Influence of operation of national experimental nuclear reactor on the natural environment

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Abstract
This paper presents the impact of experimental nuclear reactor operations on the national environment, based on assessment reports of the radiological protection of active nuclear technology sources. Using the analysis of measurements carried out in the last 15 years, the trends are presented in selected elements of the environment on the Świerk Nuclear Centre site and its surroundings. In addition, the impact of research results is presented from the fifteen year period of environmental analysis on building public confidence on the eve of the start of construction of the first Polish nuclear power plant.

Introduction

Nuclear technologies rouse many emotions in Polish society. In light of the events at Chernobyl in 1986 and Fukushima in 2011 doubts and questions are raised about the safety of these technologies and their impact on the environment and people living in the vicinity of such power plants, or working at them.

In Poland a research nuclear reactor has been in operation since 1958 at the Institute of Nuclear Research in Świerk, near Warsaw. Long-term observations of the reactor's operation substantiate the determination of its impact on the environment. Monitoring, analysis of environmental measurements, and their archiving has been provided by the Radiation Measurements Laboratory, which is now part of the National Centre for Nuclear Research. Results obtained at the Laboratory are reported in this paper.

Continuous radioecological monitoring is an element of the reactor's nuclear safety and radioecological protection, and ensures its proper operation in accordance with national and international guidelines.

1. Domestic nuclear technologies

The first nuclear power programs in Poland date back to the 1950s, when development of the first nuclear power plant and the first Polish nuclear-powered ship was planned. As it is known, the project of Żarnowiec Nuclear Power Plant Under Construction has not lived to see completion, one of the reasons being the negative result of a public opinion survey.

The end of the 1950s was also the time of work on the first Polish research reactor's commissioning. On June 14, 1958 the first Polish (water experimental nuclear) research reactor, called Ewa, was commissioned. This facility enabled the development of science in the field of nuclear technology. In more than thirty years of its operation the reactor enabled: studies of material structures, application of nuclear techniques in medical diagnosis and treatment, and the search for their new industrial applications, as well numerous scientific research programmes.

In 1974 the second Polish research reactor was launched – Maria, named in honour of fellow Pole, and twice winner of the Nobel Prize, Maria Skłodowska-Curie. It is one of the eight research reactors operated in Europe with the capacity of over 15 MW and the neutron flux larger than $1{\cdot}10^{14}$ (n/cm$^2{\cdot}$s). The Maria reactor allows for the continuation of scientific research, use of radioisotopes, research of neutron beams, neutronography, neutron therapy, and activation analysis. Technical and economic factors, including the core's user-oriented configuration option, service life and operating effectiveness, as well as the facility's location far away from big cities, are the reasons for Maris's further operation. The facility is expected to operate for more than twenty years.

Operation of nuclear facilities requires an adequate level of safety and radiological protection of the country. For this purpose the Central Laboratory for Radiological Protection was set up to exercise the protection against harmful effects of ionizing radiation on the population and individuals professionally exposed to radioactive contamination. The Laboratory has over 50 years of experience in assuring proper radiological protection related to the operation of nuclear technology in the country, as well as to the impact of facilities operated beyond its borders.

2. Analysis of environmental measurement results from research in the last 15 years

The Radiation Measurements Laboratory (LPD) of the National Nuclear Research Centre as part of its statutory activities takes measurements at and provides monitoring of the centre in Świerk, resulting in the assessment of its radiological protection. As part of its research the Lab assesses: the Institute personnel's exposure to ionizing radiation, protection of the population and the environment on the site and in the surroundings of the centre in Świerk and the National Radioactive Waste Repository (KSOP) in Różan. This paper reports the results of environmental impact tests of the facilities, which are the main sources of radiation hazards at NCBJ, with particular consideration of the facilities of the Maria reactor and decommissioned Ewa reactor.

One of the nuclear facilities monitored at Świerk centre is the reactor, Maria, which in 2010 was operated for 3,803 hours at powers of 30 kW – 23 MW. In a wet storage pool on the facility site there are MR-6 type interim spent fuel storage facilities, as well as MR-6 type fresh fuel storage facilities. During the reactor operation a twenty-four hour dosimetry service is provided. At an outage inspection is conducted on the first shift, whereas during repair works in radiological emergency conditions inspection is performed on both shifts. The dosimetry service includes ongoing monitoring of areas, and of process and laboratory facilities. The service included measurements of the distribution of dose powers and radioactive contamination, inspection of the dosimetric status of control and measurement devices, and of overall and personal protective equipment. In 2010, 64 control measurements were performed of water, filters, gases, and swabs, including 40 measurements of water samples from the interim storage pool from the rector's primary and secondary circuits. Moreover, systematic measurements of fuel elements' tightness were performed in the WNEP system dedicated for this purpose.

Another monitored nuclear facility is the building of the decommissioned nuclear reactor, Ewa, along with the reloading chamber and local storage, and RK-10 type spent fuel wet interim storage facilities. In the framework of the 2010 radiological protection assessment, the internal exposure of personnel was inspected. Maria reactor's personnel were subjected to measurements of the activity of radionuclides inside human bodies taken with a whole body counter (WBC). 82 employees were inspected, while all subjects were administered a committed effective dose well below 0.1 mSv (Sv – sievert, an SI unit describing physical quantities relating to the ionizing radiation effect on living organisms, 1 Sv = J/kg).

On the site of Świerk centre, pursuant to "Radiological monitoring program on the site and in the surroundings of Świerk centre" approved by the then IEA director, the radionuclides concentration in environmental samples was measured. The environmental sampling map is shown in fig. 1.

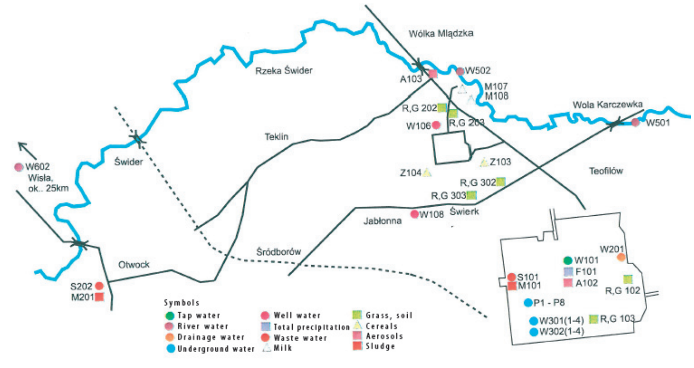

Fig. 1. Environmental sampling locations on the site and in the surroundings of Świerk centre [6]

It should be remembered that every day a man is exposed to various types of radiation. Some are perceptible to the human senses, such as: heat and light, while others are not, such as ionizing radiation from the sky, earth, air, or food. Ionizing radiation is a type of radiation that penetrates matter, changing electrical charges of electrically neutral atoms. According to its penetration capacity, ionizing radiation can be divided into: alpha particles, beta particles, gamma rays and X-rays, and neutrons. In tab. 1 radiation sources and their world-wide average doses are listed.

Radiation source	World-wide average doses, mSv
Cosmic	0.39
Gamma	0.46
Internal (from food and beverages)	0.23
Radon	1.3
Medical	0.3
Fallout	0.007
Exposure at work	0.002
Release from nuclear facilities	0.001
Manufactured goods	0.0005
Total	**2.69**

Tab. 1. List of radiation sources (based on the report of the United Nations Scientific Committee on the Effects of Atomic Radiation – UNSCEAR 1996)

Out of the above mentioned, gamma radiation is used for radiation evaluation of the environment, which reflects external exposure of people to natural and artificial sources of ionizing radiation existing in the environment or anthropogenic. Gamma radiation is highly capable of penetrating matter. Only a high-density material, such as lead or concrete, can screen off the radiation.

Safety requirements demand continuous monitoring of the radiological protection of a source and its surroundings. The centre is monitored in 22 control points, from which current protection status data is collected. Background gamma radiation control locations on the site of the Świerk centre are shown in fig. 2.
Under the control scheme of radioactive pollution of the environment the radioactivity of selected environmental elements is systematically measured, such as: atmospheric aerosols from the centre's site and surroundings, surface water from the Vistula and Świder rivers, tap (potable) water on the centre site, underground water on the centre site, well water from nearby farms, drainage/rain water flowing out from the centre site to the Świder river, or precipitation from the centre site.

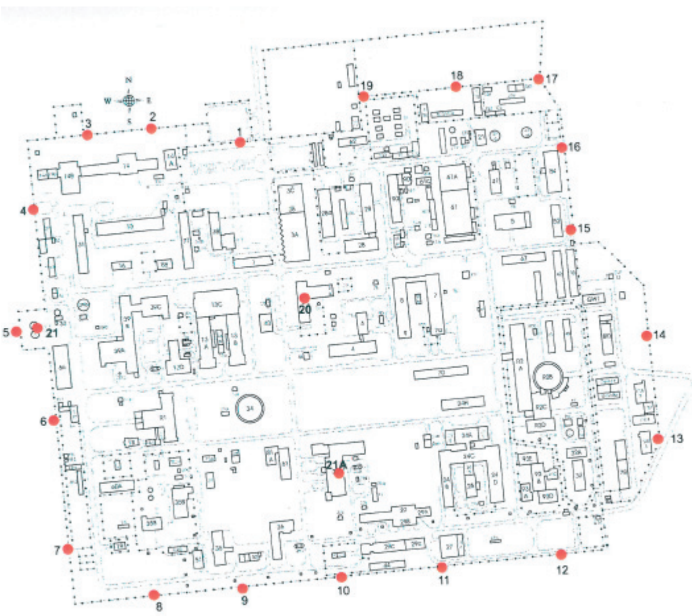

Fig. 2. Background gamma radiation control locations on the site of Świerk centre [6]

Measurements of radionuclide concentrations in environmental samples

Concentrations of natural and artificial radioactive isotopes in the main components of the environment and, consequently, in basic foods, allows assessing humans' internal exposure through oral absorption. Based on historical measurements, trends of changes in the environment resulting from the coexistence of nuclear technology with the domestic ecosystem can be observed.
The analysis was based on the findings contained in the reports of radiological protection assessment reports [6] for the last 25 years. Results from the years 1996–2010 were published, except for 1999 and 2006, for which there is no data. All values shown in fig. 3–9 are average annual values compiled on the basis of data obtained from the current monitoring.

Fig. 3 presents a chart of the total beta activity measured in rain/drainage water on the Świerk centre site in 1996–2010, drawn up on the basis of the reports [6].

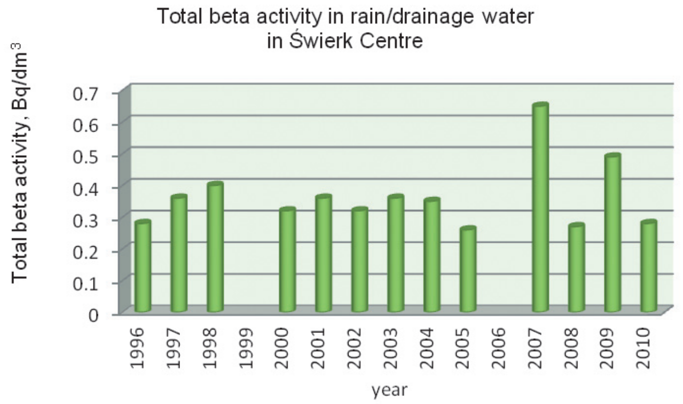

Fig. 3. Analysis of total beta activity in drainage water on Świerk centre site, on the basis of [6]

Beta particles, the total activity of which was observed in rain/drainage water, feature penetration capabilities. They can be contained by a thin layer of water, glass, or metal. They pose a threat if a radiation emitting substance has penetrated inside the human body. The radionuclide concentrations recorded in the rain/drainage waters are much lower than the limits adopted by LPD Laboratory and approved by the Nuclear Supervision [8], and in the last few years did not exceed 0.7 Bq/dm^3.

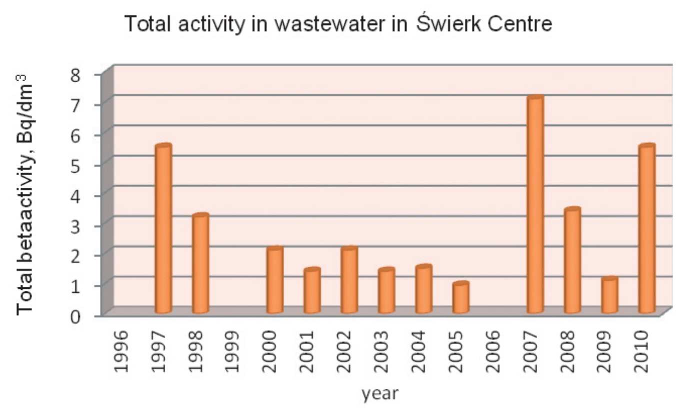

Fig. 4. Analysis of total beta activity in wastewater from Świerk centre pumping station, on the basis of [6]

In 2010, from the Świerk centre 82 700 m^3 of general wastewater were disposed of to sewerage, the equivalent total activity of which amounted to ca. 4.2 ·10^8 Bq (Bq – Becquerel, a radioactive body unit) and the average weekly activity did not exceed 0.81 ·10^8 Bq. The equivalent activity consists of the sum of total activities beta, gamma, alpha, and strontium Sr-90 activity. Fig. 4 summarizes the total beta activity in the Świerk Centre wastewater for the past 15 years, expressed in Bq/dm^3 in relation to the year .
No recorded activity exceeded the maximum permissible equivalent wastewater activity, which, in accordance with the requirements set by Regulation 08/16/1965 EK/N-2112-45/63-65 of the Minister of Health and Social Care of 16 August 1965, may not exceed weekly 2.6 ·10^9 Bq. The maximum equivalent wastewater

concentration shown in fig. 4 does not exceed 7 Bq/dm³, which is well below the guideline value from the aforementioned Regulation, where the permissible activity was determined at 3.7 kBq / dm³ .

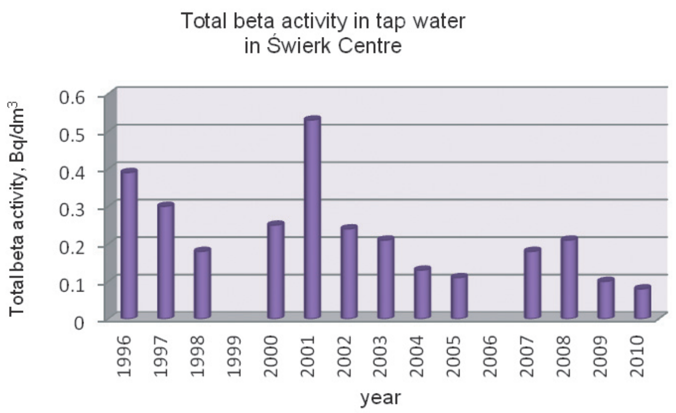

Fig. 5. Analysis of total beta activity in tap water in Świerk centre, on the basis of [6]

The figure above shows a graph of the annual average of total beta activity in tap water in the Świerk centre, which in the analysed period did not exceed 0.6 Bq/dm³. This summary was compiled on the basis of the results of analysis of total beta activity measured in tap water in the Świerk centre, based on reports for 1996–2011. Since 2001, a detrimental trend can be seen in the total annual average of beta activity. For example, the 2010 maximum did not exceed 0.08 Bq/dm³ .

Under the protection assessment scheme the radionuclide concentrations in waters of the Świder and Vistula rivers were analysed. Historical data, as in the case of tap water, show a downturn trend of the annual average total beta activity in river waters near the Świerk centre, starting from 2000, as shown in fig. 6. A similar total beta activity variability can be seen in the Vistula River waters. In both cases, the measured values do not exceed 0.35 Bq/dm³ throughout one year.

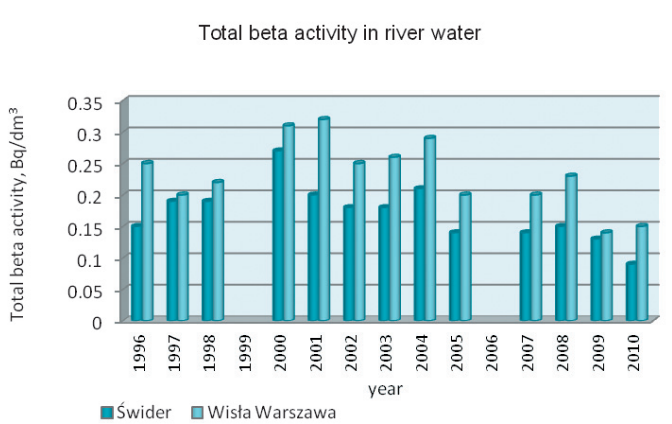

Fig. 6. Analysis of total beta activity in river water on Świerk centre site, on the basis of [6]

Air condition is assessed by measuring instantaneous radiation values, among other criteria. It should be noted that gamma radiation includes cosmic and earth radiation, which originates from radionuclides contained in the surface layer of soil. The recorded air pollution with artificial isotopes was mainly caused by the presence of the following isotopes: caesium Cs-137 (activity 0.1 – ca. 14.6 µBq/m³ in 2010), beryllium Be-7 and radon Rn-222. Specific activities of the beryllium and radon isotopes amounted to several milibecquerels and becquerels per cubic metre, respectively. Below, in tab. 2 the annual average concentration of Cs-137 in the air in Poland is presented, and in fig. 7 and 8 the specific activities of Be-7 aerosols on the site of the Świerk centre and in its surroundings.

year	concentration [µBq/m³]
1990	5.75
1991	5.5
1992	5
1993	4.75
1994	3.75
1995	2.25
1996	2.125
1997	1.5
1998	1.6
1999	1.5
2000	1.4

Tab. 2. Annual average Cs-137 concentration in the air in Poland [1]

The summary of measurements in tab. 2, in the example of the decade 1990–2000, presents a systematic reduction in Cs-137 concentration in the air in Poland. Similar conclusions for the 1996–2010 analysis period can be drawn on the basis of the analysis of specific activity of aerosols, in the example of beryllium-7, both on the site of the Świerk centre and in its surroundings. Fig. 7 and 8 show an upward trend from 2000 to 2008, but in the last 3 years the trend has been declining. Data collected on the basis of reports of radiological protection assessment show that in the analysed period the specific activity did not exceed 5,000 µBq/m³ and 8,000 µBq/m³ in the centre's surroundings and on its site, respectively.

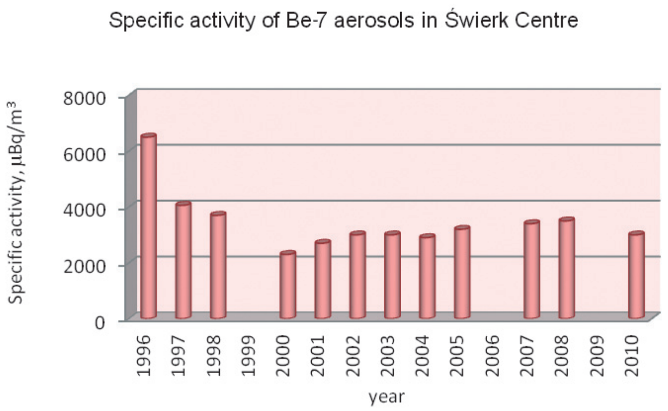

Fig. 7. Analysis of radionuclide concentrations in aerosols on the Świerk centre site

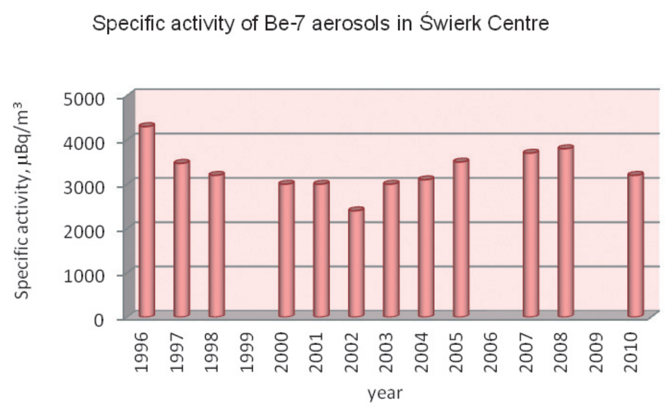

Fig. 8. Analysis of radionuclide concentrations in aerosols in Świerk centre surroundings

Based on the collected data, it appears that the radionuclide concentrations in the tested environmental elements in the centre surroundings have not changed in comparison with the past. In addition, a summary of the assessment of the environmental impact of domestic research reactors operations is in the 2010 report [6], which contains the following statement: "radioactive substance concentrations in the environment on the site and in the surroundings of the Świerk centre generally do not differ from the levels recorded in the reference points and other controlled locations. No negative impact of Świerk centre's nuclear and isotopic facilities on the surrounding environment was ascertained".

In the planned nuclear power plant the Radiation Measurements Laboratory's role will be taken over by an environmental and radiological protection department, the structure of which will accommodate a chemical laboratory of the primary and secondary circuit, environmental measurements laboratory, and a complex of radiological protection labs and facilities, and equipment that assures safe work in conditions of the nuclear plant's normal and emergency operations, as well as at fuel reloading.

3. Ecological aspects as asocial factor of the domestic nuclear power generation development

Like any investment, a capex project in the energy sector should create a positive financial flow in the long term. However, the economic and technological reasons may not be comparable to sociological factors. The events at Chernobyl and Fukushima have significantly violated the sense of security of Polish citizens with regard to the operation of nuclear units on Polish territory. The example of the Swedish social campaign for the launch of a radioactive waste repository shows how long-term the process of building trust and positive public opinion is. Only appropriate marketing activities, supported by reliable knowledge, can convince of the safety of nuclear facility operations. The test results reported here show that it is possible to safely operate an experimental nuclear facility in the Polish realities, allowing the development of nuclear science and industry, and at the same time inspiring the hope that the same will be accomplished in the planned energy facility – a nuclear power plant.

In the development of the first Polish nuclear power plant it is worth leveraging on the knowledge of communication with the general public worked out and gathered, for instance, during the construction of the Sizewell B nuclear power station in the UK, which began operation in 1995, and new projects such as the construction of a nuclear power unit in Hinkly Point C and C Sizewell. Already at an early planning stage the local community is involved in the project consultation. It has the knowledge and awareness of the project development process and the opportunities that entails the construction of the power station as an industrial plant. Awareness of the risks and the high level of nuclear safety is instilled from childhood to the population living in the facility's surroundings, which affects building of social trust. Omission in the process of introducing nuclear power to the national energy system of such an important factor as the human factor could lead to re-suspension of the Polish plan to build a nuclear power plant, huge financial losses, and arrested development of the Polish energy sector.

Summary

The results of the monitoring of radiological protection of the operated nuclear technologies reported here, as well as the lack of emissions of sulphur and nitrogen oxides, particulate matter and toxic and carcinogenic chemicals, are arguments in favour of the construction of nuclear power plants in Poland. From the environmental point of view it is also confirmed with data from the ExternE-Pol study of the European Union presenting a comparison of the green house emissions at electricity generation from various primary energy carriers, presented in fig. 9. Among comparable carriers, hard coal and lignite have undoubtedly the largest environmental impact (first three bars), followed by gas. Interestingly, even renewable energy sources utilizing forces of nature, such as water, wind and biomass, emit carbon dioxide CO_2. In this context, nuclear technologies look very favourable.

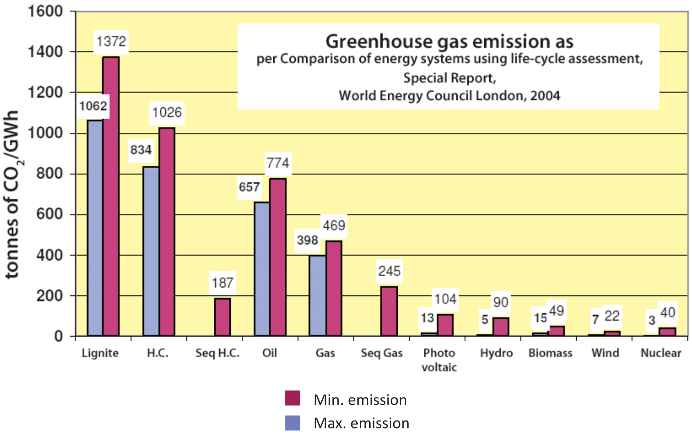

Fig. 9. Comparison of greenhouse gas emissions at electricity generation from various primary energy carriers

This paper was written as a result of a scientific internship at the then Institute of Atomic Energy POLATOM in Świerk (now National Centre for Nuclear Research, NCBJ) and collection of material for the doctoral dissertation "Analysis of determinants of the development of gas and gas-steam systems against the background of the domestic nuclear power sector".

REFERENCES

1. Atomistyka oraz bezpieczeństwo jądrowe i ochrona radiologiczna w Polsce w 2000 roku, Chairman of the National Atomic Energy Agency, Warsaw 2001.
2. Bezpieczeństwo jądrowe i ochrona radiologiczna, *Newsletter of the National Atomic Energy Agency*, Warsaw 2008, Issue 2 (72).
3. Bezpieczeństwo radiacyjne, National Atomic Energy Agency, Warsaw 2000.
4. Bouble R.W. et al., Fundamentals of Air Pollution, California 1994.
5. Bezpieczeństwo jądrowe i ochrona radiologiczna, *Newsletter of the National Atomic Energy Agency*, Warsaw 1997, Issue 1–2.
6. Filipiak B. et al., Ocena stanu ochrony radiologicznej na terenie i w otoczeniu ośrodka jądrowego w Świerku oraz Krajowego Składowiska Odpadów Promieniotwórczych w Różanie, IEA POLATOM, Radiation Measurements Laboratory, set of 25 reports from 1986–2010.
7. Program polskiej energetyki jądrowej, draft, Warsaw, 16 August 2010.
8. Filipiak B., Mlicki K., Nowicki K., Limity substancji promieniotwórczych wód deszczowo-drenażowych odprowadzanych do rzeki Świder oraz metodyka monitorowania tych wód, The Andrzej Soltan Institute for Nuclear Studies (IPJ) , Świerk 1995.

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