CENTRALNE LABORATORIUM OCHRONY RADIOLOGICZNEJ - CLOR

CENTRAL LABORATORY FOR RADIOLOGICAL PROTECTION

REPORT OF CLOR

2000-2001

RESEARCH AND OPERATIONAL ACTIVITIES

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PREFACE

Central Laboratory for Radiological Protection (CLOR), established in 1957, was under the authority of the National Atomic Energy Agency and from August 2001 is under authority of the Ministry of Economy.
The main statutory responsibility of CLOR is protection of general population and occupationally exposed persons against the hazards of ionizing radiation. CLOR fulfills this task by routine practical activities, by scientific studies, and by providing sound advice to private and governmental organizations.
The population of Poland is at present subject to ionizing radiation from natural and man-made sources at levels not much different from those in other European countries and far below a level which may cause deleterious effects detectable by sophisticated epidemiological methods. Natural sources of radiation, such as cosmic rays, terrestial radiation, radon gas in homes and other natural radionuclides entering human body with air, water and food contributed c. 2.5 mSv to the total annual radiation dose of 3.36 mSv received in 2001 by an average inhabitant of our country. The irradiation from man-made sources, such as X-ray machines, cyclotrons and radionuclides used in medical diagnostics and in industry and science, the fallout from nuclear explosions and from Chernobyl accident, now contribute c. 0.9 mSv, or c. 27% to the total radiation dose; most of the man-made dose is from medical irradiation which contributes 0.85 mSv or 25% to the total dose. The Chernobyl fallout is now responsible for only 0.012 mSv per year, or 0.4% of the total radiation dose received currently by the Polish population.
To achieve its statutory objectives, CLOR draws on a combination of its staff skills and experience in the physical, chemical, biological and medical sciences, on which radiological protection is based. The main research activities of CLOR are:
Evaluation of radiation hazard to population of Poland due to ionizing radiation from different sources,
Evaluation of radiation hazard to occupationally exposed persons,
Research on environmental radioactive contaminations,
Elaboration and implementation of improved methods of radiometry and dosimetry, and analysis and interpretation of measurement results,
Radioecology and forecasting of propagation of radioactive substances released into the environment,
Radiobiology.

The most important operational and preventive tasks fulfilled by CLOR in 2000-2001 were as follows:
Acting as the Center of Radioactive Contamination Measurements (COPSP) which co-ordinates and supervises the functioning of the Service for Measurements of Radioactive Contaminations (SPSP) – a country-wide network of 100 measurement stations run by meteorological service, sanitary-epidemiological stations, veterinary hygiene units, chemical-agricultural units as well as water supply and sewage establishments. The tasks of COPSP involve elaboration of measurement programs for SPSP network stations, determining the necessary measurement and auxiliary equipment, running intercomparisons of measurements, collection and processing of results aimed at preparation of reports and analyses of possible radiation hazard. The COPSP maintains data base on radioactive contaminations and co-ordinates monitoring of radioactive contaminations carried out both at CLOR and by other institutions in the country.
Running specialized radioactive contaminations monitoring which comprises:

- continuous air contaminations measurements by means of 10 Aerosol Sampling Stations

(ASS-500), constructed at CLOR and supervised by National Atomic Energy Agency. These stations collect air aerosols on filter in weekly cycles. The range of airflow rate through a filter is 50.000-80.000 m^3 per week. This enable performing spectrometric measurements of natural and artificial radionuclides deposited on filters in wide range of their concentrations, beginning from 0.5μBq·m^{-3}. The scintilation probe located above the filter may register artificial radioactive isotopes on the filter. At a higher radioactivity level the frequency of sampling may be increased.

- continuous gamma dose rate measurements by means of 13 permanent monitoring stations (PMS), Danish construction, owned by the National Atomic Energy Agency and managed by CLOR. They are analysing also on-line a spectrum of gamma radioactivity in the vicinity of the stations.
- measurements of air contaminations in the troposphere and lower stratosphere,
- monitoring of radioactive contamination of rivers and lakes,
- monitoring of the Baltic Sea contaminations – as a part of an international program,
- periodic monitoring of contaminations of soils,
- continuous gamma dose measurements by means of TL detectors in 254 sites all over the country.

Supervising and co-ordination of activities of the early warning network which enables early detection of any increase of radioactivity levels in the country. The network comprises 9 SPSP alarm stations situated at meteorological stations, 13 stations PMS for continuous monitoring, 10 stations ASS-500 for air contaminations monitoring; this network is supported by 13 military station,

Maintaining the National Contact Point – an obligation under the International Convention on Early Notification of the Nuclear Accident,

Running the Center of Emergency Service (ODSA) – an round-the-clock service for interventions and aid in minor radiation accidents in the country,

Maintaining the Mobile Radiometric Laboratory designed for actions outside the CLOR,

Running a laboratory for measurements of radioactive iodine in thyroid – for nuclear emergencies and assay in persons occupationally exposed to radioiodine,

Storing computerized records-a data-base-on establishments applying radioactive sources.

Participation in countermeasures against illegal turnover of radioactive sources and nuclear materials,

Personnel dosimetry – monitoring regarding doses received by persons exposed to radiation from radioactive sources; maintaining pertinent data-base,

Calibration and attestation of dosimetric instruments in use by laboratories handling radioactive sources,

Co-ordination of measurements of natural radioactivity in building materials; maintaining data-base pertaining to these measurements,

Providing professional training in radiation protection, especially for radiological protection officers,

Running secretariat of the Standardization Commission in the field of radiological protection.

These activities have country-wide range; some of them involve international co-operation. There is a close link between the operational and preventive activities, and the research and development studies carried out at CLOR. This is the case especially as regards radiation monitoring, calibration, attestation of radiation measuring instruments, and measurements of natural radioactivity in building materials.

The activities of CLOR are financed by the National Atomic Energy Agency, the State Committee of Scientific Research, State Inspectorate of Environmental Protection and by the European Commission.

Professor S. Sterliński
Director

1. ORGANIZATION

Central Laboratory for Radiological Protection has a staff of 105 of which 59 have university level background. CLOR employs 4 professors and 19 senior researchers of whom 9 have Ph.D. degree.

Management of the CLOR

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2. RESEARCH ACTIVITIES

2.1 ANNUAL EFFECTIVE DOSE (2001)

J. Henschke, M. Biernacka, K. Florowska, D. Grabowski, B. Rubel, A. Sosińska
Dosimetry Department

The average annual effective dose in 2001, calculated according to the recommendation of UNSCEAR 2000*, amounted to 3.36 mSv for the statistical inhabitant of Poland. This value is contributed by radiation of natural and artificial radionuclides present in the environment and by radiation of radionuclides present in various types of products and materials such as building materials, food, water and air.

The most considerable contribution to this value, about 74%, is from radiation of the natural radionuclides. Among them the highest individual dose arises from radon exposure (40.5%). Cosmic radiation contributes only 8.7%. Substantial contribution to the annual effective dose comes from ionising radiation used in medical diagnostics (25.3%).

The average annual effective dose 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 ionising 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, for an average inhabitant of Poland in 2001 to be 0.023 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 this value to the annual dose limit and the average annual effective dose shows that in 2001 the effective dose caused by radiation of man-made sources reached 2.3 % of the dose limit and 0.7 % 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, 2001 (3,36 mSv)

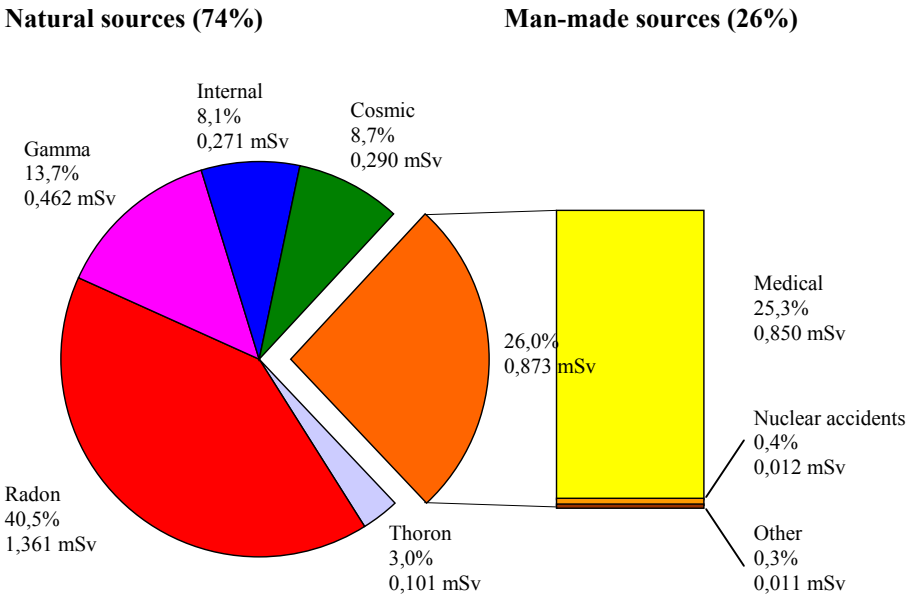
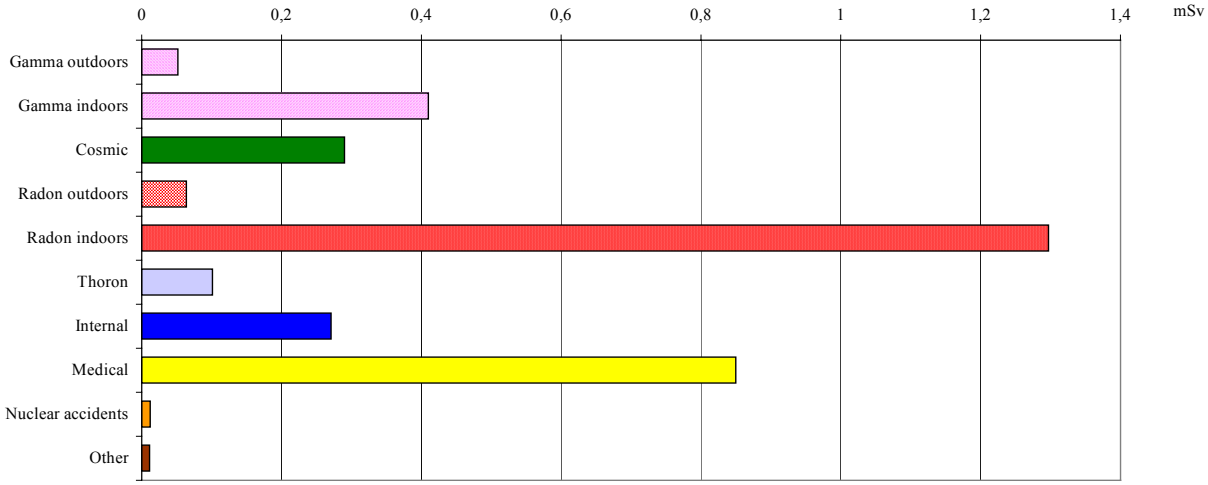


Fig 2. Average annual individual effective dose from different radiation sources in Poland, 2001 [mSv]



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

M. Biernacka, A. Koczyński, A. Sosińska
Dosimetry Department

These investigations are performed in the frame of Polish National Environmental Monitoring System. In 2000-2001 the measurements were carried out at the premises of the network of meteorological stations of the Institute of Meteorology and Water Managment.

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

Measurements of gamma radiation dose were performed at of 256 points. In the same sites soil samples were collected to determine concentration of the natural radionuclide and caesium isotopes by means of the spectrometric analysis.

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

The samples of soil in each point were taken with a knife-edge pipe of 2 inches diameter from the 10 cm thick surface layer at six places, at the circumference of the circle of 2 m radius, and in the centre of the circle. The measurements of radionuclide concentrations in soil samples were made using spectrometers with HPGe detectors, located in low-background lead shielding houses. The time of each measurement was 80 000 s.

The mean values of concentrations of natural radionuclides in soil in Poland are: for ^{226}Ra - 24.0, for ^{228}Ac - 23.3 and for ^{40}K - 399 Bq·kg^{-1}, i. e. lower as the mean world concentrations of 33, 45 and 420 Bq·kg^{-1}, respectively [1].

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

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

Table 1. The values of gamma dose rate of the outdoor radiation in Poland in 2000 – 2001.

Year	Gamma dose rate [nGy/h]			
	Terrestrial		With cosmic radiation	
	Mean	Range	Mean	Range
2000	38.7	10.8 - 105.1	72.2	43.8 - 141.6
2001	41.9	14,8 - 83.4	75.5	47.0 - 119.9

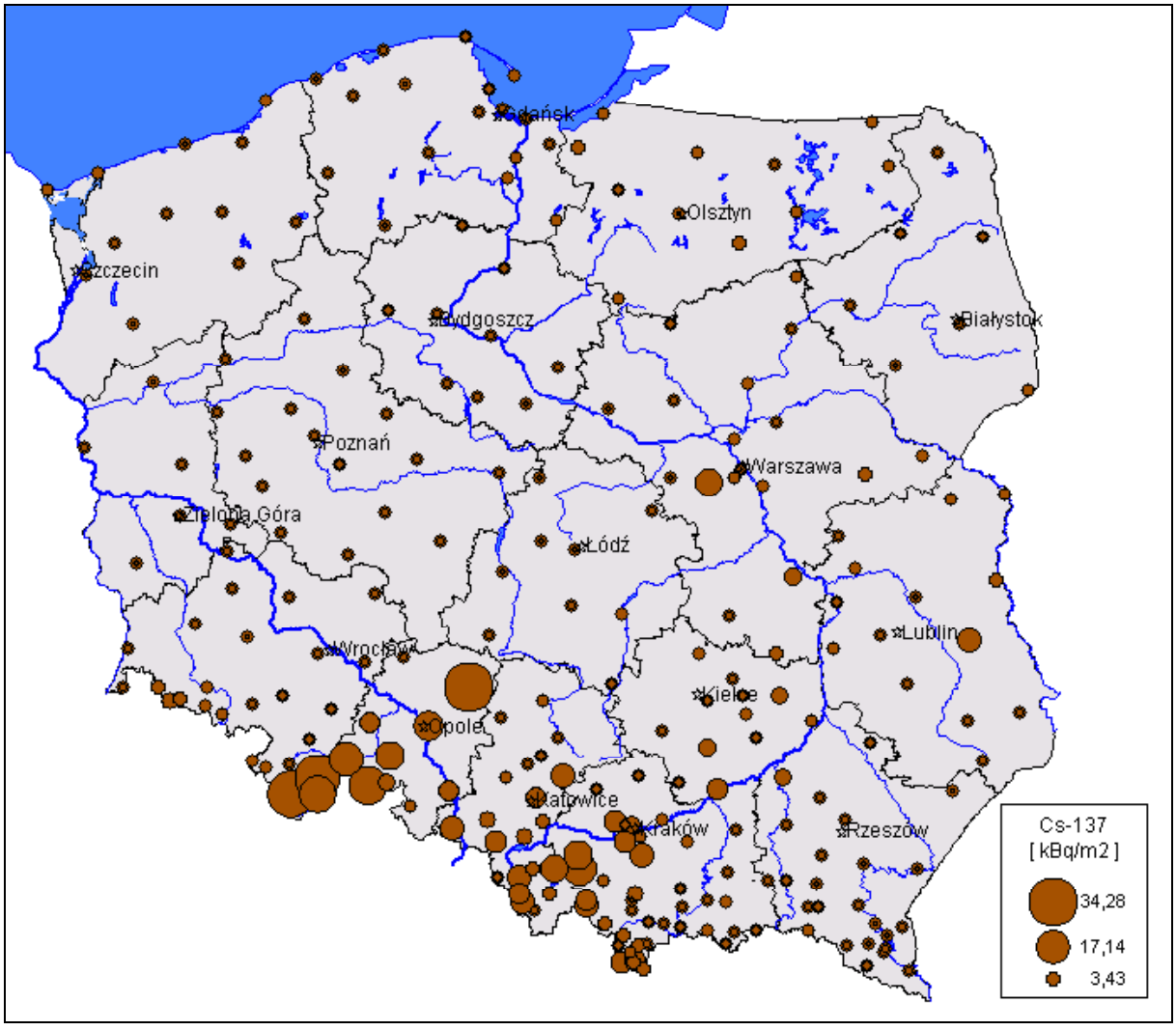


Fig. 1. ^{137}Cs deposition in the 10 cm surface layer of soil in Poland, in October 2000

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

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

2.3 INVESTIGATION OF THE INFLUENCE OF AEROSOL CONDITIONS ON THE PAEC READING OF VARIOUS INSTRUMENTS IN THE RADON CALIBRATION CHAMBER OF CLOR

K. Mamont-Ciesla, M. Kusyk

1. Introduction

A walk-in radon/aerosol exposure chamber was designed and installed in CLOR in 1999 for use in the quality assurance program for radon and radon progeny measurements [1]. The chamber body is an air-tight air-conditioned room made of sandwich elements, and lined with stainless steel. Its inner volume is of ca.12.37m^3 and the surface-to-volume ratio of ca. 2.6 m^{-1}. Climatic conditions (temperature and relative humidity) are controlled manually or automatically. Temperature may be set up from –30°C to +60°C within ±1°C and relative humidity from 10% to 95% within ±5% (for the temperature range from +10 to +60°). Dew point temperature ranges from +5°C to 45°C.

The chamber is equipped with a unique research tool - Radon Progeny Particle Size Spectrometer (RPPSS-Mk2) - from ACJ&Associates, Inc. [2] designed and manufactured by Stephen B. Solomon in Australian Radiation Protection and Nuclear Safety agency (ARPANSA), Yallambie, Australia - which makes possible to measure, among others, total potential α active energy concentration (PAEC), distribution of PAEC for 8 stages, free fraction fp, and α-active aerosol size distribution. Two radon progeny monitors, commercially available: WLx Pylon and Thomson & Nielsen Electronics Radon WL Meter were compared with the reference instrument RPPSS-Mk2 in various conditions of aerosol concentration, aerosol deposition and relative humidity in the chamber. All the instruments worked in continuous mode.

We performed an extended 6-day experiment to investigate the altering of free fraction fp, equilibrium factor F and readings of three PAEC monitors in various conditions of aerosol concentration and aerosol deposition in the CLOR radon chamber.

2. Description of the experiment

In the radon chamber filled up with radon of concentration of ca.1000Bq/m^3 three PAEC instruments working in a continuous mode were compared: RPPSS-Mk2, Pylon Monitor Model WLx and Thomson & Nilsen Electronics Radon WL Meter interacting with AlphaGuard Radon Monitor. During the experiment the temperature was constant of ca. 25°C.

The course of the experiment in time is shown in the Fig.1 and 2.

At the beginning of the experiment, point A on the time axis, the concentration of aerosols in the chamber was very low, below the detection level of the condensation nuclei counter RICH 100 (equal to 200 CN/cm^3). The instruments worked overnight continuously cleaning the atmosphere. Next day –point B- we injected aerosols by means of a TSI water generator reaching aerosol concentration of above 20 000 CN/cm^3. After ca. four hours –point C – climatic box was turned on producing very intensive movement of air. The generator still worked. In the point E the climatic box was turned off, thus mixing was stopped. After ca. 6 hours, in the point G, the aerosol generator was cut off and aerosol concentration begins to drop at natural velocity reaching in the point H such a low value that the free fraction starts to appear. There were no more intervention of experimentators till the end in the point J.

3. Results and discussion

Readings of PAEC, normalised for decay of radon, for the three instruments are plotted against time in the Fig.1 and values of the free fraction fp and equilibrium fraction F calculated for RPPSS results are illustrated in the Fig. 2.

In Tab. 1 there are given values of the condensation nuclei concentration, fp, F and PAEC in subsequent periods of the experiment.

Tab 1. Condensation nuclei concentration, fp, F and PAEC in subsequent periods of the experiment. (T/N_{verif} means T/N readings normalised for the calibration error in high aerosol level referred to RPPSS readings).

Periods		B	C	D - E	G	H	I - J
RICH100 [CN/cm^3]		0	17K	12K	24K	0	0
fp [%]		84,5	0	0	0	0	84
F [%]		8,7	57,6	10,3 - 9,1	70,9	31,69	9,7
PAEC[nJ/m^3]	**RPPSS**	412	2878	484 - 438	3201	1489	432
	WLx	30	3117	355 - 466	3135	1147	25
	T/N	73	4383	548 - 712	4194	1604	140
	T/N_{verif}	52	3131	408 - 509	2996	1146	100

In the period A - B the level of aerosols in the chamber atmosphere was very low. The counter of neutral aerosols RICH 100 reads zero and that means the concentration below 200 CN/m^3. Such a level is usually reached after dozen or so hours since closing the chamber. In this period the free fraction fp increased up to 85% and the F factor decreased from 13.4% to 8.7%. This altering of the parameters results from cleaning the atmosphere from aerosols by filters of three monitors which together draw ca. 33 l/min. (it corresponds to ca. 4 changes per day) and from natural deposition of aerosols on inner surfaces of the chamber. The PAEC readings of all three instruments decreased in this period. The readings of WLx and T/N are lower than the reading of the reference instrument RPPSS up to 6.5 and 2 times in the point B, respectively. It is assumed that RPPSS gives the true value of the total PAEC because it is corrected for the loss due to plate-out on the inlet of the filter holder.

In the B point the aerosol generator was turned on causing a drop of free fraction to zero and a rapid jump up of the F factor to the value of 57.6 % and also of the PAEC readings for all instruments which reached almost the same level. The reading of T/N monitor is ca.1.4 times higher than ones of the two other RPPSS and WLx due to the systematic calibration error in the conditions of the absence of free fraction. For the purpose of the investigation of the influence of free fraction on PAEC readings of T/N monitor they were verified with this factor.

In the C point, while the aerosol generator was still working, the climatic box was turned on causing strong mixing of the air what made the plate-out more intense. The aerosol concentration dropped from 17000 CN/cm^3 to 12000 CN/cm^3. The equilibrium factor F and PAEC values for all monitors also dropped to the values equal to the RPPSS reading in the B point. In the period from D to E the free fraction fp is zero and factor F is low of ca. 10%. In the E point the climatic box was stopped what caused next jump of the aerosol condensation, factor F and PAEC readings for all instruments. Since the G point when the aerosol generator was cut off the plate-out of aerosols and radon progeny takes place at the natural velocity and in the H point the aerosol concentration is low enough the free fraction to appear (fp>0). In the I point the free fraction reaches high value of 85%, the same as in the B point. In the period I - J the mean PAEC readings of WLx and T/N are significantly lower than one of the reference spectrometer RPPSS: ca. 17 and 4 times, respectively.

Fig. 3 shows dependence of PAEC readings of the three instruments on the free fraction fp. Increasing of fp causes decreasing of the PAEC readings reaching zero for WLx and T/N monitors for very high value of fp. It is due to very high losses of PAEC carried

by the free fraction in the inlet canal of a filter holder. Deposition of very small particles (of several nm) is ca. 100 times higher than for bigger aerosols (a few hundred nm) [3]. The losses are dependent on the geometry of the inlet canal and the flow rate of the air drawn. Monitor Wlx has the flow rate of 0.5l/min. and T/N - 1 l/min. Fig. 4 presents the relative losses of PAEC for monitors WLx and T/N calculated with respect to the reference device RPPSS against the free fraction fp. For fp = 50% the relative losses of PAEC in the inlet canal of Wlx and T/N are 50% and 26%, respectively.

The period D – E shows that it is possible to create such conditions that both values: F and fp are very low.

4. Conclusions

In the radon chamber of CLOR it is possible to reach values of the equivalent factor F in the range from 8% to above 70% (73% for the water generator TSI) and free fraction fp in the range from 0 to 85%. It is also possible to create such condition that both factors F and fp are minimal at the same time: fp=0 and F=8%.

The value of the potential α energy concentration (PAEC) in the air strongly depends on the aerosol concentration and free fraction fp. In CLOR chamber at high aerosol concentration and low fp the PAEC is higher ca. 7 times than that in low aerosol conditions and high fp, for the same radon concentration.

The PAEC readings for various devices can differ substantially in the conditions of high free fraction because of the losses of the part of PAEC carried by unattached radon progeny. Value of the losses is an individual feature of a device and depends on the geometry of the inlet canal and the applied flow rate of the drawn air.

Strong movement of the air has an influence on the level of PAEC because it increases deposition of aerosols on surfaces.

Contrary to the common opinion that values of F and fp are always „anticorrelated" it can happen that both values are very low. This confirms the observation of Paul et al. [4].

Results of this experiment confirm an opinion that the proper calibration of PAEC instruments should take into account the influence of aerosol concentration and their size distribution and that there is a necessity to work out such a system of calibration [5].

References

[1] Kalina Mamont-Ciesla, Monika Kusyk „New radon calibration chamber in CLOR" Seminar: Radon in environment, Kraków, Poland, 14-15 June 2000.

[2] Kalina Mamont-Ciesla, Monika Kusyk „Design and measurement possibilities of Radon Progeny Particle Size Spectrometer (RPPSS)", Seminar: Radon in environment, Kraków, Poland, 14-15 June 2000.

[3] Tieh-Chi Chu & Ho-Ling Liu „Simulated equilibrium factor studies in radon chamber" Appl. Radiat. Isot. 47, pp.543-550 (1996)

[4] A. Paul, S. Rottger, A. Honig, T.Sulima A. Buchholz, U. Keyser „Measurement of short-lived radon progenies by simultaneous $\alpha\gamma$-spectrometry at the German radon reference chamber" Nucl. Instr. and Meth. A 434 pp.303-312 (1999)

[5] A.Honig, A. Paul, S. Rottger, U. Keyser „Environmental control of the German radon reference chamber" Nucl. Instr. and Meth. A 416, pp.525-530, (1998)

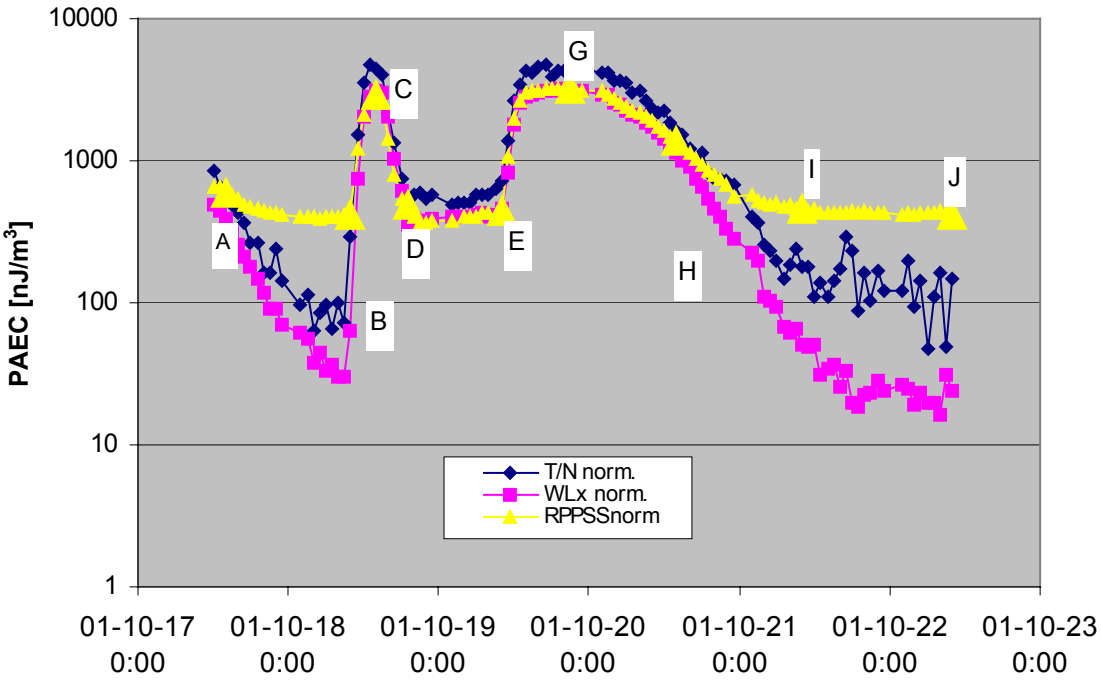


Fig 1. Change of PAEC readings for three instruments due to variations of aerosol conditions. Values of PAEC are normalised for the decay of radon.

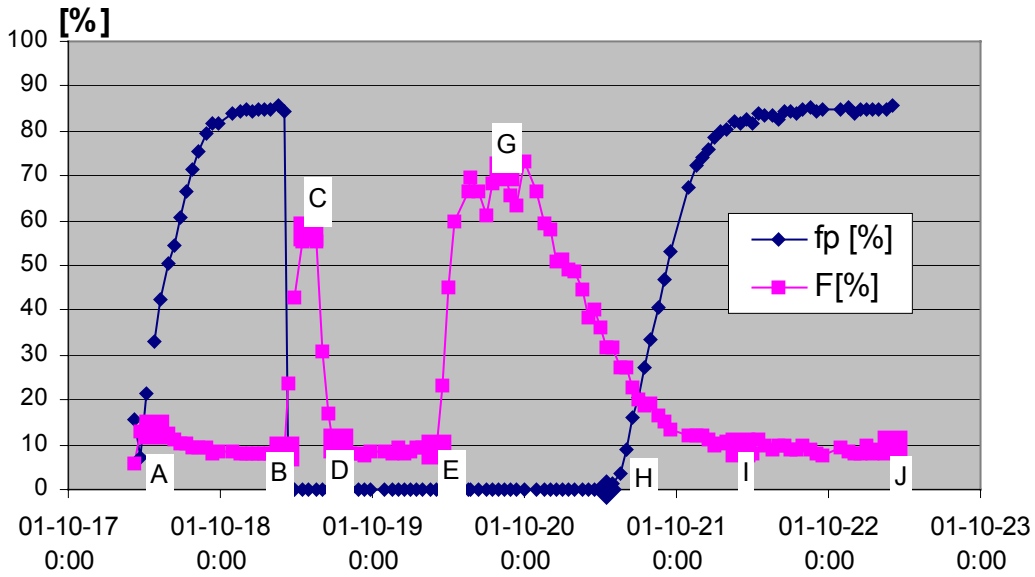


Fig. 2. Change of factors fp and F due to variations of aerosol conditions.

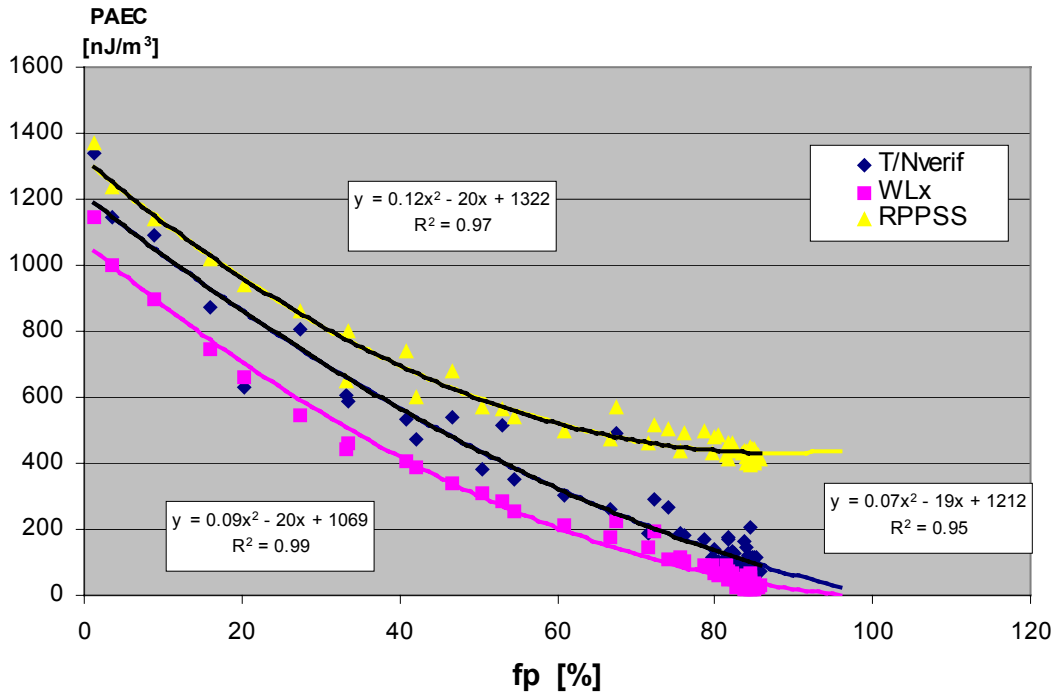


Fig. 3. PAEC as function of free fraction fp.

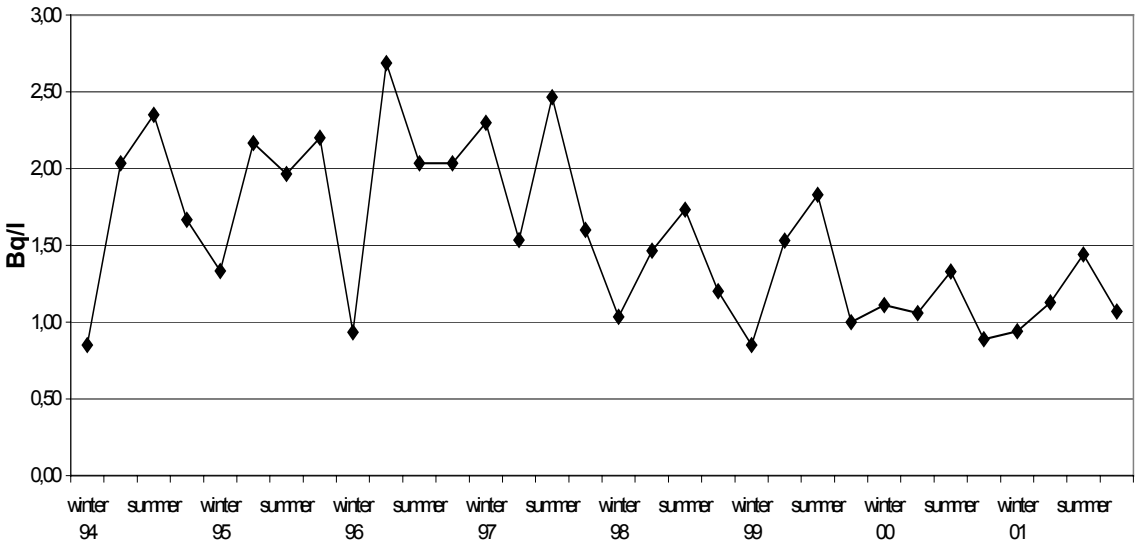


Fig.4 Relative loss of PAEC as function of free fraction fp.

2.4 TRANSFER OF RADIOCAESIUM TO CROPS FROM DIFFERENT SOIL TYPES IN POLAND AS A FUNCTION OF RADIOCAESUIM INTERCEPTION POTENTIAL AND SOIL CHRACTERISTICS

Paweł Krajewski, Lidia Rosiak
Radiation Hygiene Department

Under the EC-funded SAVE project (Spatial analysis of vulnerable ecosystems in Europe: Spatial and dynamic predictions of radiocaesium fluxes in European foods) [1] a user-friendly software system was developed, to allow the mid- to long-term impacts of radiocaesium deposition in Western Europe to be quantified, and vulnerable areas identified. At the core of the system is a semi-mechanistic radiocaesium soil to plant transfer model developed and parameterised following experiments undertaken to quantify the uptake of radiocaesium over a wide range of soils types [2], [3], [4]. The aim of the Inco-Copernicus Spatial Analysis of Vulnerable Ecosystems in Central Europe (SAVEC) project was to modify the SAVE model and apply it to the Czech Republic, Hungary and Poland using spatial input databases collated for each of the three Central European countries. Within SAVEC, it was feasible to derive model input spatial databases from national data sets with a view to improving the reliability of model predictions. The novel soil-plant transfer model was validated baseed on measurements conducted in Poland during the project period.

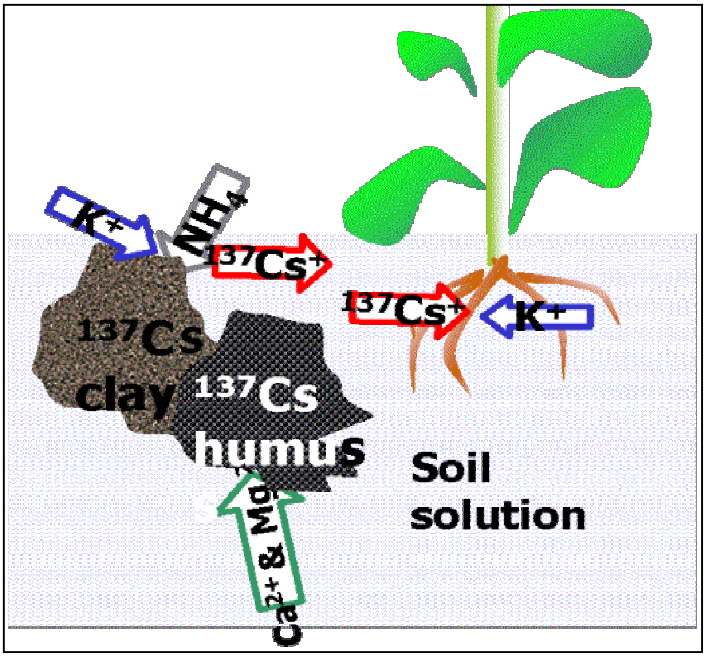


Fig. 1 Relationship between conceptual pools of radiocesium considered in the model.

The soil-plant ^{137}Cs pathway is conceptually presented in Fig. 1 for three compartments: the soil solids (minerals-clay, particulate organic matter-humus), the soil solution and the plant. The exchange between the soil solids and the soil solution is the soil chemical reaction. The uptake of ^{137}Cs from soil solution is a reaction that is under control by plant physiology i.e. the ion uptake process in the root cells and the translocation to the above –ground parts. The ion uptake has a particular role in the entire soil-plant transfer process. Several studies of solution cultures have now come to a same conclusion that root uptake ^{137}Cs is sharply reduced with increasing concentration of K [5], [6]. Caesium is not a nutrient but may

be absorbed by the transport systems of its nutrient analogue K. High concentrations of K^+ ions effectively reduce the chance that a Cs^+ ion enters the plant through K channels or carriers in the membranes of root cells. This leads to the concept that plant availability of ^{137}Cs in soils is controlled by both its mobility in soil and by the K koncentration in the soil solution. A higher uptake of ^{137}Cs was found when the mobility of ^{137}Cs was high combined with low soluble K concentration. It was also explained why the clay content had no effect of ^{137}Cs availability. Increased clay content reduces, on the one hand, the ^{137}Cs mobility in soil but, on the other hand, also reduces K mobility leading to the higher chance of a ^{137}Cs ion being absorbed. These two effects are counteracting each other. The detailed description of SAVE semi-mechanistic soil to plant transfer model one can be found in [6], [7], [8].

Validation of SAVE semi-mechanistic soil to plant transfer model

Traditionally, soil textural groups (organic, sand, loam and clay) have been used to classify representative transfer factors (TF) for grass and other crops [9]. This method provides a rather coarse explanation of variations in radiocaesium TF, and is often found to show large variability within soil groups (Fig. 2).

The present work has focussed on collation and evaluation of detailed data on soil proprieties in Poland to give more representative prediction of soil to plant transfer factors. Base on results of measurements a validation of SAVE semi-mechanistic soil to plant transfer model was performed. Eighty seven soils were sampled (0-10 cm, 10-25 cm) in Poland in the period 1998-2000. The soils were selected to cover a wide range of textural clases and soil types. The sampling strategy was based on the number of major soil groups within each region of the country, with additional sampling in highly productive agricultural areas. The evaluation of soils types and soil texture was made based on SGDBE Poland Map (Soil Geographical Data Base of Poland, 1:1M, ver.1.0 1996 made by the Laboratory of Remote Sensing and Spatial Information System in Warsaw University of Technology). However, for many places the dominant soil type STU (Soil Typological Unit) is the same as well as the secondary STU, therefore the number of soil samples was limited to approximately 60-80 samples for further soil analyses Tab. 1. The key soil properties (pH, ON%, clay%, CEC, K_{ex}) were measured using agreed protocols Tab. 2 and ^{137}Cs concentration in soil and grass samples was measured using gamma spectrometry. The radiocaesium interception potential (RIP) (a parameter used to quantify the radiocaesium retention properties of a given soil) was also measured in representative soils. The RIP is a function of the solid:liquid distribution coefficient (K_d) and the soil solution K concentration m_k.

$$RIP = K_d \times m_k$$

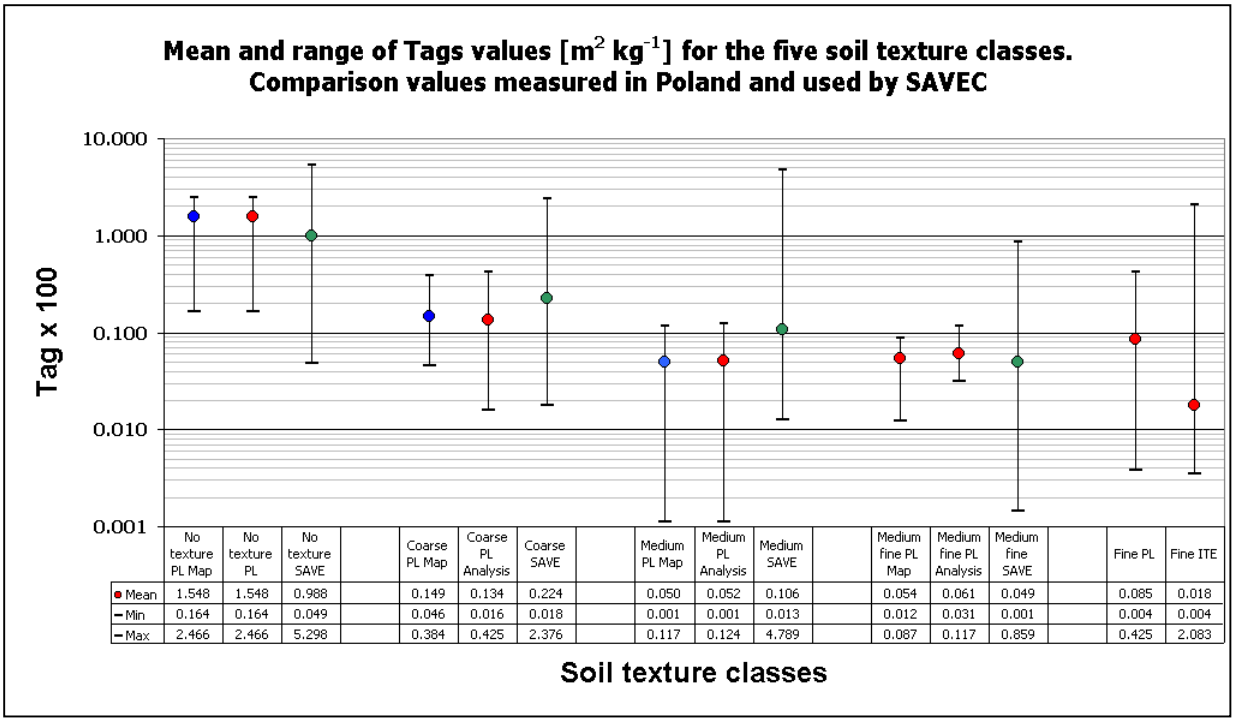
Tab. 1. Sampling statistic

Soil Type	Coverage	Soil	Grass
Orthic Luvisol	15.2%	12	6
Leptic Podzol	13.7%	4	-
Orthic Podzol	11.9%	5	3
Stagno-Gleyic Luvisol	11.0%	15	6
Cambic Arenosol	10.3%	5	3
Eutric Cambisol	10.1%	7	2
Eutric Fluvisol	6.5%	12	5
Eutric Histosol	4.7%	3	3
Molli-Fluvic Gleysol	4.0%	3	3
Dystric Cambisol	1.8%	5	3
Stagno-Gleyic Podzoluvisol	1.6%	4	2
Ranker	1.6%	4	1
Dystric Podzoluvisol	1.4%	2	
Haplic Phaeozem	1.0%	2	2
Orthic Rendzina	1.0%	4	4
Total	95.9%	87	43

Tab. 2 Agreed protocol for soil property measurements.

Parameter	Methodology/ Norm	Methodology description
pH(H_2O)	PN-ISO390-1997	The same as ISO-10390-1994
pH($CaCL_2$)	as above	As above
Organic matter content/ organic Carbon(%)	own method	For soils <15%, Turin method For soils>15%, -weight loss on ignition at 500^oC
Exchangeable cations (Na, K, Ca, Mg) [mg /100g soil]	own method	Exchangeable cations (Na, K, Ca, Mg) in 1N ammonium acetate (pH 7) extract; Na and K by flame atomic emission spectrophotomerty, Ca and Mg by flame atomic absorption spectrophotometry
Exchangable acidity [milimol/100g soil]	PN-R-04027:1997	For mineral soils: Exchangeable acidity is measured by titration with 0.1N NaOH.
Cation exchange capacity	own method	Cation exchange capacity- titration of 0.1 N HCl soil extract with 0.1n NaOH
Particle size analysis	PN-R-04033 1998 PN-R-04032 1998	International classification: Sand 2.0-0.05 mm Silt 0.05 -0.002 mm Clay <0.002 mm

In the SAVE IT model, it was assumed that soil solution K concentration (m_k) is in equilibrium between the clay and humus fractions. The model then derives m_k from the exchangeable potassium data of a given soil using Gapon exchange coefficients and the cation exchange capacity. The results of measurement according to soil textural groups are presented in Tab. 3.



	No texture PL Map	No texture PL	No texture SAVE	Coarse PL Map	Coarse PL Analysis	Coarse SAVE	Medium PL Map	Medium PL Analysis	Medium SAVE	Medium fine PL Map	Medium fine PL Analysis	Medium fine SAVE	Fine PL	Fine ITE
Mean	1.548	1.548	0.988	0.149	0.134	0.224	0.050	0.052	0.106	0.054	0.061	0.049	0.085	0.018
Min	0.164	0.164	0.049	0.046	0.016	0.018	0.001	0.001	0.013	0.012	0.031	0.001	0.004	0.004
Max	2.466	2.466	5.298	0.384	0.425	2.376	0.117	0.124	4.789	0.087	0.117	0.859	0.425	2.083

Fig. 2. Transfer factors of ^{137}Cs from soil to gras as a function of soil texture.

Using data obtained for Poland, two approaches were used to validate the semi-mechanistic soil-to-plant transfer model:

(1) TFs predicted using measured RIP values and estimated soil solution K concentration from exchangeable K, and
(2) TF values predicted using % clay, % organic matter, exchangeable K and pH.

Moreover, the theoretically calculated RIP values were compared with measured values.

The SAVE model assumes a default RIP value for clay of 55 mol kg^{-1}. Based on the clay content (determined as a fraction of particles < 2μm), a relationship between measured and modelled RIP for 86 soils in Poland was plotted Fig. 3. There is reasonable agreement between measured and predicted RIP values ($r^2 = 0.55$); however, it should be noted that the mineralogical composition of the clay component has an important influence on the number of sites in a given soil that is able to fix ^{137}Cs irreversibly.

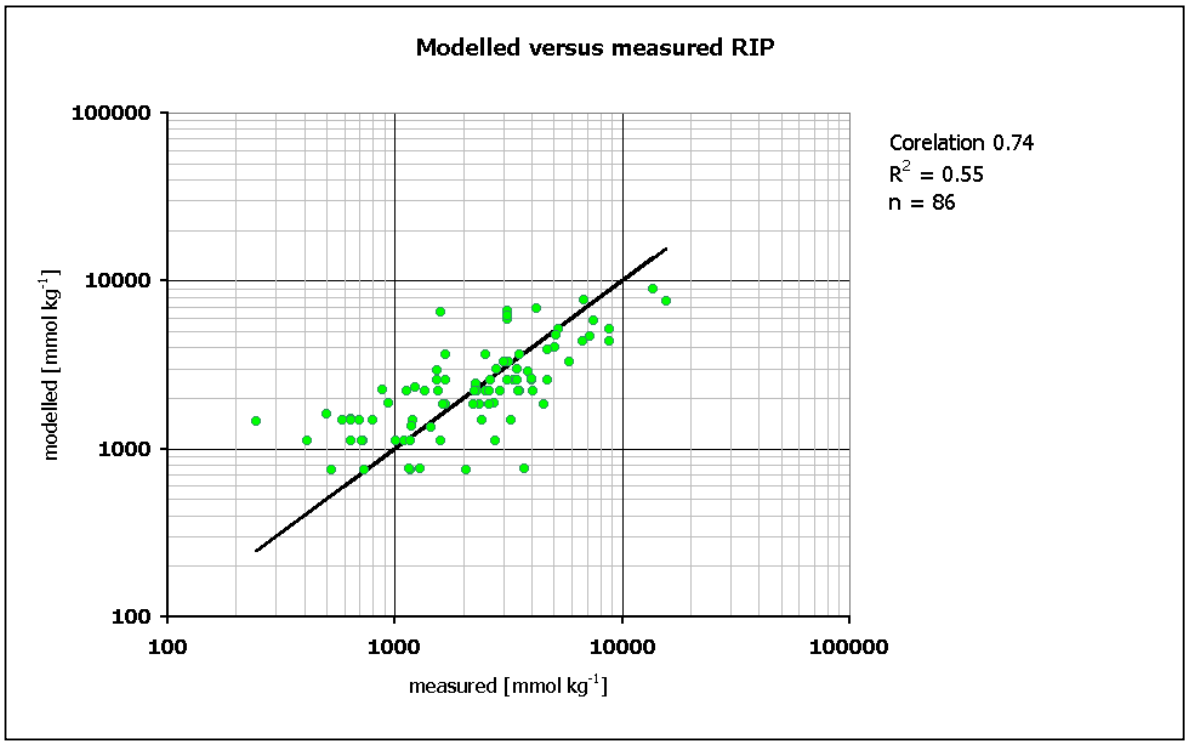


Fig. 3. Observed versus predicted RIP values for 86 soil samples collected in Poland. The 1:1 relationship is shown as a solid line.

The model also gave a satisfactory prediction of transfer factors when measured RIP values were used Fig 4. The significant correlation (r^2= 83, RI=2.8) shows that the model is partially "resistant" to different species grown on the pasture field. The best fit to the experimental data was achieved after changing of some model parameters: RIP value for clay was set at 37 mol kg^{-1} and a higher radiocaesium TF for the pasture field compared with rye grass. Based on experimental data, radiocaesium appears to have a longer environmental half-life (hence bioavailability) in Poland compared to the assumptions in the SAVE model. (SAVE: P_{fast} = 81.4%; $T_{1/2\ fast}$ = 1 year; $T_{1/2\ slow}$ = 10 years; Poland: P_{fast} = 68%; $T_{1/2\ fast}$ = 0.71 year; $T_{1/2\ slow}$ = 15.4 years). The effective predictive power of the SAVE model is shown in Fig . 5. There is remarkable improvement in predictions of ^{137}Cs TF for various plants (r^2=0.55 and Reliability Index = 3.3) compared with previously applied Tags values (presented on Fig. 2).

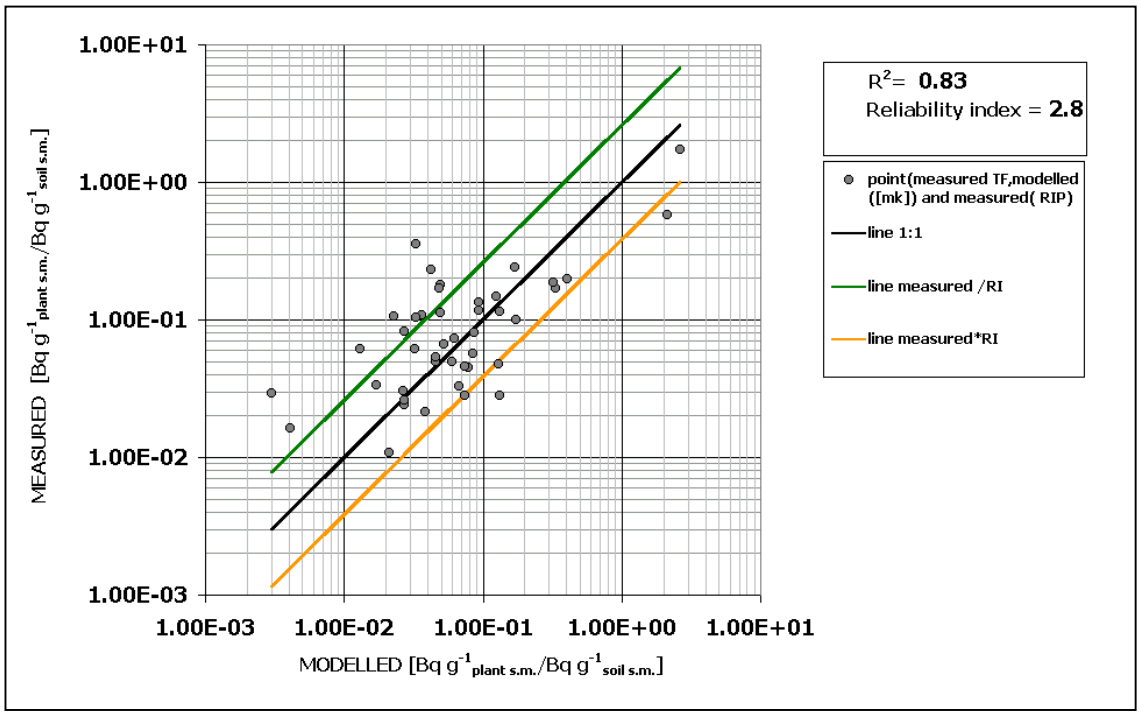


Fig. 4. Observed versus predicted radiocaesium transfer factor for grass (45 samples) when measured RIP values were used in model. The 1:1 relationship is shown as a solid line.

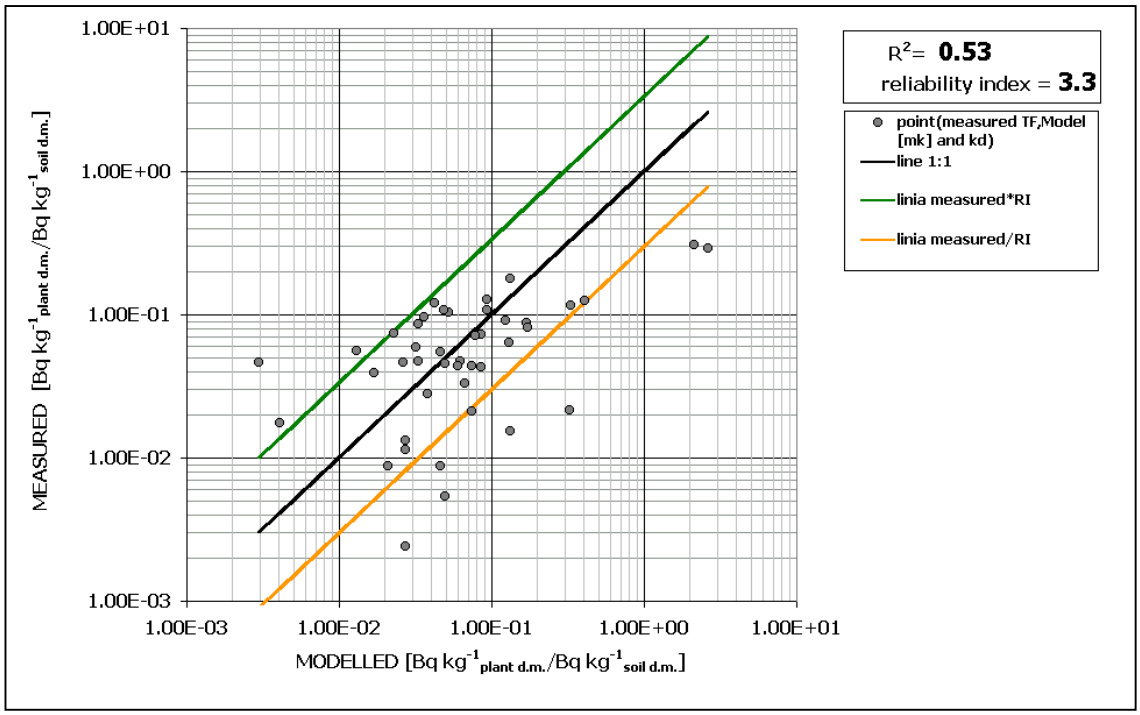


Fig. 5. Observed versus predicted radiocaecium transfer factors for grass (45 samples) when TF has been estimated from: % clay, % organic matter, exchangeable K and pH . The 1:1 relationship is shown as a solid line.

Tab. 3. Summary of the measurements results

Soil textural groups acc. FAO 1998	pH			Clay (< 2 μ) [%]		
	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX
Coarse	5.5	*4.2*	*7.2*	4.2	*2.0*	*10.0*
Medium	5.8	*4.2*	*7.5*	9.5	*1.0*	*25.0*
Medium fine	4.7	*4.6*	*4.7*	18.5	*8.0*	*19.0*
No Tex (Humus)	4.7	*4.7*	*4.7*	6.0	*4.0*	*8.0*
TOTAL	5.6	*4.2*	*7.5*	7.1	*1.0*	*25.0*

Soil textural groups acc. FAO 1998	Organic matter content [%] OM			Exchangeable potassium K^+		
	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX
Coarse	2.7	*1.3*	*5.1*	0.39	*0.10*	*2.61*
Medium	3.6	*1.3*	*21.5*	0.57	*0.17*	*4.15*
Medium fine	3.7	*3.6*	*3.9*	0.20	*0.19*	*0.20*
No Tex (Humus)	34.8	*10.8*	*58.9*	0.32	*0.20*	*0.44*
TOTAL	4.1	*1.3*	*58.9*	0.47	*0.10*	*4.15*

Soil textural groups acc. FAO 1998	Cation Exchange Capacity CEC			Exchangeable Ca^{2+}+Mg^{2+}		
	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX
Coarse	5.10	*2.81*	*8.38*	1.45	*0.46*	*4.40*
Medium	7.38	*3.78*	*18.08*	2.49	*0.61*	*12.27*
Medium fine	8.10	*6.36*	*9.13*	2.56	*1.24*	*4.88*
No Tex (Humus)	19.21	*4.04*	*45.16*	3.96	*1.68*	*7.91*
TOTAL	6.82	*2.81*	*45.16*	2.09	*0.46*	*12.27*

Soil textural groups acc. FAO 1998	^{137}Cs concentration in grass			^{137}Cs concentration in soil		
	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX
Coarse	7.1	*0.7*	*51.9*	39.3	*9.8*	*114.4*
Medium	3.5	*0.1*	*19.5*	67.1	*8.3*	*323.5*
Medium fine	8.4	*0.3*	*16.5*	71.8	*10.4*	*133.2*
No Tex (Humus)	44.9	*40.5*	*49.4*	19.3	*15.5*	*23.1*
TOTAL	7.3	*0.1*	*51.9*	54.5	*8.3*	*323.5*

Soil textural groups acc. FAO 1998	Radiocaesium interception			Soil-grass transfer factors		
	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX
Coarse	1599	*381*	*5137*	0.146	*0.017*	*0.454*
Medium	4378	*1583*	*13719*	0.051	*0.004*	*0.131*
Medium fine	2898	*1583*	*4213*	0.079	*0.033*	*0.124*
No Tex (Humus)	521	*195*	*847*	2.375	*2.135*	*2.614*
TOTAL	2897	*195*	*13719*	0.208	*0.004*	*2.614*

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2.5 CONCENTRATION OF ^{226}RA IN GRASS IN VARIOUS VEGETATIVE PERIOD

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The uptake of ^{226}Ra from soil to plant depends on ^{226}Ra concentration in soil, especially exchangeable radium, kind of plants and their parts, weather conditions and possibly other factors. During this study it was found that vegetative period is one of important parameters determining the ^{226}Ra incorporation into grass. The grass *Dactylis glomerata* was cultivated on the experimental fields for six consecutive years in the same place and on two kinds of soil. Analyses of both soils for ^{226}Ra concentration carried out twice a year indicated lack of significant differences in total as well as exchangeable ^{226}Ra concentrations in soils during the period of six years. The grass was harvested twice in each vegetative season. Vegetative period (for cut I) is the time elapsing from sowing to cutting in first year of cultivation. In next years vegetative period was assumed as time elapsing from slight cutting of new spring leaves, to cut I. Vegetative period for cut II was defined as time elapsing between cut I and cut II. Average ^{226}Ra concentrations in grass (after rinsing in distilled water) grown on two soils during six years in given vegetative periods are presented in Table 1.

Table 1. ^{226}Ra concentration in *Dactylis glomerata* grown on two kinds of soil in six subsequent years

Year	Vegetative period, days	Average ^{226}Ra concentration, Bq kg^{-1}_{dw}	
		Soil I	Soil II
Cut I			
1995	69	0.59±0.10[a)]	0.42±0.08[a)]
1996	60	0.41±0.05	0.37±0.09
1997	45	0.51±0.04	0.33±0.06
1998	30	0.47±0.04	0.39±0.02
1999	49	0.21±0.01	0.22±0.03
2000	66	0.49±0.06	0.49±0.03
Cut II			
1995	83	0.87±0.12	0.71±0.12
1996	43	0.50±0.08	0.49±0.10
1997	41	0.48±0.06	0.49±0.08
1998	110	1.10±0.16	0.63±0.04
1999	121	0.86±0.06	0.89±0.08
2000	63	0.40±0.02	0.50±0.06

[a)] standard deviation

The correlation between the vegetative period and ^{226}Ra incorporated in grass is significant (r = 0.78). With lengthening the time of grass growing on the field the quantity of ^{226}Ra incorporated in the plant increases. It is a general tendency; however, the vegetative period being not the only factor influencing the radium uptake by the grass, some disturbances are observed. The least squares fit calculation gives the following equation:

$$y = 0.0062x + 0.1323$$

where: y is the concentration in grass (Bq kg^{-1}_{dw});
x is the vegetative period (days).

This relationship between ^{226}Ra concentration in grass and a vegetative period is shown in Fig. 1.

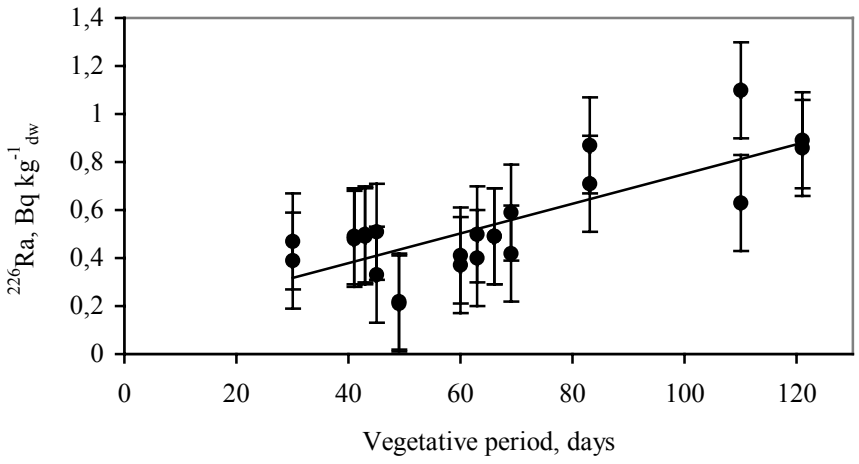

Fig. 1.The relationship between ^{226}Ra concentration in grass and a vegetative period

2.6 RETROSPECTIVE EVALUATION OF ^{131}I DEPOSITION DENSITY AND THYROID DOSE IN POLAND AFTER THE CHERNOBYL ACCIDENT

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1. Deposition density of ^{131}I and ^{137}Cs

The ^{131}I deposition in Poland after the Chernobyl accident on 26 April 1986 was evaluated from the determined ^{129}I deposition and the estimated $^{129}I/^{131}I$ ratio at the time of the arrival of the fallout. Concentrations of ^{129}I and ^{127}I were determined by neutron activation analysis in uncultivated soils from 16 locations in Poland. Analysis of ^{137}Cs in soils was carried out by gamma spectrometry. The atomic ratio of $^{129}I/^{131}I$ at the time of the fallout arrival was estimated using the $^{129}I/^{131}I$ ratio at the time of the accident, which on the basis of the core inventory data was assumed to be 22.8 [1]. It was estimated from time of the fallout arrival and from the weighed mean atomic ratio, that the $^{129}I/^{131}I$ ratio for Poland was 32.8.

Deposition density of ^{129}I was calculated from the concentrations in the soil layers. From the concentrations determined in analyzed samples, there was subtracted the background, associated with ^{129}I originating from the natural sources and from the nuclear weapon tests. It was assumed that the background of ^{129}I was 6×10^7 atoms per gram of soil [2].

Deposition density of ^{137}Cs was calculated from the concentrations in all the layers in which it was present. The ^{137}Cs present in soil before the Chernobyl accident originating from the nuclear weapon tests was not subtracted because of its low content [3].

The deposition densities of ^{131}I and the $^{131}I/^{137}Cs$ ratios for the locations studied are presented in Table 1.

Table 1. Deposition density of ^{131}I estimated from the determined deposition of ^{129}I, and $^{131}I/^{137}Cs$ ratios at various locations in Poland

Location	^{131}I (atoms m^{-2}) (10^{11})	^{131}I (kBq m^{-2})	$^{131}I/^{137}Cs$ (kBq/kBq)
Biała Wieś	6.56	633	214
Kórnik	2.20	213	133
Olesno	6.60	638	5.41
Bierdzany	7.75	729	10.7
Wola Filipowska	3.06	295	33.3
Czernichów	0.65	63.2	9.29
Kuryły	1.87	180	36.9
Siekierki	4.57	442	107
Goworowo	5.96	575	105
Szumowo	4.76	459	71.2
Wilków Polski	5.76	556	174
Brwinów	4.36	421	18.6
Liw	2.10	203	64.8
Krynica	1.13	109	14.3
Platerów	5.41	522	60.4
Biała Podlaska	1.65	159	26.9

The deposition of ^{131}I varied in a wide range from about 63 kBq m^{-2} (Czernichów) to 729 kBq m^{-2} (Bierdzany). High depositions occurred in the locations with rainfall (Olesno, Bierdzany, Brwinów) and also in the locations without rainfall (Biała Wieś, Wilków Polski and eastern region: Siekierki, Goworowo, Szumowo).

Activity ratios $^{131}I/^{137}Cs$ varied from 5.41 (Olesno) to 215 (Biała Wieś). Usually, this ratio was lower in the locations, where rainfall occurred (Olesno, Bierdzany, Brwinow).

2. Relationship between deposition of ^{131}I and ^{137}Cs

Knatko and Dorozhok [4] found the following empirical relationship between the deposition of ^{131}I and ^{137}Cs in Belarus:

$$\ln\left(\frac{^{131}I}{^{137}Cs}\right) = a + b\ln(^{137}Cs)$$

where ^{131}I and ^{137}Cs are deposition densities of these radionuclides in kBq m^{-2}, constants a and b were 3.52±0.19, and -0.37±0.03, respectively.

The same relationship was found in the present work, with a = 5.32±0.37, b=–0.78±0.16, and correlation coefficient r = 0.79.

3. Evaluation of average committed effective doses for thyroid of children and adults

The effective doses were calculated from the ^{131}I deposition for 5-year old children, 10-year old children and adults, using the computer model CLRP [5]. The calculations were carried out for two routes of intake:

- intake by inhalation
- intake by inhalation and ingestion.

For each of the intakes calculations for the situations without and with countermeasures were considered.

Ranges of average committed effective doses for thyroid of 5-year old children, 10-year old children and adults in various locations in Poland are presented in Table 2. For adults, the doses varied from 1.0 mSv to 11.1 mSv in the case of no countermeasures; the application of the iodine prophylaxis on 29 April 1986 reduced the doses by 61%, whereas its application on 30 April reduced the doses by 28%.

In the case of no countermeasures, the 5-year old children received the doses by about 1.6 times higher (1.5 to 17.6 mSv) than the adults, whereas the 10-year old children absorbed the doses by about 1.5 times higher (1.4 to 16.5 mSv) than the adults. With the application of the iodine prophylaxis on 29 April 1986, the doses were reduced by 62% for 5-year old children and 10-year old children, whereas with the application of the prophylaxis on 30 April 1986 the doses were reduced by 28%.

Table 2. Ranges of average committed effective doses for thyroid of 5-year old children, 10-year old children and adults in various locations in Poland, mSv

Age	From inhalation		From inhalation and ingestion	
years	No CM*)	With CM**)	No CM*)	With CM**)
5	1.5 – 17.6	0.6 – 9.9	15.4 - 178	11.1 – 128
10	1.4 – 16.5	0.5 – 9.4	10.4 - 120	7.3 – 83.8
Adults	1.0 – 11.1	0.2 – 3.3	3.7 – 45.2	2.6 – 29.6

*Without countermeasures

**With countermeasures

Doses from inhalation and ingestion for adults varied from 3.7 mSv to 45.2 mSv in the case of no countermeasures. The 5-year old children received the doses about four times higher (15.4 to 178 mSv) than the adults, and the 10-year old children received doses about three times higher (10.4 to 120 mSv). For all the age groups the iodine prophylaxis reduced the doses by about 30%.

4. Conclusion

Retrospective evaluation of the deposition of short-lived ^{131}I is possible from the measured deposition of long-lived ^{129}I and from the $^{129}I/^{131}I$ atomic ratio at the time of the fallout arrival. Ratio $^{129}I/^{131}I$ increases with time because ^{131}I rapidly decays, whereas ^{129}I is practically stable. In order to evaluate this ratio at the time of the fallout arrival, the $^{129}I/^{131}I$ ratio at the moment of the reactor accident must be known; the latter ratio can be calculated from the reactor core inventory data and/or determined from the measurements of environmental samples shortly after the accident.

Data on the ^{131}I deposition can be used for the evaluation of effective doses for thyroid of the population.

In the present work the above method was used to evaluate the deposition of ^{131}I in Poland. From the data obtained, effective doses for thyroid of the population were calculated. The doses were similar to those evaluated from the content of ^{131}I in thyroids, being measured in one of the regions studied [6]. The similarity of the doses estimated in this work with the doses calculated from the ^{131}I content in thyroid demonstrates that the applied method for the evaluation of the ^{131}I depositions and doses is correct.

#)The manuscript of the work has been submitted for publication in Health Physics.

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Acknowledgements

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2.7 SAVEC
SPATIAL ANALYSIS OF VULNERABLE AREAS IN CENTRAL EUROPE*×

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Prior identification of vulnerable areas with spatial models that include variation in radiocaesium transfer due to different soil properties would allow post-accident management decisions to be prioritised and effectively implemented. Under the EC-funded SAVE project (Spatial analysis of vulnerable ecosystems in Europe: Spatial and dynamic predictions of radiocaesium fluxes in European foods) a user-friendly software system was developed to allow the mid- to long-term impacts of radiocaesium deposition in Western Europe to be quantified and vulnerable areas identified [1]. Fig.1. presents the schematic representation of the SAVE model. At the core of the system is a semi-mechanistic radiocaesium soil to plant transfer model Fig. 2. developed and parameterised following experiments undertaken to quantify the uptake of radiocaesium over a wide range of soils types [2], [3]. The aim of the Inco-Copernicus Spatial Analysis of Vulnerable Ecosystems in Central Europe (SAVEC) project was to modify the SAVE model and apply it to the Czech Republic, Hungary and Poland using spatial input databases collated for each of the three Central European countries. Within SAVEC, it was feasible to derive model input

* EU Contract No. ERB IC15-CT98-0206; Project duration dates: 01.09.1998 – 31.08.2001

× Institutions involved in the project: ITE = Institute of Terrestrial Ecology, UK, NU = Nottingham University, UK, CLOR = Central Laboratory for Radiological Protection, Poland, NRPI = National Radiation Protection Institute, Czech Republic, NRPA = Norwegian Radiation Protection Authority, Norway, UV = University of Veszprém, Hungary, RISSAC = Research Institute of Soil Science and Agrochemistry, Hungary, NIFC = National Institute of Food Control, Hungary

spatial databases from national data sets with a view to improving the reliability of model predictions. The SAVE-IT software system has been successfully modified for application in the Czech Republic, Hungary and Poland, with input spatial databases of soil properties, land cover, agricultural production and diets generated. The final version of the model has been submitted with the deliverable on 'Identification of areas in Poland, Hungary and the Czech Republic vulnerable to radiocaesium deposition'. Predicted cow milk ^{137}Cs activity concentrations following the Chernobyl accident made using the three input soil property data sets are broadly similar and are in reasonable agreement with national monitoring data .
During the 3-year period of the project, two other deliverables, in addition to the yearly progress reports, were submitted. The deliverable on 'Development of critical loads maps for radiocaesium for the Czech Republic, Hungary and Poland' [4], [5] explored the use of the critical loads methodology to quantify the impact of radiocaesium deposition in the three countries. The deliverable on 'Critical groups due to dietary habits in Poland, Hungary and the Czech Republic' [6] outlined the application of the SAVEC approach for identifying potential critical groups in the three countries based on dietary preferences and consumption data. Overall, the project demonstrated the usefulness of the SAVE approach in allowing improved estimates of both individual and collective dose by incorporation of spatial variation in radiocaesium transfer.

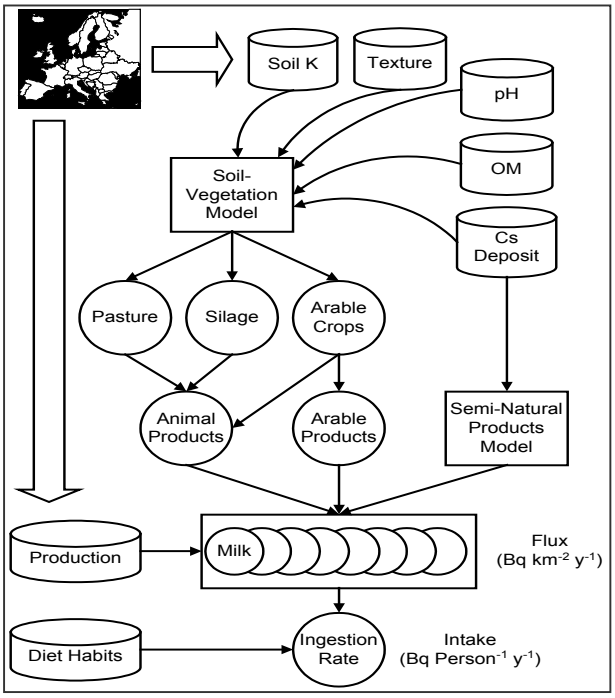

Fig.1. Schematic representation of the SAVE model

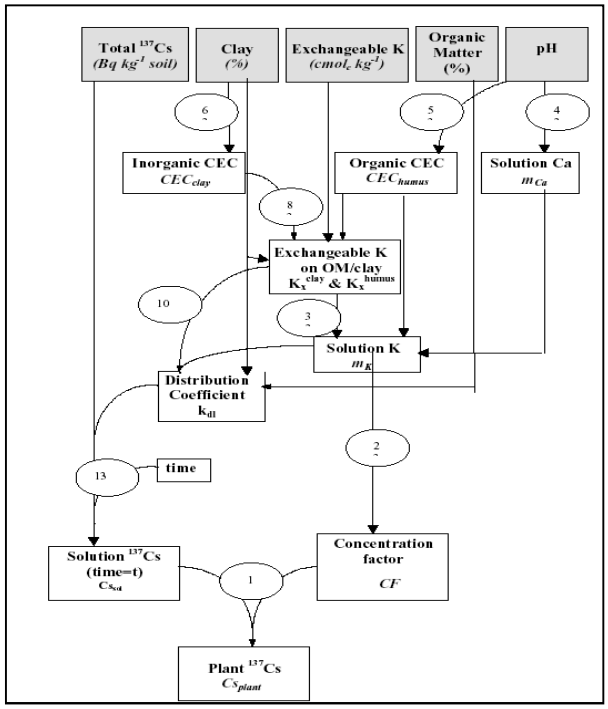

Fig. 2. Relationship between conceptual pools of radiocesium considered in the model. Shaded boxes indicate model input data**.**

The example of the model application for determination of areas in Poland of elevated radiocesium ^{137}Cs fluxes is presented [4].

To identify areas vulnerable to radiocaesium deposition in Poland two deposition scenarios have been used for the analysis presented in this report. A Chernobyl Scenario (i.e. the estimated spatial pattern of deposition from the Chernobyl accident is assumed and a deposition day of the year of 120 used. Under the Uniform Scenario Poland is assumed to received the same total radiocaesium deposition as under the Chernobyl case but it is uniformly distributed and is equal to the mean value of 2400 Bq.

Spatial vulnerability can be assessed using a number of different criteria. In the simplest case one can identify those areas which are predicted to produce food products with relatively high activity concentration. This approach is perhaps most relevant in assessing those areas where consumers of locally produced foods may be at risk. However given the widespread distribution of food and the intensive agricultural production of some regions a more useful measure of vulnerability for the population as a whole is radionuclide 'flux'. This combines activity concentration in food products with agricultural production to estimate the output of radiocaesium, from a spatial unit, to the foodchain as a whole. The flux predictions do not relate to the eventual destination of food produced within a region, it represents vulnerability assessed at the point of production. To accurately assess vulnerability at the point of consumption one would require an incredible knowledge of food distribution. In the results presented below we shall consider vulnerability in terms of flux.

For each of the scenarios, predictions have been made for the radiocaesium activity concentration of a range of agricultural food products (fresh milk (cow, goat, sheep), beef, sheep meat, pork, chicken, fruit, leafy vegetables, root vegetables, potatoes, and cereals) over a 10 year period following deposition. The predictions of food product activity concentration are combined with spatially distributed estimates of agricultural food production to estimate radiocaesium flux (Bq grid sqaure^{-1} month^{-1}). These results have been combined on a regional basis and by food product for the first 2 years after deposition and examples for milk flux are presented below. The flux results can potentially link to population ingestion dose, which is dominated by the first few years after deposition. Therefore in this case it is most appropriate to present results for the first 2 years after deposition as these will be the greatest contributors to dose and show the greatest single temporal change between years.

Tab. 1 presents the total annual flux (i.e. all food products combined) for each region for the first two years after deposition under both scenarios. The relative distribution between regions is given in Tab. 2 Under the uniform scenario Mazowieckie and Lubelskie voivodities are the two greatest contributors to national flux due to their relatively high agricultural production. The relative contribution of both regions increases with time, more markedly for Lubelskie. Tab. 3 shows the relative contribution of the different food products to national flux for the two scenarios and time periods. The pattern is very similar for both scenarios, although it does change with time in both cases. The results suggest that cereals, potatoes and pork are the most important products in terms of human food chain exposure to radiocaesium. The pork predictions are likely to be anomalous due to oversimplification of pig management within the model. Cereals and potatoes are predicted to contribute the most to total annual fluxes as a consequence of the high level of cereal production in Poland.

Within Poland agricultural production tends to be biased towards the South-Eastern part of the country. Therefore the spatial distribution of radiocaesium flux is relatively biased more towards these regions than activity concentration. Once again the Chernobyl scenario 1 year after deposition shows a spatial distribution influenced by the pattern of deposition Fig 3. As in the case of the activity concentration maps the areas of high transfer (due to soil characteristics) are picked out as areas of relatively high flux. However the bias in agricultural production increases the relative importance of some grid squares.

This is most clearly illustrated by Fig. 3 b(ii). As in the case of the activity concentration maps the flux predictions show numerous localised regions of elevated vulnerability.

Limitations of the spatial data, model and assumptions mean that results from this analysis are preliminary. Caution should be taken in interpreting these results as they are limited, in particular, by the reliability of the spatial soils data used in the models. These data are derived from soil classifications on low resolution maps and thus have limitations. It is intended that the updated version of SAVEC model will include best possible soils data and improved assumptions (e.g. for agricultural management) enabling the best possible predictions to be made.

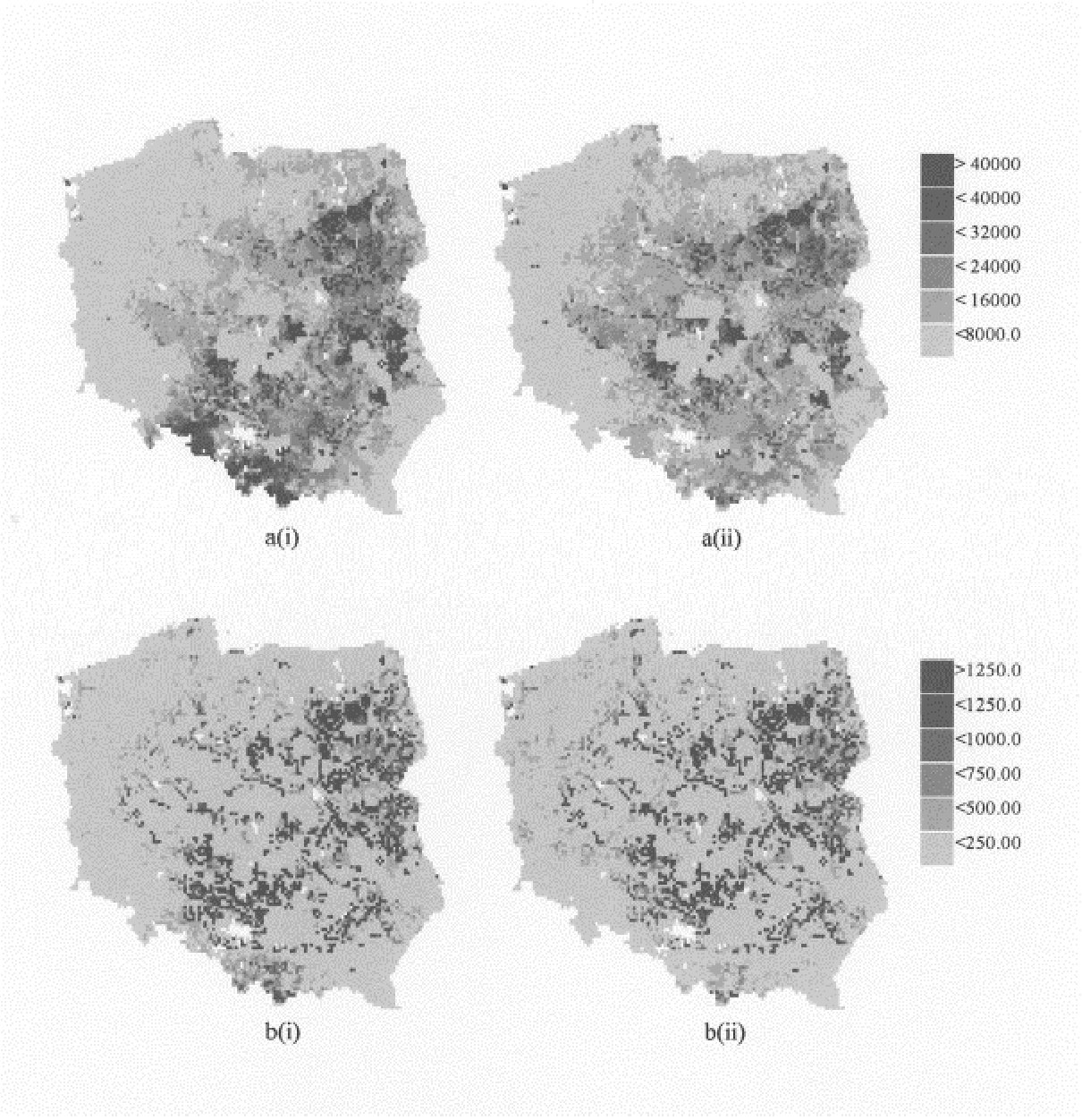

Fig. 3. Predicted radiocaesium flux via cow milk (Bq grid square^{-1} month^{-1}) for Poland at (a) t=1 year and (b) 10 years for (i) Chernobyl and (ii) uniform scenarios.

Tab. 1. Predicted total annual radiocaesium flux for Poland and its major regions for all products combined.

Region	Annual radiocaesium flux (GBq)			
	Chernobyl		Uniform	
	Year 1	Year 2	Year 1	Year 2
Dolnośląskie	11.84	0.85	13.87	1.08
Kujawsko-Pomorskie	13.07	1.68	19.51	2.51
Lubelskie	33.56	3.97	28.29	3.11
Lubuskie	2.80	0.31	5.66	0.62
Łódzkie	21.45	2.73	25.64	3.21
Małopolskie	21.19	1.86	12.83	1.08
Mazowieckie	47.57	5.14	43.08	4.84
Opolskie	25.43	2.35	9.51	0.89
Podkarpackie	10.75	1.12	12.78	1.22
Podlaskie	17.35	2.29	17.71	2.34
Pomorskie	7.05	0.63	10.24	0.93
Śląskie	17.51	2.03	9.81	1.25
Świętokrzyskie	14.38	1.22	11.34	1.02
Warminsko-Mazurskie	11.95	1.01	12.97	1.08
Wielkopolskie	25.70	3.59	35.79	4.96
Zachodniopomorskie	6.97	0.60	11.55	0.97
Poland	291.80	30.44	282.80	30.70

Tab 2..Distribution of predicted total annual radiocaesium flux between the major voivodities of Poland.

Voivodity	% of national annual radiocaesium flux			
	Chernobyl		Uniform	
	Year 1	Year 2	Year 1	Year 2
Dolnośląskie	4.1	2.8	4.9	3.5
Kujawsko-Pomorskie	4.5	5.5	6.9	8.2
Lubelskie	11.5	13.1	10.0	10.1
Lubuskie	1.0	1.0	2.0	2.0
Łódzkie	7.4	9.0	9.1	10.5
Małopolskie	7.3	6.1	4.5	3.5
Mazowieckie	16.3	16.9	15.2	15.8
Opolskie	8.7	7.7	3.4	2.9
Podkarpackie	3.7	3.7	4.5	4.0
Podlaskie	5.9	7.5	6.3	7.6
Pomorskie	2.4	2.1	3.6	3.0
Śląskie	6.0	6.7	3.5	4.1
Świętokrzyskie	4.9	4.0	4.0	3.3
Warmińsko -Mazurskie	4.1	3.3	4.6	3.5
Wielkopolskie	8.8	11.8	12.7	16.2
Zachodniopomorskie	2.4	2.0	4.1	3.2

Tab. 3. Distribution of predicted total annual radiocaesium flux between the major food products for Poland.

Product	% annual national radiocaesium flux			
	Chernobyl		Uniform	
	Year 1	Year 2	Year 1	Year 2
Beef	5.4	0.7	5.3	0.7
Cereals	32.2	9.5	33.2	9.4
Fresh Milk {Cow}	5.7	2.6	5.7	2.5
Fresh Milk {Goat}	0.0	0.0	0.0	0.0
Fresh Milk {Sheep}	0.0	0.0	0.0	0.0
Fruit	8.6	0.4	7.8	0.3
Leafy Vegetables	1.5	2.2	1.4	2.1
Pork	10.7	44.5	11.4	45.6
Potato	27.4	32.8	26.9	32.6
Poultry	0.9	3.8	0.8	3.4
Root Vegetables	0.1	0.4	0.1	0.4
Sheep Meat	7.5	3.1	7.4	3.0

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2.8 ASSESSMENTS OF ^{137}CS AND ^{226}RA DOSES FOR AQUATIC AND TERRESTRIAL REFERENCE ORGANISMS IN POLAND

Paweł Krajewski

Background

Progress in risk reduction is characterised by a gradual shift in focus along the sequence: protection of workers, protection of the general public, product and practice safety, environmental protection. Accordingly, the national legislation of several countries now includes provisions on protection of the environment from the harmful effects of radiation [1]. Environmental protection is specifically addressed in a number of international conventions and agreements, including "Convention on Environmental Impact Assessement in a Transboundary Contex" (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].

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 [4]. Regarding environmental protection, the ICRP statement that "...if man is adequately protected then other living things are also likely to be sufficiently protected" [5], [6], 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 [7]. The inclusion of radiation as a stressor within ecological risk assessments is also a consideration. 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 recently convened a technical committee examining protection of the environment from the effects of ionizing radiation and provided recommendations and discussion points for moving forward with the development of protection frameworks and dose assessment methods for biota. The resulting 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. Nevertheless U.S. Department of Energy elaboreted the screening metothology that enables to estimate upper limit doses for reference organisms of fauna and flora for selected radionuclides [8]. This methodology was adopted as a starting point to create a framework for assessing the impact of radioactive contamination on the environment in European Community Countries [9], [10].

Methods

Four organism types and their corresponding dose limits were used in deriving the screening and analysis methods contained in DOE standard. The principal exposure pathways are considered for aquatic animal, riparian animal, terrestrial plant, and terrestrial animal organism types respectively. Avoiding impairment of reproductive capability is the critical biological concern in establishing the dose limits for aquatic and terrestrial biota [8], [11], [12], [13]. The choice of organisms for the methodology evolved from consideration of the existing and proposed radiation protection standards for biota. Biota standards had been set

for aquatic animals, and were being considered for terrestrial plants and animals. Accordingly, the screening methodology had to accommodate these three general categories.

Aquatic Animals: The absorbed dose to aquatic animals should not exceed 10 mGy d^{-1} (3600 mGy y^{-1}) from exposure to radiation or radioactive material releases into the aquatic environment.

Terrestrial Plants. The absorbed dose to terrestrial plants should not exceed 10 mGy d^{-1} (3600 mGy y^{-1}) from exposure to radiation or radioactive material releases into the terrestrial environment.
Terrestrial Animals. The absorbed dose to terrestrial animals should not exceed 1 mGy d^{-1} (360 mGy y^{-1}) from exposure to radiation or radioactive material releases into the terrestrial environment.

A fourth, riparian animal, was added after recognizing that the riparian pathways of exposure combined aspects of both the terrestrial and aquatic systems.

Riparian animal The absorbed dose to riparian animals should not exceed 1 mGy d^{-1} (360 mGy y^{-1}) from exposure to radiation or radioactive material releases into the aquatic and the terrestrial environment.

The pathways of exposure evaluated for each of the four organism types were developed based on consideration of the likelihood of dose occurring through a specific route, or "pathway." (Fig 1). Based on the potential pathways of exposure, annual doses were derived for surface water, sediment, and soil. Calculated using conservative assumptions, the doses are intended to preclude the relevant biota from being exposed to radiation levels in excess of the relevant existing or recommended biota dose limits.

Results
The annual doses[1] from ^{137}Cs (bomb-tests-fallout&Czarnobyl origin) and ^{226}Ra (natural radionuclide) to reference organisms of fauna and flora were calculated both at average and maximum concentrations of these radionuclides measured in surface water, sediment, and soil in Poland [14], [15], [16]. The results are presented in Tab. 1 and Tab. 2 for ^{137}Cs and ^{226}Ra respectively. The numbers in parentheses present values of doses corresponding to the maximum concentrations measured in water, soil and sediment. 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.) are about 10% of the dose limit (360 mGy y^{-1}).
The doses from ^{226}Ra to riparian animals living in inland aquatic environment are 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 suggests considering the need of conducting an analysis through site-specific screening, site-specific analysis and employ site-representative parameters and conditions or an actual site-specific biota dose assessment.

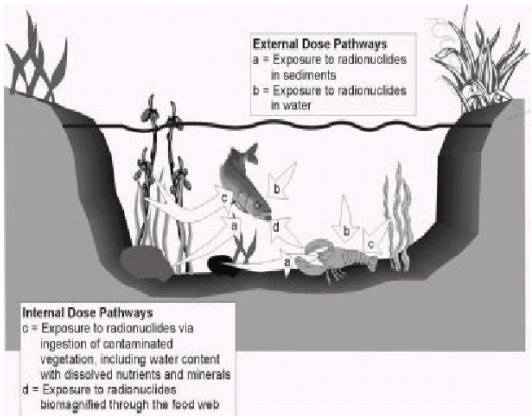
[1] Equivalent dose

Tab. 4. Annual ^{137}Cs doses to to reference organisms of fauna and flora in Poland

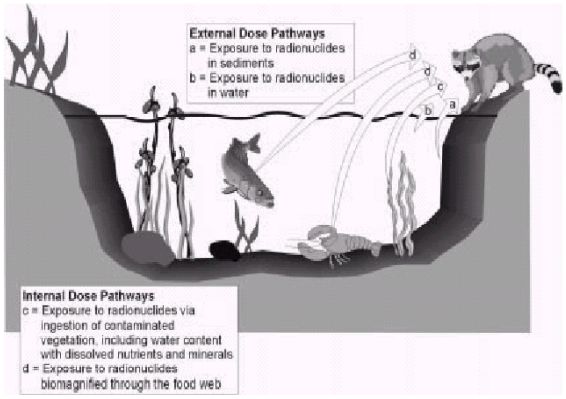
^{137}Cs	Terrestrial Environment					
	Concentration in water [Bq m^{-3}]			Concentration in soil [Bq kg^{-1} d.w]		
	4 (14)			25 (380)		
Terrestrial Plants	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	-	-	8×10^{-6} (2.8×10^{-5})	2.4×10^{2} (3.6×10^{3})	1.02 (1.6×10^{1})	1×10^{-1} (1.5)
	Total dose = 1.12 (1.7×10^{1}) mGy y^{-1}; Percentage of dose limit (3600 mGy y^{-1}) = 0.03% (0.5%)					
Terrestrial Animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	1.4×10^{-2} (4.7×10^{-2})	5.8×10^{-5} (2.0×10^{-4})	8×10^{-6} (2.8×10^{-5})	5×10^{2} (7.6×10^{3})	2.1 (3.2×10^{1})	1×10^{-1} (1.52)
	Total dose = 2.2 (3.4×10^{1}) mGy y^{-1}; Percentage of dose limit (360 mGy y^{-1}) = 0.6% (9.5%)					
^{137}Cs	Aquatic Environment (inland)					
	Concentration in water [Bq m^{-3}]			Concentration in sediment [Bq kg^{-1} d.w]		
	4 (14)			88 (237)		
Aquatic animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	8.8×10^{1} (3.1×10^{2})	3.8×10^{-1} (1.3)	8×10^{-6} (2.8×10^{-5})			1.8×10^{-1} (4.7×10^{-1})
	Total dose = 5.5×10^{-1} (1.8) mGy y^{-1}, Percentage of dose limit (3600 mGy y^{-1}) = 0.02% (0.05%)					
Riparian animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	1.9×10^{2} (6.5×10^{2})	8.0×10^{-1} (2.8)	8×10^{-6} (2.8×10^{-5})	2.4×10^{1} (6.4×10^{1})	1×10^{-1} (2.7×10^{-1})	1.8×10^{-1} (4.7×10^{-1})
	Total dose = 1.1 (3.5) mGy y^{-1}, Percentage of dose limit (360 mGy y^{-1}) = 0.3% (1%)					
^{137}Cs	Aquatic Environment (sea water)					
	Concentration in water [Bq m^{-3}]			Concentration in sediment [Bq kg^{-1} d.w]		
	62 (86)			150 (390)		
Aquatic animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	1.4×10^{3} (1.9×10^{3})	5.8 (8.1)	1.2×10^{-4} (1.7×10^{-4})			3.0×10^{-1} (7.8×10^{-1})
	Total dose = 5.5×10^{-1} (8.9) mGy y^{-1}, Percentage of dose limit (3600 mGy y^{-1}) = 0.02% (0.25%)					
Riparian animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	2.9×10^{3} (4.0×10^{3})	1.2×10^{1} (1.7×10^{1})	1.2×10^{-4} (1.7×10^{-4})	4.0×10^{1} (1.0×10^{2})	1.7×10^{-1} (4.5×10^{-1})	3.0×10^{-1} (7.8×10^{-1})
	Total dose = 1.2×10^{1} (1.8×10^{1}) mGy y^{-1}, Percentage of dose limit (360 mGy y^{-1}) = 3.6% (5.1%)					

Tab. 5 Annual ^{226}Ra doses to to reference organisms of fauna and flora in Poland

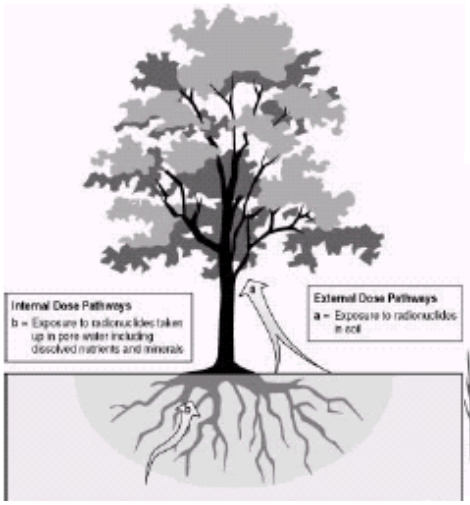
^{226}Ra	Terrestrial Environment					
	Concentration in water [Bq m^{-3}]			Concentration in soil [Bq kg^{-1} d.w]		
	4 (16)			25 (100)		
Terrestrial Plants	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	-	-	2.7×10^{-5} (1.1×10^{-4})	2.7 (1.1×10^{1})	8.2 (3.3×10^{1})	3.5×10^{-1} (1.4)
	Total dose = 8.6 (3.4×10^{1}) mGy y^{-1}; Percentage of dose limit (3600 mGy y^{-1}) = 0.24% (0.95%)					
Terrestrial Animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	4.3×10^{-2} (1.7×10^{-1})	1.3×10^{-1} (5.2×10^{-1})	2.7×10^{-5} (1.1×10^{-4})	3.2×10^{1} (1.3×10^{2})	9.7×10^{1} (3.9×10^{2})	3.5×10^{-1} (1.4)
	Total dose = 9.8×10^{1} (3.9×10^{2}) mGy y^{-1}; Percentage of dose limit (360 mGy y^{-1}) = 27% (109%)					
^{226}Ra	Aquatic Environment (inland)					
	Concentration in water [Bq m^{-3}]			Concentration in sediment [Bq kg^{-1} d.w]		
	4 (14)			19 (40)		
Aquatic animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	1.2×10^{1} (4.2×10^{1})	3.7×10^{1} (1.3×10^{2})	2.7×10^{-5} (9.5×10^{-5})			1.3×10^{-1} (2.7×10^{-1})
	Total dose = 3.7×10^{1} (1.3×10^{2}) mGy y^{-1}, Percentage of dose limit (3600 mGy y^{-1}) = 1% (3.6%)					
Riparian animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	1.3×10^{1} (4.5×10^{1})	3.9×10^{1} (1.4×10^{2})	2.7×10^{-5} (9.5×10^{-5})	1.4×10^{1} (3.0×10^{1})	4.3×10^{1} (9.1×10^{1})	1.3×10^{-1} (2.7×10^{-1})
	Total dose = 8.2×10^{1} (2.3×10^{2}) mGy y^{-1}, Percentage of dose limit (360 mGy y^{-1}) = 23% (63%)					
^{226}Ra	Aquatic Environment (sea water)					
	Concentration in water [Bq m^{-3}]			Concentration in sediment [Bq kg^{-1} d.w]		
	2			36 (48)		
Aquatic animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	6.0	1.8×10^{1}	1.4×10^{-5}			2.5×10^{-1} (3.3×10^{-1})
	Total dose = 1.8×10^{1} 1.9×10^{1}) mGy y^{-1}, Percentage of dose limit (3600 mGy y^{-1}) = 0.5% (0.5%)					
Riparian animal	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]	Concentration [Bq kg^{-1}]	Internal [mGy y^{-1}]	External [mGy y^{-1}]
	6.4	1.9×10^{1}	1.4×10^{-4}	2.7×10^{1} (3.6×10^{1})	8.2×10^{1} (1.0×10^{2})	2.5×10^{-1} (3.3×10^{-1})
	Total dose = 1×10^{2}(1.3×10^{2}) mGy y^{-1}, Percentage of dose limit (360 mGy y^{-1}) = 28% (36%)					



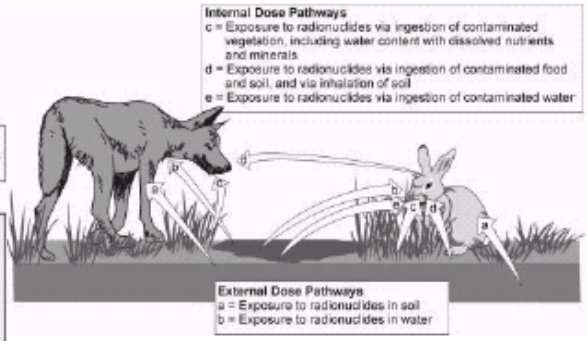
Aquatic Animals



Riparian Animals



Terrestrial Plants



Terrestrial Animals

Fig. 5. The pathways of exposure evaluated for four reference organism types

Source: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, US. Department of Energy Technical Standard, DOE-STD-xxxx-YR

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2.9 URANIUM ISOTOPES IN SURFACE WATERS AND BOTTOM SEDIMENTS IN POLAND

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The activity concentrations of ^{234}U, ^{235}U and ^{238}U were determined in waters (filtered water and suspended matter) and bottom sediments of the Vistula and Odra rivers including their two major tributaries, of four small rivers flowing directly into the Baltic Sea and of six lakes throughout the country. The samples were collected in 1999 and 2000. Uranium isotopes were determined in the same samples in which analyses of ^{137}Cs, ^{226}Ra and ^{3}H were performed in the frame of the program of the monitoring of radioactive contamination of rivers and lakes in Poland. The method of sampling and the sites of sample collection have been described elsewhere [1].

Uranium isotopes were determined in samples of 5 liters of water and in 2 grams of bottom sediments. To the samples of water, ^{232}U tracer was added for the yield determination, and concentrated HNO_3, then the samples were evaporated to dryness. To the residue, 8 M HNO_3 was added and heated until the residue was dissolved. The samples of bottom sediments were air-dried, sieved through a 2-mm mesh to remove the roots of plants and stones and then dried at 105^{o} C. The 5-g dry sample was placed in a muffle furnace and heated at 450^{o} C until organic matter was ashed, then it was transferred to a Teflon beaker. ^{232}U tracer was added and silica was removed by digestion with HNO_3 and HF. Finally, the residue was dissolved in 8 M HNO_3. Further analytical procedure was performed according to the method described earlier [2].

The activity concentration of ^{234}U in filtrated water varied from 1.13 mBq l^{-1} in Rogóżno lake, up to 20.2 mBq l^{-1} in the Vistula river at Zator. The average activity concentration ratio $^{234}U/^{238}U$ was 1.32±0.23, ranging from 1.10 (Wadąg and Nysa Łużycka) to 1.98 in Zator (Table 1).

In suspended matter (insoluble fraction of the uranium isotopes) the activity concentration was about 20% of the total content of uranium in water.

In bottom sediments (Table 2) the highest activity concentration of the uranium isotopes occurred in the Vistula river (Zator and Kraków), in Odra river (Chałupki and Wrocław) and in Nysa Łużycka. The average activity concentration ratio $^{234}U/^{238}U$ was 1.01 ±0.06, ranging from 0.85 in Odra, Wrocław to 1.11 in Wisła, Zator. This indicates that these uranium isotopes are closer to equilibrium in bottom sediments, than in water.

The concentrations of ^{235}U in water and bottom sediments were up to two orders of magnitude lower than those of ^{234}U and ^{238}U. These activity concentrations corresponded to the content 0.63±0.12 weight % of the total uranium in filtrated water and 0.65±0.15 weight % ^{235}U in bottom sediments. These contents are slightly lower then the content of ^{235}U in the natural uranium (0.7%), however, it is within the standard deviation.

The elevated concentration of uranium isotopes in water of the upper Vistula river (Zator, Kraków) can be ascribed to the mine waters, discharged from some coal mines in the Upper Silesia. This is also reflected by elevated uranium concentrations in the bottom sediments in the upper course of Vistula river down to Warsaw.

In the Odra river (Chałupki, Wrocław, Głogów) and in the Nysa Łużycka (Gubin) an enhanced uranium concentration was observed in the bottom sediments, but not in water. This suggest that the enhanced concentration in the bottom sediments results from the mining activity in the Lower Silesia in the past.

The comparison of the activity concentrations of ^{226}Ra (data from [1]) with those of the uranium isotopes (this study) has indicated that ^{226}Ra and ^{234}U and ^{238}U in the waters and sediments are not in equilibrium, however, statistical analysis of data has shown the occurrence of the relationship between these isotopes in bottom sediments; Fig. 1 shows such a relationship between ^{226}Ra and ^{238}U; it is expressed by the equation:

$$y = 0.442x + 5.0936$$

where y is activity concentration of ^{226}Ra in bottom sediments, and x – activity concentration of ^{238}U. The value of correlation coefficient, r, is 0.87.

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Table 1. Average activity concentrations of ^{234}U, ^{235}U and ^{238}U in filtrated water and suspended matter of rivers and lakes, in 1999 and 2000, mBq l^{-1}

Rivers and lakes	Sampling location for rivers	U-234		U-235		U-238	
		water	suspended matter	water	suspended matter	water	suspended matter
Vistula	Zator	20.2±2.10[a)]	1.38±0.27	0.33±0.07	<0.07	10.2±1.24	0.84±0.12
	Kraków	14.9±1.83	1.39±0.64	0.50±0.23	<0.07	7.90±1.05	0.86±0.46
	Annopol	10.3±1.22	1.93±0.68	0.35±0.13	<0.07	7.38±0.93	1.54±0.66
	Warszawa	10.9±0.12	1.82±1.04	0.30±0.05	<0.07	7.69±0.17	1.41±0.69
	Kiezmark	13.5±2.47	2.66±0.64	0.43±0.09	0.11±0.01	10.5±1.46	2.26±0.40
Bug	Wyszków	13.0±5.04	4.11±1.59	0.41±0.18	0.12±0.06	9.94±4.48	3.15±1.16
Narew	Pułtusk	10.6±2.86	1.66±0.20	0.35±0.03	0.07±0.01	8.71±2.25	1.50±0.18
Odra	Chałupki	6.90±1.56	0.69±0.54	0.17±0.04	0.16±0.09	4.52±1.03	0.52±0.41
	Wrocław	10.6±5.15	2.96±0.95	0.33±0.19	0.08±0.02	6.76±3.17	1.98±0.62
	Głogów	7.64±1.30	1.86±0.57	0.21±0.01	0.07±0.01	5.40±1.15	1.33±0.42
	Krajnik	11.8±1.48	2.50±0.09	0.40±0.06	0.08±0.02	9.73±1.24	2.10±0.31
Nysa Łużycka	Gubin	5.52±1.15	0.47±0.44	0.25±0.07	<0.07	4.47±0.95	0.41±0.33
Warta	Poznań	9.51±2.36	1.68±0.08	0.31±0.26	0.07±0.01	7.93±3.89	1.24±0,12
Rega	Trzebiatów	7.77±0.49	0.78±0.38	0.37±0.07	<0.07	6.94±0.06	0.64±0.35
Wieprza	St.Kraków	5.26±1.33	0.97±0.90	0.08±0.03	<0.07	4.14±1.02	0.90±0573
Łeba	Cecenowo	7.65±1.44	0.68±0.14	0.32±0.07	<0.07	6.38±0.91	0.58±0.08
Pasłęka	N.Pasłęka	7.39±0.41	1.22±0.48	0.18±0.05	<0.07	6.93±0.35	1.03± 0.39
Lakes	Partęczyny	7.99±3.97	2.98±1.17	0.28±0.18	0.11±0.04	7.11±4.23	2.57±1.07
	Drawsko	3.36±1.68	3.64±1.16	0.12±0.08	0.16±0.07	3.00±1.78	3.34±1.07
	Wadąg	9.21±1.15	7.20±2.68	0.31±0.16	0.22±0.08	8.40±0.57	6.46±2.50
	Rogóźno	1.13±0.08	0.33±0.10	<0.07	<0.07	0.85±0.11	0.26±0.08
	Niesłysz	2.53±1.80	0.88±0.94	0.08±0.06	<0.07	2.02±1.29	0.74±0.68
	Wigry	4.67±2.29	3.26±0.63	0.13±0.04	0.10±0.01	4.16±2.28	2.94±0.61

a) mean ± standard deviation

Table 2. Average activity concentrations of ^{234}U, ^{235}U and ^{238}U in bottom sediments collectedfrom rivers and lakes in 1999 and 2000, Bq kg^{-1}

River and lakes	Sampling location for rivers	U-234	U-235	U-238
Vistula	Zator	30.6±0.66[a)]	0.97±0.28	27.5±1.41
	Kraków	21.1±0.56	0.79±0.15	21.3±1.56
	Annopol	13.7±6.24	0.54±0.26	13.8±5.79
	Warszawa	15.9±8.85	0.43±0.32	15.0±7.96
	Kiezmark	6.85±1.24	0.373±0.08	6.80±1.69
Bug	Wyszków	8.24±1.99	0.29±0.04	8.17±1.56
Narew	Pułtusk	9.28±1.36	0.45±0.25	8.80±0.67
Odra	Chałupki	28.5±5.16	1.86±0.50	29.2±6.97
	Wrocław	30.2±2.28	1.19±0.35	35.5±17.7
	Głogów	17.3±10.3	0.92±0.56	17.4±9.33
	Krajnik	7.23±0.23	0.27±0.05	7.48±0.35
Nysa Łużycka	Gubin	28.7±16.7	1.37±0.66	27.9±15.8
Warta	Poznań	7.04±1.74	0.34±0.02	6.94±1.93
Rega	Trzebiatów	9.42±1.21	0.38±0.06	8.62±1.03
Wieprza	St.Kraków	7.90±1.51	0.33±0.03	7.46±0.66
Łeba	Cecenowo	8.80±0.28	0.30±0.14	8.52±0.88
Pasłęka	N.Pasłęka	12.7±0.35	0.56±0.37	12.1±0.42
Lakes	Partęczyny	8.13±0.67	0.27±0.08	7.92±0.54
	Drawsko	8.13±1.92	0.35±0.04	8.35±1.28
	Wadąg	9.35±1.06	0.43±0.15	9.12±0.59
	Rogóźno	3.55±0.95	0.11±0.02	3.77±1.01
	Niesłysz	7.17±3.25	0.24±0.06	6.62±2.68
	Wigry	11.7±4.86	0.52±0.36	12.1±4.28

[a)] mean ± standard deviation

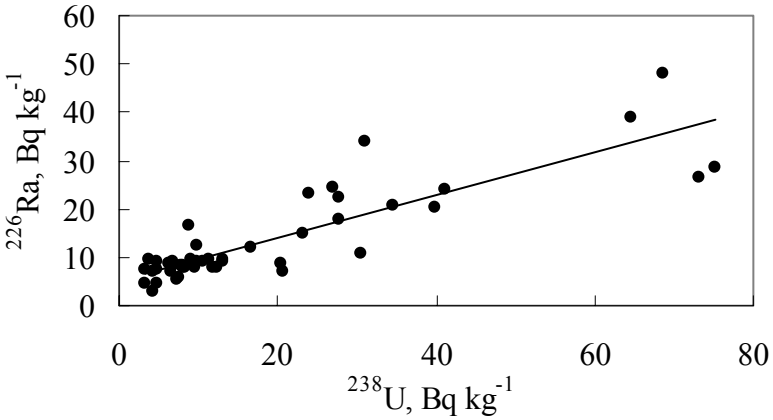

Fig. 1. Relationship between ^{238}U and ^{226}Ra concentrations in bottom sediments of rivers and lakes

2.10 DISTRIBUTION OF ^{137}Cs, ^{210}Pb, ^{226}Ra and ^{238,240}Pu IN BOTTOM SEDIMENTS FROM SOUTHERN BALTIC SEA.

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Studies on the distribution of ^{137}Cs, ^{226}Ra and ^{238,240}Pu in bottom sediments from the Southern Baltic Sea in the years 2000-2001 were performed by CLOR for the long term Monitoring Program of Radioactive Substances in the Baltic Sea, coordinated by Helsinki Commission. Its Polish part, HELCOM MORS, enables observation of the current contamination of marine environment and its changes in time. Additionally, from vertical distributions of ^{210}Pb and ^{239,240}Pu, the sedimentation rate in different regions of Baltic Sea can be evaluated.

The total inputs of ^{137}Cs from the Chernobyl accident and from the fallout after nuclear weapons tests, into the Baltic Sea area were estimated as 4.7 PBq and 0.93 PBq, respectively [1]. The input of ^{137}Cs to the Baltic Sea from discharges of western European nuclear reprocessing plants and nuclear installation in the Baltic Sea region were 0.38 PBq and 0.65 10^{-3} PBq, respectively [2].

Bottom sediment samples were collected from various regions of southern part of the Baltic Sea, during the sampling cruises into the Baltic Sea with r/v "Baltica" organised once a year by Institute of Meteorology and Water Management (Table.1).

Tab. 1. Sampling stations for bottom sediment in HELCOM MORS program.

Stations code	Sampling area	Depth	Co-ordinates
P 110	Gulf of Gdansk	64-71	54°30'N ;19°06.8E
P 116		86-90	54°39.1'N ;19°17.6E
P 1	Gdansk Deep	106-107	54°50'N ;19°20'E
P 140	Open sea area	88-89	55°33'N ;18°24'E
P 5	Bornholm Basin	88-91	55°15'N ;15°59'E
P39		63-68	54°44.5'N ;15°08'E

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 ^{210}Pb was determined by beta activity measurement of ^{210}Bi deposited on a nickel disk. The reliability of applied methods was checked by participation in inter-comparison exercises organised by IAEA and Risø National Laboratory.

The concentrations of ^{137}Cs in sediments differ depending on sampling site and sampling depth. The highest concentrations were found in the Gulf of Gdansk. In the upper 0-3 cm layer of sediments, ^{137}Cs concentrations in years 2000-2001 ranged from 176 Bq kg^{-1}dw to 393 Bq kg^{-1}dw and their values systematically decreased along the profiles (Fig 1),except for P116 sampling station (see below). In the sediments from Bornholm Basin, the ^{137}Cs concentrations were evidently lower (74.3 Bq -129 Bq kg^{-1}dw). The average deposition of ^{137}Cs, in the years 2000-2001, ranged from 2170±511 Bq m^{-2} in Bornholm Basin to 3820±703 Bq m^{-2} in Gulf of Gdansk

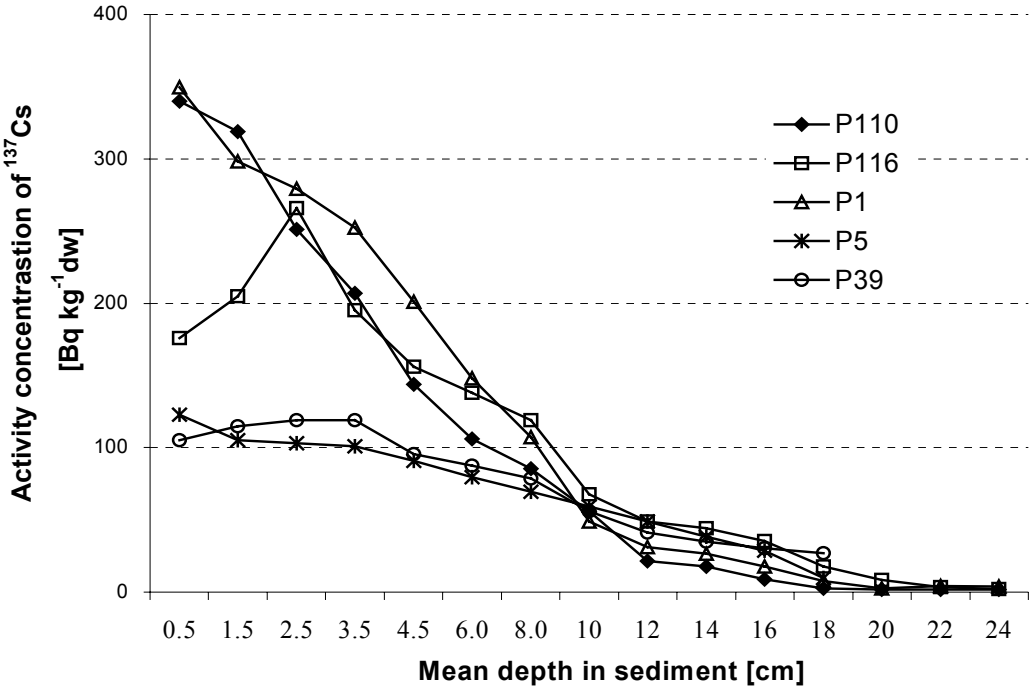

Fig 1. Vertical distribution of ^{137}Cs in bottom sediments from Southern Baltic Sea, 2001.

Similarly as for radiocaesium the highest concentrations of plutonium in bottom sediments were found in Gulf of Gdansk, however the maxima of ^{238}Pu and ^{239,240}Pu were observed always in deeper layers (Fig.2). In core samples from station P110 , taken in 2000 and 2001 years, the maxima of ^{239,240}Pu concentration: 6.1±0.66 Bq kg^{-1} dw and 8.03±0.38 Bq kg^{-1}dw were observed in 5-7 cm layer 7-9 cm layers. The concentrations of plutonium in P5 (Bornholm Basin) were uniform along the profiles even to the depth of 11 cm and the average concentrations of ^{239,240}Pu and ^{238}Pu were 1.05±0.09 and of 0.04±0.009 Bq kg^{-1}dw respectively in 2001. The deposition of ^{239,240}Pu ranged from 30.4±1.02 Bq m^{-2} in Bornholm Basin (P5) to 194±4.70 Bq m^{-2} in Gulf of Gdansk (P110). Similar values were found in previous years.

The distributions of ^{226}Ra concentration were uniform along the profiles, however, differences between particular sub-regions were observed. Lower concentration of ^{226}Ra, 26.0±0.90 Bq kg^{-1}dw, were found in Gulf of Gdansk and higher, 49.5±3.44 Bq kg^{-1}dw in the Bornholm Basin

Determinations of ^{210}Pb were performed in core samples from Gdansk Basin. The unsupported ^{210}Pb concentration ranged from 316±16.0 Bq kg^{-1}dw to 488±16.6 Bq kg^{-1}dw in the first 0-1cm layers and decreased exponentially along the profiles (Fig.2). The deposition of unsupported ^{210}Pb in the 2001 year ranged from 6280±193 Bq m^{-2} to 10000 ±177 Bq m^{-2} for sediment layers 0-19 cm.

Decrease of ^{137}Cs concentration in bottom sediment proceeds very slowly. The ^{137}Cs concentrations are similar to these observed in 1990 (258-395 Bq kg^{-1}dw in 0-3 cm layer). However, the pattern of ^{137}Cs vertical distribution in P116 core samples indicates that the maximum of its concentration observed earlier in the layer 0-1cm, was moved to the 2-3 cm layer in 2001 year. Concentrations of ^{137}Cs in bottom sediments from Gdansk Basin decrease exponentially with depth and in the deeper layers of the cores the influence of global fallout contamination was still observed.

The main source of plutonium in Southern Baltic Sea was global fallout. The highest concentrations of plutonium were observed always in deeper layers of the sediment cores. The ratios of ^{238}Pu to ^{239,240}Pu in majority of samples examined since 1991 ranged 0.03-0.05, being similar to the ratios found for the cumulative deposit from global fallout after the nuclear weapons tests [3]. The sedimentation rate in the region P110, calculated from plutonium distribution and max. global fallout dated to 1963, ranged from 1.6 mm year^{-1} to 2.1 mm year^{-1}. The loss of soft surface sediments and slicing errors during sampling may significantly affect the result of sedimentation rate if the calculation is based on ^{239,240}Pu peaks and this could be the reason of wide range of sedimentation rates.

Dating by ^{210}Pb is another method, particularly in the environment with uniform sediment accumulation rates. Under the assumption of steady deposition of ^{210}Pb from atmosphere and an exponential decrease of unsupported ^{210}Pb, the average sedimentation rate in P110 area was evaluated to be 2.1±0.4 mm year^{-1}. The unsupported ^{210}Pb concentrations were calculated as a difference between ^{210}Pb and ^{226}Ra concentrations determined along the profiles. These values are in good agreement with sedimentation rates, equal to 1.86-2.25 mm year^{-1}, calculated by Pempkowiak et al. [4] from heavy metal deposition.

In general, the patterns of vertical distributions of unsupported ^{210}Pb were similar to ^{137}Cs distributions. It is suggested that a continued sedimentation of ^{137}Cs and/or ^{210}Pb – containing matter can be responsible for such a distribution of these radionuclides in the bottom sediments. In the patterns of vertical distribution of ^{239,240}Pu maximum concentration was observed in the deeper layer (Fig.2).

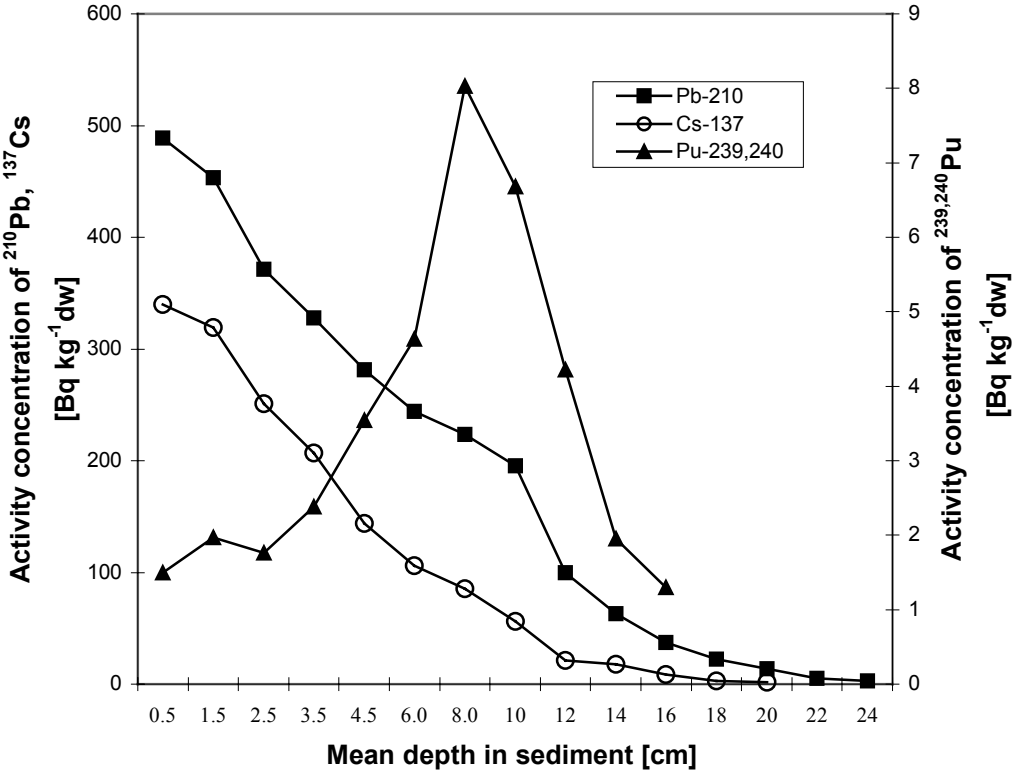

Fig.2. Vertical distribution of ^{137}Cs, ^{210}Pb and ^{239,240}Pu in bottom sediments from Gulf of Gdansk (P110) in 2001.

Conclusions

- The highest concentrations of ^{137}Cs, originated from the fallout after Chernobyl accident, were observed in upper 0-3 cm layer of sediment. The patterns of ^{137}Cs vertical distributions suggested that ^{137}Cs containing sedimentation matter are still in new-formed layers of the bottom sediments.
- The maxima of $^{239,240}Pu$ concentrations observed in deeper layers of sediments indicate that nuclear weapon tests were the main source of plutonium contamination.
- The sedimentation rates in Gulf of Gdansk (P110) based on vertical distribution of ^{210}Pb and $^{239,240}Pu$, ranged from 1.6 to 2.3 mm $year^{-1}$.

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2.11 INFLUENCE OF THE DOSE-RATE ON INDUCTION OF AN ADAPTIVE RESPONSE IN CULTURED C3H10T1/2 CELLS

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The term “adaptive response” was used for the first time in 1984 to describe a phenomenon by which preexposure of human lymphocytes to low concentrations of [^{3}H]thymidine causes the cells to become adapted so that they became less susceptible to chromosomal damage caused by a subsequent higher radiation dose (1). To explain such response to ionizing radiation it was postulated that a low ”conditioning dose” induces in human lymphocytes a chromosomal break repair mechanism which, if operates at the time the cells are exposed to a challenge dose, reduces the number of aberrations observed, below that in cells receiving the ”challenge dose” only.

The adaptive response of human lymphocytes was found to be dependent on the adapting (conditioning) dose, dose-rate and expression time. For X-rays, the adaptive response is typically induced by exposing the cells to the conditioning dose in the range 0.5-20 cGy delivered at a dose-rate around 0.2 Gy/min (2). The induction of the adaptive response takes place between 4-6 hours after exposure to the conditioning dose and remains effective for three cell cycles (3).

Radiation-induced chromosomal aberrations are the initial biological cause of such radiation-induced end-points as micronucleus formation, cellular survival and neoplastic transformation. Thus, adapted cells should be also less susceptible to radiation-induced micronucleus formation, cell killing and neoplastic transformation.

In view of the potential importance of the adaptive response to the cancer risk from multiple radiation exposures, we decided to look for a radioadaptation in the C3H10T1/2 mouse embryo fibroblasts (4). These immortal but non-tumourigenic C3H10T1/2 cells can be transformed into demonstrably malignant ones by exposure to high doses of ionizing radiation. In previous annual report we have indicated that conditioning of C3H10T1/2 cells with X-ray dose of 5 cGy given at a dose-rate of 1 Gy/min induced the adaptive response protecting these cells against micronuclei formation by subsequent irradiation to 4 Gy X-rays at 6 h after the first dose. In the experiments described in this report, we looked for the influence of conditioning dose-rate on adaptive response in C3H10T1/2 cells.

Examination of the adaptive response was carried out with the same frequency of micronuclei, i.e., a number of micronuclei per 1000 cells scored, as the criterion of the response. An observed micronucleus frequency was related to the expected one, calculated as the sum of micronuclei frequency for conditioning and challenge doses minus the control. When the value of the observed micronucleus frequency was lower than the expected value, it was interpreted as induction of the adaptive response.

Cell culture. The initial culture of the C3H10T1/2 mouse embryo fibroblasts was generously supplied by the Cancer Centre and Institute of Oncology in Warsaw. Cells were routinely maintained in Eagle's basal medium (Gibco) supplemented with 10% heat inactivated foetal calf serum (Bioproduct Ltd, Hungary) and 25 μg/ml gentamicin sulphate (Gibco). Cultures were incubated in 2% CO_2 in air at 37°C. In this study the cells in passage 9-13 were used. Aliquots of $5x10^5$ cells were transferred to several 25 cm^2 culture flasks and incubated for 24 hours prior to irradiation with the conditioning dose. For irradiation, the culture medium was removed, and the cells were irradiated at room temperature.

X-irradiation. The 250 kVp X rays were generated from an X-ray generator (Pantak) operated at 250 kV and 11 mA with a 1 mm Cu filter. The conditioning dose of 5 cGy was delivered to cells at dose-rates of approximately 0.2, 0.4, 0.6, 0.8 and 1.0 Gy/min. Immediately after irradiation, the medium was returned to the cultures and the cells were allowed to adapt at 37°C during 6 hour incubation period. The challenge dose of 4 Gy was delivered at a dose-rate of approximately 1.0 Gy/min. Control cells were sham irradiated.

Micronucleus assay. Immediately after completion of irradiation with the challenge dose the cells were detached using 0.15% trypsin solution (Sigma) and seeded into 75 cm^2 flasks containing 3 μg/ml cytochalasin B (Sigma). Following 48 hours incubation at 37°C, the cells were washed twice in phosphate-buffered saline (PBS), detached by trypsin treatment, collected in complete medium, separated by centrifugation, resuspended in 1% sodium citrate (w/v) and incubated for 20 min at 37°C. The cells were then collected by centrifugation, resuspended in 1:1 sodium citrate: (3:1 methanol:glacial acetic acid) and incubated for 10 min at room temperature. The suspension was again centrifuged and the cells resuspended at room temperature in 3:1 methanol:glacial acetic acid. Samples were held for 10 min at room temperature and then recovered by centrifugation. Microscopic preparations were made by dropping cells on wet slides and staining with Giemsa. Micronuclei were counted only in cells arrested in a binucleate state with cytochalasin B.

As may be seen in Table 1, no reduction in micronucleus frequency was demonstrated when the C3H10T1/2 cells were conditioned with the dose of 5 cGy given at the dose-rate of 0.2, 0.4 and 0.6 Gy/min, respectively. However, when the dose-rate was increased to 0.8 and 1.0 Gy/min, there were statistically significant differences between the observed and expected micronucleus frequency.

This indicates that preexposure of C3H10T1/2 cells to the dose of 0.05 Gy, given with the dose-rate higher than 0.6 Gy/min, induced in these cells the adaptive response that protected them against micronucleus formation induced by a subsequent exposure to 4Gy. In adapted cells the micronucleus frequency was about 20-30% lower than in their non-adapted counterparts.

Findings obtained in this study show that the C3H10T1/2 mouse embryo fibroblasts can adapt to X-ray radiation when preexposed to the conditioning dose as low as 5 cGy, and these adapted cells are more resistant to radiation induced chromosome breaks, as indicated by reduction in micronucleus frequency. However, it should be noted that in contrast with human lymphocytes, where radioadaptation is seen after a conditioning dose of 5 cGy given at a dose-rate around 0,2 Gy/min (2), the adaptive response of C3H10T1/2 mouse embryo fibroblasts requires the conditioning dose of 5 cGy given at 4 to 5 times higher intensity. The ability of fibroblastic cells to adapt when exposed to high dose-rate low doses was described previously for human fibroblasts as the model system (5).

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Tab. 1. Effect of 5 cGy X-ray preirradiation at different dose-rates on micronucleus formation in C3H10T1/2 cells challenged with 4 Gy X rays.

Dose-rate [Gy/min]	Dose [Gy]	Number of cells scored	Number of micronuclei per cell scored	
			Observed	Expected
	None (control)	7073	0.010±0.001	
	4	4843	0.222±0.007	
0.2	0.05	5102	0.010±0.001	
0.2	0.05+4 after 6 h	5883	0.247±0.006	0.222
0.4	0.05	5902	0.009±0.001	
0.4	0.05+4 after 6 h	6092	0.221±0.006	0.221
0.6	0.05	4398	0.012±0.002	
0.6	0.05+4 after 6 h	5315	0.238±0.007	0.224
0.8	0.05	5114	0.013±0.002	
0.8	0.05+4 after 6 h	4973	0.181±0.007*	0.225
1.0	0.05	5511	0.010±0.001	
1.0	0.05+4 after 6 h	4908	0.154±0.006*	0.222

*Significantly lower than expected ($p<0.05$)

2.12 DURATION OF AN ADAPTIVE RESPONSE INDUCED BY LOW-DOSES OF X RADIATION IN CULTURED C3H10T1/2 CELLS

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As shown in our previous study, adaptation of the C3H10T1/2 mouse embryo fibroblasts to X-rays requires the conditioning dose of at least 5 cGy delivered at the rate exceeding 0.6 Gy/min.

Questions arise about how long this phenomenon lasts and how long it takes to develop. To address these questions, the conditioned cells were allowed to adapt for time periods 2-72 hours prior to the subsequent irradiations.

Briefly: for adaptation of the C3H10T1/2 cells to X radiation, they were preexposed to 5 cGy delivered at the rate of 1 Gy/min and incubated at 37^{o}C during 2, 4, 6, 24, 48 and 72 hour period prior to the challenging dose of 4 Gy of X-rays. All irradiations were performed with the same dose-rate of 1 Gy/min. For micronucleus assay, the cells were cultured in the presence of 3 μg/ml of the cytochalasin B. After 48 hours, they were fixed and stained with Giemsa. Micronuclei were counted only in cells arrested in a binucleate state.

Table 1 shows the cumulative results of a series of experiments that were carried out to determine the duration of adaptive response in the C3H10T1/2 cells. The data indicate that full adaptation occurs at 4-6 h after the conditioning dose of 5 cGy and disappears after a time interval of 48-72 hours. Because under those experimental conditions, the doubling time of C3H10T1/2 cells was around 20 hours, their adaptation lasted for 2-3 cell cycles.

Thus for the C3H10T1/2 mouse embryo fibroblasts, once induced adaptation to acutely administered X-rays was relatively long-lived, protecting 2-3 cell generations against micronucleus formation due to the challenge dose of 4 Gy. Whether the adapted cells are also protected against radiation-induced neoplastic transformation is currently investigated.

Tab. 1. Effect of time interval between the conditioning and challenged dose on micronucleus formation in C3H10T1/2 cells

Dose [Gy]	Number of cells scored	Number of micronuclei per cell scored	
		Observed	Expected
None (control)	7073	0.010±0.001	
4	4843	0.222±0.007	
0.05	5511	0.010±0.001	
0.05+4 after 2 h	4039	0.221±0.008	0.222
0.05+4 after 4 h	4770	0.218±0.007	0.222
0.05+4 after 6 h	4908	0.154±0.006*	0.222
0.05+4 after 24 h	5838	0.160±0.005*	0.222
0.05+4 after 48 h	5601	0.157±0.005*	0.222
0.05+4 after 72 h	4548	0.248±0.007	0.222

*Significantly lower than expected ($p<0.05$)

2.13 COMPARISON BETWEEN FLUORESCENCE IN SITU HYBRIDIZATION (FISH) AND CONVENTIONAL CYTOGENETICS FOR DICENTRIC AND TRANSLOCATION DETECTION FOR BIOLOGICAL DOSIMETRY OF IONIZING RADIATION

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Ionizing radiation is very efficient in induction of dicentrics and translocations in human peripheral blood lymphocytes irradiated at the G_o phase of the cell cycle. The frequency of these most common forms of chromosome aberrations increases with the increase of an absorbed radiation dose in the manner dependent on the dose-rate and the linear energy transfer (LET). Since radiation-induced dicentrics and translocations occur with a similar frequency per unit dose after *in vitro* and *in vivo* exposure, their scoring in metaphase preparations of peripheral blood lymphocytes of an overexposed subject is the most suitable method for the biological estimation of an absorbed radiation dose (1). Time-unstable dicentrics are the aberrations of choice for the dose estimation during a reasonably short period after radiation overexposure, whereas stable translocations are considered to be the most suitable for long-term retrospective dosimetry.

Dicentric chromosomes are very obvious. Therefore it is easy to score them by conventional solid-staining with Giemsa. In contrast, detection of translocations is rather difficult unless some special procedures are employed to recognize the individual translocated chromosomes. Currently translocations can be precisely detected by the fluorescence *in situ* hybridization (FISH) technique (2). With FISH two or more pairs of homologue chromosomes can be uniformly hybridized along their length by using fluorescently labeled specific whole-chromosome DNA probes (so-called "chromosome painting"). Use of an appropriate counterstain results in visualization of the remaining unpainted chromosomes in a different color. Thus all aberrations derived from exchanges between painted and unpainted chromosomes and between chromosomes painted in different colors can be recognize by their bi- or multi-colored painting patterns. The simultaneous application of a pancentromeric DNA probe for centromere painting allows the precise discrimination between bi- or multi-colored chromosomes with two or more visible centromere signals (e.g. dicentrics and multicentrics) or with one centromere signal (e.g. translocations) in the same cell (3).

To record the aberrations involving painted chromosomes, the Protocol for Aberration Identification and Nomenclature Terminology (PAINT) system (4) has been proved to be very useful. With PAINT each bi-or multicolored chromosome is described individually. The letters "A" and "a" are used to indicate an unpainted chromosomal material that is counterstained with an appropriate counterstain. The capital letter designates a portion of the chromosome that contains a centromere, whereas the small letter is used for that without a centromere. The successive letters of the alphabet are used to indicate a material that is painted in different colors. Thus a nomenclature t(Ba) indicates a translocated chromosome with an acentric piece of unpainted material "a" attached to a centric portion of painted chromosome "B". Similarly a nomenclature dic(AB) indicates a dicentric involving two centric pieces of painted "B" and unpainted "A" material.

FISH analysis of bicolored aberrations detects only a proportion of the total dicentrics and translocations present in a cell. Therefore, when FISH results are compared to those obtained by conventional Giemsa staining, they must be converted to the whole genome equivalents by the following formula provided by Lucas *et al.* (5): $F_p = 2.05 f_p(1-f_p)F_G$, where

F_p is the frequency of dicentrics or translocations detected by FISH, f_p is the painted fraction of the genome, and F_G is the whole genome aberration frequency.

In the present study two-color FISH with the cocktail of whole chromosome DNA probes specific for human chromosomes #1 and #4 applied together with the pancentromeric DNA probe for all centromeres was used for simultaneous detection of dicentrics and translocations in G_o female lymphocytes exposed *in vitro* to X rays at doses ranging from 0 (non-irradiated control) to 4 Gy. Simple and complex aberrations involving painted chromosomes were recorded by the (PAINT) system (4). The suitability of the FISH painting for detection of dicentrics and translocations was compared with the conventional Giemsa staining for the detection of dicentric aberrations in the whole genome. The particular emphasis was put on FISH application to biological dosimetry of ionizig radiation.

The data on the whole genome dicentric frequencies obtained from conventional Giemsa stained preparations of lymphocytes irradiated *in vitro* with X-ray doses from 0 to 4 Gy are presented in Table 1. Up to the dose of 0.5 Gy all of the aberrant cells had only one dicentric aberration, whereas at higher doses the fraction of cells with multiple dicentrics became significant.

The spectrum of simple dicentric and translocations formed between painted and unpainted chromosomes, and between chromosomes painted with different colors in cells irradiated with doses of 1, 2 and 4 Gy is shown in Table 2. Bi-colored complex aberrations, not seen in Giemsa staining, are presented in Table 3. The complex aberrations occurred only at the highest dose of 4 Gy and their number expressed as a ratio to the total painted dicentrics and translocations did not exceed 7%. These aberrations were reduced to a set of component dicentrics and translocations and included in the final totals.

The experimental data on painted dicentrics and translocations with the corresponding genomic aberration frequencies, calculated by the formula derived by Lucas *et al*. (5), are given in Table 4. For all three doses, the estimates of genomic dicentric frequencies were similar to the frequencies observed using classical scoring method. When the pooled data from all three doses were used, the dicentrics which involved painted chromosomes #1 and #4 yielded on average about 27% of dicentrics scored in the whole genome by Giemsa staining. Since whole-chromosome paints to chromosomes #1 and #4 paint approximately 14.3% of the total DNA content of a normal female cell, this result was in very good agreement with an expected 26% predicted by two-color version of Lucas formula. The agreement for dicentric data gave confidence that translocations frequencies detected by chromosome painting could be converted to genomic translocation frequencies by the same formula. However, the data on painted translocations show that for all three doses, translocations which included complete, incomplete and terminal exchanges plus those involved in complex translocation, are on average about two times more numerous than dicentrics. As may be seen in Table 2, for doses of 1 and 2 Gy the majority of both translocations and dicentrics was observed as complete exchanges. At the dose of 4 Gy approximately 60.5% translocations were deemed as complete, 27.8% as incomplete exchanges and 11.7% as terminal ones. For dicentrics the observed percentages of complete, incomplete and terminal types were respectively 57.8%, 29.7% and 12.7%. Since formation of X-ray-induced exchange-type aberrations is expected to follow a linear-quadratic model (1), the dose-response relationships for translocations and dicentrics detected by FISH and conventional cytogenetics were fitted to an equation $Y=\alpha D+\beta D^2$, where Y is the dicentric or translocation frequency, using an iteratively re-weighted least-squares method. Since no dicentric and translocated chromosomes were observed at the 0 Gy dose, zero background levels of dicentrics and translocations were assumed for the purpose of this fitting. The results of fitting

to a linear-quadratic relationship are shown in Table 5 and lower than that for Giemsa staining. Since painting chromosomes #1 and #4 detected only 27% of total dicentrics occurred in an irradiated cell, at least 385 FISH painted metaphases would need to be scored to obtain the same amount of information about dicentrics as in 100 Giemsa stained cells.

Thus this study have demonstrated that two-color FISH for chromosomes #1 and #4 and all centromeres detects correctly dicentrics and translocations induced *in vitro* in human periperal blood lymphocytes. This has proved that the same FISH assay has also the potential for cytogenetic assessment of an absorbed dose after *in vivo* overexposure to ionizig radiation. However in comparison with the conventional cytogenetic dosimetry, such FISH dosimetry is more rapid and reliable, by-passing the need to karyotype the cells.

Employed FISH assay is also able to provide a meaningful dosimetry for high dose exposures and for high-LET radiations which are particularly efficient in induction of complex chromosome aberrations. Because these aberrations can be easily scored by their bi- or multi-colored painting patterns and resolved into the component dicentrics and translocations, the information provided by them do does not need be ignored and can be included in the dose estimate.

Since the frequencies of radiation-induced translocations exceed the dicentric frequencies, at least in human lymphocytes, translocations which are aberrations of choice for long-term retrospective dosimetry may be also used for estimation of these recent radiation exposures that result in a low or zero dicentric levels.

The presented work has been performed in the Department of Radiation Genetics and Chemical Mutagenesis of Leiden University Medical Centre (the Netherlands) under the fellowship of the International Atomic Energy Agency in Vienna.

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Tab. 1. Frequency and distribution of dicentrics scored by conventional Giemsa staining in G_o human lymphocytes following X-irradiation with doses from 0 (non-irradiated control) to 4 Gy

Dose [Gy]	No. of metaphases scored	No. of dicentrics	Dicentric frequency ±SE*	Dicentrics per metaphase					
				0	1	2	3	4	5
0	590	0	0	590	0	0	0	0	0
0.10	100	3	0.030 ± 0.017	97	3	0	0	0	0
0.25	100	3	0.030 ± 0.017	97	3	0	0	0	0
0.50	100	7	0.070 ± 0.026	93	7	0	0	0	0
1.00	220	31	0.141 ± 0.025	192	25	3	0	0	0
2.00	271	88	0.325 ± 0.035	196	65	8	1	1	0
4.00	93	118	1.269 ± 0.117	23	39	20	6	4	1

*dicentrics/metaphases scored ± √dicentrics/metaphases scored

Tab. 2. Simple dicentrics and translocations involving chromosomes ≠1 and ≠4 in G_o human lymphocytes following X-irradiation with doses 1, 2 and 4 Gy

		Aberrations observed per dose point		
Observation	PAINT nomenclature	1 Gy	2 Gy	3 Gy
Dicentrics	dic(BA) + ace(ba)	5	13	17
	dic(BA) + ace(b)	-	-	12
	dic(BA)	-	-	4
	dic(CA) + ace(ca)	-	6	15
	dic(CA) + ace(c)	-	-	6
	dic(C)	-	1	7
	dic(BC) + ace(bc)	1	1	1
	dic(BC) + ace(b)	-	-	1
	dic(BC)	-	-	1
	dic(BB) + ace(bb)	1	2	4
Translocations	t(Ba) + t(Ab)	5	14	41
	t(Ba) + ace(ba)	1	9	12
	t(Ba) + ace(b)	1	-	17
	t(Ba)	-	-	4
	t(Ab)	-	-	9
	t(Ca) + t(Ac)	4	11	25
	t(Ca) + ace(ca)	2	12	9
	t(Ca) + ace(c)	-	-	10
	t(Ca)	-	-	9
	t(Ac)	-	-	10
	t(Bc) + t(Cb)	-	1	8
	t(Bc) + ace(bc)	-	1	3
	t(Bc) + ace(c)	-	-	1
	t(Bc)	-	-	1
	t(Cb) + ace(c)	-	-	2
	t(Cb)	-	-	1

Table 3. Complex aberrations involving chromosomes ≠1 and ≠4 in G_o human lymphocytes following X-irradiation with dose of 4 Gy

PAINT nomenclature	No. of complex aberrations scored	No. of component aberrations identified as	
		dicentric	translocation
tri(ABA)	2	4	-
tri(ACA)	2	4	-
tri(BAA)	1	1	-
dic-t(ABa)	1	1	1
dic-t(BAc)	1	1	1
dic-t(BBa)	1	1	1
dic-t(AAb)	3	-	3
t-t(aBa)	1	-	2
t-t(bAb)	2	-	4
t-t(aCa)	3	-	6

Table 4. Frequency of dicentrics and translocations scored by FISH in G_o human lymphocytes following X-irradiation with doses 0 (non-irradiated control) 1, 2 and 4 Gy.

Dose [Gy]	No. of metaphases scored	Full genome-equivalent cells*	Total no.of dicentrics	Genomic dicentric frequency ±SE**	Total no.of translocations	Genomic translocation frequency±SE***
0	385	100	-	-	-	-
1	146	38	7	0.184 ± 0.069	13	0.342 ± 0.094
2	310	81	23	0.283 ± 0.059	48	0.592 ± 0.085
4	251	65	80	1.231 ± 0.138	180	2.769 ± 0.206

* calculated as a number of metaphases scored x 0.26

** dicentrics/ full genome equivalent cells ± √dicentrics/full genome equivalent cells

*** translocations/ full genome equivalent cells ± √translocations/full genome equivalent cells

Tab 5. Results of fitting a linear-quadratic relationship, $Y=\alpha D +\beta D^2$, to X-ray-induced translocation and dicentric frequencies measured by FISH and Giemsa staining in G_o human lymphocytes.

	α ±SE	β ±SE
Translocations by FISH	0.0206±0.1129	0.1667±0.0313
Dicentrics by FISH	0.0374±0.0581	0.0669±0.0161
Dicentrics by Giemsa staining	0.0478±0.0211	0.0669±0.0059

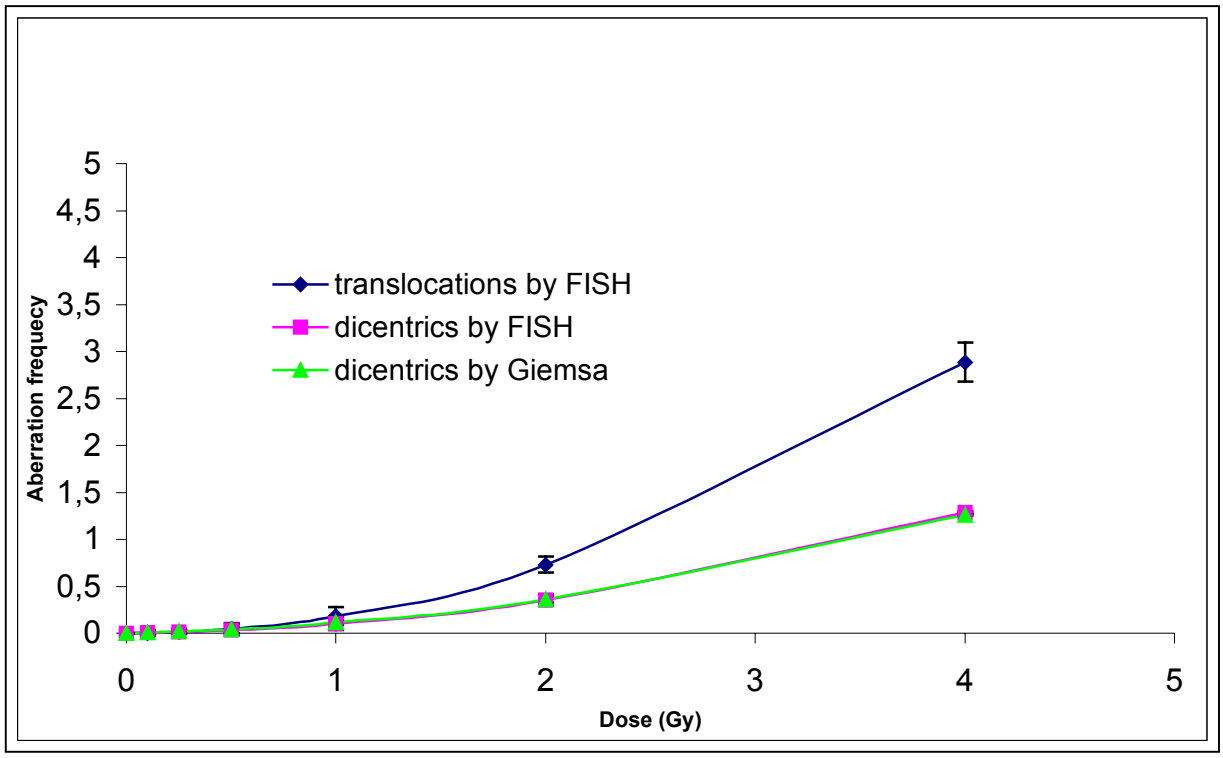

Figure 1. Dose-response curves for translocations by FISH(dark blue), dicentrics by FISH (pink) and dicentrics by Giemsa staining (green)

3. OPERATIONAL ACTIVITIES

3.1.1 RADIATION MONITORING

The monitoring of radioactive contamination of the environmental components and foodstuffs in Poland is integrated by the Service of Radioactive Contamination Measurements (SPSP), which is managed by CLOR and supervised by the National Atomic Energy Agency (PAA).

The Service comprises of:

1. A network of measuring stations, acting within the meteorological stations, the stations for sanitary supervision, veterinary hygiene establishments, chemical-agricultural stations, water supply and sewage units. These stations systematically measure gamma dose rate and the radioactivity in samples of components of the environment and foodstuffs. The monitoring of radioactivity is carried out in air aerosols, total fallout, atmospheric precipitation, surface water, tap water, sewage, soil, plants and foodstuffs.
2. Early warning network

The early warning network (see figure below) consists of:

- 9 stations of the Service of Radioactive Contamination Measurements acting within the Institute of Meteorology and Water Management,
- 10 aerosol sampling stations ASS-500 run by different institutes, under supervision of CLOR,
- 13 permanent monitoring stations (PMS).

Nine in-field stations of the Institute of Meteorology continuously measure gamma dose rate, and radioactivity of air aerosols and of total fallout.

Ten high volume air sampling stations type ASS-500 work in a weekly cycle in normal radiological situation. In the case of emergency the frequency of sampling can be increased as needed. This enable performing spectrometric measurements of natural and artificial radionuclides deposited on filters in wide range of their concentrations.

Eleven permanent monitoring stations measure gamma dose rate and analyse on-line the spectrum of gamma radioactivity in the vicinity of the station.

3. The Centre of the Radioactive Contamination Measurements (COPSP) supervises and co-ordinates all activities related to the detection and measurements of radioactive contamination all over the country and carries out the necessary research. The function of the COPSP is executed by the Central Laboratory for Radiological Protection (CLOR) and supervised by PAA.

The tasks of the Centre are as follows:

- elaboration of measurements program for the stations,
- elaboration of unified measurement methods,
- selection of equipment for the stations,
- collection and elaboration of measurement results reported by the stations,
- elaboration of reports and analyses of the radiological hazard level.

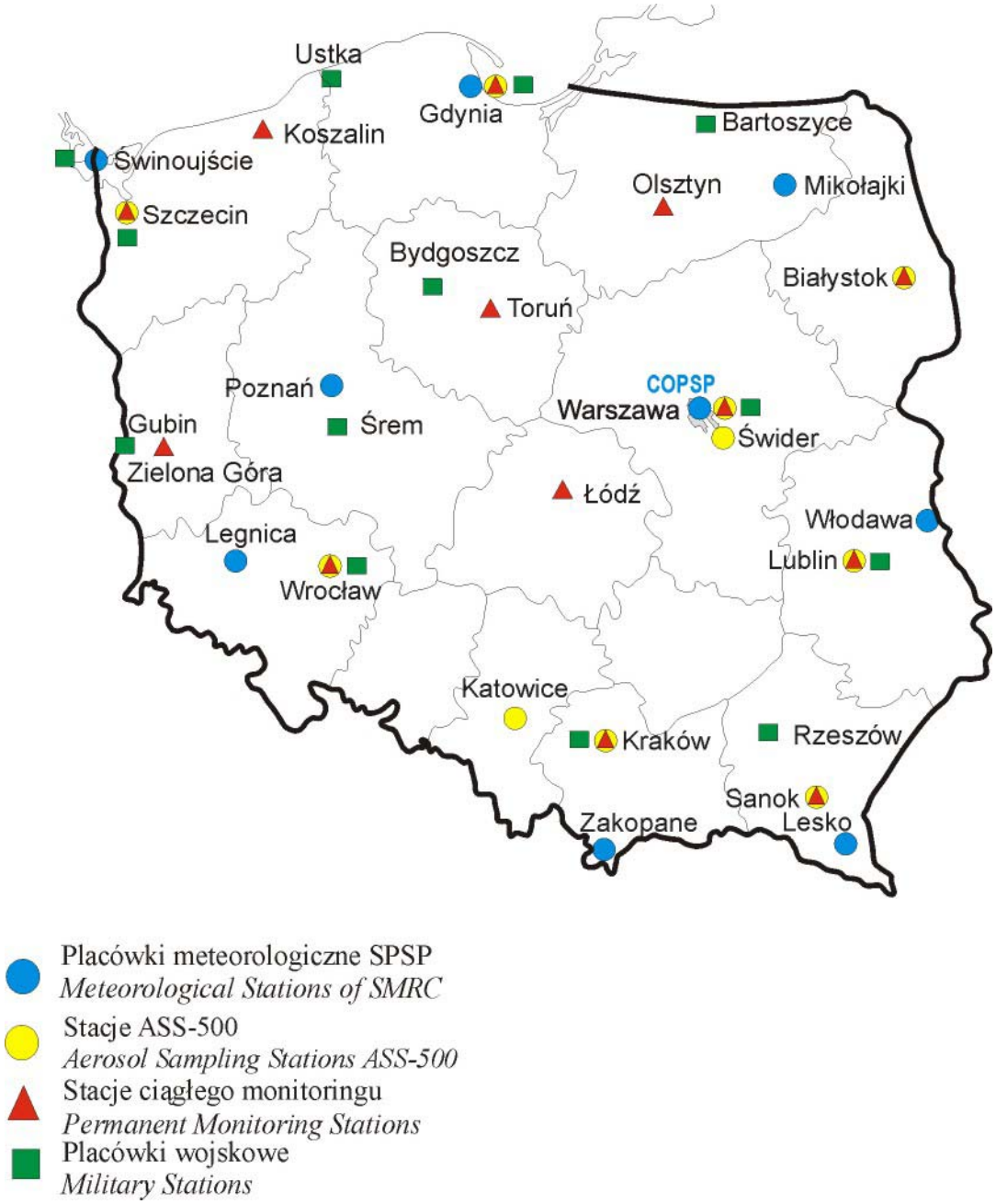

Fig. 1. Polish Radiation Monitoring System

3.1.2 PERMANENT MONITORING STATIONS (PMS) NETWORK IN POLAND

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POLISH-DANISH COOPERATION – HISTORICAL OVERVIEW

The PMS network in Poland originated in consequence of an agreement signed between Polish National Atomic Energy Agency and Danish Emergency Management Agency in May 1994. In the years 1995-1999 the automatic „on-line" network consisting of first eleven stations, produced by Greenwood Engineering, Denmark, was installed in Poland and put into operation. These stations were located in Białystok, Gdynia, Koszalin, Kraków, Lublin, Olsztyn, Sanok, Szczecin, Warszawa, Wrocław and Zielona Góra. The central system managing the measurement network was installed simultaneously at CLOR in Warsaw. In 2001 two new PMS stations started operation in Łódź and Toruń. The location of the PMS stations is presented in Figure 1. The PMS system is a part of the Early Warning System in Poland.

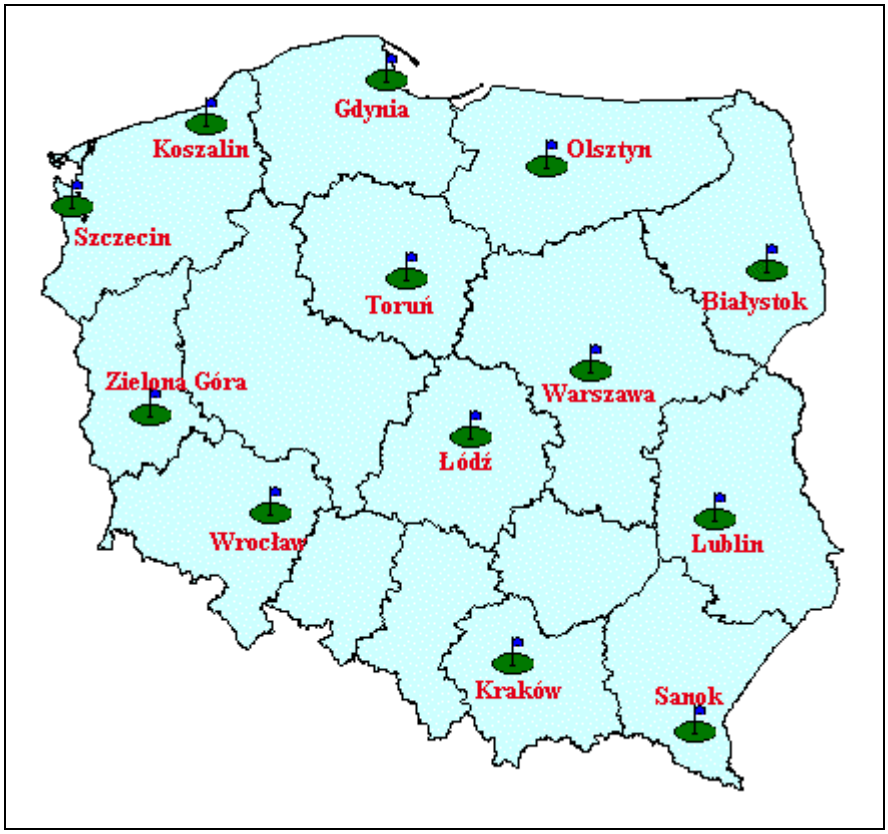

Fig. 1. The location of the PMS Stations in Poland.

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

to perform full service of the PMS system in Poland and to utilize the potential of ARGOS_NT and NUCINFO.

DESCRIPTION OF THE PMS SYSTEM

The PMS stations continuously monitor radioactive contamination of the environment and store collected data on the disk in the station computer. The parameters monitored are: background gamma radiation spectra measured by 3"x3" NaI(Tl) scintillation detector and deconvoluted into four components: natural radium, natural thorium, natural ^{40}K and the 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 is connected to PMS system. The block diagram of the PMS station is presented in Figure 2.

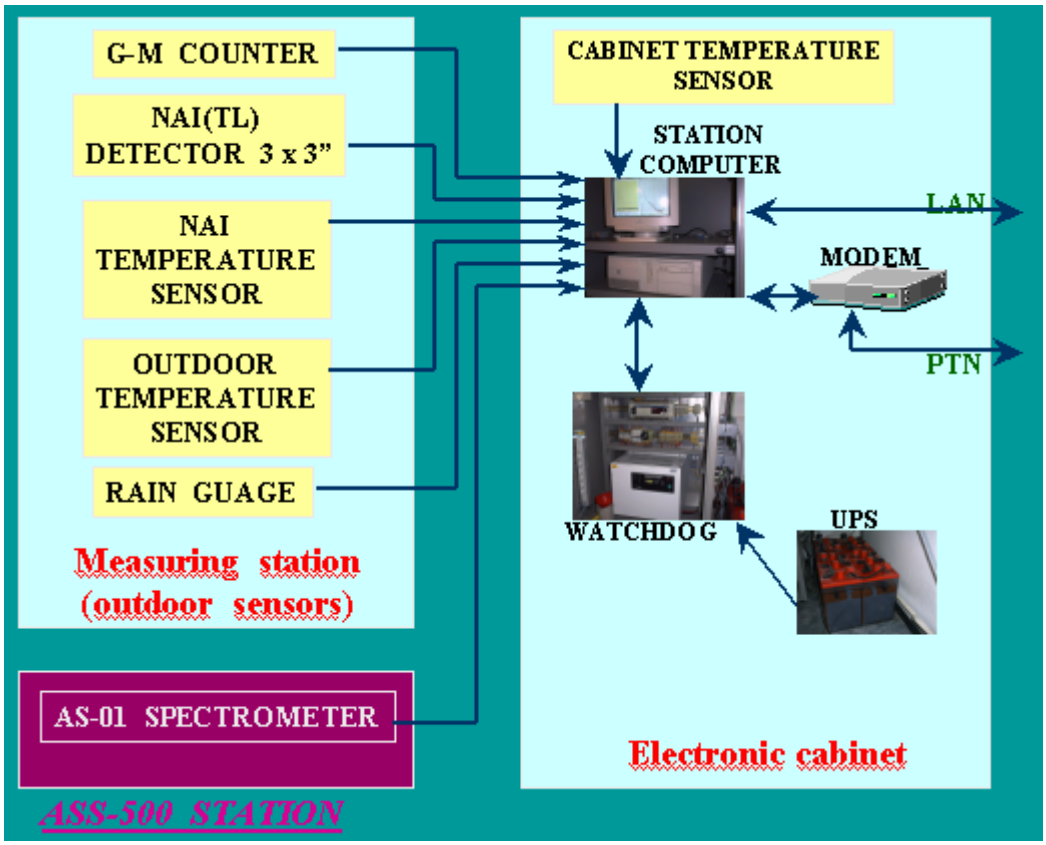

Fig. 2. PMS station block diagram.

The data collected by the station computer are transmitted to the central system which is located in Dosimetry Department of CLOR in Warsaw. The central system consists of two computers: one controlling the transmission and second having the MS SQL Server 6.5 (upgraded to version 7.0 in 1998) 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 – as is the case in Warsaw), transmission interval (in normal situation of 10 hours) and to set up the alarm

thresholds. After detection of a radiation level exceeding given threshold (set approximately 10% higher than background level) the station calls the central computer and forces immediate data transmission. In the same time the information about alarm is sent (in SMS format) to mobile phone of system operator. The audible alarm is generated on the central computer. In normal situation the station data are averaged hourly, but in emergency there is a possibility to switch to 10-min averages. Figure 3 shows the user interface of the central system at CLOR.

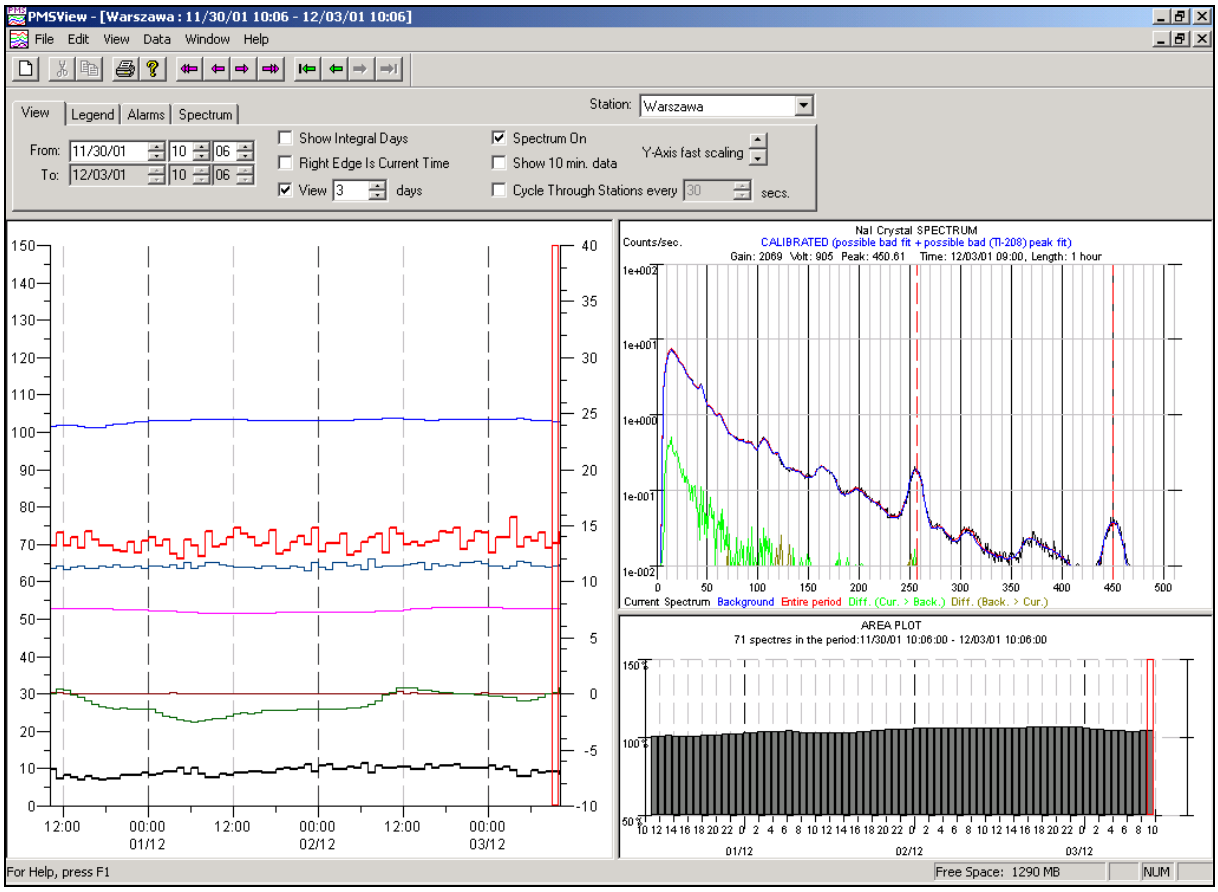

Fig. 3. PMS server graphical user interface.

THE MONITORING RESULTS OF THE PMS STATION NETWORK

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

Table 1. Monthly report (November 2001).

PMS STATION	Number in PMS network	Dose rate measured by G-M counter [μGy/h]			Dose rate from Th component (NaI(Tl) detector) [μGy/h]		
		AVER.	MIN	MAX	AVER.	MIN	MAX
Gdynia	**5**	0,107	0,104	0,111	- *)	- *)	- *)
Lublin	**6**	0,113	0,106	0,121	- *)	- *)	- *)
Białystok	**7**	0,084	0,081	0,089	- *)	- *)	- *)
Warszawa	**8**	0,072	0,069	0,078	0,065	0,064	0,066
Kraków	**9**	0,103	0,100	0,109	0,098	0,094	0,100
Szczecin	**20**	0,095	0,092	0,101	0,077	0,076	0,078
Wrocław	**21**	0,086	0,083	0,094	- *)	- *)	- *)
Sanok	**22**	0,085	0,079	0,092	0,076	0,066	0,080
Zielona Góra	**40**	0,079	0,076	0,082	0,074	0,073	0,075
Koszalin	**41**	0,081	0,078	0,089	0,077	0,076	0,077
Olsztyn	**42**	0,079	0,076	0,083	0,072	0,070	0,073
Łódź	**50**	0,074	0,071	0,078	0,063	0,060	0,066
Toruń	**51**	0,091	0,088	0,094	0,087	0,086	0,089

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

More detailed reports are prepared every quarter-year. The excerpt from the report of second quarter of 2001 is presented in Table 2 and Figure 4.

Table 2. PMS quarterly report.

Number in PMS network	Month	Gamma dose rate (G-M)			Dose rate from Th (NaI)			Month rainfall
		AVER.	RANGE		AVER.	RANGE		
			MIN	MAX		MIN	MAX	
		[μGy/h]	[μGy/h]	[μGy/h]	[μGy/h]	[μGy/h]	[μGy/h]	[mm]
5 Gdynia	**IV**	0,105	0,102	0,111	- *)	- *)	- *)	69,2
	V	0,105	0,103	0,108	- *)	- *)	- *)	42,0
	VI	0,106	0,105	0,110	- *)	- *)	- *)	64,9
	quarter	**0,106**			**-**			**176,1**
					MAX. PRECIPITATION:			20,7
6 Lublin	**IV**	0,109	0,106	0,118	0,107	0,105	0,108	39,5
	V	0,111	0,107	0,115	0,110	0,107	0,112	23,4
	VI	0,112	0,109	0,115	0,109	0,107	0,111	41,8
	quarter	**0,111**			**0,109**			**104,7**
					MAX. PRECIPITATION:			11,2
7 Biały-stok	**IV**	0,084	0,081	0,088	- *)	- *)	- *)	52,0
	V	0,084	0,081	0,090	- *)	- *)	- *)	76,6
	VI	0,084	0,083	0,087	- *)	- *)	- *)	50,2
	quarter	**0,084**			**-**			**178,8**
					MAX. PRECIPITATION:			36,6

Table 2 (continued). PMS quarterly report.

Number in PMS network	Month	Gamma dose rate (G-M)			Dose rate from Th (NaI)			Month rainfall
		AVER.	RANGE		AVER.	RANGE		
			MIN	MAX		MIN	MAX	
		[μGy/h]	[μGy/h]	[μGy/h]	[μGy/h]	[μGy/h]	[μGy/h]	[mm]
8 War-szawa	**IV**	0,072	0,070	0,081	0,065	0,064	0,066	90,5
	V	0,073	0,070	0,078	0,066	0,065	0,068	73,6
	VI	0,072	0,070	0,077	0,066	0,065	0,067	81,5
	quarter	**0,072**			**0,066**			**245,6**
					MAX. PRECIPITATION:			33,9
9 Kra-ków	**IV**	0,104	0,096	0,117	0,097	0,084	0,100	168,7
	V	0,105	0,100	0,109	0,101	0,097	0,104	57,3
	VI	0,105	0,101	0,110	0,101	0,098	0,104	14,7
	quarter	**0,105**			**0,100**			**240,7**
					MAX. PRECIPITATION:			36,4
20 Szcze-cin	**IV**	0,094	0,092	0,098	0,076	0,076	0,077	48,3
	V	0,095	0,093	0,103	0,078	0,077	0,079	47,4
	VI	0,095	0,093	0,097	0,077	0,076	0,079	2,1
	quarter	**0,095**			**0,077**			**97,8**
					MAX. PRECIPITATION:			32,3
21 Wroc-ław	**IV**	0,085	0,081	0,089	0,062	0,060	0,066	48,7
	V	0,086	0,084	0,091	0,068	0,062	0,072	31,2
	VI	0,086	0,083	0,090	0,065	0,060	0,071	57,4
	quarter	**0,086**			**0,065**			**137,3**
					MAX. PRECIPITATION:			21,5
22 Sanok	**IV**	0,086	0,083	0,095	0,078	0,075	0,080	91,9
	V	0,087	0,085	0,093	0,080	0,065	0,083	89,8
	VI	0,087	0,083	0,095	0,078	0,070	0,081	153,9
	quarter	**0,087**			**0,079**			**335,6**
					MAX. PRECIPITATION:			32,2
40 Zielona Góra	**IV**	0,079	0,077	0,082	0,074	0,074	0,075	42,5
	V	0,079	0,077	0,082	0,075	0,074	0,077	5,2
	VI	0,079	0,077	0,084	0,075	0,074	0,076	0,1
	quarter	**0,079**			**0,075**			**47,8**
					MAX. PRECIPITATION:			6,3
41 Kosza-lin	**IV**	0,081	0,079	0,088	0,077	0,076	0,078	58,2
	V	0,082	0,080	0,085	0,079	0,078	0,080	36,9
	VI	0,082	0,079	0,093	0,078	0,077	0,079	149,2
	quarter	**0,082**			**0,078**			**244,3**
					MAX. PRECIPITATION:			52,3
42 Olsztyn	**IV**	0,079	0,077	0,083	0,073	0,071	0,074	49,8
	V	0,082	0,078	0,089	0,077	0,074	0,078	43,6
	VI	0,080	0,078	0,089	0,074	0,072	0,076	89,4
	quarter	**0,080**			**0,074**			**182,8**
					MAX. PRECIPITATION:			21,2

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

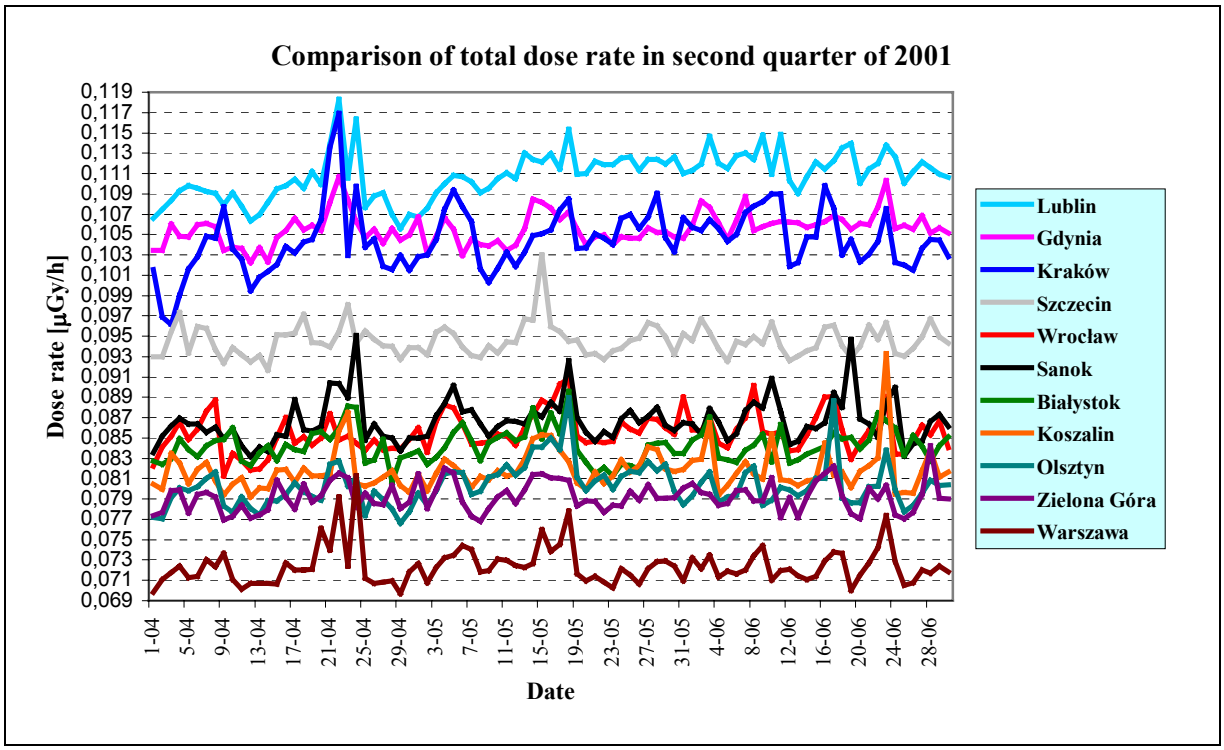

Figure 4. Comparison of the total gamma dose rate on seven PMS stations in second quarter of 2001.

The lowest dose rate was observed at Warszawa in February 2000 and at Lublin station in September 2001 (59 nGy/h), the highest dose rate was detected at Krakow station in July 2000 (181 nGy/h) - the result of heavy rainfall and, thus, radon washout. The average dose rate value for Poland in 2000 was 90 nGy/h and in 2001 was 89 nGy/h. Table 3 shows the averages, minima and maxima of the dose rate measured by PMS stations in Poland in 1999.

Table 3. Gamma dose rate in 2000-2001 – average, minimum and maximum for all PMS stations.

Station	Gamma dose rate [nGy/h]			
	Average	Average	2000 - 2001	
	2000	2001	MIN	MAX
BIAŁYSTOK	84	84	60	137
GDYNIA	104	107	95	150
KOSZALIN	82	81	62	140
KRAKÓW	110	104	89	171
LUBLIN	109	110	90	161
ŁÓDŹ	-	73	60	91
OLSZTYN	80	79	62	126
SANOK	86	86	66	145
SZCZECIN	95	95	70	143
TORUŃ	-	90	80	105
WARSZAWA	71	72	59	124
WROCŁAW	86	86	75	159
ZIELONA GÓRA	79	79	66	126

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

3.1.3 RADIOACTIVITY OF GROUND-LEVEL AIR IN POLAND IN 2000 AND 2001: RESULTS FROM AEROSOL SAMPLING STATIONS TYPE ASS-500.

Maria Bysiek, Małgorzata Biernacka

Dosimetry Department

Ten ASS-500 aerosol sampling stations were located in Warsaw, Świder, Białystok, Katowice, Kraków, Lublin, Gdynia, Wrocław, Szczecin and Sanok. All the stations were working without longer breaks. This resulted in collecting of 512 weekly aerosol samples in 2000 and 516 in 2001. Filters with the deposited aerosol, i.e. the total dust, were kept at least for 2 days in room temperature, then pressed into tablets 3-6 mm thick and 50 mm in diameter, and measured with HPGe detectors and multichannel analizers.
In 2000 the average mass of the weekly sampled total dust was 2.92 g with a range of 1.00 - 8.0 g. The average volume of filtered air was 70175 m^3, ranging 21677-112776 m^3. In 2001 the average mass of the total dust samples was 2.84 g, ranging 0.90 -11.10 g. The average volume of the filtered air was 72748 m^3, ranging 20181 - 127777 m^3. The wide ranges of the weekly samples of total dust and filtered air resulted from using different types of aerosol samplers, as well as from different dustiness at the particular sites. In computing and analysing the results of concentrations of radionuclides in the ground-level air it was assumed, that concentrations lower than the lower detection limit, LLD (confidence level 70 %), were at the LLD values, instead of the zero ones.
Log-normal probability plots of contents of ^{137}Cs, ^{7}Be, ^{40}K, ^{210}Pb, ^{226}Ra and ^{228}Ra in 1 g of total dust, and in 1 m^3 of air, for data from all stations in 2000 and 2001, reveal rather good fitness to straight lines. As usually, some irregularities at both ends of the lines can be seen. The lines for ^{226}Ra in total dust and air are particularly irregular, what is the result of different detection possibilities of the monitoring stations. In the both years some improvements in the measuring techniques, like more effective HPGe detectors and modern programs for activity calculations, have been introduced. In the end of 2001 only one station in the network (equipped with a GeLi detector) exhibited detection limits for ^{226}Ra, ^{228}Ra and ^{40}K several times higher than the average detection limits of the other stations.

Arithmetic means for air and total dust in 2000 and 2001 are presented in Table 1 and Table 2. It can be seen, that in many cases the maxima of the two parameters of air contamination are not in the same periods, or at the same sampling sites.

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

- 2000: 0.79 for ^{137}Cs; 0.56 for ^{7}Be; 0.67 for ^{40}K; 0.71 for ^{210}Pb; 0.78 for ^{226}Ra; 0.85 for ^{228}Ra.

- 2001: 0.82 for ^{137}Cs; 0.71 for ^{7}Be; 0.72 for ^{40}K; 0.74 for ^{210}Pb; 0.81 for ^{226}Ra; 0.85 for ^{228}Ra.

The calculated r^2 values indicate, that the mean strength of the relationships is about 0.6 , ranging 0.3-0.7. This means, that the activity of 1 m^3 of air is mainly caused by the activity of the sampled dust, but also that there exist some other factors, like the amount of total dust in 1 m^3 of air or unknown parameters of the analytical procedures responsible for the left r^2=0.4.

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

- 2000: 0.54 for ^{137}Cs, 0.29 for ^{7}Be, 0.56 for ^{40}K, 0.52 for ^{210}Pb, 0.07 for ^{226}Ra, 0.08 for ^{228}Ra.
- 2001: 0.39 for ^{137}Cs, 0.05 for ^{7}Be, 0.46 for ^{40}K, 0.32 for ^{210}Pb, 0.09 for ^{226}Ra, 0.21 for ^{228}Ra.

The r^2 values indicate, that the mean strength of these relationships is rather small (0.13, ranging 0.002-0.31) and does not totally explain the above mentioned left mean strength of 0.4. This suggest that a mean strength of 0.3 can be anticipated for reasons of analytical origin.

Examination of linear correlations between the concentrations of ^{137}Cs and ^{7}Be and between ^{137}Cs and ^{40}K in total dust and in air revealed very weak relationships. The values of (r) were in 2000:–0.03 and 0.20 (dust), 0.27 and 0.46 (air); in 2001: 0.12 and 0.25 (dust) , 0.06 and 0.29 (air).

Linear correlation between concentration of ^{210}Pb and ^{7}Be for data from all stations in 2000 and 2001, for total dust and for air, was weak. For the 2000 data the correlation coefficients were 0.13 (dust) and 0.16 (air), for 2001 data 0.33 (dust) and 0.18 (air). Examination of correlation coefficients for quarterly data revealed that the highest positive correlation coefficients, 0.52 (dust) and 0.75 (air), occurred in the third quarter of 2000, and 0.60 (air) and 0.61 (dust) in the second quarter of 2001. In the period of 1996-1999 the highest values were similar and have been obtained for the second quarters.

General weekly trends of 4 radionuclides in dust and air are presented in Fig 1-4. It can be seen, that ^{137}Cs concentrations were generally lower in 2001. The source of the highest ^{137}Cs concentration in 2000 (14.6 $\mu Bq/m^3$) measured at Białystok in the week 42 was not identified. The levels of the highest concentrations of this radionuclide in 2001 were about two times lower and have occurred in May at the stations Świder and Lublin.

Acknowledgement

In 2000 this project was supported by the National Environmental Protection and Water Management Fund.

Table 1. Annual summaries of ground-level air contamination, Poland, 2000-2001.

Radio-nuclide	Concentration, $\mu Bq/m^3$ Mean ± σ/√n	Range	n	Maximum of concentration Location	Period
2000					
^{131}I	0,5±0,02	<0,1- 4,3	512	Świder	21.08-28.08
^{137}Cs	1,5±0,06	<0,1-14,6	512	Białystok	16.10-23.10
^{7}Be	2490±50	820-8930	512	Świder	2.05- 8.05
^{40}K	17,8±0,5	<1,7-149,0	512	Świder	25.09- 2.10
^{210}Pb	470±16	94-1727	334	Lublin	20.11-27.11
^{226}Ra	6,5±0,3	<1,5-20,8	490	Szczecin	16.10-23.10
^{228}Ra	1,7±0,07	<0,3-11,4	507	Sanok	23.10-30.10
2001					
^{131}I	0,5±0,02	<0,1- 5,4	515	Warszawa	3.12-10.12
^{137}Cs	1,2±0,04	<0,1- 6,4	515	Lublin	21.05-28.05
^{7}Be	2390±40	440-6670	516	Świder	12.06-18.06
^{40}K	15,2±0,5	<1,3-100,5	515	Wrocław	14.05-21.05
^{210}Pb	402±12	84-1639	400	Świder	3.12-10.12
^{226}Ra	4,8±0,2	<1,2-31,6	515	Lublin	5.03-12.03
^{228}Ra	1,4±0,06	<0,3- 8,4	515	Sanok	23.07-30.07

n = number of results obtained at all sampling sites.

Table 2. Annual summaries of total dust contamination, Poland, 2000 - 2001.

Radio-nuclide	Concentration, Bq/g Mean ± σ/√n	Range	n	Maximum of concentration Location	Period
2000					
^{131}I	0,01±0,001	<0,001-0,245	512	Świder	21.08-28.08
^{137}Cs	0,03±0,001	<0,002-0,228	512	Białystok	16.10-23.10
^{7}Be	62,0±1,2	10,9-169,3	512	Sanok	1.05- 8.05
^{40}K	0,41±0,01	<0,04-2,23	512	Świder	25.09- 2.10
^{210}Pb	10,7±0,29	2,5-30,4	334	Sanok	13.11-20.11
^{226}Ra	0,15±0,005	<0,026-<0,68	490	Sanok	12.07-17.07
^{228}Ra	0,04±0,002	<0,006-0,497	507	Sanok	6.03-13.03
2001					
^{131}I	0,012±0,001	<0,001-0,09	515	Świder	20.08-27.08
^{137}Cs	0,03±0,001	<0,002-0,23	515	Świder	3.12-10.12
^{7}Be	65,3±1,6	8,0-242,8	516	Świder	23.07-30.07
^{40}K	0,387±0,014	<0,05-4,34	515	Białystok	23.04-30.04
^{210}Pb	10,5±0,31	1,4-71,4	400	Świder	3.12-10.12
^{226}Ra	0,13±0,004	<0,023-<0,62	515	Sanok	10.09-17.09
^{228}Ra	0,038±0,002	<0,005-0,393	515	Sanok	23.07-30.07

n=number of results obtained at all sampling sites.

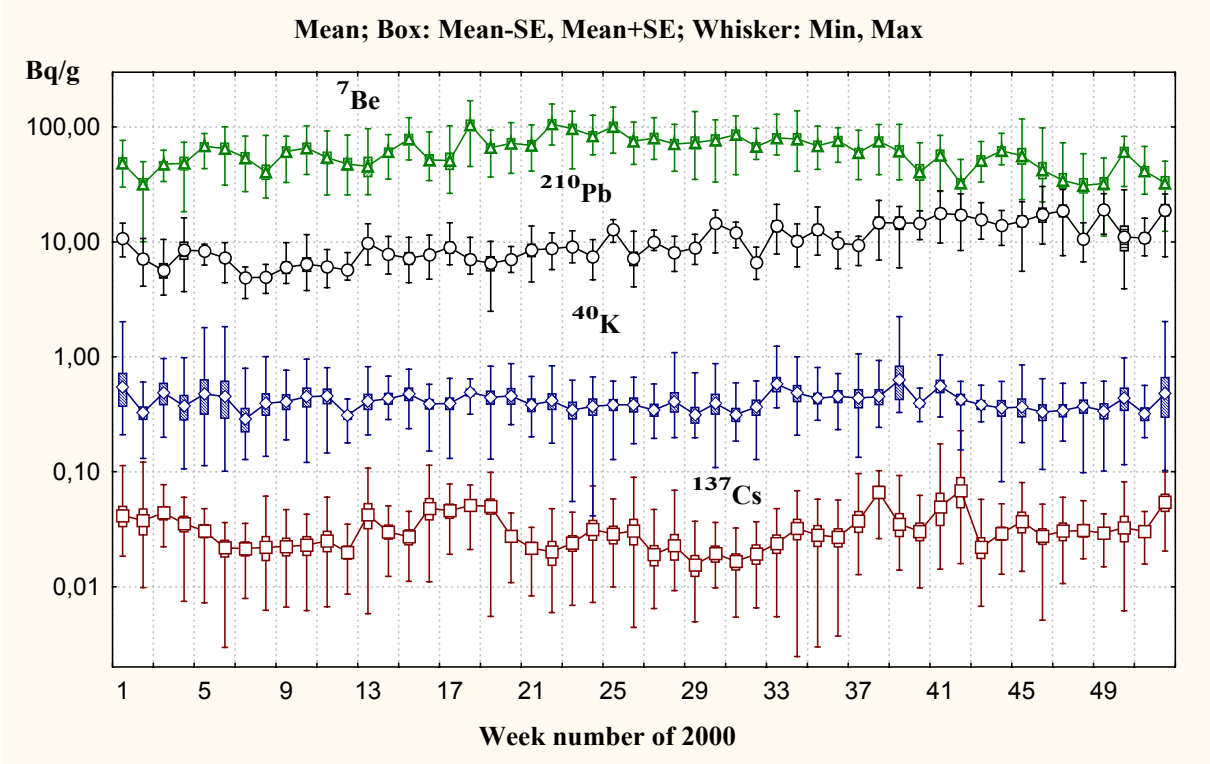

Fig. 1. Weekly changes of radionuclide concentrations in ground-level total dust in Poland in 2000, Bq/g,

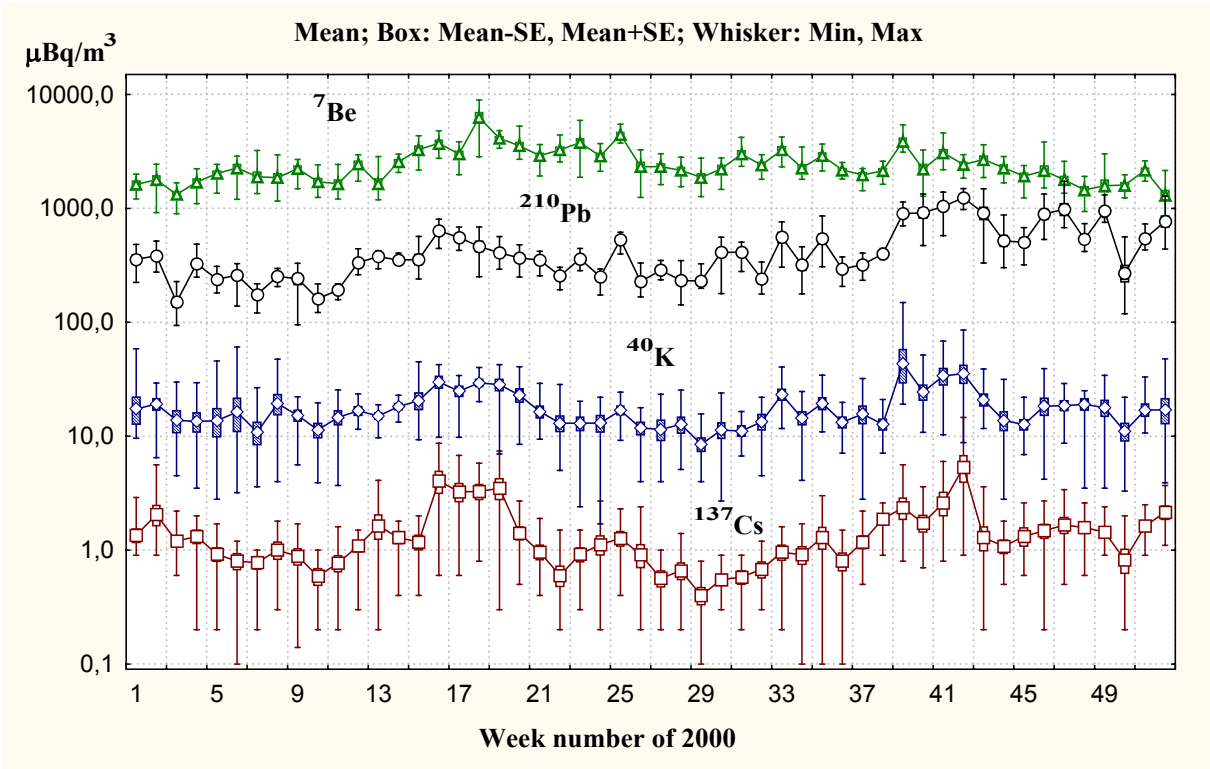

Fig.2.Weekly changes of radionuclide concentrations in ground-level air in Poland in 2000, µBq/m^3 .

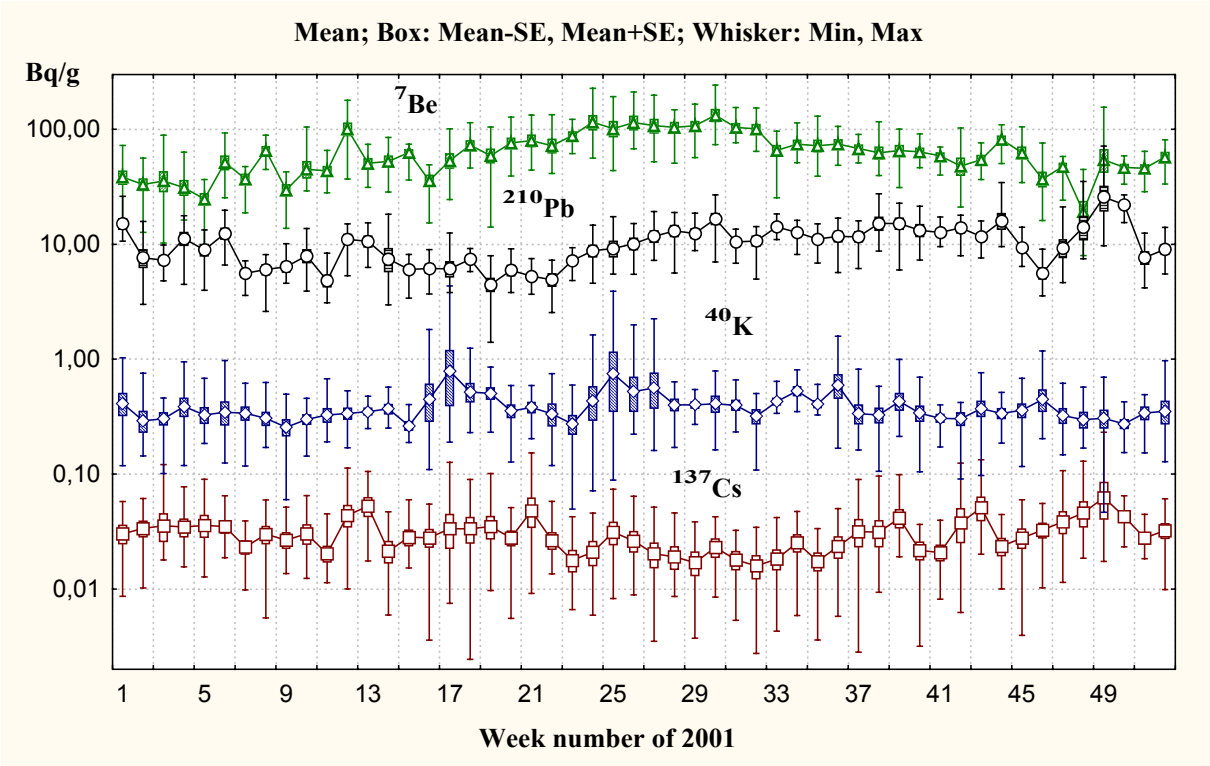

Fig.3. Weekly changes of radionuclide concentrations in ground-level total dust in Poland in 2001, Bq/g.

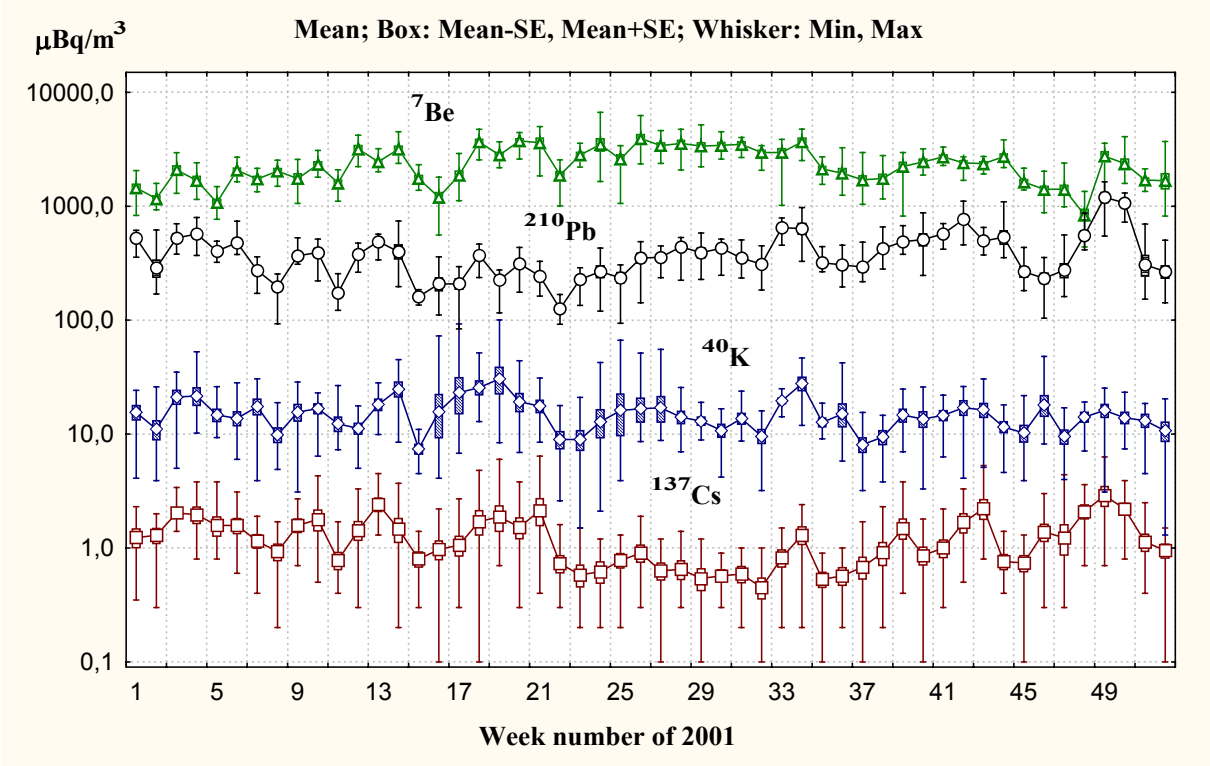

Fig. 4. Weekly changes of radionuclide concentrations in ground-level air in Poland in 2001, µBq/m^3 .

3.1.4 RADIOACTIVITY OF AIR AND FALLOUT IN POLAND; RESULTS FROM THE STATIONS OF THE INSTITUTE OF METEOROLOGY AND WATER MANAGEMENT WORKING IN THE SERVICE OF RADIOACTIVE CONTAMINATION MEASUREMENTS

D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska,
Radioactive Contamination Department

In the frame work of the Service of Radioactive Contamination Measurements (SPSP) 9 field stations of the Institute of Meteorology and Water Management have been designated as warning stations. They are carrying out on-line measurements of gamma dose rate by FHZ 601A Intelligent Probe with a proportional counter. Besides, the aerosol monitor FHT 59 (with a glass filter strip and an Si detector) serves for monitoring of concentrations of aerosol alpha- and beta radioactivity in air. The total beta activity and the artificial and natural alpha activity are measured simultaneously, the artificial beta activity is being calculated. The accuracy of calculation depends on actual equilibrium of the natural decay series. The Computer Measuring Program analyses the results as they come, forms mean hourly

results and compares them with alarm threshold. Then, the results (daily means, minimum, maximum of dose rate, natural and artificial alpha activity, artificial beta activity of air) are coded and sent to the COPSP by dedicated meteorological communication line once a day in normal situation. In emergency situation all the results are sent to the COPSP every hour as a special coded message which has the top priority before any other meteorological data. In the period of 1987-2001 no emergency radiological situation has been registered in Poland.

The meteorological stations measure also the total beta activity in fallout daily samples at 120 hours after collection. Activity of annual fallout is calculated as a sum of daily samples activities. Activity of Cs-134, Cs-137 and Sr-90 is determined in monthly samples of total fallout, by gamma spectrometry and radiochemistry.

Total beta activity and activity of Cs-134, Cs-137 and Sr-90 of mean annual fallout in Poland

years	beta activity [kBq m^{-2}]	Cs-134 [Bq m^{-2}]	Cs-137 [Bq m^{-2}]	Sr-90 [Bq m^{-2}]
1985	0,41	-	6	2
1986	19,01	753	1511	22
1987	0,53	8	22	3,9
1988	0,45	3	12	4,0
1989	0,43	1,6	8	1,9
1990	0,39	1,0	7,6	2,0
1991-1999	0,39-0,34	0,5-0,1	5,3-0,8	1,6-<1,0
2000	0,34	-	0,7	<0,3
2001	0,34	-	0,7	<0,3

3.1.5 RADIOACTIVITY OF THE ENVIRONMENT AND FOOD IN POLAND IN 2000-2001

D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska,
Radioactive Contamination Department

The analysis of the level of radioactive contamination in environmental and food samples was carried out in Poland in 2000-2001. The results were compared to the data from the period 1985-1986. Since the Chernobyl accident gradual decrease of contamination level has been observed. The gamma dose rate and the contamination of air, fallout, tap and surface water decreased to the level of 1985. The only contamination enhanced in relation to pre-Chernobyl period was the content of caesium isotopes in soils; as a consequence, food contamination was higher, particularly products of animal origin. At present, the main source of additional dose is ingestion of artificial isotopes with food. No significant regional differences in the distribution of the level of caesium over the territory of Poland have been registered. Milk is the main contributor of caesium to the diet; its share is about 30% of annual intake of caesium. In Poland the average annual effective dose resulting from the contaminated food consumption was is 13 μSv per caput in 2000 and 12μSv per caput in 2001.

Table 1. Mean activity of ^{134}Cs, ^{137}Cs, ^{90}Sr in annual fallout in Poland [Bq m^{-2}]

	^{134}Cs	^{137}Cs	^{90}Sr
1985	-	6	2
1986	753	1511	22
2000	-	0,7	< 0,3
2001	-	0,7	< 0,3

* Raport CLOR nr 143, 2001 and Raport CLOR nr 144, 2002

Table 2. Mean activity of ^{137}Cs in foodstuffs in Poland for periods 1985-1986 and 2000-2001 [Bq kg^{-1}]

	1985	1986	2000	2001
milk	0,3	5,2	0,7	0,8
meat	0,8	16,4	2,6	1,9
poultry	0,3	3,1	0,8	0,9
fish	0,3	6,3	1,8	1,3
eggs	-	2,4	0,7	0,7
potatoes	0,2	1,2	0,7	0,7
vegetables	0,7	5,0	0,6	0,7
fruit	0,4	8,2	0,5	0,5
cereals	0,6	7,4	0,2	0,2

Table 3. Annual mean intake of ^{134}Cs, ^{137}Cs, ^{90}Sr via ingestion in Poland [Bq/year]

	^{134}Cs	^{137}Cs	^{90}Sr
1985	-	325	110
1986	2054	4324	131
2000	-	529	<110
2001	-	494	<110

Table 4. Per capita annual effective dose due to radionuclides intakes via ingestion in Poland [μSv]

	^{134}Cs	^{137}Cs	^{90}Sr
1985	-	4	6
1986	34	54	7
2000	-	7	<6
2001	-	6	<6

In tables 3 and 4 the forest mushrooms were not taken into account although the activities of caesium in them were much higher than in other tested foodstuffs. The share of forest mushrooms to the average individual diet is relatively small in Poland and their contribution to the annual mean intake via ingestion is negligible.

Table 5. The mean activity of ^{137}Cs in forest mushrooms in Poland, [Bq/kg fresh mass]

	Boletus edulis	Cantharellus cibarius	Xerocomus badius
2000	59	50	166
2001	59	48	184

In 2000 and 2001 Department of Radioactive Contamination took part in international intercomparisons of radioisotopes determination organised by PROCORAD (FRANCE) and IAEA in 2000. Gamma emitters were determined in urine samples by gamma spectrometry. Statistical evaluation shows that the results of determination carried out in the Department are satisfactory.

Table 6. Obtained results in international intercomparisions

Test material		2000					2001	
		PROCORAD		IAEA			PROCORAD	
		Eu-152 [Bq/l]	Mn-54 [Bq/l]	Cs-137 [Bq/l]	Co-60 [Bq/l]	Mn-54 [Bq/l]	Co-57 [Bq/l]	Mn-54 [Bq/l]
SAMPLE B	our result	8,75	10,80	5,12	7,16	10,70	7,36	8,12
	certified sample	9,51	9,57	4,76	6,75	9,57	7,13	7,51
SAMPLE C	our result	7,47	5,10	2,99	4,27	5,30	5,29	5,74
	certified sample	8,16	4,78	2,86	4,05	4,78	5,10	5,25

3.1.6 MOBILE SPECTROMETRIC LABORATORY

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Dosimetry Department

INTRODUCTION

In 1999, following the Agreement between Polish and Danish governments, the Danish side donated Toyota LandCruiser GX-90 car with the Mobile Spectrometric Laboratory installed.

Fig. 1.
Mobile Spectrometric Laboratory.

In 2000 the car was transferred to the Central Laboratory for Radiological Protection and, according to the agreement, it will be used for:

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

EQUIPMENT

Fig. 2.

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

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

Fig. 3.

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

The Mobile Spectrometric Laboratory is also equipped with the GR-660 system mounted on the back seat of the car in the special shockproof container. The GR-660 system consists of the on-board computer with touch screen connected to the computer with a long cable. Such connection allows the operator to sit on the front seat of the car. The computer stores the collected measurement data and performs the on-line visualization. The second element of the GR-660 system is 256-channel spectrum analyzer Exploranium GR-320 connected to the detector placed on the roof of the car (Fig. 3). The computer works under the control of Windows NT 4.0.

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

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

Fig. 5.
Geographic Positioning System.

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

Fig. 6.
Exploranium miniSpec GR-130.

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

RESULTS

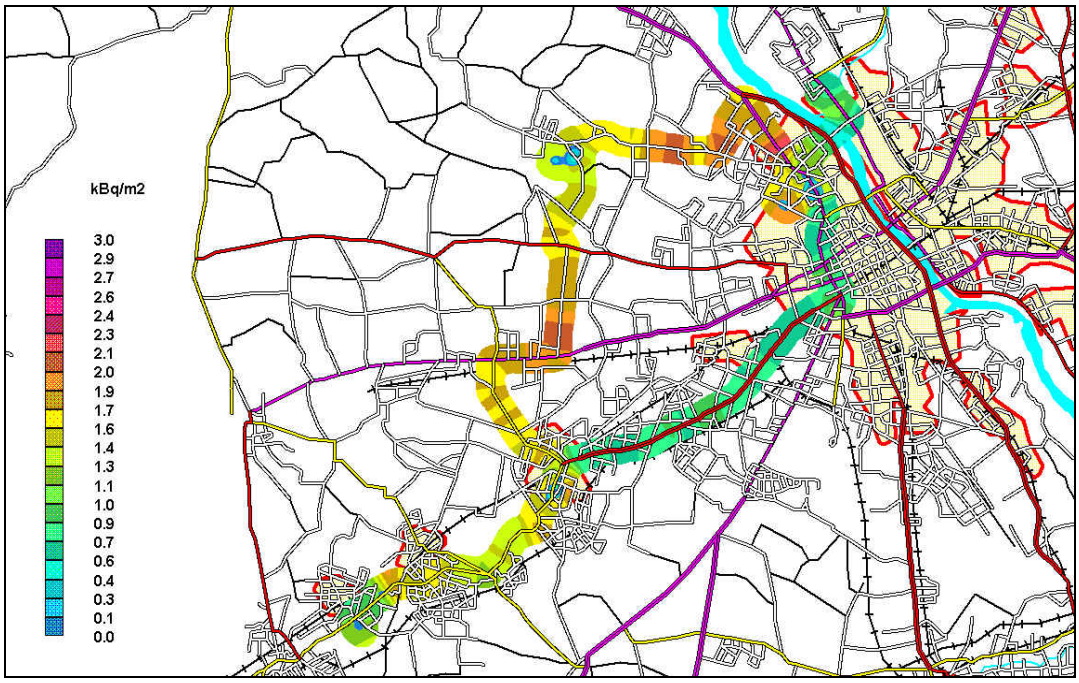

Fig. 7. Surface concentration of Cs-137

In Fig. 7. Cs-137 deposition density [kBq/m2] is presented. The map was produced using MapInfo software and basing upon the results from the Mobile Spectrometric Laboratory during the survey on the route near Warsaw (Warsaw- Milanowek).
The northern part of the road passed by the forest terrain, and the lower (southern part) was on the main road in urban area. It can be seen that the Cs-137 concentration is slightly higher in the northern, forest area.

3.1.7 TRITIUM IN PRECIPITATION IN POLAND

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Natural production of tritium through reactions of atmospheric ^{14}N and ^{16}O atoms with cosmic rays in upper atmosphere has led to its occurrence in continental surface waters at concentrations in the range of 0,2-0,9 Bq/l. After the series of nuclear weapons tests conducted in 1954 - 1963 the level of environmental tritium increased as a result of releases of 186000 PBq of tritium into the stratosphere and, to a smaller extent, into the troposphere (United Nations Scientific Committee on the Effects of Atomic Radiation, 2000).From there, it is deposited on the Earth surface by precipitation (Libby, 1958). In addition tritium was released from power reactors in airborne effluents. Between 1990 and 1997 the total annual release from this source ranged between 4000 and 10000 TBq (UNSCEAR, 2000).

The purpose of this work was to determine the concentrations of HTO and their seasonal variations in the precipitation in Poland and to compare them with those for tap and surface water.

The study was performed in the period 1994 - 2001. Samples of the precipitation were collected in meteorological station in Warsaw-Bielany (Lat. 52.29^{o}N, Long. 20.97^{o}E, 105 msl).

For the tritium determination liquid scintillation counting combined with electrolytic enrichment was applied according to the method described by Cameron (1967), with minor modifications. The details of the applied method were described elsewhere (Radwan et al., 2001).

In the monthly precipitation samples tritium concentration ranged from 0.5±0.1 Bq/liter in November 2000 to 3.6 ±0.8 Bq/liter in August 1997.

Tritium concentrations in precipitation demonstrate distinct seasonal changes. To obtain average concentrations for winter, spring, summer and autumn, means for three consecutive months were combined (December, January and February for winter and so on). During eight years of the observation the lowest concentration of tritium was always observed in the winter season.

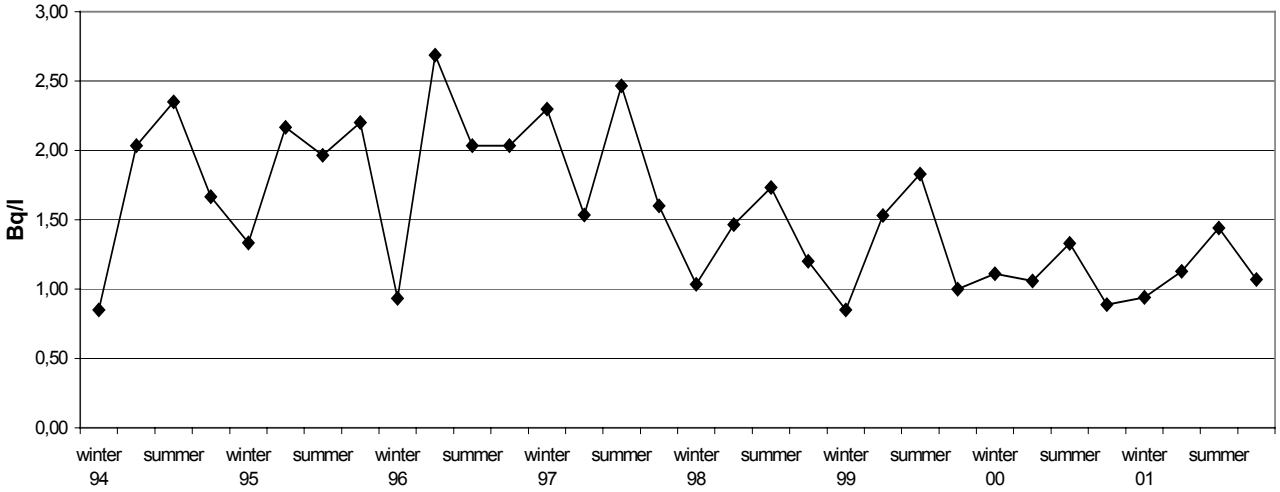

Fig.1. Mean seasonal tritium concentrations in precipitation in Warsaw.

Tritium concentrations in the precipitation in Poland are typical for our latitude and comparable to those observed in other European countries (IAEA Technical Reports, 1994), where in recent years it has returned close to pre-tests-period values but is still slightly higher than natural level (Rozanski et al., 1991). Systematic tritium monitoring in precipitation enables detection of enhanced tritium concentration caused by incidental releases of this radionuclide from operating nuclear facilities in neighbouring countries.

The study on content of radioactive substances in surface waters in Poland (Wardaszko et. al., 2001) indicates that tritium concentration in those waters are in the range of 1.0 to 2.3 Bq/liter, while in monthly samples of tap water its level is less differentiated being in the range of 0,9 –1,7 Bq/liter.

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3.1.8 MONITORING OF RADIOACTIVE CONTAMINATION OF RIVERS AND LAKES (WATER AND BOTTOM SEDIMENTS)[1)]

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Radiation Hygiene Department

This monitoring project, initiated in 1994, was continued in the years 2000-2001, delivering further data on the levels of 3 most significant radionuclides in the aquatic environment: ^{137}Cs, ^{226}Ra and ^{3}H. Like in previous years, concentrations of ^{137}Cs and ^{226}Ra were determined separately in filtrated water, suspended matter and bottom sediments, and those of ^{3}H – in water. The sampling program was as before and covered drainage areas of two main rivers of the country: Vistula and Odra, 4 seashore rivers and 6 lakes in different lake districts. The sampling frequency was: twice a year for Vistula and Odra with tributaries and once a year for all others. ^{137}Cs and ^{226}Ra have been determined radiochemically whereas^{3}H was enriched by electrolysis and measured in the liquid scintillation spectrometer.

The results obtained in the years 2000 and 2001 indicate that, in general, low contamination of the investigated components of the aquatic environment with post-Chernobyl ^{137}Cs is still present in waters and that concentrations of ^{226}Ra in rivers of southern Poland is slightly elevated above natural level, as a results of mining activities in Upper Silesia. Levels of ^{3}H continue to be low but in excess of natural level.

In the Odra river drainage area the mean concentration of soluble ^{137}Cs in 2000 was 4.2 mBq l^{-1} and was 1.3 times higher than in Vistula drainage area (3.2 mBq l^{-1}). In the sediments the concentrations of this radionuclide were, correspondingly, 12.5 Bq $kg^{-1}_{d.w.}$ and 7.8 Bq $kg^{-1}_{d.w.}$. In 2001 these values were slightly lower. The water from both drainage areas exhibits slow decreasing of ^{137}Cs concentrations in the course of the last 8 years, whereas in the bottom sediments the decreasing of concentrations can be seen since 1996. In Baltic coastal region concentration of ^{137}Cs was very low throughout this period; the same was observed as regards ^{226}Ra and ^{3}H.

As regards lakes some of them exhibited slightly higher ^{137}Cs concentrations (lakes Rogóźno in Lublin voivodship in water and bottom sediments, and Wadąg in Masurian lake district in bottom sediments), in agreement with the pattern of geographical distribution of radioactive contamination of soils with the fallout from Chernobyl accident.

^{226}Ra levels observed in different types of waters can be divided into 2 groups: one is natural level, very low – below 5 mBq l^{-1} – and rather constant in time, the other is higher and differentiated; the ^{226}Ra occurrence in this group is due to human activities, both industrial (release of radium-rich coal mine waters) and agricultural (use of phosphate fertilisers). Clearly enhanced levels have been observed in upper Vistula and, to a smaller degree, middle Odra.

The concentration of ^{226}Ra in water and bottom sediments along Vistula river and Odra river in 2000 and 2001 are presented on the Fig. 1 and Fig. 2 respectively.

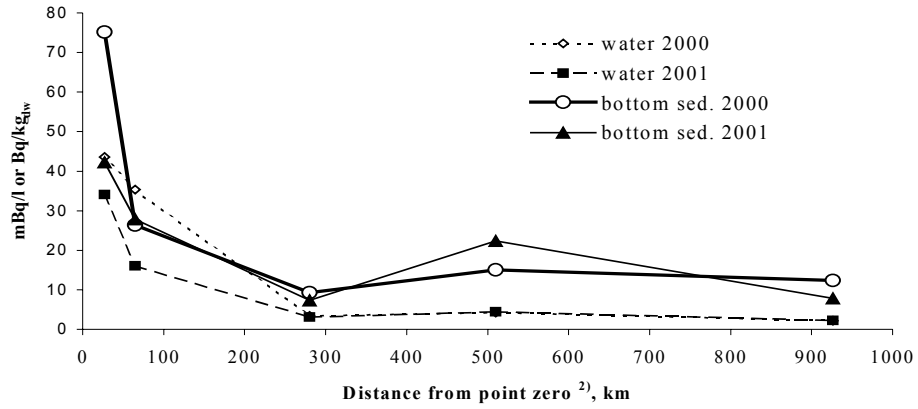

Fig.1 ^{226}Ra concentrations in water and bottom sediments along Vistula river in 2000 and 2001

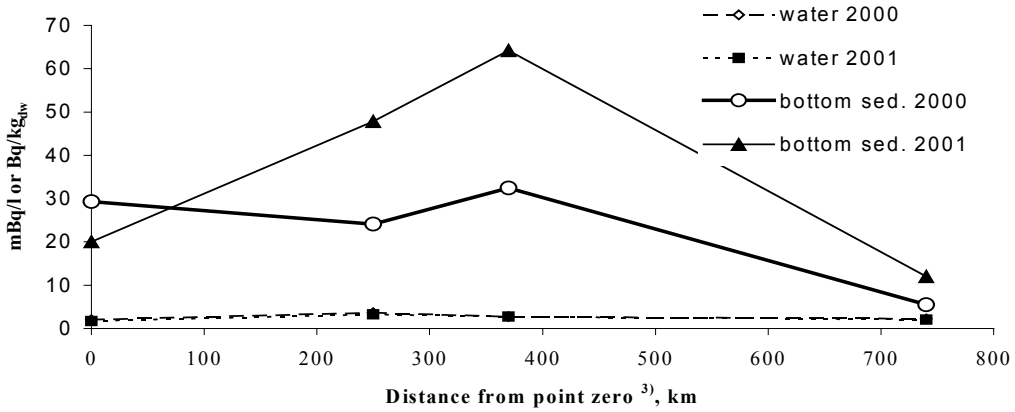

Fig.2 ^{226}Ra concentrations in water and bottom sediments along Odra river in 2000 and 2001.

These clearly enhanced values of ^{226}Ra concentrations in upper Vistula, which collects waters from tributaries flowing through the Upper Silesian coal basin, confirm the influence of industrial activities upon ^{226}Ra levels.

The self-purification mechanisms functioning in river waters are responsible for such degree of reduction of ^{226}Ra concentration in water along the river that lower Odra and lower Vistula displays no enhancements of this radionuclide in bottom sediments.

The occurrence of elevated concentrations of ^{226}Ra in bottom sediments in middle Odra may be an evidence for past flows of water containing more radium than natural levels, from copper mining basin.

[1)] Project supported by the National Environmental Protection and Water Management Fund
[2)] conventionally assumed by waterways authority at the mouth of river Przemsza to Vistula (about 130 km from the sources of Vistula)
[3)] the border of the country in Chalupki

3.1.9 RADIONUCLIDES: ^{40}K, ^{137}Cs AND ^{226}Ra IN BALTIC SEA FISH.

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Radionuclides occurring in sea environment, especially in seawater, are incorporated into the marine organisms and give rise to radiation exposure of humans from ingestion of seafood. In ours studies ^{40}K ^{137}Cs and ^{226}Ra concentrations were determined in four fish species: herring, sprat, cod and plaice. Fish samples were cached in four sub-areas of Southern Baltic Sea.

During two year period about 60 fish samples were examined. The average concentrations of ^{40}K, ^{137}Cs and ^{226}Ra in fish flesh, depending on species, are presented in Tab.1. The highest concentration of ^{137}Cs, similarly as in previous years, was found in flesh of cod (9.4±0.89 Bq kg^{-1}ww) and the lowest in plaice (6.6±0.85 Bq kg^{-1}ww). Higher concentration of ^{226}Ra was observed in samples of cod and sprat (0.061-0.071 Bq kg^{-1}ww) then of herring and plaice (0.030-0.039 Bq kg^{-1}ww).
Temporal changes of radiocaesium concentrations in fish observed in the period of 1985-2001yearsare given in Fig. 1.

Table 1. The average concentrations of ^{40}K, ^{137}Cs and ^{226}Ra in Baltic Sea fish flesh in 2001

Species	**Fish lenght [cm]**	**^{40}K [Bq kg^{-1}ww]**	**^{137}Cs [Bq kg^{-1}ww]**	**^{228}Ra [Bq kg^{-1} ww]**
Cod	21-43	115±7,1	9,4±0,89	0,065±0,019
Sprat*	9-15	112±4,6	7,8±0,68	0,071±0,018
Herring	14-26	120±16,5	7,4±1,43	0,030±0,007
Plaice	21-30	85,5±3,3	6,6±0,85	0,039±0,002
average		**108±15**	**7,8±1,0**	**0,051±0,020**

* whole fish

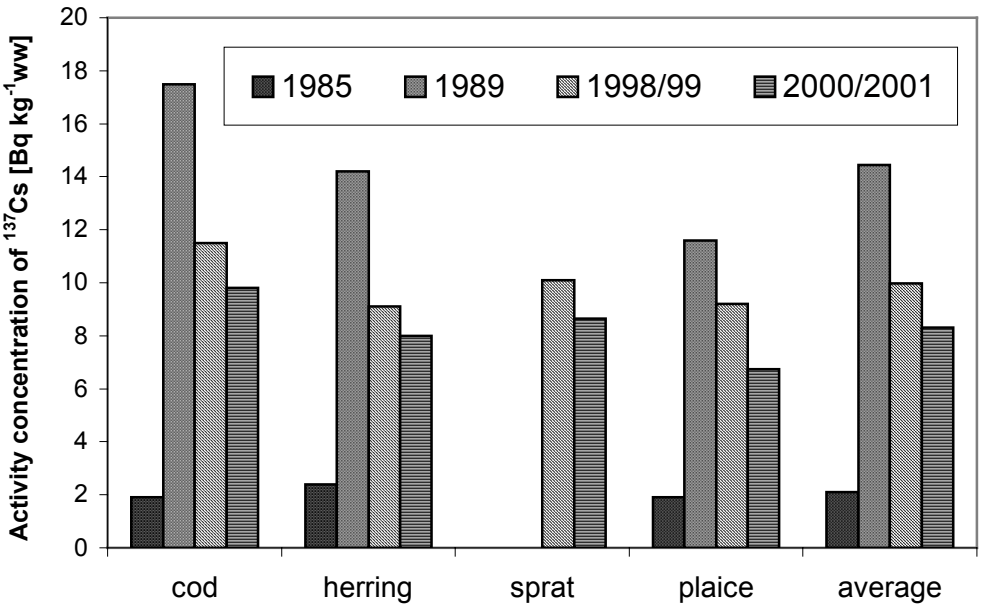

Fig.1. Average concentration of ^{137}Cs in Baltic Sea fish flesh

In the region of Southern Baltic Sea, maximum average concentration of ^{137}Cs in fish of 14.4±2.9 Bq kg^{-1}ww, was observed in 1989 and was 7 times higher then before Chernobyl accident (2.1±0.3 Bq kg^{-1}ww). During subsequent years, a decrease of ^{137}Cs concentrations in fish was observed and in 2001 the average value for all species (7.8±1.0 kg^{-1}ww) was about 50% lower then in 1989. These changes are explained by cleaning processes occurring in sea water where ^{137}Cs concentration decrease from about 100Bq m^{-3} in 1989 to less then 60 Bq m^{-3} in 2000 [1,2].

Taking into account average ^{137}Cs concentrations obtained in 2001, the average committed effective dose due to yearly intake from fish consumption were calculated as 0.53μSv year^{-1} (Table 2). The average ^{210}Po concentration in fish from the Baltic Sea (3.5 Bq kg^{-1}ww) [3]corresponds to a dose of 21.2 μSv year^{-1}.

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

	^{40}K	**^{137}Cs**	**^{226}Ra**	**^{210}Po**
Activity concentration [Bq kg^{-1}ww]	108	7.8	0.05	3.5
Dose coefficient [μSv Bq^{-1}]	0.006	0.013	0.28	1.2
Dose [μSv/year]	**3.4**	**0.53**	**0.07**	**21.2**

However, ^{137}Cs, from the Chernobyl fallout, contributed about 88% to the radiation dose from man-made radioactivity in Baltic Sea ecosystem [4] this dose is almost 50 times smaller than the dose from for natural radionuclides (polonium and potassium).

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3.1.10 RADIOLOGICAL MONITORING OF THE ENVIRONMENT IN THE SURROUNDING OF RADIOACTIVE WASTES REPOSITORY IN RÓŻAN AND CENTRE ŚWIERK.

L. Kownacka, W. Bekiert, K.Isajenko, P. Krajewski, P. Lipiński, I. Radwan, A. Żak.

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

1. **Radiological monitoring around KSOP-Różan**
2.

In the vicinity of KSOP-Różan the following samples were collected:
- river water (Narew) - twice a year,
- well water - four times a year,
- spring water - four times a year
- ground water - four times a year,
- soil – twice a year
- grass - twice a year
- corns - once a year
-

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

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

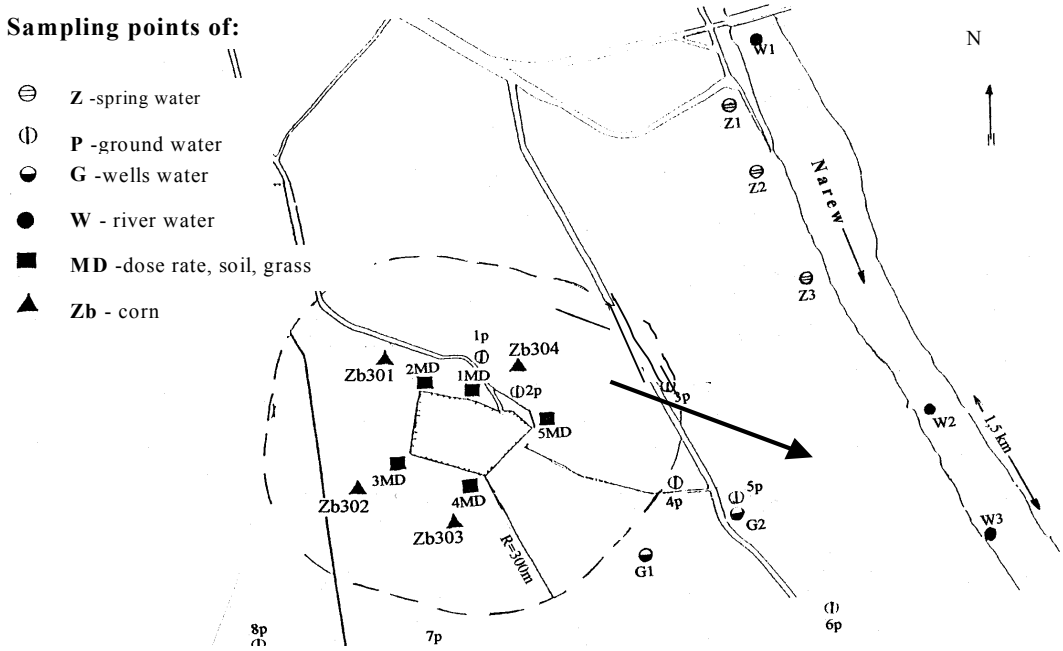

Fig.1. The map of KSOP-Różan with environmental sampling points. The thick arrow indicates the direction of ground water flow.

Table 1. Mean gross β and α activity and tritium concentrations in the samples of water from KSOP-Różan area.

	Number of samples	β gross activity Bq/dm^3	α gross activity Bq/dm^3	tritium concentrations Bq/dm^3
River Narew	6	**0.130** (0.118-0.143)	**0.016** (0.011-0.024)	**1.68** (0.8-3.2)
Wells water	8	**0.109** (0.050-0.170)	**0.019** (0.016-0.021)	**1.5** (0.8-2.1)
Springs water	12	**0.074** (0.026-0.167)	**0.013** (0.009-0.019)	**2.5** (0.5-3.2)
Ground water	32	**0.127** (0.036-0.848)	**0.018** (0.006-0.049)	**3.1** (1.6-8.4) **82.7*** (72.8-96.6)*

* in one sampling point (2p).

The gross β and α activity in the various samples of water are at low levels. According to regulations in Poland, radioactivity of drinking water must be lower then 1.0 Bq/dm^3 as regards gross β activity and 0.1 Bq/dm^3 for gross α activity. The tritium concentrations in river and well water, are at low level, similar to that in other surface waters measured in Poland [1]. The tritium concentration in the samples of ground water were slightly higher at all sampling points, except point 2p where the measured concentrations were constantly much higher than at other points.

Table 2. Mean concentrations of ^{137}Cs and ^{40}K in various environmental samples from KSOP-Różan area.

	Number of Samples	^{137}Cs Bq/kg	^{40}K Bq/kg
Soil samples	10	**21.35** (14.7-30.5)	**466** (405-554)
Corn samples	4	**0.37** (0.26-0.57)	**151** (136-166)
Grass samples (dry)	10	**16.5** (1.2-73.8) 954.5*	**496.6** (284-833)

* in one grass sample in autumn the concentration of ^{137}Cs was higher.

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

The mean gamma radiation dose rate (including cosmic radiation) around KSOP-Różan measured two times in the year was 98.5 (91-111) nGy/h.

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

2. Radiological monitoring around Świerk Centre

In the vicinity of Świerk Centre the following samples were collected:

- river water (Świder and Wisła) – twice a year ,
- well water – twice a year,
- milk – twice a year,
- soil– twice a year,
- grass– twice a year,
- corns - once a year
- atmospheric aerosol - once a week.
-

In the water samples gross β and α activity were measured and in the samples of milk, soil, grass, corns and atmospheric aerosol the gamma spectra analyses were performed.

Around this centre the gamma dose rates were controlled and the radioactive contaminations of surrounding terrain were measured using the Mobile Spectrometric Laboratory.

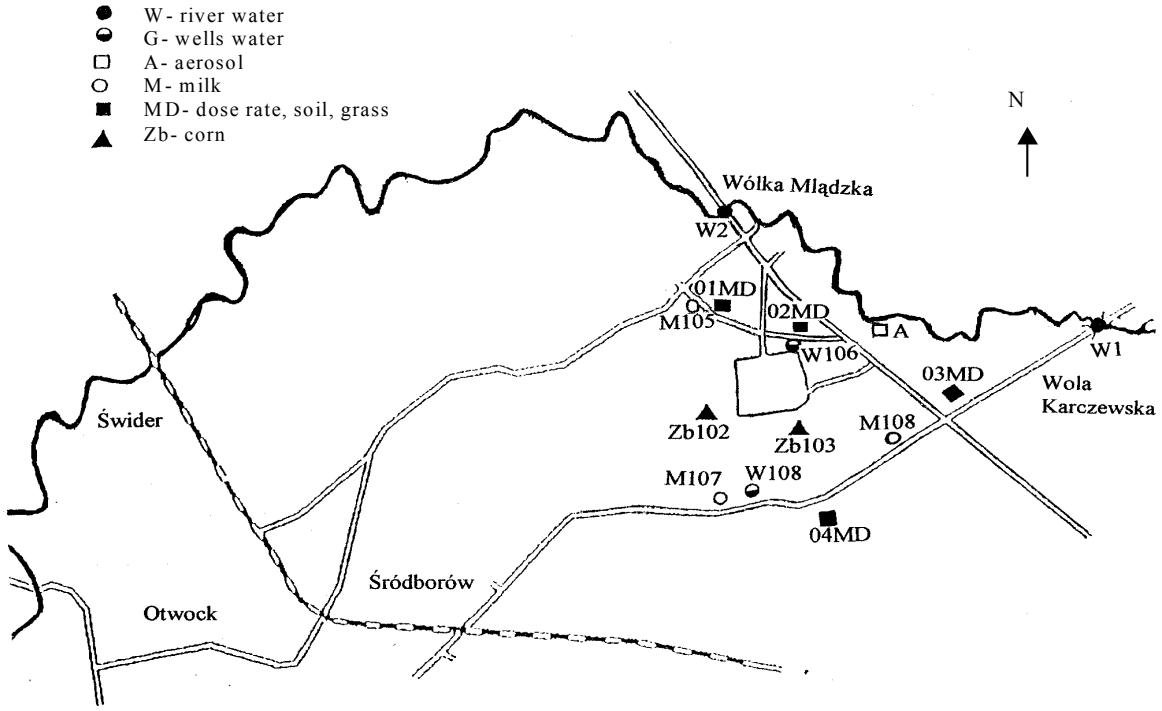

Fig.2. The map of Świerk Centre with environmental sampling points

Table 3. Mean β and α gross activity and tritium concentrations in the samples of water from Świerk Centre.

	Number of samples	β gross activity Bq/dm^3	α gross activity Bq/dm^3
River Świder	4	**0.134** (0.117-0.143)	**0.010** (0.008-0.011)
River Wisła	2	**0.198** (0.146-0.250)	**0.010** (0.010-0.011)
Wells water	4	**1.408** (1.075-1.725)	**0.014** (0.010-0.020)

The gross β and α activities in water of both rivers were at the low level. In wells the activities were higher. The water samples from both wells were also analysed by gamma spectrometric method, the concentration of ^{137}Cs in both well water samples were below the lower limit of detection (<0.01Bq/dm^3) and concentrations of ^{40}K were from 0.60 to 1.10 Bq/dm^3.

Table 4. Mean concentrations of ^{137}Cs and ^{40}K in various environmental

samples.

	Number of samples	^{137}Cs	^{40}K
Soil samples, Bq/kg	8	**8.65** (0.3-13.8)	**245** (124-373)
Corn samples, Bq/kg	2	**0.63** (0.53-0.74)	**150** (147-153)
Grass samples, Bq/kg (dry)	8	**12.1** (0.3-38.8)	**683.2** (489-803)
Milk samples, Bq/l	6	**0.52** (0.24-1.25)	**42.6** (36.6-54.0)
Atmospheric aerosol samples, $\mu Bq/m^3$	90	**2.9** (0.4-31.8)	**15.1** (<5.0-44.0)

In all environmental samples around Świerk Centre (table 4) the radioactivity of ^{137}Cs and ^{40}K were at the same levels as in the other regions in Poland.

The mean gamma radiation dose (including cosmic radiation) around Świerk Centre measured twice in the year was 75 (66-81) nGy/h, while the mean gamma radiation dose (including cosmic radiation) calculated for the whole country is 75.5 (47.0-119.9) nGy/h.

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

References

[1] I. Radwan, Z. Pietrzak-Flis,T. Wardaszko. Tritium in surface water, tap water and in precipitation in Poland during the 1994-1999 period. Jour. of Radioanalytical and Nuclear Chemistry, Vol.247,1, 2001,71-77.

[2] Radiologiczny Atlas Polski, 1997. Bibloteka Monitoringu Ochrony Środowiska, CLOR, Warszawa 1998

3.1.11 INVESTIGATION OF RADIOACTIVITY OF RAW AND BUILDING MATERIALS

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Dosimetry Department

The Central Laboratory for Radiological Protection (CLOR) supervises the operation of laboratories monitoring concentration of natural radionuclides in raw and building materials, organizes training of the personnel and collects results of the measurements. Since 1980 till 2001 the results of the measurements of 24313 samples were stored in our computer data base.

The number of samples investigated in 2000 and 2001 at different laboratories are given in Table 1. The minimum, average and maximum values of natural radioisotope concentrations, measured in these samples are presented in Table 2.

The group of industrial wastes used as raw materials is the most numerous, because in this group radionuclide concentrations most frequently exceed permissible limits. The group of final building materials is also investigated more intensively because their activity content is directly linked with the radiation exposure of inhabitants.

The lowest values of natural isotope concentrations in natural raw materials appear in marble, chalk, gypsum and limestone. Therefore the 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.
According to the Instruction No. 234/95 of Institute of Building Technology (Recommendations for investigating the natural radioactivity of raw and building materials) the following two criteria of usability of a building material in housing and public building construction have been established:

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

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

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

Coefficient f_2 is connected with the additional limitation for the ^{226}Ra concentration in the product coming from radon emanation:

$$f_2 = S_{Ra}$$ where S_{Ra} is the ^{226}Ra concentration in Bq/kg.

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

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

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

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

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

The values of qualification coefficients f_1 and f_2 in 2000 and 2001 are presented in Table 2.

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

The changes of coefficients f_1 and f_2 in years 1980 - 2001 for the fly ashes, building ceramics and lightweight and cellular concrete are shown in Fig. 1.

Table 1. Numbers of samples investigated in 2000-2001 at laboratories supervised by CLOR.

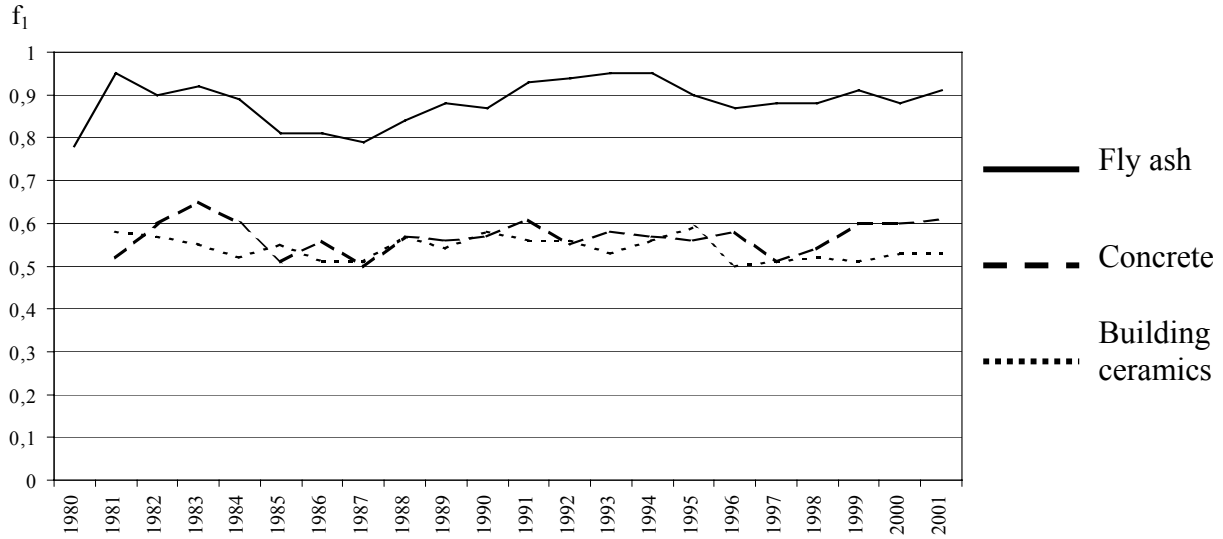
Laboratory investigating raw and building materials	**Number of samples**	
	2000	**2001**
Design and Research Office of Building Ceramic Industry in Toruń	512	377
Central Laboratory for Radiological Protection in Warszawa	127	61
Central Laboratory of Concrete Industry "CEBET" in Warszawa	298	276
Power Plant in Łódź	80	72
Establishment of Technology and Management of Power Plant Waste "Energopomiar" in Katowice	263	284
POLLYTAG S.A. Laboratory in Gdańsk	303	326
Institute of Building Materials of Natural Origin in Opole	101	0
Institute of Nuclear Physics in Kraków	0	34
Power Plant II in Gdańsk	126	233
Power Plant in Bydgoszcz	82	88
LAFARGE Laboratory – Kujawy	41	75
EKOBET – SIEKIERKI Laboratory	142	90
Power Plants in Warszawa	30	138
Power Plants in Poznań	0	13
Technical University in Wrocław	0	15
Total	**2105**	**2082**

Table 2. Concentration of natural radionuclides and the values of qualification coefficients f_1 and f_2 measured in selected building and raw materials in 2000-2001.

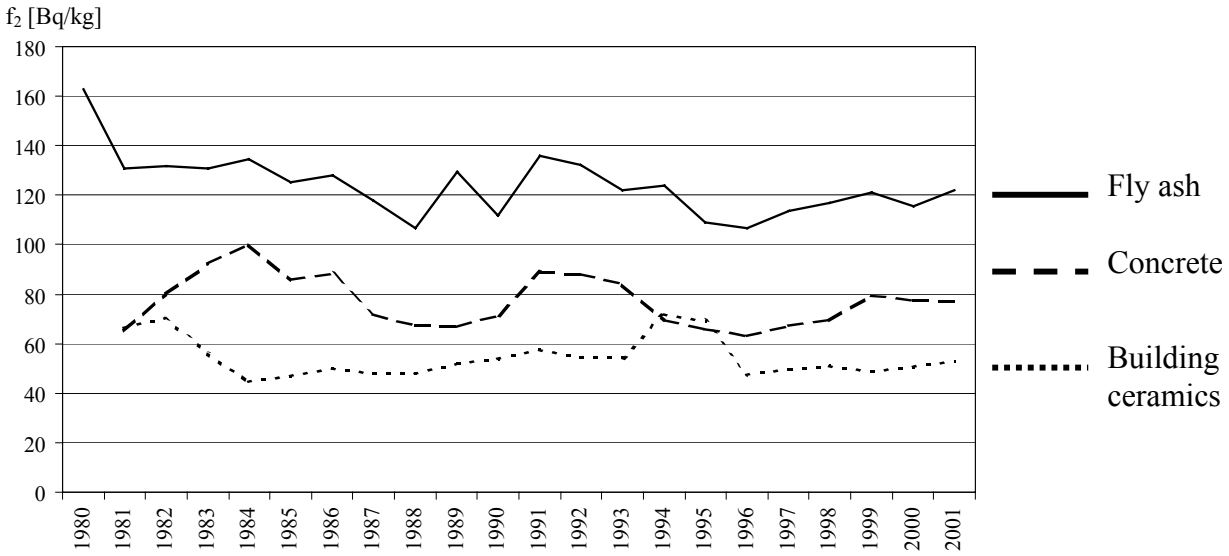
Name of building raws or materials	Number of samples	Concentration of natural radionuclides (S_K, S_{Ra}, S_{Th})*) [Bq·kg^{-1}]			Values of coefficients*)	
		potassium ^{40}K	radium ^{226}Ra	thorium ^{228}Th	f_1	f_2 [Bq·kg^{-1}]
		NATURAL ORIGIN RAW MATERIALS				
Marble	0	-	-	-	-	-
Chalk	2	43 – 74 – 104	4 – 6 – 9	4 – 4 – 5	0,04 – 0,05 – 0,06	4 – 6 – 9
Gypsum	43	12 – 40 – 101	2 – 8 – 32	1 – 3 – 11	0,01 – 0,04 – 0,12	2 – 8 – 32
Limestone	4	37 – 84 – 145	9 – 17 – 31	1 – 4 – 8	0,05 – 0,08 – 0,10	9 – 17 – 31
Lime	1	102	12	5	0,08	12
Sand	11	8 – 219 – 363	1 – 9 – 19	1 – 6 – 14	0,01 – 0,11 – 0,18	1 – 9 – 19
Marl	2	132 – 145 – 157	14 – 14 – 15	7 – 8 – 8	0,10 – 0,11 – 0,11	14 – 14 – 15
Clinker	12	17 – 160 – 294	23 – 32 – 60	1 – 17 – 23	0,07 – 0,20 – 0,28	23 – 32 – 60
Still stock	15	196 – 676 – 964	19 – 42 – 99	35 – 50 – 144	0,38 – 0,51 – 0,94	19 – 42 – 99
Clay	7	201 – 571 – 847	6 – 31 – 59	6 – 32 – 41	0,09 – 0,37 – 0,52	6 – 31 – 59
Clump	3	499 – 741 – 890	50 – 61 – 79	62 – 69 – 73	0,53 – 0,65 – 0,76	50 – 61 – 79
		INDUSTRIAL ORIGIN RAW MATERIALS				
Fly ashes	1513	49 – 679 – 1284	8 – 118 – 269	2 – 91 – 169	0,04 – 0,89 – 1,40	8 – 118 – 269
Boiler slag	646	40 – 583 – 1047	9 – 92 – 248	5 – 74 – 142	0,16 – 0,72 – 1,30	9 – 92 – 248
Metallurgical slag	27	36 – 221 – 701	12 – 103 – 161	6 – 41 – 99	0,06 – 0,51 – 0,83	12 – 103 – 161
Copper slag	12	700 – 859 – 970	249 – 293 – 332	41 – 48 – 54	1,03 – 1,22 – 1,38	249 – 293 – 332
Phospho-gypsum	0	-	-	-	-	-
Ash aggregate	499	227 – 655 – 963	52 – 107 – 185	35 – 85 – 103	0,40 – 0,83 – 1,06	52 – 107 – 185
		BUILDING MATERIALS				
Cement	94	6 – 245 – 563	12 – 49 – 118	7 – 28 – 78	0,11 – 0,31 – 0,70	12 – 49 – 118
Lightweight and cellular concrete	377	155 – 527 – 845	12 – 77 – 146	10 – 58 – 98	0,14 – 0,60 – 0,93	12 – 77 – 146
Other concrete	12	80 – 338 – 528	5 – 28 – 76	8 – 15 – 47	0,07 – 0,23 – 0,52	5 – 28 – 76
Building ceramics**)	728	66 – 722 – 1131	4 – 52 – 105	2 – 46 – 95	0,06 – 0,53 – 0,84	4 – 52 – 105

*) Values: minimum - average - maximum

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



Mean annual values of coefficient f_2 [Bq/kg]



3.2 MONITORING OF OCCUPATIONAL EXPOSURE
3.2.1 MEASUREMENT OF IODINE CONTENT IN THYROID OF OCCUPATIONALLY EXPOSED PERSONNEL

G. Krajewska
Department of Radiation Hygiene

The main goal of monitoring programe for measurement of radioiodine content in thyroid was to establish measurement assembly and develop the risk assessment methods for people internally contaminated with ^{131}I in the event of radiological emergency. Monitoring devices and dose estimation methods are tested by measurements of activity of ^{131}I and ^{125}I in thyroid of occupationally exposed workers.

The measurement assembly of the Laboratory for monitoring of radioiodine in thyroid for population in emergency situation in CLOR consists of two independent measuring units:

1. Stationary Unit for measuring ^{131}I and ^{125}I with low limit of detection.
2. Mobile Unit for „in situ" measurements of ^{131}I and ^{125}I, to be used for fast screening of people in radiological emergency and for monitoring occupationally exposed persons in locations remote from CLOR.

The ^{131}I content in the thyroid of staff members working with radioiodine has been measured in seven Departments of Nuclear Medicine performing therapy and diagnosis of thyroid disease in Poland. The measurements were performed with mobile detection unit for „in situ" measurements of ^{131}I and ^{125}I (Canberra-Packard prod.) in selected low background places. Overall about one hundred thyroid measurements were performed.
The measured personnel can be divided into three categories according to internal contamination risk to unsealed sources of ^{131}I:
1. technical staff mainly performing routine diagnostic investigation,
2. nuclear medicine staff (physician, nurse) working with *in vivo* administration of ^{131}I to patients,
3. hospital services staff (orderlies, cleaners) performing auxiliary activities to the patients.

All individuals actively working with iodine show measurable amounts of the radioiodine in their thyroids. The average measured activity in the thyroid of the nuclear medicine staff was 400 Bq ranging 30 Bq - 3500 Bq. There is no apparent correlation between the measured ^{131}I levels and risk categories. The average and range of ^{131}I activity measured in thyroids for all medical units were: 590 Bq, (30 Bq - 3000 Bq), 300 Bq, (30 Bq - 3000 Bq) and 140 Bq, (30 Bq - 700 Bq) for categories 1, 2 and 3 respectively. Nevertheless the 1 and 2 categories show higher ^{131}I thyroid level comparing to category 3. Fig. 1 shows the typical gamma spectrum of the thyroid.

On the basis of these results , the effective dose equivalent for particular persons due to inhalation of ^{131}I was calculated with a conservative assumption that ^{131}I thyroid content remains constant during the whole year. This assumption seems to be partly supported by several measurements the same workers in particular medical units, in which the stable level of ^{131}I content in thyroid was observed.

The occupational exposure limit of 50 mSv corresponds to a ^{131}I thyroid constant level of 16 kBq. Calculated average effective dose equivalent for particular medical units is below 10 per cent of 50 mSv/year.

For electronic data base containing most relevant information on workers occupationally exposed with ^{131}I a specially designed software "POMTAR"was developed as Visual Basic Application. It enables storage and analyis data on occupational activity with unsealed radioactive sources and thyroid monitoring results for people from nuclear medicine. The software can be used in the dose assessments and occupational hazard optimization.

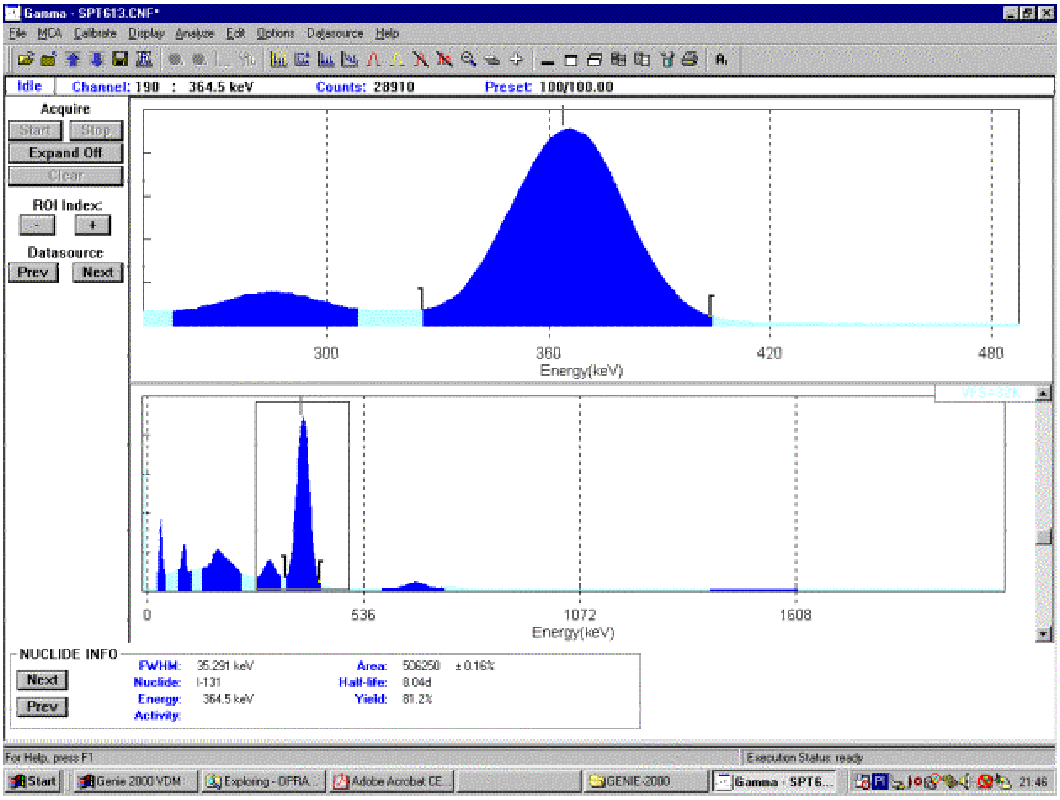


Fig.1 . Typical spectrum of ^{131}I measured in the thyroid of nuclear medicine worker

3.2.2 OCCUPATIONAL EXPOSURE TO EXTERNAL RADIATION MONITORED BY CLOR IN 2000 – 2001

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External Radiation Monitoring and Calibration Department

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 [1] the radiation workers who may be exposed to doses exceeding three tenths of the relevant annual limits need systematic control of personal doses. 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 Hp(10). The operational dose quantity for exposure of skin and extremities is Hp(0.07).

Mandatory monitoring of about 6000 radiation workers from about 370 institutions was performed with photographic dosemeters, TLD and track detectors. For gamma, beta and

thermal neutrons the Kodak Personal Monitoring Film Type 2 and TL - LiF:Mg,Ti detectors were used, while fast neutrons monitoring was performed by means of the Kodak NTA nuclear emulsion. The detection limit (MDL) of monitoring system was 0.4 mSv.

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

To accomplish the estimation of occupational radiation hazard in different groups of workers the values of personal dose equivalent Hp(10) are summed up and grouped for each calendar year. For Hp(10) lower than MDL the reported effective dose is 0.2 mSv. The distributions of persons per annual doses are presented in Table 1.

Annual collective dose equivalents and annual mean dose equivalents calculated for persons employed in different groups and for the whole monitored population are given in Table 2.

Table 1. Distribution of annual doses from occupational exposure monitored in different work groups in 2000÷2001.

GROUP	Year of control	Number of persons					%*)
		Total	Annual personal dose equivalent range [mSv]				
			1÷5	5÷15	15÷50	>50	
SCIENTIFIC	**2000**	1811	1797	13	1	0	99.2
	2001	1797	1771	23	3	0	98.5
INDUSTRIAL	**2000**	1453	1412	32	9	0	94.2
	2001	1391	1358	28	5	0	97.6
MEDICAL	**2000**	2434	2425	8	1	0	99.6
	2001	2311	2295	14	2	0	99.3
OTHER	**2000**	362	361	0	1	0	99.7
	2001	371	367	4	0	0	98.9
ALL GROUPS	**2000**	6060	5995	53	12	0	98.9
	2001	5870	5791	69	10	0	98.6

*) Per cent of persons who received annual dose < 5 mSv.

Table 2. Annual collective dose equivalent and annual mean dose equivalent calculated for persons employed in different groups and for the whole population being monitored in 2000÷2001.

Group	Number of persons		Annual mean dose equivalent [mSv]		Annual collective dose equivalent [man mSv]	
	2000	**2001**	**2000**	**2001**	**2000**	**2001**
SCIENTIFIC	1811	1797	0.97	0.88	1755	1573
INDUSTRIAL	1453	1391	1.47	1.21	2143	1675
MEDICAL	2434	2311	0.87	0.81	2125	1871
OTHER	362	371	0.93	0.84	335	311
ALL GROUPS	6060	5870	1.05	0.93	6357	5412

Annual radiation doses smaller then 0,1 of annual dose limit for occupational exposure in 2000 and 2001 received 94% of radiation workers in industrial group, and about 99% of workers in other groups.

The annual personal doses monitored by CLOR in 2000 and 2001 in different work sectors present similar occupational exposures monitored during the last few years [3]. This may be regarded to the small changes of the radiation conditions in the workplaces.

For many years the most exposed group of radiation workers is industrial group where the highest annual mean doses are registered every year.

References

[1] PRAWO ATOMOWE. Dziennik Ustaw Nr 3 poz.18 z 2001 r., Warsaw, 2001.
[2] International Commission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection.* ICRP Publication 60. Ann. ICRP 21(1-3) (Oxford: Pergamon Press) 1991.
[3] CLOR. *Research and operational Activities.* Annual Report 1998-1999. Warsaw, 2000.

3.3 CALIBRATION OF MEASURING DEVISES

3.3.1 GAMMA-RAY FIELD MEASUREMENTS FOR DETERMINATION OF REFERENCE BEAM PARAMETERS AT THE CLOR CALIBRATION LABORATORY

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To attain the status of Secondary Standard Dosimetry Laboratory the upgrading process of the Calibration Laboratory has been done in the 1996-1999. It included modernization of irradiation facilities and dosimetric equipment bringing them to the present state of art, as well as of the laboratory premises. The new Gamma Calibration System for calibration of dosemeters and survey meters and irradiation of personal dosemeters (films, TLD) is presented in Figure 1. The system consists of the following elements:

- gamma irradiator type STS-OB85 with two lead absorbers (attenuation factor of 1/10 and of 1/100 with Cs-137), sources: ^{137}Cs (740 GBq), ^{60}Co (37 GBq), ^{241}Am (7,4 GBq),

- motorized and computerized calibration bench 6,0 m long, constructed by MIKRO System and CLOR, Poland,
- laser alignment system, TV equipment.

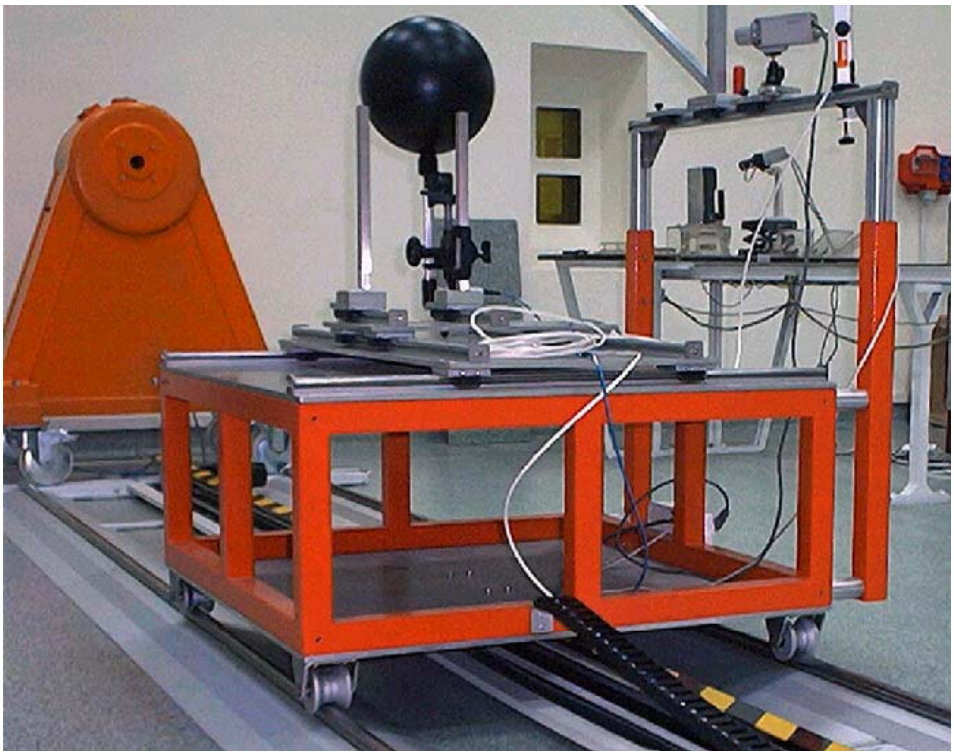


Fig. 1. Gamma Calibration System

Measurements of gamma radiation, emitted by ^{137}Cs, ^{60}Co, ^{241}Am, were made along 6 meters long guide rail for three cases:

- direct radiation,
- with one absorber – lead disc 22 mm thick,
- with two absorbers – lead discs: 22 mm + 18 mm,

for determination of reference beam parameters.

For these measurements, high-class electrometer type UNIDOS with the following of ionization chambers was used:

- protection level chamber type 23361, sensitive volume 30 cm^3, range 720 μGy/h- 3,5 kGy/h,
- protection level chamber type LS-01, sensitive volume 1000 cm^3, dose rate range 24 μGy/h – 100 Gy/h,
- low level chamber type LS-10, sensitive volume 10 000 cm^3, range 2,4 μGy/h – 11 Gy/h.

The aim of the investigation of reference beam parameters along guide rail was to demonstrate fulfilling the requirements of Standard ISO 4037- 1 [1] which are the following:

- the air-kerma rate due to radiation scattered by environment shall not exceed 5% of that due to the direct radiation;
- the value of the air-kerma rate at the point of the test shall be determined for lead absorbers by dosimetric measurements.

The results of the investigations are presented in Table 1.

Tab. 1. The characteristic of metrological parameters for Gamma Calibration System No 1

SOURCE AND NOUMBER OF ABSORBERS		A – DOSE RATE IN AIR B – PROCENTAGE PART OF SCATTERED RADIATION C – MEASUREMENT RANGE OF GUIDE RAIL		
		Ion. chamber 30 cm^3	Ion. chamber 1000 cm^3	Ion. chamber 10000 cm^3
^{241}Am	0	——	23,76 – 2,61 [μ Gy/h] < 5% 0,7 – 2,0 [m]	8,26 – 2,9 [μ Gy/h] > 5% 1,2 – 2,0 [m]
^{137}Cs	0	101,36 – 1,32 [mGy/h] < 1,5% 0,7 – 6,0 [m]	100,56 – 1,34 [mGy/h] < 3,5% 0,7 – 6,0 [m]	33,70 – 1,34 [mGy/h] ≤ 5% 1,2 – 6,0 [m]
	1	7,57 – 0,88 [mGy/h] < 1,5% 0,7 – 6,0 [m]	7,52 – 0,098 [mGy/h] < 1,5% 0,7 – 6,0 [m]	2,47 – 0,99 [mGy/h] < 5% 1,2 – 6,0 [m]
	2	——	983,2 – 12,50 [μ Gy/h] < 3,5% 0,7 – 6,0 [m]	314,2 – 12,55 [μ Gy/h] < 5% 1,2 – 6,0 [m]
^{60}Co	0	18,05 – 0,70 [mGy/h] < 1% 0,7 – 3,5 [m]	18,05 – 0,24 [mGy/h] ≤ 1% 0,7 – 6,0 [m]	6,08 – 0,24 [mGy/h] < 2% 1,2 – 6,0 [m]
	1	4,45 – 0,82 [mGy/h] < 3,1% 0,7 – 1,6 [m]	4,46 – 0,06 [mGy/h] ≤ 2% 0,7 – 6,0 [m]	1,48 – 0,06 [mGy/h] < 2% 1,2 – 6,0 [m]
	2	——	1501,5 – 76,7 [μ Gy/h] ≤ 5% 0,7 – 3,0 [m]	489,0 – 19,1 [μ Gy/h] < 1,5% 1,2 – 6,0 [m]

The measurements of dose distribution uniformity of irradiation field, i.e. dose rates along the horizontal and vertical axis for ^{137}Cs and ^{60}Co were made at 200, 140, 100 cm source-detector distances using ionization chamber type TM30002 (0,6 cm^3 sensitive volume). All values were normalized to the dose value at the center of the irradiation field. Results of the measurements made possible to determined, for simultaneous irradiation of several dosemeters on the front face of the slab phantom, circle of diameter given by the approximate locus of the 98% or 95% isodose contour with respect to the dose in the center of the phantom [2], [3]. The example of results is presented in Figure 2.

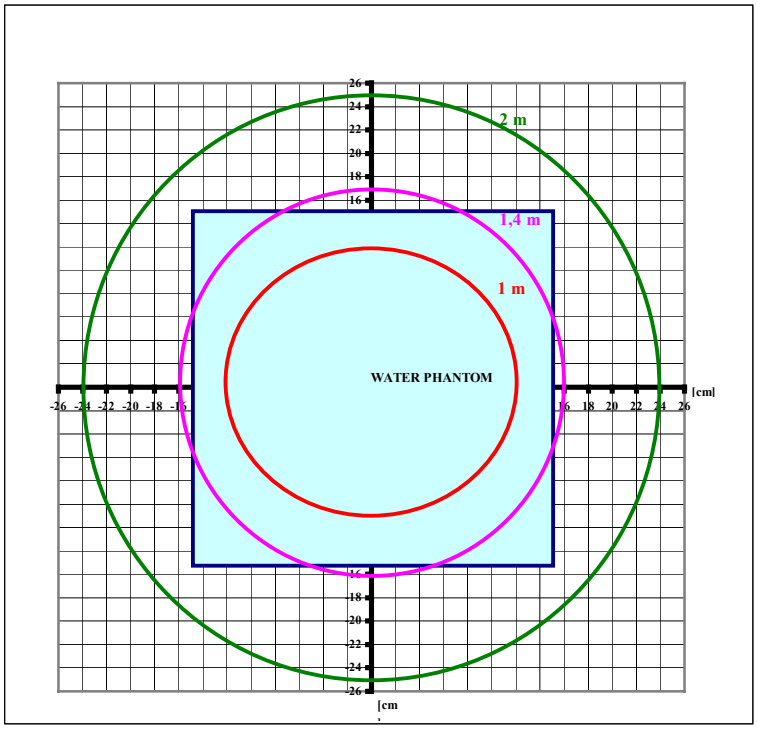


Fig. 2. Dose distribution of irradiation field along the horizontal and vertical axis for ^{60}Co at three source-detector distances

On the basis of the results of the present study, the area and personal dose meters should be calibrated according to parameters of the reference gamma radiation beam estimated for our new Gamma Calibration System.

References

[1] ISO Standard 4037-1, (1996): "X and gamma reference radiation for calibrating dosemeters and doserates meters and for determining their response as a function of photon energy, Part 1: Radiation characteristics and production methods".

[2] ISO Standard 4037-2, (1997): "X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy, Part 2: Dosimetry for radiation protection over the energy ranges 8 keV to 1,3 MeV and 4 MeV to 9 MeV".

[3] ISO Standard 4037-3, (1999):„X and gamma reference radiation for calibrating dosemeters and doserates meters and for determining their response as a function of photon energy, Part 3: Calibration of area and personal dose meters and the measurement of their response as a function of photon energy and angle of incidence".

3.3.2 THE ACTIVITY OF CALIBRATION LABORATORY FOR RADIATION PROTECTION (2000-2001)

H. Dzikiewicz –Sapiecha, R. Siwicki, M. Bogusz, T. Balcer
External Radiation Monitoring and Calibration Department

The activity of the CLOR Calibration Laboratory came under the four main headings:

1. Calibration of dosimetric instruments:
   - dose rate and dose meters used for area monitoring,
   - digital dose rate and dose meters for personal monitoring,
   - alpha and beta contamination radiation meters,
   - reference irradiations of the personal dosemeters (films and TLD).
2. Development of calibration methods for the implementation of new calibration procedures in compliance with ISO and IEC standards.
3. Quality assurance programme realised to fulfil the ISO standards requirements for X-ray and gamma reference energies and for reference beam parameters in the energy range between 33 keV and 1,25 MeV parameters [1], [2], [3].
4. Irradiations for biological dosimetry – research work
   Parallel to above work, the Laboratory staff was involved in training of radiation protection officers and preparation of standard ISO 4037-1 [1] polish version .

The irradiation facilities and dosimetric equipment at the Calibration Laboratory is presented below:

1. X-ray Calibration System
   - X-ray Calibration Unit - Pantak, type HF320,
   - calibration bench 8 m length, constructed by CLOR and MIKRO System, Poland,
   - additional equipment and accessories: laser alignment system, TV equipment,
2. Gamma Calibration System No.1
   - gamma irradiator type STS-OB85 with two lead absorbers (attenuation factor of 1/10 and of 1/100 for Cs-137), radiation sources: ^{137}Cs (740 GBq), ^{60}Co (37 GBq), ^{241}Am (7,4 GBq),
   - motorized and computerized calibration bench 6,0 m long, constructed by MIKRO System and CLOR, Poland,
   - laser alignment system, TV equipment.
3. Gamma Calibration System No.2 constructed in the seventies by CLOR and Polon, consisting of:
   - gamma irradiator with low activity sources ^{137}Cs and ^{60}Co,
   - motorized bench 7 meters long,
4. Beta Secondary Standard, type BSS2, sources: ^{147}Pm (3,7GBq), ^{85}Kr (3,7GBq) and ^{90}Sr (460 MBq), sensors for air pressure and temperature measurements, control computer.
5. Neutron calibrator, type STS OB26 with Am241/Be-neutron source (activity 185 GBq),
6. Wide area alpha and beta reference sources: ^{241}Am,^{14}C, ^{147}Pm,^{204}Tl,^{36}Cl, ^{90} Sr/^{90}Y, activities range from 1 Bq/cm^2 to 20 Bq/cm^2, calibration certificates of the German Calibration Service (DKD),

7. Reference dosemeters and equipment:

7.1 PTW UNIDOS - Universal Dosemeter, reference class dosemeter used as a secondary standard for radiation protection,

7.2 PTW UNIDOS - Universal Dosemeter, used as a working standard, completed by the following chambers and acccesories :

- protection level chamber type 23361 (30 cm^3 sensitive volume),
- protection level chamber type LS-01 (1000 cm^3 sensitive volume,

- low level chamber type LS-10 (10 000 cm^3 sensitive volume).

7.3 PHANTOMS - PMMA phantom of 30 cm x 30 cm x 30 cm dimensions
- water phantom of 30 cm x 30 cm x 30 cm dimensions.

The general requirements for dosimetric equipment are given in the Regulation of the National Atomic Energy Agency's President "On Requirements to be met by Dosimetric Equipment Designed for Radiation Protection Applications as well as Those Relating to Records Kept of Dosimetric Measurements Results" (1988). The national regulations as well as the international recommendations and standards (ISO, IEC) were applied for calibration of radiation protection instruments.

In period 2000-2001, the total number of calibrations was about 1700 meters per year. Figure 1 and Figure 2 show the diagrams of the contribution of different type meters to the total number of instruments calibrated in the year 2001.

Fig.1. The contribution of different types of dose- and doserate meters to the 997 instruments

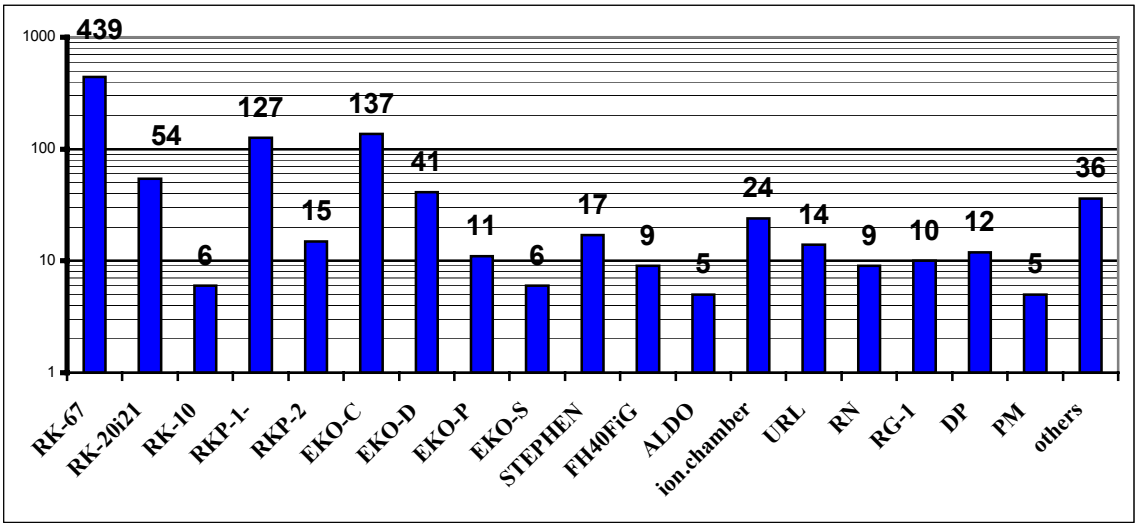
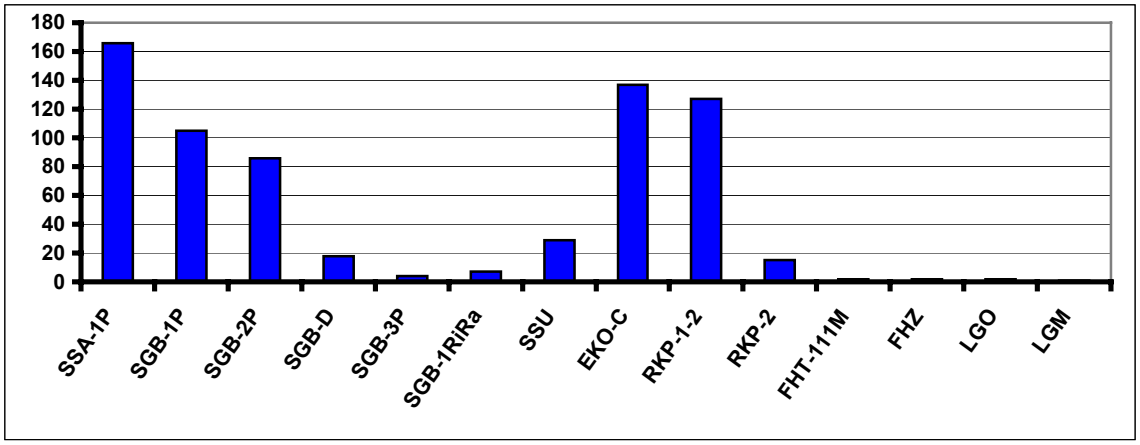


Fig.2. The contribution of different types of contamination meters to the 701 instruments



As indicated on Fig.1, the number of dose rate meters with no energy compensated detectors is about 50% of all instruments calibrated at our Laboratory. On the other hand, less than 10% of the total number of instruments used have been designed to measure the new

ICRU quantities - ambient and personal dose equivalent. This means that situation of radiation protection instrumentation is not adequate to the actual IEC standards.

In the new "Atomic Law", there is the requirement of dosemetric instruments to be calibrated by accredited laboratories. The work in our laboratory is concerned the general quality policy, transparency problems of everyday activity and relationships between the laboratory and clients. Calibration procedures, laboratory equipment maintenance, safety procedures, validation methods and estimation of measurement uncertainty, and rules for personnel competence requirements and responsibilities, were prepared to demonstrate that the laboratory operates a quality system compliant with ISO/IEC Guide 25 and PN-EN 45001 standard. The introduction of the new polish standard PN-EN ISO/IEC 17025: 2001 "Ogólne wymagania dotyczące kompetencji laboratoriów badawczych i wzorcujących", which replaced above mentioned standards, required harmonization our accreditations documents.Up till now, 18 documents describing the general quality system are ready, as well as the improved, to be presented to the accreditation bodies.

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3.4 POLISH POINT OF CONTACT IN THE INTERNATIONAL NOTIFICATION SYSTEM OF NUCLEAR ACCIDENTS AND RADIOLOGICAL EMERGENCIES

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

PPC has no received from International Atomic Energy Agency-Emergency Response Centre (IAEA-ERC) any messages about accident in nuclear power plants.

The IAEA-ERC has sent information about following emergency:

- "Kursk" nuclear submarine was flooded (August 2000),
- Co-60 radioactive contamination was discovered in wrist watches sold in certain French stores (December 2000-January 2001),
- 28 patients have been affected at the National Oncology Institute in Panama (May-June 2001).

In 1998-1999 PPC participated in the following exercises:

- exercise ALEX N-1 in March 2001. An accident at Baria Fictitious Nuclear Power Plant (Sweden) was simulated,
- exercise JINEX-1 in May 2001 organised by France,

- Exercise" Maria reactor incident making use RODOS system" in September 2001 organised in Poland.

There was also several routine communication tests.

3.5 TRAINING, INFORMATION AND STANDARDIZATION

J. Henschke, Sz. Rosiński, 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 Commission 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 are organized courses for radiation protection inspectors (qualifications B and C types), for operators of accelerators (qualifications C1 type), for heads of plants equiped with accelerators and for heads of laboratories of the I class (qualifications E type), for inspectors in establishements installing the smoke detectors (qualifications B2 type) and for inspectors in regional groups installing the smoke detectors (qualifications C2 type).

Table 1. Number of of qualifications given in 2000 and 2001.

type / year	B	C	C1	E	B2	C2	together
2000	224	100	100	26	1	12	463
2001	279	109	295	83	2	3	771
together	**503**	**209**	**395**	**109**	**3**	**15**	**1234**

Additional training courses for firemen, border guards or for staff of laboratories belonging to the Service of Radioactive Contaminations Measurements (SPSP) are also organized.

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 5583 volumes. The library is a subscriber of 26 Polish and 3 foreign journals.

In 2000–2001 the Secretariat of the Commission for Radiological Protection Standardization prepared the following documents:

- nine standards: PN-ISO 9697 „ Water quality – Measurement of gross beta activity in non-saline water",
  PN-ISO 1757 „ Personal photographic dosemeters",
  PN-ISO 4037-1 „ X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1:Radiation characteristics and production methods",
  PN-ISO 4037-2 „ X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy –

Part 2: Dosimetry for radiation protection over the energy energy ranges 8 keV to 1.3 MeV and 4 MeV to 9 MeV",

PN-ISO 4037-3 „ X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and the measurement of their response as a function of energy and angle of incidence",

PN-ISO 10703 „ Water quality – Determination of the activity concentration of radionuclides by high resolution gamma - ray spectrometry ",

PN-ISO 6980 „ Reference beta radiations for calibrating dosimeters and dose-rate meters and for determining their response as a function of beta-radiation energy",

PN-ISO 7503-1 „ Evaluation of surface contamination – Part 1: Beta - emitters (maximum beta energy greater then 0.15 MeV) and alpha-emitters",

PN-ISO 8690 „ Decontamination of radioactively contaminated surfaces - Method for testing and assessing the ease of decontamination"

- 106 drafts of ISO standards were obtained for comments. Official opinion on the drafts has been worked out;
- eight meetings of the Commission for the Radiological Protection Standardization were organized.

3.6 PREVENTION AND EMERGENCY SERVICE

Roman Tańczyk
Prevention and Emergency Service Department

Dispatch Center of Emergency Service (ODSA) CLOR, has the following duties:

a. Accepting notices on radiological accidents and incidents,
b. „First-aid" advising and recommendations,
c. Supervising the remedial actions after radiological accidents and incidents,
d. Notification of the police on the radiological emergency, if necessary.

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

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

Table 1. Radiological incidents in Poland.

Kind of incident	Number of radiological incidents in year:	
	2000	2001
Robbed, damaged or lost sources	17	8
Uncontrolled source in a public area, smuggling or illegal possessing of sources	14	7
Fire in the place of radiation source	1	1
Disturbance in work of devices with a source	8	3
other	16	13
Total	56	33

In 2000 - 2001 ODSA collaborated with the:

- National Fire Guard in preventing accidents involving radiation hazard,
- Border Guard in preventing uncontrolled exportation and importation of radiation sources,
- Police and State Security services in preventing illegal nuclear and radioactive traffic.

In the ODSA data base of users of radioactive sources, at the end of the 2001-year, there were approximately 2285 users, registered at the CLOR. The sources are utilized in medicine, research, industry and agriculture. Dealers and producers of radioactive sources are also registered. Documents on licensing and activities of the users are stored in CLOR. Type and number of plants and sealed sources are presented in Table 2 and 3.

Table 2. Number of registered plants using radioactive sources.

Kind of plants	Number of plants		
	Begun using sources in 2000 - 2001 years	Finished using sources in 2000 - 2001 years	Total at the end of the 2001 year
Industrial plants - sealed sources	8	96	1047
Laboratories - unsealed sources	1	28	370
Laboratories - unsealed and unsealed sources	0	1	49
Laboratories - sealed sources	5	22	351
Laboratories - accelerators and sealed sources	0	0	19
Laboratories - accelerators	1	0	25

Magazines of radioactive materials	13	26	424
Total	27	172	2285

Table 3. Number of registered sealed sources used at the end of the 2001-year

Isotope	Number of sealed sources	Total activity [TBq]
Am-241	1881	15,00
Pu-239	4153	10,93
Pu-238	262	1,41
Co-60	7130	6070,94
Cs-137	2234	977,62
Kr-85	206	0,91
Ra-226	530	1,48
Sr-90	578	0,31
other	1805	
Total	18779	

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A. Żak, M. Biernacka, P. Lipiński, K. Mamont-Cieśla: *„The results of measurements of raw and building materials in Poland in the context of the indoor Rn-222 concentration limitation”*, The Science of the Total Environment, 2000, 272, 105-106.

5. PARTICIPATION IN CONFERENCES, SYMPOSIA AND SEMINARS. ORAL AND POSTER PRESENTATIONS

8th International Conference on Nuclear Engineering, Baltimore, Md., USA, 2-6 April 2000.
Z. Jaworowski: *„Beneficial radiation and regulations”*.

10th International Congress of the International Radiation Protection Association „Harmonization of Radiation, Human Life and the Ecosystem”, Hiroshima, Japan, 14-20 May 2000.
Poster presentations:
B. Rubel, D. Grabowski, W. Muszyński: *„Radiation monitoring network in Poland – structure and activities”*.
B. Rubel, D. Grabowski, W. Muszyński: *„Concentration of caesium isotopes in foodstuffs in Poland”*.

25th Annual Meeting on Radiation Protection of the Health, Balatonkenese, Hungary, 30 May – 2 June 2000.
A. Nényei, A.G. Gillet, S.M. Wright, R. Creamer, A.L. Sanchez, N.M.J. Crout, P. Krajewski, I. Malatova, R. Mirchi, B. Kanyár, J. Somlai, K. Eged, K. Bujtás, S. Trajan, B. Varga: *„A global comparison of critical loads for radiocaesium in Central Europe”*.

3rd Meeting of Radiation Protection Inspectors, Puszczykowo near Poznań, Poland, 31 May – 2 June 2000.
H. Dzikiewicz-Sapiecha: *„Direct reading personal dose equivalent (rate) monitors – X, gamma and beta radiation”*.

XIXth All-Polish Meeting: Present problems of radiological protection and protection against HF electromagnetic fields, Ustrzyki Górne, Poland, 5-9 June 2000.
K. Isaajenko, P. Lipiński, W. Bekiert: *„Monitoring of radiological situation in Poland”*.

Meeting of Project Group for Monitoring of Radioactive Substances in the Baltic Sea – Helsinki Commission, Sopot, Poland, 5-9 June 2000.
M. Suplińska, D. Grzybowska: *„Monitoring of radionuclides in the Baltic Sea in 1999”*.

Sixth Meeting of the International Technical Working Group (IRWG-6), Vienna, Austria, 8-9 June 2000.
S. Sterliński: *„Work by the Central Laboratory for Radiological Protection in Combating Illicit Trafficking of Radioactive Substances and Nuclear Material in Poland in 1999”*.
S. Sterliński: *„Comments on a second round – Robin Test (a high enriched uranium)”*.
S. Sterliński: *„Guidance to be followed in the response to illicit cases with involved nuclear material and other radioactive sources”*.

Seminar: Radon in environment, Kraków, Poland, 14-15 June 2000.
M. Karpińska, S. Wołkowicz, Z. Mnich, M. Zalewski, K. Mamont-Cieśla, K. Antonowicz: *„Evaluation of radon hazard in selected areas of Suwalszczyzna”*.
M. Kusyk: *„Intercomparison of passive methods of radon measurement in dwellings”*.
K. Mamont-Cieśla, M. Kusyk: *„Design and measurement possibilities of Radon Progeny Particle Size Spectrometer (RPPSS)”*.
Poster presentations:
L. Fuks, K. Mamont-Cieśla, M. Kusyk: *„Investigation of Polish active coals determined to sorption and radon detection”*.
K. Mamont-Cieśla, M. Kusyk: *„New radon calibration chamber in CLOR”*.

First Annual Meeting on Radiological Monitoring and Information Systems in Baltic Sea States, Falenty near Warsaw, Poland, 14-16 June 2000.
L. Kownacka: *„Measurement of the Vertical Distribution of Radionuclides Concentration in the Atmosphere”*.
P. Lipiński, M. Biernacka, K. Isajenko: *„Polish Radiological Monitoring Networks (ASS-500, PMS and SPSP Systems)”*.
P. Lipiński, M. Biernacka, K. Isajenko, A. Żak: *„Integration of ASS-500 and PMS Systems in Poland”*.
T. Wardaszko, I. Radwan, Z. Pietrzak-Flis: *„Monitoring of Radioactive Contamination of Polish Rivers Flowing into the Baltic Sea”*.

Workshop: An International Approach to Reducing the Threat from Diverted Hazardous Materials, Stanford University, USA, 16-17 June 2000.
G. Smagała: *„Poland’s approach to reducing the threat from diverted hazardous materials”*.

Conference of the National Atomic Energy Agency: Man – Environment – Hazards, Szklarska Poręba, Poland, 27-28 June 2000.
K. Mamont-Cieśla, M. Kusyk, Sz. Rosiński, A. Sosińska: *„Radon investigation in air of dwellings and in water of households in south-western Poland”*.

30th Annual Meeting of European Society for Radiation Biology (ESRB), Warszawa, 27-31 August 2000.
E. Boużyk, A. Wójcik, M. Kowalska, J. Buraczewska, G. Kobiałko, I. Szumiel: *„Validation of the micronucleus- centromere assay for biological dosimetry"*.
M. Kowalska, R. Siwicki: *„Adaptive response against micronucleus formation in C3H10T1/2 mouse embryo fibroblasts"*.

European Workshop on Individual Monitoring of External Radiation, Helsinki, Finland, 4-6 September 2000.
A. Koczyński, A. Chęć, D. Łach, M. Dąbek: *„External radiation occupational exposure monitored in Poland by CLOR in 1999"*.

International meeting on Intercomparison of Radiological Measurements for Monitoring Purposes, Vienna, Austria, 11-12 September 2000.
D. Grabowski, W. Muszyński: *„Radiation Monitoring System in Poland"*.

36th „Berlin Kolloquium", Berlin, Germany, 20-24 September 2000.
Z. Pietrzak-Flis: *„Implementation of the Council Directive 97/43 Euratom into practice (control of justification and optimization, rights of the patient) in Poland"*.
Z. Pietrzak-Flis: *„Radioactivity in building materials (regulations and supervision) in Poland.*
Z. Pietrzak-Flis: *„Electrosmog and mobile telecommunication (problems of acceptance in the general public, regulations, risk assessment) in Poland"*.
Z. Pietrzak-Flis: *„Quality assurance and quality control in radiation protection in Poland"*.

The Third International Meeting on Low-Level Air Radioactivity Monitoring, Dąbrówno near Nidzica, Poland, 24-29 September 2000.
M. Bysiek, M. Biernacka, P. Lipiński: *„Radioactivity of Ground- Level Air in Poland in 1998-1999. Results from ASS-500 Stations in Network"*.
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska: *„Radiation Monitoring Network in Poland"*.
K. Isajenko, P. Lipiński, W. Bekiert: *„Permanent Monitoring System (PMS) in Poland"*.
A. Koczyński, M. Biernacka, A. Chęć, A. Sosińska: *„Systematic TLD Measurement of Background Radiation in Poland"*.
L. Kownacka: *„Natural and Artificial Radionuclides in the tropospheric and lower stratospheric air over Poland"*.
P. Lipiński, M. Biernacka, K. Isajenko, A. Żak: *„The Development of the ASS-500 Stations in Poland – on line Control of the Radioactivity on the Filter"*.

International Conference on Radiation and its Role in Diagnosis and Treatment, Teheran, Iran, 18-20 October 2000.
Z. Jaworowski: *„Ionizing Radiation and Radioactivity in 20th Century"* – invited lecture.

IAEA/WCO Joint Technical Committee Meeting, Vienna, Austria, 30 October – 3 November 2000.
G. Smagała: *„Poland's approach to illicit trafficking in radioactive materials"*.

International Conference on Biosphere Modelling and Assessment Methods, IAEA, Vienna, Austria, 6 – 10 November 2000.
P. Krajewski: *„CLRP model calculation for Scenario IPUT"*.

International Conference: Days of Radiation Protection, Jachymov, Czech Republic, 28 November – 1 December 2000.
I. Malatova, L. Tecl, R. Mirchi, Š. Foltanova, J. Minařik, P. Krajewski, B. Kanyár: ***„Ingestion of Cs-137 in the Czech Republic, Poland and Hungary after the Chernobyl Accident"***.

Meeting on starting support project in the field of combating illicit trafficking of nuclear materials, ITU, Karlsruhe, Germany, 8-10 November 2000.
S. Sterliński, A. Merta: *„Initial Assessment on Polish Situation in the Field of Combating Illicit Trafficking of Radioactive and Nuclear Materials"*.

IAEA Consultant's Meeting, Vienna, Austria, 8-12 January 2001.
G. Smagała: *„National Strategies and Programmes for Detecting and Locating Orphan Sources and Their Subsequent Management – Poland's Practice"*.

Seminar on up-to-date issues of radiation protection and protection against electromagnetic fields, Duszniki Zdrój, Poland, 2-7 April 2001.
H. Dzikiewicz-Sapiecha: *„Metrological control and calibration of instruments used for radiation protection purposes"*.

Lecture in the Central Mining Institute, Katowice, Poland, 4 April 2001.
K. Mamont-Cieśla: *„Problems of calibration of instruments for measurement of alpha potential energy concentration of radon daughters"*.

IIIrd National Conference on Radiochemistry and Nuclear Chemistry, Kazimierz Dolny, Poland, 6-9 May 2001.
K. Isajenko, P. Lipiński, M. Biernacka, W. Bekiert: *„Monitoring of radioactive contamination in Poland using automatic stations"*.
A. Koczyński, M. Biernacka, A. Chęć, A. Sosińska: *„Thermoluminescence measurements of gamma dose in natural environment in Poland"*.
L. Kownacka: *„Vertical distribution of Be-7 and Pb-210 in the tropospheric and lower stratospheric air"*.
P. Krajewski, L. Rosiak: *„Transfer of radiocaesium to crops from different soil types in Poland as a function of radiocaesium interception potential and soil characteristics"*.
Z. Pietrzak-Flis, P. Krajewski, I. Radwan, Y. Muramatsu: *„Deposition of I-129 in Poland after the Chernobyl accident evaluated from concentrations of this radionuclide in soil"*.
Z. Pietrzak-Flis, I. Radwan, P. Krajewski: *„Distribution of Cs-137 in uncultivated soils in Poland after the Chernobyl accident"*.
L. Rosiak, Z. Pietrzak-Flis: *„Relationships between Ra-226, barium and calcium in soil and plants"*.
M. Suplińska, A. Adamczyk, E. Chrzanowski: *„Vertical distribution of Cs-137, Pb-210, Ra-226 and Pu-239,240 in bottom sediments from Southern Baltic Sea"*.
A. Żak, M. Biernacka, K. Florowska: *„Row and building materials with enhanced natural radionuclides concentrations using in housing and industry activities in Poland"*.
Poster presentations:
M. Biernacka, W. Bekiert, A. Koczyński, A. Sosińska: *„Systematic measurements of natural radionuclides and caesium isotopes concentrations in surface layer of soil in Poland"*.

M. Bysiek, M. Biernacka: *„Radioactivity of ground level air in Poland. Results of investigations from the network of ASS-500 stations”*.
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska: *„Activity of Cs-137 in forest mushrooms in Poland in 2000”*.
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska: *„Cs-137 in milk as an indicator of environment's contamination”*.
J. Henschke, M. Biernacka, K. Florowska, D. Grabowski, B. Rubel, A. Sosińska: *„Evaluation of effective dose from different radioactive sources for statistical inhabitant of Poland in 2000”*.
M. Kusyk, K. Mamont-Cieśla: *„Radon concentration in drinking water in three regions in south-western Poland”*.

International Conference on Security of Material Measures to Prevent, Intercept and Respond to Illicit Uses of Nuclear Material and Radioactive Sources, Stockholm, Sweden, 7-11 May 2001.
G. Smagała, R. Tańczyk: *„Domestic Co-operation in Combating Illegal Nuclear Traffic – Experience of the Emergency Service Centre”*.

IRPA Regional Congress on Radiation Protection in Central Europe, Radiation Protection and Health, Dubrovnik, Croatia, 20-25 May 2001.
B. Kanyár, B. Howard, I. Malatova, P. Krajewski, N.M.J. Crout, A.L. Sanchez, P. Strand, R. Mirchi, A. Nényei: *„Preliminary Results on the Spatial Analysis of Vulnerable Areas in Central Europe (SAVEC)”*.
A. Koczyński, M. Biernacka, A. Chęć, A. Sosińska: *„12 Years TLD Measurements of Background Gamma Radiation in Poland”*.
A. Liland, I. Malatova, B. Kanyár, P. Krajewski, K. Eged, J. Somlai, J. Tecl, S. Tarjan: *„Identification of critical groups in Poland, Hungary and Czech Republic through diet questionnaires”*.
A. Lailand, L. Skuterud I. Malatova, B. Kanyár, P. Krajewski, A. Sanchez, S. Borghuis, S. Filtanova, R. Mirch, S. Trajan, B. Varga: *„Spatial variation of estimated Cs-137 intakes in Poland, Hungary and Czech Republic after the Chernobyl accident and comparison with whole body measurements”*.
Poster presentations:
M. Biernacka, W. Bekiert, A. Koczyński, A. Sosińska: *„Systematic Measurements of Radioactive Contamination of the Earth Surface in Poland”*.
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska: *„Activity of Cs-137 in forest mushrooms in Poland in 2000”*.
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, G. Smagała, J. Świętochowska: *„Control system of radioactive contamination in food samples in Poland”*.
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel, J. Świętochowska: *„The effective dose due to radinuclides intake via ingestion in Poland in 1986-1999”*.

4th Meeting of Radiation Protection Inspectors, Wągrowiec near Poznań, Poland, 29 May – 2 June 2001.
H. Dzikiewicz-Sapiecha: *„Testing and calibration of radiation protection dosemeters and dose rate meters used for X and gamma radiation measurements”*.
H. Dzikiewicz-Sapiecha: *„Operational quantities ICRU in area and individual monitoring in relation to limiting quantities for radiation protection purposes”*.

Seminar: Mobile measurements and nuclear emergency preparedness, Roskilde, Denmark, 30-31 May 2001.
K. Isajenko, P. Lipiński: *„Mobile Spectrometric Laboratory – its use in Poland"*.

4th International Group Meeting on Spatial Analysis of Vulnerable Areas in Central Europe (SAVEC), Jabłonna near Warsaw, 30 May – 1 June 2001.
W. Bekiert, M. Biernacka, A. Koczyński, A. Sosińska: *„Systematic Measurements of Natural Radionuclides and Caesium Isotopes Concentration in the Earth Surface in Poland"*.
P. Krajewski: *„Work Package 3: Fluxes of radiocaesium – progress in 2000"*.
W. Muszyński: *„Radiation monitoring network in Poland"*.

3rd International Conference on Health Effects of the Chernobyl Accident: Results of 15-Year Follow-Up Studies, Kiev, Ukraine, 4-9 June 2001.
P. Krajewski: *„Thyroid Dose Reconstruction for the Population of Poland after the Chernobyl Accident"*.

Sixth Meeting of Project Group for Monitoring of Radioactive Substances in the Baltic Sea – Helsinki Commission, Stockholm, Sweden, 12-14 June 2001.
M. Suplińska, A. Adamczyk: *„Monitoring of radioactive substances in Southern Baltic Sea in 2000. Bottom sediments and biota"*.
M. Suplińska, M. Białkowski: *„Vertical distribution of Cs-137, Pb-210, Ra-226 and Pu-239,240 concentrations in bottom sediments and evaluation of sedimentation rate in Gulf of Gdańsk"*.

Symposium: The effect of Chernobyl accident on the development of thyroid disorders in Poland, Warsaw, Poland, 24 August 2001.
P. Krajewski: *„Reconstruction of the thyroid dose for the population of Poland after the Chernobyl accident"*.

XXXIst Annual ESNA Meeting, Chania, Crete, Greece, 8-12 September 2001.
Z. Pietrzak-Flis, P. Krajewski, I. Radwan, Y. Muramatsu: *„Deposition of I-129 and Cs-137 in Poland after The Chernobyl accident"*.

XIIth Conference of the Polish Society for Radiation Research, Kraków, Poland, 10-12 September 2001.
K. Mamont-Cieśla, M. Kusyk: *„Study of aerosol and climatic conditions influence in calibration chamber on readings of radon mining instrument and evaluation of effective dose"*.
M. Kowalska, R. Siwicki: *Induction conditions and duration of an adaptive response induced by low-doses of X radiation in cultured C3H10T1/2 cells"*.
S. Sommer, A. Kryścio, W.U. Miller, C.Streffer, M. Kowalska, E. Bożyk, I. Buraczewska, I. Szumiel, A. Wójcik: *„The micronucleus-centromere assay for biological dosimetry"*.
Poster presentations:
D. Grabowski, W. Kurowski, W. Muszyński, B. Rubel: *„Early warning stations of radioactive contamination in Poland"*.
M. Karpińska, K. Mamont-Cieśla, Z. Mnich, M. Zalewski, S. Wołkowicz, J. Kapała: *„Comparison of radon concentration determined by means of short and long term expositions in buildings"*.
B. Rubel, D. Grabowski, W. Kurowski, W. Muszyński: *„Effective doses for population of Poland via ingestion of contaminated food in 1986-2000"*

37th „Berlin Kolloquium”, Berlin, Germany, 10-14 October 2001.
P. Krajewski: *„Safety of radiation sources in Poland”*.
P. Krajewski: *„UV-radiation – solaria in Poland”*.
P. Krajewski: *„Medical exposition (regulations and supervision) in Poland”*.
Z. Pietrzak-Flis: *„Natural radioactivity in drinking and mineral water (regulations and supervision) in Poland”*.
Z. Pietrzak-Flis: *„Radioactive discharges from nuclear facilities in Poland”*.

Central European Scientific Conference ECOpole'01, Jamrozowa Polana near Duszniki Zdrój, Poland, 18-20 October 2001.
Z. Pietrzak-Flis, plenary lecture: *„Risk assessment of Polish population from ingested radionuclides”*.

International Conference on Medical Physics and Engineering in Health Care, Poznań, Poland, 18-20 October 2001.
Poster presentation:
K. Florowska, M. Biernacka, D. Grabowski, B. Rubel, A. Sosińska: *„Evaluation of radiation hazard to population of Poland due to ionizing radiation from natural and artificial radionuclides in environment and from man-made sources and medical diagnostics”*.

VIIIth International Conference: Ashes from power industry, Międzyzdroje, Poland, 24-26 October 2001.
M. Biernacka, J. Henschke: *„Radioactivity of natural environment in Poland”*
K. Mamont-Cieśla, A. Żak: *„Sources of ionizing radiation in buildings and methods of decreasing of radon concentration level in dwelling air”*.
A. Żak, K. Florowska: *„Natural radioactivity of building materials, minerals and industrial wastes. Criteria of its limitation in Poland and other countries”*.

Coordination Meeting of Low Enforcement Services and Radioanalytical Laboratories on Combating Illicit Trafficking of Nuclear and/or Radioactive Materials, Vienna, Austria, 19-21 November 2001.
G. Smagała: *„Domestic cooperation in combating illegal nuclear traffic – Experience of the Central Laboratory for Radiological Protection (CLOR)”*.

Symposium: Entwicklungen im Strahlenschutz, Munich, Germany, 28-29 November 2001.
Z. Jaworowski: *„Ionizing Radiation in 20th century and beyond”* – invited lecture.