REPORT
ON NUCLEAR AND RADIATION SAFETY IN UKRAINE FOR 2021

State Nuclear Regulatory Inspectorate of Ukraine

Dear Readers!

Today, nuclear energy plays a leading role in ensuring energy safety, economic stability and development of the state. The current system for state safety regulation of nuclear energy use in Ukraine is functioning and being developed in accordance with the requirements of the law, taking into account international safety standards, recommendations of international organizations and best world practices.

Ensuring an appropriate level of nuclear and radiation safety in the course of activities in nuclear energy use is determined by meeting fundamental safety principles and implementation of the safety culture at all levels among entities, state administration and regulatory bodies, and other parties involved.

Independence, institutional stability of state safety regulation of nuclear energy use is a guarantee of proper state control over compliance with nuclear and radiation safety requirements on the territory of our country, observance of the constitutional right of Ukrainian citizens for safe living conditions, as well as ensuring a worthy contribution of Ukraine to the support of international safety regimes.

In 2021, important regulatory decisions were made that had a significant impact on ensuring the sustainable and safe operation of the nuclear energy system, in particular, on the possibility of safe long-term operation for Zaporizhzhia NPP Unit 5. Moreover, based on the results of the periodic safety review, the possibility of further safe operation was confirmed for Rivne NPP Unit 2 and Zaporizhzhia NPP Unit 6 at the power levels determined in the design of these power units.

Construction and commissioning of a new nuclear facility - Dry Spent Fuel Storage Facility (ISF-2) was completed at the Chornobyl NPP. The State Nuclear Regulatory Inspectorate of Ukraine issued a license for the operation of ISF-2. The storage facility is designed for acceptance, preparation for storage and long-term storage (within 100 years) of spent nuclear fuel accumulated during ChNPP operation.

In addition, the Chornobyl NPP was issued a license for operation of the confinement system and the Shelter after completion of the stage of trial and commercial operation of the New Safe Confinement start-up package 1. The operation of the system is aimed at transformation of the Shelter into an environmentally safe system, management of radioactive waste that will be generated during these activities, ensuring safety of personnel, the public and the environment.

Measures were also taken in the area of safety improvement for spent nuclear fuel, radioactive waste management facilities, uranium plants, and the use and production of radiation sources. In particular, the Skhidny Mining and Processing Plant was issued a license for uranium ore mining at the Inhulska, Smolinska, and Novokostiantynivska mines.

More details on important events and measures to improve nuclear and radiation safety in Ukraine you can find at the pages of the Report.

We express our gratitude to everyone who took part in the preparation of the materials, we propose sending your feedback, suggestions and comments to: pr@snriu.gov.ua.

Sincerely yours,
Acting Chairman – Chief State Inspector for Nuclear and Radiation Safety of Ukraine
Oleh Korikov

TABLE OF CONTENTS

I. STATE REGULATION OF NUCLEAR AND RADIATION SAFETY (RULE-MAKING)

State regulation of nuclear and radiation safety provides, in particular, the establishment of regulatory criteria and requirements that determine conditions for nuclear energy use (rule-making).

The nuclear legislation system of Ukraine includes, besides legislative acts, regulations of the Cabinet of Ministers of Ukraine that establish the mechanism for the implementation of laws and procedure for activities in the area of nuclear energy (without technical aspects).

In 2021, activities were continued to improve the national legislation, standards and rules on nuclear energy use, taking into account new challenges, international experience, up-to-date approaches to safety regulation, recommendations of the International Atomic Energy Agency (hereinafter referred to as the IAEA), Western European Nuclear Regulators Association (hereinafter referred to as the WENRA), European Nuclear Safety Regulators Group (hereinafter referred to as the ENSREG).

SNRIU legislative activities were carried out in accordance with the Plan of Legislative Work of the Verkhovna Rada of Ukraine for 2021 approved by the Resolution of the Verkhovna Rada of Ukraine No. 1165 of 2 February 2021. In particular, the Cabinet of Ministers of Ukraine submitted the following draft laws to the Verkhovna Rada of Ukraine:

On Amendments to the Law of Ukraine “On Licensing Activities in Nuclear Energy Use” (registration No. 6425 dated 13 December 2021). The Draft Law envisages improvement of the procedure for issuing permits to perform activities in nuclear energy use;

On Amendments to the Law of Ukraine “On Nuclear Energy Use and Radiation Safety” (registration No. 5860 dated 20 August 2021). The Draft Law was developed to improve the terms in nuclear energy use, taking into account the legislation of the European Union (hereinafter referred to as the EU), as well as to bring some provisions of the Law of Ukraine “On Nuclear Energy Use and Radiation Safety” in line with the EU legislation, legislative standards, taking into account the practice of applying the Law.

In 2021, a number of regulatory documents were approved by the Government. In particular, Resolution of the Cabinet of Ministers of Ukraine No. 773 dated 28 July 2021 amended paragraph 6 of the Technical Specifications for packaging for storage and disposal of radioactive waste.

Resolution of the Cabinet of Ministers of Ukraine No. 1075-r of 8 September 2021 established a Commission for Action Coordination of participants of the state interaction plan between central and local executive authorities in the event of sabotage against nuclear facilities, nuclear materials, other radiation sources during their use, storage or transport, as well as against radioactive waste during its management, and determined general coordination of the participants' actions.

In addition, SNRIU continued implementing the European Union legislation on safety of nuclear energy use in the areas defined in Article 342 and Appendix XXVII-B, part “Nuclear Energy” of the Association Agreement between Ukraine, on the one part, and the European Union, the European Atomic Energy Community and their member states, on the other part.

Activities were continued on the next step in implementation of Council Directive 2013/59/Euratom dated 5 December 2013 laying down basic safety standards for protection against the dangers arising from the effects of ionizing radiation and involved implementation of the Action Plan for Establishing the Unified State System for Accounting and Control of Individual Doses, which is Appendix 1 to Cabinet Resolution No. 1141 “Some Issues in Establishing the Unified State System for Accounting and Control of Individual Doses” dated 18 November 2020 (establishment of a unified state system for accounting and control of individual doses that reflects the basic radiation protection principles set forth in the Directive).

In the area of safety of nuclear facilities (hereinafter referred to as NF), the Requirements for NPP Safety Assessment in terms of external natural impacts were approved and put into effect. They detail and specify the requirements for NPP safety assessment in terms of external natural impacts established in the General Safety Provisions for NPPs and Requirements for NPP Safety Assessment.

In order to establish detailed requirements for the scope, content, development, revision and support of emergency documents and justification materials and to bring national legislation in terms of requirements for NPP emergency documents into compliance with a number of WENRA reference levels, the Requirements for NPP Emergency Documents were approved and put into effect.

At the same time, two regulatory documents on safety of uranium ore mining and processing were approved and put into effect:

General Radiation Safety Provisions for Mining and Processing of Uranium Ores;

On Amendments to Certain Regulatory Documents on Mining, Processing of Uranium Ores, which amended accordingly the Safety Requirements and Conditions (Licensing Conditions) for Processing of Uranium Ores, Requirements for the Annual Radiation Safety Report on Uranium Ore Processing and Requirements for Frequency and Content of Reports Provided by Licensees in Nuclear Energy Use

In order to specify the existing NRS requirements in terms of investigation and accounting of operational events, establish requirements for accounting, informing procedure, organize and conduct investigation of NPP operational events in Ukraine, as well as harmonize national standards and rules on nuclear and radiation safety (hereinafter referred to as NRS) with updated WENRA reference levels for operating reactors and with IAEA international safety standards, the Provisions on the Procedure for Investigation and Accounting of NPP Operational Events were approved and put into effect.

To bring the terms in line with the requirements of the legislation and some provisions of regulatory documents on physical protection, as well as to regulate the issue of information management on physical protection of nuclear facilities, nuclear materials, other radiation sources, access to which is restricted, the Amendments to Certain Regulatory Documents of the State Nuclear Regulatory Inspectorate of Ukraine on Physical Protection, which amended the Requirements for Restricted Areas, Control and Management of Access to Restricted Areas and the Rules for Physical Protection of Nuclear Facilities and Nuclear Materials were approved and put into effect.

II. SAFETY OF NUCLEAR FACILITIES

Regulatory Support to Operational Safety of NPP Units and Their Long-Term Operation

15 NPP units are operated in Ukraine, of which 13 are VVER-1000 and 2 are VVER-440. The share of electricity produced at NPPs is more than 50% of the total amount of electricity in Ukraine.

The operator of all operating NPPs in Ukraine is State Enterprise "National Nuclear Energy Generating Company Energoatom" (hereinafter referred to as Energoatom).

In accordance with the requirements of the Law of Ukraine "On Nuclear Energy Use and Radiation Safety" and the provisions of the Convention on Nuclear Safety, the operating organization ensures stable and safe NPP operation. In addition, in accordance with the requirements of national standards and rules on NRS, IAEA recommendations, the operating organization should systematically implement measures to improve safety of existing NPPs also taking into account many years' experience and international practice.

Operational safety of NPP units is improved by Energoatom through implementing the measures envisaged by the Comprehensive (Integrated) Safety Improvement Program for NPPs (C(I)SIP) approved by Resolution of the Cabinet of Ministers of Ukraine No. 1270 on 7 December 2011.

In accordance with this Resolution, the operating organization develops and agrees annual schedules for implementing safety improvement measures for power units with the Ministry of Energy of Ukraine, SNRIU and State Emergency Service. The program is developed until 2023 and includes 1295 measures. Within the regulatory support of C(I)SIP, SNRIU already approved reports on implementing 1063, which is ~ 82%. A total of 232 measures remain to be taken.

Control of implementing C(I)SIP measures is provided through:
consideration and approval of annual schedules of implementing C(I)SIP measures with determining their deadlines;
consideration of quarterly reports on implementing C(I)SIP measures and control of compliance with the deadlines;
control of the scope of C(I)SIP measures planned for implementation before scheduled outage of Ukrainian NPP units;
control of implementing planned C(I)SIP measures during kick-off meetings before the start-up of Ukrainian NPP units after scheduled outage with core refueling;
control of the actual scope and quality of implementing C(I)SIP measures during inspections by SNRIU inspectors.

The schedule for 2021 planned to implement 78 C(I)SIP measures, from which 26 C(I)SIP measures were not completed and postponed by the operating organization to the next years due to insufficient financial resources required for their implementation

Within the regulatory support of C(I)SIP, SNRIU approved reports on the implementation of 66 measures.

In 2021, Ukrainian NPP units implemented measures to qualify power unit equipment, instrumentation during and after accidents, implement the forced pressure relief system from the gas purification system, ensure seismic resistance of systems and civil structures, develop the seismic probabilistic safety analysis, and others, which are also provided by the National Action Plan upon the stress test results.

Ukraine once joined the European initiative to conduct stress tests for NPPs in EU member states and neighboring countries (Declaration on Stress Tests). Stress tests for Ukrainian NPPs were carried out in accordance with the methodology to conduct stress tests for European NPPs agreed by the European Commission and ENSREG (13 May 2011, Declaration of ENSREG, Annex 1 "EU Stress Test Specifications").

In 2021, the current status of implementing safety improvement measures was clarified, as well as deadlines for implementing certain individual measures of the National Action Plan determined based on the stress test results and schedules for their implementation at NPPs, which were updated in accordance with ENSREG requirements.

Long-Term Operation of NPP Units

Long-term operation of an NPP unit is the calendar duration of NPP unit operation, which is determined upon the results of assessing its technical condition, maintenance and repair and is confirmed by the results of the periodic safety assessment for a period exceeding the period established in the power unit design.

By the end of 2021, long-term operation is provided for 12 NPP power units out of 15, the table provides the information on the design lifetime and long-term operation.

NPP	Unit	Reactor	Expiration of design lifetime/long-term operation
ZNPP	1	VVER-1000/320	23 December 2015/23 December 2025
	2	VVER -1000/320	19 February 2016/19 December 2026
	3	VVER -1000/320	5 March 2017/5 March 2027
	4	VVER -1000/320	4 April 2018/4 April 2028
	5	VVER -1000/320	27 May 2020/27 May 2030
	6	VVER-1000/320	21 October 2026
PNPP	1	VVER-1000/302	2 December 2013/2 December 2023
	2	VVER-1000/338	12 May 2015/31 December 2025
	3	VVER-1000/320	10 February 2020/10 February 2030
RNPP	1	VVER-440/213	22 December 2010/22 December 2030
	2	VVER-440/213	22 December 2011/22 December 2031
	3	VVER-1000/320	11 December 2017/11 December 2037
	4	VVER-1000/320	7 June 2035
KhNPP	1	VVER-1000/320	13 December 2018/13 December 2028
	2	VVER-1000/320	7 September 2035

Table. Information on the design lifetime and long-term operation

In general, the main attention in the current year in the area of regulatory support for nuclear facility safety was focused on the preparation for long-term operation and periodic safety review of Pivdennoukrainsk NPP Unit No. 1 (in accordance with the requirements of the state language standards and Ukrainian spelling rules, Energoatom Order No. 01-228-n of 21 April 2022 "On Changing the Name of Separate Entity "South-Ukraine NPP" renamed Energoatom Separate Entity "South-Ukraine NPP" into Energoatom Separate Entity "Pivdennoukrainsk NPP" (PNPP)), as well as on the regular periodic safety review of Rivne NPP Unit No. 2 and Zaporizhzhia NPP Unit No. 6. At the same time, on 5 January 2021, a license was issued for activities at the life stage "operation of a nuclear facility" for ZNPP-5.

Preparation for Long-Term Operation of PNPP-1

In 2013, PNPP obtained a license for long-term operation of Unit No. 1 with a subsequent safety review in 10 years, namely, 2 December 2023.

In April 2021, the Program for Implementing Measures to Justify the Possibility of Further Operation of Pivdennoukrainsk NPP Unit No. 1 during the Period of Long-Term Operation. PM.1.3812.0263 was agreed.

The program provides a set of activities to assess the technical condition of unit systems and components, extend their service life, manage aging, implement safety improvement measures, and develop the periodic safety review report of the power unit. In 2021, the state NRS review of PSRR materials for PNPP-1 was started, namely, the results of assessing the safety factors:

NPP Unit Design;

Operational Safety;

Operational Documents;

Human Factor.

In accordance with the Schedule for Periodic Safety Review of PNPP-1, the completion of the state NRS review of the indicated documents, as well as the state NRS review of the results of assessing the remaining ten safety factors, is scheduled for 2022. The state NRS review of the Comprehensive Safety Analysis for PSRR of PNPP-1 is scheduled for the period from November 2022 to March 2023.

The deadline for completion of the periodic safety review for PNPP-1, taking into account consideration of the full set of PSRR materials by SNRIU, is 30 September 2023.

Safety Review of NPP Units

In order to meet the requirements of Article 33 of the Law of Ukraine "On Nuclear Energy Use and Radiation Safety", General Safety Provisions of Nuclear Power Plants, Requirements for Safety Assessment of Nuclear Power Plants, Requirements for Periodic Safety Review of Nuclear Power Units, Energoatom conducts periodic safety review of NPP units and develops periodic safety review reports based on the results. The work on safety review of the operating NPP units of Ukraine is performed by the operating organization in accordance with the Summary Schedule for Periodic Safety Review of Ukrainian NPP Units and Detailed Schedules for Periodic Safety Review of Each NPP Unit agreed with SNRIU.

Safety Review of RNPP-2

According to the valid license to perform activities at the stage of life cycle "operation of RNPP-1, 2 nuclear facilities", the deadline for the periodic safety review for RNPP-2 is until 14 June 2021.

In 2021, the state NRS review of the full set of PSRR components for RNPP-2 was conducted. The SNRIU Board Ordinance approved the Conclusion of the State Review on Nuclear and Radiation Safety based on the PSRR materials for RNPP-2 and the possibility of further safe operation for RNPP-2 was recognized as justified at the capacity levels indicated in the design until 22 December 2031.

Safety Review of ZNPP-6

According to the valid license to perform activities at the stage of life cycle "operation of ZNPP nuclear facility", the operating organization ensures that safety review of power units is carried out in accordance with the requirements of current regulations in accordance with the schedules agreed with SNRIU. The "Detailed Schedule for Periodic Safety Review of ZNPP-6" establishes the deadline for the completion of the periodic safety review for Unit No. 6 and approval of the full set of PSRR materials by SNRIU – 28 December 2021.

The state NRS review of the full set of PSRR components for ZNPP-6 was conducted. The SNRIU Board Ordinance approved the Conclusion of the State Review on Nuclear and Radiation Safety based on the PSRR materials for ZNPP-6 and the possibility of further safe operation for ZNPP-6 was recognized as justified at the capacity levels indicated in the design until the expiration of the design unit lifetime until 21 October 2026.

Aging Management of NPP Unit Structures and Components

According to the General Requirements for the Aging Management of Components and Structures and Long-Term Operation of NPP Units, the development and implementation of aging management programs is a necessary condition for safe long-term operation of NPP units.

Aging management programs have been developed for all power units of Ukrainian NPPs. SNRIU controls the status of implementing their measures.

Within implementing the Association Agreement between Ukraine, on the one hand, and the European Atomic Energy Community and their Member States, on the other hand, the first thematic peer review on aging management was carried out. In 2019, the National Action Plan for Aging Management (Ukraine) was developed, and in 2021 – the Updated National Action Plan for Aging Management (Ukraine) was developed presenting the results of the activities performed and clarification of plans for the future period

Construction of New Nuclear Facilities

Safety regulation of construction and commissioning of new nuclear facilities is provided by performance of a state review and approval of technical specifications for systems and equipment, test programs for systems and equipment important to nuclear facility safety, safety analysis reports, operational and technical documents of nuclear facilities (technological procedures, operating manuals, etc.), participation in testing of systems and equipment important to nuclear facility safety, and issuance of authorizing documents.

In 2021, the following nuclear facilities were under construction:

ChNPP dry spent nuclear fuel storage facility (ISF-2) designed for long-term (within 100 years) storage of all Chornobyl nuclear fuel;

Centralized dry spent nuclear fuel storage facility (CSFSF) designed for long-term (within 100 years) storage of RNPP, KhNPP and PNPP nuclear fuel;

“Neutron Source based on a subcritical assembly driven by a linear electron accelerator” nuclear subcritical facility (Neutron Source);

KhNPP-3; 4.

ChNPP Dry Spent Fuel Storage Facility

On 23 April 2021, ChNPP obtained a license to carry out activities at life stage “operation of a nuclear facility - dry spent fuel storage facility (ISF-2)”. This decision was made upon:

Conclusion of the state review on nuclear and radiation safety of ChNPP document “Dry Spent Fuel Storage Facility (ISF-2). Final Safety Analysis Report. NI-2210110, rev.1” approved by SNRIU Board Ordinance No. 03 of 22 April 2021;

Certificate of Survey No. AIO-36/15-19 of 9 April 2021 performed by SNRIU from 22 March 2021 to 2 April 2021 to determine the ability and preparedness of the applicant (ChNPP) to conduct the declared activities.

As of the end of 2021, 1,644 spent fuel assemblies were transported to ISF-2, of which 1,581 are packaged in 17 double-wall dry shielded canisters and placed in concrete storage modules for long-term storage.

KhNPP-3, 4

SNRIU, on behalf of the Cabinet of Ministers of Ukraine, reviewed and commented the draft Law of Ukraine “On Siting, Design and Construction of Khmelnytsky NPP Units No. 3 and No. 4”.

In 2021, the state NRS review of Energoatom documents on the work performed on topic “Updating the Survey and Confirmation of the Durability and Reliability of Civil Structures, Buildings and Structures of KhNPP-3, 4” was carried out.

“Neutron Source Based on a Subcritical Assembly Driven by a Linear Electron Accelerator” Nuclear Subcritical Facility

In accordance with the arrangements made at the Washington Summit, set out in the Joint Statement of the Presidents of Ukraine and the United States in April 2010, and the Memorandum of Understanding between the Governments of Ukraine and the United States of America on Cooperation in Nuclear Safety Issues signed on 26 September 2011, the Neutron Source is being constructed in the National Science Center “Kharkiv Institute of Physics and Technology” (KIPT).

The project is being implemented under support of the U.S. Argonne National Laboratory. The Neutron Sources is designed for scientific and applied research in nuclear physics, radiation materials science, biology, chemistry and production of medical radioisotopes.

On 19 August 2021, the last fuel assembly provided for by the initial startup program of the Neutron Source was loaded into Neutron Source core. Thus, loading of nuclear fuel into the Neutron Source core established by the initial startup program can be considered completed.

The operating organization, NSC KIPT, needs to:

provide revision according to the comments of the state review of reporting documents on the initial startup results;

fulfill conditions of individual permit No. EO 001018/2/15 dated 1 July 2020;

prepare and approve documents in accordance with the list of documents attached to the application for issuing an individual written permit for Neutron Source pilot and commercial operation approved by SNRIU (letter No. 15-24/08/7895-7386 of 26 June 2019).

Centralized Spent Nuclear Fuel Storage Facility

Activities on the construction of the centralized storage facility for spent fuel of VVER RNPP, KhNPP, PNPP, which is constructed using the Holtec International technology, are carried out in accordance with the conditions of the license to conduct “construction and commissioning of a nuclear facility: spent fuel storage facility (CSFSF)” issued by SNRIU on 29 June 2017.

In 2021, Energoatom continued to develop and approve, according to the established procedure, sets of technical specifications and design documents for systems and equipment important to safety.

As of the end of the year, in accordance with the CSFSF Licensing Plan, the following were agreed: 6 terms of references for manufacturing CSFSF systems and components (3 - in 2021); 17 test programs for equipment important to safety out of 17 developed according to the project; 16 technical specifications for equipment important to safety out of 17 developed under the project (6 in 2021).

As of 31 December 2021, the state review on nuclear and radiation safety was performed and the Conclusions of the following projects were provided to State Enterprise “Ukrderzhbudekspertyza”: modifications of RNPP and KhNPP units in order to introduce the Holtec International technology for fuel management at power units;

Reconstruction of the railway section from the. Vilcha station to the Yaniv station in the exclusion zone of the Ivankiv district of the Kyiv region";
Access railroad track from the Vilcha – Yaniv existing railway line to the construction site of the centralized spent fuel storage facility CSFSF (New construction). Correction;
Reconstruction of the bridge across the Uzh river near the former Cherevach village in the exclusion zone of the Ivankiv district, Kyiv region;
Reconstruction of the bridge across the forest river near the former Zalissia village in the exclusion zone of the Ivankiv district, Kyiv region.

Activities were continued on manufacturing, testing (with the participation of regulatory body representatives) and supply of basic equipment important to safety, as well as on the modernization of SNF management systems at NPPs in order to introduce containers into the handling schemes for SNF management, which are provided in the CSFSF design.

At the end of the year, the implementation of the modification projects for RNPP, KhNPP and PNPP units as part of their preparation for SNF unloading using equipment developed according to the Holtec International technology was not completed

In February 2021, based on the results of the survey conducted by SNRIU from 27 January to 29 January 2021, a decision was made to amend the license in terms of supplementing the list of positions in which performance of organizational and administrative functions related to CSFSF nuclear and radiation safety is possible only if there is an SNRIU license obtained according to the established procedure.

According to the special conditions of the current license, Energoatom may start CSFSF commissioning after obtaining an SNRIU individual permit according to the established procedure.

Westinghouse Nuclear Fuel

Until 2005, all nuclear fuel used at NPP units was exclusively of Russian production. In order to avoid dependence on a monopoly supplier and diversify nuclear fuel sources, Ukraine has started licensing (qualification) of nuclear fuel produced by Westinghouse.

Safety regulation of Westinghouse fuel implementation at Ukrainian NPPs is carried out through the state NRS review and approval of documents of the operating organization on safety justification for the use of Westinghouse fuel and modification of other systems important to safety, which are necessary for this fuel management.

As of the end of 2020, the operation of Westinghouse nuclear fuel was continued in the cores of 6 power units of Ukrainian NPPs: PNPP-2, PNPP-3, ZNPP-1, ZNPP-3, ZNPP-4 and ZNPP-5, the cores of these units are loaded exclusively with Westinghouse nuclear fuel.

In 2021, justification materials for the possibility of Westinghouse fuel operation at RNPP-3 and conceptual technical solution for the introduction of Westinghouse VVER-440 fuel assemblies at RNPP- 2 were considered.

Spent Nuclear Fuel Management Facilities

In the NPP process cycle, one of its important components is management of spent nuclear fuel (SNF) generated during operation of power units.

During SNF management, it is necessary to consider the factors determined by this material specifics: high level radioactivity and presence of valuable components in SNF (uranium, plutonium).

In Ukraine, as in most countries, a "deferred decision" was introduced, which provides long-term SNF storage. This approach will allow making a decision on the NFC final stage later, taking into account the development of technologies in the world and economic benefits for the state.

Operation of ZNPP Dry Spent Fuel Storage Facility

The dry spent fuel storage facility (DSFSF) is operated at the ZNPP site. The DSFSF project was developed upon the licensed and repeatedly tested SNF storage technology of the Duke Engineering & Services (USA). The principle of SNF storage is as follows: 24 fuel cartridges with low energy release (<1 kW) after 5 years of storage in SFP are placed in a special basket, filled with helium (inert gas with high thermal conductivity) and sealed, then the basket is placed in a concrete ventilated storage cask (VSC).

The storage facility is designed for 380 VSC, in which 9000 cartridges with SNF can be placed (DSFSF Stage 1 with a capacity of 100 VSC was commissioned in 2001, and Stage 2 with a capacity of 280 VSC - at the end of 2011).

During 2021, SNRIU considered and agreed 4 technical solutions "On the content of loading multiplace sealed baskets with spent nuclear fuel".

As of the end of 2021, there are 173 ventilated concrete casks at the DSFSF site.

Operation of ChNPP ISF-1

ISF-1 is operated in accordance with the conditions of the SNRIU license to conduct activities at life stage "operation of a nuclear facility: spent fuel storage facility" of 25 June 2008. On 21 April 2021, amendments were made to this license, which concerned:

a) inclusion of position deputy technical director (for infrastructure) in the "List of ChNPP officials, whose official duties include organizational and administrative functions related to nuclear and radiation safety, whose activities can only be carried upon licenses,

b) inclusion of an additional condition for obtaining individual permits for the following activities and operations:

unloading of conditioned spent nuclear fuel from ISF-1;

unloading of damaged nuclear fuel from ISF-1.

On 21 May 2021, an individual permit was issued to ChNPP for unloading of conditioned spent nuclear fuel from the spent nuclear fuel storage facility (SNF-1). On the basis of the individual permit, in 2021, the release of ISF-1 from conditioned SNF was started.

In addition, in 2021, ChNPP implemented measures aimed at eliminating deviations from the requirements of new regulation "Safety Requirements for Nuclear Fuel Management" and measures for long-term operation of SNF of this storage facility.

Analysis of Operational Events at Nuclear Facilities

During the year, SNRIU received and considered 24 informational messages on events occurred at Ukrainian NPPs:

16 – on NPP operational events;

8 – on deviation in NPP operation.

Since 2007 only 1 operational event was recorded at ChNPP (3 July 2013), statistical data on NPPs in commercial operation are provided further in the report.

Distribution of NPP operational events by NPP sites:

ZNPP (6 units) – 6 operational events;

RNPP (4 units) – 5 operational events;

KhNPP (2 units) – 4 operational events;

PNPP (3 units) – 1 operational event. The events occurred in 2021 were classified by the following categories:

P05/1 "Reactor shutdown with scram (preliminary protection) or reactor power limiter during operation of the power unit caused by: failures of equipment (components); human errors and/or erroneous decisions, natural or man-induced external events" – 3; P05/2 "Disconnection of the power unit from the grid with automated emergency systems, protection of the turbine unit and turbine generator during operation of the power unit caused by: failures of equipment (components); human errors and/or erroneous decisions, natural or man-induced external events" – 1; P07/1 "Failures of category A and B equipment and piping important to NPP safety, safety class 1 and 2 components, control rod(s) with a drive mechanism (drive mechanisms) that has not led to accidents and incidents of categories P01/1-P02/2, P04, P08-P10" – 2;

P08 "NPP power decrease to 25 % and more of the previous power level caused by: failures of equipment (components); human errors and/or erroneous decisions, natural or man-induced external events" – 5;

P09 "Actuation of any safety system or safety system train in standby in any reactor operating state that has not led to incidents of categories P05, P07/1, P07/2 and P08" – 3;

P10 "Inoperability of safety system train(s) for a period not exceeding that allowed by the Technical Specifications for Safe Operation" – 2.

A significant part (56.25 %) of NPP operational events occurred during the year led to reactor shutdown, unloading or disconnection of the power unit from the grid (categories P05, P08). This reduces the residual design life for equipment of systems important to safety and decreases the regulated number of load cycles of reactor components.

Abnormal occurrence is a deviation from normal operation that may be caused by failure of equipment, external impact, human error or procedural drawbacks. Several abnormal occurrences can be detected during an event. The event investigation commission identifies direct and root cause of each abnormal occurrence.

Abnormal occurrences are divided into three groups:

1) abnormal occurrences caused by equipment failure.

2) abnormal occurrences caused by procedural drawbacks.

3) abnormal occurrences caused by human error.

During 16 operational events at Ukrainian NPPs in 2021, 18 abnormal occurrences were recorded. Their analysis revealed that 63% of abnormal occurrences were associated with equipment failures, 18.5% with procedural drawbacks, and 18.5% with human errors. For 11% of abnormal occurrences during NPP operational events, the event investigation commissions did not identify root causes.

III. EMERGENCY PREPAREDNESS AND RESPONSE SYSTEM IN UKRAINE

The creation of legislative and regulatory safety requirements and mechanisms for their control, a personnel training system, knowledge verification and professional development, introduction of the authorizing principle of the nuclear energy use for peaceful purposes, and the safety culture philosophy at all levels are aimed, first of all, at preventing emergencies in the field of nuclear energy use. Despite the very low probability of occurrence of emergencies, readiness to respond to them, to protect the personnel, public and the environment, is one of the main principles of state policy in the field of nuclear energy use.

The licensee, the employer, the regulatory body, the state administration authorities have to develop measures well in advance to ensure preparedness and response to a nuclear or radiation emergency at the scene of an event development, and, if necessary, at the local, regional, national and international levels so that in the predicted cases, the radiation risks were insignificant, and for difficult-to-predict events, the consequences were significantly limited by timely response, including providing the population with up-to-date, understandable and reliable information.

Despite the very low probability of utility/general accidents with the release of radioactive substances outside the industrial sites of nuclear installations, the emergency plans of NPPs and other nuclear facilities provide for the following emergency response measures in the framework of the Unified State Civil Protection System: immediate notification of dispatching services and the state regulatory body on events in the NPP operation and their classification by impact on safety;
prompt assessment and projecting of the situation, as a basis for recommendations to local authorities regarding decision-making and implementation of urgent measures for radiation protection of the public (sheltering, iodine prophylaxis, evacuation, consumption restriction of local food products and water from open water reservoirs);
carrying out enhanced radiation monitoring in the sanitary control and observation areas of a nuclear facility.

The emergency preparedness and response system of Energoatom is a component of the functional subsystem "Safety of Electric Power and Nuclear Industrial Complexes" of the Unified State Civil Protection System.
The SNRIU maintains its own response capabilities, in terms of alerting and informing, and exercises oversight over the state of emergency preparedness of entities operating in the field of nuclear energy use, in accordance with the requirements of the NRS rules and standards, conditions of authorizing documents. In addition, the regulator organizes and participates in exercises, trainings, seminars, including using simulators, complex tasks and up-to-date technologies, and provides informational support on emergency preparedness and response to its own staff, personnel of licensees and colleagues from other authorities and organizations.
To ensure operation of the functional nuclear and radiation safety subsystem of the Unified State Civil Protection System and to improve its own response preparedness system, as a competent authority under the Convention on Prompt Notification of a Nuclear Emergency, round-the-clock duty is organized in accordance with para. 2 of the Resolution of the Cabinet of Ministers of Ukraine No. 1570 of 2 October 2003 “On Identification of Competent NATIONAL Bodies for the Implementation of International Conventions in the Field of Nuclear Energy Use” (as amended), in order to receive emergency notification and information at any time, as well as requests for assistance in the event of a nuclear accident or radiation emergency.
Information reports on incidents occurred in other countries are analyzed on permanent basis in the framework of the international information system INES-NEWS and the system for exchanging information about incidents and emergencies (USIE); information exchange with the IAEA and competent authorities of other countries is ensured as part of emergency exercises and trainings, periodic communication testing with competent authorities and/or communication points of Austria, Belarus, Bulgaria, Latvia, Germany, Norway, Poland, Romania , Slovakia, Turkey, Hungary China, Finland and Sweden.

During 2021, the staff of the SNRIU Information and Emergency Center (SNRIU IEC) took part in international IAEA exercises and organized special trainings, in the framework of bilateral agreements on prompt notification and information exchange, in the event of a radiation accident:
ConvEx-2b, organized to master the procedures for providing and receiving assistance in the event of a nuclear or radiological emergency;
ConvEx-2a, organized with the objective of checking the capabilities and skills of the competent bodies and national INES coordinators in filling out standard forms in accordance with the development of a conditional emergency;
ConvEx-3, based on the scenario of a hypothetical accident at the Barakah NPP (United Arab Emirates) to practice emergency response procedures in case of a nuclear or radiological emergency associated with a significant radioactive release, which requires the application of protective measures for the public and may lead to transnational and/or cross-border consequences (jointly with the State Emergency Service, UkrHMC and Rivne NPP);
joint Ukrainian-Norwegian exercises (project “Strengthening Emergency Preparedness and Response in Ukraine” with the support of DSA, the Norwegian Radiation and Nuclear Safety Authority) under the scenario of a conditional accident with loss of control over RS on the territory of Ukraine/Norway, to practice the actions of central executive authorities, including issues of informing the public and the mass media, in the event of detection of radiation sources out of regulatory control and/or in illegal circulation, and a conditional emergency at a research nuclear facility, to verify the effectiveness of the emergency plan of the Institute for Nuclear Research of the National Academy of Sciences of Ukraine and the procedures for the interaction of the operating organization with the regional civil protection subsystem in Kyiv.

In addition, SNRIU took part in international IAEA exercises without activating the IEC in format:

ConvEx-1a, on testing the continuous availability of national contact points for receiving notifications and their functioning, availability of access to the USIE web portal;

ConvEx-1b, on testing the continuous availability of national contact points and the ability of national competent authorities to respond promptly to receiving an alert; ConvEx-1c, to verify the access rights of USIE administrators of the USIE web portal.

As part of cooperation with the European Commission (project UK/TS/58 “Support to Ukrainian Regulatory Authority”) jointly with the Karlsruher Institut für Technologie, in particular, Task H2.2 “Use of JRODOS Calculations to implement HERCA–WENRA Approach”, an online training on the practical application of the JRODOS decision support system for radiation accidents to build models of atmospheric dispersion was organized.

JRODOS users in Ukraine attended the training, in particular, from the State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS), Zaporizhzhia NPP, Rivne NPP, Khmelnytsky NPP, Pivdennoukrainsk NPP, Energoatom Emergency Technical Center and Atomremontservice, State Agency of Ukraine for the Exclusion Zone Management (SAUEZM), Chornobyl NPP, Ecocenter, the Institute of Problems of Mathematical Machines and Systems of the National Academy of Sciences of Ukraine, the Ukrainian Center for Water and Environmental Problems, and the Ukrainian Hydrometeorological Center (UkrHMC) of the State Service of Ukraine for Emergencies. A meeting of JRODOS users in Ukraine on the expansion of the JRODOS functionality in the IEC, methodology for assessing and forecasting cross-border impacts in the event of radiation accidents was also organized and held with participation of a KIT expert.

In September 2021, the third joint exercise of the mobile radiation reconnaissance laboratories of Germany and Ukraine took place in the framework of the project of the Federal Agency for Radiation Protection of Germany (BfS) and the State Specialized Enterprise Ecocenter with the assistance of the Embassy of Germany in Ukraine on the territory of the Chornobyl Exclusion Zone. Inspectors of the SNRIU Headquarters and SNRIU inspectors in the Exclusion Zone together with the crews of the mobile radiation reconnaissance laboratories of the SSTC NRS, Rivne NPP, “Emergency and Technical Center” of the Energoatom took part in the exercises.

During the training, the up-to-date technologies of aerial gamma imaging (using helicopters and drones) and mobile radiation reconnaissance, skills in using portable and mobile equipment, transmission channels and compatibility of measurement results, behavior culture in real radiation conditions and interaction procedures in response to nuclear and radiation emergencies were tested.

During 2021, the SNRIU took part in the following events:

CIAS IAEA webinars on emergency preparedness and response; IAEA technical meeting on emergency preparedness and emergency response related to new generation reactors; seminar on the implementation of the International Radiation Monitoring Information System (IRMIS); international conference on the development of emergency preparedness for responding to emergencies at the national and international level; 22nd All-Ukrainian Scientific and Practical Conference “Capabilities of Functional and Regional Subsystems of the Unified State System of Civil Protection for the Prompt Solution of Tasks as Assigned”; an online seminar for a wide range of specialists on the implementation of up-to-date European approaches to responding to nuclear and radiation emergencies (HERCA-WENRA approaches), which are based on early warning mechanisms, agreed criteria and procedures for the introduction of protective measures and assessment of transboundary impact. The experience of participating, organizing and conducting educational and training events under quarantine conditions opens up new opportunities for the use of modern information technologies and communication platforms for the purposes of maintaining preparedness to respond at an appropriate level.

IV. STATE RADIATION MONITORING SYSTEM

Background radiation monitoring on the territory of Ukraine has been carried out for more than 60 years and today remains the only independent (outside the NPP sites and the Exclusion Zone) source of information on the radiation state of the environment.

Assessment of the environmental radioactivity is a component of the complex system of hydrometeorological observations, which, according to the Law of Ukraine "On Hydrometeorological Activity", are carried out at meteorological, hydrological stations and observation posts subordinate to the Department of Hydrometeorology of the State Emergency Service of Ukraine.

The observation network (excluding the uncontrolled territories of Donetsk and Lugansk regions and Crimea) consists of 163 points of discrete measurements of the exposure dose rate (EDR) of gamma radiation (48 of which are located along the state border of Ukraine, and 27 in the NPP areas); 51 dry precipitation collection point; 7 points with stationary aspiration units for estimating the volumetric aerosol activity. Monitoring of the content of cesium-137 and strontium-90 radionuclides is carried out at 9 points of surface water sampling on the main rivers of Ukraine. Independent background monitoring of the environment radiation state in 100-km zones around nuclear power plants is periodically performed.

Analytical support for monitoring observations is provided by the Borys Sreznevsky Central Geophysical Observatory (CGO), the Radioecological Laboratory of the Kakhovka Hydrometeorological Observatory, and the Regional Laboratory of the Rivne Hydrometeorology Center.

The environment radiation monitoring department of the UkrHMC develops methodologies and programs of radiation monitoring, as well as carries out scientific research.

The UkrHMC Center for Forecasting the Consequences of Radiation Accidents organizes and coordinates monitoring of the radiation state of the environment in the event of emergencies, including outside Ukrainian territory, which could potentially be accompanied by cross-border radiation consequences for the environment and the public. The information exchange between the SNRIU and UkrHMC is based on an Interdepartmental Agreement, in the framework of the functional nuclear and radiation safety subsystem of the Unified State Civil Protection System, as well as in coordination with the IAEA.

Figure. UkrHMC background observation points

In accordance with the "Environmental Contamination Observation Program of Hydrometeorological Organizations of the State Emergency Service of Ukraine" (Order of the Ministry of Internal Affairs of Ukraine No. 931 of November 16, 2018), the following is carried out: EDR measurement of gamma radiation daily at 08:00 in the winter or at 09:00 in the summer time (if necessary - more often) once a day at a height of 1 m from the ground surface; sampling of dry atmospheric precipitation on horizontal gauze tablets with a two-day exposure of each sample; sampling of atmospheric aerosols using air filter units during 3 days with 6-hour air pumping; sampling of surface water in 5 reservoirs of the Dnipro system and in 4 reservoirs on the Desna, Danube, and Southern Bug rivers with a frequency of once a month and in the Dnipro-Bug estuary (once a quarter).

Indicators of the radiation state of the environment include data on: gamma radiation exposure dose rate; total beta-activity of atmospheric aerosols and precipitation; content of strontium-90 and cesium-137 in air and surface water.

Analytical laboratories of the radiometric network units have limited technical capabilities for the implementation of up-to-date measurement methodologies and assessment of radionuclide content of artificial and natural origin according to the EU legislation. The network of hydrometeorological observation points lacks for automated monitoring of atmospheric aerosol contamination with the function of tracking the levels of their gamma and beta activity, which, in case of emergencies, will require additional time for assessment.

The transmission of data from operating NPPs and the Chornobyl Exclusion Zone to UkrHMC in an automated mode is currently limited to EDR values and is carried out in the framework of the application of the European Decision Support System for Radiation Accidents JRODOS. The data is submitted through the UkrHMC servers to relevant state executive bodies, organizations and institutions. According to the agreement between the European Commission and UkrHMC of 7 October 2021, EDR indicators are transferred to the European Radiological Data Exchange System EURDEP, and according to the Agreement between the IAEA and UkrHMC of 15 August 2021, EDR indicators are transferred to the international IAEA radiation monitoring information system IRMIS.

The concentration of radionuclides of natural origin in atmospheric air is determined by weather conditions. According to the CGO, the total beta activity of the surface layer of the atmosphere is formed mainly by natural radioactive elements: isotopes of uranium, thorium and their fission products, and during 2021 was in the range of 4.1 x 10^{-5}Bq/m³ - 30.5 x 10^{-5}Bq/m³.

The concentration of man-made cesium-137 in the surface air layer at most control points ranged from 0.03x10^{-5}Bq/m³ to 1.0x10^{-5}Bq/m³. At the Chornobyl control point (Exclusion Zone), decadal fluctuations of the concentration of cesium-137 in the air were in the range of 0.1x10^{-5}Bq/m³ - 4.9x10^{-5}Bq/m³. The volumetric activity of cosmogenic beryllium-7 in air aerosols was in the range of 45x10^{-5}Bq/m³ - 1130x10^{-5}Bq/m³.

Determination of the content of beta-emitting radionuclides in atmospheric precipitation is carried out in two-day exposure samples.

Measurement of the isotopic composition of gamma-emitting radionuclides is carried out using samples combined for a month by the gamma spectrometric method.

The average density of beta-active fallout across the country did not exceed 1.7 Bq/m² per day in 2021. There were no cases of extremely high values of the total beta activity of precipitation in 2021. The highest content of beta-emitting radionuclides in fallout (3.0 Bq/m² per day) was observed in the sample taken on 29-30 November 2021 at the Volodymyr-Volynsky control point.

The content of cesium-137 in atmospheric fallout at most control points was in the range of 0.1-0.7 Bq/m² with an average value of 0.3 Bq/m² per month. At sampling points in the area of guaranteed voluntary resettlement (meteorological stations Korosten, Ovruch) and in the Exclusion Zone (meteorological station Chornobyl), the total content of cesium-137 in fallout reached values of 0.6-2.1 Bq/m² per month. The fallout density of cosmogenic beryllium-7 on the territory of Ukraine during the year ranged from 16 to 447 Bq/m² per month.

Exceeding of the permissible values of the Radiation Safety Standards of Ukraine (hereinafter - NRBU-97) of concentrations of radionuclides in atmospheric air on the territory of Ukraine during 2021 was not observed.

Radiation monitoring of surface water based on the content of cesium-137 and strontium-90 is carried out to obtain representative data on the actual state and changes in concentration of artificial radionuclides in surface water, forecasting and prevention of accidents and other emergencies with radiation consequences for water bodies.

According to the CGO monthly reports, the range of concentration fluctuations of ^{90}Sr and 137Cs in surface water for 2021 are given in the table:

No.	Water body – sampling location	^{90}Sr, solution, Bq/m³ (min-max)	^{137}Cs (min-max)	
			suspension, Bq/m³	solution, Bq/m³
1	Dnipro river - Nedanchychi	2.6 –7.2	≤0.6 – 2.1	≤0.2 – 2.1
2	Kyiv reservoir – Hydroelectric power station (Vyshgorod)	14.7 – 32.3	≤0.6 –10.0	2.8 – 11.0
3	Desna river - Chernigiv	2.6 – 5.8	≤0.2 – ≤0.4	≤0.1 – 1.2
4	Kaniv reservoir – Kyiv (Hydropark)	13.30 – 29.9	≤0.5 – 9.2	1.6 – 11.0
5	Kaniv reservoir - Hydroelectric power station (Kaniv)	8.5 – 17.0	≤0.3 – 3.6	≤0.5 – 1.8
6	Kakhovska reservoir - Hydroelectric power station (Nova Kakhovka)	7.4 – 17.8	≤0.2 – 0.3	≤0.3 – ≤0.5
7	Pivdenny Bug river - Mykolaiv	3.8 – 6.1	≤0.3 – ≤0.9	≤0.4 – 4.4
8	Danube river - Izmail	6.5 – 11.6	≤0.3 – ≤2	0.4 – 2.7
9	Dnipro-Buzky estuary - Ochakiv	7.4 – 9.5	≤0.5	≤0.8 – 1.6

Table. The range of fluctuations in the concentration of ^{90}Sr and 137Cs in surface water of Ukraine for 2021

The content of cesium-137 and strontium-90 in controlled water bodies was significantly lower in 2021 than the permissible concentrations established by NRBU-97. Twice a year, surveys on the state of radiation contamination of surface waters in Ukraine and monthly reports are posted in the "Radioecology" Section on the CGO website, at the link http://cgo-sreznevskyi.kyiv.ua, in the "Contamination Data" Section. In accordance with the Procedure for state monitoring of water, approved by the Resolution of the Cabinet of Ministers of Ukraine No. 758 of 19 September 2018, the State Water Resources Agency of Ukraine and SAUEZM are also identified as subjects of state water monitoring.

Radiological Monitoring of the Chornobyl NPP Exclusion Zone

In accordance with Articles 10 and 13 of the Law of Ukraine “On the Legal Regime of the Territory Exposed to Radioactive Contamination due to the Chornobyl Disaster” in the zones of exclusion and unconditional (mandatory) resettlement, mandatory measures are taken to: prevent the transfer of radionuclides from the territory of the zones and radioactive contamination of the environment; monitoring of the environment state as well as medical and biological monitoring; maintaining the territory in a proper sanitary and fire prevention conditions; application of methods of fixation of radionuclides in the place of their location. Implementation of the legally defined tasks on radiological and environmental monitoring in the Exclusion Zone territory is ensured by Ecocenter in accordance with the Regulations approved by the SNRIU.

The system of radiological and ecological monitoring and radiation dosimetry control in the Exclusion Zone was formed after the accident and went through a 35-year path of development in difficult conditions, which were determined by high radioactive contamination levels, their significant gradients and heterogeneity, dynamics over time, anthropogenic activity, zone status as a radiation hazardous, uninhabitable territory.

Round-the-clock collection and processing of information on radiation state for timely detection of exceeding of established reference levels and development of draft management solutions is carried out with the support of a complex system of radiation monitoring and early warning consisting of:

39 sensors measuring the equivalent gamma radiation dose rate "Gamma TRACER", located on the territory of the Exclusion Zone, the ChNPP industrial site and in the city of Slavutych with the range of EDR measurement: 20 nSv/h - 10 Sv/h.

14 aspiration units "AURA-02" for measuring the concentration of radioactive aerosols in the surface layer of the atmosphere by pumping through a Petryanov filter, and further measurements in laboratory conditions;

3 automated monitoring stations for controlling water level, temperature, and pH parameters of the Prypyat River;

3 Vaisala MAWS301 automated weather stations for measuring air temperature, pressure, wind speed and direction;

ground acoustic station "SODAR XFAS" for measuring wind speed and direction;

data integration system (DIS): designed for the non-distribution of radiation-contaminated materials, equipment and vehicles outside the Exclusion Zone as part of 3 "MPS KORDON-MN" portal monitors with gamma radiation and neutron flow measurement units, including online video surveillance of the control and dosimetry point "Dytyatky" and archiving of video files.

The monitoring system of the Exclusion Zone is integrated with the RODOS software complex, adapted to the specific conditions of the zone and is designed for forecasting the spread of radioactive substances at distances of up to 800 km and assessing the radiation impact of radiation accidents, including forest fires, floods, and tornadoes in areas with enhanced radiation contamination levels, which causes secondary rise and transfer of radionuclides by air and water.

A software module “ChornobylFire”, developed in 2015 under the project of the Organization for Security and Cooperation in Europe (OSCE) and the international initiative “Environment and Security” (ENVSEC) is used to estimate radiation doses received by personnel during firefighting in the Exclusion Zone.

For prompt information exchange in the unified international IRIX format, the SSE “Ecocenter” developed and implemented in 2021 software for transmitting monitoring data from PED control posts through the Center for Forecasting the Consequences of Radiation Accidents from the UkrHMC to the IAEA.

According to the analysis results of the information on the radiation status of the Exclusion Zone, which is provided by the SSE Ecocenter to the SNRIU, the following main indicators were identified: the volumetric activity of radionuclides in the surface layer of the atmospheric air in the near zone at the points of the automated radiation monitoring system (ARMS) varied in the range of:

137Cs - 4.7E-06 – 2.7E-03 Bq/m^3, (max. at ARMS VRP-750 in February; 90Sr - 1.7E-06 – 1.0E-03 Bk/m^3 (max. at ARMS Naftobaza in July) ; 238Pu - 1.4E-09 – 8.1E-05 Bq/m^3 (max. at ARMS Naftobaza in July);

239+240Pu - 1.7E-09 – 2.0E-04 Bq/m^3 (max. at ARMS Naftobaza in July) ;

241Am – 7.4E-08 – 6.1E-05 Bq/m^3 (max. at ARMS VRP-750 in February).

At the ARMS points of the far zone, the values of the volumetric activity of radionuclides in the surface layer of the atmospheric air varied in the range of:

137Cs –1.1E-06 – 6.1E-04 Bq/m^3, (the maximum value was recorded at ARMS Chystohalivka in May);

90Sr –2.2E-07 – 5.7E-05 Bq/m^3 (max. at ARMS Chystogalivka in February);

238Pu–6.2E-11 – 2.6E-07 Bq/m^3 (max. at ARMS Buryakivka in February);

239+240Pu - 1.1E-09 – 5.6E-07 Bq/m^3 (max. at ARMS Buryakivka in February); 241Am – 2.3E-08 – 7.4E-06 Bq/m^3 (max. at ARMS Buryakivka in April).

In the places of the longest stay of the EZ personnel at the Chornobyl ARMS point, the volumetric activity of radionuclides in the surface layer of the atmospheric air varied in the range of:

137Cs - from 2.8E-06 to 6.6E-05 Bq/m^3 (maximum value in May);

90Sr - from 9.4E-07 to 1.0E-05 Bq/m^3 (in August);

238Pu - from 7.8E-11 to 7.0E-08 Bq/m^3 (in September);

239+240Pu - from 1.4E-09 to 1.8E-07Bq/m^3 (in September);

241Am - from 2.8E-08 to 7.8E-06 Bq/m^3 (in July).

At the Dytyatky ARMS point, the volumetric activity of radionuclides in the surface layer of atmospheric air varied in the range of:

137Cs – from 7.2E-07 to 3.9E-05 Bq/m^3 (maximum value in October);

90Sr - from 2.2E-07 to 3.6E-06 Bq/m^3 (in October);

238Pu - from 6.1E-11 to 5.9E-08 Bq/m^3 (in November);

239+240Pu - from 1.2E-09 to 3.7E-08Bq/m^3 (in February);

241Am - from 2.2E-08 to 7.6E-06 Bq/m^3 (in March).

The volumetric activity of radionuclides in the surface layer of the atmospheric air of the Buryakivka RWDS varied in the range of:

137Cs – from 4.5E-06 to 5.4E-04 Bq/m^3 maximum value (in September);

90Sr - from 1.1E-06 to 4.8E-05 Bq/m^3 (in February);

238Pu - from 8.7E-11 to 4.6E-07 Bq/m^3 (in March);

239+240Pu - from 2.1E-09 to 9.6E-07Bq/m^3 (in March);

241Am - from 6.1E-08 to 3.9E-05 Bq/m^3 (in May).

The average monthly density of atmospheric precipitation in the near zone ranged from 0.02 to 12.9 Bq/(m^2´day) with maximum values in May at the observation point “1 km south” - 12.9 Bq/(m^2´day) and at observation point "3 km southwest" in August - 11.4 Bq/(m^2/day).

The average monthly density of atmospheric precipitation in the far zone ranged from 0.004 to 1.0 Bq/(m^2´day) with maximum values at the observation point Chystohalivka in July.

In general, the volumetric activity of radionuclides in the surface layer of the EZ air (at the ARMS points) in 2021 decreased compared to last year by 2 to 50 times. This decrease in the values of the volumetric activity of radionuclides in the EZ air compared to 2020 is explained by favorable weather conditions, in particular, precipitation, and the absence of massive fires in natural ecosystems that lasted in the spring of 2020.

Surface Water

The measured volumetric activity of 137Cs in water suspension in the rivers was the lowest in the water of the Pripyat River near the city of Chornobyl - 2.0 - 37 Bq/m^3 and the Uzh River near the village of Cherevach - 1.0 - 15 Bk/m^3. The highest volumetric activity of 137Cs in water suspension was observed in water samples near the outlet hydrotechnical structure of the left bank polder (GTS No. 7) 2100 Bq/m^3. This regularity is also characteristic for the measured volumetric activity of 137Cs in solution samples: the lowest values in the water of the Pripyat River are 5.0 - 52 Bq/m^3 and the Uzh River are 8.0 - 77 Bq/m^3, the highest in the water samples near GTS No. 7 2400 Bk/m^3.

The measured volumetric activity of 90Sr was the lowest in the Pripyat River in the range of 25–120 Bq/m^3 and the Uzh River – 25–140 Bq/m^3, the highest in the water near the outlet hydrotechnical structure of the left bank polder 990 - 20,000 Bq/m^3.

Among the monitored water bodies, the maximum values of volumetric activity of radionuclides were observed in Lake Azbuchyn: 90Sr – 740,000 Bq/m^3 – in June, 910,000 Bq/m^3 – in July, 960,000 Bq/m^3 – in August; 137Cs in suspension water in November – 1970 Bq/m^3, in December – 1660 Bq/m^3, 137Cs in solution: in May – 10200 Bq/m^3, in June – 14800 Bq/m^3, in July – 14300 Bq/m^3. In Lake Hlyboke: 90Sr – 110,000 Bq/m^3 in May and October; 137Cs in suspension water – 360 Bq/m^3 and 137Cs in solution – 7400 Bq/m^3 in February.

Ground Water

Monitoring of radionuclide content in ground water was carried out on three aquifer complexes: Quaternary (145 wells), Eocene (water intake for the ChNPP, Pripyat city) and Cenomanian - Lower Cretaceous (water intake for Chornobyl and city water supply). The volumetric activity of radionuclides in water from the Eocene aquifer complex (Yaniv branch of the Pripyat water intake) was: 137Cs – 0.9-2.1 Bq/m^3; 90Sr – 2.5-8.5 Bq/m^3.

Volumetric activity of radionuclides in water from the Cenomannian-Lower Cretaceous aquifer complex (water intake in the Chornobyl city) was determined at the level of: 137Cs – 0.4-1.0 Bq/m^3; 90Sr – 3.0-6.0 Bq/m^3.

Volumetric activity of radionuclides in water directly at the places of consumption (water supply to the city of Chornobyl): 137Cs – 0.1-3.5 Bq/m^3; 90Sr – 1.8-9.4 Bq/m^3.

The maximum values of the volumetric activity of 90Sr in the water of the control and observation wells of the aquifer complex in Quaternary deposits were recorded in the areas of Lake Azbuchyn, old Budbaza, Semikhodsky Zaton, Yanivsky Zaton and were 1100000, 98000, 65000, 61000 Bq/m^3, respectively. In the area of the village Lisove, in the water of wells K-13D and 172/Q2, the maximum volumetric activity of 137Cs reached 29,000 Bq/m^3 and 33,000 Bq/m^3, respectively. Stable high values of the volumetric activity of 137Cs in the water of these wells are observed after the flooding in 2013 of the territory of the radwaste interim confinement sites in the Exclusion Zone (RICS) with melt and rain water. Outside the radioactive waste disposal areas, the vast majority of 90Sr content values are within 100-400 Bq/m^3, and 137Cs - 20-40 Bq/m^3. The radiation status of ground water within the boundaries of the RWDS Buryakivka, Pidlisny, and ChNPP Stage 3 is characterized by a certain stability without the trend of the of 90Sr content increase as the main contaminant. In the measured samples, the content of 90Sr ranged from 20 to 3800 Bq/m^3.

Based on the results of groundwater monitoring, the following trends are observed:
an increase in the volumetric activity of 90Sr in ground water in the areas of Lake Azbuchyn, RWDS Pidlisny, as a result of the drainage of the reservoir - cooling pool;
an increase in the volumetric activity of 90Sr in the area of the ChNPP Stage 3 after stabilization of the regime, as a result of the drainage of the reservoir - cooling pool;
stabilization of ground water levels at the Pidlisny ChNPP Stage 3 with the trend for a further drop in levels depending on geological, hydrogeological and climatic factors; a decrease in the level of underground water at the Buryakivka RWDS (climatic and hydrogeological factors) with a tendency to increase of the volumetric activity of 90Sr in individual wells (wells 139, 147).

Gamma Radiation Equivalent Dose Rate in the Air

In 2021, EDR values in the Exclusion Zone ranged from 60 to 9440 nSv/h with the maximum value at the ARMS DGS-2 point in January.
Compared to last year, in the Exclusion Zone as a whole, there is a 4% decrease in EDR indicators of gamma radiation, which is explained by the radioactive decay of 137Cs (the main radionuclide forming the gamma background of the Exclusion Zone).
After the erection of the New Safe Confinement (NSC) in the design position since 2016, a decrease in EDR (20-50%) has been observed on the territory of the ChNPP industrial site (ARMS points: DGS-2, VZS-2 and solid waste storage facility). Exceeding of the reference levels of gamma radiation EDR for 2021 was not registered.

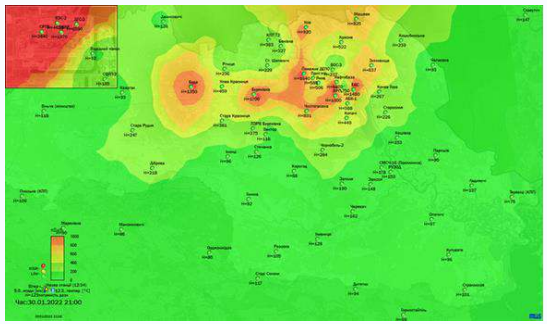


Figure. Online visualization of EDR measurements on the Internet Portal http://www.srp.ecocentre.kiev.ua/MEDO-PS/index.php

The radiation and environmental monitoring system of the Exclusion Zone adequately responds to changes in the radiation state of the surface layer of the atmosphere and, in case of a worsening of the situation, is the basis for submitting proposals to the SAUEZM for the appropriate decision-making.
According to the Resolution of the Cabinet of Ministers of Ukraine No. 380 of 7 June 2017 “On Approval of the Project ““Construction of the Centralized Storage Facility for Spent Nuclear Fuel of VVER of National Nuclear Power Plants”, informing state bodies, local self-government authorities and the public on the radiation safety state of the facility and the environment at all stages of its construction and operation shall be carried out on a permanent basis, in real time, with the use of an automated system for monitoring the radiation situation of the Exclusion Zone territory suffered from radioactive contamination.

Facility Radiation Monitoring System of the Institute for Nuclear Research of the NASU

Radiation monitoring of the environment in control area (300 m) and observation area (5 km) of the VVR-M research nuclear reactor of the Institute for Nuclear Research of the National Academy of Sciences of Ukraine (NASU) in Kyiv, is carried out by the Center for Environmental Problems of Nuclear Energy, by: sampling at stationary stations; gamma radiation EDR monitoring; monitoring of the specific beta activity and content of the main dose-forming artificial radionuclides in atmospheric precipitation and precipitation; monitoring of the specific beta activity of drainage water from sewage collectors; determining the effectiveness of man-made and natural barriers; control of radioactive contamination of soil and vegetation.

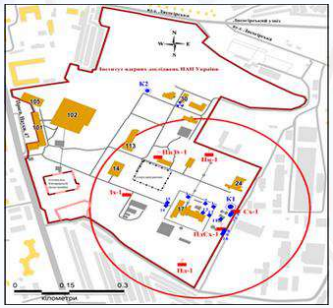


Figure. Layout of stationary radiation monitoring points in the control area of the research nuclear reactor VVR-M

According to the Report of the Institute for Nuclear Research of the National Academy of Sciences of Ukraine, for In 2021, the gamma radiation EDR at a distance of 1 m from the ground at control points of the control and observation areas was in the range of values obtained during many years and ranged from 0.08 (Nyzhny Sady) to 0.17 μSv/h (Korchuvate) (with a measurement error of 20% and the reference EDR level of 0.26 μSv/h).
The maximum density of fallout of beta-active radionuclides was observed at the point in the northwest direction at a distance of 270 m from the reactor ventilation stack in 2015 – 280 Bq/m^2. In 2021, the fallout values at this point are registered at the level 86.6 Bq/m^2.
The value of the beta-active aerosols concentration in the atmospheric air for the period 2012-2021 was at the limit of the measuring equipment sensitivity. The average quarterly beta-activity of discharges was from 0.25 to 0.93 Bq/l, which corresponds to the levels of natural activity of underground and surface water in the location area of the Institute for Nuclear Research. The average volumetric activity of 137Cs in vegetation samples for the reporting period was 4.3 Bq/kg, which does not exceed the permissible level set by NRBU-97, which is 40 Bq/kg. According to the observations carried out by the Institute for Nuclear Research, there is no radiation impact on environmental compartments and the public during normal operation of the research reactor.
For operator-independent research of the range of natural fluctuations of the gamma background in the air, informing the staff, visitors and the public on the radiation situation at the border of the 5-kilometer observation area of the Institute for Nuclear Research of the National Academy of Sciences of Ukraine, in the daily mode and in case of emergencies, in the SNRIU Headquarters (9/11, Arsenalna St., Kyiv), its own radiation and information complex was installed in 2021. The complex measures and displays information on the gamma radiation EDR in the atmospheric air on a light panel and a personal computer in automatic mode. Under exceeding the threshold EDR level (0.3 μSv/h, which is approximately two background values), a sound and light alarm is triggered. The RadMonitor software installed at the workplace of the SNRIU press secretary, allows to visualize the data of EDR measurements, save them, draw graphs and print reports on the measurement results for a certain period.

During the year, EDR fluctuations were observed in the range of 0.12-0.18 μSv/h with predominant values of 0.13-0.14 μSv/h.

In case of exceeding the set EDR threshold level, sound and light alarms are activated, the responsible SNRIU officials or SNRIU IEC duty officers must additionally check the EDR level with the RadEye radiometer-dosimeter and, in case of confirmation of exceeding the threshold level, notify the SNRIU management, and in case of registration of EDR 0.5 μSv/hour and above, operational duty service of the State Emergency Service of Ukraine.

According to the results of facility and industry monitoring observations, no emergencies and other events accompanied by changes in the radiation situation on the territory of Ukraine were not recorded in 2021.

Radiation Monitoring Systems in NPP Observation Areas

Personnel and public exposure doses are the main criteria for assessing the radiation impact of NPPs, which are defined by regular measurements and calculations.

The assessment of the radiation impact of the NPP is carried out based on information on the amount of gas-aerosol releases and water discharges of radioactive substances into the environment, personnel exposure doses, the content of radionuclides in the environmental compartments in the NPP observation areas.

The NPP radiation monitoring procedures approved by the SNRIU establish the scope, types and periodicity of measurements and observations for radiological monitoring of radiation sources and the environment.

A radiation protection component is a set of protective barriers on the pathway of radionuclides entering the environment and control of their integrity.

The radiation monitoring results and information on the state of radiation safety at the NPP are provided in the quarterly and annual reports of the NPP and Energoatom, the main data of which are given below.

Radiation Monitoring of Atmospheric Air

In the area of the NPP location, radiation monitoring of the atmospheric air is controlled according to the following parameters: levels of gaseous and aerosol releases into the atmosphere through the NPP ventilation stacks; concentration of radionuclides in atmospheric air; activity of radioactive fallout from the atmosphere (fallout density); gamma radiation dose rate in the area.

Levels of NPP Gaseous and Aerosol Releases into the Atmosphere

The levels of NPP gaseous and aerosol releases into the atmosphere are determined by: continuous monitoring of the radioactivity of inert radioactive gases (IRG), long-lived nuclides (LLN), iodine radionuclides in the NPP ventilation stacks by automated systems of gas-aerosol releases; gamma spectrometric analysis of aerosol samples deposited on AFA-RMP-20 filters and taken from the NPP ventilation stacks; gamma spectrometric analysis of samples of gas and aerosol fractions of radioactive iodine taken from the NPP ventilation stacks.

Permissible levels of gaseous and aerosol releases are developed and approved for each NPP in accordance with the established procedure.

Monitoring parameter		ZNPP	RNPP	PNPP	KhNPP
IRG, TBq/day	RL	0.77	0.87	2.0	0.814
	LR	69	61	45	46
Iodine, MBq/day	RL	24	44	140	16
	LR	6000	5100	3800	4100
LLN, MBq/day	RL	8.8	15	4.3	5.9
	LR	2200	400	800	1000
Cs-137, MBq/month	RL	120	42	55	80
	LR	28590	11250	13380	20080
Cs-134, MBq/month	RL	130	48	55	85
	LR	30420	12775	13380	21290
Co-60, MBq/month	RL	65	35	39	45
	LR	16120	5170	9730	11250

Table. Reference levels (RL) and limits of NPP gaseous and aerosol releases (LR), IRG, long-lived nuclides and iodine radionuclides into the environment in 2021

The total gaseous and aerosol release index is a quantitative estimate of the amount of gaseous and aerosol releases, expressed as a percentage in relation to the permissible release level of radioactive substances (IRG, LLN, iodine, 137Cs, 90Sr, 60Co, 58Co, 110mAg, 3H and other radionuclides) and is the sum of these relation.

Total indexes of gas-aerosol releases of radioactive substances for 2021 at Zaporizhzhia NPP, Rivne NPP, Khmelnytsky NPP and Pivdennoukrainsk NPP do not exceed the level of one percent of the permissible release and are: Zaporizhzhia NPP: 0.84%; Rivne NPP: 0.78%; Khmelnytsky NPP: 0.18%; Pivdennoukrainsk NPP: 0.21%.

According to the data of scheduled observations, exceeding of the permissible and reference levels of gas-aerosol releases in 2021 at the Ukrainian NPP was not registered. The levels of total indices of gas-aerosol releases of radioactive substances into the environment, according to the data of many years of observations, remain stably low.

Content of Radioactive Substances in the Atmospheric Air of Populated Areas

The table presents summary information on the levels of content of reference radionuclides cesium-137 and strontium-90 in atmospheric air within the 30-km NPP observation areas in 2021.

NPP	Cesium-137		Strontium-90	
	zero background	2021	*zero background*	2021
ZNPP	2.2 ± 0.7	1.3 – 1.4	11.1± 5.9	< 0.1
RNPP	11.1 – 59.2	3.0 – 7.5	–*	– *
PNPP	2.4 – 3.0	<1.8	0.9 – 3.0	0.4 – 0.7
KhNPP	2.96 – 4.07	0.3 – 2.4	6.29 – 7.77	0.1 – 0.2

**In accordance with the radiation monitoring Procedures, no monitoring of 90Sr in atmospheric air of the settlements is envisaged under normal operation.*

The content of cesium-137 and strontium-90 radionuclides in the atmospheric air around the NPP compared to the “zero background” demonstrates that these concentrations are of the same order. The radiation state of the atmospheric air in the areas of the NPP location remained at the “zero background” level in 2021 taking into account the global fallout and the impact of the consequences of the Chornobyl NPP accident.

In the area of operating nuclear power plants location, the gamma radiation EDR values in 2021 were within the following limits: Zaporizhzhia NPP: 0.05-0.25 μSv/h; Pivdennoukrainsk NPP: 0.07-0.12 μSv/h; Rivne NPP: 0.05-0.15 μSv/h; Khmelnytsky NPP: 0.09-0.14 μSv/h.

The fluctuation of the EDR level is at the level of long-term observations. In 2021, the radiation indicators of the atmospheric air did not exceed the standard values, the state of radiation contamination of the atmospheric air in the area of the NPP location remained stable.

Radiation Monitoring of Surface Water

The radiation state of surface water at the NPP locations is monitored in accordance with radiation monitoring procedures and concerns the following facilities:

radioactive discharges of nuclear power plants into external water bodies, such as cooling pools, rivers, water reservoirs.

Radioactive discharges from the NPPs into external water bodies (cooling pools) are formed, mainly, due to the discharge of unbalanced water from chemical water treatment tanks and due to blow down of spray pools of essential consumers of technical water supply. A limit for the discharge of radioactive substances into the environment (outside the industrial site) has been established for each nuclear power plant.

Annual levels of water discharges of the main radionuclides at all NPPs of the Energoatom are quantitatively assessed by the discharge index. The discharge index is expressed as a percentage in relation to the set discharge limit. As of the third quarter of 2021, the total discharge indices of liquid radioactive substances by radionuclides (3H, 137Cs, 134Cs, 60Co, 54Mn, 90Sr) were: Zaporizhzhia NPP: 1.66%; Rivne NPP: 0.84%; Pivdennoukrainsk NPP: 2.69%; Khmelnytsky NPP: 0.15%.

At the Pivdennoukrainsk NPP the maximum water discharge index of radionuclides was 2.69%, i.e. the actual maximum discharge of radioactive substances is no more than 2.69% of the permissible discharge level.

In 2021, at all Energoatom NPPs there were no exceeding of permissible levels of water discharge of radioactive substances into open water bodies, and there were no trends in increase of water discharge indices of radionuclides compared to the period of 2018-2020.

Content of Radioactive Substances in Surface Water Bodies

In 2021, the content of radioactive substances in the water of the cooling pool of the Zaporizhzhia NPP was 137Cs - < 4.9 Bq/m^3, 90Sr varied from 15.0 to 20.0 Bq/m^3 during the year, specific the activity of 137Cs was less than 4.9 Bq/m^3, for 90Sr the average specific activity was 16.0 Bq/m^3 in the water of the Kakhov Reservoir during the year. The content of strontium in the water of the reservoir is due to the incoming of emergency releases of Chornobyl origin in the Dnipro River. According to the “zero background” data, the concentration of radionuclides in the water of the Kakhov Reservoir before the ZNPP start-up was: 137Cs - (2.6±0.8) Bq/m^3, 90Sr - (24.3±1.2) Bq/m^3.

According to “zero background” data, the concentration of 137Cs in the water of the Styr River before the start-up of the Rivne NPP was 3.7-22.2 Bq/m^3. During 2021, the content of this radionuclide in the water of the Styr River before the NPP (the village of Mayunichi) was less than 2.4 Bq/m^3, in the reference river station (the village of Sopachyv) it was less 3.2 Bq/m^3. The concentration of radionuclides in the water of the Pivdenny Bug River before the start-up of the Pivdennoukrainsk NPP was for 137Cs - 13.0 Bq/m^3, for 90Sr - 13.0-17.0 Bq/m^3; in the water of the cooling pool: 137Cs – 31.0 Bq/m^3, 90Sr – 7.4 Bq/m^3. In 2021, the concentration of radionuclides in the water of the cooling pool for 137Cs was registered at a level of less 3.8 Bq/m^3, in the river - also less than 3.8 Bq/m^3, for 90Sr in the cooling pool it was within 11.0-15.0 Bq/m^3, in the river - from 11.0 to 12.0 Bq /m^3. According to the “zero background” data, the concentration of radionuclides in the water of the Horyn River before the start-up of the Khmelnytsky NPP was 7.4 Bq/m^3 for 137Cs and 14.8 Bq/m^3 for 90Sr. In 2021, the concentration of 137Cs radionuclides in the water of the cooling pool was registered in the range of 7.77–12.3 Bq/m^3, in the Horyn River – 9.1–11.3 Bq/m^3; for 90Sr in the reservoir - 5.7 - 9.99 Bq/m^3, in the Horyn river - 3.64 - 5.83 Bq/m^3.

The analysis of the content of cesium and strontium radionuclides in the water of the NPP surface water bodies compared to the “zero background” demonstrates that these concentrations are values of the same order and may differ due to natural conditions: season, floods, drought, etc.

In 2021, tritium monitoring was carried out in the water of the Zaporizhzhia NPP cooling pool and the adjacent water area of the Kakhovsky Reservoir, at the Rivne NPP, Pivdennoukrainsk NPP and the Khmelnytsky NPP: in the water of the Styr, Pivdenny Bug and Horyn rivers.

According to the monitoring results, the tritium content in the water of the Zaporizhzhia NPP cooling pool did not exceed 340.0 kBq/m^3. The maximum concentration of tritium in the water of the Kakhovsky Reservoir was registered at the level of 45.0 kBq/m^3. The specific activity of tritium in the water of the Styr River before the Rivne NPP was registered at the level of 6.90 kBq/m^3, after the Rivne NPP (control river station): 20.9 kBq/m^3.

For Pivdennoukrainsk NPP, the maximum tritium content registered in the water of the Pivdenny Bug River before and after the NPP was 20.0 kBq/m^3 in the water of the cooling pool it constituted 281.0 kBq/m^3.

As for the Khmelnytsky NPP, tritium content was registered in the water of the cooling pool in the range from 62.7 to 74.5 kBq/m3, in the water of the Horyn river, before the NPP it was from 1.67 to 6.83 kBq/m^3, after the NPP (control river station): 2.5–14.1 kBq/m^3. According to NRBU-97, the permissible tritium concentration in drinking water is 3.0E+4 kBq/m^3.

During 2021, the radiation indicators of the surface water state did not exceed the standard values.

The Content of Radioactive Substances in Soil at the Radiation Monitoring Points of NPP Observation Areas

Indicators of the soil contamination density are within the limits of “zero background” values. The highest levels of soil contamination are observed in the area of the Rivne NPP, which can be explained by the uneven nature of radioactive fallout caused by the Chornobyl accident.

NPP	*zero background*	control area	control area-10 km	10-20 km	> 20 km
ZNPP	1180	170	100	140	170
RNPP	444 – 5070	856	1800	2640	602
PNPP	1376	98	251	264	269
KhNPP	1180	120	183	199	273

Table. Cesium-137 contamination density of the surface soil layer at radiation monitoring points at different distance from the NPP was Bq/m^2 in 2021

As can be seen from the table, in the observation area at different distances from the NPP, the density of soil contamination may be higher than in the control area. This situation can be explained by the removal and mixing of the natural top layer of the soil as a result of intensive technogenic activity within the control area. In 2021, the operation of the NPPs did not lead to any changes that could indicate a deterioration of the radiation situation of the territories around the NPP sites.

Radiation parameters in 2021 did not exceed regulatory values and did not cause deterioration of the environment. Radiation protection of the personnel, public and the environment was ensured at a sufficient level.

V. SAFETY OF RADIOACTIVE WASTE MANAGEMENT

Safe management of radioactive waste (radwaste) is one of the most important factors for the sustainable development of nuclear energy in Ukraine, as well as the use of radiation and nuclear technologies in medicine, science and industry.

Radioactive Waste Management at NPP Sites

The production of electrical energy at NPPs is accompanied by radwaste generation. According to the annual reports of the Energoatom, on average, for 1 billion kWh of the electricity produced, depending on the type of reactor, up to 27 m^3 of solid radwaste (hereinafter referred to as SRW) and 35 m^3 of liquid radwaste (hereinafter referred to as LWR) are generated. The index of radwaste generation is an important characteristic of NPP operation efficiency since the costs of the operating organization for radwaste management (temporary storage, conditioning, processing, characterization and preparation for transfer for disposal) are included in the cost of electricity generation.

Minimization of radwaste generation as one of the basic principles of radwaste predisposal management safety is subject to internal control by the operating organization and state oversight.

Since 2015, the Energoatom has introduced regulatory document SOU NAEK 083:2015 “Establishment of Reference Levels for Radwaste Generation and Transfer to Storage Facilities at NPPs. Guidelines”, according to which NPP developed, agreed and put into effect technical specifications to determine the reference levels of radwaste generation and transfer to storage facilities that are periodically reviewed.

The reference levels of radwaste generation at NPPs were not exceeded.

The main LRW source is drain water (radioactively contaminated effluents that enter the active drains) – uncontrolled primary leaks; leaks of the spent fuel pool; rooms, equipment decontamination water; discharges from showers, air locks; discharges from laboratories, including sampling; regeneration and washing water of a unit desalination facility and filters of special water treatment facilities (hereinafter referred to as SWT); equipment operational flushing with reagents, in particular evaporators.

Figures. Storage of LRW in NPP storage facilities

LRW consists of evaporation bottom - a product of drain water processing at evaporation installations, as well as spent filter materials (ion exchange resins) and sludge. Products of evaporation bottom processing at deep evaporation installations in the form of salt fusion cake belong to SRW in accordance with Order of the Ministry of Health of Ukraine No. 2935 dated 17 December 2020 “On Amendments to the Basic Radiation Safety Rules of Ukraine” registered in the Ministry of Justice of Ukraine on 25 January 2021 under No. 98 /35720.

The accumulation of spent sorbents and sludge tends to increase due to the lack of a plant for spent sorbent and sludge processing. Therefore, the priority task of the operating organization is to develop formulations for the immobilization of spent sorbents and sludge to ensure the possibility of their processing, as provided by measure 2.3 of the Comprehensive Program for Radioactive Waste Management at the Energoatom PM-D.0.18.174-16 “Development of Formulations for the Immobilization of NPP Spent Filter Materials and Sludge and Immobilization of an Experimental Batch of NPP Filter Material and Sludge”.

According to the design of the operating NPPs, special storage facilities for the storage of salt fusion cake were not envisaged. Temporary storage of containers with salt fusion cake at NPP sites is provided in the cells of solid radioactive waste storage facilities.

At the Zaporizhzhia NPP, Rivne NPP, Khmelnytsky NPP, there is a constant accumulation of salt fusion cake packages and, accordingly, filling of rooms (cells) used to store containers with salt fusion cake is increased. For stable NPP operation, a constant availability of free volume for process radwaste should be provided. The construction of a light hangar storage facility has started to allow salt fusion cake storage at ZNPP.

If there is a lack of technologies and equipment for processing liquid radioactive waste at the Pivdennoukrainsk NPP, in order to prevent complete filling of LRW tanks, the evaporation bottom is reevaporated using SWT evaporators, which leads to an increase in salt content of the evaporation bottom and, in the future, to the formation of solid salt deposits in tanks. The implementation of technologies and equipment for evaporation bottom processing at the Pivdennoukrainsk NPP is an urgent task in the context of long-term operation of power units.

Solid waste sources at NPPs are materials that are generated during repair and maintenance of process equipment; personal protective equipment for personnel; parts of equipment and piping, spent special ventilation filters.

The main volume of SRW (more than 80%) is generated during maintenance and repair, as well as reconstruction (modernization) of power units. Most of SRW volume is rags, thermal insulation, metal, fragments of concrete structures (75 - 80%). SRW is collected at the places of its formation, sorted into categories (according to the dose rate of gamma radiation) and transported to a solid radwaste storage facility. Solid radwaste storage facilities at NPP sites are reinforced concrete structures consisting of separate compartments for radioactive waste, depending on the level of activity. The compartments are equipped with the fire alarm system, automatic fire extinguishing system and exhaust ventilation with air purification. Separate compartments of solid radwaste storage facilities are additionally equipped with the moisture detection and retrieval system.

Due to putting SRW treatment plants of RNPP and ZNPP into commercial operation in 2019, most of the low-level waste generated in the reporting period was processed at the installations of the radwaste treatment plant (hereinafter referred to as RWTP). In 2020-2021, SRW was extracted for release of storage tanks and subsequent radwaste processing at the compaction and incineration installations, as well as at the KTRO-200 supercompaction installation for containers temporarily stored in the rooms of SRW storage facilities.

However, the trend towards an increase in the accumulation of radwaste of all categories at NPPs remains, which is associated with an increase in the scope of maintenance and replacement of equipment during the refueling outage, and with the current lack of the ability of the Central Radioactive Waste Management Enterprise (hereinafter referred to as CRME) to accept NPP radwaste for long-term storage and disposal at the Vektor.

ZNPP radwaste treatment plant

Figure. ZNPP radwaste treatment plant

Figure. ZNPP SRW fragmentation installation

By ZNPP Order No. 775 dated 5 June 2020 “On Putting the Solid Radioactive Waste Retrieval Facility into Commercial Operation”, the facility for solid radioactive waste retrieval was put into commercial operation.

According to ZNPP Order No. 1555 dated 10 December 2019 “On Putting the Radioactive Waste Treatment Plant into Commercial Operation”, the radioactive waste treatment plant was put into commercial operation. From the start of RWTP operation until December 2021, the following has been processed:

At the incineration installation – 968 m^3;

At the supercompaction installation – 951.27 m3 (4679 KTRO-200 and 91 PU-0.17 containers);

Processing product obtained – 1784 KTROf-0.28 packages and 29 KTROf-0.2 packages.

By ZNPP Order No. 1337 dated 23 October 2020 “On Putting the Ultrasonic Decontamination Installation for Metal Radioactive Waste into commercial operation”, the installation was put into commercial operation. 2500 kg of metal radioactive waste have been decontaminated since the start of installation operation.

Due to these activities, the reduction of SRW volume entering ZNPP storage facilities is approximately 38%.

Figure. Compaction installation at ZNPP

Figure. Radwaste after compaction

Figure. Incineration installation at ZNPP RWTP

RNPP Radwaste Treatment Plant

The Rivne NPP solid radioactive waste treatment plant is in commercial operation in accordance with Certificate No. 175-154-A-TsDtaRAV of 27 December 2019 and RNPP Order No. 1148 “On Putting RWTP into (Commercial) Operation of 27 December 2019. In pursuance of para. 11 of the “Meeting Minutes of the Council of NPP Deputy Chief Engineers, whose Competence Covers the Issue of Radioactive Waste Management” No. 10 dated 2 January 2020, RNPP developed the “Technical Solution for Processing RNPP Low-Level Radioactive Waste” that meet the acceptance criterion for the incineration installation of ZNPP RWTP No. 175-47-TR-TsDtaRAV, which was approved by the State Nuclear Regulatory Inspectorate on 20 August 2020.

In pursuance of subpara. 1, para. 5.3, Conclusion of the State Nuclear and Radiation Safety Review of Documents “Radioactive Waste Treatment Plant. Safety Analysis Report. 175-1-OAB-TsDiRAO” and “Technical Specifications for Safe Operation of the Radioactive Waste Treatment Plant. 175-1-R-TsDtaRAV”, Rivne NPP developed the “Generalized Report on Seismic Resistance Confirmation for Normal Operation Systems and Components Important to Safety of RNPP RWTP” 175-22-ZV-TsDtaRAV, which was approved by the State Nuclear Regulatory Inspectorate of Ukraine.

Taking into account the documents confirming seismic resistance of installations and equipment important to RNPP RWTP, the State Nuclear Regulatory Inspectorate of Ukraine agreed document “Solid Radioactive Waste Retrieval Facility. Program and Test Procedure M731.00.00.000PM.

The effect of implementing the RNPP SRW treatment plant as a whole allowed reducing the volume of radwaste entering SRW storage facility cells for temporary storage by 41%. The amount of the received processing product for 2021 in the form of radwaste packages KTRVf-0.2 is 204 pcs.

Figure. RNPP RWTP

Figure. Supercompaction installation for RNPP SRW

In order to prepare a batch of radioactive waste for the transfer for disposal, the Rivne NPP developed the “Technical Solution on the Procedure for Processing the Salt-Bitumen Compound with Subsequent Disposal” and agreed it with the State Nuclear Regulatory Inspectorate of Ukraine. According to this Technical Solution, in 2020-2021, the Rivne NPP, in cooperation with the Ecocenter, performed physical and chemical characterization of a specific radwaste flow - salt-bitumen compound (SBC) in accordance with the Methodology for Physical and Chemical Characterization and Report on the Results of Physical and Chemical Characterization was developed. The Report on the Results of Physical and Chemical Characterization was approved by the State Nuclear Regulatory Inspectorate of Ukraine and recommended for use to justify safety at the stages of transport, storage, preparation for disposal and disposal of this radwaste batch.

The first 60 packages of RNPP SBC were transferred to CRME in November-December 2021.

Construction of Khmelnytsky NPP Radioactive Waste Treatment Plant

In 2021, measures were taken to construct a RWTP for processing radwaste accumulated in storage facilities and generated during KhNPP operation into a form suitable for safe temporary and long-term storage.

A construction contractor was identified, systems and components important to safety were tested at manufacturing enterprises and delivered to the Khmelnytsky NPP site, the Plan for Decommissioning of a Modular Storage Facility for Radwaste in BB-Cube Containers, whose site is planned to be used for RWTP needs was approved, as well as the conceptual technical solution for implementing the RWTP radiation monitoring system and its integration into the radiation monitoring system of the KhNPP special building.

According to the design, KhNPP RWTP includes: installations for solid radwaste retrieval from the storage facility; sorting and fragmentation installations;

installations for incineration, compaction (supercompaction), cementing, activity measurement, decontamination of metal and equipment; system for determining characteristics of drums with radioactive waste, internal transport for servicing these installations.

According to the results of the state NRS review, the following were agreed: technical specifications "Incineration Installation for Solid and Liquid Radioactive Waste on Organic Fuel with a Monitoring System for RWTP Emissions. Book 1. DNR 155104-1" and "Incineration Installation for Solid and Liquid Radioactive Waste on Organic Fuel with a Monitoring System for RWTP Emissions. Book 2. DNR 155104-1-ME0533BB-TSV01"; processing Book 2 DNR 155104-1-ME0533BB-TSV01";

program of acceptance (factory) tests ME0533-D211-030 "Monitoring System for Chemical and Radiation Emissions of the Incineration Installation for Solid and Liquid Radioactive Waste on Organic Fuel of KhNPP Radwaste Treatment Plant; programs and methodologies of factory acceptance tests for certain components and systems of the incineration installation for solid and liquid radwaste on organic fuel with the emission monitoring system;

program of acceptance tests at the KhNPP site "Monitoring System for Chemical and Radiation Emissions of the Incineration Installation for Solid and Liquid Radioactive Waste on Organic Fuel of the KhNPP Radwaste Treatment Plant" ME0533-D211-031;

terms of reference for the radiation monitoring system of the KhNPP Radioactive Waste Treatment Plant.

In December 2021, the "Plan (Roadmap) for Authorizing Activities at the Stages of KhNPP RWTP Construction and Commissioning" was approved as a working document for interaction within the licensing process and obtaining an individual permit for commissioning a new infrastructure facility at the KhNPP site".

Priority Measures on Radwaste Management at NPP Sites

The main area in radioactive waste management is forming an up-to-date infrastructure for the safe management of radioactive waste from their generation and collection to transfer of radwaste packages that will meet the acceptance criteria to relevant radwaste storage facilities for disposal. The main areas of activities and measures for 2017-2021 are defined in the Comprehensive Program for Radioactive Waste Management of the Energoatom.

Based on the preliminary review results of updated document "Comprehensive Program for Radioactive Waste Management of the Energoatom PM-D.0.18.174-21", SNRIU was notified on the possibility of putting the program into effect in the proposed version from the beginning of 2022 to ensure continuity of planning and reporting on radioactive waste management. The decision to approve the document in terms of completeness and adequacy of the measures provided by the program to ensure safety of facilities and activities for radwaste processing and storage at NPP sites in accordance with NRS standards and rules will be taken by SNRIU based on the results of the state NRS review. The updated Comprehensive Program for Radioactive Waste Management of the Energoatom for 2022-2026 provides the following priority measures for radioactive waste management at NPP sites:

construction and commissioning of RWTP at the sites of the Khmelnytsky NPP (2022) and Pivdennoukrainsk NPP (2023);

formation of temporary light storage facilities for storage of containers with conditioned radioactive waste at the sites of the Zaporizhzhia NPP (2022) and Pivdennoukrainsk NPP (2025);

ensuring, jointly with CRME, the acceptance of Rivne NPP SBC from the for disposal in the engineered near-surface disposal facility for low- and medium-level short-lived radioactive waste (hereinafter referred to as ENSDF) of the Vektor;

implementation of a set of measures to develop the optimal formulation for the immobilization of filter materials and sludge, testing and processing of an experimental batch of filter materials and sludge at Zaporizhzhia NPP (2022);

studies of NPP radwaste samples in a specialized laboratory regarding the content of alpha-, beta-, gamma-emitting nuclides to calculate radionuclide vectors for various radioactive waste flows (2022); completion of joint work with the Storage Operator on the development and justification of the acceptance criteria for long-term storage and/or disposal of conditioned radwaste from NPPs in the existing Vektor storage facilities (Lot-3, SRW-1, SRW-2);

preparation and coordination of technical solutions for acceptance of radwaste from Ukrainian NPPs to storage facilities SRW-1, SRW-2 with SNRIU;

formation of sites for the release of radioactive materials from regulatory control, etc.

Within project of the Instrument for Nuclear Safety Cooperation U4/01/14A "Determination of Waste Forms that Ensure Safe Processing, Storage and Disposal of Radioactive Waste Stored at Ukrainian NPPs", technical reports "Detailed Analysis of Problematic Radwaste Flows" and "Sampling Methodology and Methodology for Selection of Tools" were developed. They can be used by the operating organization for radiological characterization of the main radwaste flows and obtaining data for the development of technologies to process problematic radwaste and possible methods for its disposal.

The characterization process refers to problematic waste flows such as ion exchange resins, evaporation bottom and salt fusion cake. Moreover, document "Methodology for Characterization of ZNPP Filter Materials and Sludge" in terms of radiation properties was also agreed, within the agreement "Development of Formulations for the Immobilization of NPP (ZNPP) Filter Material and Sludge and Immobilization of an Experimental Batch of NPP (ZNPP) Filter Materials and Sludge Using the Mobile Line" (MET/02/15-11-2019).

Radioactive Waste Management at RADON

The collection and storage of radioactive waste generated from the use of radiation sources in medicine, science, various industries, including spent radiation sources transferred to the category of radioactive waste, is provided by state specialized enterprise for radioactive waste management RADON ASSOCIATION (RADON), which includes the Central Production Site (CPS), Dnipro Interregional Affiliate (DIA), Lviv Interregional Affiliate (hereinafter referred to as LIA), Odesa Interregional Affiliate (OIA), Kharkiv Interregional Affiliate (KhIA).

In accordance with the conditions of the licenses issued by SNRIU for processing, storage of radioactive waste, the RADON provides:
operation of storage facilities for radwaste container storage;
maintenance, control and monitoring of finally closed radwaste repositories, which were filled in the previous period (before 1996) using the disposal technology;
collection, conditioning and transport of radioactive waste to storage facilities;
operation of decontamination points for overalls, underwear, personal protective equipment;
maintenance of the state radwaste accounting system;
participation in the mitigation of radiation accidents.

Radwaste storage facilities operated by the RADON CPS, DIA, LIA, OIA, KhIA are hangar-type buildings, which provide container storage of radwaste and spent radiation sources. These buildings were constructed on the RADON sites in the 1990s when the decision was made to transfer state specialized enterprises for radioactive waste management to the technologies of radioactive waste storage.


Figures. Container storage of radwaste in hangar storage facilities

Finally closed radwaste repositories filled up to 1996 by the disposal technologies are a system of near-surface reinforced concrete radwaste disposal facilities of a modular type with a capacity of 200 m^3 and 400 m^3, constructed according to standard designs in the 1960-1970s. The RADON provides maintenance, monitoring and reassessment of their safety to make decisions on safety of each specific repository; periods during which these repositories can provide reliable isolation of radioactive waste; technological solutions on the removal of radioactive waste and decommissioning of repositories.

In the last three years, RADON experts, in cooperation with international experts, within EU project U4.01/14C “Comprehensive Safety Assessment of the Radioactive Waste Management Sites Operated by the RADON, and Design of Restoration for Certain Facilities”, performed a comprehensive safety assessment of RADON sites.

In 2021, the RADON CPS, DIA, LIA, OIA, KhIA received radioactive waste from 44 entities, as a result of whose activities or as a result of the mitigation of radiation accidents and incidents radioactive waste was generated.

In total, during 2021, 938 radiation sources transferred to the radwaste category, with a total activity of 1.13E + 13 Bq, as well as 2095.5 kg of solid radwaste with a total activity of 2.34E + 10 Bq were accepted into RADON storage facilities.

The RADON transferred radwaste in the form of spent radiation sources in the amount of 186 pcs. to the Centralized Long-Term Storage Facility for Spent Radiation Sources (hereinafter referred to as CLTSF).

The RADON is also involved in urgent actions of the competent authorities to eliminate emergencies related to the detection of abandoned radiation sources or radiation sources in illicit trafficking. All such radiation sources are sent to RADON CPS, DIA, LIA, OIA, KhIA storage facilities, which ensure their safe and controlled storage and confinement from getting into the environment and places accessible to the public.

In particular, in July 2021, an emergency team of representatives of the RADON affiliates carried out a set of complicated and radiation-hazardous activities to remove a part of the installation for express and instrumental neutron activation analysis containing fast neutron source DShN-108 (hereinafter referred to as the part of the Installation with DShN-108) from the basement of the Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the National Academy of Sciences of Ukraine.

After its removal, a part of the Installation with DShN-108 is placed in the PK-N108 packaging made for transport and temporary storage of this part. of the Installation with DShN-108.

PK-N108 consists of external protective container ZK-1 and internal container KN-1. Each container has the shape of a parallelepiped and consists of a tank and a lid. Biological protection is provided by 160 mm and 110 mm paraffin layers in the outer and inner containers, respectively. Paraffin is in metal casing made of 1.5 mm thick sheet steel. PK-N108 was tested for the performance of biological protection functions.


Figures. Removal of the Installation with DShN-108 from the Semenenko Institute of Geochemistry, Mineralogy and Ore Formation

After being removed and placed in the PK-N108 container, the part of the Installation with DShN-108 was transported for temporary storage to CLTSF, which is located at the Vektor in the Chornobyl Exclusion Zone. In accordance with the Technical Solution agreed with SNRIU on Acceptance of the Part for Express and Instrumental Neutron Activation Analysis Containing Fast Neutron Source, PK-N108 was located for temporary storage in CLTSF storage area in a pit designed for storage of neutron sources.


Figures. Placement of PK-N108 with the part of the Installation with DShN-108 at CLTSF

For reference:

On 19 February 2018, during preparation for repair in the basement of the Semenenko Institute of Geochemistry, Mineralogy and Ore Formation named of the National Academy of Sciences of Ukraine, personnel of the institute identified an increased level of exposure dose rate by available radiation monitoring devices in one of the basements, where, according to historical data, in the 60-70s of the 20th century there was an installation to study rock samples by neutron activation analysis methods using Pu-Be IBN-108 fast neutron source.

The Installation manufactured in the USSR was on the balance of one of the scientific institutions in Moscow and transferred for temporary use in 1975 within establishing a laboratory for research in the field of isotope geochemistry and cosmochemistry, geochronology, radiochemistry and geochemistry of technogenesis in Kyiv. The practical use of this laboratory was terminated after the ChNPP accident and establishment of new scientific institution - the Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine. The equipment was dismantled and the neutron source was left in the basement shaft, data on the presence of the Installation and, in particular, the neutron sources as well as documents for this Installation, for the neutron source, were lost.

The Institute administration took priority measures to ensure radiation safety and access control, informed executive authorities according to the established procedure and organized an immediate survey of the territory and rooms involving experts from the Institute for Nuclear Research of the National Academy of Sciences of Ukraine, Main Office of the State Emergency Service of Ukraine in Kyiv and Civil Protection Department of the Sviatoshynskyi District Administration for decision making and further actions, in accordance with the Procedure for Interaction between Executive Authorities and Legal Entities Engaged in Activities in Nuclear Energy Use in Case of Detection of Radioactive Materials in Illicit Trafficking approved by Resolution of the Cabinet of Ministers of Ukraine No. 813 of 2 June 2003.

Radioactive Waste Management in the Exclusion Zone (Radioactive Waste Long-Term Storage and Disposal)

The main activities for radwaste management in the exclusion zone (except the ChNPP site) are carried out by CRME, which is the operating organization at all life stages of radwaste disposal facilities, and also performs radwaste processing and long-term storage.

On the territory of the exclusion zone, CRME conducts:

design and construction of facilities for radwaste long-term storage prior to its disposal in a geological repository, including vitrified radwaste from SNF reprocessing, as part of Vektor Stage 2;

operation of CLTSF at the Vektor (in terms of comprehensive (hot) tests);

operation of two parallel ENSDF modules constructed at the Vektor site;

operation of radioactive waste disposal facility No. 21A Buryakivka RWDS;

measures to maintain the existing facilities for management of emergency Chornobyl radwaste generated in the first years of the Chornobyl accident mitigation in proper condition: Buryakivka RWDS, Pidlisnyi RWDS, ChNPP Stage III RWDS (their monitoring, reconstruction, stabilization, safety improvement, inspection, safety review, remediation), as well as maintenance, inspection, monitoring, removal of trenches and piles of RICS;

commissioning of near-surface disposal facilities for low- and intermediate-level short-lived radwaste resulting from the Chornobyl accident, of two types: SRW-1 - for radwaste disposal in reinforced concrete containers, SRW-2 - modular facility for disposal of unpackaged and large-sized radwaste;

prospecting and research activities on siting for geological repository for long-lived and high-level radioactive waste.

Figure. Engineered near-surface disposal facility for SRW (modular type) at the Vektor

Figure. Engineered near-surface disposal facility for SRW (modular type) at the Vektor

Centralized Long-Term Storage Facility for Spent Radiation Sources

CLTSF is an important element of the management system for radwaste in the form of spent radiation sources (hereinafter referred to as SRS) and should ensure centralized placement of radwaste in the form of radiation sources.

CLTSF operation includes acceptance, processing (conditioning) and long-term storage (50 years) of radwaste in the form of SRS of various types and design accumulated at the sites of RADON specialized radioactive waste management enterprises, as well as radiation sources that are used in medicine and industry after completion of their operation and transfer to the radwaste category.

During 2021, CRME continued to conduct comprehensive (hot) tests of CLTSF using radiation sources.

Since the start of operation, 21,492 radiation sources were accepted for storage at CLTSF, of which 328 radiation sources were accepted during 2021.

Figure. Centralized long-term storage facility for spent radiation sources

Figure. Section for storage of spent radiation sources at CLTSF

Construction of Long-Term Storage Facility for Vitrified High-Level Radioactive Waste Resulting from VVER-440 SNF Reprocessing

In Ukraine and many other countries, SNF is not considered radioactive waste, but is regarded as a valuable raw material with the possibility of further use as nuclear technologies are developed.

At present, the technologies for industrial SNF reprocessing are owned by three countries: Great Britain, France and the Russian Federation. SNF from Ukrainian NPPs is sent to enterprises of the Russian Federation that provide services for SNF reprocessing and technological storage of its processed products, which is in line with international practice and is carried out in accordance with the national legislation of the parties.

According to the Agreement between the Government of Ukraine and the Government of the Russian Federation on scientific, technical and economic cooperation in nuclear energy of 14 January 1993 and contractual obligations, the Energoatom should return radwaste obtained after SNF reprocessing to Ukraine.

The construction of a storage facility at the Vektor site for interim long-term (100 years) storage of vitrified high-level waste (hereinafter referred to as HLW) from VVER-440 SNF reprocessing is provided by the National Target Environmental Program for Radioactive Waste Management.

In 2020, SAUEZM Order approved project “Construction of an Interim Storage Facility for High-Level Waste (HLW) Returned from the Russian Federation after Reprocessing Spent Nuclear Fuel from Ukrainian NPPs (Correction)” based the positive conclusion of the comprehensive state review. The storage facility should be constructed by CRME in accordance with the approved Project and within the license issued by SNRIU for processing and storage of radioactive waste. In 2021, measures were continued to determine the contractor for the development of working documents, justification of operation and construction safety for the storage facility.

Engineered Near-Surface Disposal Facility for Low- and Intermediate Level Short-Lived Waste

ENSDF was constructed in 2009 within the design of the ChNPP Industrial Complex for Solid Radioactive Waste Management (hereinafter referred to as ICSRM) for the disposal of radwaste packages from the ChNPP Liquid Radioactive Waste Treatment Plant (LRTP) and Solid Radioactive Waste Treatment Plant (SRTP). The disposal facility consists of two parallel sections, each has 11 reinforced concrete compartments (modules) equipped with a central drainage gallery, two mobile frame structures with overhead cranes.

The disposal facility capacity is 50.210 m^3 of radioactive waste packages.

In 2021, CRME, according to the license to operate a radioactive waste disposal facility, continued to fill two symmetrical ENSDF modules A1 and D1. Since the start of operation, ENSDF has accepted 8895 radwaste packages for disposal, with a total volume of 2197.08 m^3 of radwaste packages with a total activity of 1.5710E+13 Bq. Four tiers of radwaste packages were filled and concreted in each of modules A1 and D1.

Within disposal facility operation, the operator takes measures to ensure control over the state of civil structures of the disposal facility modules, functioning of the central drainage gallery under the disposal facility

Figure. ENSDF compartments

Figure. Concreting of tiers in ENSDF

In order to transfer radioactive waste from the NPPs to CRME, during 2021, the Rivne NPP took measures to ensure the possibility of transferring packages of radwaste in the form of RNPP SBC to CRME, in particular:

SNRIU developed and approved a number of technical solutions and operational documents of CRME on justifying the possibility of SBC acceptance at CRME facilities; in September 2021 based on the results of the state NRS review for the technical documents provided by CRME, as well as the results of comprehensive tests of equipment and systems important to safety of the facility (site in the Vektor building for container preparation for disposal No. 20) for the interim storage of radwaste packages with RNPP salt-bitumen compound prior to their disposal at the Vektor ENSDF, SNRIU issued an individual permit to CRME for the operation of this storage facility. At the beginning of December, for interim storage on the Vektor territory.

The next step will be the preparation of SBC packages for disposal in ENSDF. This is planned at ChNPP radioactive waste management facilities.

Figures. Transport and placement of radwaste packages with RNPP SBC in the interim storage facility at the Vektor

Buryakivka Radioactive Waste Disposal Site

Buryakivka RWDS has 30 near-surface disposal facilities (trenches) for radwaste disposal. All 30 trenches are completely filled and finally closed. In order to expand the production capacity of RWDS Buryakivka, in 2018 an additional storage facility (trench) No. 21A was constructed.

Figure. Buryakivka RWDS

In 2021, within the license to operate radwaste disposal facilities, CRME continued to operate radioactive waste disposal facility 21A Buryakivka RWDS, as well as maintain and support finally closed 30 radwaste disposal facilities of this site in a safe condition.

The total volume of radwaste in 30 trenches of Buryakivka RWDS is 690 thousand m^3 with a total activity of 2.54 E + 15 Bq. Trench No. 21A of Buryakivka RWDS accepted for disposal 23583.70 m^3 of radioactive waste with a total activity of 1.77E + 12 Bq in 2021.

Pidlisnyi and ChNPP Stage III Radioactive Waste Disposal Sites

These disposal sites were constructed in 1986-1988 during the priority measures to mitigate the consequences of the Chornobyl accident.

During 2021, CRME carried out routine activities to ensure safety of the Pidlisnyi and ChNPP Stage III radioactive waste disposal sites (RWDS).

Figure. Pidlisnyi RWDS

Figure. ChNPP Stage III RWDS

Radwaste Interim Confinement Sites (RICS)

RICS are territories adjacent to ChNPP, with a total area of about 10 hectares, where in the course of priority measures for mitigation of ChNPP accident consequences, the trenches and piles were constructed to confine radwaste. For the most part, such radwaste was civil structures, household items, topsoil, etc. contaminated due to the emergency release. Nine RICS are located in the exclusion zone: Yaniv Station, Naftobaza, Pishchane Plato, Rudyi Lis, Stara Budbaza, Nova Budbaza, Pripyat, Kopachi, Chystoholivka.

CRME surveys RICS, taking into account the degree of hazardous environmental impact, in order to close the most hazardous trenches and piles.

In 2021, in accordance with the Technical Specifications for Safe Operation of RICS, CRME carried out routine activities to ensure safety.

Figure. RICS

Radwaste Disposal Facilities: SRW-1 i SRW-2 at the Vektor

There are two near-surface solid radwaste disposal facilities with a total capacity of 19.200 m^3 at the final stage of construction (acceptance tests of systems and equipment is planned) at the Vektor:

SRW-1 is a disposal facility for short-lived low- and intermediate-level radwaste in reinforced concrete containers (volume of 9800 m^3);

SRW-2 is a disposal facility for short-lived low- and intermediate-level large-sized, bulk radwaste, radwaste in drums, kraft bags, cage-type containers (volume of 9400 m^3).

In 2021, CRME performed activities to survey the current state of buildings and equipment, and their maintenance. Programs have also been developed for acceptance tests of systems and equipment important to safety of SRW-1 and SRW-2 radwaste disposal facilities and infrastructure objects.

Figure. SRW-1 and SRW-2 disposal facilities

Construction of Geological Repository for Radwaste Disposal

Measures for the construction of a geological repository for radioactive waste disposal are defined in the Strategy for Radioactive Waste Management in Ukraine and the National Target Environmental Program for Radioactive Waste Management.

Since 2018, within the European Commission's Instrument for Nuclear Safety Cooperation, project INSC U.04.01/14B “Development of the National Plan for the Geological Disposal of Radioactive Waste in Ukraine and its Implementation Schedule” has been implemented in Ukraine.

Within this project, Technical Report “Development of a Detailed National Plan for Deep Geological Disposal” was developed. It was reviewed by SNRIU in 2021, with the involvement of experts from the Institute for Nuclear and Radiation Safety of France (IRSN) and SSTC NRS, and received positive review results for further implementation of plan measures at the level of state program documents.

Safety of Management of Radioactive Materials containing Naturally Occurring Radionuclides

The implementation of activities related to the use of nuclear technologies, nuclear materials, radiation sources in science, production, medicine and industrial sectors of Ukraine and related to the use of nuclear energy, lead to the generation of radioactive waste. At the same time, radioactive materials and waste containing naturally occurring radionuclides can be generated in the course of other economic activities that are not related to the use of nuclear energy, in particular, oil and gas production, production of mineral fertilizers, mining of iron ores, coal and other minerals.

Today, on the territories of production sites, in particular, enterprises of the oil and gas industry, where spent radioactively contaminated process equipment and other materials containing naturally occurring radionuclides (tubing, sludge, bulk waste) are stored, whose activity or specific activity exceeds the levels of release from regulatory control and which should be managed with implementing measures for radiation protection of the public and the environment, similar to the measures for radwaste management.

The need to address the issue of ensuring safety in the management of technologically enhanced naturally occurring radiation sources (hereinafter referred to as TENORS) and materials (spent equipment, other waste) containing naturally occurring radionuclides are determined by the decisions of the National Security and Defense Council of Ukraine and relevant Decrees of the President of Ukraine (No. 35/2021 of 29 January 2021 and No. 111/2021 of 23 March 2021). The main executor of these Decrees of the President of Ukraine, in terms of elaborating the issue of legislative regulation for the management of materials, equipment and waste, in particular, of the oil and gas industry contaminated with naturally-occurring radionuclides, is the Ministry of Environmental Protection and Natural Resources of Ukraine.

SNRIU takes an active position regarding the need to find ways to solve the issues of handling materials and waste contaminated with TENORS at the state level.

Interdepartmental meetings to consider ways to legally regulate TENORS management were initiated, participation in meetings of the Working Group on the management of materials and waste contaminated with TENORS generated in the oil industry (the working group was formed by SAUEZM) was provided; on 12 November 2021, a meeting of the SNRIU Board was organized and held to consider the issue “On Safety Regulation of the Management of Materials and Waste Containing Naturally Occurring Radionuclides”.

For reference: *In some countries, in particular, the USA, Ukraine, geological formations containing deposits of minerals (oil and gas) containing natural radionuclides are called naturally occurring radioactive materials (NORM). Since natural radionuclides are concentrated and impacted by the surface environment and human contact during mining, these materials are classified as Technologically Enhanced Naturally Occurring Radioactive Material (TENORM). In Ukraine: Technologically Enhanced Naturally Occurring Radiation Sources (TENORS).*

Management of Waste Containing Naturally Occurring Radionuclides at Specialized Enterprises

To date, the sites of a number of specialized radwaste management enterprises have already accumulated a certain amount of waste contaminated with naturally occurring radionuclides accepted in previous years as radwaste. In relation to this waste, specialized enterprises develop and implement measures for its further management (processing, decontamination, temporary storage and disposal). At the same time, the development and industrial implementation of relevant technologies requires significant financial costs.

Management of Radwaste in the Form of Tubing Contaminated with Naturally Occurring Radionuclides at RADON KhIA

780 m3 (780.44 t) of tubing is stored at the Kharkiv SISP, in a warehouse for temporary storage at RWDS.

Figure. Warehouse for temporary storage of tubing contaminated with naturally occurring radionuclides (filled)

According to the license conditions of RADON KhIA, activities are being carried out on the experimental decontamination of tubing stored at RWDS, and release of decontaminated tubing from regulatory control.

Figures. The installation for experimental activities on practicing the technology for decontamination of tubing contaminated with naturally occurring radionuclides is located at RADON KhIA RWDS

Tubing Management in the Exclusion Zone

In the period from 2006 to 2010, the former Compleks (at present CRME) accepted for storage at Buryakivka RWDS site No. 100 approximately 2600 m^3 of tubing.

Moreover, about 3,643.563 tons of tubing are stored at the Leliv Equipment Decontamination Site in the exclusion zone.

Figure. Storage of tubing (accepted as radwaste) at Buryakivka RWDS site No. 100

Figure. Storage of tubing at the territory of Leliv Equipment Decontamination Site, exclusion zone

In order to conduct experimental activities on the decontamination of tubing stored at this facility, CRME finalizes documents for obtaining an individual permit for commissioning an experimental installation for hydrodynamic cleaning of oil and gas equipment from salt deposits contaminated with naturally occurring radionuclides DUGA (DUGA experimental installation) mounted on the territory of the decontamination site for special vehicles located on the border of the conditionally dirty and conditionally clean zones at Buryakivka RWDS.

Figures. DUGA experimental installation

Decommissioning of ChNPP Units No. 1, 2, 3

ChNPP-1, 2, 3 are decommissioned by the operating organization upon the license issued by SNRIU on 22 March 2002, re-issued on 3 November 2020, and individual permit of series of 31 March 2015 for implementation of the final closure and safe enclosure stage for ChNPP-1, 2 and 3 (FCSE).

ChNPP implements the FCSE stage in accordance with the “Program for the Implementation of the Final Closure and Safe Enclosure Stage for ChNPP-1, 2 and 3” and project “Final Closure and Safe Enclosure of ChNPP-1, 2 and 3”.

According to SNRIU request and to optimize decommissioning, in 2021, ChNPP analyzed program and design documents for the FCSE stage, as well as the activities already performed, and prepared a decision “On Ensuring Compliance with the FCSE Project Implementation Deadlines” and “List of Documents Submitted for Consideration by SNRIU as part of Implementing the Project of the Final Closure and Safe Enclosure for ChNPP-1-3. These documents were reviewed and approved by SNRIU.

Within the FCSE stage, ChNPP performs dismantling of equipment that is not important to safety and is not subject to further safe storage.

During dismantling, significant amount of radioactively contaminated materials and equipment is formed, which can be released from regulatory control in the future.

For this purpose, an installation for the release of radioactive materials from regulatory control is being implemented at ChNPP. In 2021, ChNPP completed the trial and commercial operation of this installation and developed a report on its performance. This report is currently under SNRIU consideration.

In 2021, regulatory support was provided for ChNPP activities during FCSE stage implementation and documents related to the preparatory work for the safe enclosure of certain ChNPP rooms, decisions on the management of materials formed as a result of dismantling of buildings and structures, operational and technical documents were considered.

Radioactive Waste Management Facilities at ChNPP

Radwaste accumulated during ChNPP operation, mitigation of the accident of 1986, generated during Units No. 1, 2, 3 decommissioning and Shelter transformation into an environmentally safe system are stored in radwaste storage facilities at the ChNPP site: SRW storage facilities, LRW storage facilities, LRW and SRW storage facilities, or are transferred for disposal. A number of facilities designed for radwaste management were constructed at the ChNPP site within the international technical assistance projects.
In 2021, they were commissioned and operated.

Liquid Radioactive Waste Treatment Plant

Figure. LRTP at the ChNPP site

The technological process of LRTP provides processing of LRW in the form of evaporation bottom of evaporators, pulp of spent ion-exchange resins, perlite pulp and sludge.

In 2021, within the individual SNRIU permit of 11 December 2014, ChNPP conducted processing of evaporation bottom at LRTP and performed preparatory work for processing of ion-exchange resins. After processing, packages with cemented LRW are transferred for disposal to ENSDF located at the Vektor in the exclusion zone.

Due to the amendments to the Safety Conditions and Requirements (Licensing Conditions) for the Implementation of Activities in Radioactive Waste Management approved by SNRIU Order No. 110 on 22 October 2002, registered in the Ministry of Justice of Ukraine on 6 November 2002 under No. 874/7162, ChNPP activities on LRTP operation should be carried out under an individual license for processing, storage of radioactive waste.

In April 2021, ChNPP applied to SNRIU with an application and a package of relevant documents for obtaining a license for LRTP operation.

Based on the results of considering the submitted documents and the inspection conducted, the ability of ChNPP to carry out the declared type of activities was confirmed. On 20 May 2021, a license was issued for processing, storage of radioactive waste, namely, for LRTP operation.

ChNPP carries out current LRTP operation, namely processing of evaporation bottom from tank 4A-201/3 of the liquid radwaste storage facility, in accordance with the conditions of the above license. In 2021, 389.88 m^3 of evaporation bottom was processed at LRTP.

Industrial Complex for Solid Radwaste Management

ICSRM includes:

Lot 0 – temporary storage facility designed for storage of group III waste (high-level waste) and low- and intermediate-level long-lived radwaste (TSF HLW and LIL-LLW) was commissioned in 2010, SNRIU individual permit of 10 December 2010;

Lot 1 - Solid Radwaste Retrieval Facility (SRRF);
Lot 2 – Solid Radwaste Treatment Plant (SRTP);
Lot 3 – ENSDF constructed at the Vektor site – commissioned in 2011.

Due to the amendments to the Safety Conditions and Requirements (Licensing Conditions) for the Implementation of Activities in Radioactive Waste Management, ChNPP activities on ICSRM should be carried out under individual licenses for processing, storage of radioactive waste.

In 2021, applications and relevant documents submitted by ChNPP for obtaining licenses within ICSRM operation were considered.

Operation of TSF HLW and LIL-LLW (Lot 0)

TSF HLW and LIL-LLW are designed for temporary storage of solid radwaste, which is pre-sorted at SRTP, and which cannot be disposed in ENSDF located at the Vector in the exclusion zone.

Radwaste accumulated during ChNPP operation, generated during decommissioning of ChNPP-1, 2, 3, Shelter transformation into an environmentally safe system, and ISF operation is subject to temporary storage.

In September 2021, based on the results of considering the documents provided by ChNPP and the inspection conducted, the ability of ChNPP to operate TSF HLW and LIL-LLW was confirmed and a license was issued for processing, storage of radioactive waste, namely, to operate TSF HLW and LIL-LLW.

ChNPP provides current operation of TSF HLW and LIL-LLW in accordance with the conditions of the above license.

At the end of 2021.49 radwaste packages (38 HLW packages and 11 LIL-LLW packages) are stored in the storage facility.

Commissioning of SRRF and SRTP (Lot 1, 2)

SRRF is designed to extract solid radwaste from the SRW storage facility, load it into containers and transfer this SRW for processing to SRTP.

Figure. Solid radwaste treatment plant at the ChNPP site

SRTP is designed for processing SRW accumulated during ChNPP operation, as well as radwaste generated during decommissioning of ChNPP-1, 2, 3, ISF operation and Shelter transformation into an environmentally safe system.

The main technological processes of SRW processing are compaction, incineration and cementing.

According to the "ICSRM Commissioning Program" 57PR-CPTRO, three stages of SRRF and SRTP commissioning are envisaged:
Stage 1 - tests with homogeneous "sealed" SRW with known characteristics (completed under an individual permit dated 13 May 2010),
Stage 2 - tests with homogeneous "open" SRW with known characteristics (completed under an individual permit dated 23 May 2014),
Stage 3 – tests with heterogeneous SRW with unknown characteristics (activities are currently underway at this stage). The measures for stage 3 of SRRF and SRTP commissioning are determined by the agreed "Solution on Stage 3 of Hot Tests for ICSRM SRRF and SRTP" and "Work Program for Stage 3 of Comprehensive SRTP Hot Tests" (78PR-TSORO) in May 2021.

In October 2021, based on the results of considering the documents provided by ChNPP and the inspection conducted, the ability of ChNPP to commission SRRF and SRTP (stage 3 of hot tests) was confirmed and a license was issued for radwaste processing and storage, namely, commissioning of SRRF and SRTP.

According to the work program 78PR-TsORO, stage 3 of tests provides the retrieval of solid radwaste from the eastern "light" compartment of the SRW storage facility, its sorting and loading into 165-liter drums, compaction of the drums with radwaste and cementing the compacted briquettes in container KZ-3 container. In addition, this work program provides processing of large-size SRW.

Currently, ChNPP conducts stage 3 of SRRF and SRTP tests in accordance with the conditions of the above license and work program 78PR-TSRO.

Confinement-Shelter Operation

In 2021, the priority area of SNRIU activities was implemented: safety assessment and licensing of ChNPP activities as part of Confinement-Shelter commissioning.

After the confinement arch was placed in the design position above the Shelter in 2016, a meeting of the SNRIU Board was held to discuss approaches to licensing the operation of these unique facilities.

Considering the purpose of the Confinement-Shelter, a gradual change in Shelter state during its transformation within the confinement, definition/status of these facilities, their uniqueness, current regulatory requirements for issuing licenses/permits in nuclear energy use, lack of direct provisions on licensing of activities at these facilities, SNRIU Board Ordinance No. 09 dated 1 December 2016 determined that one of the most acceptable approaches is issuing a license for an individual activity: processing, storage of radwaste.

After completion of the trial and commercial operation of Confinement-Shelter Startup Package 1, at the end of May 2021, ChNPP sent an application and a package of documents to SNRIU for obtaining a license for processing and storage of radioactive waste that exists and is generated during Shelter transformation into an environmentally safe system as part of Confinement-Shelter operation.

During consideration of licensing documents, the state NRS review of a number of ChNPP documents was performed:

Report on the Trial and Commercial Operation of New Safe Confinement Startup Package 1;

Safety Analysis Report of Confinement-Shelter Operation;

Technical Specifications for Confinement-Shelter Operation;

Confinement-Shelter Emergency Plan;

Program for Radiation and Dose Monitoring and Environmental Monitoring of the Confinement-Shelter;

Acceptance Criteria for Radioactive Waste Transferred to the Radwaste Storage, Processing Facility (ChNPP Confinement-Shelter).

The documents are updated and meet the NRS requirements.

As part of the licensing process, with the involvement of SSTC NRS, on 5-9 July 2021, a survey of ChNPP was conducted to verify adequacy and reliability of the information provided by the applicant, and ChNPP ability to perform the declared type of activity.

During the survey, ChNPP ability to operate the Confinement-Shelter was confirmed. The results of considering the safety analysis report for the Confinement-Shelter operation and ChNPP survey were discussed at the meeting of the SNRIU Board on 29 July 2021. Board Ordinance No. 09 dated 29 July 2021 approved the Safety Analysis Report of the Confinement-Shelter.

On 12 August 2021, based on considering the results of the ChNPP application and documents, taking into account the survey results and solution of the SNRIU Board, a license was issued for processing, storage of radioactive waste that exists and is generated during Shelter transformation into an environmentally safe system as part of the Confinement-Shelter operation. The license validity period (until 31 December 2033) is established taking into account the next Confinement-Shelter safety review.

The license establishes certain conditions for activities, in particular: update the Confinement-Shelter SAR until 31 December 2022, prohibit the transfer of any radioactive waste to the Confinement-Shelter if it is generated outside it, ensure monitoring of fuel-containing materials (FCM), manage uncontrolled Shelter radwaste, etc.

ChNPP carries out current activities under the above-mentioned license.

In 2021, there was an information in some media about “fission reactions renewed in uranium fuel masses buried deep in the destroyed reactor hall” of the ChNPP Shelter.

SNRIU analyzes reports on the Shelter safety status, including for the period of 2016-2020, during which there was a tendency to increase the average and maximum values of the neutron flux density (hereinafter referred to as NFD) in places where FCM are concentrated. At the same time, the operational limits/operational safety limits determined by the Shelter technical specifications were not exceeded.

Taking this into account, SNRIU proposed ChNPP to conduct a more detailed analysis of the Shelter nuclear safety state due to the trend of NFD increase in certain places of FCM accumulation.

According to ChNPP, upon the studies performed by the Institute for Safety Problems of NPPs, NFD increase after NSC arch placing in the design position over the Shelter in 2016 was predictable and is associated with a change in the temperature and humidity regime after arch sliding on.

As part of Shelter operation, systems and equipment are provided to support FCM in a subcritical state. According to the Shelter technical specifications, when the operational safety limits are exceeded in terms of NFD indexes, neutron-absorbing solutions are supplied to FCM surface.

According to the ChNPP, starting from January 2021, NFD increase has decreased.

Shelter NRS is ensured by a system of organizational and technical measures during current operation of the facility and in implementing projects for its transformation into an environmentally safe system.

During activities at the Shelter, radiation and dose monitoring is provided and dose loads on personnel of ChNPP and contracting organizations are accounted.

According to ChNPP, in 2021 the average individual dose for ChNPP personnel working at the Shelter or at the Confinement-Shelter site was 1.10 mSv, the average level of individual doses for personnel of contracting organizations was 2.75 mSv.

The reference levels of individual annual exposure doses (13 mSv/year) for personnel of ChNPP and contracting organizations were not exceeded.

Solid and liquid radioactive waste is generated during activities at the Shelter and adjacent territory. The source of main SRW formation at the Confinement-Shelter is decontamination activities, and the source of secondary radwaste is the use of personal protective equipment and waste after maintenance, repair, modernization of systems and equipment of the Confinement-Shelter.

During the reporting period, during operation in rooms and on the territory of the Confinement-Shelter, 9.0 m^3 (3.9 tons) of low-level SRW with a total activity of 2.85 × 108 Bq were collected and transferred to Buryakivka RWDS. Compared to the same period in 2020, the amount of SRW transferred to Buryakivka RWDS decreased by 9.6 m^3 (3.7 tons) regarding volume and by 1.95×108 Bq regarding activity. The main cause of the decrease in solid radwaste generation is the completion of the main construction activities within NSC. The sources of liquid radwaste generation (radioactive water) are decontamination of rooms, equipment and tools, dust suppression, and the operation of changing rooms.

During 2021, in order to prevent the entry of radioactive substances into groundwater and to improve the radiation situation, 141 m^3 of radioactively contaminated water with a total activity of 3.499 × 109 Bq were collected and pumped out of the Shelter rooms.

Taking into account the need to establish a systematized set of nuclear and radiation safety requirements and rules for the Confinement-Shelter, SNRIU experts continued to develop regulatory document “Safety Requirements for the Confinement-Shelter”. In 2021, regulatory document revision 1 was sent to SAUEZM and ChNPP for response. This regulatory document is currently being finalized, also taking into account the feedback received.

VII. PHYSICAL PROTECTION OF NUCLEAR FACILITIES, NUCLEAR MATERIAL, RADIOACTIVE WASTE AND OTHER RADIATION SOURCES

Effectiveness Improvement Measures of the State Physical Protection System

Physical protection of nuclear facilities and nuclear material is the most important area in safety of activities in nuclear energy use. The priority tasks of the state policy in nuclear energy use to ensure security are aimed at fulfilling the international obligations of Ukraine, in terms of achieving the main physical protection goals: minimize the risks of sabotage, theft or any other illicit seizure of radioactive materials and strengthen the nuclear weapons non-proliferation regime.

During oversight activities, the following was performed: scheduled state inspection of the RADON physical protection system, control state inspection of the ChNPP physical protection system; inspections of the Institute for Nuclear Research of the National Academy of Sciences of Ukraine and IZOTOP State Enterprise; ChNPP surveys (ISF-1, ISF-2) (within issuing a license for training, retraining and skill improvement for experts on physical protection of nuclear facilities, nuclear weapons, radioactive waste, other radiation sources).

In order to prevent the threat of sabotage, theft, and other illicit actions by internal offenders, SNRIU physical protection experts elaborated 11 Plans for Interaction in Case of Sabotage, Physical Protection Plans, 24 Certificates for Determination of Physical Protection Level, 137 Lists of Positions of Employees, whose work requires registration of work permit to perform special activities, considered and agreed facility design threats. 22 SNRIU inspectors and 19 heads of private enterprises using radiation sources were granted permits to perform special activities.

9 permits were issued for the use of land and water bodies located in the control areas of nuclear hazardous facilities.

Measures for NPP physical protection in 2021 were organized and implemented under conditions of real threats caused by the military aggression of the Russian Federation in the East of Ukraine, and a hybrid impact on the social and political situation in the state.

Under these conditions, in order to ensure stable operation of nuclear power facilities and uninterrupted power supply to consumers, significant efforts were aimed at ensuring physical protection, strengthening of guard, access control, facility regimes and practical development of protection measures against terrorists and sabotage at NPPs, as well as system monitoring of crisis situations and developing new approaches to protect nuclear facilities.

The following was provided during the year:

continuity of NPP physical protection system functioning;

protection of NPP divisions by units of the National Guard of Ukraine for NPP protection;

protection of fresh and spent nuclear fuel during transport through the territory of Ukraine, including 11 rail transportations of fresh nuclear fuel through the territory of Ukraine.

There were no cases of theft, any other illicit seizure of nuclear materials, radioactive waste and other radiation sources.

Facility Design Threats for NPPs were developed for all NPPs, upon which activities are conducted to finalize the Plans for Interaction in Case of Sabotage.

The existing system of measures to ensure protection against terrorists and sabotage of nuclear facilities and nuclear materials, as well as other NPP facilities, was formed and is operated within the current legal and regulatory framework.

Units of departmental paramilitary guards of NPPs protect 139 facilities.

During the annual exercises to check preparedness of forces and means involved in ensuring NPP physical protection and protection against terrorists of NPPs, preparedness of the NPP departmental paramilitary guards was inspected. The inspection results showed that the NPP departmental paramilitary guards have a sufficient level of preparedness to perform their tasks to prevent possible terrorist acts or sabotage at NPPs.

Within G7 initiative “Global Partnership against the Spread of Weapons and Materials of Mass Destruction", measures are taken to reconstruct and re-equip the engineering and technical means of the physical protection system under international contracts in the area of ensuring physical protection of NPPs.

Bilateral tactical and special exercises were held at all NPP industrial sites to test forces and means of the military units of the National Guard of Ukraine for protection of NPPs involved in the response to crisis situations. During the exercises, the procedures and algorithms of actions were worked out by experts of the NPP physical protection services

No violations of the regulatory requirements on physical protection of nuclear facilities, nuclear materials radioactive waste, radiation sources in terms of loss of control over radioactive material, unauthorized interference in the operation of the engineering and technical means of the NPP physical protection systems, granting access to special activities without a special inspection were registered.

Design Activities

According to the project of forming a system for physical protection monitoring during transport, the IZOTOP transferred six special minibuses equipped with a system for physical protection monitoring for transport of radiation sources and a transport monitoring point was established.

The Sumy Regional Clinical Oncological Dispensary and Oleksandria Oncological Dispensary were assisted in the discharge, withdrawal and disposal of high-level radioactive materials as part of the technology replacement project.

Detection of Radioactive Materials in Illicit Trafficking

During the year, SNRIU, as a determined responsible organization, ensured active interaction and information exchange with the IAEA Illicit Trafficking Database (ITDB).

In February, the Directorate of the Security Service of Ukraine and the Main Directorate of the National Police of Ukraine in the Zhytomyr region detected and seized 2 Robotron SM24-024 metal containers containing Kr-85 (Krypton - 85) radiation sources at the Miropol Paper Factory LLC (Miropol village) due to the termination of production and actual activities.

On 10 March, officers of the National Police of Ukraine and Security Service of Ukraine found 36 items with the RADIATION HAZARD sign in an abandoned building (Lugansk region, Katerynivka village).
According to the results of the state review by the Nuclear Forensics Laboratory of the Center for Environmental Nuclear Energy Problems of the Institute for Nuclear Research of the National Academy of Sciences of Ukraine, it was

determined that these are uncontrolled R-22 switching arresters in the form of cylindrical glass objects that were usually used in electronic equipment, ignition units of aircraft engines. Arresters produced in 1978-1983 contain Sr-90 (Strontium), in 1984-1990 - H-3 (tritium). The maximum total activity of R-22 arresters is 2.2x106 Bq. The seized objects were transferred to the RADON for storage.

The State Border Service of Ukraine occasionally seizes objects with a decreased level of gamma radiation containing the Radium-226 radionuclide at checkpoints. These are various types of watches, including aviation watches, altimeters, compasses, etc. In May, during border control at the Chonhar checkpoint, a citizen of Ukraine who tried to take an aviation watch with an increased level of gamma radiation out of Ukraine was detained.

On 27 March, during the entrance dose monitoring performed by experts of the radiation safety service of PJSC ArcelorMittal Kryvyi Rih, the Kordon automated control system detected a car with a load of scrap metal with an increased level of gamma radiation at the Promyslova station. The maximum dose rate of gamma radiation on the car surface was 2.3 μSv/h. The departure station was Lubny. Cargo supplier was UkrMetAlliance LLC. During scrap metal sorting, a pipe fragment was seized. The seized pipe fragment of scrap metal was transferred to the RADON DIA radwaste disposal site by supplier UkrMetAlliance LLC.

On 10 May, 2 watches contaminated with Ra-226 (Radium - 226) and Th - 232 (dose rate of 1.2 μSv/hour) were detected and seized in the passenger's luggage at the exit point at the Boryspil airport and also on 9 October 2021, another clock (0.65 μSv/h) was detected.

On 19 May, during the entrance dose monitoring performed by experts of the radiation safety service of the PJSC “ArcelorMittal Kryvyi Rih”, the Kordon automated control system detected a car with a load of scrap metal with an increased level of gamma radiation at the Promyslova station. The maximum dose rate of gamma radiation on the car surface was 1.9 μSv/h. The departure station was Lykhachevo YUZHN. Cargo supplier was Maksimet Company LLC. During scrap metal sorting, a pipe fragment was seized.

On 11 June, in the Modrytsky forest area near Boryslav, Drohobych district, Lviv region, a local resident, when searching for metal objects using a metal detector in the ground at a depth of 0.3 m, found an object with the CAUTION RADIOACTIVITY sign, about which the resident informed the local authority - Executive Committee of the Boryslav City Council of the Drohobych district, Lviv region. Then, RADON LIA identified and seized an E-2M block of gamma relay affected by corrosion, weighing 93 kg, without identification inscriptions. The equivalent dose rate of gamma radiation at a distance of 10 cm is 6.7 μSv/h (according to the preliminary estimate from Cs-137 source). The item was sent to the Institute for Nuclear Research of the National Academy of Sciences of Ukraine for state review.

On 5 July, contamination of a cargo of scrap metal was detected at the checkpoint of the Kherson Commercial Sea Port. When scrap metal was sorted, fragments of pipes with a total weight of 44 kg, contaminated with Ra-226 natural radionuclides, were seized. The equivalent dose rate of gamma radiation at a distance of 10 cm is 4.85 μSv/h. Scrap metal was seized and transferred to the radioactive waste disposal facility of the RADON OIA.

On 13 September, at the Kalanchak checkpoint (Kherson region), an aviation watch contaminated with Ra-226 (4.11 μSv/h) owned by a citizen of Ukraine was seized at the exit.

Metallurgical enterprises PrJSC Azovstal Metallurgical Plant (Mariupol) and PJSC ArcelorMittal Kryvyi Rih (Kryivyi Rih) detected 7 cases of delivery of scrap metal radioactively contaminated with natural Ra-226 radionuclides during scrap metal acceptance. The RADON Dnipro and Odesa Interregional Affiliates transported the seized radiation-hazardous fragments of scrap metal to storage sites that are safe for the public and the environment.

On 27 September, military watches were found in the amount of 3 pieces in a bag at the garbage dump on the Tadzhytska Street, 2, Lviv. The total exposure dose rate at a distance of 0.1 m from the watches is 5.1 μSv/h. Seized by RADON LIA for storage.

In addition, Ukrainian experts on nuclear facility physical protection are actively involved in international events.

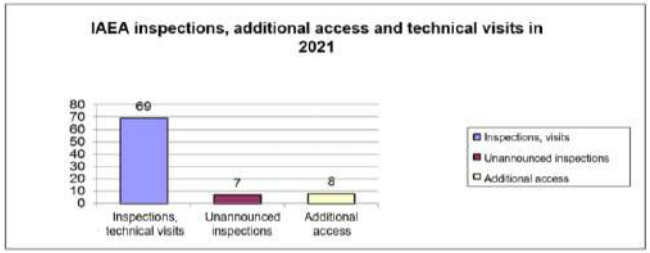
Jointly with representatives of the IAEA Division of Nuclear Security, a workshop was held in Sofia (Republic of Bulgaria) for representatives of Georgia, Republic of Moldova and Ukraine to discuss the next steps of activities under the program to support national, bilateral and regional measures of response to events in the area of nuclear security, detection of radioactive materials in illicit trafficking.

Ukrainian experts took part in online meetings aimed at combating the illicit transfer of firearms, explosives, chemical, biological, nuclear materials and radioactive materials across the Ukrainian-Moldovan state border under support of the European Union Border Assistance Mission to Ukraine and the Republic of Moldova (EUBAM), and working meeting on the GEIGER project - an analytical platform that collects data from law enforcement agencies and other government agencies on incidents related to the investigation of terrorist and criminal actions of the Republic of Moldova.

VIII. NUCLEAR WEAPON NON-PROLIFERATION SAFEGUARDS

IAEA Inspection Activities in Ukraine

The legal basis of the international non-proliferation regime is the Treaty on the Non-Proliferation of Nuclear Weapons. Ukraine joined it as a non-nuclear-weapon state at the end of 1994 and, fulfilling Article 3 of the Treaty, accepted international control over all its peaceful nuclear activities by signing an Agreement with the IAEA on application of safeguards. According to this Agreement, the IAEA carries out inspection activities in Ukraine and verifies the compliance of the reports provided by Ukraine with the actual state of nuclear materials in the country. Since 2012, the IAEA has started applying integrated safeguards in Ukraine and reduced inspection activities. To confirm the declared inventory amount of nuclear material and the absence of undeclared nuclear activities, the Agency conducted scheduled and unscheduled inspections and obtained complimentary access to nuclear installations and enterprises of Ukraine.



The following inspection activities were implemented at nuclear facilities: Zaporizhzhia NPP: 10 inspections and 1 technical visit, Khmelnytsky NPP: 6 inspections, 1 complimentary access and 1 technical visit, Pivdennoukrainsk NPP: 3 inspections and 1 technical visit, Kharkov Institute of Physics and Technology: 3 inspections (2 unannounced ones), 1 technical visit and 1 complimentary access, Kyiv Institute for Nuclear Research: 4 inspections (2 unannounced ones), Chornobyl NPP: 15 inspections (2 unannounced ones), 5 technical visits, CSFSF: 1 inspection and 1 technical visit, Rivne NPP: 7 inspections (including 1 unannounced), 1 technical visit and 1 complimentary access.

Inspection measures covered the following enterprises: Lviv Interregional Branch of SSE Radon, Municipal Enterprise “Central City Hospital of Chervonograd City Council”, Lviv State Oncological Regional Treatment and Diagnostic Center, Ukrmetalurgizotop, Dniprodzerzhynsk Chemical Plant, State Enterprise Skhidny Mining and Processing Plant (SkhidGZK), State Institution “The Institute of Environmental Geochemistry of National Academy of Sciences of Ukraine”, Central Production Site of the Radon Association, Institute of Organic Chemistry of NAS of Ukraine, State Enterprise "USIE IZOTOP", National Military Medical Clinical Centre "Main Military Clinical Hospital" and “Center of Industrial Diagnostics and Control” LLC, ArcelorMittal Kryvyi Rih, PJSC.

IAEA inspections were also carried out in the temporarily occupied territories, in the locations of nuclear materials that are subject to safeguards, in accordance with the requirements of the Agreement between Ukraine and the IAEA on the application of safeguards: in OJSC “Donetsk Metallurgical Plant” and "Lugansk Regional Clinical Oncology Dispensary".
During the IAEA technical visits, installation, replacement and adjustment of remote monitoring equipment, equipment testing, installation of IAEA seals were carried out. In particular, during the year, test transport and technological operations continued with the use of Holtec Company equipment for the spent fuel transport to the CSFSF site at the Rivne, Khmelnytsky, and Pivdennoukrainsk NPPs.
According to the results of the IAEA inspections, no significant comments from the Agency were recorded.

State Accounting and Control of Nuclear Material

The SNRIU ensures keeping of the state NM information bank data with information on the quantity and composition of nuclear materials in any material balance area or in an individual enterprise. During the year, 245 reports on nuclear materials and 12 preliminary notifications on export/import of nuclear materials were received, processed and submitted to the IAEA. Other information was regularly provided under the Agreement: changes in the design of the nuclear facilities, schedules of repairs of the main equipment during core opening, schedules for receiving and shipping nuclear materials at Ukrainian NPPs, information on the radiation doses of IAEA inspectors received during inspection activities, etc.

Implementation of the Additional Protocol to the Safeguards Agreement

The Additional Protocol to the Safeguards Agreement covers the entire nuclear fuel cycle, from ore extraction to waste disposal, including scientific research, and provides the IAEA with expanded powers in the field of monitoring countries' peaceful nuclear activities. The purpose of the Additional Protocol is to ensure that the non-nuclear states that have signed the Treaty do not have undeclared nuclear weapons and do not conduct undeclared nuclear activities.

Information on export supplies of agreed equipment and non-nuclear material from Ukraine was provided to the IAEA on a quarterly basis to implement the Additional Protocol to the Agreement and annual update of the information was performed in accordance with the Additional Protocol to the Agreement (34 declarations). Activities to collect data required for responding to IAEA inquiries in accordance with Article 2a.i of the Additional Protocol for research and development related to nuclear fuel cycle and non-nuclear material were conducted.

Implementation of Bilateral International Agreements on Cooperation in Peaceful Use of Nuclear Energy

SNRIU exchanged information on international transfers of nuclear material in compliance with international agreements with:
Euratom, according to the Agreement between the European Atomic Energy Community and the Cabinet of Ministers of Ukraine for Cooperation in the Peaceful Uses of Nuclear Energy;
Canadian Nuclear Safety Commission, according to the Agreement between the Government of Ukraine and the Government of Canada for Cooperation in the Peaceful Uses of Nuclear Energy;
Australia's Bureau of Safeguards and Non-Proliferation, in the framework of the Administrative Agreement between the SNRIU;
Australian Bureau of Safeguards and Non-Proliferation, in accordance with the Agreement between the Government of Ukraine and the Government of Australia on Cooperation in the Field of Use of Nuclear Energy for Peaceful Purposes.

Support of Efficiency of the Safeguards Infrastructure in Ukraine

Considerable attention was paid to improving the qualifications of specialists engaged in the implementation of safeguards in Ukraine. A series of webinars was held as part of the “International Safeguards Engagement Program” of the National Nuclear Security Administration of the U.S. Department of Energy for SNRIU inspectors, Chornobyl NPP personnel, and officials responsible for interaction with IAEA inspectors.

IX. SAFETY OF RADIOACTIVE MATERIAL TRANSPORT

In accordance with the Ukrainian legislation, regulation of the nuclear material (NM) transport safety is carried out by: issuing authorizing documents, such as licenses for the right to carry out activities related to the NM transport, permits for international transport of NM (during import, export, transit), approval certificates for the safe transport of RM and carrying out state oversight measures.

During 2021, the SNRIU issued 84 permits for international transport of NM, including in the framework of Ukraine's implementation of international agreements on cooperation in the field of nuclear materials transport, 4 permits for the NM transit to Hungary and the Slovak Republic. Applications for amendments and reissuing of 14 licenses for the right to carry out NM transport activities were considered. 9 state oversight measures were carried out, including 2 scheduled inspections, 1 unscheduled and 6 – inspection surveys. 11 approval certificates were issued:

9 certificates of approval of special conditions for the NM transport and 2 certificates of approval of the design of packaging sets for NM transport, namely: HI-STAR 190 ML, designed for transport of spent fuel and PKTVU-20 for NM transport in the form of fissionally released materials and neutron radiation sources.

Transport overpack HI-STAR 190 ML, designed and manufactured by Holtec International for the transport of spent fuel of VVER-1000 and VVER-440 reactors from Ukrainian NPP power units (Rivne NPP, VP Khmelnytsky NPP, Pivdennoukrainsk NPP) to the CSFSF site in sealed multi-purpose containers by rail transport: carriage Model 14-9068 as part of a special freight train.

Packaging PKTB(U)-20, designed and manufactured by NT-Engineering LLC for NM transport in the form of fissionally released materials, neutron RS, including beryllium, which include radionuclides 233U, 235U, 238Pu, 239Pu, 241Pu, 241Am, 244Cm, 248Cm, and PM of a special form , with the exception of NM In gaseous or liquid form, as well as in powder without primary packaging; nuclear materials in liquid state (solutions, concentrates, etc.).

For the transport of spent fuel within the boundaries of the NPP sites and CSFSF, in 2021, the SNRIU amended the license issued to Energoatom and issued a certificate of approval of the HISTAR PC design.

In accordance with the Agreement between the SNRIU and the Norwegian Radiation and Nuclear Safety Authority (DSA) on Cooperation in the Field of Nuclear and Radiation Safety of 2014 and the Protocol on Amendments to the Agreement of 2018, in the framework of the project Improvement of the Regulatory Framework for the Safe Transport of Radioactive Materials (COMPLIANCE), the following regulatory documents were developed: Procedure for Issuing Certificates for the Safe Transport of Radioactive Materials; Requirements for the Structure and Content of Safety Analysis Reports Submitted as Part of the Documentation for Obtaining Certificates; Requirements and Safety Conditions (Licensing Conditions) for the Transport of Radioactive Materials; "Requirements for the Safety Analysis Report on the Transport of Radioactive Materials; Requirements for the Management System in the Field of Safe Transport of Radioactive Materials.

X. SAFETY IN USE AND PRODUCTION OF RADIATION SOURCES

Activities with radiation sources can be allowed only after confirmation by the entity of the ability to comply with the requirements of radiation safety standards and rules and safety justification of using radiation sources.

Region	Total number of radiation source owners	Number of radionuclide radiation source owners	Number of generating (nonradionuclide) radiation source owners	Number of owners simultaneously owning radionuclide and nonradionuclide radiation sources
Northern part				
Kyiv city	492	41	427	24
Kyiv	221	33	177	11
Vinnytsia	150	5	143	2
Zhytomyr	131	16	112	3
Chernigiv	88	5	80	3
Cherkasy	115	6	105	4
Total	**1197**	**106**	**1044**	**47**
Eastern part				
Kharkiv	409	64	300	45
Poltava	168	23	134	11
Sumy	213	12	193	8
Total	**790**	**99**	**627**	**64**
Central part				
Dnipropetrovsk	466	52	388	26
Kirovograd	85	6	75	4
Total	**551**	**58**	**463**	**30**
Southeastern part				
Donetsk	497	55	421	21
Zaporizhzhia	207	16	181	10
Lugansk	231	24	197	10
Total	**935**	**95**	**799**	**41**
Northwestern part				
Volyn	112	9	101	2
Rivne	145	6	136	3
Ternopil	123	3	119	1
Khmelnytsky	159	9	147	3
Total	**539**	**27**	**503**	**9**
Western part				
Zakarpattia	99	4	91	4
Ivano-Frankivsk	209	14	191	4
Lviv	280	23	243	14
Chernivtsi	80	6	69	5
Total	**668**	**47**	**594**	**27**
Southern part				
Odessa	269	37	214	18
Mykolayiv	105	9	90	6
Kherson	113	5	105	3
Total	487	51	409	27
Total in Ukraine	**5167**	**483**	**4439**	**245**

Table. Distribution of the number of radiation source owners depending on the district and region of Ukraine as of the end of 2021

In 2021, regulatory control was provided over the activities of 5167 entities using radiation sources (636 more than in 2020) and 15 entities producing radiation sources, including 2862 entities conducting activities using radiation sources, which are not released from licensing, and have relevant permits. Last year, 302 licenses were issued, 54 licenses were canceled, and 338 licenses for using radiation sources were extended.

To meet the requirements of para. 250.4, Article 250 of the Tax Code of Ukraine, SNRIU prepared a list of enterprises, institutions, organizations, nuclear entities whose activities may generate radioactive waste in 2022 for regions, which was provided to the State Tax Service of Ukraine.

In 2021, participation in implementing project "Decommissioning of Irradiation Installations and Ensuring Safe Storage of Radiation Sources" continued as part of the cooperation program between SNRIU and GRS (Germany).

State Register of Radiation Sources and Individual Exposure Doses

In Ukraine, an effective information (automated) system for accounting, registration and control of radiation sources has been established and is functioning - the State Register of Radiation Sources. According to the Decree of the Cabinet of Ministers of Ukraine No. 1141 dated 18 November 2020 "Some Issues of Establishing a Unified State System for Monitoring and Recording Individual Exposure Doses", the functions of the State Register of Radiation Sources were expanded in terms of registering individual exposure doses and its name was changed to the State Register of Radiation Sources and Individual Exposure Doses (hereinafter referred to as the State Register of Radiation Sources and Doses). Radiation sources in the State Register of Radiation Sources and Doses are registered in accordance with the Procedure for State Registration of Radiation Sources and Individual Exposure Doses approved by Resolution of the Cabinet of Ministers of Ukraine No. 1718 of 16 November 2000 (as amended by Resolution of the Cabinet of Ministers of Ukraine No. 949 of 1 September 2021.

These changes brought the Procedure for Registration of Radiation Sources into line with up-to-date requirements, taking into account the experience gained, and introduced the procedure for monitoring and keeping records of individual exposure doses. During the year, state registration of radiation sources and methodological support of the State Register of Radiation Sources on organizational issues were provided.

As of 31 December 2021, 26,095 radiation sources are used in Ukraine, information about which is entered into the information (automated) system of the State Register of Radiation Sources and Doses (of which 8,553 are sealed radionuclide sources, only during 2021, 300 sealed radiation sources and 17,542 non-radionuclide installations generating radiation were registered, of which 1,538 units of new radiation sources were registered during 2021).

During 2021, 991 radiation sources were deregistered, including: 475 radionuclide sources (453 radionuclide sources were transferred to the radwaste category and transported to the RADON; 1 source was lost; 3 sources were entered twice or erroneously, 18 sources were exported); 516 non-radionuclide installations (501 sources were taken out of service; 14 sources were added twice or erroneously; 1 source was stolen).

Registration center	Totally registered items	Including	
		Sealed radionuclide	Non-radionuclide installations
RC (Kyiv)	619	59	560
RC (Dnipro)	298	74	224
RC (Zaporizhzhia)	207	32	175
RC (Kharkiv)	339	70	269
RC (Rivne)	200	21	179
RC (Odesa)	335	103	232
RC (Ivano-Frankivsk)	370	31	339
Total	**2368**	**390**	**1978**

Table. The number of operations performed on the registration of new sources and after a change of owner for 12 months of 2021 by regions

In addition, for 2021, the State Register of Radiation Sources and Doses received information on the import of radiopharmaceuticals and radionuclide generators, namely:

35 reports on the import of the Tc-99m radionuclide generator into the territory of Ukraine used in medical practice for health care institutions (the supplier of Tc-99m-radionuclide generators was the Institute of Atomic Energy (POLATOM));

60 reports of the IZOTOP on the importation of radiopharmaceuticals and 3 reports of MTM LLC.

During 2021, the following radionuclides were delivered to healthcare institutions as part of radiopharmaceuticals: 131 - total activity 6.9 TBq; 125 - total activity 23.8 GBq; Sr-89 - total activity 10.2 GBq.

The official SNRIU website published the List of enterprises, institutions and organizations that have licenses to use radiation sources in terms of maintenance of radiation sources, and the List of entities that confirmed compliance of the training and knowledge testing system on radiation safety with the requirements of SNRIU Order No. 143 of 2 October 2014, registered with the Ministry of Justice of Ukraine on 2 December 2014 under No. 1549/26326.

As part of international technical assistance project "Combating the Illicit Use and Trafficking of Radioactive Materials in the Eastern Region of Ukraine. Task 1. Extraordinary Inventory of Radioactive Materials (INVENTORY)", SNRIU inspectors, involving SSTC NRS experts, took measures for an extraordinary inventory of radiation sources owned by:

Open Joint Stock Company "Azovstal Metallurgical Plant" and Private Joint Stock Company "Azovelektrostal";
Private Joint Stock Company "Mariupol Illlch Metallurgical Plant";
Municipal Non-Profit Enterprise "Mariupol Oncological Dispensary";
Limited Liability Company "Svyatovarvarynska Enrichment Plant";
Private Joint Stock Company "Pokrovske Mine Administration";
Limited Liability Company "Velykyi Shovkovyi Shliakh";
Private Joint Stock Company "Rubizhanskyi Cardboard and Packaging Plant";
Limited Liability Company "Severodonetsk Skloplastyk Scientific and Production Association";
Subsidiary "Slavyanskyi Kurort Health and Resort Rehabilitation Center" of the private joint-stock company of medical and health-improving institutions of trade unions of Ukraine "Ukrprofzdorovnytsia";

Municipal Non-Profit Enterprise "Kramatorsk Regional Territorial Medical Association".

Production of Radiation Sources

In Ukraine, as of the end of 2021, 15 entities had valid licenses for the production of radiation sources. In 2021, radiation sources were produced by: LLC "X-ray Equipment Plant KVANT" (Kharkiv), Kyiv Production Association "Medaparatura"; Company "RADMIR" (Kharkiv); LLC "Research and Production Company KRAS".

According to the reports provided, in 2021, the RADMIR produced 29 non-radionuclide installations exported abroad. The RADMIR produces SIMA X-ray mammography digital systems with a maximum accelerating voltage of 39 kV and MADIS X-ray mammography digital systems with a maximum accelerating voltage of 45 kV.

LLC "ELVATECH" produced 381 non-radionuclide installations, of which 74 were for the needs of Ukraine and 307 were exported abroad to different countries.

LLC "ELVATEX" produces SER-01 X-ray energy spectrometers with a maximum accelerating voltage of 50 kV and SER-02 X-ray energy spectrometers with a maximum accelerating voltage of 40 kV.

These are portable laboratory devices used for primary X-ray excitation of sample atoms in generating devices with low-power X-ray tubes. Spectrometers are designed to determine the elemental composition of substances used in metallurgy, mining and chemical industries, mechanical engineering, processing, etc.

"X-ray Equipment Plant KVANT" produced KRD 50 X-ray diagnostic systems with a maximum accelerating voltage of 150 kV.

During 2021, the state review on nuclear and radiation safety of 5 technical specifications for the production of radiation sources was carried out.

SNRIU analyzed 15 annual reports of licensees for the production of radiation sources. Based on the results of considering the reports, 6 licensees were provided with comments on information completeness with the need to improve the reporting documents. Regarding LLC "TELEOPTIK" a protocol was drawn up and Order No. 33-17/02/2021-YuO was issued on bringing to administrative responsibility for failure to provide an annual report in full.

Peculiarities of State Safety Regulation of Medical Radiation Sources

Medicine is the most common area of applying radiation sources in Ukraine.

In Ukraine, as well as throughout the world, there is a tendency towards an increase in the level of oncological diseases, the mortality rate from which, according to statistics from the Ministry of Health of Ukraine, ranks second in Ukraine.

Thus, at the beginning of 2021, 1 million 187.6 thousand patients with oncological diseases were registered in healthcare institutions. Diagnosis and treatment of diseases is provide using the latest technologies with radiation sources.

In addition, computed tomography (CT) has become one of the most common methods for imaging various diseases, and during the COVID-19 pandemic, it practically acquired the status of a screening method.

At the same time, diagnostics using CT is accompanied by rather high exposure to radiation for the patient. As of 31 December 2021, 860 CT scanners were in use in Ukraine, while at the beginning of the pandemic (30 December 2019), 598 CT scanners were in use.

Figure. Computed tomography scanner

According to the State Register, 15112 units of equipment were used in Ukraine in 2021 for X-ray diagnostics, which is 1345 units more than in 2020 (of which 10,201 are X-ray diagnostic devices, 562 are mammographs, 3,099 are dental X-ray devices, 860 are CT and PET tomography scanners, 43 are other medical radiation sources), 188 devices for gamma therapy, 114 devices for X-ray therapy; 45 electron accelerators.

One of the SNRIU priorities in 2021 was the regulatory support of implementing the activities of the program of the President of Ukraine “Great Construction” in terms of providing basic healthcare institutions with up-to-date X-ray equipment (X-ray diagnostic devices and CT devices). The implementation of these activities is associated with risks due to the fact that, on the one hand, it was necessary to issue an appropriate permit to use equipment supplied under this Program as soon as possible, and on the other hand, to be sure that this equipment or technology will be used in a safe way.

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In 2021 alone, 817 medical radiation sources were registered in the State Register of Radiation Sources and Doses, of which 161 were CT scanners, 7 were linear accelerators, 493 were X-ray diagnostic devices, 25 were mammographs, 119 were dental X-ray devices, 12 – other radiation sources others.

In addition, the issue of putting into operation angiographs supplied to healthcare institutions in the Volyn, Zhytomyr, Zaporizhzhia, Mykolayiv and Rivne regions in 2017-2019 was under the constant control of SNRIU. In 2021, all equipment was put into operation.

Figure. Angiograph

When X-ray equipment, linear accelerators were supplied, issues related to incompliance by licensees with the requirements of legislation in nuclear energy use arose. Thus, healthcare institutions of Ukraine received equipment or notifications of its deliveries from suppliers within the timeframes that did not allow them to submit applications to SNRIU for issuing licenses or amending licenses for using radiation sources in time. As a result, in addition to licensing conditions, the requirements of the Procedure for State Registration of Radiation Sources were also not met. SNRIU applied financial sanctions: fines were imposed on both equipment suppliers and recipients (healthcare institutions) in the amount from UAH 17,000 to 34,000.

At the same time, not all healthcare institutions had preliminarily prepared premises to place equipment (angiographs, computed tomography scanners, digital X-ray machines, linear accelerators) and duly approved projects for the placement of this equipment, which in turn led to long-term storage, delay of putting into operation and inefficient use for the intended purpose.

During 2021, X-ray equipment was assessed during consideration of licensing documents to issue (amend, reissue) licenses for the production and use of medical radiation sources for their compliance with the requirements of Article 17 of the Law of Ukraine “On Human Protection against Ionizing Radiation” in accordance with the Methodological Explanation for Assessing Compliance of Medical Radiological Equipment with the Provisions of Article 17 of the Law of Ukraine “On Human Protection Against Ionizing Radiation”, which entered into force in 2020.

In addition, the issue of bringing the technical specifications for the production of X-ray radiological equipment into compliance with the requirements of Article 17 of the mentioned Law by all domestic manufacturers (licensees) was under SNRIU control.

Figure. Special equipment

Two radiation safety training programs were assessed and agreed:

Compliance with Radiation Safety Rules During the Use of Radiation Sources in Healthcare Institutions Providing Dental Services;

Compliance with Radiation Safety Rules During the Use of Radiation Sources in Medical Institutions.

In order to study the state of radiation therapy in Ukraine, the Grygoriev Institute of Medical Radiology and Oncology of the National Academy of Medical Sciences of Ukraine, according to the Schedule for a National Postal TLD Audit of the Dosimetric Calibration Quality for Radiation Beams of Radiation Therapy Devices in Medical Institutions of Ukraine for 2021, in accordance with the Provisions on the Organization and Conduct of a National TLD Audit of the Calibration Quality for Radiation Beams of Radiation Therapy Devices Using the Postal Dose Method, 4 cycles of TLD audits were organized, based on whose results relevant response measures were developed.

Within the National TLD audit and IAEA/WHO international dosimetric audit in 2021, radiation beams from 22 remote beam therapy devices were monitored in 14 oncological healthcare institutions.

An annual questionnaire of oncological healthcare institutions was organized under the DIRAC program and based on the IMPACT questionnaire of the IAEA mission on the state of radiodiagnosis and radiotherapy.

Management of Radiation Sources in Energoatom Separate Entities

Radiation sources in separate entities of the Energoatom are managed in accordance with the series license for the use of radiation sources issued by SNRIU, valid until 19 December 2024.

In 2021, two amendments were made to this license in accordance with the established procedure (Amendment No. 3 was made on 30 July 2021, Amendment No. 4 on 29 September 2021), which allow the use of radiation sources by the following Energoatom entities: Zaporizhzhia NPP, Rivne NPP, Khmelnytsky NPP, Pivdennoukrainsk NPP, Atomremontservis, Emergency Technical Center, Atomenergomash, Automation and Mechanical Engineering and the following activities with radiation sources: operation, maintenance, charging, recharging, repacking, commissioning and decommissioning of installations with radiation sources, installation, dismantling, adjustment, storage, receipt (purchase), transfer (sales).

Radiation sources are used to perform the following activities: radiographic inspection of welds and base metal of products, equipment and piping; control of boron concentration in the primary coolant and adjacent systems; calibration measurements of radiometric and spectrometric equipment; verification; measurements of the density and moisture content of soils in the basement of buildings and structures.

Radiation sources are stored taking into account their properties in storage facilities or special safes, radiation sources are used to perform work in entities in accordance with the requirements of OSPU-2005 of health and safety certificates.

Organizational, technical and health measures aimed at radiation safety of personnel, as well as the main actions of personnel in the event of a radiation accident during the management of radiation sources are regulated by documents of separate entities, put into effect according to the established procedure.

To assess and measure doses received by personnel, the following types of radiation monitoring are considered: radiation dose monitoring; radiation monitoring over the non-proliferation of radioactive contamination.

Radiation dose monitoring is provided by measurements: individual equivalent exposure dose of personnel; dose rate of gamma radiation in NPP rooms and on the NPP industrial site; neutron dose rates in the central hall of the reactor, in adjacent rooms, in the places of installation and repair of boron concentration meters, in the places for management of fresh and spent fuel; activity concentration of aerosols, iodine isotopes in rooms.

Radiation monitoring the non-proliferation of radioactive contamination is provided by: monitoring the level of contamination by radioactive substances for personnel skin, footwear and clothing, vehicles and cargo when crossing the borders of the strict access area; monitoring the level of contamination by radioactive substances for personnel clothing and footwear, vehicles and cargo when crossing the borders of the NPP territory.

During activities related to the use of radiation sources, radiation hazardous factors, which are determined by the action of gamma and neutron exposure in the use of sealed radiation sources, are monitored. The measurement is provided in accordance with the radiation monitoring regulations during NPP operation.

All personnel involved in the work with radiation sources belong to category A and are subject to mandatory individual dose monitoring. The reference (administrative) exposure levels for personnel performing activities with radiation sources in 2021 in the Energoatom were not exceeded.

All persons from category A personnel, including those temporarily involved in activities with radiation sources, are allowed to perform such activities only after training, briefing and checking their knowledge of the safety rules for these activities and instructions in force in the separate entities.

During 2021, no radiation accidents and incidents with radiation sources on the balance sheet of ZNPP, RNPP, PNPP, KhNPP, Atomremontservis, Emergency Technical Center, Atomenergomash, Automation and Mechanical Engineering were registered.

Separate subdivision	Data on radiation sources of separate subdivisions upon the results of inventory 2021 (real-time data)			Information on violations in the area of using radiation sources based on the results of inspections conducted by state regulatory bodies
	Total number of radiation sources	Radiation sources purchased in 2021	Radiation sources transferred to specialized enterprises in 2021	
ZNPP	1205	10	24	One prescription on violations was received. The requirement of the prescription was met
RNPP	725	8	60	One prescription on violations was received. The requirement of the prescription was met
KhNPP	532	4	166	No violations during activities with radiation sources were registered
PNPP	375	54	48	No violations during activities with radiation sources were registered
Atomremontservis	3	Not purchased	Not transferred	One prescription on violations was received. The requirement of the prescription was met
Emergency Technical Center	94	3	Not transferred	No violations during activities with radiation sources were registered
Automation and Mechanical Engineering	21	Not purchased	Not transferred	No violations during activities with radiation sources were registered
Atomenergomash	8	Not purchased	Not transferred	One prescription on violations was received. The prescription on eliminating the violations during the use of radiation sources is at the stage of compliance
Total in Energoatom	2963	79	298	Four prescriptions were received. The requirements of three prescriptions were met in full, one is at the stage of compliance

Table. Generalized data on the use of radiation sources by the Energoatom separate entities in 2021

XI. SAFETY OF URANIUM SITES

Ukraine belongs to the world's leading uranium mining countries and has a number of explored uranium deposits, the largest of which are located within the Kirovograd region.

SkhidGZK today is the only enterprise in Ukraine that carries out a full cycle of activities on the extraction and processing of uranium ores. Uranium ore is mined using the underground method at the Vatutinske (Smolinska mine), Michurinske, Tsentralne (Inhulska mine) and Novokostiantynivske (Novokostiantynivska mine) deposits in the Kirovograd region under the SNRIU license for mining activities.

SkhidGZK includes three enterprises for the extraction of uranium ores: Smolinska, Inhulska and Novokostiantiynivska mines and an enterprise for uranium ore processing - hydrometallurgical plant.

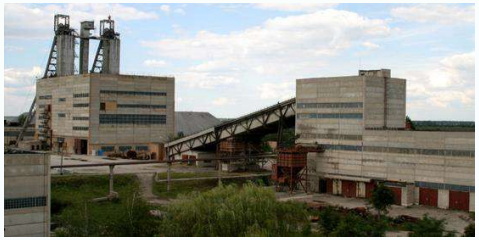

Figure Smolinska mine

The Smolinska mine is located in the Smoline village, Mala Vyska region, Kirovograd region. Since 1973, the mine has been developing the Vatutinske uranium ore deposit. Mining operations are currently underway at a depth of 640 m.

Considering that the reserves of the Vatutinske deposit are practically exhausted, in 2021, the implementation of preparatory measures to terminate the activities of the Smolinska mine has started.

SNRIU approved the Draft Order of the Cabinet of Ministers of Ukraine On Approval of the Concept of the State Target Environmental Program “Decommissioning of Uranium Facilities for 2022-2026”.

Currently, the state NRS review of feasibility study “Decommissioning of the SkhidGZK Smolinska Mine” is being carried out. The Inhulska mine is located on the outskirts of Kropyvnytsky and since 1969 has been developing the Michurinske and Tsentralne uranium ore deposits. Currently, ore deposits are mined at a depth of up to 420 m.

Figure. Inhulska mine

The Novokonstantynivska mine located near the Oleksiivka village, Mala Vyska district, Kirovograd region develops the Europe's largest Novokostiantynivska uranium ore deposit. The mine is in trial and commercial operation. Currently, ore deposits are mined at depths from 180 to 300 m. The design capacity of the deposit is 1,500 thousand tons of uranium ore per year, with a subsequent increase to 2,500 thousand tons per year.

Figure. Novokostiantynivska mine

Processing of uranium ores and production of uranium concentrate (U_3O_8) is carried out at the hydrometallurgical plant in Zhovti Vody. In 2021, about 455 tons of uranium oxide concentrate were produced in Ukraine.

Waste from processing uranium ores (tailings) with a high content of naturally occurring radionuclides are placed using a pulp piping in the Balka Shcherbakivska tailing storage facility located at a distance of about 5 km from Zhovti Vody.

In 2021, liquidation and remediation activities continued at the facilities and industrial site of the former Prydniprovsky Chemical Plant, which are located in Kamyanske.

From 1949 to 1991, the former Prydniprovsky Chemical Plant processed uranium-containing blast furnace slag, uranium concentrates and uranium ore from various deposits in the Soviet Union and Eastern Europe.

Due to this, a number of tailing storage facilities and uranium waste storage facilities were formed on the territory of the former plant and beyond its boundaries. They contain up to 42 million tons of uranium ore processing waste with a total activity of 2.7x1015 Bq.

The exposure dose rate of gamma radiation at some radioactively contaminated facilities of the Prydniprovsky Chemical Plant reaches 350 μSv/h.

Activities on bringing the territory and facilities of the former Prydniprovsky Chemical Plant are conducted by State Enterprise “Barrier” under the current license.

In 2021, State Enterprise “Barrier” continued to implement the measures provided by the State Targeted Environmental Program for Bringing Uranium Facilities of the Prydniprovsky Chemical Plant to a Safe State for 2019-2023 approved by Resolution of the Cabinet of Ministers of Ukraine No. 756 of 21 August 2019.

In addition, on the territory of the former Prydniprovsky Chemical Plant, the implementation of international technical assistance projects “Implementation of Urgent Measures to Eliminate an Emergency State of the Prydniprovsky Chemical Plant in Kamyanske (former Dniprodzerzhynsk) in Ukraine” implemented at the expense of the European Commission and “Risk Reduction, Control of Radioactive Contamination and Improvement of Environment Monitoring System at the Prydniprovsky Chemical Plant in Ukraine” funded by the Government of Norway.

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XII INTERNATIONAL COOPERATION AND EUROPEAN INTEGRATION

The year of 2021, despite the restrictions associated with COVID-19, was full of international events and measures that took place both online and offline.

Cooperation of EU Countries in Nuclear Energy Use and Radiation Safety

Active interaction was continued with European institutions and associations aimed at the implementation of cooperation projects, as well as the fulfillment by Ukraine of its obligations in the context of strengthening the NRS regulatory system and safety of NPP operation.

Together with the European Commission, within the Instrument for Nuclear Safety Cooperation (INSC), the implementation of project "Strengthening capabilities of the State Nuclear Regulatory Inspectorate of Ukraine in regulation of nuclear activities, licensing and analysis of severe accidents for nuclear facilities" (U3.01/14-15, U3.01/18 (UK/TS/51-58) was continued, which, inter alia, is aimed at elaborating a strategy for development of SNRIU regulatory capabilities and planning of SNRIU resources, implementation of HERCA-WENRA approaches to improve interstate coordination of implementing protective measures during nuclear accidents, support of regulatory activities on radwaste management, decommissioning and remediation, as well as support of licensing nuclear fuel diversification for Ukrainian NPPs

Figure. Work meeting within project UK/TS/51-58

After granting Ukraine an observer status in ENSREG, SNRIU representatives got an opportunity to participate in plenary meetings and follow the main trends in EU policy on safety improvement of NPP operation, radioactive waste management, updating relevant EU legal acts, development of proposals for strengthening cooperation with non-EU countries, etc. In accordance with the voluntary commitments, Ukraine submitted the Updated National Action Plan upon Stress-Test Results and the Updated National Action Plan upon First Topical Peer Review on Ageing Management to ENSREG in 2021. An SNRIU representative was included in the ENSREG group on the evaluation of stress-test results in the Republic of Turkey.

Figure. Updated National Action Plan upon Stress Tests Results, as well as Updated National Action Plan upon First Topical Peer Review on Ageing Management

Within the participation in WENRA activities, SNRIU experts took active part in the plenary meetings of the association and activities of working groups: Reactor Harmonization Working Group (RHWG), Working Group on Waste and Decommissioning (WGWD), Working Group on Research Reactors (WGRR). WENRA priority activity in 2021 was the development of Technical Specifications within the preparation for the ENSREG Second Topical Peer Review on Fire Safety. The work was continued on updating the WENRA reference levels, WENRA interaction with other European institutions was intensified, in particular with the European Nuclear Installation Safety Standards Association, European Nuclear Security Regulators Association, etc.

Figure. WENRA plenary meeting on 13-14 April 2021

International Atomic Energy Agency

In 2021, IAEA provided support for the implementation of three national projects of the Technical Cooperation Program for Ukraine. Experts of state bodies, enterprises, scientific institutes and medical institutions took part in workshops, courses, and internship provided by IAEA both online and offline.

On the occasion of ChNPP accident commemoration, IAEA Director General Rafael Mariano Grossi visited Ukraine on 26-27 April. He held a number of meetings with the country leadership, visited NSC and ISF-2.

Figure. Visit of IAEA Director General to ChNPP

Verification activities of IAEA inspectors at Ukrainian facilities were conducted in the ordinary course. On 13-14 July, a meeting of the High-Level Safeguards Implementation Review Group (SIRG) was held in Kyiv. The IAEA delegation was headed by Massimo Aparo, Deputy Director General and Head of the Department of Safeguards. During the meeting, current issues of applying IAEA safeguards in Ukraine were discussed.

Figure. Visit of representatives of the IAEA Department of Safeguards to ChNPP

Activities were continued to improve the national legislation taking into account IAEA safety standards. Ukrainian experts actively participated in the work of the Nuclear Safety Standards Committee (NUSSC), Radiation Safety Standards Committee (RASSC) and the Nuclear Security Guidance Committee (NSGC).

From 20 to 24 September, the 65th session of the IAEA General Conference was held in Vienna. Ukraine was represented at the General Conference by the official delegation headed by the SNRIU Chairman. During the plenary week, key issues of organization activities were discussed, in particular, the approval of Agency budget for 2022, definition of priorities for the programs of activities to ensure nuclear and radiation safety, radioactive waste management safety, and nuclear security. The results of the verification activities carried out in 2021 were also discussed, areas for improving the efficiency of the existing safeguards system, areas for developing up-to-date science and technologies, and planning a technical cooperation program were agreed.

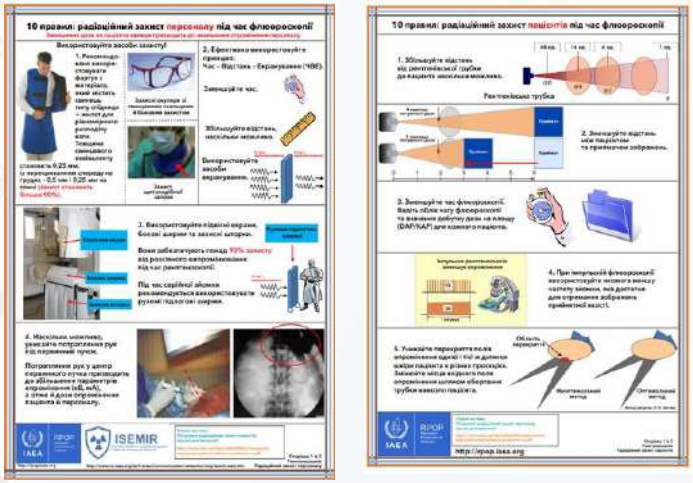
In his speech, the Head of the Ukrainian delegation emphasized the significant contribution of IAEA to accomplishing tasks in the area of nonproliferation, ensuring nuclear safety and security, and thanked the Agency for its continued support in the implementation of cooperation projects aimed at ChNPP decommissioning and NSC construction.

On 10-14 October, SNRIU representatives took part in the IAEA Conferences on the development of preparedness for response at the national and international levels. During the event, the experience of maintaining preparedness and organizing and conducting exercises under quarantine restrictions using remote communication technologies was presented, namely: the main results of joint exercises by the scenarios of conditional accidents with loss of control over radiation sources and progression of emergency events at a research nuclear installation. Among the important events that took place under the auspices of IAEA, it is also necessary to highlight the International Conference on Radioactive Waste Management. Ukraine was represented at the event by experts from SNRIU, SSTC NRS, SAUEZM and ChNPP.

Within the event, key programs and development prospects for the future were identified, in particular, regarding the issues of radioactive waste, spent nuclear fuel disposal and disposal facilities in geological formations. The results of the Conference show the significant progress of the IAEA member states in radioactive waste management, implementation of the latest technologies, development of new approaches and prospects

At the end of the year, the SNRIU Chairman and experts took part in the 27th Annual Forum for Regulatory Bodies of Countries Operating VVER NPPs. The event was held online and was full of interesting discussions, exchange of important information on operating experience, implementation of state oversight over safe operation of VVER NPPs during the period since the previous Forum meeting in 2019. The event was attended by representatives of the regulatory authorities of Armenia, Iran, Russian Federation, Hungary, Bulgaria, Czech Republic, Slovakia, Finland, Turkey, Egypt. Representatives of IAEA, research organizations of Germany (GRS) and France (IRSN) were among the participants.

In 2021, Ukraine joined the IAEA outreach activities for the first time. The State Nuclear Regulatory Inspectorate, jointly with SSTC NRS, translated IAEA posters on radiation protection of patients and doctors into Ukrainian. Posters in Ukrainian are presented on the IAEA official website at the link: https://www.iaea.org/resources/rpop/resources/posters-and-leaflets.



Figures. IAEA posters on radiation protection in Ukrainian

Bilateral Cooperation Programs

2021 was eventful for bilateral cooperation programs. The United States, Sweden, Norway and other countries should be singled out among the main partners of the State Nuclear Regulatory Inspectorate.

In the framework of cooperation with the U.S. Nuclear Regulatory Commission, a number of important events took place, including: signing of the updated Executive Agreement on the Participation of the State Nuclear Regulatory Commission in the Thermohydraulic Code Application and Support Program (CAMP Program) dated 25 March 2021 and Executive Agreement on the Participation in the Severe Accident Research Program (CSARP) dated 16 April 2021.

An online spring meeting of users of computer codes on radiation protection of the RAMP Program developed and operated under support of the U.S. Nuclear Regulatory Commission, was held from 12 to 16 April. SNRIU and SSTC NRS act as co-organizers of the event. Ukraine joined the RAMP Program in June 2019 and is an active user of computer codes for assessing the environment, atmospheric indexes, calculations for emergency response and supporting licensed activities, etc.

During the 65th session of the IAEA General Conference, the SNRIU Chairman met with Chairman of the U.S. Nuclear Regulatory Commission Christopher Hanson. During the meeting, a wide range of issues of bilateral cooperation was discussed, from licensing the construction of new nuclear facility types to decommissioning aspects. The parties confirmed their interest in continuing cooperation in the areas of mutual concern. At the end of the meeting, a Memorandum was signed, which fixed the areas and work planned for implementation in 2021-2022.
The scheduled implementation of U.S. NRC project for SNRIU "Technical Support of the State Nuclear Regulatory Inspectorate" was continued
In 2021, cooperation with the U.S. Trade and Development Agency (USTDA) was intensified. During the year, Ukrainian experts actively participated in a series of workshops to discuss the development of technologies for small modular reactors, which were held by the Agency for Central and Eastern Europe countries.

On 14 December, the signing ceremony of the Grant Agreement between the U.S. Trade and Development Agency and the Ukrainian Science and Technology Center took place. According to the Grant Agreement, the U.S. Government provides financial support for the activities to analyze the national legislation of Ukraine on the possibility of licensing the construction of small modular reactors. SNRIU acts as a beneficiary of the activities performed under the Grant Agreement.

Figure. Signing of USTDA grant

In 2021, cooperation projects with the U.S. State Department were successfully implemented: "Improving Cybersecurity in the State Nuclear Regulatory Inspectorate of Ukraine" and "Combating Illegal Use and Trafficking of Radioactive Material in the Eastern Region of Ukraine. Task 1. Extraordinary Inventory of Radioactive Materials (INVENTORY)". As a result of implementing these projects, a comprehensive modernization of the SNRIU information and telecommunications system and formation of the information protection system were provided to strengthen cybersecurity of the regulatory body of Ukraine.

8 extraordinary physical inventories of radiation sources were carried out at 18 enterprises (institutions) located in the area of the Joint Forces Operation in the territories controlled by Ukraine to expand SNRIU capabilities; work with the Register of Radiation Sources was performed and information about sources at enterprises was updated; information system "Inventory of Radiation Sources and other Radioactive Materials" was developed, which included the information on radiation sources located in the territory of Donetsk and Lugansk regions.

Figures. SNRIU inspectors during extraordinary inspections

The scheduled implementation of the project of cooperation with the U.S. Department of Energy "Improving the Security of Radiation Sources Used in Ukraine" was continued. As part of the project, activities were performed to modernize physical protection systems at facilities using spent radiation sources, activities were performed to modernize the Central Monitoring Station installed in the State Nuclear Regulatory Inspectorate under USA support.

Under the project, the Office of Radiological Security of the U.S. Department of Energy, together with the State Nuclear Regulatory Inspectorate of Ukraine and leadership of the Ministry of Internal Affairs of Ukraine conducted training workshops for trainers of the security police response forces at the Kharkiv National University of Internal Affairs and Lviv State University of Internal Affairs.

Figure. Training workshop, Lviv

On 10-13 August, Ukrainian experts took part in the workshop on technical experience exchange regarding international practice in the area of cybersecurity, which was held at the Pivdennoukrainsk NPP under support of the U.S. Department of Energy.

During the year, an active cooperation in the area of nuclear and radiation safety was implemented with the Swedish Radiation Safety Authority (SSM) under the Agreement between the State Nuclear Regulatory Inspectorate of Ukraine and Swedish Radiation Safety Authority on cooperation in the area of nuclear and radiation safety.

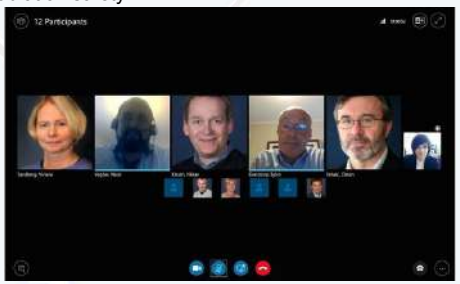


Figure. Coordination meeting with Swedish colleagues.

The following projects were implemented:
information support of the State Nuclear Regulatory Inspectorate of Ukraine, development and filling of an independent web resource on nuclear safety, radiation protection and non-proliferation of nuclear weapons – www.Uatom.org;
modernization of the application software for the information system of the State Register of Radiation Sources;
update of the SNRIU anti-virus software;
technical support of the State Nuclear Regulatory Inspectorate for maintenance of the nuclear material accounting database (STAR);
information support of SNRIU authorizing and oversight activities;
Based on the results of the coordination meeting on 8 September 2021, which was held online, the main areas of bilateral cooperation for 2022 between the State Nuclear Regulatory Inspectorate of Ukraine and the Swedish Radiation Safety Authority were agreed.

On 19-20 April, a coordination meeting for representatives of SNRIU, SSTC NRS and Norwegian Radiation and Nuclear Safety Authority (DSA) took place via videoconference, during which they discussed ongoing cooperation projects and outlined the main tasks, deadlines, expected results of implementing bilateral cooperation projects.

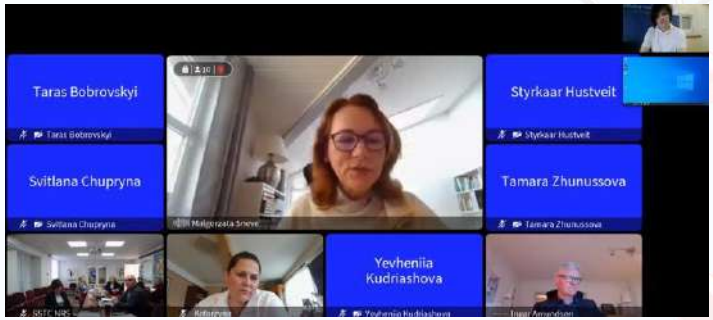


Figure. Bilateral meeting representatives of DSA, Norway.

During the next coordination meeting via videoconference with Norwegian colleagues on 12 October, a roadmap of bilateral cooperation for 2021-2025 was agreed and five priority project areas were identified for the near future, three of which were launched in 2021:

Development of regulatory document "Acceptance Criteria for Medical Radiological Equipment in Diagnostic Radiology";

Development of regulatory document "Radiation Safety Rules in Interventional Radiology".

Development of draft regulatory document "General Provisions for Security of Nuclear Installations, Nuclear Materials, Radioactive Waste, Other Radiation Sources".

This year, the State Nuclear Regulatory Inspectorate initiated bilateral cooperation with the Nuclear Regulatory Authority (NDK) of the Republic of Turkey. On 21 September in Vienna (Republic of Austria), the first meeting was held at the level of chairmen of regulatory bodies of Ukraine and Turkey. The participants discussed issues of mutual interest in terms of developing bilateral cooperation, as well as the status of preparation for signing the Memorandum of Understanding between the State Nuclear Regulatory Inspectorate of Ukraine and the Nuclear Regulatory Authority (NDK) of the Republic of Turkey, whose signing is scheduled for 2022.

Protection of the public and the natural environment against negative consequences of radiation through the effective implementation of the state policy in nuclear energy use, ensuring compliance with nuclear and radiation safety requirements in accordance with the national legislation and fulfillment of international obligations remains the main priority for Ukraine in the future.

LIST OF ABBREVIATIONS

ARMS - Automated Radiation Monitoring System
C(I)SIP – Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs
CGO - Borys Sreznevsky Central Geophysical Observatory
ChNPP – Chornobyl NPP
ChNPP – Chornobyl Nuclear Power Plant
CLTSF – Centralized Long-Term Storage Facility for Spent Radiation Sources
CPS – Central Production Site
CRME – Central Radioactive Waste Management Enterprise
CSFSF – Centralized Spent Fuel Storage Facility
CT – Computed Tomography

DIA – Dnipro Interregional Affiliate
DSFSF – Dry Spent Fuel Storage Facility
DUGA experimental installation – experimental installation for hydrodynamic cleaning of oil and gas equipment from salt deposits contaminated with naturally occurring radionuclides
EDR – Exposure Dose Rate
Energoatom – National Nuclear Energy Generating Company "Energoatom"

ENSDF – Engineered Near-Surface Disposal Facility for Low- and Intermediate-Level Short-Lived Radioactive Waste
ENSREG – European Nuclear Safety Regulators Group

EU – European Union
FCM – Fuel-Containing Materials
FCSE – Final Closure and Safe Enclosure

HLW – High-Level Waste
IAEA – International Atomic Energy Agency
ICSRM – Industrial Complex for Solid Radioactive Waste Management

IEC – Information Emergency Center
ISF – Interim Spent Fuel Storage Facility
ITDB - Illicit Trafficking Database
KhIA – Kharkiv Interregional Affiliate
KhNPP – Khmelnytsky NPP
LIA – Lviv Interregional Affiliate
LRTP – Liquid Radwaste Treatment Plant
LRW – Liquid Radioactive Waste
Neutron Source - Neutron Source Based on a Subcritical Assembly Driven by a Linear Electron Accelerator" Nuclear Subcritical Facility
NFD – Neutron Flux Density
NM – Nuclear Material
NPP – Nuclear Power Plant
NRBU-97 – Radiation Safety Standards of Ukraine
NRS – Nuclear and Radiation Safety
NSC – New Safe Confinement
NSC-Shelter – New Safety Confinement–Shelter System
OIA – Odesa Interregional Affiliate
Part of Installation with DShN-108 – part of the installation for express and instrumental neutron activation analysis containing fast neutron source DShN-108
PNPP – Pivdennoukrainsk NPP
PSRR – Periodic Safety Review Report
RADON – State Specialized Enterprise Radon Association
Radwaste – Radioactive Waste
RICS – Radioactive Waste Interim Confinement Site in the Exclusion Zone
RNPP – Rivne NPP
RS – Radiation Source
RWDS – Radioactive Waste Disposal Site
RWTP – Radioactive Waste Treatment Plant
SAUEZM – State Agency of Ukraine for Exclusion Zone Management
SBC – Salt-Bitumen Compound
SIRG –Safeguards Implementation Review Group
SISP – State Interregional Specialized Plant
SkhidGZK – Skhidny Mining and Processing Plant
SNF – Spent Nuclear Fuel

SRTP – Soldi Radwaste Treatment Plant
SRW – Solid Radioactive Waste
SST NRS – State Scientific and Technical Center for Nuclear and Radiation Safety
State Register of Radiation Sources and Doses – State Register of Ionizing Radiation Sources and Individual Exposure Doses
TENORS - technologically enhanced naturally occurring radiation sources
UkrHMC – Ukrainian Hydrometeorological Center

Vector – Vector Site
VVER – Water-Cooled Water-Moderated Power Reactor
WENRA – Western European Nuclear Regulators' Association
ZNPP – Zaporizhzhia NPP

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