinki Commissiom, sponsored by National Atomic Energy Agency, Warsaw.*

2.8 MONITORING OF RADIOACTIVE CONTAMINATION OF SURFACE WATERS AND BOTTOM SEDIMENTS

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RADIATION HYGIENE DEPARTMENT

Monitoring of ^{137}Cs and ^{90}Sr in surface waters and of ^{137}Cs, ^{238}Pu and ^{239}Pu in bottom sediments has been conducted in the years 2004-2005. Samples were collected twice a year (in spring and autumn) from the following rivers: Vistula (5 sampling points) and its tributary Narew and Bug, Odra (4 sampling points) and its tributary Warta. Samples were also collected from six lakes localized in main lake districts of the country. Locations of the sampling points are given in Fig. 1.

^{137}Cs and ^{90}Sr in water and ^{238}Pu and ^{239,240}Pu in bottom sediments were determined radiochemically [1-3], whereas for determination of ^{137}Cs in bottom sediments gamma spectrometry was used. Reliability of the applied methods was checked in the inter-calibration exercises organized by the National Atomic Agency.

Table 1 presents average activity concentrations of ^{137}Cs and ^{90}Sr in surface waters in the years 2004 and 2005 and ^{90}Sr :^{137}Cs ratios. The activity concentrations of ^{137}Cs in water ranged from 1.77 to 7.99 mBq/l in 2004 and from 1.40 to 7.86 mBq/l in 2005. These concentrations were lower than the activity concentrations of ^{90}Sr which ranged from 2.25 to 10.7 mBq/l in 2004 and from 2.49 to 11.8 mBq/l in 2005.

Figure 1. Sampling locations for water and bottom sediments

Table 1. Average activity concentrations of ^{137}Cs and ^{90}Sr in surface waters and ^{90}Sr:^{137}Cs ratios in 2004 and 2005, mBq L^{-1}

River or lake (l)	Sampling location	2004			2005		
		^{137}Cs	^{90}Sr	$\frac{^{90}Sr}{^{137}Cs}$	^{137}Cs	^{90}Sr	$\frac{^{90}Sr}{^{137}Cs}$
Vistula	*Kraków*	3.95±0.67[a)]	4.66±0.66	1.18	3.45±0.59	4.43±0.54	1.28
	Annopol	1.77±0.38	3.99±0.60	2.26	1.40±0.32	3.70±0.43	2.65
	Warszawa	2.29±0.36	5.05±0.72	2.21	2.10±0.40	4.38±0.60	2.09
	Płock	1.89±0.33	3.83±0.59	2.03	2.16±0.45	4.06±0.72	1.88
	Kiezmark	3.55±0.58	4.44±0.66	1.25	2.19±0.40	4.99±0.62	2.28
Narew	Pułtusk	2.48±0.37	5.07±0.69	1.33	2.27±0.44	4.27±0.55	1.88
Bug	Wyszków	2.09±0.35	3.87±0.62	2.04	1.71±0.37	4.05±0.52	2.38
Odra	Chałupki	6.26±0.93	8.32±0.93	1.34	5.47±0.76	4.65±0.53	0.85
	Wrocław	6.54±0.98	8.75±0.94	1.40	3.42±0.57	4.36±0.50	1.28
	Głogów	5.08±0.81	7.11±0.81	1.70	3.74±0.57	5.61±0.65	1.50
	Krajnik	2.40±0.49	4.06±0.62	1.72	1.83±0.39	3.51±0.41	1.92
Warta	Poznań	2.28±0.45	3.92±0.61	1.76	2.44±0.39	4.05±0.50	1.66
Wigry (l)	St.Folwark	2.86±0.44	2.25±0.44	0.79	1.98±0.40	2.49±0.45	1.26
Wadąg (l)	Myki	1.93±0.41	3.88±0.60	2.01	2.32±0.40	3.41±0.50	1.47
Partęczyny (l)		3.46±0.58	4.56±0.78	1.32	2.97±0.47	3.22±0.61	1.09
Drawsko (l)	St.Drawsko	2.41±0.47	4.25±0.70	1.76	1.60±0.35	3.66±0.41	2.29
Niesłysz (l)	Niesulice	2.45±0.51	3.46±0.56	1.41	2.87±0.59	3.40±0.44	1.18
Rogóźno (l)	Rogóźno	7.99±1.07	10.7±1.21	1.34	7.86±0.92	11.8±0.93	1.50

[a)] Value ± combined uncertainty (CU) at confidence level of 95%.

The $^{90}Sr/^{137}Cs$ ratios indicated that in 2004 the concentrations of ^{90}Sr in rivers were 1.18 to 2.26 times higher than those of ^{137}Cs. In the lakes, except Wigry, concentrations of ^{90}Sr were from 1.32 to 2.01 times higher than those of ^{137}Cs. In 2005 only in water collected in Chałupki (Odra) concentration of ^{90}Sr was lower than that of ^{137}Cs (0.85), whereas for other waters from rivers and lakes the ratio of $^{90}Sr/^{137}Cs$ ranged from 1.09 to 2.65.

In terrestrial environment strontium cations have higher mobility than cesium cations and are easier leached from soil with water to rivers and lakes. ^{137}Cs is strongly bound with soil particles and particularly with clay. In consequence the level of ^{90}Sr increases in surface waters. In terrestrial ecosystems the concentrations of ^{137}Cs is many times higher than that of ^{90}Sr. Nuclear weapons tests have introduced to the Northern Hemisphere ^{137}Cs in amounts 1.7 times higher than of ^{90}Sr [4].

The release of ^{137}Cs from the damaged nuclear reactor in Chernobyl was about 8 times higher than that of ^{90}Sr [5].

Activity concentrations of ^{137}Cs and ^{90}Sr in waters slightly decreased in 2005 in comparison to 2004. The average concentrations of ^{137}Cs in the Vistula catchment area were about 1.7 times lower than in the Odra catchment area, and about 1.4 times lower than in waters of the lakes (Table 2). In case of ^{90}Sr concentrations the differences between catchment areas were smaller. The average concentrations in the Odra catchment area in 2004 were 1.6 times higher than in the Vistula catchment area and 1.2 times higher than in the lakes catchment area. In 2005 concentrations of ^{90}Sr remained on the same level.

Table 2. Mean activity concentrations of 137Cs and 90Sr in waters of Vistula, Odra and lakes catchment areas in 2004 and 2005

Catchment area	^{137}Cs, mBq L^{-1}		^{90}Sr, mBq L^{-1}	
	2004	2005	2004	2005
Vistula	(14)[a]	(14)	(14)	(14)
	2.57 ± 0.85[b]	2.18 ± 0.64	4.23 ± 0.44	4.27 ± 0.40
Odra	(10)	(10)	(10)	(10)
	4.51 ± 2.08	3.38 ± 1.39	6.48 ± 2.36	4.43 ± 0.78
Lakes	(12)	(12)	(12)	(12)
	3.52 ± 2.85	3.27 ± 2.31	4.85 ± 2.98	4.65 ± 3.50
Mean	(36)	(36)	(36)	(36)
	3.45 ± 2.01	2.87 ± 1.58	5.12 ± 2.17	4.44 ± 1.96

[a] Number of analyzed samples [b] Mean ± SD

^{137}Cs and ^{90}Sr in waters along the Vistula river and the Odra river in 2004 and 2005 are presented in Fig. 2 and Fig. 3, respectively. In Vistula the level of both radionuclides was rather stable and did not depend much on the location of sampling points. In 2004 in the upper and middle Odra the level of ^{137}Cs and ^{90}Sr in waters was similar and further it decreased, being the lowest in Krajnik.
Activity concentrations of ^{137}Cs and ^{90}Sr in five of six lakes are similar and only in the Rogóżno lake the level of the radionuclides studied was distinctly higher. Higher level in the

latter lake might be ascribed to a low water exchange. This lake is small and has small inflow and small outflow.

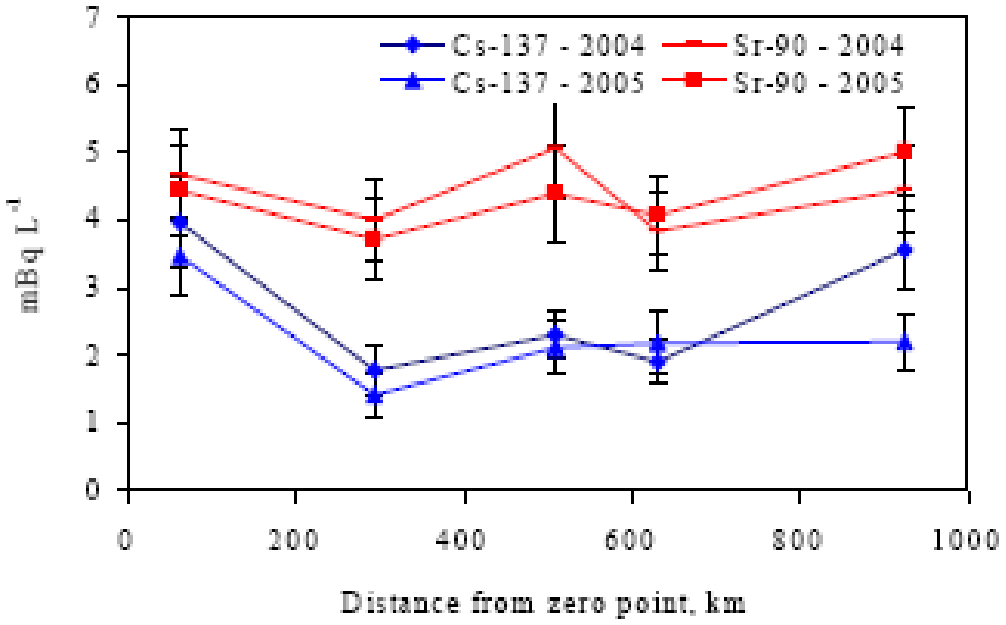

Figure 2. Activity concentrations of 137Cs and 90Sr in water along the Vistula river in 2004 and 2005. Bars show Combined Uncertainty (CU) at confidence level of 95%. Zero point is 130 km from the sources of the Vistula river.

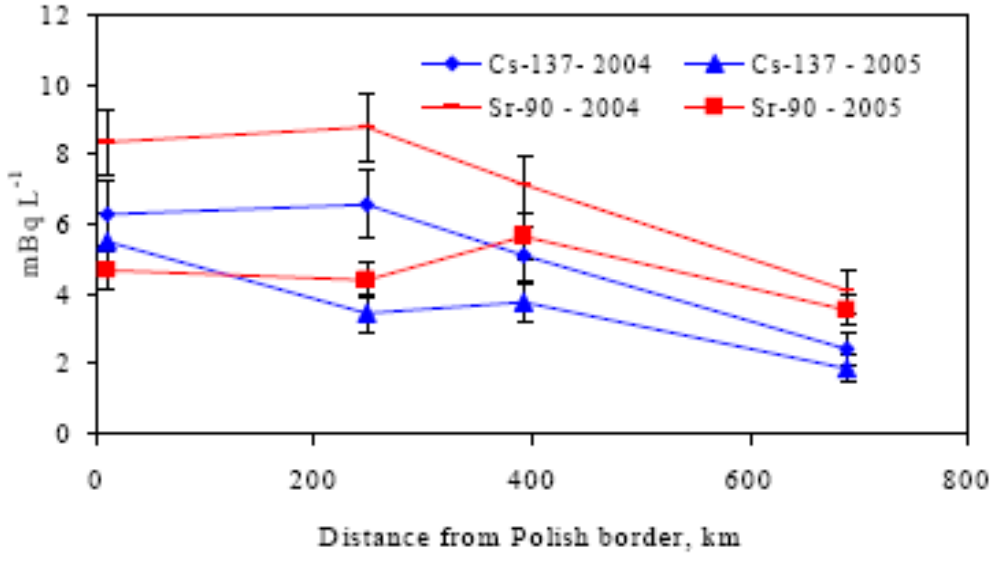

Figure 3. Activity concentrations of 137Cs and 90Sr in water along the Odra river in 2004 and 2005. Bars show CU at confidence level of 95%.

Average activity concentrations of ^{137}Cs and ^{239,240}Pu in bottom sediments collected from rivers and lakes are given in Table 3. In 2004 annul activity concentrations of ^{137}Cs in bottom sediments of rivers ranged from 0.89 Bq kg^{-1}dw in Płock (Vistula) to 24.3 Bq kg^{-1}dw in Chałupki (Odra), whereas in lakes they varied from 5.82 Bq kg^{-1}dw in Drawsko to 35.4 Bq kg^{-1}dw in Niesulice. In 2005 in the majority of samples the level of ^{137}Cs decreased, being in rivers from 0.54 Bq kg^{-1}dw in Płock to 27.8 Bq kg^{-1}dw in Głogów (Odra). In lakes, similarly as in the previous year, ranges of average activity concentration of this radionuclide were not so wide as in rivers, being from 6.52 Bq kg^{-1}dw in Drawsko to 14.8 Bq kg^{-1}dw in Rogóźno.

Similar as for ^{137}Cs in water, activity concentrations of this radionuclide in sediments were the lowest in the Vistula catchment area. In the Odra river catchment area concentration of ^{137}Cs was about three times higher in comparison to Vistula catchment area and about four times higher in lakes (Table 4). The average concentration of ^{137}Cs was 1.7 times lower in 2005 than in 2004.

Table 3. Average activity concentrations of ^{137}Cs and ^{239,240}Pu in bottom sediments of rivers and lakes in 2004 and 2005

River or lake (l)	Sampling location	2004		2005	
		^{137}Cs Bq kg^{-1} dw	^{239,240}Pu mBq kg^{-1} dw	^{137}Cs Bq kg^{-1} dw	^{239,240}Pu mBq kg^{-1} dw
Vistula	*Kraków*	7.10±0.67[a)]	28.2±5.31[b)]	2.87±0.79[a)]	12.7±6.39[b)]
	Annopol	2.33±0.30	21.9±3.57	1.28±0.24	40.6±12.2
	Warszawa	6.79±0.64	13.7±3.93	1.78±0.22	21.2±7.23
	Płock	0.89±0.12	9.44±2.96	0.54±0.16	12.6±5.45
	Kiezmark	1.53±0.16	7.12±4.18	1.77±0.22	12.0±3.88
Narew	Pułtusk	9.08±0.78	9.36±3.54	9.68±0.99	10.3±3.59
Bug	Wyszków	5.18±0.50	24.4±7.34	1.64±0.25	23.7±6.50
Odra	Chałupki	24.3±2.94	76.8±7.75	4.02±0.46	22.4±8.54
	Wrocław	23.9±2.09	125±14.3	5.26±0.68	36.6±17.6
	Głogów	16.8±1.59	34.6±4.49	27.8±2.99	46.8±13.9
	Krajnik	1.06±0.14	6.87±2.79	1.73±0.52	26.1±10.3
Warta	Poznań	1.69±0.22	7.42±2.82	5.19±0.66	25.7±11.7
Wigry (l)	St. Folwark	12.1±0.94	15.4±6.63	6.99±0.52	22.6±7.63
Wadąg (l)	Myki	17.2±0.52	14.4±4.02	9.48±1.07	16.2±7.89
Partęczyny (l)		11.0±3.22	23.5±7.88	9.80±0.89	9.50±5.88
Drawsko (l)	St.Drawsko	5.82±1.08	15.5±9.61	6.52±0.56	22.6±13.1
Niesłysz (l)	Niesulice	35.4±1.46	355±24.5	11.6±2.82	57.2±19.6
Rogóźno (l)	Rogóźno	34.3±2.89	29.1±5.50	14.8±2.39	27.9±9.77

[a)] Value ± combined uncertainty at confidence level of 95%.

[b)] Value ± combined uncertainty at confidence level of 68%.

Table 4. Mean activity concentrations of 137Cs and 239,240Pu in bottom sediments of Vistula, Odra and lakes catchment areas in 2004 and 2005

Catchment area	^{137}Cs, Bq/kg		^{239,240}Pu, mBq/kg	
	2004	2005	2004	2005
Vistula	(14)[a]	(14)	(14)	(14)
	4.70 ± 3.16[b]	2.80 ± 0.13	16.3 ± 8.42	19.0 ± 10.8
Odra	(10)	(10)	(10)	(10)
	13.6 ± 11.5	8.78 ± 3.28	50.1 ± 50.6	31.4 ± 10.0
Lakes	(12)	(12)	(12)	(12)
	19.3 ± 12.6	9.86 ± 0.20	75.5 ± 137	26.0 ± 16.5
Mean	(36)	(36)	(36)	(36)
	12.0 ± 11.1	6.97 ± 0.82	45.4 ± 82.6	24.8 ± 13.1

[a] Number of analyzed samples
[b] Mean ± SD

Activity and Odra rivers are presented in Fig. 4 and Fig. 5, respectively. In samples collected in 2004 in Kraków and Warszawa there was observed the highest level of ^{137}Cs. In other samples from 2004 and in all the samples collected in 2005 concentrations did not differ significantly. In the Odra river a high level of ^{137}Cs was found in Chałupki, Wrocław and Głogów in 2004 and only in Głogów in 2005.

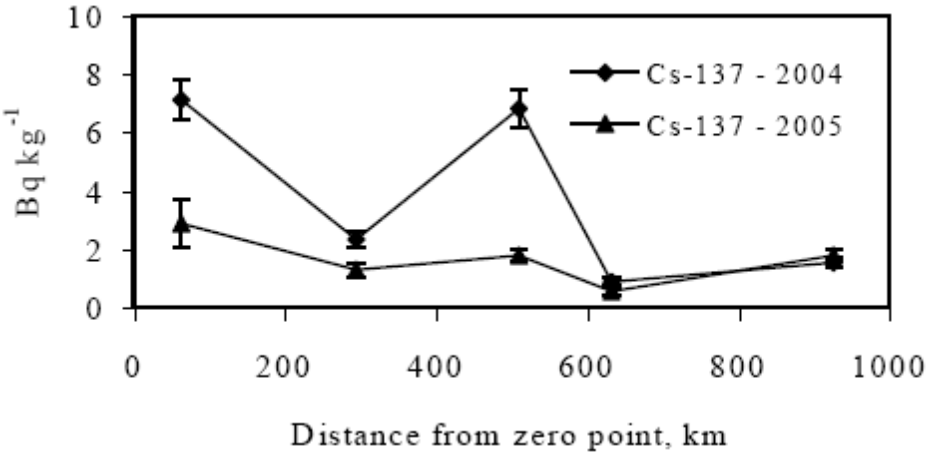

Fig. 4. Activity concentrations of ^{137}Cs in bottom sediments along the Vistula river in 2004 and 2005. Bars show CU at confidence level of 95%.

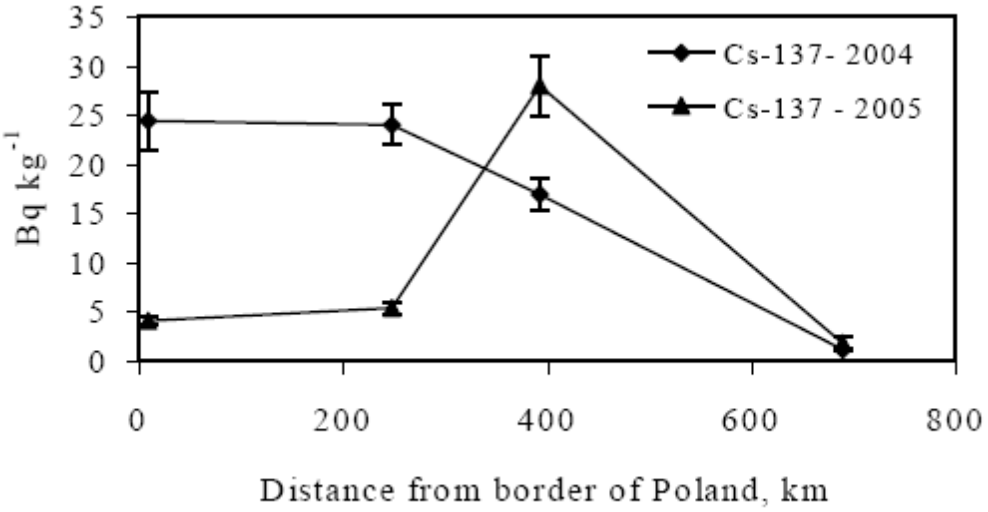

Figure 5. Activity concentrations of 137Cs in bottom sediments along the Odra river in 2004 and 2005. Bars show CU at confidence level of 95%.

Presently, ^{137}Cs existing in terrestrial and aquatic ecosystems has originated mainly from the deposition after the Chernobyl accident. Monitoring of ^{137}Cs content in bottom sediments of rivers and lakes was conducted in the period of 1994–2001 [6, 7]. During this time the concentration of ^{137}Cs in particular locations fluctuated. Concentrations of ^{137}Cs during the period studied decreased due to the decay of this isotope, however, the pattern of its geographical distribution has not markedly changed.

Average annual concentrations of ^{239,240}Pu in bottom sediments in 2004 and 2005 were in the range from 6.87 to 355 mBq kg^{-1} (Table 3, Fig. 6 and 7). Elevated concentrations were found in the upper and middle Odra, in Annopol (Vistula) and in lake Niesulice.

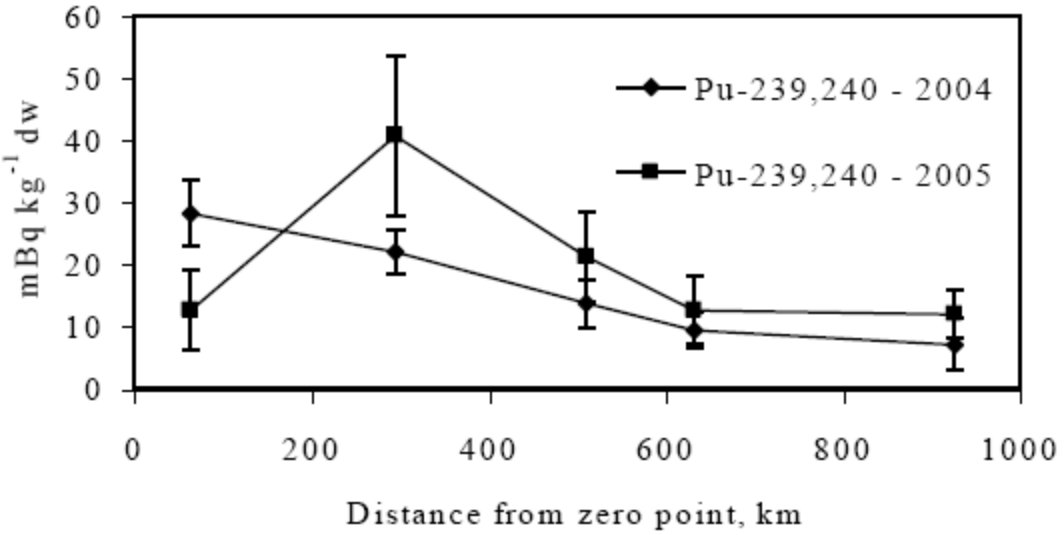

Fig. 7. Activity concentrations of ^{239,240}Pu in bottom sediments along the Odra river in 2004 and 2005. Bars show CU at confidence level of 68%.

The results of ^{137}Cs and ^{90}Sr determinations in water and of ^{137}Cs and plutonium in bottom sediments have indicated that no additional releases of these radioisotopes into the aquatic ecosystems in Poland took place in 2004 and 2005.

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ACKNOWLEDGEMENT

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

2.9 RADIOLOGICAL SITUATION IN SURROUNDINGS OF WASTES REPOSITORY IN RÓŻAN

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+DEPARTMENT OF RADIATION HYGIENE

***DOSIMETRY DEPARTMENT**

The Central Laboratory for Radiological Protection performs the measurements of levels of environmental radioactivity in the surroundings of KSOP-Różan (National Repository of Radioactive Wastes in Różan), starting from 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:

1. river water (r. Narew) - twice a year from the two control points,
2. well water - twice a year from the two control points,
3. spring water - twice a year from the tree control points,
4. ground water - three times a year from the eight control points,
5. soil – twice a year from the five control points,
6. grass - twice a year from the five control points,
7. corns - once a year from the four control points,
8. atmospheric aerosol - twice a year from the two points (on the leeward of KSOP-Różan)

In the 20 litre 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 concentrations 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, corns and atmospheric aerosol the gamma spectra analyses were performed.
Around this repository also the gamma dose rates were controlled (twice a year from the five control points).
All methods of sampling (except sampling of atmospheric aerosol) 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”.

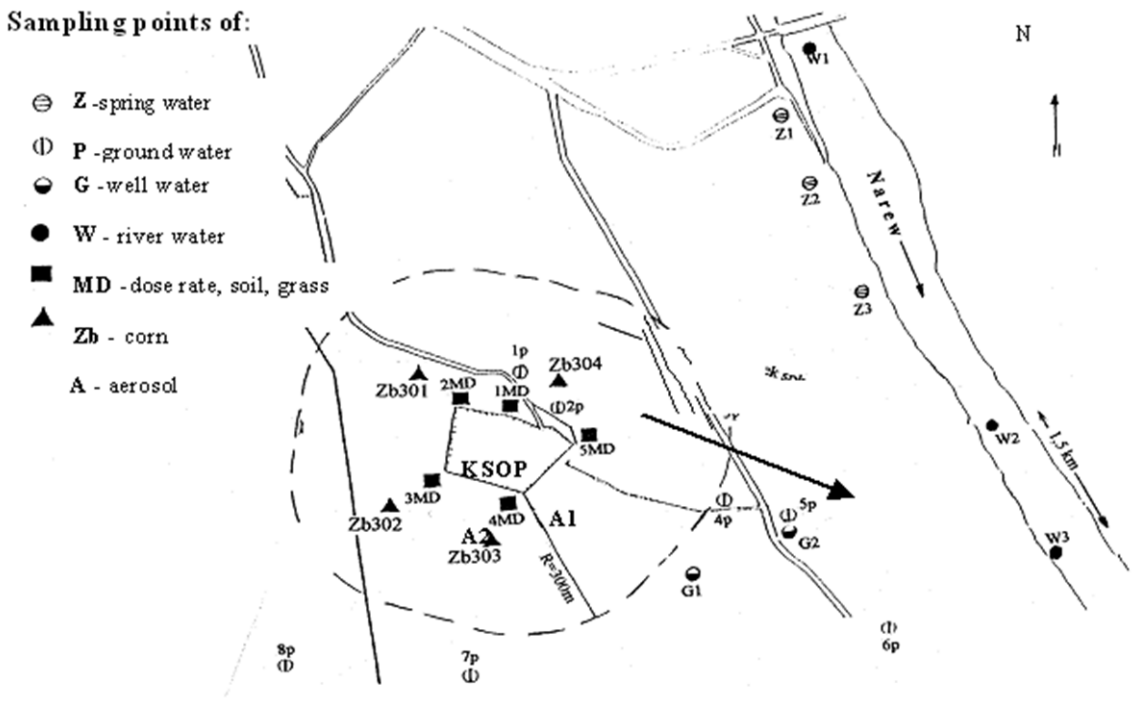

Fig. 1. Map of KSOP-Różan with environmental sampling points. Thick arrow indicates the direction of ground water flow.

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

Type of sample	Radiocesium concentrations mBq/dm^3		gross β activity Bq/dm^3		Tritium concentrations Bq/dm^3	
	2004	2005	2004	2005	2004	2005
River Narew	2.2 (1.8-2.6)	1.7 (1.4-1.9)	-	-	0.5 (0.4-0.6)	1.4 (1.3-1.6)
Wells water	0.8 (0.6-1.1)	0.9 (0.7-1.2)	-	-	1.2 (1.1-1.3)	0.9 (0.7-1.2)
Springs water	1.7 (1.6-1.9)	1.6 (0.8-2.5)	-	-	1.4 (1.3-1.5)	1.7 (1.3-2.2)
Ground water	-	-	0.143 (0.025-0.501)	0.121 (0.036-0.478)	1.5** (<04-2.6) 48.2*** (41.8-55.4)	1.6** (05-3.9) 49.0*** (45.8-52.8)

* 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 radiocesium and gross β activity in the various samples of water are at very low levels. 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 also at very low levels, except point 2p where the measured concentrations were constantly much higher than at other points.
The concentrations of ^{90}Sr were also determined in the summary annual samples in wells water – in 2004 and 2005 the concentrations were 1.6 mBq/dm^3 and 1.0 mBq/dm^3, respectively.

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	
	2004	2005	2005	2005
Soil	21.2 (11.7-28.7)	32.9 (19.3-74.9)	490 (410-777)	485 (423-576)
Corn	0.5 (<0.2-0.5)	<0.12 (<0.07-<1.5)	132 (128-135)	119 (104-139)
Grass (dry)	- (<0.5-15342)	- (2.9-252)	604 (205-1246)	553 (211-976)

The concentrations of ^{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 ^{137}Cs in the sampling control points in 2004 were in the same levels as in the other places in Poland [2]. In 2005 the concentrations of ^{137}Cs in soil samples were higher especially in spring time (23.8-74.9 Bq/kg). 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 concentrations of ^{137}Cs were very high in comparison with concentrations obtained in previous years. The highest concentrations were observed in autumn 2004 (145-15342 Bq/kg). In the same year in spring time the concentrations in all control places were on the normal level (<0.5 - 7.4 Bq/kg). In 2005 the concentrations of ^{137}Cs were steel higher then the normal level encountered in Poland.
The samples of atmospheric aerosol were collected on the Petrianov FPP 15-1.5 filter. The amount of the air passing by each sampling filter was 500 m^3. The samples were taken in spring (A1) and autumn (A2). The concentrations of ^{137}Cs in all samples were below the detection limit (<18μBq/m^3), only the natural radionuclides were at the same levels as in other regions of Poland. The concentrations of ^{7}Be were from 1970 to 3440 μBq/m^3 and ^{210}Pb from 128 to 1010 μBq/m^3.
The mean gamma radiation dose rate (including cosmic radiation) around KSOP-Różan were in the same levels as it was in previous years; in 2004 it was 98 (88-111) nGy/h and in 2005 was 103 (92-126) nGy/h.

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ACKNOWLEDGEMENT

Project supported by the National Atomic Energy Agency.

2.10 ASSESMENT OF RADIOLOGICAL SITUATION IN SURROUNDING OF ŚWIERK CENTRE.

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+DEPARTMENT OF RADIATION HYGIENE

***DOSIMETRY DEPARTMENT**

Since 2001 Central Laboratory for Radiological Protection surveyed the radiological situation in the surrounding of Świerk Centre. In this work we present the results obtained for 2004 and 2005.
Following samples were collected:
river water (r. Świder) – twice a year from the two control points ,
river water (r. Wisła) - once a year from the one control point,
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,
corn - once a year from the four control points,

In the 20 litre samples of river, well and from municipal sewage-treatment plant water flowing to Wisła river, after evaporation to 220 ml, the preliminary gamma spectrometric analyses were performed, then, the concentration of radiocesium were determined with a radiochemical method. In 1 litre water samples from the river and wells the concentrations of tritium were determined – only in 2005. In the soil, grass, corns and atmospheric aerosol the gamma spectrometric analyses were performed. Around the Centre the gamma dose rates were controlled - once a year in the five control points.

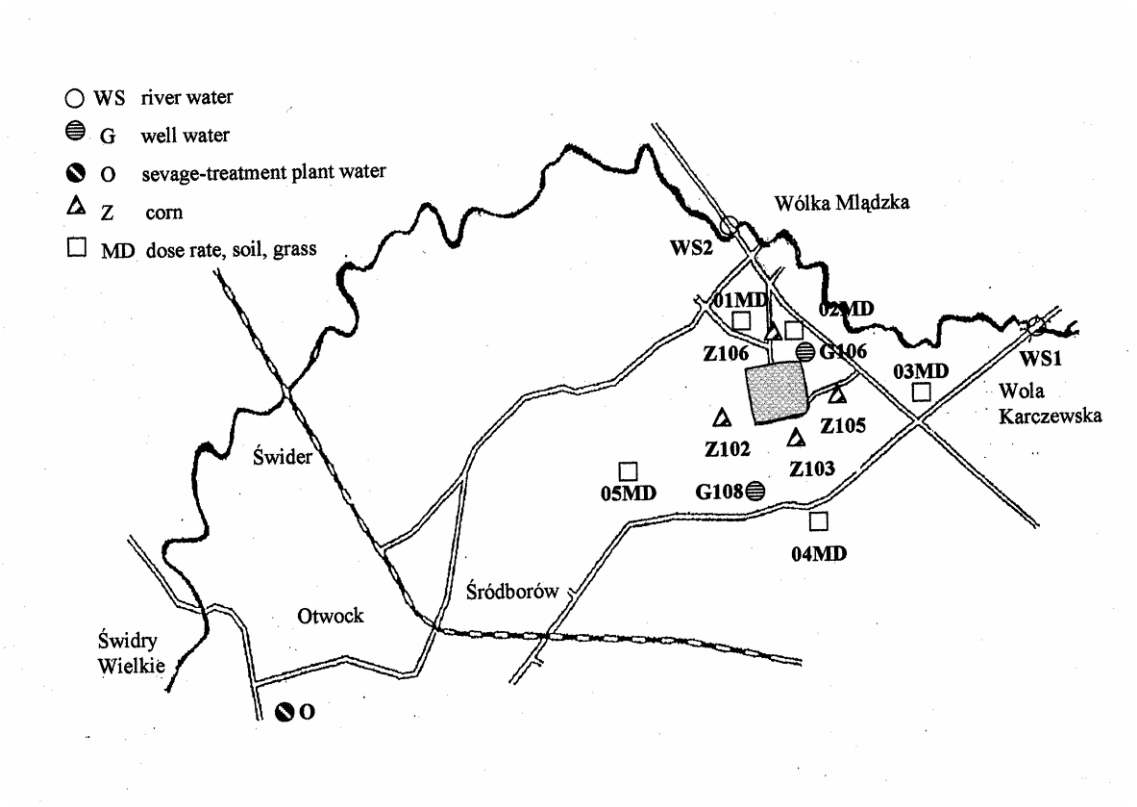

Figure 1. Map of Świerk Centre with environmental sampling points

All methods of sampling and measurements were conducted according to procedure 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 radiocesium and tritium in the samples of water from Świerk Centre area (activity range in parenthesis).

Type of sample	Radiocesium concentrations mBq/dm^3		Tritium concentrations Bq/dm^3
	2004	2005	2005
River Świder	1.3 (1.0-1.4)	1.2 (1.1-1.4)	0.8 (0.6-1.0)
River Wisła	2.3	2.0	1.0
Wells	4.0 (2.9-5.3)	6.1 (4.7-8.1)	1.05 (1.0-1.1)
Municipal sewage-treatment plant	7.2 (6.3-8.0)	7.1 (6.8-7.4)	-

The concentrations of radiocesium and tritium in the all samples of water are at low levels, similar as in other regions of Poland.
The concentrations of ^{90}Sr were also determined in the comprehensive annual samples in wells water – in 2004 and 2005 the concentrations were 12.5 and 9.8 mBq/dm^3, respectively.

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

Sample	^{137}Cs Bq/kg		^{40}K Bq/kg	
	2004	2005	2004	2005
Soil	8.3 (0.15-15.8)	13.8 (7.8-21.5)	226 (132-351)	244 (125-392)
Corn (dry)	<0.15 (<0,1-<0.2)	<0.5 (0.11-<1.5)	100 (79-145)	98 (69-120)
Grass (dry)	7.9 (0.9-31.4)	13.2 (4.9-39.2)	370 (268-484)	590 (436-780)

The concentrations of ^{137}Cs and ^{40}K in the soil samples were low, and comparable to concentrations measured in many other places in Poland [1]. The concentrations of both isotopes in all corn samples were very low. In grass samples the concentrations of ^{40}K were similar as in other areas in Poland. The same situation was observed as regards ^{137}Cs concentrations for grass samples, except the samples taken in point of 01MD where these concentrations were always higher.
The mean gamma radiation dose rate (including cosmic radiation) around Świerk Centre measured in 2004 was 70 (61-77) nGy/h and in 2005 was 71 (59-83) nGy/h. The mean gamma radiation dose rate in whole Poland was 75.5 (47-119.9) nGy/h [1].

References:

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ACKNOWLEDGEMENT

Project supported by the National Atomic Energy Agency.

2.11 INVESTIGATION OF RADIOACTIVITY OF RAW AND BUILDING MATERIALS

A. Żak, M. Biernacka, A. Ząbek

DOSIMETRY DEPARTMENT

Central Laboratory for Radiological Protection (CLOR) supervises operation of the 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. 31638 samples were analysed up to 2005.

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

According to the Regulations the concentration of the natural radioactive isotopes in raws and building materials, as well as wastes is analyzed by means of two indicators:

- activity indicator f_1 newly-defined as

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

- activity indicator 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.

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

f_1 = 1, f_2 = 200 Bq/kg related to raws and building materials applied in construction for public or livestock;

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 constructions in the local urbanization plans, and for leveling of such terrains;

f_1 = 3, 5, f_2 = 1000 Bq/kg related to industrial wastes for constructions situated on the ground not mentioned above and for leveling of the terrains not mentioned above;

f_1 = 7, f_2 = 2000 Bq/kg related to industrial wastes 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.

Article 4 of the Regulations determines, in addition, that while using industrial wastes for the leveling of the terrain quoted in article 3 pt. 2 and 3, and for construction of road, sport and recreation object it should be assured that achievement of required values of f_1 and f_2 will cause the absorbed dose rate at 1 meter above terrain, road or object to be less than 0.3 microgrey per hour (300 nGy/h). In can be achieved in particular by putting the additional layer of another material.

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

In 2004 and 2005 results for 3341 samples were investigated at laboratories supervised by CLOR and the results were included in the CLOR data base.
Concentration of natural radionuclides and the values of the activity indicators f_1 and f_2 for the samples collected in 2004 and 2005 are presented in Table 1.

Three samples of lightweight and cellular concretes in the group of building materials exceed the limit value of the activity indicator f_1 (f_1 = 1), but the excess is lower than 20%.

One sample of this group of building materials exceeds the limit value of the activity indicator f_2 (f_2 = 200 Bq/kg), but the excess is also lower than 20%.

In general the values of the activity indicators f_1 are about 20% higher then the values of the qualification coefficients f_1 used from 1980 to 2002. In order to make them comparable in the whole period of time (from 1980 up to now) a factor F was introduced.

It relates both f_1 factors to the mean values of f_1 for clay according to the following definitions:

$$F = \frac{\text{qualification coefficient } f_1}{0{,}506} \quad \text{from 1980 to 2002}$$

and

$$F = \frac{\text{activity indicator } f_1}{0{,}610} \quad \text{since 2003.}$$

where:

0,506 is a mean value of the qualification coefficient f_1 for clay.
0,610 is a mean value of the activity indicator f_1 for clay.

The time course of the mean annual values of the factors F and f_2 are presented in Fig. 1 and Fig. 2, respectively.

Fig. 1. Mean annual values of the F factor

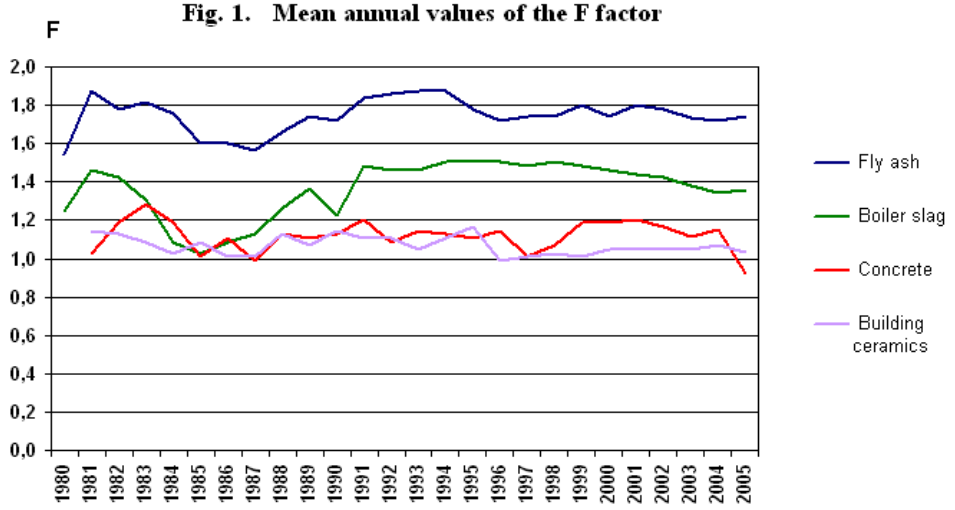

Fig. 2. Mean annual values of the activity indicator f_2 [Bq/kg]

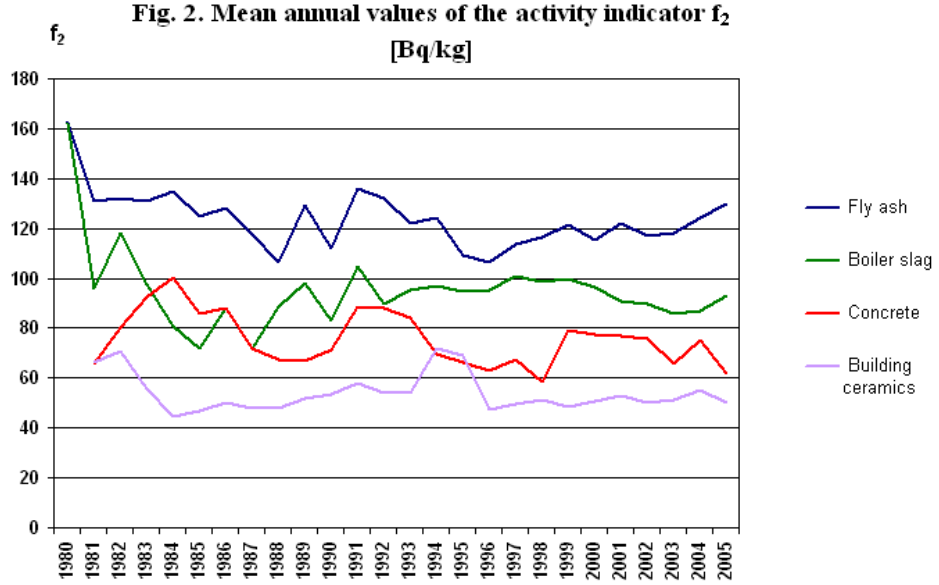

Table 1. Concentration of natural radionuclides and the values of activity indicators f_1 and f_2 measured in selected building and raw materials in 2004 and 2005.

Name of building raws or materials	Number of samples	Concentration of the natural radionuclides (S_K, S_{Ra}, S_{Th})*) [Bq·kg^{-1}]			Values of activity indicators*)	
		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	72– 78 – 84	14.4 – 17.2 – 20.1	2.8 – 3.5 – 4.2	0.09 – 0.10 – 0.12	14.4 – 17.2 – 20.1
Gypsum	11	10 – 26 – 98	1.4 – 8.2 – 17.3	0.2 – 1.2 – 3.7	0.01 – 0.04 – 0.06	1.4 – 8.2 – 17.3
Limestone	0	–	–	–	–	–
Lime	0	–	–	–	–	–
Sand	13	1 – 295 – 875	3.7 – 19.9 – 90.8	3.6 – 17.4 – 86.6	0.06 – 0.25 – 0.95	3.7 – 19.9 – 90.8
Marl	1	170	18.6	8.6	0.16	18.6
Clinker	4	48 – 153 – 285	23.1 – 30.0 – 46.8	11.4 – 15.1 – 18.6	0.16 – 0.22 – 0.32	23.1 – 30.0 – 46.8
Still stock	1	730	35.0	41.0	0.57	35.0
Clay	0	–	–	–	–	–
Clump	0	–	–	–	–	–
RAW MATERIALS OF INDUSTRIAL ORIGIN						
Fly ashes	1312	71 – 674 – 1180	11.6 – 124.4 – 340.0	7.5 – 87.5 – 177.2	0.23 – 1.06 – 1.78	11.6 – 124.4 – 340.0
Boiler slag	517	30 – 573 – 922	16.1 – 89.1 – 241.0	13.0 – 70.9 – 143.6	0.05 – 0.83 – 1.67	16.1 – 89.1 – 241.0
Metallurgical slag	5	22 – 113 – 248	16.1 – 84.9 – 177.1	6.6 – 22.6 – 39.0	0.09 – 0.43 – 0.76	16.1 – 84.9 – 177.1
Copper slag	0	–	–	–	–	–
Phospho-gypsum	0	–	–	–	–	–
Ash aggregate	229	459 – 689 – 816	85.0 – 127.3 – 166.2	66.7 – 81.5 – 95.0	0.87 – 1.06 – 1.18	85.0 – 127.3 – 166.2
BUILDING MATERIALS						
Cement	170	25 – 271 – 1237	14.1 – 33.6 – 110.2	9.0 – 25.9 – 64.4	0.03 – 0.30 – 0.80	14.1 – 33.6 – 110.2
Lightweight and cellular concrete	210	105 – 449 – 960	10.2 – 69.6 – 225.3 (1)	4.7 – 52.7 – 106.1	0.10 – 0.64 – 1.17 (3)	10.2 – 69.6 – 225.3
Other concrete	4	48 – 220 – 405	14.0 – 26.1 – 54.5	7.1 – 16.4 – 34.7	0.12 – 0.24 – 0.47	14.0 – 26.1 – 54.5
Building ceramics**)	575	55 – 701 – 1330	1.0 – 53.0 – 107.0	2.0 – 46.4 – 86.0	0.13 – 0.64 – 0.93	1.0 – 53.0 – 107.0

*) minimum - average - maximum

**) Bricks, hollow ceramic bricks, roof tiles, shapes etc

ACKNOWLEDGEMENTS

This work was partially sponsored by the Ministry of Scientific Research and Information Technology.

3 PROTECTION OF GENERAL POPULATION AND OCCUPATIONALLY EXPOSED PERSONS

3.1 ANNUAL EFFECTIVE DOSE (2005)

J. Henschke, M. Biernacka, D. Grabowski, B. Rubel

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 from natural and man-made sources, calculated according to the recommendation of UNSCEAR 2000[*)], amounted in 2005 to 3.35 mSv for the statistical inhabitant of Poland.

The most considerable contribution to this value, 74% (2.48 mSv/year), is from radiation of the natural radionuclides. Among them the highest individual dose arises from radon exposure (40.6% or 1.36 mSv/year). Cosmic radiation contributes only 8.4% (about 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 ionising 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.
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.
The investigations carried out by the Central Laboratory for Radiological Protection allow to estimate the value of the annual effective dose, caused by radiation of man-made sources (without medical diagnostics), for an average inhabitant of Poland in 2005 to be 0.016 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.

Comparing the value of 0.016 mSv to the annual dose limit for population (1 mSv) and to the average effective dose (3.35 mSv) shows that in 2005 this value reached 1.6% of the dose limit and 0.5% of the average annual effective dose to which the statistical inhabitant of Poland was exposed.

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

Fig. 1. Contribution of different radiation sources to the average annual individual effective dose in Poland, 2005 (3.35 mSv)

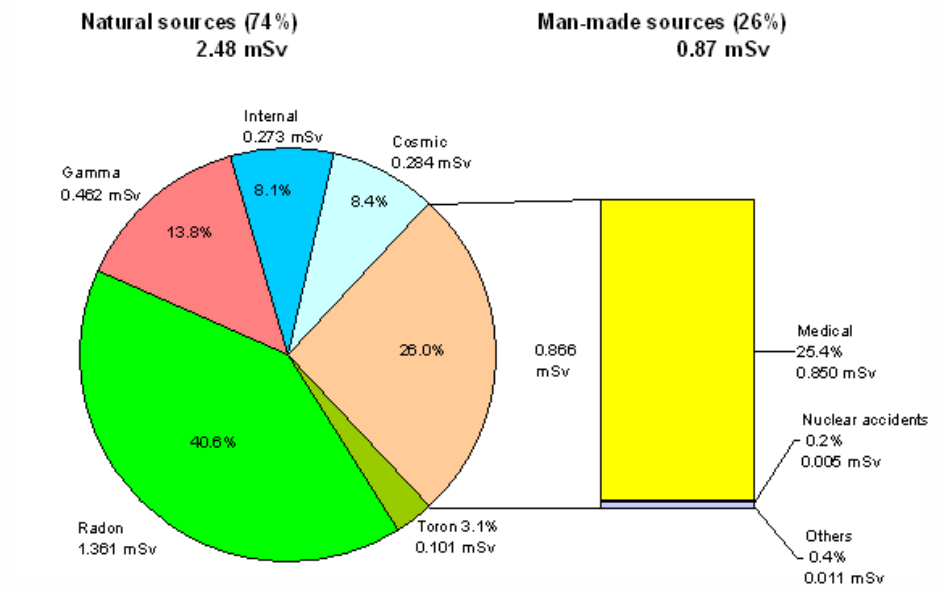
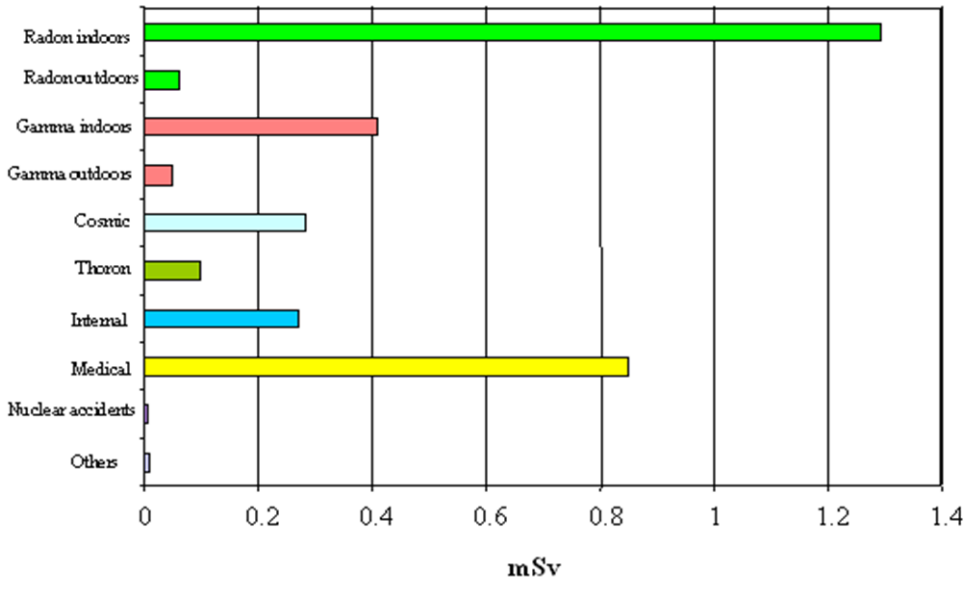


Fig. 2. Average annual individual effective dose from sources in Poland in 2005



3.2 OCCUPATION EXPOSURE TO EXTERNAL RADIATION MONITORED BY CLOR IN 2004 – 2005

M. Wasek, M. Wyszkowski*

AB 450

DOSE CONTROL AND CALIBRATION DEPARTMENT

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A personal monitoring service in 2004-2005 has been carried out for about 3700 radiation workers. It was based on film and thermoluminescent methods. For whole body photon and beta the Kodak personal Monitoring Film Type 2 was used. As regards extremity dosimetry, the hand doses were recorded using TL dosimeters with LiF:Mg, Ti sintered detectors (for about 150 persons).
The individual monitoring of workers depend on radiation conditions in the area concerned and on the type of work. According to the Polish Atomic Low (Article 17) [1] two categories of workers shall be established, depending on magnitude of exposure:

1. 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,
2. 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]. The operational dose quantity used for estimation of effective dose equivalent from external radiation is the personal dose equivalent $H_p(10)$. The operational dose quantity for exposure of skin and extremities is $H_p(0,07)$. The detection limit of monitoring system was 0,4 mSv.
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.

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 ebgaged 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 monitored in different work groups in 2004.

GROUP	Number of persons Annual personal dose equivalent range [mSv]					
	Total	below 2	below 6	below 20	Above 20	% *)
SCIENTIFIC	1105	1097	1097	1102	3	99,3
INDUSTRIAL	948	931	948	948	0	98,2
MEDICAL	1283	1275	2171	1283	0	93,4
OTHER	273	260	269	272	1	95,2
ALL GROUPS	3609	3563	3585	3605	4	98,7

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

Table 2. Distribution of annual doses from occupational exposure monitored in different work groups in 2005.

GROUP	Number of persons Annual personal dose equivalent range [mSv]					
	Total	below 2	below 6	below 20	above 20	% *)
SCIENTIFIC	1041	1014	1035	1041	0	97,4
INDUSTRIAL	832	819	830	831	1	98,4
MEDICAL	1713	1680	1700	1713	0	97,6
OTHER	267	261	265	267	0	98,1
ALL GROUPS	3853	3774	3830	3853	0	97,9

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

Annual dose equivalent greater then limit (20 mSv per year) received 4 persons in 2004 (in scientific and other sector) and 1 person in 2005 (in industrial sector).
The annual personal doses monitored by CLOR in 2004 and 2005 in different workers groups present similar occupational exposures monitored during the last few years [3-5]. This may be regarded to the small changes of the radiation conditions in the workplaces.

Prawo Atomowe. Dz. U z 2001 r. Nr 3 poz.18, Nr 100, poz. 1085 i Nr 154, poz. 1800 z 2002 r. Nr 47, poz. 676, Nr 135, poz. 1145.
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Research and operational activities. Report of CLOR 2002-2003

3.3 ENVIRONMENTAL ASSESSMENT OF THE MATERIAL DEPOSITED ON THE FORMER URANIUM MINING DISPOSAL DUMP IN RADONIÓW.

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Radoniów is a small town located in Lubomierz district near Jelenia Góra (south-west part of Poland). Since the end of World War II up to the end of sixties uranium mining activities were performed in the vicinity of the town. Uranium deposits were almost entirely exploited and the traces of the mining activities are the post-uranium dumps on the east side of mount Głębiec. The area of the terrain is about 6.85 ha. The material present on the dumps (containing high amount of uranium) is to be – according to the plans of the district authorities - used as the bedding for the construction of the road around the town (PHARE contract).
The measurements performed by the Central Laboratory for Radiological Protection (CLOR) and ordered by MOSTOSTAL-Warszawa (developer of the road) were to asses the usability of the dumped material for road construction.
The distribution of all measurement and sampling (surface and deep) points is presented in Figure 1.

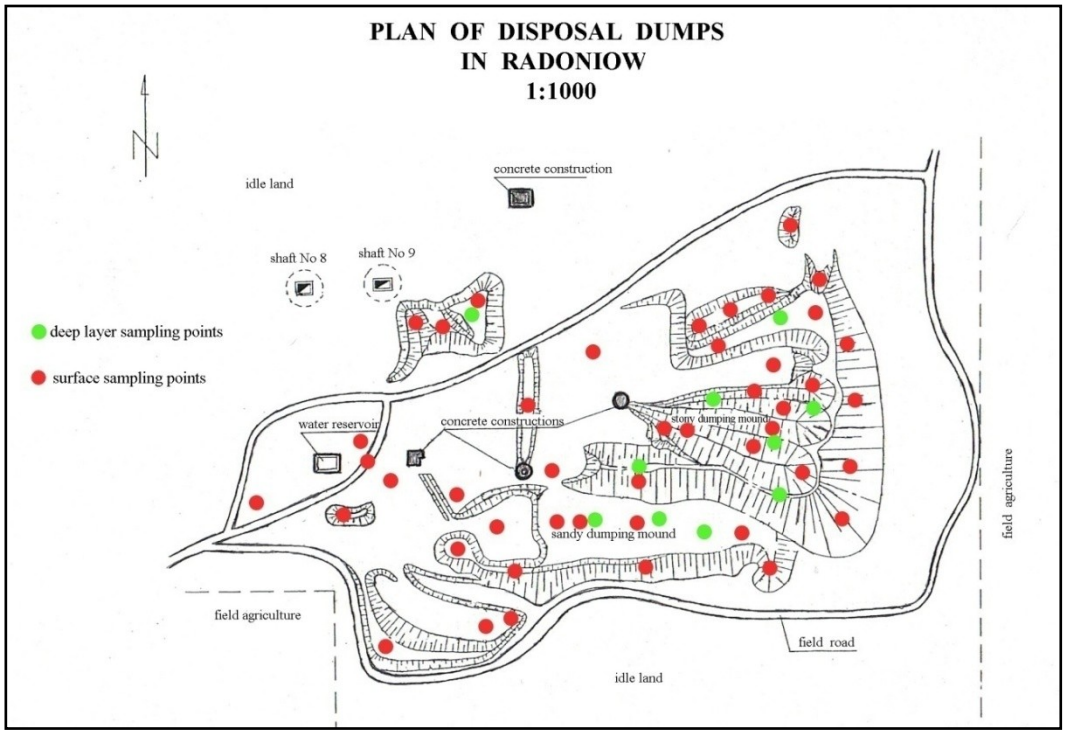

Figure 1. Measurement and sampling points

The assessment program consisted of:

- environmental measurements at the disposal site (dumps) of the uranium mine in Radoniów;
- assessment of the usability of the materials from the dumping site for the construction of the circular road passing by Radoniów (part of the state road No. 30);
- analysis of the risk for the workers having contact with the material deposited on the dumps in Radoniów.

The following tasks were performed:

1. Sampling for further laboratory analyses in Dosimetry Department of CLOR (gamma spectrometry with natural contamination analyzers - AZAR-90 and MAZAR-95)

The following samples were taken:

- 41 samples of the surface material of the dump (10 cm depth);
- 10 samples from the deep layers of the dump (taken by the specialized geological company “Geological Services”);
- 2 samples representing local natural environment.

The method applied for the determination of the activity of the samples is based upon comparison of concentrations of natural radionuclides: potassium ^{40}K, radium ^{226}Ra and thorium ^{228}Th (see [1]). Basing upon measured concentrations of potassium ^{40}K, radium ^{226}Ra and thorium ^{228}Th the values of radioactivity indices f_1 and f_2, and the dose rate above flat indefinite plane of thick (few meters) layer of the measured material were calculated.

2. Measurement of the whole area by the Mobile Spectrometric Laboratory based upon Toyota Land Cruiser having NaI(Tl) crystal with the volume of 4 liters, GR-660 spectrometer and Geographic Positioning System (DGPS).
3. Measurements of gamma dose rate using Exploranium GR-130 handheld spectrometer (also used for collection of the spectra at some spots), current-type pressurized ionization chamber and RKP-1 radiometer.
4. Measurements of beta radiation above the dumped material the surface of the dumped material with RKP-1 radiometer.

Table 1. The results of the measurements of the radionuclide concentration in the samples (including calculation of f1 and f2 coefficients), gamma dose rate and beta surface radioactivity.

Nuclide concentration **[Bq/kg]**			
	Average	**Range**	**in neutral points**
^{40}K	1627	782 – 5704	740; 686
^{226}Ra	2172	252 – 8726	95; 49
^{228}Th	95.3	37.5 – 782.4	38.5; 36.0
Coefficient **[unit]**			
f_1 [-]	8.26	2.33 – 34.90	0.76; 0.57
f_2 [Bq/kg]	2172	252 – 8726	95; 49
Gamma dose rate [nGy/h]			
Radiometer RKP-1	680	300 - 1800	
Exploranium GR-130	662	288 - 1988	142; 117
Surface beta radioactivity [Bq/cm^2]			
Radiometer RKP-1	0.52	0.16 – 1.92	

Analysis of the results of measurements

Analysis of possible application of materials for construction

During the analysis the Regulation [2] was taken into account – especially § 3 and § 4
Obtained results of f_1 and f_2 coefficients given in Table 1 proved that:

1. None of samples the satisfies the requirements of w § 3 pt. l of the Regulation,
2. 2 samples satisfy § 3 pt. 2,
3. 12 samples of not satisfying § 3 pt. 2 satisfies § 3 pt. 3,
4. 19 samples of not satisfying § 3 pt. 3 satisfies § 3 pt. 4,
5. 18 samples does not satisfy § 3 pt. 4.
6. In addition, two “hot spots” were detected.

Analysis of ionizing radiation risk for the employees working with the materials from the dumps.

The fundamental legal act is "Atomic Law" of 29 November 2000 - the article no 13. The values of dose limits of ionizing radiation for specific population groups are given in the Regulation by Council of Ministers of 28 May 2002 "on limiting doses of ionizing radiation".
The exposure for ionizing radiation ranged from 0.90 mSv/year to 2.54 mSv/year. Most exposed workers were those working directly on the dump in places not satisfying the Regulation by Council of Ministers of 3 December 2002 § 3 pt. 4.
The concentration of radium on the dump (excluding "hot spots") exceeded 3 to 50 times the concentration of radium in the vicinity of the dump. Thus, protective measures such as limitation of dusting and protection of material losses, were recommended.

Conclusions

The following conclusions were drawn:

- Material on the disposal dumps was inhomogeneous with respect to concentration of natural isotopes: particularly ^{226}Ra. Neighboring points with totally different concentration of ^{226}Ra were found. Highest concentration of radium was at "hot spots". This material shall not be used in any applications, and shall be recultivated on-site. Remaining material can be used for road construction after mixing with material having low natural isotope concentration. It should be stressed that the road built using those materials shall comply additionally with § 4 requirements i.e. reducing absorbed dose rate at 1 meter above road surface to the value not exceeding 300 nGy/h;
- The exposure of workers employed directly on the dumps and road construction (not shielded by cabin walls) would exceed value of l mSv/year. For the period of the construction of the road less than 2 years the limitation of working hours below 2100h is not mandatory. The exposure would not exceed 1 mSv for the workers employed as operators of special building vehicles.
- For more details please refer to [3].

References:

1. "Guidelines on the Determination of Natural Radioactivity in Raws and Building Materials", Instruction 234/2003 of Institute of Building Technology.
2. The Regulation of Council of Ministers of 3 December 2000 "on natural radioactive isotope content I 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", Law Gazette no 220/2002 pos. 1850.
3. "Environmental Assessment Of The Material Deposited On The Former Uranium Mining Disposal Dump In Radoniów", A.Żak, M.Biernacka, P.Lipiński, K.Isajenko, Proceedings from NORM IV Conference, Szczyrk, Poland, May 2004 (pages 839-857)

3.4 MEASUREMENT OF IODINE AND TECHNETIUM CONTENT IN THYROID OF OCCUPATIONALLY EXPOSED PERSONNEL

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Introduction

In 1997, the Central Laboratory for Radiological Protection set up programme "The Laboratory for monitoring of radioiodine in thyroid for population in emergency situation". Its main goal 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 , I-125 and Tc-99m in thyroid of occupationally exposed workers.

The monitoring assembly of the Laboratory consists of two independent measuring units:
Stationary Unit for measuring of iodine and technetium with low limit of detection
Mobile Unit for "in situ" measurements of iodine and technetium. 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 and technetium contents of occupationally exposed personnel were performed with mobile detection unit (prod. Canberra-Packard) (FIG.1.), which consists with:

- 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,
- The InSpector NaI – it is a full featured 8192-channel, battery-powered, portable Multichannel Analyzer, paired with the notebook computer,
- 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,

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.

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

Personnel Monitoring

In the period 2004-2005 the measurements of I-131 and Tc-99m 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 cm, using a 200-300 seconds counting time. The background was measured with detector placed 10 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.
The examined persons can be divided into following categories :

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

Results

The measurements of radioiodine and technetium content in the thyroid were performed in eight medical units that use I-131and Tc-99m for therapy and diagnosis of thyroid diseases. About of one hundred exposed persons were investigated. The results of measurements are presented in Table I.
All individuals actively working with iodine and technetium show measurable amounts of this radioisotopes in their thyroids (FIG.2. , FIG.3.). The average measured activity of I-131 in the thyroid of the nuclear medicine staff was 120 Bq, ranging from 68 Bq to 500 Bq. The average and range of I-131 activity measured in thyroids for all medical units were: 150 Bq, (60 Bq - 500 Bq), 80 Bq, (72 Bq - 100 Bq), 68 Bq, (68 Bq - 68 Bq) for), for categories 1, 2, 3 respectively. Nevertheless, the categories 1 and 2 show higher I-131 thyroid level then category 3. The average measured activity of Tc-99m in the thyroid of the nuclear medicine staff was about 1100 Bq, ranging from 100 Bq to 60000 Bq.

Conclusions

The results of I-131 content in the thyroid of staff members working with radioiodine in eight 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 20 per cent of 20 mSv/year.

Table I. The measured I-131 and Tc-99m content and assessment of effective doses from inhalation of iodine for personnel of Nuclear Medicine Units

Medical Unit No.	Category	Measured I-131 thyroid content [Bq]	Measured Tc-99m thyroid content [Bq]	Effective Dose Equivalent from inhalation of I-131 [mSv]
		Mean (Min – Max)	Mean (Min - Max)	Mean
1.	1	68 (60 – 84)	175 (30-350)	0.38
	2	74 (68-76)	-	
	3	-	-	
2.	1	80 (76-84)	7000 (1200-10600)	0.42
	2	74 (68-76)	300 (200-400)	
	3	-	-	
3.	1	82 (76-92)	19600	0.46
	2	74 (68-76)	525	
	3	-	-	
4.	1	110 (84-150)	100 (70-200)	0.8
	2	95 (90-100)	-	
	3	-	-	
5.	1	130 (120-160)	-	1.0
	2	74 (68-76)	-	
	3	-	-	
6.	1	73 (70-75)	60000	1.0
	2	72 (68-76)	1100	
	3	-	-	
7.	1	360 (200-500)	-	4.0
	2	72 (68-76)	-	
	3	68	-	
8.	1	70 (68-74)	14780	1.0
	2	72 (70-74)	450 (230-670)	
	3	-	-	

FIG.1. Mobile detection unit for I-131 and Tc-99m measurements

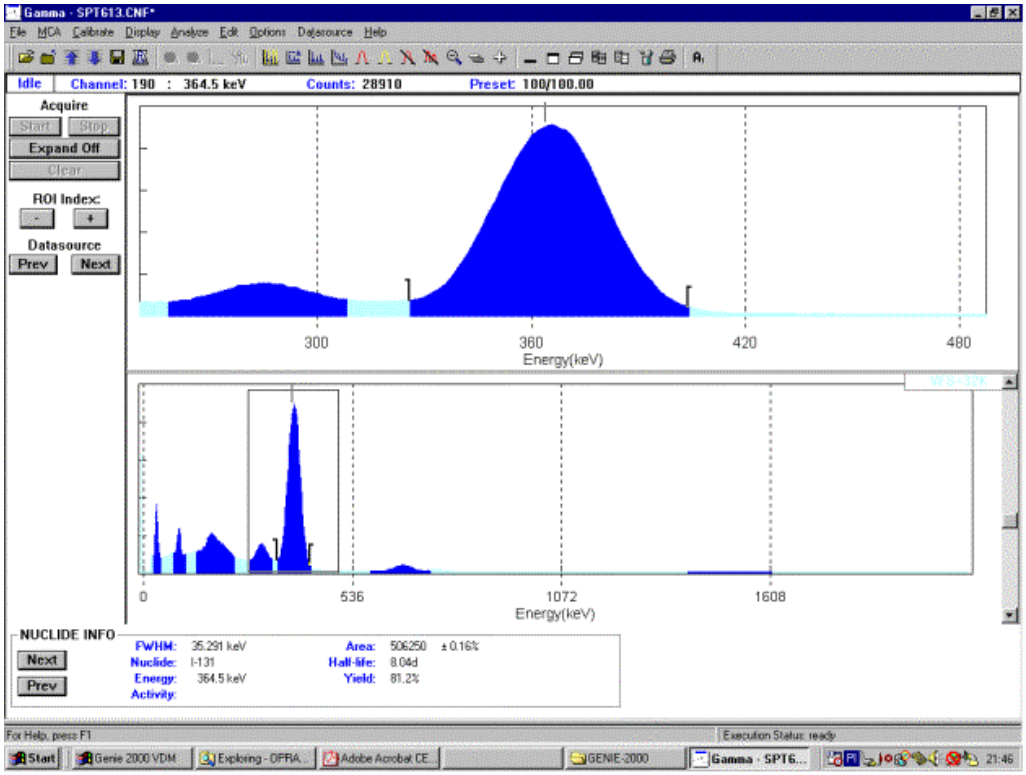


FIG.2. Typical spectrum of I-131with photopeak of 364keV collected at thyroid of exposed worker

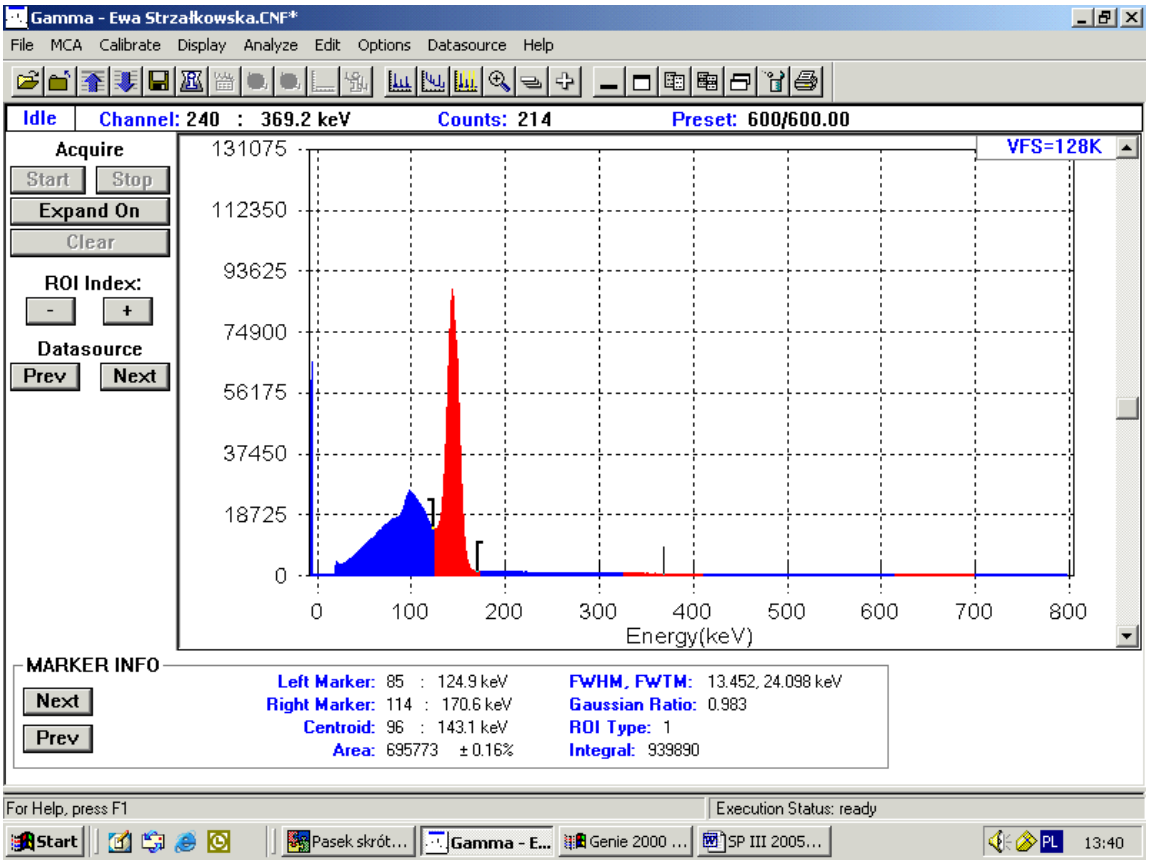
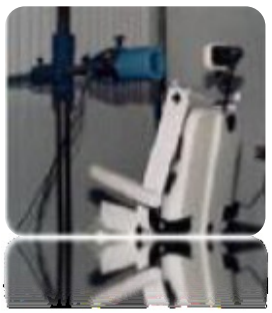


FIG.3. Typical spectrum of Tc-99m with photopeak of 144keV collected at thyroid of exposed worker

References

1. Krajewska G. , *Laboratory for Monitoring of Radioiodine in Thyroid for Populatin in Emergency Situation*, in *Annual Report 1996-1997*, edited by Central Laboratory for Radiological Protection, Warsaw, (1998).
2. Krajewska G. , Krajewski P., *Thyroid Monitoring System for Measurement of Iodine Content in Thyroid of Occupationally Exposed Personnel*, Radiation Protection Dosimetry , 89, 215-220, (2000).



3.5 CONSTRUCTING LOW-LET CALIBRATION CURVES FOR RADIATION BIOLOGICAL DOSIMETRY BY CYTOGENETICS

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Cytogenetic data from stimulated human peripheral blood lymphocytes are sensitive and reliable indicators of ionizing radiation. For this reason the analysis of chromosomal alteration in lymphocyte preparations from a peripheral blood is currently the most extensively used method for biological estimation of absorbed dose following external radiation exposure (*IAEA, Vienna 2001: Cytogenetic Analysis for Radiation Dose Assessment: A manual. Technical Reports Series No. 405*). It does not require a large blood sample, can be performed at any moment and can not be intentionally modified by the subject under study.

Such a radiobiodosimetry makes an important contribution to radiological protection when physical dosimetry is lacking or inadequate to quantify doses from accidental exposure to different types of ionizing radiation. It is used in cases of doubts about dosimetry records or claims for compensation for radiation injuries that are not supported by official dosimetry records. It is also useful in cases of human populations chronically exposed to ionising radiation.

Three different cytogenetic endpoints are currently available for performing radiation biodosimetry after whole-body exposure in the range of 0 Gy to 4 Gy. These are dicentrics, translocations measured by fluorescence in situ hybridisation (FISH) technique and micronuclei. Stable translocations are more effective in detecting old or long term exposures. For this reason they are applied in dosimetry a decade or more after exposure. Unstable dicentrics and micronuclei are used for dose assessment soon after exposure. However, the easy and rapid scoring of micronuclei makes them particularly useful for mass screening of person possibly exposed during a major radiation accident.

Since the *in vivo* and *in vitro* irradiation of peripheral blood lymphocytes produces similar frequencies of chromosome damage per grey, a frequency of dicentrics, translocations or micronuclei measured in the lymphocytes of exposed persons can be converted into an estimate of absorbed dose by reference to an experimentally obtained dose-response calibration curve. This curve should be produced by *in vitro* irradiation of the blood samples with different doses of comparable radiation quality. The doses given to the blood must be supported by reliable and accurate physical dosimetry, and inter-individual variability in the cytogenetic dose-response and the background frequency of chromosomal alterations standardized by taking the lymphocytes from several male and female donors.

In the years 2004-2005 the dose-response relationships for X ray- and ^{60}Co γ ray-induced dicentric, FISH-based reciprocal translocations and micronuclei were studied in the lymphocytes of a selected group of donors. This group, which was representative of a heterogeneous working population, consisted of three woman and three man aged between 24 and 57 years. All blood donors were volunteers informed about the aim of the study and experimental details. The study was supported by the Ministry of Education and Science under the grant No. 6T11 0051 2002C/05826 and its aim was to construct low-LET calibration curves for radiobiodosimetry based on dicentrics, micronuclei and reciprocal translocations measured by FISH.

Briefly, peripheral blood was taken with heparinized syringes and kept at 37^{o}C until the time of irradiation. The blood samples were irradiated with X-rays (180 kVp) and ^{60}Co γ-rays at a dose rate 0.35 Gy min^{-1}. All irradiations were carried out at room temperature with doses of 0.25, 0.50, 0.75, 1.0, 2.0, 3.0 and 4.0 Gy. The irradiated blood was than stored at 37^{o}C for 3 h before culturing. A control blood was treated identically but received no dose. Whole-blood cultures were established by adding 0.5 ml of blood to 5 ml of RPMI1640 medium supplemented with 20% fetal calf serum, heparin, gentamycin and phytohaemagglutinin (PHA) as a mitogen and incubated at 37^{o}C in a humidified atmosphere of 5% CO_2. The blood for chromosome analysis was cultured for 48 and 62 h, depending on dose. For the final 4h colcemid (0.5 μg ml^{-1} final concentration) was added to arrest the lymphocytes in metaphase. For micronuclei the blood was cultured for 72 h. After 44 h, cytochalasin B (6 μg ml^{-1} final concentration) was added to block cytokinesis and induce binucleate cells. At the end of incubation period the cultures were harvested by hypotonic treatment in 75mM potassium chloride for 20 min at 37^{o}C followed by up to six fixes in 3:1 methanol: acetic acid solution. After the final wash, the pellet was resuspended on 0.5 ml fixative and 30 μl of the lymphocyte suspension was dropped onto the center of a clean glass slide held horizontally.

For the scoring of dicentrics, the slides were solid stained in 2% Giemsa and examined under a light microscope (Eclipse E-200 Nikon from Nikon Co., Japan). A chromosome with two centromeres accompanied by an acentric fragment was classified as a dicentric. Tricentric aberration with two accompanying acentric fragments was equivalent to two dicentrics. Dicentric chromosomes were recorded only in complete metaphases, i.e. containing 46 centromeres For the dose response a total of 5700 cells were examined. In the range of 0 Gy – 0.75 Gy 1000 metaphases were scored per each dose point and each donor. At the higher dose points the number of scored cells was, respectively, 700, 500, 300 or 200.

Scoring of reciprocal translocations, which are symmetric counterparts of dicentrics, was possible due to a two colour FISH painting for chromosomes 1 and 4 together with a pancentromeric probe to all human centromeres and DAPI conterstain. A chromosome was deemed to contain a translocation if it exhibited a single centromeric signal and possessed a bicoloured junction between a painted and DAPI stained material. A translocation was classified as reciprocal if two bicoloured chromosomes were observed. They were viewed under the Eclipse E-200 Nikon microscope with an epi-fluorescence attachment and a triple-band filter for simultaneous observation of FITC, Rhodamine and DAPI. Only cells that had the correct amount of painted material, i.e. four painted chromosomes each with a painted centromere, were scored. Because chromosome pairs 1 and 4 represented approximately

14% of the DNA content in the human genome, FISH analysis of bicoloured aberrations detected only 26% of the total reciprocal translocations presented in a cell.

Therefore, to obtain the total genomic reciprocal transformation frequency (F_G) the frequency of reciprocal translocations detected by FISH (F_P) was divided by 2.05 f_P (1-f_P) where f_P = 0.14 was the painted fraction of the genome. For scoring or micronuclei the slides were conventionally stained with 2% Giemsa stain and analysed under a light microscope. A small oval or round object that was morphologically identical to the main nuclei w scored as micronuclei. Micronuclus scoring was limited only to binucleate cytokinesis-blocked lymphocytes. To determine the micronucleus frequency 1000 binucleate cells were scored per each dose point and each donor.

The individual dose–response curves obtained for X ray - and ^{60}Co γ ray-induced dicentrics, translocations or micronuclei had a typical linear-quadratic shape (Figure 1). It was a strong evidence that the formation of chromosomal alteration follows a linear-quadratic model $Y = A+aD+bD^2$ where Y is the measured frequency of the events, D is the dose, A is the control background frequency of the events, and a and b are coefficients which describe the relationship.

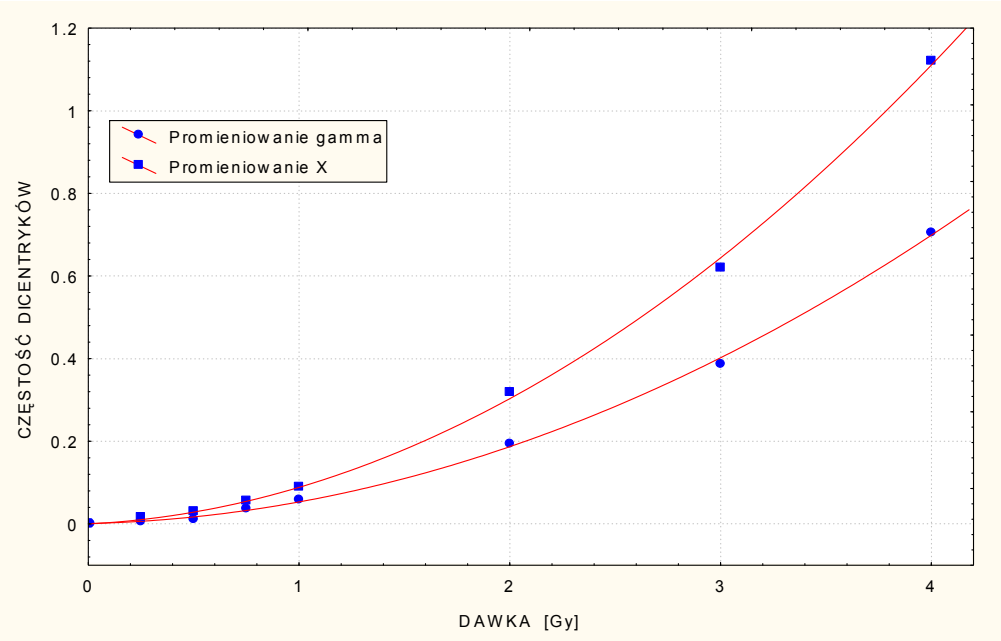

Fig. 1. **Dicentric dose-response curves for donor 1.**

In order to produce *in vitro* calibration curves, the mean dicentric, translocation or micronuclei frequency was obtained for each dose by combining the data of the six donors. The mean dose–response data were then fitted by the linear-quadratic dose-response curve using the method of iteratively reweighed last squares. The objective of curve fitting was to determine values of the linear and quadratic coefficients which best fit the data points. The results of curve fitting are shown in Table 1.

Table 1. The coefficients of the in vitro calibration – cytogenetic assay curves.

	X rays		^{60}Co γ rays	
	a±SE	**b±SE**	**a±SE**	**b±SE**
Dicentric assay	0.026±0.005	0.071±0.002	0.017±0.005	0.043±0.001
FISH based translocation assay	0.030±0.004	0.078±0.001	0.012±0.005	0.044±0.001
Micronucleus assay	0.056±0.011	0.049±0.003	0.020±0.006	0.036±0.002

Since an unknown absorbed dose is a function of the coefficients of the calibration curve and the measured frequency (Y_{obs}) of aberrations or micronuclei from the exposed person, an estimate of the dose (D_x) can be calculated from the equation:

$$D_x = \{-a + [a^2 + 4b(Y_{obs} - A)]^{1/2}\}/2b$$

where A is the experimentally obtained control background frequency.
Consequently, a standard error on dose estimate is described by the formula:

$$U(D_x) = (1/(a+2b\,D_x)) \times \{[(A/n_o + D_x^2\,V_{aa} + 2\,D_x^3\,V_{ab} + D_x^4\,V_{bb}) + Y_{obs}/n]^{1/2}\}$$

where V_{aa}, V_{ab} and V_{bb} are variances and covariance's of calibration coefficients, n_o is the number of cells scored to obtain A and n is the number of cells scored to obtain Y_{obs}. The numerical values of n_o, V_{aa},V_{ab}, V_{bb}, A and n_o are derived from curve constructing, and for our calibration curves these are listed in Table 2.

Table 2. Parameters needed for standard error calculations.

Parameter	Dicentric assay		FISH based translocation assay		Micronucleus assay	
	X rays	^{60}Co γ rays	X rays	^{60}Co γ rays	X rays	^{60}Co γ rays
A	0.001	0.001	0.009	0.009	0.016	0.016
n_o	12000	12000	3000	3000	12000	12000
V_{aa}	0.000030	0.000022	0.000016	0.000022	0.000118	0.000041
V_{ab}	-0.000009	-0.000006	-0.000005	-0.000006	-0.000034	-0.000012
V_{bb}	0.000003	0.000002	0.000001	0.000002	0.000010	0.000004

Proposed minimum detection levels for our dose measurements are shown in Table 3. As may be seen, minimum detection levels of doses measured by the micronucleus or FISH based translocation assay are higher than those for dicentrics. These differences are the result of the inter-individual variation in the background frequency of translocations and micronuclei in human peripheral blood lymphocytes.

Table 3. **Minimum detection levels for cytogenetic dose measurements.**

	X rays	**^{60}Co γ rays**
Dicentric assay	0.16 Gy	0.22 Gy
FISH based translocation assay	0.27 Gy	0.44 Gy
Micronucleus assay	0.25 Gy	0.47 Gy

4 QUALITY ASSURANCE AND TECHNICAL COMPETENCE

4.1 THE ASSURANCE AND MAINTENANCE OF THE QUALITY SYSTEM IN LABORATORY OF PERSONAL AND ENVIRONMENTAL DOSES FOR RADIOLOGICAL PROTECTION

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AB 450

Dose Control and Calibration Department

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In 2005, in the purpose of assuring and maintaining Laboratory of Personal and Environmental Doses (PDIŚ) the following activities were performed:

1. Six scheduled internal audits:

- "Measurement traceability"
- "Treatment of objects intended for investigation calibrations"
- "Supervision of research equipment"
- "Document control"
- "Complaints"
- "Research into quality control"

The first four of them were conducted before the yearly audit and organized under the supervision of the Polish Centre for Accreditation. They aimed at controlling the key areas of the quality system, which determine its effectiveness in setting the equivalent dose. The two last audits were a yearly recapitulation of activities performed by PDIŚ. There were no complaints from customers, and on the basis of the research of quality control made, the high quality of services offered by PDIŚ was confirmed.

2. Review of Quality Management

On a basis of presented papers and discussions, prof. Dr hab. Sl. Sterlinski, Director CLOR stated the following facts:

- The correctness of the quality system operation in PDIŚ is according to the requirements of PN - EN the ISO / IEC 17025:2001 + Ap1:2003 norm.
- The maintenance of the technical competences to perform analysis is within the established range of accreditation .

3. Testing analysis of photometric detectors devoted to determine the individual equivalent dose $H_p(10)$ are according to accepted procedures of the quality system applied by PIDŚ. Research results are shown in documents QD 3.1 and QD 3.2. This type of analysis was performed periodically every 2 months in order to detect any errors or shortcomings of the quality system, which could affect the final service quality. The analysis has not detected any shortcomings within the established range of accreditation.

4. Testing a workplace for photochemical processing of photometric detectors.

The testing was held before every measuring and calibration cycle.

5. Ten internal trainings of PDIŚ technical staff covering the following issues:

- Implementation of new standardization and calibration documents and cards into the quality system;
- The advantages and disadvantages of the photometric technique in comparison to the technique with the thermoluminescence detectors;
- The interactions between ionizing radiation and matter.
- Assuring the quality of test and calibration results

6. Quarterly calibration of two densitometers used in a comparative research method.

7. Participation in an audit organized under the supervision of the Polish Centre for Accreditation.

This audit has highlighted four observations: inaccuracy of the quality system (2 – small size and 2 - medium size). These inaccuracies were caused mainly by the old and over used computer equipment responsible for controlling the densitometers and archiving the results. Action to correct these inaccuracies was taken by the end of 2005.
The final conclusion of the audit, in spite of above mentioned inaccuracies, was that the Laboratory PDIŚ has maintained the implemented quality system according to the requirements of PN - EN ISO / IEC 17025:2001 + Ap1:2003 norm.

The work executed in 2005 by PDIŚ was done according to a timetable prepared earlier and in agreement with procedures, general instructions and research procedures included into quality system.

4.2 SOME ASPECTS OF THE QUALITY SYSTEM AT SCOPE OF CALIBRATION OF RADON AND RADON PROGENY DEVICES AT RADON DOSIMETRY GROUP, CLOR

O. Stawarz, K. Mamont-Ciesla

Dosimetry Department

Outline

Radon Dosimetry Group (RDG) has introduced quality assurance system at scope of calibration of radon and radon progeny devices and delivery an exposure of detectors in standard radon concentration. The task was partially subsidized by the National Atomic Energy Agency.
At the beginning of 2003 the first internal audit took place to specify scope of the quality assurance system and list of required documents. Since then the documents have been created, corrected and updated if it was necessary.
During last two years twelve internal audits took place to review the whole scope of quality system: organization, document control, review of requests, tenders, and contracts, purchasing services and supplies, service to the client and his complaints, corrective and preventive actions, control of records, management reviews, technical requirements, personnel, accommodation, environmental conditions, calibration methods, validation, equipment, measurement traceability assuring the quality of calibration results and reporting the results. After each internal audit all observations and remarks were taken into account and the documents, forms and records were corrected, updated or completed.
The management review headed by the director of CLOR took place at the beginning of 2005. It was finished with the decision to apply to Polish Accreditation Centrum (PCA) for accreditation as a radon and radon progeny calibration laboratory. The application has been submitted and in the middle of year the initial audit was held.
The main objection of the auditor was the lack of intercomparison results with an acredited laboratory.

Radon facilities at Radon Dosimetry Group

Radon Dosimetry Group owns calibration walk-in chamber of 12.35m^3 with ante-room (Fig. 1) equipped with two flow-through standard radon sources (137.27 kBq and 502.5 kBq), two radon monitors: AlphaGUARD and AlphaGUARD PRO manufactured by Genitron, Radon Progeny Particle Size Spectrometer (RPPSS – Fig. 2), radon progeny monitors: Rn WL Meter (Thomson&Nielsen Co.) and WLx (Pylon Inc.), pumps, generator of aerosols (TSI), counter of neutral aerosols RICH 100, humidity meter, flowmeters, computers and printers.
Standard concentration of radon in the chamber is calculated on the basis of the activity of the radon source, time of radon generation in the source and the volume of the chamber. At least one a year this value is compared with the the results measured by AlphaGUARD monitors which are considered reference devices in the calibration procedure, because consistancy of their results with the Pylon source, stability during many years and linearity in

these monitors are very good. In the Table 1 there are results of such comparisons performed from 2000 to 2006.

Table 1. Comparison of results of AlphaGUARD PQ2000 PRO monitor (AG PRO) with radon concentrations calculated on the basis of standard source activity (137.27 kBq), time of radon generation in the source and volume of the chamber, in years 2000-2006. In AG monitor the calibration factor was equal to 1 all the time (introduced by the producent and never changed).

Date of the comparison	Rn conc. from activity of Pylon Rn source [Bq/m^3]	Expanded uncertainty (k=2)	Rn conc. from AG [Bq/m^3]	Expanded uncertainty (k=2)	AG PRO / Pylon Rn source	En
25.10.00	11178	447	10699	513	0.96	0.70
04.12.00	5783	231	5525	464	0.96	0.50
09.01.01	3410	134	3659	314	1.07	-0.73
30.04.03	11178	447	11776	1391	1.05	-0.41
11.03.04	11178	447	11072	756	0.99	0.12
29.12.04	11178	447	10368	767	0.93	0.91
04.03.05	11178	447	10140	1088	0.91	0.88
20.10.05	11178	447	11200	952	1.00	-0.02
02.01.06	11178	447	10816	754	0.97	0.41
16.03.06	11178	447	10816	772	0.97	0.41

For calibration of radon progeny devices the Radon Progeny Particle Size Spectrometer serves as a reference monitor. It is calibrated in the absolute way, and not by comparison with other monitor, for the average value of α particle energy on a filter equal to 7.2 MeV (= 1.152 \10^{-3} nJ) and a particle counting efficiency calculated from geometrical dimensions of detector-filter configuration.
Concentration of potential α energy coresponding to counting frequency N/ t for the flow ν is calculated from the following formula:

$$PAEC = \frac{1.152 \cdot N/t}{\nu \cdot eff}$$

where: PAEC – potential α energy concentration [nJ/m^3]

4.2.1.1 N – number of pulses counted in the time t

ν – flow rate [l/min]
eff – counting efficiency of the detector – filter configuration
t – counting time [min.]

The RPPSS is an open-face instrument that ensures that there is no lost of potential alpha energy concentration resulting from deposition of small particles in the air inlet parts of the

instrument. It makes it possible to calibrate other radon progeny meters against the RPPSS taking into account dependence of reading on the equivalent factor F between radon and its progeny. In the Fig. 4 there are presented results of such calibrations of Rn WL Meter performed in 2005.

Rn WL Meter is an external accessory of AlphaGUARD PQ2000 PRO monitor. It is a small, portable, working in continuous mode radon progeny measuring head connected with the main unit which collects one-hour results of PAEC in its memory. The dependence of correction coefficients K, defined as a ratio of the results from RnWL Meter to RPPSS, on the equivalent factor F has a shape of log-normal function: $K = 0.29 \ln(F) + 1.38$.

On the basis of this curve the mean correction coefficients in five ranges of the equivalent factor F were calculated (Table 2).

Table 2. The mean correction coefficients for Rn WL Meter in five ranges of the equivalent factor F (for 2005 results).

F	Mean value	Uncertainty
0.80 -1.00	1.35	0.16
0.60 - 0.79	1.27	0.15
0.40 - 0.59	1.17	0.14
0.20 - 0.39	1.02	0.12
0.10 - 0.19	0.81	0.09

Interlaboratory comparisons

In order to satisfy the requirements of auditor concerning intercomparison measurements the Radon Dosimetry Group participated in two intercomparison exercices. One was organized by the Slovak Legal Metrology, accredited for organizing interlaboratory comparisons, at the Slovak Medical University in Bratislava, June 2005. The radon monitor AlphaGUARD PQ2000 PRO used in RDG as reference was compared.

In October 2005 the same AlphaGUARD PQ2000 PRO monitor and its external unit for radon progeny measuring Rn WL Meter were compared with devices of National Institute for Nuclear, Biological and Chemical Protection (SUJCHBO) in Pribram-Kamenna, Czech Republic. SUJCHBO has accreditation as a calibrating laboratory in the scope of radon and radon progeny devices.

In Table 3 and 4 there are presented results of the comparisons and calculated for them factor $E_{n\ recommended}$ by the Polish Center of Accreditation (PCA) as a criterion to estimate an interlaboratory comparison.

The factor E_n is calculated from the following formula:

$$E_n = \frac{x_{lab.} - x_{ref.}}{\sqrt{u^2_{lab.} + u^2_{ref.}}}$$

where:

$x_{lab.}$ – result of the laboratory applying for accreditation (RDG, CLOR)
$x_{ref.}$ – result of the reference laboratory
$u_{lab.}$ – expanded uncertainty of the result of the RDG, CLOR
$u_{ref.}$ – expanded uncertainty of the result of the reference laboratory.

The PCA criterion says that the comparison is satisfactory if $|E_n|$ is less or equal to 1.

Table 3. The summary of the comparisons of the radon concentration measurements

		Reference laboratory	RDG, CLOR	
Place of comparison	F [%]	$CRn_{ref.} \pm u_{ref.}$ [Bq/m^3]	$CRn_{clor} \pm u_{clor}$ [Bq/m^3]	$\lvert E_n \rvert$
Bratislava		20 272 ± 2838	19 613 ± 602	0.2
Pribram – Kamenna	40	1 850 ± 160	1 800 ± 109	0.3
	44	2 610 ± 250	2 488 ± 204	0.4
	26	2 560 ± 195	2 496 ± 129	0.3
	84	2 450 ± 124	2 472 ± 137	0.1
	84	2 890 ± 245	2 952 ± 155	0.2

Table 4. The summary of the comparison of the equilibrium equivalent radon concentration (EER) measurements

		Reference laboratory	RDG, CLOR	
Place of comparison	F [%]	$EER_{ref.} \pm u_{ref.}$ [Bq/m^3]	$EER_{clor} \pm u_{clor}$ [Bq/m^3]	$\lvert E_n \rvert$
Pribram – Kamenna SUJCHBO	40	737 ± 43	816 ± 93	0.8
	84	2 050 ± 430	2 051 ± 236	0.0
	80	27 400 ± 1200	25 590 ± 2888	0.6

For all results the factor $|E_n|$ is less than 1. Thus the comparisons in all measurements points for both radon and radon progeny concentrations (EER) are satisfactory.

Technical supervision

Technical supervision of instruments is a very important element of the quality system. It is executed according to a schedule and checking instructions worked out for the all equipment which is used for calibration. It ensures repeatability of results and constant readiness of laboratory to calibrate.

The portable devices equipped with rechargeable batteries need to be discharged and charged once a month. Pylon radon sources should be systematically tested if there is no leakage. The AlphaGUARD monitor readings are checked against radon concentrations calculated on the basis of Pylon source activity, time of radon generation and volume of radon chamber. In RPPSS the background, flow rate and efficiency of alpha particles counting is checked a couple of times a year. Also the flow rate and efficiency in Rn WL Meter are measured regularly. The temperature and humidity meters of the radon chamber are compared to certificated meters once a year.

Fig. 1. Radon calibration walk-in chamber of CLOR

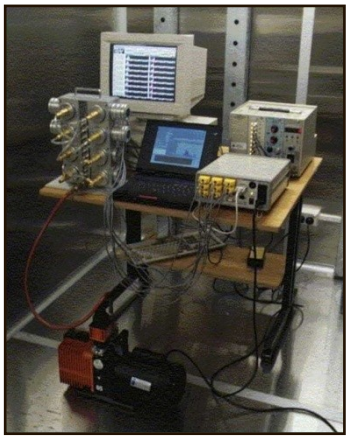

Figure 2. Radon Progeny Particle Size Spectrometer (RPPSS)

Figure 3. Radon and radon progeny monitors in the calibration chamber

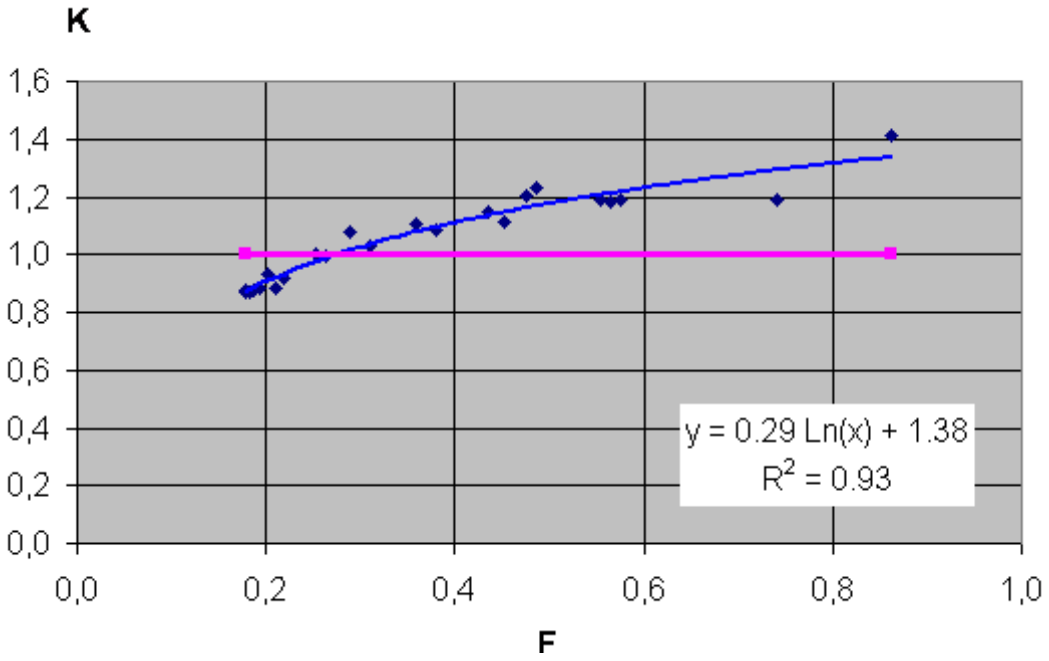

Figure 4. Calibration of Rn WL Metr against RPPSS (K= Rn WL Meter/RPPSS)

4.3 NATIONAL INTERLABORATORY COMPARISON OF PASSIVE METHODS OF RADON CONCENTRATION MEASUREMENTS IN CLOR RADON CHAMBER

O. Stawarz, K. Mamont-Ciesla

DOSIMETRY DEPARTMENT

In June 2005 a national intercomparison of passive methods of radon measurements was organized for Polish laboratories in CLOR calibration chamber. Nine laboratories with track and charcoal detectors participated.

There were 3 exposure exercises differing with the value of radon concentration and radon exposure, duration, aerosol concentration and also with the relative humidity. The conditions are described in Table 1.

Participants were to submit three five charcoal detector sets: one set for each exposure exercise or/and four five track detector sets: one for each exposure and additionally one as a transport set. The sets of charcoal detectors were sent back to participants to be analyzed

after each exposure with information about the time of exposure, the relative humidity and temperature.

Duration of exposure of charcoal detectors were adjusted to requests of the particular participants. Track detectors were sent back all together after three exposures had finished and the participants were supposed to group them into four sets dependently on readout results and to calculate mean values corresponding to transport and each exposure after subtraction of exposure mean for transport set.

Table 1. Conditions of radon concentration, climatic and aerosol parameters in the calibration chamber during three exposure exercises.

	Exposure I		Exposure II		Exposure III	
	Track det.	Charcoal det.	Track det.	Charcoal det.	Track det.	Charcoal det.
Rn conc. [Bq/m^3]	3 080	3 427$^{*)}$, 3 781	2268	3 726$^{*)}$, 5 655	11 146	12 331$^{*)}$,16 263
Duration [h]	96	from 48 to72	168	from 24 to 72	96	from 19 to 72
Relative humidity [%]	48	48	46	45	87	86
Temperature [ºC]	24	23	23	23	28	28
Aerosol conc. [cm^{-3}]	<200	<200	20 000	25 000	6 500	9 000

Altogether six sets of track detectors and seven sets of charcoal detectors with five of PicoRad type in them were submitted to compare. The results for two sets of track detectors were not sent to organizers. The results sent by participants are presented and compared with the reference value in Table 2 for track detectors and in Table 3 for charcoal detectors. The reference value was determined by means of AlphaGUARD PQ2000 PRO monitor. To estimate the

$$E_n = \frac{x_{lab.} - x_{ref.}}{\sqrt{u_{lab.}^2 + u_{ref.}^2}}$$

comparisons the E_n factor, recommended by the Polish Center of Accreditation, was applied. It is calculated from the following formula:

where:

$x_{lab.}$ – result of the participant

$x_{ref.}$ – the reference value

$u_{lab.}$ – expanded uncertainty of the result of the participant

$u_{ref.}$ – expanded uncertainty of the reference value

The PCA criterion says that the comparison is satisfactory if $|E_n|$ is less or equal to 1.

Table 2. The summary of the intercomparison of the track detectors.

Ref. value: [kBq h/m^3]	Exposure I 296 ± 9		Exposure II 381 ± 12		Exposure III 1 070 ± 33	
Code of lab.	Participant's value	| E_n |	Participant's value	| E_n |	Participant's value	| E_n |
S1	146 ± 21	6.6	202 ± 34	5.0	579 ± 46	8.7
S2	-	-	-	-	-	-
S3	-	-	-	-	-	-
S4	477 ± 70	2.6	629 ± 88	2.8	1 411 ± 174	1.9
S5	348 ± 59	0.9	465 ± 99	0.8	1 311 ± 197	1.2
S6	327 ± 43	0.7	434 ± 73	0.7	1 247 ± 229	0.8

Table 3. The summary of the intercomparison of the charcoal detectors.

Ref. value: [Bq /m^3]	Exposure I 3 781 ± 119 (3 427 ± 107)*)		Exposure II 5 655 ± 178 (3 726 ± 116)*)		Exposure III 16 263 ± 498 (12 331 ± 374)*)	
Code of lab.	Participant's value	| E_n |	Participant's value	| E_n |	Participant's value	| E_n |
W1	3 144 ± 186	2.9	4 662 ± 285	3.0	13 981 ± 661	2.8
W2	2 650 ± 250	4.1	3 640 ± 300	5.8	15 840 ± 1100	0.4
W3	5 120 ± 360	3.5	5 385 ± 370	0.7	12 050 ± 840	5.7
W4	2 718 ± 35	8.6	4 170 ± 34	8,2	11 987 ± 70	8.5
W5*)	1 386 ± 2	19.1	1 975 ± 19	14.9	293 ± 9	32.2
W6*)	3 300 ± 330	0.4	2 610 ± 261	3.9	4 000 ± 400	15.2
W7	3 608 ± 133	1.0	5 323 ± 239	1.1	17 269 ± 610	1.3

Conclusion: The results are very far from being satisfactory. Thus the intercomparisons should be organized more frequently.

4.4 THE ACTIVITY OF CALIBRATION LABORATORY - SECONDARY STANDARD DOSIMETRY LABORATORY (SSDL) FOR RADIATION PROTECTION IN POLAND

H. Dzikiewicz–Sapiecha, M. Bogusz, R. Siwicki

DOSE CONTROL AND CALIBRATION DEPARTMENT

INTRODUCTION

In 1960, the Calibration Laboratory at Central Laboratory for Radiological Protection (*CLOR*) was established. In1967, the Central Office for Quality and Measures in its capacity of the National Primary Laboratory notified Laboratory at *CLOR* for calibration of ionizing radiation dosemeters and contamination monitors used for radiation protection.

Taking into consideration the coherent relationships between national and international measurement systems, the upgrading process of Calibration Laboratory to attain the status of Secondary Standard Dosimetry Laboratory for radiation protection was done in year1999. The role of SSDL is to provide traceable and reliable calibrations in the goal of achieving an uncertainty of the calibration factors of the order adequate to radiation protection criteria.

In 2003, Polish Center for Accreditation stated that SSDL at CLOR meets the requirements for Calibration Laboratory (Accreditation Certificate No. AP 057) operated under the quality assurance programme (QA) compliant with ISO/IEC International Standard 17025:2001 “General requirements for the competence of testing and calibration laboratories”.

FACILITIES & DOSIMETRY EQUIPMENT

SSDL has been equipped in the facilities and equipment of the present state of art with various irradiation apparatus and sources for X-, γ-, β-rays and the necessary calibration fields for each radiation.The basic effort has been done to demonstrate that SSDL operates system compliant with PN-ISO Standards 4037 - 1, 2, 3.
The following irradiation facilities are used for X and gamma radiation:

1. X-ray Pantak Calibration Unit, model HF320 combined with calibration bench 8 m long,
2. gamma irradiator type STS-OB85/3.01 (^{137}Cs, ^{60}Co, ^{241}Am) combined with motorized and computerized calibration bench 5,5m long,
3. gamma irradiator(low activity sources:^{137}Cs, ^{60}Co) combined with motorized bench 7 m long.

The reference dosemeters and equipment are used:

1. PTW UNIDOS - Universal Dosemeters,
2. two reference dosemeters used as a secondary standard and working standard with the following chambers and accessories:
   - protection level chamber type 23361 (30 cm^3),
   - protection level chamber type LS-01 (1000 cm^3),
   - low level chamber type LS-10 (10 000 cm^3),
   - PMMA phantom (30 cm x 30 cm x 30 cm),
   - water phantom (30 cm x 30 cm x 15 cm).

The following wide area alpha and beta reference sources are used for calibration of surface contamination meters: ^{41}Am, ^{14}C, ^{36}Cl, ^{147}Pm, ^{204}Tl, ^{90}Sr (Amersham Buchler GmbH & Co KG).

Activities

In the period 2004–2005, the Calibration Laboratory activity has been realised under main following headings:

1. **Calibration** of different type meters and quantities:
   - dosemeters and doserate meters used for area monitoring,
   - electronic dosemeters and doserate meters for individual monitoring,
2. alpha and beta contamination radiation meters,
3. **Reference irradiations** of the individual passive dosemeters (films and TLD)
4. **Quality assurance programme** realised to fulfill the PN-ISO 4037 - 1, 2, 3 standards and ISO/IEC 17025:2001 International Standard requirements
5. **Biological samples irradiations** for research studies.

Parallel to these works, the Laboratory staff have been involved in training of radiation protection officers and preparation of polish version of standard ISO 4037-3 [3].

The Calibration Laboratory affords clients to clarify the client's request and to monitor the Laboratory performance in relation to the work performed.
Figure 1 and Figure 2 show the diagrams of different type number of instruments calibrated in 2002-2005. In the period 2004 and 2005, the total number of calibrations was about 1000 instruments per year. About 30 types of dose and doserate meters and 20 types of contamination monitors have been calibrated.

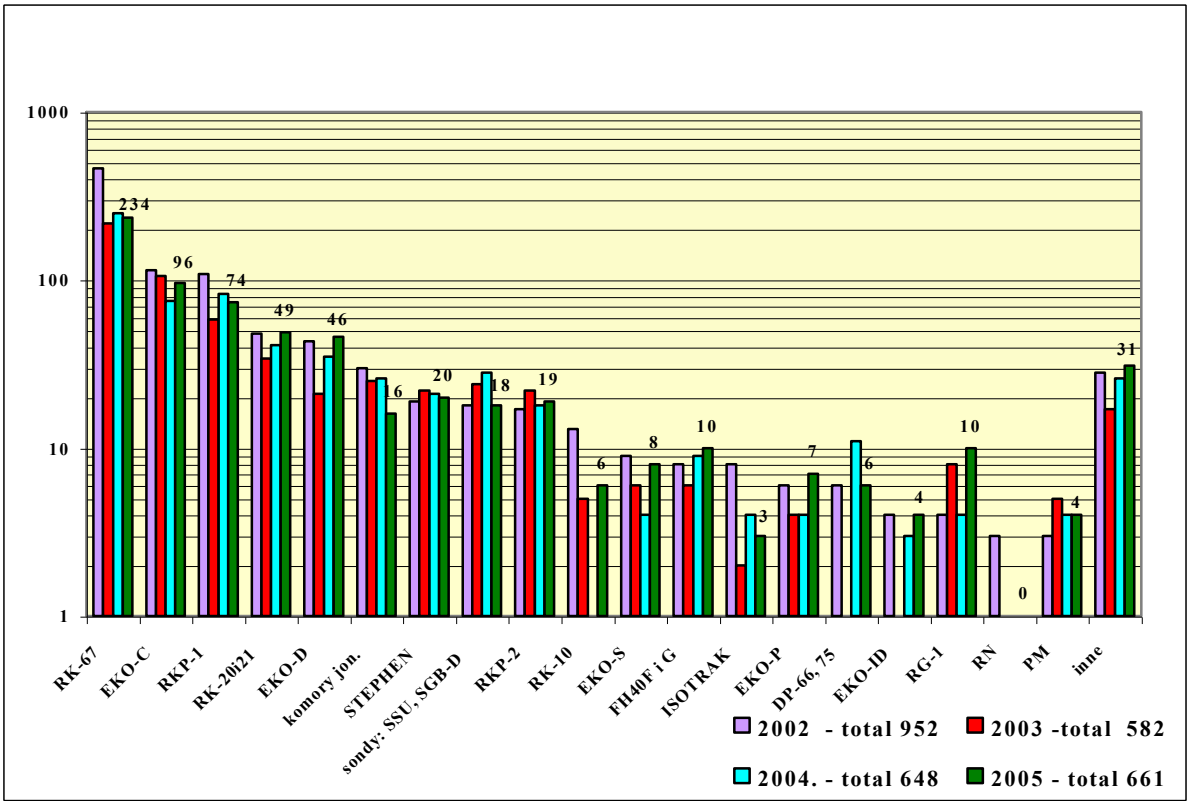

Figure 1. The contribution of different dose and doserate types in the total nstrument number calibrated in a year

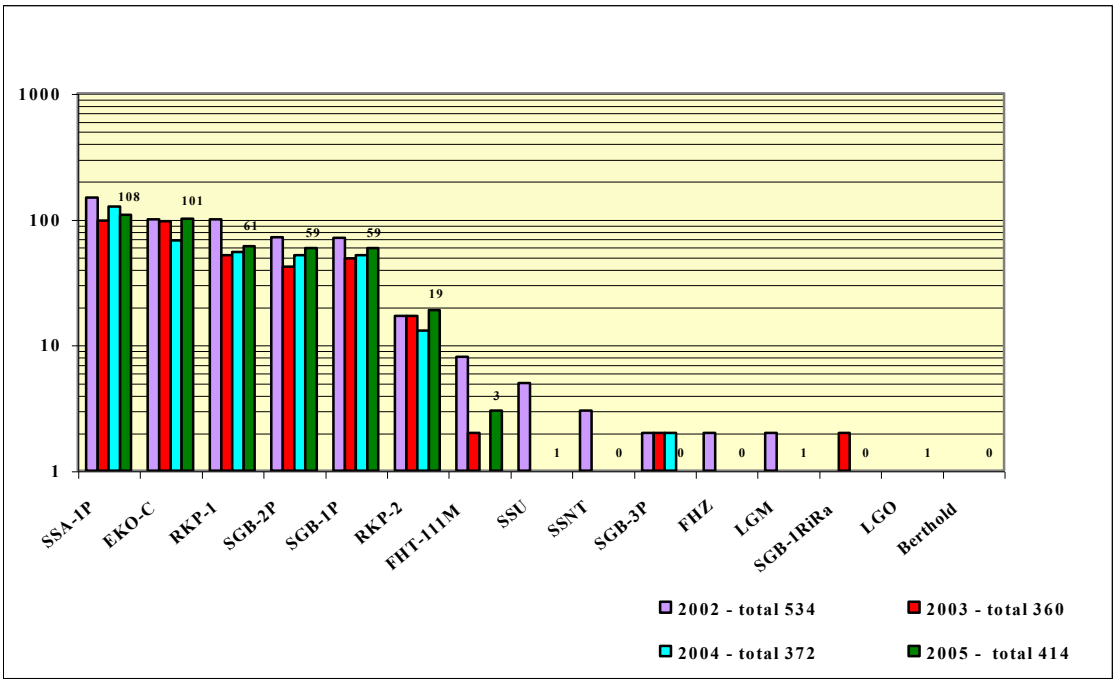

Figure 2. The contribution of different contamination meter types in the total instrument number calibrated in a year

In order to meet the requirements of ISO 17025, the quantification of the expanded uncertainties of experimental data have been carried out using well defined concepts, like those expressed in the "Guide to the Expression of Uncertainty in Measurement"(ISO-1998).

References

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3. International Organization for Standardization, 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 Personal Dosemeters and the Measurement of Their Response as a Function of Energy and Angle of Incidence, International Standard ISO 4037-3, ISO, Geneva (1999).

ZAKRES AKREDYTACJI
LABORATORIUM WZORCUJĄCEGO
Nr AP 057

wydany przez
POLSKIE CENTRUM AKREDYTACJI
01-382 Warszawa, ul. Szczotkarska 42

Wydanie nr 3 Data wydania: 7 sierpnia 2006 r.

PCA AP 057	Nazwa i adres organizacji macierzystej **CENTRALNE LABORATORIUM OCHRONY RADIOLOGICZNEJ** **ul. Konwallowa 7** **03-194 Warszawa**
	Nazwa, adres, telefon, fax i e-mail laboratorium **PRACOWNIA WZORCOWANIA - DOZYMETRYCZNE** **LABORATORIUM WZORCÓW WTÓRNYCH** **ul. Konwallowa 7** **03-194 Warszawa** **tel. (0-22) 814-01-17, fax: (0-22) 811-18-18, e-mail: dlww@clor.waw.pl**
Kategoria laboratorium stacjonarne	Dziedziny akredytacji - promieniowanie jonizujące - wzorcowe pola promieniowania jonizującego
	Kierownictwo laboratorium mgr inż. Hanna Dziklewicz-Gaplecha - kierownik laboratorium mgr inż. Ryszard Siwicki - zastępca kierownika laboratorium

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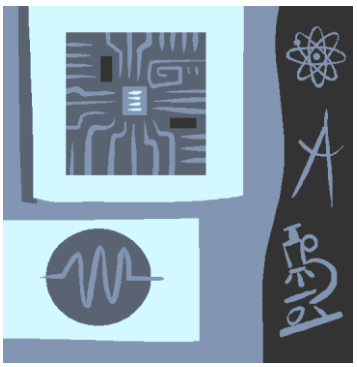

5 TRAINING AND DISSEMINATION, PUBLIC INFORMATION, STANDARDIZATION

5.1 TRAINING, INFORMATION AND STANDARDIZATION

J. Henschke, J. Rostek, M. Zielonka

TRAINING AND INFORMATION DEPARTMENT

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

CLOR organizes systematic training of persons who intend to have qualifications needed for work with ionizing radiation. For this aim in 2004 and 2005 were organized courses for radiation protection inspectors (qualifications IOR-0, IOR-1 and IOR-3 types), for operators of accelerators used for other then medical purposes (qualification A-A type), for operators of accelerators used for medical purposes and of teletherapy equipment (qualification S-A type) and for operators of equipment for brachytherapy with radioactive sources (qualifications S-Z type). The numbers of persons trained in 2004 and 2005 are shown in Table 1.

Table 1. Number of persons trained in 2004 and 2005

type / year	IOR-0, IOR-1 and IOR-3	A-A, S-A, S-Z	together
2004	126	89	215
2005	119	76	195
together	245	165	410

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 5689 volumes. The library is a subscriber of 12 Polish and 3 foreign journals.

In 2004-2005 the Secretariat of the Committee for Radiological Protection Standardization prepared for publication the following standards:

1. PN-ISO 2919 „Radiation protection - Sealed radioactive sources - General requirements and classification"
2. PN-ISO 4037-4 „X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 4: Calibration of area and personal dosemeters in low energy X reference radiation field"
3. PN-ISO 8690 „Decontamination of radioactively contaminated surfaces - Method for testing and assessing the ease of decontamination"
4. 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"
5. 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"
6. PN-ISO 12790-1 „Radiation protection – Performance criteria for radiobioassay – Part 1: General principles"
7. PN-ISO 12794 „Nuclear energy – Radiation protection – Individual thermoluminescence dosemeters for extremities and eyes"

Official opinion on the 41 drafts of ISO standards which were obtained for comments has been worked out.
Five meetings of the Committee for the Radiological Protection Standardization were organized.

6 INTERNATIONAL AND NATIONAL COOPERATION

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.

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)

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.

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

Peer-reviewing of the NCRP documents and reports.

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.

Helsinki Commission, Baltic Marine Environmental Protection Commission, Helcom Mors

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

V.G Khlopin Radium Institute, St Petersburg

Bilateral cooperation on Baltic Sea radioactive contaminations researches

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)

Physik-Technik-Innovation, Elagen, Germany

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

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

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.

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.

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).

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.

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.

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.

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.

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