

A. GIRGŽDYS*, M. PEČIULIENĖ*, D. JASAITIS*,
G. GRIGALIŪNAITĖ-VONSEVIČIENĖ*

NATURAL IONIZING RADIATION IN SOME RESORTS AND RECREATIONAL LOCATIONS IN LITHUANIA

The results of dosimetric and radiometric analyses of ionizing radiation emitted by natural radionuclides conducted in the Curonian Spit and other recreational locations nearby water reservoirs in Vilnius, Lithuania, are presented. The research was carried out with mobile measuring instruments, data registration and accumulation equipment, applying Global Positioning System.

The distribution of equivalent dose rates in the locations has been measured. Soil samples were taken from the locations where equivalent dose rate was measured and specific activities of major gamma radiators were evaluated using spectrometric analysis. The coefficient correlation was detected between ^{40}K , ^{226}Ra , ^{232}Th and ^{137}Cs specific activities and equivalent dose rates above sample collection location. The coefficient of correlation between ^{40}K and ^{226}Ra specific activity in soil and in bottom mud water is identified.

1. INTRODUCTION

Cosmic radiation and ionizing earth radiation, spread by radionuclides in earth crust, atmosphere and water, have constantly affected life development. Over 60 natural radionuclides are found in earth crust, 32 of them belong to the most radioactive series: uranium–radium, uranium–actinium and thorium [1].

The impact of internal and external natural exposure upon all human beings has not changed for thousands of years. An individual approximately gets the dose of 2 mSv internal and external exposure annually. Internal exposure exceeds external exposure twice [1].

Radionuclides enter human body through respiratory system and food chain and become one of the exposure sources. Release of radicals – the result of ionizing radiation – destroys the membrane of various cells or affects the cells themselves. Even

* Department of Physics, Faculty of Fundamental Sciences, Vilnius Gediminas Technical University, Saulėtekio Ave. 11, LT-10223, Vilnius, Lithuania. grv@fm.vtu.lt

small quantities of radionuclides can do harm to human body, therefore additional ionizing radiation must be reduced to minimum.

The information about ionizing radiation and radionuclide distribution is essential to understand and distinguish between two radiation sources, i.e., human-made radiation sources and natural ones. Since people are mainly exposed to natural radiation, the determination of its the dose and effect on health improves the understanding of radiation damage [2].

Ionizing and cosmic radiation of radioactive substances, found in the air on the earth's surface, are responsible for equivalent dose rate in the earth's surface air. Equivalent dose rate is the most important parameter, because it reflects the impact of ionizing radiation upon human beings.

According to UNSCEAR 2000, the global-average individual whole-body radiation dose from natural sources is 2.4 mSv per year, with a typical range between 1 and 10 mSv per year [3]. For example, annual average effective dose from terrestrial radiation is 1.03 mSv for Latvia, 0.45 mSv [4] for Poland [5], [6]. However, in many regions of the world, the natural annual doses are much higher, for instance, about 35 mSv in India, 80 mSv in France, 150 mSv in the city of Ramsar (Iran) or more than 700 mSv at the Brazilian beaches [7]–[9].

Additional sources of radioactive pollution are in urgent need of constant control, they must be monitored and their impact must be registered. Unfortunately, nowadays we are faced with the consequences of the multi-year pollution. Lithuanian environment has been affected by nuclear explosions and a nuclear power plant accident in Chernobyl. Transport of radioactive substances from highly polluted regions of Ukraine (9.2 mSv per year) and Belarus (5.2 mSv per year) is still in progress [3]. Moreover, there is always potential danger of release of radioactive substances into environment due to possible accidents at venues of nuclear industry.

The issue of radionuclides behaviour in the water has been very important nowadays [10]–[12]. The capability of open water reservoirs to accumulate pollutants should lead to anxiety because water, especially in urban areas, is intended as the source of potable water.

The aims of this study were:

- to define the doses of ionizing radiation affecting the people who live or are on holiday in the one of the most popular Lithuanian resorts, i.e., the Curonian Spit;
- to estimate the dose of ionizing radiation in open water reservoirs, both in the soil near reservoirs and above reservoirs water in Vilnius;
- to estimate the correlation coefficients between specific activity of such radionuclides as ^{40}K and ^{226}Ra , ^{232}Th and ^{137}Cs and equivalent dose rate above sample collection location;
- to estimate the coefficient of correlation between specific activity of such radionuclides as ^{40}K and ^{226}Ra in the soil and in the water reservoir bottom mud.

2. INVESTIGATION METHODS

The equipment depicted in figure 1 was used to measure gamma radiation equivalent dose rate emitted by natural radionuclides present in the soil.

Equivalent dose rate was measured with a portable radiometer SRP-08-01. During measurement the equipment detector was kept 1 m above the earth's surface and 30 cm above the water surface. The measuring range of the radiometer SRP-08-01 is between 0 and 27000 nSv/h. Equivalent dose rate above different surfaces can be measured with this equipment.



Fig. 1. Measuring equipment

The radiometer is connected to data register from which accumulated data are transferred to a portable computer. The portable computer is connected to the Global Positioning System (GPS). The latter is a very precise radio-navigation system providing information about the position of objects in space, their velocity, direction and the distance covered, the distance to selected points, exact time at a given moment, geographical sunrise/sunset time and moon phases of a given location. GPS works in the same way in any place of the world irrespective of weather conditions, day time or season [13].

The following data are accumulated in the portable computer: location coordinates, time and readings of the radiometer. Radiometrical measurements were carried out continuously along the measurement route, at each point performing three, four measurements and indicating their average values. While noticing an increased equivalent dose rate, the same territory was measured additionally at a slower pace.

The equipment is easily transported, therefore, it is easy to evaluate the changes of an equivalent dose rate in a big measurement area.

With the aim of measuring more precisely the influence of the natural and artificial gamma radioactivity sources (^{40}K , ^{226}Ra , ^{232}Th and ^{137}Cs) on irradiance, their specific

activity in the soil in equivalent dose rate measurement places was evaluated. The gamma spectrometry was used to identify their specific activity. The soil was collected with a special device. A metal ring of 15 cm diameter and 5 cm height was hammered into the soil, which was separated with a spade while taking a sample.

A gamma spectrometric system (CANBERRA) was used to establish the specific activity of radionuclides. To identify the specific activity of radionuclides in the soil, a sample sensor distinguishes between them due to a high resolution (2 keV). The signal of equipment is linear and characterized by wide energy interval, impulse amplitude irresponsibility of impulse counting velocity, high impulse increasing speed and irresponsibility of magnetic fields.

The specific activity of the soil whose main source of radiation is gamma radiation is identified by using 24–72 hour measurement expositions. Radionuclides were identified according to the following lines: ^{40}K – 1460 keV, ^{226}Ra – 186 keV, ^{208}Tl – 583 keV, ^{137}Cs – 662 keV. It is known that there is no radioactive balance between specific activity of ^{232}Th and its decay product ^{208}Tl . The ratio of their specific activity equals 1.6 [14].

The background was evaluated continuously during the measuring period, its level varied insignificantly. Its ^{40}K radioactivity changes constituted less than 4% of signal volume.

General rules [15] for calculating the coefficients of correlation between some radionuclides specific activity and equivalent dose rate above the sample collection location were applied.

3. MEASUREMENT RESULTS

According to the above described measuring methods, dosimetry was applied to the soil surface air in the most popular Lithuanian resort the Curonian Spit and near and above some water reservoirs in Vilnius.

Figure 2 depicts the results of equivalent dose rate measurements in the air above the soil surface in the Curonian Spit. Geographical longitude and latitude respectively correspond to the axes of abscissas and ordinates. The most frequent average values of equivalent dose rate are presented in figure 2. They mostly depend upon the bed surface type, because first of all gamma radiation depends upon the quantity of radionuclides in soil (different soil composition). Another reason is short-life-time of radon decay products present in the air and their different distribution in the surface soil. The lowest dose rate in the air above the soil surface was measured in the sandy seaside beach (from 22 nSv/h to 60 nSv/h), the highest one – above asphalt surface (from 57 nSv/h to 90 nSv/h). This natural change of radiation could be explained by anthropogenic activity. In figure 2, one can clearly distinguish urban areas from roads.

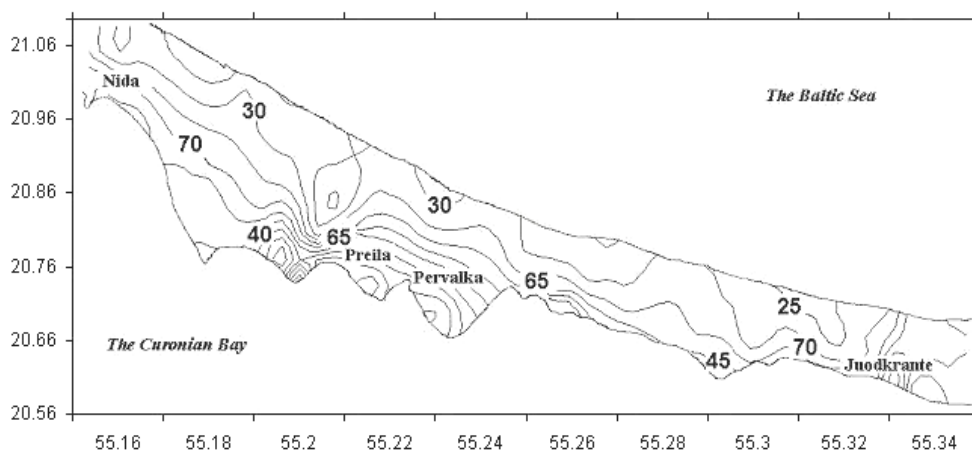


Fig. 2. Distribution of average values of equivalent dose rate (nSv/h) in the Curonian Spit

Table 1

Equivalent dose rate measured in the air above the soil surface at different watersides

Waterside	Location	Number of measurements	Minimum value (nSv/h)	Maximum value (nSv/h)	Average value (nSv/h)	Mean square deviation (nSv/h)
Waterside at Juodkrante	the Curonian Spit	300	22	60	35	1
Waterside at Preila		150	24	87	44	3
Waterside at Pervalka		50	24	58	43	2
Waterside at Nida		50	36	46	40	1
Waterside at Lake Salote	Vilnius	30	42	89	60	3
Waterside at Lake Tapeliai		30	38	97	74	3
Waterside at the River Neris (Valakampiai)		30	27	62	47	2

Table 1 indicates minimum, maximum and average values of equivalent dose rate measured in the air above soil surface at different watersides in the city of Vilnius and the Curonian Spit. It is obvious from table 1 that the biggest difference between minimum and maximum values is detected at the seaside near Preila, the smallest difference – near Nida. The difference between the minimum and maximum values is about

53%. As we mentioned above, seashores are sandy. The riverside at Neris is also sandy, meanwhile waterside at Lake Salote is clay loam, at Lake Tapeliai – clay and sandy loam. The equivalent dose rate received by a person who spent three hours at the waterside in Vilnius might range from 141 nSv to 222 nSv, while at the seaside it is less than 132 nSv.

Information about the distribution of equivalent dose rate values above open-water reservoirs of the city of Vilnius was collected due to continuous data registration. The registration was especially important to search for pollution sources. Table 2 presents the results of measurements. Each number is an average value of measurement in the place of interest. Average equivalent dose rate values above shallow water reservoirs are higher due to ionizing radiation of radionuclides, which are in the bottom mud and deposits. Based on the results of measurements it can be inferred that water absorbs radiation.

Table 2

Average values of equivalent dose rate (nSv/h) above water reservoirs in Vilnius

Lakes	Number of measurements	Average values of equivalent dose rates (nSv/h)	Area (ha)	Depth (m)	Ponds (water reservoir address)	Number of measurements	Average values of equivalent dose rates (nSv/h)	Area (ha)	Depth (m)
Salotes	34	20	9.8	-3	Ozo Street	10	57	0.01	-1.5
Tapeliai	40	14	12.5	-15	40 Verkiu Street	8	60	0.008	-1
Juodis	28	17	8.2	-3,5	143 Kalvariju Street	10	58	0.01	-1
Skarbelelis	15	16	2.25	-10	10 Dvarcioniu Street	8	68	0.003	-0.6
Near the village of Dvarcionys	12	56	1.6	-15	87 Verkiu Street	8	72	0.002	-0.5

Detailed analysis of equivalent dose rate distribution above water reservoirs near Buivydiskes has been performed. It is noticed that towards the middle of the reservoir the equivalent dose rate decreases. Equivalent dose rate above the water close to the waterside is 30–70 nSv/h, while in the middle – 20 nSv/h. This difference stems from numerous natural factors. Firstly, the thicker the bottom of the reservoirs, the lower the gamma radiation. Gamma radiation decreases ten times when water layer reaches 0.5 m, while at 1 m depth it is less than 1% [16]. Secondly, while shifting away from the waterside towards water, the influence of soil layer (20–30 cm) radiation decreases because spatial corner decreases too, i.e., gamma radiation depends on waterside geometry and radionuclide quantity. The third reason is short lifetime of the products of radon decay in the air and unequal distribution of their quantity above the water reser-

voir.

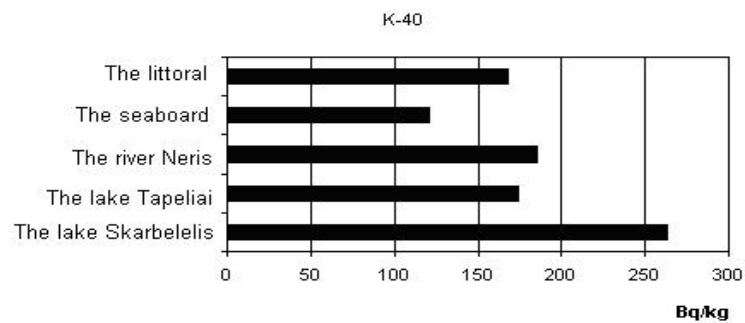
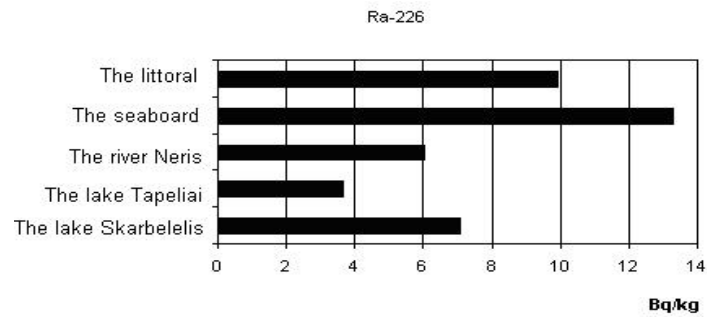
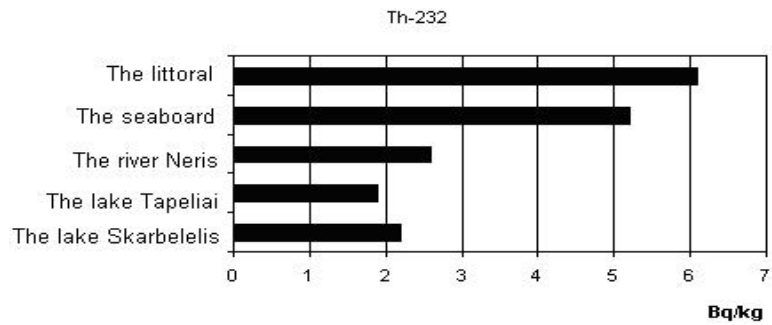
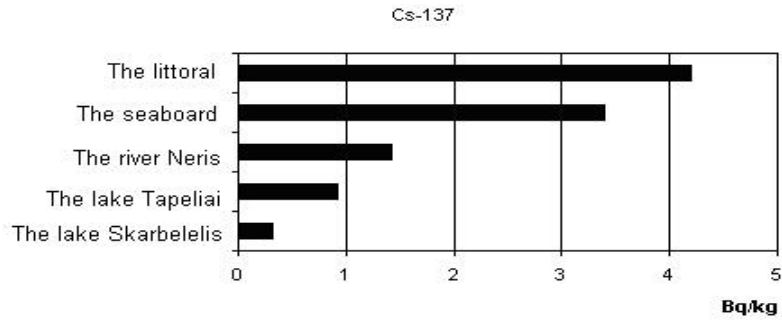


Fig. 3. Specific activity of radionuclides (Bq/kg) in bottom mud of water reservoirs

Of natural radionuclides found in soil, ^{40}K has the highest specific activity (figure 3). Figure 3 presents spectrometric measurements of radionuclides in bottom mud of some water reservoirs. The specific activity of ^{40}K and other natural radionuclides in the samples fluctuated between 0 and 300 Bq/kg. Specific activity of ^{40}K itself in different venues ranged from 0 to 300 Bq/kg. This could happen due to different mud composition and different quantities of deposits. The specific activity of artificial radionuclide ^{137}Cs fluctuated between 0 and 5 Bq/kg.

It should be stressed that the specific activity of radionuclides occurring in the soil is higher than that in the bottom mud of water reservoir. In the soil, the most common value of the specific activity of ^{40}K ranges from about 400 to 500 Bq/kg, and in bottom mud it approaches 200 Bq/kg. These values are smaller than an average specific activity of the same radionuclide in the soil of Central Europe and Lithuania [17], [18]. This can be explained as follows: the part of ^{40}K in one or another form sinks to the bottom of lake where its quantity reduces. The value of the specific activity of artificial radionuclide ^{137}Cs both in the soil and in the water reservoir bottom mud ranges between 0.1 and 5 Bq/kg.

Table 3

The coefficients of correlation between equivalent dose rate in the air close to soil surface and specific activities of radionuclides in the soil

	Equivalent dose rate (nSv/h)	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{137}Cs (Bq/kg)
Equivalent dose rate (nSv/h)	1				
^{40}K (Bq/kg)	0.66	1			
^{226}Ra (Bq/kg)	0.69	0.81	1		
^{232}Th (Bq/kg)	-0.24	0.07	0.24	1	
^{137}Cs (Bq/kg)	0.20	-0.18	-0.33	-0.86	1

The specific activity of such gamma radiation sources as ^{40}K , ^{226}Ra , ^{232}Th and ^{137}Cs in the soil and the equivalent dose rates in the air above soil surface were measured. The coefficients of correlation between specific activities of ^{40}K , ^{226}Ra , ^{232}Th and ^{137}Cs in the soil and the equivalent dose rates above the place of sample collection were established (table 3). For the soil, the coefficient of correlation between ^{40}K and ^{226}Ra specific activities is positive and equal to 0.81. The coefficients of correlation between equivalent dose rates and the specific activities of such main gamma radiators as ^{40}K and ^{226}Ra are high (coefficients of correlation testify to the interdependence of those radionuclides). Negative coefficient of correlation (-0.24) between equivalent dose rate and ^{232}Th specific activity is calculated. The coefficients of correlation between specific activity of natural radionuclides and artificial ^{137}Cs are negative and close to

zero. Particularly strong negative coefficient of correlation (-0.86) is between specific activities of ^{137}Cs and ^{232}Th . Weakly positive and statistically unreliable coefficient of correlation is detected between ^{137}Cs specific activity and equivalent dose rate in the air above the soil. No correlation coefficient was found between ^{232}Th and ^{40}K (0.07); however, this does not mean that they are absolutely independent.

According to [17], external equivalent dose rate caused by ^{40}K radiation approximately makes up 33% of the value of equivalent dose rate in the air above the soil surface. According to the investigation results, ^{40}K specific activity is about 22 times higher than that of ^{226}Ra . Besides, gamma radiation energy is higher (^{226}Ra , 186 keV; ^{40}K , 1460 keV). It is known that the major part of ^{226}Ra decay products (^{214}Pb , ^{214}Bi , ^{210}Pb) that remain in soil also affects considerably equivalent dose rate.

The coefficient of correlation between ^{40}K and ^{226}Ra specific activities is positive for the bottom mud and equal to 0.82. Within the limits of deviation the latter result coincides with the coefficient of correlation between ^{40}K and ^{226}Ra specific activities identified in the soil.

4. CONCLUSIONS

1. The method for measuring environmental equivalent dose rate is an advanced one. It enables us to continuously register equivalent dose rate and to measure location co-ordinates using GPS.

2. Equivalent dose rate evaluated ranges from 22 nSv/h on seaside to 90 nSv/h above asphalt in the Curonian Spit. The results obtained prove that the rise in the equivalent dose rate is affected by anthropogenic activity.

3. The values of the average equivalent dose rate above the soil surface exceed considerably those measured above the water surface (by about 19%).

4. The specific activities of such radionuclides as ^{226}Ra , ^{40}K , ^{232}Th and ^{137}Cs were measured in open water reservoirs in the city of Vilnius and the Curonian Spit. It is estimated that their specific activities are higher in soil than in water reservoirs bottom mud.

5. The coefficients of correlation between the specific activities of such radionuclides as ^{40}K and ^{226}Ra in the soil and the equivalent dose rates in the air above the soil surface above a sample collection place are positive; they reach, respectively, 0.66 and 0.69.

6. The coefficients of correlation between ^{137}Cs specific activity and specific activity of natural radionuclides, i.e., ^{226}Ra , ^{40}K , are negative and close to zero, whereas that between ^{232}Th specific activity and ^{226}Ra and ^{40}K specific activities is strongly negative (-0.86).

7. The coefficients of correlation between ^{40}K and ^{226}Ra specific activities in the

soil and in the bottom mud of water reservoir are positive and coincide within the limits of deviation (0.81 ± 0.08).

REFERENCES

- [1] NEDVECKAITĖ T., *Radiacinė apsauga Lietuvoje*, Mokslo ir enciklopedijų leidybos institutas, Vilnius, 1998, 22–32.
- [2] QUINDOS L.S., FERNANDEZ P.L., SOTO J., RODENAS C., GOMEZ J., *Natural radioactivity in Spanish soils*, *Health Phys.*, 1994, 66(2), 194–200.
- [3] UNSCEAR, *Sources and Effects of Ionizing Radiation*, United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, United Nations, 2000.
- [4] Latvian State of the environment report' 1997 (www.vkmc.gov.lv).
- [5] BEM H., WIECZORKOWSKI P., BUDZANOWSKI M., *Evaluation of technologically enhanced natural radiation near the coal-fired power plants in the Łódź region of Poland*, *Journal of Environmental Radioactivity*, 2002, 61, 191–201.
- [6] LIS J., PASIECZNA A., STRZELECKI R., WOLKOWICZ S., LEWANDOWSKI P., *Journal of Geochemical Exploration*, 1997, 60, 39–53.
- [7] SOHRABI M., DURRANI S.A., *High Levels of Natural Radiation, Rasmar, Iran*, IAEA, 1990.
- [8] THAMPI M.V., *Cytogenetic and epidemiological studies on newborns in the high level natural radiation areas of Kerala*, *Radiobiology 2000 – International Conference on Radiobiology*, Trivandrum, India, 2000.
- [9] Terrestrial sources of radiation:
http://resources.yesican.yorku.ca/trec/radiation/final/earth_sources.html.
- [10] ROBINS J.A., JASIŃSKI A.W., *Chernobyl fallout radionuclides in lake Śniardwy, Poland*, *Journal of Environmental Radioactivity*, 1995, 27, 13–34.
- [11] HAKANSON L.A., *Compilation of empirical data and variations in data concerning radiocesium in water, sediments and fish in European lakes after Chernobyl*, *Journal of Environmental Radioactivity*, 1999, (44), 21–42.
- [12] KONOPLEV A., KAMINSKI S., KLEMT E., KONOPLEVA I., MILLER R., ZIBOLD G., *Comparative study of ¹³⁷Cs partitioning between solid and liquid phases in Lake Constance, Lugano and Vorsee*, *Journal of Environmental Radioactivity*, 2002, (58), 1–11.
- [13] Global Positioning System: <http://www.gpsworld.com/gpsworld>.
- [14] AYCIK G.A., ERKAN A., *Radioactivity measurements of coals and ashes from coal-fired power plants in the Southwestern part of Turkey*, *Journal of Environmental Radioactivity*, 1997, (35), 23–35.
- [15] BRANDT S., *Statistical and Computational Methods in Data Analysis*, INC, New York, 1970.
- [16] *Справочник по ядерной физике*, Государственное издательство физико-математической литературы, Москва, 1963, 130–162.
- [17] KONSTANTINOVA M., BUTKUS D., *Estimation of exterior equivalent dose rate caused by natural origin gamma radiation being in soil*, *Health Sciences*, 2003, (3), 50–54.
- [18] MALCZEWSKI S., TEPER L., DORDA J., *Assessment of natural and anthropogenic radioactivity levels in rocks and soils in the environs of Świeradów Zdrój in Sudetes, Poland, by in situ gamma-ray spectrometry*, *Journal of Environmental Radioactivity*, 2004, 73(3), 233–245.

NATURALNE PROMIENIOWANIE JONIZUJĄCE W WYBRANYCH MIEJSCOWOŚCIACH
WYPOCZYNKOWYCH I REKREACYJNYCH NA TERENIE LITWY

Przedstawiono wyniki dozymetrycznych i radiometrycznych pomiarów naturalnego promieniowania jonizującego na terenie Mierzei Kurońskiej. Badania prowadzono, korzystając z przenośnego urządzenia rejestrującego wyposażonego w system GPS. Stwierdzono korelację między aktywnością promieniotwórczą radionuklidów ^{40}K , ^{226}Ra , ^{232}Th i ^{137}Cs a równoważną dawką promieniowania jonizującego w miejscach pomiarów. Zaobserwowano również korelację między aktywnością promieniotwórczą radionuklidów ^{40}K i ^{226}Ra w glebie i osadach dennych.