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Reference

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Nuclear legacy, threat assessment, regulatory challenges, regulatory cooperation.

Abstract
This report analyses the current nuclear and radiation threats to safety and security in Ukraine from a regulatory perspective and identifies main challenges, threats and gaps in the Ukrainian regulatory framework within the responsibility of the State Nuclear Regulatory Inspectorate of Ukraine.

Referanse
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Emneord
atomarv, trusselvurdering, regulatoriske utfordringer og myndighetssamarbeid

Resymé
Denne rapporten revurderer de viktigste kjernefysiske og strålingstruslene mot sikkerhet i Ukraina fra et regulatorisk perspektiv og identifiserer de nåværende hovedutfordringene, truslene og hullene i det ukrainske regelverket unner ansvaret til State Nuclear Regulatory Inspectorate of Ukraine.

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Approved:

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Ukrainian Regulatory Threat Assessment 2024

In Memoriam: Ms. Malgorzata Karpow Sneve

With profound sorrow and heartfelt gratitude, we remember Ms. Malgorzata Karpow Sneve, the visionary Director of the Regulatory Cooperation Programme at DSA, whose dedication and leadership were instrumental in the establishment of the cooperation between the Norwegian Directorate for Radiation Protection and Nuclear Safety (DSA) and the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU).

Ms. Sneve's commitment to nuclear safety and regulatory cooperation was unmatched. From the very inception of the partnership in 2014, she saw the necessity and importance of building bridges between sister regulatory authorities, fostering a collaborative spirit that transcended borders. Her unwavering belief in the power of international involvement to strengthen regulatory frameworks and enhance safety standards laid the foundation for the ongoing cooperation that has flourished to this day.

Her vision and tireless work not only established the DSA-SNRIU partnership but also created a framework for collaboration that united experts and institutions across countries and disciplines. Ms. Sneve's work was not just about technical cooperation; it was about forging strong, lasting relationships based on trust, mutual respect, and a shared commitment to the highest standards of nuclear safety. Through her leadership, the close friendship between DSA and SSTC NRS was fostered, ensuring a comprehensive and collaborative approach to the challenges facing the nuclear sector.

Her dedication to this cause, especially during times of crisis, was evident in her ability to see the broader picture and act decisively to address urgent needs. As we continue to build on the cooperation she started, her legacy of commitment, foresight, and international solidarity remains a beacon for all of us working in the field of nuclear safety and regulation.

This report stands as a tribute to her extraordinary contributions, her tireless advocacy for the safety of people and the environment, and her steadfast belief in the power of cooperation to overcome even the most daunting challenges. While we mourn the loss of a remarkable colleague and friend, we also celebrate her vision and the lasting impact she has made on the nuclear safety community, both in Ukraine and across the globe.

Ms. Sneve’s memory will continue to inspire us as we carry forward the work she started, ensuring that the partnership between DSA, SNRIU, and SSTC NRS remains strong and continues to grow in the years ahead. Her legacy lives on in every step we take toward a safer, more secure world.

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1 EXECUTIVE SUMMARY

The enhancement and ongoing evolution of Ukraine's national system for state regulation of nuclear and radiation safety rest upon adherence to IAEA safety standards, EU Directives, recommendations from international organizations, and the incorporation of best practices observed in countries with advanced programs in the application of technologies involving ionizing radiation. The international collaboration of the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) plays a pivotal role in shaping the national system and attaining the corresponding international standards within this domain. Bilateral cooperation with the Norwegian Radiation and Nuclear Safety Authority (DSA) was and remains one of the most important components of the SNRIU international program. This was initiated with the signing of the Agreement [1] on 18 November 2014. The agreement solidifies a commitment to long-term cooperation in the regulation of nuclear energy safety, management of radioactive materials, and regulatory oversight of other sources of ionizing radiation. Providing a systematic and transparent framework for collaboration, the Agreement [1] outlines a structured approach, including periodic assessments of threats and challenges that might adversely impact SNRIU's role as the central executive power authority in nuclear and radiation safety (NRS) state regulation. Such assessments serve to identify priority areas for ongoing collaboration between DSA and SNRIU, aiming to address or mitigate the consequences of identified threats effectively.

Threat Assessment Reports [2], [3], and [4] in the regulatory domain, which, with the support of DSA, have been periodically reviewed and developed by the SNRIU and the State Enterprise "State Scientific and Technical Center for Nuclear and Radiation Safety" (SSTC NRS), as an organization of scientific and technical support to the regulator, since 2014, are vivid examples of the successful implementation of the approach to providing a stable foundation for planning, coordinating, and effectively implementing collaborative activities in line with the principles outlined in Agreement [1].

In 2020, another threat assessment was carried out, and the Roadmap for cooperation between the DSA and the SNRIU for 2021-2025 was agreed. However, the full-scale war launched by Russia against Ukraine on 24 February 2022 drastically affected the lives of the Ukrainian people and led to a number of challenges and threats to the global community. The nuclear energy sector, like the entire energy system of Ukraine, was among the main targets of the Russian aggressors, which became an unprecedented challenge for maintaining nuclear and radiation safety. These circumstances led to an urgent need to reassess regulatory threats and challenges and, jointly with DSA, identify further urgent projects aimed at eliminating or mitigating these threats, focusing on the following key areas:

- Analysis of the status of threats identified in [2]-[4] and measures taken at both national and international levels to eliminate or mitigate them;

- Identification of new, compared to [2]-[4], threats and challenges that may negatively affect the safety and security of radiation sources and facilities and the SNRIU's activity and its ability to perform its functions, in particular, threats associated with Russia's war against Ukraine, and identification of opportunities and resources for addressing or mitigating these new threats;

- Determination, guided by the analysis conducted, of strategies for addressing identified threats, utilizing the SNRIU's resources and international assistance.

This Report and the Roadmap of cooperation between the nuclear regulatory authorities of Norway and Ukraine for the period 2024-2028 were developed based on the findings of the threat assessment analysis.

2 LIST OF ABBREVIATIONS

BNL	–	Brookhaven National Laboratory
C(I)SIP	–	Comprehensive (Integrated) Safety Improvement Program for Operating Nuclear Power Units
ChEZ	–	Chornobyl Exclusion Zone
ChNPP	–	Chornobyl Nuclear Power Plant
CNSC	–	Canadian Nuclear Safety Commission
CRP	–	Coordinated Research Projects
CSDRS	–	Centralized Long-Term Storage Facility for Disused Radiation Sources
CSFSF	–	Centralized Spent Fuel Storage Facility
DRS	–	Disused Radiation Sources
DSA	–	Norwegian Radiation and Nuclear Safety Authority
DSFSF	–	Dry Spent Fuel Storage Facility
DSS	–	Decision Support System
DWDS	–	Decontamination Waste Disposal Site
EBRD	–	European Bank for Reconstruction and Development
Energoatom	–	State Enterprise 'National Nuclear Energy Generating Company Energoatom'
ENSDF	–	Engineered Near-Surface Disposal Facility for Solid Radioactive Waste
ENSREG	–	European Nuclear Safety Regulators Group
EU	–	European Union
Euratom	–	European Atomic Energy Community
FURN	–	Finnish-Ukrainian Radiation and Nuclear Safety Cooperation Project
HALEU	–	High Assay Low Enriched Uranium
HERCA	–	Heads of European Radiological Protection Competent Authorities
HLW	–	High-Level Waste
IAEA	–	International Atomic Energy Agency
IEC	–	Information and Emergency Center
ILW	–	Intermediate-Level Waste

INES	–	International Nuclear and Radiological Event Scale
INSC	–	Instrument for Nuclear Safety Cooperation
IRMIS	–	International Radiation Monitoring Information System
IRRS	–	Integrated Regulatory Review Service
ISF	–	Interim Spent Fuel Storage Facility
JRC	–	Joint Research Centre
KhNPP	–	Khmelnytsky Nuclear Power Plant
KIPT	–	National Science Center 'Kharkiv Institute of Physics and Technology'
KIT	–	Karlsruhe Institute of Technology
LLW	–	Low-Level Waste
MDG	–	Mobile Diesel Generator
MPC	–	Multipurpose Canister
NATO	–	North Atlantic Treaty Organization
Neutron Source	–	'Neutron Source Based on a Subcritical Assembly Driven by a Linear Electron Accelerator' Nuclear Subcritical Facility
NORM	–	Naturally Occurring Radioactive Material
NPP	–	Nuclear Power Plant
NRBU	–	Radiation Safety Standards of Ukraine
NRI	–	Nuclear Research Institute
NRS	–	Nuclear and Radiation Safety
NSC	–	New Safe Confinement
OECD NEA	–	Nuclear Energy Agency of Organisation for Economic Co-operation and Development
ONR	–	Office for Nuclear Regulation (United Kingdom)
PChP	–	Production Association 'Prydniprovsk Chemical Plant'
PNPP	–	Pivdennoukrainsk Nuclear Power Plant
PWR	–	Pressurized Water Reactor
RAMP	–	Radiation Protection Computer Code Analysis and Maintenance Program
RanidSONNI MRL	–	RanidSONNI Radiation Reconnaissance Vehicle (Mobile Radiological Laboratory)
RICS	–	Radioactive Waste Interim Confinement Site
RNPP	–	Rivne Nuclear Power Plant
RVPK	–	Graphite-Moderated Channel-Type Reactor

RWDS	–	Radioactive Waste Disposal Site
SBO	–	Station Blackout
SESU	–	State Emergency Service of Ukraine
SFP	–	Spent Fuel Pool
SMR	–	Small Modular Reactor
SNRIU	–	State Nuclear Regulatory Inspectorate of Ukraine
SPPS	–	State Physical Protection System
SRTP	–	Solid Radwaste Treatment Plant
SRW	–	Solid Radioactive Waste Disposal Facility
SSE ChNPP	–	State Specialized Enterprise 'Chornobyl Nuclear Power Plant'
SSM	–	Swedish Radiation Safety Authority
SSTC NRS	–	State Enterprise 'State Scientific and Technical Center for Nuclear and Radiation Safety'
STCU	–	Science and Technology Center of Ukraine
STUK	–	Radiation and Nuclear Safety Authority in Finland
TSOF	–	Technical Support Organizations Forum
UkrHMC	–	Ukrainian Hydrometeorological Center
USCPS	–	Unified State Civil Protection System
USIE	–	Unified System for Information Exchange in Incidents and Emergencies
USNRC	–	United States Nuclear Regulatory Commission
USTDA	–	United States Trade and Development Agency
VDTS	–	Vehicle Decontamination and Treatment Site
VLLW	–	Very Low-Level Waste
VVER	–	Water-Cooled Water-Moderated Power Reactor
VVR-M	–	Upgraded Water-Cooled Water-Moderated Reactor
WANO	–	World Association of Nuclear Operators
WENRA	–	Western European Nuclear Regulators Association
WGRR	–	Working Group on Research Reactors
ZNPP	–	Zaporizhzhia Nuclear Power Plant

3 INTRODUCTION

DSA and SNRIU entered into the Agreement [1] on Cooperation Related to Nuclear and Radiation Safety on November 18, 2014. A bilateral cooperation program in the field of nuclear and radiation safety regulation, developed based on this Agreement [1], defines technical information exchange and cooperation in the following areas:

- Safety of nuclear facilities;
- Safety of radioactive waste (radwaste) management, including disposal;
- Safety and security of radiation sources;
- Emergency preparedness and response;
- Safety of remediation of legacy sites, in particular uranium mining and uranium processing plants;
- Radiation protection;
- Safety and security of the transport of radioactive materials;
- Safety of management of radioactive materials containing naturally occurring radionuclides;
- Regulation and control of medical exposure to radiation; and
- Security of nuclear materials, radioactive waste, and other radiation sources.

Based on periodic assessments of the current and anticipated state of nuclear and radiation safety (NRS) regulation in Ukraine (Regulatory Threat Assessment Reports [2]-[4] and this Report), the tasks and scope of specific projects aimed at developing and strengthening SNRIU's regulatory capabilities in the specified areas are jointly identified and implemented with DSA's expert and financial support. As of August 2023, 19 projects have been completed since the start of the cooperation, and 17 projects are at various stages of implementation.

Based on the results of these projects, Ukraine's regulatory framework has been significantly improved in the areas of radioactive waste management, radiation protection in medicine, radiation safety in the uranium industry, emergency preparedness and response, transport of radioactive materials, nuclear security, and decommissioning. This progress has been achieved through the introduction of new regulatory requirements developed using leading European practices. Current joint projects aim to further strengthen the regulatory regime and improve practices in the following areas:

- Radiation monitoring of environmental objects near nuclear facilities;
- Classification of radwaste for disposal in various storage facilities; and
- Radiation surveys of territories affected by hostilities and military occupation, as well as resuming regulatory control over relevant facilities and sites in these territories.

Due to DSA's support and as a result of these projects, Ukraine has implemented 10 top-level regulations [5]–[14] that establish general safety provisions and requirements for:

- Institutional control of uranium sites;
- Activities associated with uranium ore mining and processing;
- Use of radiation sources in medicine, particularly in brachytherapy;
- Predisposal radwaste management and radwaste management during disposal;
- Decommissioning of nuclear facilities;
- Transport of radioactive materials;
- Development of NPP emergency documents; and
- Development of documents required to obtain licenses for nuclear facility decommissioning.

The implementation of these regulations has eliminated a number of significant threats to effective regulation in line with modern international standards and practices, as identified in previous assessments [2]-[4].

Within the current cooperation projects, DSA and SNRIU are also working on a significant number of regulations that are at various stages of development. These regulations will establish a legal basis for ensuring NRS in various regulatory areas. Ten regulations have been drafted within these projects and are at different stages of approval by relevant state agencies. In addition to rulemaking, SNRIU benefits from DSA's support in performing other functions, such as using best practices to organize meaningful and effective communication with stakeholders, the media, and the public, and strengthening practical emergency response skills through joint emergency exercises. Since the last regulatory threat assessment in 2020, many significant steps (linked or unrelated to DSA–SNRIU cooperation) have been taken in Ukraine's nuclear sector, including:

- Adoption of the Law of Ukraine “On Amendments to Certain Laws of Ukraine on Nuclear Energy Use” No. 613-IX, restoring the independence of the state nuclear regulatory body in licensing and oversight decisions, thus fulfilling Ukraine's international obligations;
- Adoption of the Law implementing the provisions of Council Directive EU 2013/59/Euratom [15], establishing requirements for occupational and medical exposure in planned exposure situations, public protection in existing exposure situations, and safety regulation during uranium ore management;
- Obtaining an individual permit for operating the Shelter New Safe Confinement to confirm the ability of the Shelter's systems, structures, and components to perform their design functions;
- Obtaining a permit for the initial startup of the "Neutron Source Based on a Subcritical Assembly Driven by a Linear Electron Accelerator" Nuclear Subcritical Facility for scientific and applied studies;
- Development and approval of the Seventh National Report of Ukraine on obligations under the Joint Convention on the Safety of Spent Nuclear Fuel Management and the Safety of Radioactive Waste Management;
- Achieving observer status in the European Nuclear Safety Regulators Group (ENSREG);
- Regulatory decisions enabling the safe long-term operation of Zaporizhzhia NPP Unit 5, Rivne NPP Unit 2, and Zaporizhzhia NPP Unit 6 at power levels consistent with their design;
- Granting a license to operate the dry spent nuclear fuel storage facility (ISF-2) at the ChNPP site, designed for long-term storage (up to 100 years) of spent nuclear fuel;
- Obtaining a license to operate the Confinement and Shelter by Chornobyl NPP after completing trial and commercial operations of Startup Package 1 of the New Safe Confinement; and
- Implementing safety improvements in spent nuclear fuel management, radioactive waste management, uranium ore mining and processing, and the use of radiation sources.

These examples highlight SNRIU's focus on a wide range of tasks over the past years. Many of these tasks remain relevant today. The complexity of these tasks, combined with Ukraine's current political, security, and economic challenges, intensifies existing issues and creates new significant challenges for regulatory activities.

Given the need for continued cooperation between DSA and SNRIU to address these challenges, both parties agreed on the relevance of a new Ukrainian regulatory threat assessment. The results are presented in this Report.

On February 24, 2022, Russia launched a full-scale war against Ukraine, causing unprecedented threats to the Ukrainian state and nation. Invaders targeted civil and energy infrastructure, including NPPs and other nuclear facilities. Ukraine's nuclear and radiation safety sphere faces challenges from the reckless actions of Russian military groups, who violated international law and safety standards by turning nuclear facilities into military bases. The ongoing seizure of Zaporizhzhia NPP, operational safety violations, violence, psychological pressure on personnel, and attacks on NPPs pose significant threats not only to Ukraine but to the broader region and environment.

Despite these challenges, SNRIU, supported by SSTC NRS and international partners, continues to perform its regulatory functions as defined by law, except for facilities in temporarily occupied territories. Detailed descriptions of these activities are presented in SNRIU's annual reports on nuclear and radiation safety in Ukraine (https://snriu.gov.ua/en/annual-and-national-reports/annual-reports).

Sections 2–8 of this Report analyze the current state of safety regulation in Ukraine's nuclear energy sector, focusing on progress in areas defined by Agreement [1], changes in the national nuclear sector, and the impacts of these changes on SNRIU activities. Section 9 identifies major threats and proposes solutions. Section 10 summarizes completed, ongoing, and planned projects under DSA–SNRIU cooperation, along with other initiatives involving international partners and SNRIU's independent efforts.

4 ORGANIZATION OF THE REGULATORY AUTHORITY, PRIORITIES AND INFORMATION POLICY

4.1 General Organizational Aspects of SNRIU Activities

The previous Regulatory Threat Assessment Reports [2]-[4] describe in detail the basic principles pertaining to the state regulation of nuclear and radiation safety in Ukraine, as well as the obligations and tasks entrusted to SNRIU in accordance with current legislation. This information has not changed and remains relevant for the development of this Report. Further basic information on the organizational aspects of current SNRIU activities is provided in this section.

The main functions of the nuclear regulatory authority, as determined by the Convention on Nuclear Safety [16] and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [19], are entrusted to SNRIU. SNRIU operates as a central executive authority whose activities are directed and coordinated by the Cabinet of Ministers of Ukraine, in compliance with the Statute of the State Nuclear Regulatory Inspectorate of Ukraine [17].

The main functions of SNRIU are to:

- Identify safety criteria and requirements to be legally established for the safe use of nuclear energy (rule-making);
- Issue permits and licenses for activities in the area of nuclear energy and the application of radiation sources (licensing/authorization);
- Conduct state oversight of compliance with laws, regulations, rules, limits, and conditions of licenses and standards on nuclear and radiation safety, and apply enforcement measures according to legislation in cases of non-compliance (oversight).

The main tasks of SNRIU are to:

- Establish and implement state policy for the safe use of nuclear energy and radiation sources;
- Exercise state regulation of the safety of nuclear energy and radiation sources;
- Fulfill the responsibilities of a competent authority for the physical protection of nuclear material and nuclear facilities in compliance with the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities [18], the safe transport of radioactive material in compliance with [10], and emergency notification in compliance with the Convention on Early Notification of a Nuclear Accident [21].

As of the beginning of 2023, SNRIU oversees the state regulation of nuclear and radiation safety (NRS) for:

- 15 operating nuclear power units, including the power units of Zaporizhzhia NPP, which have been occupied by Russian troops since March 2022;
- Two Khmelnytsky NPP (KhNPP) Units 3 and 4 under construction;
- Three ChNPP Units 1-3 undergoing decommissioning;
- Two operating spent fuel storage facilities at Zaporizhzhia and Chornobyl NPPs, and two spent fuel storage facilities under construction in the exclusion zone;
- The research reactor VVR-M of the National Academy of Sciences of Ukraine in Kyiv;
- The neutron source commissioned at the KIPT site;
- Radioactive waste management activities and facilities;
- The Shelter facility and New Safe Confinement at the Chornobyl NPP site;
- Uranium ore mining and processing, including the closure of uranium plants;
- The transport of radioactive material through Ukraine; and
- The use and fabrication of radiation sources.

The current organizational structure of SNRIU is shown in Fig. 2.1. The distribution of SNRIU staff by departments, age, and gender is presented in Fig. 2.2. SNRIU is supported by its technical support organization, SSTC NRS, which provides scientific, technical, expert, and analytical support to SNRIU in compliance with current legislation and the SSTC NRS Statute.

To develop recommendations on significant issues and identify the most essential areas of NRS regulation, the SNRIU Board [22] works on a permanent basis. The SNRIU Board consists of the SNRIU Chairman (Board Head), SNRIU and SSTC NRS management, leading independent experts, and representatives of public organizations.

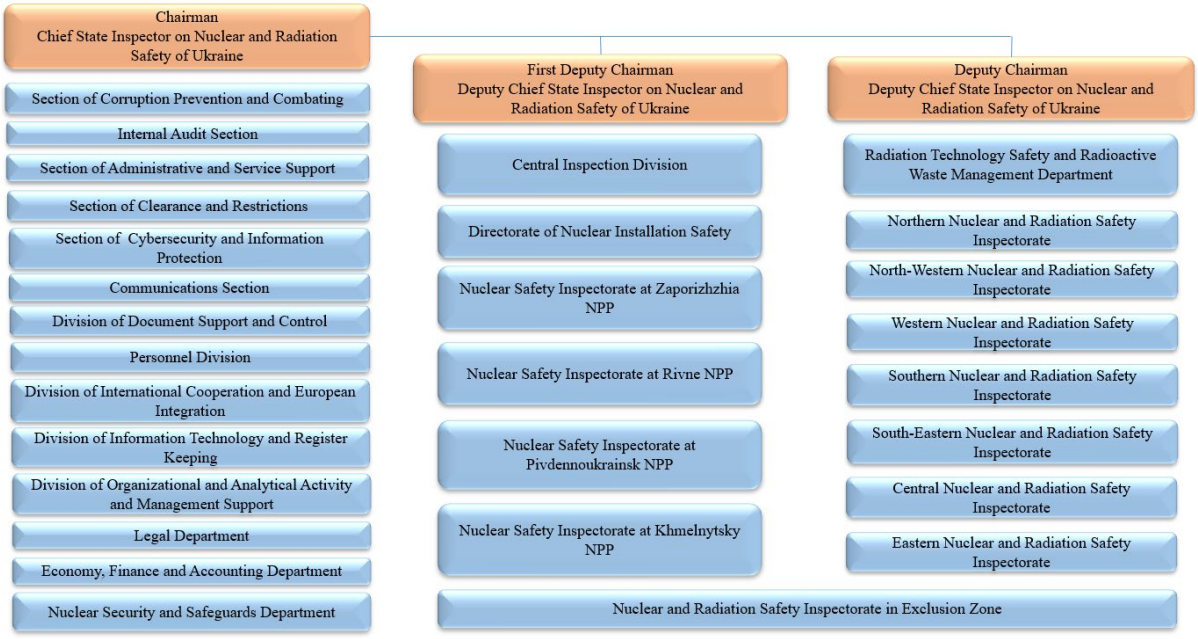
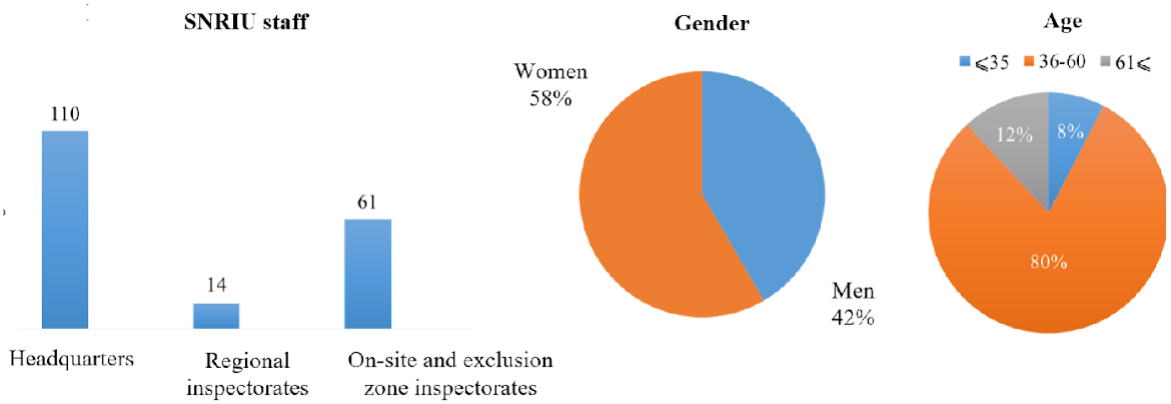


Fig. 2.1 – SNRIU organizational structure



Total staff number – 278, Vacancies – 93

Fig. 2.2 – SNRIU staff

4.2 Priority Areas of SNRIU Activities

To implement the tasks defined by laws, regulations, and instructions from the President and the Government of Ukraine, as well as international obligations aimed at ensuring nuclear and radiation safety (NRS) and security, SNRIU has identified the following priority areas for its activities in the coming years:

- Strengthening the independence, institutional stability, and efficiency of state safety regulation of nuclear energy use by developing and implementing up-to-date regulations at the level of Ukrainian laws, Cabinet of Ministers resolutions, and general and specific requirements for nuclear and radiation safety and nuclear security, in line with IAEA Safety Standards and EU Directives;
- Regulatory support for:
  - Restoring the safety level of nuclear facilities at the Zaporizhzhia NPP after de-occupation;
  - Implementing new/foreign nuclear technologies in the country;
  - Activities involving modified technology for unloading spent nuclear fuel, including the transport and storage of spent fuel at the Centralized Spent Fuel Storage Facility (CSFSF);
  - Introduction of Westinghouse nuclear fuel at VVER-440 power units (RNPP Units 1 and 2);
  - Operation of the Shelter and Confinement;
  - Operation of radioactive waste management facilities at the Vektor site, including long-term radioactive waste storage and disposal facilities, to implement an integrated process for radioactive waste management;
  - Bringing former uranium production facilities and the Prydniprovsk Chemical Plant site into a safe condition and ensuring radiation protection of the public;
  - Manufacturing and use of radiation sources, including commissioning new, up-to-date X-ray diagnostic equipment and linear accelerators by healthcare institutions;
- Oversight, taking into account the optimization principle in nuclear energy use;
- Functioning of a unified state system for monitoring and accounting for individual exposure doses;
- Fulfilling Ukraine's obligations under the Agreement on the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons [18], Conventions [16], [19]-[21], and obligations arising from Ukraine's participation in ENSREG, the Western European Nuclear Regulators Association (WENRA), etc.;
- Further development of SNRIU's bilateral and multilateral international cooperation.
- This and other sections of the Report provide a detailed description of current SNRIU activities in the above areas, identify new challenges that adversely impact their implementation, and suggest ways to eliminate or minimize these adverse impacts.

4.3 Current Information Policy of the SNRIU

The right of free access to information about the state of the environment in Ukraine is guaranteed at the highest legislative level. It is provided for in Article 50 of the Constitution of Ukraine and should not be classified. In addition, the openness and accessibility of information related to the safety of nuclear energy use is one of the basic principles of state policy in nuclear energy use and radiation protection. The Provisions [17] entrust SNRIU with the task of informing the public about the development and implementation of state policy on the safety of nuclear energy use. Furthermore, SNRIU is responsible for preparing and reviewing the state of nuclear and radiation safety within Ukraine, facilitating international exchange of the latest information on nuclear events, and notifying the media about radiation accidents in Ukraine. In cases of potential transboundary transfer of radioactive substances, SNRIU must also provide notifications outside Ukraine.

After Russia's full-scale invasion of Ukraine, new serious challenges arose for SNRIU's well-established and smoothly functioning information activities. These challenges were caused by the occupation, first of the Chornobyl NPP and then the Zaporizhzhia NPP by Russian military forces, damage and destruction of several facilities in the Chornobyl exclusion zone, continuous shelling of the neutron source, and violations of safety standards and regulations concerning the Pivdennoukrainsk, Rivne, and Khmelnytsky NPPs. Specific incidents include airspace violations over NPP no-fly zones, safety system blackouts, and rocket attacks near NPPs (see Section 3.2.4 of this Report for more details). These events are unprecedented in the global nuclear community and represent a complete disruption of the standards and approaches developed by countries operating NPPs under the guidance of the IAEA.

This situation created a real challenge for the entire nuclear community, particularly for Ukraine. Key questions arose: how to communicate about the occupation of nuclear facilities, what messages to convey to the public living near NPPs or in occupied zones, and how to effectively inform all citizens? How should information be presented to the media to ensure they disseminate facts and official, reliable information? What is the appropriate timing for notifications? How should messages be directed to the international community? These communication efforts fall under crisis communication but differ significantly, as the occupation of an NPP by a hostile country's military forces is an unprecedented event requiring non-standard approaches.

The war in Ukraine and its associated threats to nuclear energy, science, and medicine have also led to the spread of numerous fake news stories, disinformation, and manipulative messaging. The information overload, coupled with uncertainty, unpredictability, and polarized views, has increased public tension and panic. One of the first SNRIU projects aimed at raising public awareness about nuclear and radiation safety issues in post-occupation periods was the SURVEY Project, implemented by SSTC NRS. This project, carried out in de-occupied territories of the Kyiv region in 2022 with the technical and financial support of DSA, included significant communication efforts to reduce public concerns about potential risks associated with the transfer of radioactive substances from the Chornobyl exclusion zone by the occupiers (see Section 5 of this Report for more details).

Since Russia's full-scale invasion of Ukraine, the Uatom.org website, which has been operated by SNRIU and SSTC NRS since 2010 with support from SSM, Sweden, has become a critical platform for informing the public. In the event of hacker or phishing attacks or the blocking of SNRIU's official website, Uatom.org plays an important role in disseminating information about the state of nuclear and radiation safety. Through this platform, SNRIU has conducted explanatory work for Ukrainian citizens on several important topics:

- Actions in case of a radiation accident [23];
- Safe management of abandoned radioactive sources [24];
- The benefits and risks of iodine prophylaxis [25].

Even nearly two years after the full-scale invasion, SNRIU continues to face new challenges and uncover gaps in its communication with the public. To address these issues, the following steps are necessary to improve SNRIU's information policy:

- Enhancing the communication skills of its experts, including employees involved in the Ukrainian/SNRIU Information and Emergency Center (IEC);
- Increasing media representatives' awareness of nuclear and radiation threats and their consequences;
- Improving mechanisms for interaction between government bodies responsible for nuclear and radiation safety and the media.

These are the main tasks of the COMMUNICATION Project, recently launched by SNRIU with DSA support. Through the cooperation of the two regulators, this project aims to strengthen the communication skills of nuclear and radiation safety experts and improve their ability to convey information to the public. Interaction with media representatives will enhance journalists' basic knowledge of nuclear and radiation safety, radiological risks during war and hostilities, and the production of accurate information materials. This will, in turn, increase the effectiveness of the media as a tool for disseminating truthful, reliable, and vital information to the public.

One of the next steps in SNRIU and DSA cooperation in this area should be the creation of a separate platform (website) dedicated to information about implemented bilateral cooperation projects and their results. This resource can serve as a means of ensuring transparency and accessibility of data on cooperation achievements for other stakeholders. Additionally, it could act as a catalyst for further

collaboration between SNRIU and DSA, contributing to the development and strengthening of their interaction and facilitating the planning of future initiatives.

5 SAFETY OF NUCLEAR FACILITIES

5.1 General Description

As of 2023, nuclear facilities in Ukraine include nuclear power plants (NPPs), spent fuel storage facilities, research reactors, and other facilities (see Fig. 3.1). Nuclear and radiation facilities located in the Chornobyl exclusion zone include facilities for the management of spent nuclear fuel, radioactive waste, and radiation sources; ChNPP units at the decommissioning stage; the New Safe Confinement; and the Shelter.

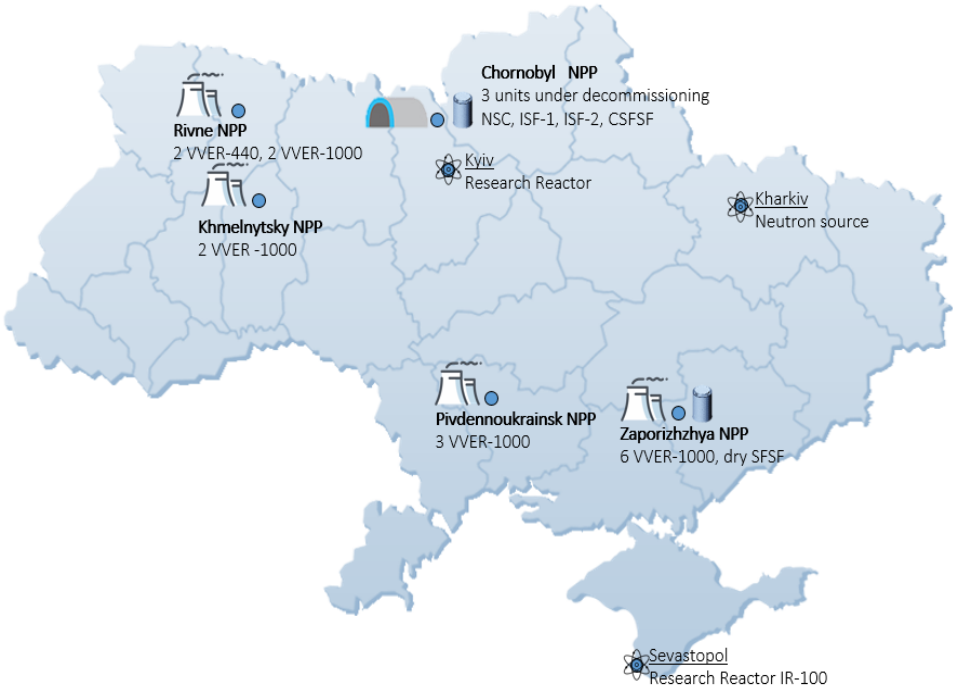


Fig. 3.1 – Nuclear facilities in Ukraine

5.2 Nuclear Power Plants

5.2.1 General Information and Current Status

Currently, 15 VVER NPP units are in operation in Ukraine across four sites. Thirteen power units are equipped with VVER-1000 reactors (V-320, V-302, V-338), and two power units operate with VVER-440 reactors (V-213). The sole operator of all operating NPPs in Ukraine is the Energoatom Company.

In addition, there are three Chornobyl NPP units with high-power pressure-tube reactors that are in the decommissioning stage. Currently, the stage of safe closure of these power units is being implemented.

Nuclear generation plays an important role in Ukraine's energy balance (see also Reports [2], [3], and [4]). NPPs are the main source of electricity in Ukraine and a critical component of its energy safety and security. In 2022 and 2023, nuclear energy not only became more significant but also faced several challenges and threats due to Russia's full-scale invasion of Ukraine.

In February 2022, the Russian Federation launched a full-scale invasion of Ukraine. For the first time in the history of nuclear energy, unprecedented aggression against NPPs and other nuclear facilities occurred. On February 24, 2022, Russian troops captured all nuclear facilities in the Chornobyl exclusion zone. On March 4, 2022, the Zaporizhzhia NPP in southeastern Ukraine became the first operating NPP in the world to be subjected to an armed attack and artillery shelling. This resulted in damage to the ZNPP site infrastructure and the occupation of the ZNPP and its satellite town. Since mid-2022, the ZNPP site and its surrounding area have been repeatedly shelled. Military operations in the ZNPP area have caused multiple losses of external power supply to the ZNPP, requiring the safety systems to rely on diesel generators.

During 2022–2023, Russia carried out massive, targeted attacks (including missile strikes and the use of unmanned aerial vehicles) on Ukraine's critical infrastructure, including the energy system. These attacks affected not only the Zaporizhzhia NPP but also other NPPs in Ukraine, due to damage to distribution substations and switchyards, leading to frequency fluctuations in the Ukrainian grid. As a result of these attacks, nuclear generation became an even greater priority and of extreme importance during the Russian aggression.

In these conditions, new threats emerged (see this section and Sections 6 and 9 of the Report for more details), caused by the unprecedented Russian aggression:

- Seizure of the Chornobyl NPP and exclusion zone by the Russian military (see Section 6 of the Report for more details) and the largest NPP in Europe, ZNPP, resulting in the loss of regulatory control over these facilities;
- A significant number of operational events at all Ukrainian NPPs due to Russian military aggression (see para. 3.2.4 of this Report for more details).

To ensure the safety regulation of the Chornobyl NPP and facilities in the exclusion zone after Ukraine regained control over this territory, it was urgently necessary to develop priority regulatory documents regarding the conditions for resuming regulatory control over nuclear hazardous facilities affected by hostilities and occupation. This threat was of the highest priority and was addressed within the framework of DSA and SNRIU cooperation through the implementation of the ZONE Project (see Sections 6 and 10 of this Report for more details).

Under the conditions of the ongoing ZNPP occupation during the development of this Report, Energoatom, due to circumstances beyond its control, is unable to meet all licensing limits and conditions for the safe operation of ZNPP units. Additionally, SNRIU inspectors cannot conduct oversight directly at the ZNPP site, as Russian troops are present on-site. Consequently, SNRIU Order No. 501 of August 18, 2022, amended the licenses for the operation of ZNPP Units 1 and 2. Unit 1 was required to operate in refueling-cold shutdown mode, and Unit 2 in cold shutdown. Order No. 338 of June 28, 2023, amended the licenses for the operation of ZNPP Units 3–6. Unit 3 is to operate in maintenance shutdown-cold shutdown mode, while Units 4, 5, and 6 are to remain in cold shutdown.

Access by the legitimate operator, Energoatom, and Ukrainian-licensed personnel to fully manage the units at the Zaporizhzhia Nuclear Power Plant (ZNPP) in accordance with SNRIU regulatory requirements remains restricted. This continues to hinder the implementation of optimal and internationally recognized safety measures. In addition, during the night of 5–6 June 2023, the destruction of the Kakhovka reservoir dam — located approximately 150 km downstream from the ZNPP — led to a significant drop in the reservoir's water level. As this reservoir was a critical source of cooling water for the plant, its loss introduced new nuclear and radiation safety risks at the ZNPP site. In this situation, keeping all reactors in cold shutdown has been recognized as the most effective way to minimize nuclear safety hazards, limit equipment degradation, and ensure efficient use of the remaining water resources.

However, available information indicates that the occupying ZNPP management is implementing modifications to systems and components without proper safety justification or approvals. Proper maintenance and technical inspections are not being carried out, and Russian personnel involved in activities at the ZNPP are not licensed under Ukrainian legislation.

Given the above, SNRIU needed to assess the overall course, timeframes, and potential consequences of an accident caused by a total NPP blackout and/or loss of the ultimate heat sink, taking into account the current state of the power units. This state differs significantly from the conditions considered in the national stress tests following the Fukushima accident. To conduct this assessment, the RECONSTRUCTION Project was recently launched with DSA support.

After the de-occupation of the ZNPP and its surrounding territory, SNRIU will face the task of resuming state regulatory control over the nuclear facilities at the ZNPP. This threat, concerning the resumption of state regulatory control, is of the highest priority and is already being addressed within the framework of DSA and SNRIU cooperation through the implementation of the ZONE 2 Project (see Section 10 of this Report for more details).

5.2.2 NPP Safety Improvement

According to the requirements of the Law of Ukraine “On Nuclear Energy Use and Radiation Safety” [27] and the provisions of the Convention on Nuclear Safety [16], the operating organization must ensure the sustainable and safe operation of NPPs. Safety improvement measures for operating NPPs are implemented systematically in compliance with national standards and NRS rules, IAEA recommendations, and long-term operating experience, while considering international best practices.

During 2020–2023, the safety improvement measures outlined in the C(I)SIP [28] program, planned for completion by the end of 2023, have been implemented (see paras. 3.2.1 [3], [4]). Between 2020 and 2023, the operating organization focused on implementing measures for RNPP Units 1 and 2, KhNPP Units 1 and 2, as well as ZNPP Units 3, 5, and 6, as part of the safety review and preparation of power units for long-term operation. The following measures were implemented at Ukrainian NPP units during this period:

- Modernizing the system for the management of transport containers with spent nuclear fuel;
- Implementing the reactor ex-vessel cooling system (see para. 3.2.1 [4] for more details);
- Providing emergency power supply using mobile diesel generators (MDGs);
- Implementing the containment venting system (see para. 3.2.1 [3], [4] for more details);
- Developing and implementing measures to reduce hydrogen concentration in the containment during beyond-design-basis accidents, among other measures.

Special mention should be made of the modernization of the system for managing transport containers with spent nuclear fuel and the implementation of the reactor ex-vessel cooling system for VVER-440 reactors at Rivne NPP Units 1 and 2.

At Ukrainian NPPs without on-site spent fuel storage facilities (RNPP, KhNPP, PNPP), modifications to the spent fuel unloading technology are being implemented to enable the transfer of spent fuel to the Centralized Spent Fuel Storage Facility (CSFSF), which uses Holtec International (Holtec) technology.

Under the loading technology used at VVER-1000 NPP units in Ukraine, spent fuel from the spent fuel pool is loaded into a double-walled multi-purpose canister (MPC, Fig. 3.2), which is pre-installed inside the HI-TRAC 190 transfer cask. Following technological operations for loading spent fuel into the MPC, the canister is sealed through welding, decontaminated, and then transferred from the HI-TRAC to the HI-STAR overpack (Fig. 3.3). The HI-STAR overpack is subsequently transported to the CSFSF for long-term storage.

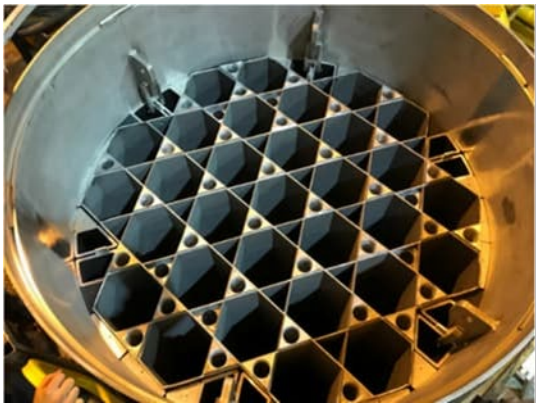


Fig. 3.2 –Holtec multipurpose canister and HI-TRAC cask

Fig. 3.3 – HI-STAR transport overpack

The reactor ex-vessel cooling system is designed to prevent the progression of a severe accident to the ex-vessel phase and, accordingly, to prevent failure of the containment system due to the impact of molten core fragments on its structures and components. Prevention of the ex-vessel phase also mitigates several phenomena that negatively impact containment systems, particularly hydrogen generation caused by the interaction of corium with concrete.

The destruction of the reactor pressure vessel is prevented by externally cooling the reactor pressure vessel, which ensures:

- Prevention of melt-through, keeping the molten material inside the reactor pressure vessel; or
- Prevention of deformations that could impair heat removal from the outer surface of the reactor pressure vessel, thereby avoiding local overheating of the vessel wall.

At RNPP Units 1 and 2, the ex-vessel reactor cooling system is manufactured by VUEZ a.s. (Slovak Republic). This system has been commissioned for commercial operation at Unit 2 and is currently in trial operation at Unit 1.

The Russian military aggression has directly impacted Energoatom's activities, particularly the implementation of C(I)SIP measures [28]. Force majeure circumstances, including damage to industrial enterprises and critical infrastructure, disruptions in logistics, and a reduction in personnel from design, construction, installation, and commissioning organizations due to mobilization and forced evacuation, have made it impossible to fully meet obligations under existing contracts. This has led to delays in the supply of necessary equipment, materials, products, and other goods, resulting in the failure to complete

planned activities and provide services within the specified timeframes. Consequently, under Resolution No. 479 of the Cabinet of Ministers of Ukraine, dated May 12, 2023, the C(I)SIP program [28] was extended until 2025.

Over the past years, and continuing today, SNRIU, with the involvement of SSTC NRS, has been addressing threats to regulatory activities related to NPP safety improvement that were identified in reports [2]–[4] and in this Report. These efforts have been carried out using internal resources as well as international assistance, including:

- **In cooperation with DSA under the GUIDELINE Project:** A new regulation, *"Requirements for NPP Emergency Documents"* [13], was developed and introduced into Ukraine's regulatory framework in 2021. This regulation is currently used in oversight activities.

- **In cooperation with the USNRC:** A new regulation, *"Requirements for Maintenance of Equipment of Systems Important to NPP Safety"* [45], was developed and implemented in 2023. This regulation establishes requirements for nuclear and radiation safety in the planning, preparation, execution, and recording of maintenance for equipment of systems important to NPP safety. It also optimizes maintenance practices for such equipment by incorporating a risk-informed approach and the concept of maintenance based on technical condition.

- **In cooperation with the USNRC under the CAMP (Code Application and Maintenance Program) and CSARP (Cooperative Severe Accident Research Program) programs:** Since 2014, SNRIU and SSTC NRS have participated in these programs to enhance capabilities in using state-of-the-art tools and methodologies for accident analysis and severe accident research. Results from these programs include the development, validation, and verification of thermohydraulic models for reactors and/or spent fuel pools (SFPs) of VVER-1000 and VVER-440 using TRACE and MELCOR codes. These models are applied in verification calculations during NRS reviews of safety analysis materials for Ukrainian NPPs and other applied studies.

- **In cooperation with the European Commission and with DSA participation:** A project has been launched [13] to support SNRIU in implementing measures for the first (aging management) and second (fire safety) ENSREG topical reviews. This project also includes several initiatives to enhance the safety and operational efficiency of Ukrainian NPP units.

5.2.3 NPP Long-Term Operation

Currently, 80% (twelve out of fifteen) of Ukrainian NPPs have been in operation for more than 30 years. Given the current situation, marked by the military aggression of the Russian Federation, shelling of Ukraine's energy system, significant damage to energy infrastructure (including thermal power plants, the Kakhovka HPP, and distribution stations), and the loss of generation capacity from ZNPP units, nuclear generation has become an extremely high priority.

According to the Energy Strategy of Ukraine for the Period Until 2035 [31], which outlines strategic guidelines for the development of Ukraine's fuel and energy system, and the Energy Strategy of Ukraine for the Period Until 2050 (approved by Resolution No. 373-r of the Cabinet of Ministers of Ukraine on April 23, 2023) [32], nuclear energy is recognized as one of the most cost-effective low-carbon energy sources. The further development of the nuclear energy sector is planned, including the doubling of nuclear generation capacity to 30 GW.

A key measure in this area is the long-term operation of existing NPP units. From 2020 to 2023, the Government of Ukraine continued its focus on the long-term operation of NPP units, in line with the

Comprehensive Work Program for Long-Term Operation of Operating NPPs [33]. As of 2023, long-term operation was authorized according to the established procedures for 12 power units of Ukrainian NPPs.

Over the next five years, the design service life of one additional power unit is set to expire (see Table 3.1), as well as the long-term operation periods for seven NPP units.

Table 3.1 – Service life of operating units of Ukrainian NPPs.

NPP	Unit	Reactor type	Expiration of service life	
			design-basis	long-term operation
ZNPP	1	VVER-1000/320	23.12.2015	23.12.2025
	2	VVER-1000/320	19.02.2016	19.12.2026
	3	VVER-1000/320	05.03.2017	05.03.2027
	4	VVER-1000/320	04.04.2018	04.04.2028
	5	VVER-1000/320	27.05.2020	27.05.2030
	6	VVER-1000/320	21.10.2026	–
PNPP	1	VVER-1000/302	02.12.2013	02.12.2033
	2	VVER-1000/338	12.05.2015	31.12.2025
	3	VVER-1000/320	10.02.2020	10.02.2030
RNPP	1	VVER-440/213	22.12.2010	22.12.2030
	2	VVER-440/213	22.12.2011	22.12.2031
	3	VVER-1000/320	11.12.2017	11.12.2037
	4	VVER-1000/320	07.06.2035	–
KhNPP	1	VVER-1000/320	13.12.2018	13.12.2028
	2	VVER-1000/320	07.09.2035	–

In accordance with current legislation, a decision on the authorization of long-term operation of a power unit is approved by the SNRIU based on the conclusions of a state NRS review of the periodic safety review report, which involves amending the license for its operation. Authorization for long-term operation may only be granted if the safety level of the nuclear power unit meets or exceeds the standards established by current regulations and rules on NRS.

Challenges in regulating the long-term operation of Ukrainian NPPs are addressed by SNRIU and SSTC NRS using their own resources and with assistance from the United States Nuclear Regulatory Commission (USNRC) and European Commission projects (see Section 10 of this Report for details).

5.2.4 Analysis of Operating Experience and Accounting of Operational Events at Ukrainian NPPs

The SNRIU, with the involvement of SSTC NRS, conducts continuous analysis of operating experience and oversees compliance with safety standards and rules during the investigation and analysis of NPP operational events. This includes planning and inspections that take into account operating experience (see Reports [2], [3], and [4] for details).

In addition, regulatory requirements for operating experience and the investigation of NPP operational events are being reviewed and improved. For instance, the SNRIU developed new regulatory requirements, NP 306.2.235-2021 Provisions on the Procedure for Investigation and Accounting of NPP Operational Events, which came into force on January 1, 2022 [35].

As a result of the Russian aggression, unprecedented events related to the aggression against NPPs occurred for the first time in 2022:

- Seizure of NPPs (ChNPP and ZNPP);
- Shelling of NPP sites (ZNPP, PNPP);
- Damage to power lines and ZNPP infrastructure;
- Shelling and damage to critical infrastructure and the energy system of Ukraine, affecting all NPPs in the country.

The number of operational events at Ukrainian NPPs in 2022 doubled compared to the previous nine years. Notably, more than half (54%) of these operational events in 2022 were caused by active hostilities from Russian occupation forces and the shelling of Ukraine's energy infrastructure.

Due to the Russian aggression, these events have led to a significant increase in the total number of operational events at Ukrainian NPPs in 2022 and 2023. Figure 3.4 illustrates the distribution of operational events for the period from 2013 to 2023.

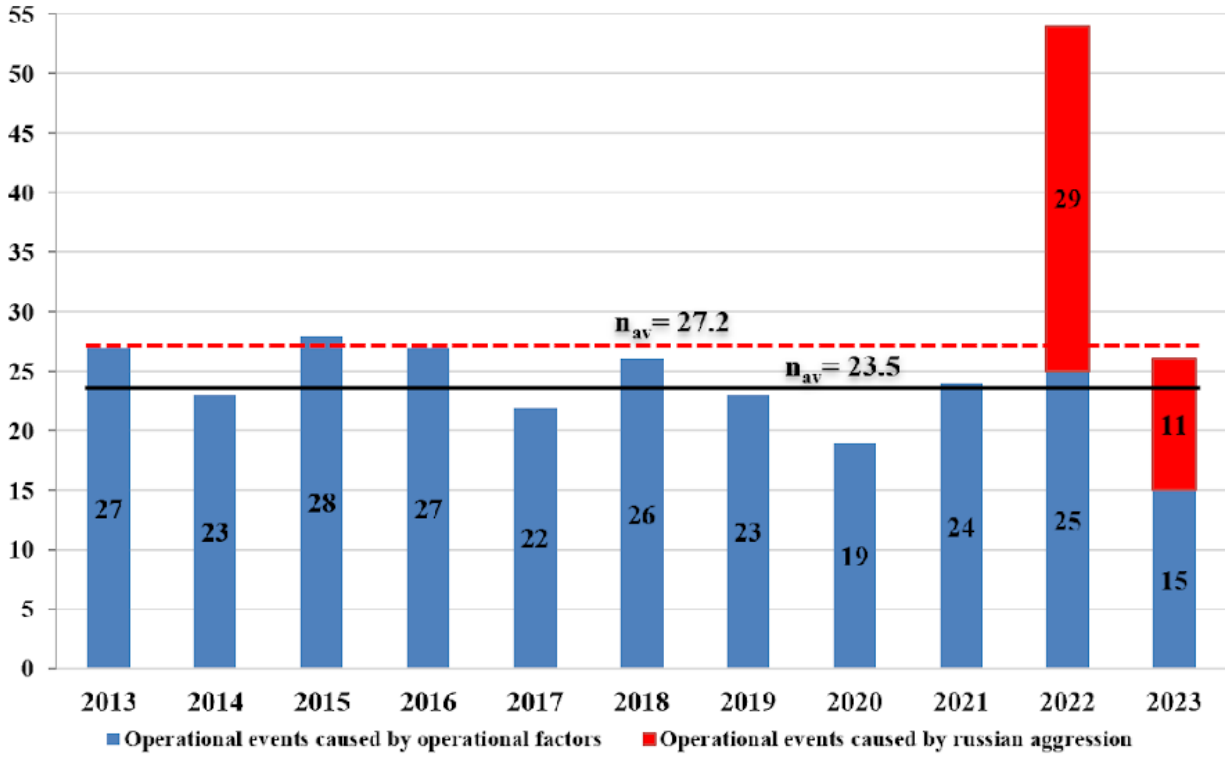


Fig. 3.4 – Number of operational events at Ukrainian NPPs in 2013 – 2023

Due to the ongoing military actions in Ukraine, 29 events were reported at Ukrainian nuclear power plants in 2022 and 11 in 2023. These incidents have had a significant negative impact on nuclear and radiation safety, as well as on the overall security environment of nuclear infrastructure. The actions leading to these events represent clear violations of international safety standards and legal norms, including:

- Articles 1 and 2 of the Charter of the United Nations,
- Article 56 of the Geneva Convention of 12 August 1949, relating to the protection of civilian infrastructure during armed conflict, and Additional Protocol I of 8 June 1977,
- Article 2 of the International Convention for the Suppression of Acts Involving the Use of Radioactive Material, which outlines unlawful uses of nuclear and radiological sources with harmful intent.

The review and timely analysis of operating experience, including events caused by wartime conditions, is critical to identifying potential vulnerabilities and developing and implementing measures to maintain safe operations. The analysis of operating experience at Ukrainian NPPs under these conditions provides an opportunity to identify important lessons on NPP safety improvements that were previously unconsidered.

The challenge of analyzing operational events from 2022 and 2023, including those caused by Russian aggression, has been given the highest priority and is being addressed with international assistance. This includes EU international assistance projects [42], cooperation with the EU JRC Clearinghouse [43], and BNL [44] (see Section 10 of this Report for details).

Additionally, a key challenge identified in Reports [2], [3], and [4] was the need for a systematic and comprehensive analysis of operating experience at Ukrainian NPPs on a permanent basis. This ensures effective utilization of lessons learned and improvements in operational safety. To address this threat, the EXPERIENCE Project was implemented under DSA and SNRIU cooperation.

The EXPERIENCE Project led to the development of SNRIU guidelines for assessing safety culture and human and organizational factors during the analysis of operating experience. The results of the EXPERIENCE Project are currently used in the analysis of investigation reports on operational events at Ukrainian NPPs and in developing SNRIU recommendations for oversight planning. The experience gained from this project was also incorporated into the revision of regulatory requirements for the investigation of operational events and the analysis of operating experience [35].

5.2.5 Introduction of Westinghouse Nuclear Fuel

Westinghouse fuel was introduced to eliminate dependence on the Russian supplier. Between 2021 and 2023, the diversification of nuclear fuel for Ukrainian NPPs continued (for details on the preconditions and process of diversification, see Reports [2]–[4]).

As of the end of 2023, Westinghouse fuel is part of the cores of PNPP Units 2 and 3, ZNPP Units 1, 3, 4, and 5, and RNPP Unit 3. PNPP Units 2 and 3, as well as ZNPP Units 1, 3, 4, and 5, have completely transitioned to Westinghouse fuel, while the core of RNPP Unit 3 is half-loaded with Westinghouse fuel. In the context of the Russian military aggression, and to eliminate dependence on Russia for the supply of nuclear fuel, the remaining units of Ukrainian NPPs are in the process of transitioning to Westinghouse fuel. The licensing of Westinghouse fuel for the “small” VVER-440 RNPP Unit 2 has already been completed.

The further implementation of Westinghouse fuel is one of the most critical issues for Ukrainian energy independence and national security. Current regulatory issues arising during the implementation and distribution of Westinghouse fuel at Ukrainian NPPs are addressed by the SNRIU independently and with technical support from SSTC NRS, including through international assistance [40].

Additionally, SSTC NRS participates in the European APIS Project (https://apis-project.eu/), which is implemented with financial support from the European Commission. The APIS Project aims to introduce a safe Westinghouse fuel supply for VVER-1000 and VVER-440 reactors. The project provides for the development of a new generation of fuel design and regulatory documents for its implementation in VVER reactors in European countries seeking to reduce or completely eliminate dependence on Russia.

5.3 Research Nuclear Facilities

As of 2023, two research reactors are located and operated in Ukraine. These include the nuclear research reactor VVR-M of the Nuclear Research Institute in Kyiv (see Fig. 3.5) and the research nuclear reactor (IR-100) along with the subcritical uranium-water assembly at the Sevastopol National University of Nuclear Energy and Industry (see Fig. 3.6).

Fig. 3.5 – Nuclear research reactor VVR-M of the Nuclear Research Institute in Kyiv

Fig. 3.6 –Nuclear research reactor IR-100

Because of the Russian occupation of the Autonomous Republic of Crimea in 2014, Ukraine lost regulatory control over nuclear facilities, including the research reactor IR-100 and two subcritical assemblies based on low-enriched and natural uranium at the Sevastopol National University of Nuclear Energy and Industry. As a result, on June 16, 2014, the SNRIU canceled the license issued to the Sevastopol National University of Nuclear Energy and Industry for the operation of the research reactor (IR-100) and the subcritical water-uranium assembly.

The nuclear research reactor VVR-M of the Nuclear Research Institute (National Academy of Sciences of Ukraine) was commissioned in February 1960 as a powerful neutron source for conducting fundamental and applied research in various fields of science and technology. The design did not specify its operational lifetime. Currently, the VVR-M research reactor is operated under an SNRIU license issued on December 29, 2014 (see [2], [3], [4] for more details).

In 2020, the Nuclear Research Institute decided to extend the operation of the VVR-M nuclear research reactor beyond 2023. To implement this decision, the Nuclear Research Institute developed the *"Schedule for Developing the Periodic Safety Review Report for the VVR-M Nuclear Research Reactor of NRI of the National Academy of Sciences of Ukraine No. PG.05-44-20/21/22"* and agreed on it with the SNRIU. Accordingly, a safety review of the VVR-M reactor commenced. As of September 2023, the schedule has been updated, and the safety review of the VVR-M reactor at the Nuclear Research Institute is ongoing.

Following Russia's full-scale invasion of Ukrainian territory in February 2022, the nuclear fuel from the VVR-M core was unloaded into the spent fuel pool. Since then, the VVR-M reactor has not operated at power. Challenges and threats associated with the safety review of the VVR-M research reactor are addressed by the SNRIU using its own resources.

Reports [3] and [4] identified a threat stemming from an inadequate regulatory framework governing specific operational aspects of research reactors, including their safety review. This issue was addressed as part of the EC Project INSC U3.01/14/U3.01/15 [41], which involved developing regulatory requirements for the safety of research reactors and the investigation and accounting of their operational events. Based on the outcomes of this project, drafts of relevant regulations were prepared. Their integration into

Ukraine's regulatory framework for nuclear and radiation safety at research facilities and reactors is ongoing, in line with the SNRIU Regulatory Control Plan [46].

On December 18, 2020, WENRA published the *Safety Reference Levels for Existing Research Reactors* [47], developed by the WENRA Working Group on Research Reactors (WGRR) [48]. In 2021, a self-assessment of national regulatory requirements against the published WENRA reference safety levels for existing research reactors began in WENRA member countries. The goal of this self-assessment is to harmonize national NRS regulatory requirements with WENRA reference levels. Ukraine, as a full member of WENRA, also initiated this process in 2021, and it remains ongoing.

5.4 Licensing and Construction of New Nuclear Facilities

5.4.1 Licensing and Construction of New KhNPP Units

Between 2020 and 2023, the operating organization Energoatom continued taking measures to resume the construction of KhNPP Units 3 (see Fig. 3.7) and 4 (see paras. 3.4.1 [3] and [4]) and conducted activities to prepare for the licensing and construction of KhNPP Units 5 and 6.

In 2021, the SNRIU, in accordance with instructions from the Cabinet of Ministers of Ukraine, reviewed and provided comments on the Draft Law of Ukraine "On Siting, Design, and Construction of Khmelnytsky NPP Units 3 and 4."

In March 2022, a state NRS review of Energoatom documents was conducted regarding the activities performed on the topic "Updating of Survey and Confirmation of the Durability and Reliability for Civil Structures, Buildings, and Installations of KhNPP Units 3 and 4." Based on the review, the documents were returned for revision.

Fig. 3.7 – Status of KhNPP Unit 3 construction

On August 31, 2021, a Memorandum on the Joint Construction of Power Units in Ukraine was signed between Energoatom and the Westinghouse Electric Company (USA). On June 2, 2022, an agreement was signed between these companies to increase the number of NPPs to be constructed in Ukraine using the Westinghouse AP1000 technology. Energoatom has initiated preparations for the construction of KhNPP Units 5 and 6 (see Fig. 3.8).

To ensure regulatory support for these activities, the SNRIU reviewed the licensing plan for the construction and commissioning of KhNPP Units 5 and 6, as well as the draft Resolution of the Cabinet of Ministers of Ukraine *"On Measures for the Construction of KhNPP Units."*

On January 20, 2023, the Cabinet of Ministers issued Order No. 52-r *"On Organizational Measures for the Construction of KhNPP Units."* According to this document, the government agreed with the Ministry of Energy's proposal to develop a feasibility study for the construction of a nuclear facility using the technical characteristics of the AP1000 reactor (Westinghouse, USA). Once developed, the feasibility study will require approval by the Cabinet of Ministers of Ukraine.

Fig. 3.8 – Khmelnytsky NPP site

The challenges faced by the SNRIU in licensing and safety assessment of new NPPs are addressed using its own resources and under international assistance (see Section 10 of this Report for more details).

5.4.2 Licensing and Commissioning of the Neutron Source

The neutron source has been under construction at KIPT since 2013 (see Fig. 3.9). The construction and commissioning of the neutron source are being carried out by the operating organization, KIPT, under a license for the construction and commissioning of the facility.

Between 2020 and February 2022, the operating organization conducted a series of activities to commission the neutron source. These activities included the initial startup of the facility, which involved nuclear fuel loading, achieving the Kef level established in the design, performing studies to experimentally determine the neutronic characteristics of the facility, and recording the results. Additionally, activities were undertaken to obtain a separate permit from the SNRIU for the trial and commercial operation of the facility.

Fig. 3.9 – Neutron source

The challenges faced by the SNRIU during the licensing and safety assessment for commissioning a new nuclear facility in Ukraine were addressed using its own resources and with the involvement of international assistance, particularly through the INSC U3.01/14 and U3.01/15 Project [41] (see Section 10 of this Report for more details).

Since the start of the full-scale invasion of Ukraine and the imposition of martial law across the country, the neutron source was placed in a deep subcritical state by the operating personnel, and all activities at the neutron source site were suspended. Beginning in March 2022, the KIPT site — where the neutron source is located — has been subjected to repeated missile strikes, shelling, and aerial bombardment. These attacks have caused significant damage to the site's buildings and infrastructure. The neutron source itself was directly impacted, resulting in damage to structures, systems, and components of the facility, including those essential to its safety functions (Fig. 3.10).

Despite the continuous shelling, the operating personnel of the neutron source, under relatively safe conditions, periodically assessed the facility's condition and damage. They monitored and evaluated the main technological parameters to ensure nuclear and radiation safety. Measurements taken with a portable dosimeter confirmed that the radiation background at the site and in the experimental hall of the neutron source building remained unchanged and within normal limits.

Fig. 3.10 – Damage of the neutron source caused by shelling

Since August 2022, following the de-occupation of the Kharkiv region, the personnel of the neutron source have initiated and continued activities to eliminate the consequences of shelling, maintain the equipment of the nuclear facility in operable condition, and restore damaged structures, systems, and components.

However, given the current situation—characterized by the facility's long-term shutdown, damage to safety-critical systems and components, as well as those not directly affecting safety due to shelling and

bombing—it is not possible to extend the licensing of the neutron source according to the existing licensing plan. This necessitates the development and implementation of specific measures.

The SNRIU has identified this as a threat that cannot be addressed using its own resources. Specifically, there is a need to develop an action plan to resume and complete the licensing of the neutron source at the construction and commissioning stage, taking into account the long-term shutdown and damage caused by Russia's shelling. This threat has been assigned the highest priority and will be addressed through cooperation between the DSA and SNRIU under the recently launched ZONE 3 Project (see Section 10 of this Report for more details).

5.5 Pre-licensing Assessment of Design for Small Modular Reactors

One of the fundamental principles of the Energy Strategy of Ukraine for the Period Until 2050 [32] is the development of up-to-date and safe nuclear generation, with a goal of doubling its capacity to 30 GW. This is planned to be achieved through the implementation of the latest technologies, including small modular reactors (SMRs). Currently, the SNRIU is conducting activities to prepare for the licensing of SMRs, focusing on two areas: studying IAEA and EU documents, and participating, with the involvement of SSTC NRS, in international projects on SMR implementation.

The first area involves analyzing developments from the IAEA Regulators' Forum. Reports developed by the Forum groups present general positions of the regulatory community on issues that have arisen or may arise during the expected licensing of SMR designs. The SNRIU, in collaboration with SSTC NRS, is studying the information in these reports to ensure proper application of the findings during the anticipated licensing of SMRs.

The second area encompasses activities performed by SNRIU/SSTC NRS within projects potentially related to the development and implementation of SMRs in Ukraine, including:

- Development of the regulatory document "Provisions on Pre-licensing Assessment of Nuclear Facility Design" under the SNRIU and USNRC cooperation program;
- NuScale consulting support for a comparative analysis of Ukraine's regulatory framework and the bases underlying the NuScale SMR design, conducted under the "Ukraine Licensing Gap Consultation" contract with NuScale, implemented with support from the USTDA and STCU;
- Implementation of the project "Support in the Technical Assessment of the US SMR Design (Pilot Phase)" under a contract with Argonne National Laboratory (USA).

Thus, the challenges and threats faced by SNRIU associated with pre-licensing assessment and potential licensing of new reactor designs, particularly SMRs, are being addressed through its own resources and with international assistance (see Section 10 of this Report for more details).

5.6 Spent Fuel Management

Currently, two facilities for interim storage of spent nuclear fuel are operational in Ukraine: a wet spent fuel storage facility at the ChNPP (ISF-1) and a dry spent fuel storage facility at the ZNPP (DSFSF), along with the ChNPP ISF-2. Additionally, a dry centralized storage facility for spent VVER NPP fuel (CSFSF) is in the commissioning stage.

The ChNPP ISF-1 was constructed between 1983 and 1986 and commissioned in 1986 as a temporary storage facility for fuel assemblies from ChNPP RVPK-1000 reactors. This facility is not designed for long-term storage of spent fuel (beyond 100 years), and its service life is limited to the period required to transfer all spent fuel to ISF-2. The ISF-2 facility is designed for the acceptance, pre-storage treatment,

and long-term storage (up to 100 years) of all ChNPP spent fuel, utilizing Holtec International (USA) technology for spent fuel management. On August 26, 2021, the SNRIU approved a decision to issue an operating license for ISF-2 to the SSE ChNPP.

The ZNPP DSFSF provides storage of ventilated storage casks containing spent nuclear fuel (VSC-VVER) during their operational period of 50 years. The design is based on dry ventilated storage cask technology developed by the American Duke Engineering & Services company (DE&S). The ZNPP DSFSF operates under a license issued by the SNRIU on August 10, 2004, for activities at the operational stage of the ZNPP, including the DSFSF. However, it should be noted that the ZNPP DSFSF, located on the ZNPP site, has been occupied by Russian troops since March 2022.

The CSFSF is designed for the long-term storage of spent fuel from RNPP, KhNPP, and PNPP. This facility also utilizes Holtec International (USA) technology for spent fuel management. Activities related to the completion of the CSFSF construction project are being carried out under a license for its construction and commissioning issued by the SNRIU on June 29, 2017. As part of this license, an individual permit for commissioning the nuclear facility was granted by the SNRIU on April 25, 2022.

The challenges faced by the SNRIU in regulating the safety of spent fuel storage facilities in Ukraine and commissioning new nuclear facilities are addressed through its own resources and international assistance (see Section 10 of this Report for details). In general, summarizing the information presented in the section *"Safety of Nuclear Facilities,"* it should be noted that the threats and challenges identified in Reports [2], [3], and [4] have been or are being eliminated through international assistance and/or bilateral projects between SNRIU and DSA, including:

- Development of Requirements for the Structure and Contents of Emergency Documents (*GUIDELINE Project*);
- Development of Guidelines for the Assessment of Safety Culture and Human and Organizational Factors in Operating Experience Analysis (*EXPERIENCE Project*);
- Development of Priority Regulatory Documents to Ensure Safety Regulation of Nuclear-Hazardous Facilities in the Chornobyl Exclusion Zone after Restoring Ukraine's Control over its Territory Following Its Temporary Seizure by Russian Troops (*ZONE Project*);
- Other completed or ongoing international cooperation projects (see Section 10 of this Report for details);
- Through the SNRIU's own resources.

At the same time, during the current analysis, new threats were identified that cannot be addressed by the SNRIU's own resources and are critical to resolve in the near future:

- Development of a Program for Restoring State Safety Regulation for the Operation of Nuclear Facilities at the Zaporizhzhia NPP Affected by Hostilities and Occupation by Russian Troops. This threat is being addressed within the recently launched *ZONE 2 Project* of DSA and SNRIU cooperation (see Section 10 of this Report for more details).
- Assessment of Time Available for Operator Response under Total SBO at ZNPP Considering Reduced Decay Power after a Long-Term Shutdown. This threat is being addressed within the recently launched *RECOVERY Project* of DSA and SNRIU cooperation (see Section 10 of this Report for more details).
- Development of an Action Plan to Renew and Complete Licensing of the Neutron Source at the Construction and Commissioning Stage, Taking into Account the Long-Term Shutdown and Damage Resulting from Shelling by Russian Troops. This threat is being addressed within the recently launched *ZONE 3 Project* of DSA and SNRIU cooperation (see Section 10 of this Report for more details).

6 RADIOACTIVE MATERIAL TRANSPORT

6.1 Overview of Ukrainian Legislation on Radioactive Material Transport

The process of transporting radioactive materials consists of preparation, loading, shipment, transit storage, unloading, and acceptance of consignments and packages at their destination point. During transport, when the material is outside facilities for the management of fresh and spent nuclear fuel, radioactive waste (radwaste), and radiation sources, including disused radiation sources, the radioactive materials remain under continuous regulatory control.

The regulatory and legal framework governing activities related to the transport of radioactive material in Ukraine has been established and includes various laws and NRS regulations for the safe transfer of hazardous cargoes [10], [27], [49]–[56], [17], [57]–[74]. These regulations define the functions and responsibilities of entities involved in radioactive material transport, as well as the roles and interactions of state regulatory bodies. The SNRIU is the competent regulatory body responsible for ensuring the safe transport of radioactive materials. Its main task is the state regulation and control of compliance with NRS regulations on the transfer of radioactive materials [10]. The SNRIU implements its responsibilities through the following activities [10]:

- **Licensing activities:** Issuing authorizing documents for activities involving nuclear energy use, including licenses for the right to perform specific activities related to the transport of radioactive materials (except in cases provided for in [10]), certificates of approval for the transport of radioactive materials, and permits for international shipments of radioactive materials.
- **Monitoring programs:** Developing and implementing programs to monitor the design, production, testing, inspection, and maintenance of packaging, special form radioactive materials, and low-dispersible radioactive materials; overseeing the preparation and storage of packages; and reviewing documents prepared by consignors and carriers [10].

In line with procedures provided in [17], the SNRIU conducts the following activities:

- Issuing authorizing documents, including licenses, certificates, and permits;
- Reviewing and assessing safety justifications;
- Conducting oversight inspections;
- Taking enforcement measures;
- Developing and implementing requirements, criteria, provisions, and guidelines to ensure the safe transport of radioactive materials.

Radioactive materials can only be transported in the presence of and in accordance with the conditions specified in a license issued by the SNRIU for activities related to radioactive material transport, as per the established procedures (except in cases described in [10]). The procedure for issuing authorizing documents (licenses for radioactive material transport, certificates of approval, and permits for international shipments) is outlined in [53], [57], [69], [10]. All entities involved in the transport of radioactive materials must implement a quality assurance system, including a program for systematic monitoring to ensure compliance with regulatory requirements, limits, and conditions of authorization, thereby ensuring safety during transport.

State oversight of compliance with NRS requirements is carried out by the SNRIU and its territorial bodies. When necessary, representatives of other state oversight (regulatory) bodies in respective safety areas, with their agreement, and technical support organizations may also be involved.

6.2 Analysis of Ukrainian Regulatory Framework on Radioactive Material Transport

Regarding the regulatory framework for radioactive material transport in Ukraine, a comprehensive assessment was conducted to identify gaps during the development of reports [2]–[4], [75], [76]. Based on the assessment results, the need to review the *"Rules for Nuclear and Radiation Safety in Transport of Radioactive Materials"* (PBPRM-2006) [65] was identified to align them with the requirements of the latest edition of the IAEA Rules *SSR-6 (Rev. 1), "Regulations for the Safe Transport of Radioactive Material"* [83]. PBPRM-2006 [65] was subsequently revised with the financial and expert support of the DSA (see para. 4.3 of this Report).

Reports [2] and [3] also justified the feasibility and necessity of developing a set of regulations at various levels to establish comprehensive requirements and standards for the safe transport of radioactive materials, incorporating provisions from IAEA standards and EU directives.

In 2019, as part of the COMPLIANCE Contract No. M21-18/12, the SNRIU, with the involvement of SSTC NRS and expert and financial support from the DSA, analyzed the Ukrainian regulatory framework for the safe transport of radioactive materials. This analysis aimed to identify gaps and implement further measures to harmonize the national regulatory framework with IAEA standards. The analysis results, presented in documents [75], [76], recommended the following actions:

- Revise the regulation *"Procedure for Issuing Certificates for the Safe Transport of Radioactive Materials"* (NP 306.6.135-2007) [69].
- Develop a regulation specifying requirements for the structure and content of the Safety Analysis Report (SAR) as part of the documentation required to obtain transport certificates for radioactive materials.
- Revise the regulation *"Safety Requirements and Conditions (License Terms) for Radioactive Material Transport"* (NP 306.6.095-2004) [58].
- Revise the regulation *"Requirements for Safety Analysis Reports for Radioactive Material Transport"* (NP 306.6.096-2004) [59].
- Revise the regulation *"Requirements for Quality Assurance Programs for the Transport of Radioactive Materials"* (NP 306.6.127-2006) [63], incorporating provisions from the IAEA document *"Management System for the Safe Transport of Radioactive Material,"* Safety Standards Series No. TS-G-1.4 [86]. This recommendation was also issued by the IAEA IRRS mission in 2008 [85].
- Develop a guideline or regulation for implementing a systematic compliance program and independent verification of compliance with regulatory standards by transport participants, incorporating provisions from the IAEA document *"Compliance Assurance for the Safe Transport of Radioactive Material,"* Safety Standards Series No. TS-G-1.5 [87]. This recommendation was also issued by the IAEA IRRS mission in 2008 [85].
- Revise the *Radiation Safety Standards of Ukraine* [67], which establish radiation safety standards for all activities involving radiation and nuclear technologies in Ukraine. Although no systematic analysis of inconsistencies in [67] was performed as part of this gap analysis, it was noted that the document contains provisions that do not align with the latest recommendations of the IAEA document *"Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards,"* General Safety Requirements Part 3, No. GSR Part 3 [84].
- Amend the regulatory document *"Provisions on Planning of Measures and Actions in Case of Accidents in Radioactive Material Transport"* (NP 306.6.108-2005) [61] to harmonize Ukraine's regulatory framework with IAEA provisions, particularly in terms of emergency preparedness requirements during radioactive material transport.

All the above threats, identified earlier in reports [2]–[4], [75], [76], [85], have been or are being addressed as part of several projects. For more details, see para. 4.3.

6.3 Development of Regulatory Framework on Radioactive Material Transport

6.3.1 Mitigation of Threats in Regulatory Activities on Radioactive Material Transport

The mitigation of threats identified in reports [2]–[4], [75], [76], [85] related to the regulatory activities on radioactive material transport is being carried out by the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) with the involvement of SSTC NRS under the following projects with DSA financial and expert support:

- **TRANSPORT**
- **COMPLIANCE**
- **RULES**

Under the TRANSPORT Project, the main regulatory document on the safe transport of radioactive materials, *"Rules for Nuclear and Radiation Safety in Transport of Radioactive Materials"* (PBPRM-2006) [65], was revised to align with the requirements of the latest edition of the IAEA Rules *SSR-6 (Rev. 1), "Regulations for the Safe Transport of Radioactive Material"* [83]. The revised document, *"Rules for the Safe Transport of Radioactive Materials"* (PBPRM-2020) [10], has been developed and enacted.

Under the COMPLIANCE Project:

- The regulatory document *"Procedure for Issuing Certificates for the Safe Transport of Radioactive Materials"* [69] was revised, and the draft regulation [77] is currently under public discussion.
- The regulatory document *"Requirements for the Structure and Content of Safety Analysis Reports of Packaging Design"* has been developed, and the draft regulation [78] is under official approval by central executive bodies.
- The regulation *"Safety Requirements and Conditions (License Terms) for Radioactive Material Transport"* [58] is under revision, and draft revision 1 [79] is under review by the SNRIU.
- The regulation *"Requirements for Safety Analysis Reports for Radioactive Material Transport"* [59] is also under revision, and draft revision 1 [80] is under review by the SNRIU.

Under the RULES Project:

- The regulation *"Requirements for Quality Assurance Programs for the Transport of Radioactive Materials"* [63] was revised, and the updated regulation [82] has passed state registration and will become valid upon official publication.
- The *Program of Compliance with the Rules for the Safe Transport of Radioactive Materials* [81] has been developed and implemented. This document is recommendatory and is applied within SNRIU activities to ensure compliance with nuclear and radiation safety requirements during the transport of radioactive materials.

The review and development of these regulatory legal acts have significantly reduced the number of gaps in Ukraine's regulatory framework for radioactive material transport identified in earlier reports [2]–[4], [75], [76]. The joint work of SNRIU and SSTC NRS in this area continues.

6.3.2 Methodological Document Development

As part of the Memorandum of Cooperation between the USNRC and SNRIU for 2021–2022, a methodological document, *"Safe Transport of Packages with Radioactive Waste and Materials"* [88], has been developed. This document establishes:

- A list of safety issues to be considered by experts during the review (technical assessment) of documents, and the sequence of their consideration.

- Assessment criteria to be followed by experts when addressing safety issues.

The document is used by SNRIU and SSTC NRS in state reviews (technical assessments) of nuclear and radiation safety documents and in the regulation of the safe transport of packages containing radioactive waste and materials.

The development of a systematic methodology for the safety assessment of packaging for the transport of radioactive materials is planned as part of the Memorandum of Cooperation between the USNRC and SNRIU for 2023–2024.

6.3.3 Addressing Additional Radiation Risks Due to Military Aggression

Russia's military aggression in Ukraine has created additional radiation risks, particularly concerning the impact of military operations on facilities housing large amounts of radioactive sources. For example, a facility at the National Scientific Center "Institute of Metrology" in the Kharkiv region was damaged during military operations. Before the Russian occupation, it contained 437 radioactive sources. Additionally, a significant number of disused radioactive sources are stored at the sites of the Radon Association's interregional branches (in Kyiv, Kharkiv, Dnipro, Odesa, and Lviv).

The evacuation of radioactive sources from such facilities is a pressing issue, particularly for sources at the NSC "Institute of Metrology." The SNRIU has been tasked with regulating the safety of radioactive material preparation, transport (evacuation), and transport under military risks—an area with no global precedent for regulation under such conditions.

In 2023, the SNRIU and SSTC NRS developed and submitted to the DSA a proposal for the **CONVEYANCE Project**, which aims to:

- Provide system support to SNRIU in regulating the safe recovery, conditioning, and transport of radioactive materials, including disused sealed radioactive sources, under conditions of military risks and facility damage caused by occupation, bombardment, shelling, or other military impacts.
- Develop two documents:

    1. *"Recommended Approach to the State Regulation of the Transport of Radioactive Materials Including Disused Sealed Radioactive Sources under Conditions of Military Risks"*.

    2. *"Recommended Procedure for the Transport of Radioactive Materials Including Disused Sealed Radioactive Sources under Conditions of Military Risks"*.

These documents will establish a framework for safety regulation during the preparation and transport of radioactive materials under military risks in Ukraine.

A significant portion of the threats and challenges identified in reports [2], [3], and [4] have been mitigated under bilateral cooperation projects between SNRIU and DSA. Other threats are still being addressed, while new risks have emerged due to military impacts. The regulatory activities of SNRIU in the safe transport of radioactive materials continue to be strengthened with support from the USNRC.

7 EMERGENCY PREPAREDNESS AND RESPONSE

7.1 USCPS Functional Subsystem for Nuclear and Radiation Safety

The tasks of the functional subsystem for nuclear and radiation safety, developed by the SNRIU within the Unified State Civil Protection System (USCPS), are detailed in the previous Threat Assessment Report [4] (see para. 5.2 of Report [4] for more details). The following activities were conducted under these tasks during 2021–2023:

1. **Performing functions as the single national point of contact** under the Convention on Early Notification of a Nuclear Accident, the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities, and related intergovernmental bilateral treaties with other countries:

    - Since February 24, 2022, the IAEA has been informed of the situation in Ukraine, following the Russian Federation's full-scale war against Ukraine. As of August 8, 2023, 73 notifications have been prepared and published on the secure website of the Unified System for Information Exchange in Incidents and Emergencies (USIE).
    - Operational information exchange was conducted between the IAEA expert group at the Zaporizhzhia NPP site and SNRIU state nuclear and radiation safety inspectors.
    - Proposals for assistance received through the USIE system were processed. Administrative and advisory activities were conducted with the IAEA coordinator and responsible specialists from the State Emergency Service of Ukraine (SESU), UkrHMC, the Ministry of Health, and other organizations to facilitate humanitarian aid to Ukraine.
    - SNRIU's authorized representative participated in the XI meeting of representatives of competent authorities under the Convention on Early Notification of Nuclear Accidents (June 13–17, 2022, IAEA).
    - Several communication tests were carried out with the United Special Operations Center of the US Department of Energy and the US National Nuclear Security Administration (June 17, September 2, October 7, November 30, and December 7, 2022).

2. **Round-the-clock collection, processing, analysis, and accounting of operational information** on the state of nuclear energy facilities in Ukraine.

3. **Operational data exchange with international information systems:**

    - In 2021, administrative agreements were signed between UkrHMC and the European Commission for submitting radiation monitoring data from Ukraine to the European Radiological Data Exchange Platform (EURDEP), and between UkrHMC and the IAEA for submitting radiation monitoring data to the International Radiation Monitoring Information System (IRMIS).

4. **SNRIU participation in emergency exercises:**

    - Emergency exercises were conducted with and without activation of the IEC. During these exercises and IAEA training sessions mentioned in para. 1, procedures for interaction with other central executive bodies and departments involved in emergency responses to nuclear and radiological accidents were tested. These included SESU, the Security Service of Ukraine, the Ukrainian Hydrometeorological Center, the Ministry of Health, the State Service of Ukraine on Food Safety and Consumer Protection, and others, at both national and regional levels.

5. **Special exercises for SNRIU emergency response personnel:**

    - SNRIU representatives participated in the IAEA technical meeting on emergency preparedness and response for new-generation reactors (October 18–22, 2021) and the IRMIS implementation workshop (November 29–December 1, 2021).

6. **Review of emergency plans** for nuclear energy facilities in Ukraine, safety analysis reports regarding the safety factor "Emergency Preparedness and Planning," and preparation of proposals for SNRIU approval.

7. **Implementation of the HERCA-WENRA approach in Ukraine:**

    - In April 2022, SNRIU and SSTC NRS representatives joined the WGE Task Force HERCA-Ukraine situational working group established by the Heads of European Radiological Protection Competent Authorities (HERCA), with support from the European Commission. The group included experts from regulatory bodies in neighboring and other European countries.
    - Ukrainian experts, along with the working group, analyzed the availability and sufficiency of regulatory documents, IEC activity coordination, communication, technical support for Ukraine and neighboring countries, and developed a draft document for presentation at the HERCA leaders' meeting in May 2022.
    - As part of the analysis of JRODOS calculations to support national decision-making in managing nuclear or radiological emergencies and implementing HERCA-WENRA principles [89], SNRIU and SSTC NRS cooperated with the Karlsruhe Institute of Technology (KIT) to analyze inconsistencies in three optional atmospheric dispersion models within the JRODOS system. The analysis determined the appropriate model based on the degree of uncertainty in the input information, defined behavior patterns, and evaluated levels of conservatism.

7.2 SNRIU Information and Emergency Center

The organizational structure of the IEC, its operational modes, staffing principles, technical equipment, and software were detailed in previous threat assessment reports [2]–[4]. Since then, no significant changes have occurred in these aspects.

By SNRIU Order dated March 4, 2022, the IEC was activated in response to the invasion of Russian troops into Ukraine and the resulting threat of emergency situations at nuclear installations and other nuclear energy facilities in Ukraine. This activation was also prompted by the military attack on the Zaporizhzhia NPP on March 4, 2022.

After two months of operation under martial law conditions, the IEC was transferred to standby mode until further orders from the SNRIU Chairman. By SNRIU Order No. 488, dated August 11, 2022, the IEC was reactivated due to the worsening situation at ZNPP caused by actions of Russian military formations, which led to a deterioration in nuclear and radiation safety.

On behalf of the SNRIU, SSTC NRS experts in the IEC Data Analysis Group assess the potential consequences of a possible accident at ZNPP using the HYSPLIT model and the JRODOS system, considering the actual meteorological conditions at the time of the calculations. In 2022 alone, more than 300 calculations were performed using HYSPLIT and over 100 using JRODOS.

7.2.1 Strengthening IEC Prediction Capabilities

Strengthening the Methodological Basis for Prediction

As part of Task H7 of the UK/TS/58 Project *"Support to the Activities of the Regulatory Body in Emergency Planning"* [90], the SSTC NRS, in cooperation with the Karlsruhe Institute of Technology (KIT), conducted a preliminary identification of potential events at six power units and the dry spent fuel storage facility at the Zaporizhzhia NPP. This work included statistical assessments to determine the configuration of potential zones for immediate and long-term countermeasures and the development of risk maps for Ukraine. The experience gained in selecting reference emergencies and the developed algorithm for analyzing statistical data will be utilized for further assessments under the RESTORATION Project (carried out with DSA expert and financial support) to determine the optimal locations and configuration of stationary radiation monitoring posts (see para. 5.4.2). This information will also contribute to the systematization of knowledge on responding to targeted attacks at operating nuclear facilities during wartime, which will be incorporated into future editions of internal guidelines for SNRIU IEC experts.

Software Update and Extension of Modeling Tools

The SNRIU Information and Emergency Center (IEC) currently employs several tools, including the InterRAS v.1.0 system (developed based on the RASCAL code), the JRODOS decision support system (EC, 2019), and the HotSpot 3.1 code (NARAC, USA, 2021), for real-time assessment and prediction of radiation accident consequences at nuclear facilities. However, significant errors in the InterRAS v.1.0 system, including a critical issue identified in 2021, rendered it unusable.

In 2023, the SNRIU IEC replaced the outdated InterRAS v.1.0 system with the RASCAL v.4.3.4 code, which has been successfully installed and is now the standard assessment tool. SSTC NRS experts gained access to the updated RASCAL code (v.4.3) through their membership in the Radiation Protection Computer Code Analysis and Maintenance Program (RAMP) implemented by the US NRC.

As of August 2023, the need for expanded emergency response tools, particularly for modeling radioactive substance dispersion in dense urban areas, is evident. Access to modern tools, such as the ARGOS code, will be provided under ongoing cooperation between SNRIU and DSA, enabling Ukrainian experts to enhance their modeling capabilities.

Combining Radiation Monitoring Capabilities with Mobile Devices and Decision Support Systems

Experience from responding to forest fires in the exclusion zone and zone of unconditional (mandatory) resettlement (ChEZ) highlighted the need for improved management principles for joint radiation monitoring and prediction of radiation consequences. Corresponding research was conducted under the IAEA Coordinated Research Project CRP J15002 (2019–2022), revealing several issues, particularly gaps in decision support systems (DSS) for optimizing movement routes for RanidSONNI reconnaissance vehicles and integrating monitoring data to refine radioactive substance dispersion models.

Under the CRP J15002 Project, universal recommendations (including timelines and action algorithms) were proposed as a foundation for planning in the "mobile monitoring-prediction" system. This approach represents a new concept for enhancing the emergency preparedness of SNRIU IEC, reflecting advancements in monitoring resources and DSS software. It may be incorporated into the next edition of IAEA document TECDOC-1092 and future internal guidelines of SSTC NRS and SNRIU IEC.

Comparative Analysis of Computer Tools

Emergency exercise results from the EXERCISE Project (see para. 5.3) demonstrated that differences

in atmospheric dispersion modeling and dose prediction tools can significantly affect decisions regarding emergency countermeasure zones for public protection.

The *Benchmarking on Assessment of Radiological Consequences* (BARCO) Project [91], implemented on SSTC NRS's initiative with ETSON support in 2020–2021, identified inconsistencies in modeling results across technical support organizations from five countries. Participants conducted calculations using their atmospheric dispersion and dose prediction tools, databases, and methods under a common scenario, release source, location, and time.

SSTC NRS provided initial data (scenario, release source, date, time, location), benchmarking parameters, and a full analysis of radiological assessment results. This benchmarking exercise ranked existing assessment tools by their degree of conservatism, providing valuable insights for emergency preparedness and response efforts.

7.2.2 Systematization and Use of Accumulated Experience in Emergency Preparedness and Response

The SNRIU and SSTC NRS have accumulated extensive experience over many years in assessing the radiation consequences of possible accidents at radiation and nuclear facilities through the activities of the SNRIU IEC and international cooperation. Experts who are part of the mobile radiological laboratory crew possess significant specialized knowledge, skills, and experience in radiation surveys, environmental sampling, and the handling of samples. However, due to the large scope of scientific and technical research and the knowledge gained, this experience and information are often not systematized beyond specific projects, making them susceptible to being lost as generations of experts change.

With the onset of the full-scale invasion of Ukraine, a need emerged for training exercises focused on preparing new experts to respond to emergencies involving complex or hazardous radiological conditions. At the same time, due to the increased risks related to the potential use of nuclear or radiological weapons, the Armed Forces of Ukraine have been developing and training specialized units responsible for planning military operations in areas with radiological contamination and for collecting evidence related to the possible use of weapons of mass destruction.

It is therefore crucial, under martial law, to retain and transfer the relevant experience of the SNRIU/SSTC NRS to the specialized military units of the Armed Forces of Ukraine. The issue of personnel training and knowledge systematization within the SNRIU/SSTC NRS will also be addressed through the implementation of the **KNOWLEDGE Project**, supported by the DSA. This project aims to facilitate the exchange of SNRIU/SSTC NRS expertise by:

- Structuring the experience and knowledge of SNRIU/SSTC NRS experts in assessing radiation consequences, analyzing radiation situations, and taking environmental samples.
- Making the SNRIU/SSTC NRS expertise accessible to new experts.
- Providing necessary methodological and educational support to specialized units of the Armed Forces of Ukraine to enable them to perform their functions effectively.

During the project, exercise modules will be developed for:

- Assessing radiation consequences.
- Modeling atmospheric dispersion.
- Ensuring radiation safety during operations in territories with unfavorable radiation conditions during combat.
- Decontamination.
- Conducting radiation surveys, measurements, and data processing.

Additionally, a special resource will be created, featuring training aids such as manuals, reference books, presentation materials, useful links, self-assessment tests, and more. These aids will consolidate the experience of SNRIU/SSTC NRS experts in assessing radiation consequences, analyzing radiation situations, and taking environmental samples.

In the future, these exercise modules can be utilized by new SNRIU/SSTC NRS experts or other specialists, including members of the Armed Forces of Ukraine, to enhance their skills in radiation safety and related fields.

7.2.3 Development of Approaches to Assess and Optimize Radiation Exposure of Military Personnel in Wartime

Given the ongoing risk of radiation accidents of varying scale and the potential consequences associated with the use of nuclear or radiological weapons, as well as deliberate attacks on nuclear facilities, it is essential to ensure advance preparedness for possible radiation hazards in Ukraine. This preparedness should include the development of individual exposure monitoring procedures, dose limits, emergency response protocols, and clearly defined chains of command and responsibilities. Currently, there is no structured or mandatory system in place for monitoring individual radiation exposure doses among military personnel in the Armed Forces of Ukraine.

Roger Hugron, Nuclear Safety Director in the Canadian Department of National Defense, stated in his presentation, “Dose Monitoring Levels and Other Radiation Protection Strategies for Members of the Canadian Armed Forces During Emergencies and Military Operations” at the conference co-sponsored by the DSA and OECD NEA, “Radiological Protection During Armed Conflict: Improving Regulatory Resilience and Operational Applications” (Oslo, November 2023; https://www.oecd-nea.org/jcms/pl_82793), that the Canadian Armed Forces employ a combination of electronic and passive dosimeters for monitoring and control, depending on the threat level.

He emphasized that the question of whether radiation safety can be neglected during combat operations should not arise at all. The principles of radiation protection—justification, optimization, and dose monitoring—must be applied in all situations, regardless of the level and scale of threats. Appropriate dose limits should be clearly defined, and military commanders at various ranks should make decisions to increase dose limits to the highest justified level only when absolutely necessary. These decisions should align with safety requirements to prevent deterministic effects on personnel involved in emergency exposure situations.

The SNRIU has decided to analyze the existing practices of radiation hygienic regulation of exposure for military personnel during combat operations and wartime. This analysis aims to ensure the application of radiation protection principles for the Armed Forces of Ukraine during martial law, considering relevant experiences from NATO, the US, Canadian Armed Forces, and others, as outlined in the recommendations of the International Commission on Radiological Protection (ICRP) [93].

The outcome of this effort will be a report containing recommendations to guide specialized institutions in establishing radiation health and safety standards for the Armed Forces of Ukraine during martial law. This analysis and the development of appropriate recommendations, in collaboration with relevant institutions within the Ministry of Health, are among the SNRIU's priority tasks.

7.2.4 Improvement of the Regulatory Framework Governing the Activities of the IEC and Establishment of Backup IEC based on a Virtual Platform

Based on the assessment results of emergency preparedness and response, there is a need to continue measures aimed at strengthening the SNRIU emergency preparedness system. This includes improving the regulatory framework governing IEC activities and creating a backup IEC based on a virtual platform.

This threat is being mitigated through ongoing cooperation between the SNRIU and USNRC (see Section 10 of this Report for more details). In accordance with the Terms of Reference, the development of the document "Provisions on the SNRIU Information and Emergency Center" was completed in September 2023. Based on this document, a revision of job descriptions for IEC personnel is planned.

7.3 Measurement of Environmental Radiation Parameters

7.3.1 Assessment of the Radiation Situation using the RanidSONNI Radiation Reconnaissance Vehicle (Mobile Radiological Laboratory)

The SNRIU uses official information received through established procedures from licensees, central executive bodies, and international organizations, as well as predictive calculations and radiation monitoring results conducted by SSTC NRS experts. The latter includes the use of the RanidSONNI radiation reconnaissance vehicle (mobile radiological laboratory, or RanidSONNI MRL) to develop reports on radiation accidents and other events that pose a threat of radiation exposure to the public or cause public concern.

Monitoring of Radiation Situation Related to Fires in ChEZ Ecosystems

- **Summer 2021:**
  No large-scale fires were recorded in the ChEZ ecosystems with high contamination density, thanks to preemptive fire-fighting measures and moderately hot weather.
- **March 2022:**
  During the occupation of the Kyiv region, notifications were received regarding several localized fires in ChEZ from March 11 to 31, 2022. Due to the inability to obtain reliable information on the scale and localization of these fires, especially in areas with low radionuclide contamination, satellite data were used, including the NASA FIRMS service (source).
  Predictive calculations of radionuclide volumetric activity in the near-surface atmospheric layer indicated low activity levels, eliminating the need for aerosol sampling in Kyiv.
- **May and August-September 2022:**
  Large-scale fires were recorded in ChEZ territories characterized by low radionuclide contamination, caused by full-scale invasion-related military operations, violations of fire safety protocols, and ineffective fire prevention measures due to mined areas.
  Predictive calculations again indicated low radionuclide volumetric activity levels in the near-surface atmosphere, confirming no need for aerosol sampling in Kyiv.

Assessment of the Radiation Situation at a Radiation Accident Site

On November 14 and 15, 2021, SSTC NRS experts conducted a radiation survey near the main building of the Institute of Chemical Technologies of the Volodymyr Dahl East Ukrainian National University in Rubizhne, Luhansk region.

This survey was requested by the Mayor of Rubizhne to provide an expert conclusion on intervention measures and countermeasure optimization, specifically the removal of contaminated soil as radioactive waste.

- **Background:**
  In 1992, the theft of five cesium-137 ampoules from the former Rubezhansky Krasitel LLC led to the breach of two ampoules, resulting in soil contamination near the university.
  A radiation survey in September 2021 confirmed the presence of contamination.
- **Findings:**
  SSTC NRS experts used the RanidSONNI MRL to identify multiple cesium-137 contamination points. Based on these findings, the Rubizhne City Council received recommendations to prevent the spread of radioactive contamination.

Participation in International Exercises

The RanidSONNI MRL has been repeatedly utilized in various activities, including participation in international exercises in ChEZ.

- **September 2021:**
  The RanidSONNI MRL crew took part in international emergency protection exercises in ChEZ, organized by the German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz). Other participants included the SSE Ecocentre, Emergency Technical Center, and Rivne Nuclear Power Plant.
- **Exercise Plan:**
  Four radiation monitoring groups were formed, each assigned specific travel routes and sampling points. Tasks included soil sampling, walking gamma surveys, and in-situ spectrometry.
  SSTC NRS experts surveyed nine routes and conducted additional measurements at 49 identified points.

7.3.2 Updating the Measurement Equipment Fleet to Solve Specific Tasks

The radiation monitoring equipment integrated into the RanidSONNI MRL [94] has nearly exhausted its service life. Its efficient use in non-standard situations related to combat operations—such as the loss or damage of radiation sources at medical institutions and industrial enterprises frequently subjected to missile attacks from Russia—could become a significant challenge, impacting the effectiveness of emergency response.

An upgrade to the measurement capacity of the RanidSONNI MRL was planned for 2022, even before the full-scale invasion, with assistance from the Finnish Radiation and Nuclear Safety Authority (STUK). With the onset of the war and considering the increased risks and Ukraine's urgent need for effective tools to respond promptly to emergencies involving potential radioactive contamination or loss of regulatory control over radiation sources, STUK decided to supply a new MRL to the SSTC NRS, the SNRIU's Technical Support Organization.

On September 27, 2022, STUK and SNRIU signed a *Memorandum of Cooperation and Information Exchange in the Field of Nuclear and Radiation Safety.* This memorandum includes provisions for strengthening the instrumental support available to SNRIU and SSTC NRS. These provisions have been incorporated into the upcoming **FURN Project**, which both regulators plan to launch shortly.

The delivery of a new MRL as part of the FURN Project is expected to significantly enhance the SNRIU's capabilities in:

- Identifying the locations and potential sources of radioactive contamination.
- Mapping contaminated territories.
- Measuring environmental samples.

Strengthening the measurement capabilities of the SNRIU and SSTC NRS has also been supported by the rapid transfer of various measurement tools from international partners to aid in sampling, field measurement, and bulk sample analysis. In May 2022, the SNRIU and SSTC NRS received 12 *FLIR identiFINDER R425* gamma-ray spectrometers (FLIR Systems, USA) from the U.S. Department of State. These spectrometers are currently being used by SSTC NRS experts to test their effectiveness in radiation surveys of territories and facilities.

Figure 5.1 FLIR identiFINDER R425 gamma ray spectrometer

In August 2022, measurement tools were received from STUK, including four *Vaisala WXT536* meteorological stations (Vaisala Oy, Finland), which will enhance the quality of predictive estimates made using the JRODOS DSS. One of the weather stations has been installed and is operational on the roof of the Slavutych Branch of the SSTC NRS, while the others will be deployed to gather meteorological data at their respective locations.

An updated model of the *RanidPro 200* neutron and gamma radiation dosimeter (Environics Oy, Finland) was also received. Once certified in Ukraine, it will replace the previous model, which has nearly exhausted its service life.

Additionally, the *Goblin 200* air aerosol sampler (Senya LTD, Finland) was provided by STUK. This device functions as a stationary monitoring post for detecting radionuclides in air aerosols at its installation site, thanks to its built-in gamma spectrometer. Since April 2023, the post has been installed on the roof of the SSTC NRS Slavutych Branch building and placed into trial operation.

Figure 5.2 Radiation monitoring post based on the Goblin 200 air aerosol sampler located on the roof of the building of INTENSA Branch in Slavutych

As part of the EQUIPMENT Project, SSTC NRS received radiation reconnaissance equipment for the de-occupied territories from the DSA. This included a gamma radiation spectrometer with Kromek QUANT GR-1 (Kromek, Great Britain) lead protection, designed to detect radionuclides and measure their activity in samples of soil, water, and food.

Additionally, as part of the Project, a portable gamma radiation spectrometer with a highly pure germanium detector, AEGIS-GC40-RDC (Mirion Technologies (Canberra), USA), was provided. This device is intended for in-situ gamma spectrometry and for determining the presence of radionuclides and their activity in collected samples of soil, water, food, and other materials.

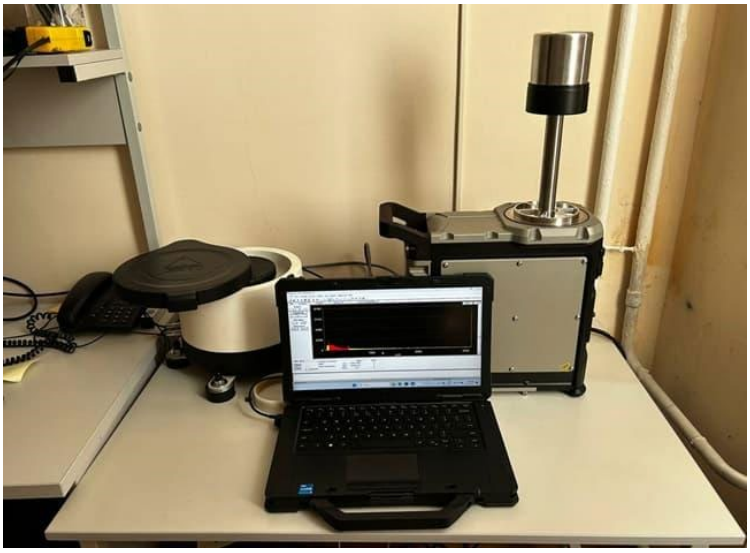


Figure 5.3 Radiation survey equipment obtained from the DSA: Kromek QUANT GR-1, AEGIS-GC40-RDC and additional software

7.4 Harmonization of the Ukrainian Regulatory and Legal Framework on Emergency Preparedness and Response with EU Directives and IAEA Standards

Ukraine continues the process of harmonizing its regulatory and legal framework for emergency preparedness with international requirements. One example of such harmonization is the development of a new draft regulation, the *"National Response Plan for Nuclear and Radiological Emergencies"* (Plan), aimed at addressing the threats identified in the Reports [2], [3]. The Plan incorporates the requirements recently introduced by IAEA Safety Standards, EU legislation, and WENRA recommendations, specifically [15], [47].

The development of the Plan was completed in February 2020 with support from the DSA under the PREPAREDNESS Project. Currently, the SNRIU is managing the legal procedures for its implementation. Throughout 2023, the Plan underwent a process of coordination and refinement based on feedback from relevant central executive authorities, other agencies, and amendments to the Ukrainian Law *"On Protection of the Population against Ionizing Radiation."* As per the Ordinance of the Cabinet of Ministers of Ukraine dated June 24, 2023, the Plan was submitted for consideration and approval to the appropriate ministries and other central executive bodies.

In summary, the threats and challenges identified in the Reports [2]–[4], as well as those identified during ongoing assessments, have been or are being mitigated through cooperation projects between the DSA and SNRIU, including:

- **Development of the Radiation Emergencies Response Plan** (PREPAREDNESS Project);
- **Strengthening SNRIU and DSA Capacities in Emergency Preparedness and Response** through a series of emergency exercises (EXERCISE Project);
- **Radiation Survey of Territories Affected by Hostile Military Occupation** (SURVEY Project, Phases 1 and 2);
- **Provision of Equipment for Radiation Survey of De-occupied Territories** (EQUIPMENT Project);
- **Management of Knowledge Vital for Protecting Personnel, the Public, and the Environment** during nuclear or radiation accidents caused by hostilities (KNOWLEDGE Project);
- **Restoration of Radiation Well-being** in liberated territories and across Ukraine in the long term (RESTORATION Project).

These efforts are supplemented by other international assistance projects supporting the SNRIU (see Section 10 of this Report for more details).

The current analysis revealed a critical threat requiring immediate mitigation: the need to analyze and provide recommendations for assessing and optimizing radiation exposure for the Armed Forces of Ukraine during wartime. Further details on this issue are presented in Section 9 of this Report.

8 RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING

8.1 Radioactive Waste Management and Decommissioning Practices in Ukraine

The main radwaste streams in Ukraine include:

- Waste from operating NPPs;
- Chornobyl accident-origin waste;
- ChNPP radwaste;
- Non-nuclear radwaste, including disused sealed radioactive sources;
- Radwaste from former military sites.

8.1.1 Radioactive Waste Management at Operating NPPs

The construction of solid radwaste treatment plants (SRTP) has been completed, and these facilities are currently in operation at RNPP and ZNPP. **Figure 6.1** provides examples of radwaste processing plants that are part of these systems.

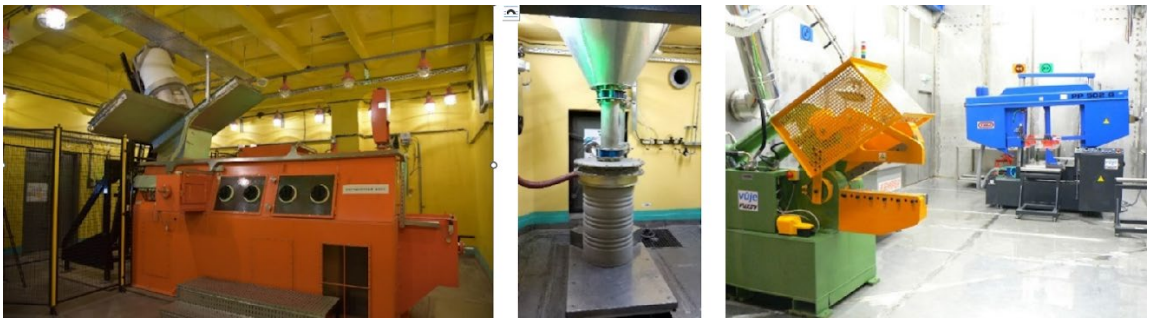


Fig. 6.1 Incineration and fragmentation facilities at ZNPP SRTP

In addition, the construction of SRTPs has commenced at KhNPP and is planned for PNPP.

There are also problematic radwaste streams at Ukrainian NPPs, specifically:

- **Ion exchange resins** stored in tanks at NPPs.
- **Salt melt and dry salt** stored in containers.

An analysis of treatment technologies for these problematic radwaste streams, aimed at ensuring end products suitable for further safe storage and disposal, was conducted under the European Commission Cooperation Project INSC U4.01/14A [95].

The treatment of radwaste in the form of a bitumen/salt compound is also ongoing. Radiation characterization of the bitumen/salt compound has been completed, including determination of the nuclide vector as well as its physical and chemical properties. A technological process for immobilizing an experimental batch of bitumen/salt compound at the ChNPP SRTP has been identified, with subsequent disposal planned at the near-surface disposal facility at the Vektor site in the Chornobyl exclusion zone.

8.1.2 Chornobyl Accident-Origin Radioactive Waste Management

There are approximately 2,000,000 m³ of accident-origin radwaste in Ukraine, primarily generated as a result of the ChNPP accident. During the acute phase of the accident, ChNPP Unit No. 4 was used to collect and confine accident-origin radwaste at the ChNPP industrial site and the surrounding area.

There are three radioactive waste disposal sites (RWDSs) in the Exclusion Zone near ChNPP: **Pidlisny**, **ChNPP Stage III**, and **Buriakivka**. The total volume of radwaste in these RWDSs is estimated at 170,000 m³. The layout of the RWDSs is shown in **Figure 6.2**.

Fig. 6.2 RWDS in the Chornobyl Exclusion Zone

The RWDS Buriakivka is a radwaste disposal facility. The Pidlisny RWDS and ChNPP Stage III RWDS are used for long-term interim storage of intermediate-level and high-level radwaste. These facilities are regarded as sites where radwaste will be stored and maintained at an adequate safety level (considering the Exclusion Zone) for an extended period of time. Eventually, the radwaste will be retrieved, treated, and disposed of.

Radioactive waste interim confinement sites (RICS) are located in the territory adjacent to ChNPP, covering an area of up to 10 km². Low-level radwaste is confined in trenches and pits, with an estimated 800 to 1,000 such sites. Typically, these trenches and pits lack engineered barriers for radioactive waste isolation, except for a soil layer, and many have been re-vegetated on the surface. Safety assessments of the RICS [96] were conducted within the framework of the U4.01/10 C+D+F Project. According to these assessments, most RICS do not require the retrieval of radioactive waste, provided the top cover of trenches and pits is maintained in good condition and a defined exclusion area (approximately 10 kilometers) is observed.

Decontamination waste disposal sites (DWDS) and vehicle sanitary treatment sites (VDTS) were constructed in areas adjacent to the Exclusion Zone during the mitigation of the ChNPP accident. These sites contain decontamination waste from settlements (e.g., topsoil, roofing materials, construction debris) and waste from decontamination equipment (e.g., trucks, buses). In total, 53 DWDS/VDTS were constructed, consisting primarily of trenches or abandoned quarries filled with decontamination waste and covered with a protective soil layer.

As part of Project INSC U4.01/12D, *"Remediation of Radioactive Waste Storage Sites Resulting from the Chornobyl NPP Accident and Situated Beyond the Exclusion Zone,"* DWDS/VDTS were ranked based on their potential hazard [97]. A screening safety assessment and hazard ranking were conducted for 17 RICS located in the Kyiv region.

- **Four DWDS/VDTS** were identified as priority sites for remediation.
- **Eight DWDS/VDTS** were identified as candidates for release from control due to low activity (compared to background contamination) and estimated low exposure to humans (doses << 1 mSv/year).
- **Other DWDS/VDTS** require more detailed assessments to support decision-making on radwaste retrieval or non-retrieval.

Radwaste has already been retrieved from the Pisky-1 pilot site, and the territory has been remediated [98], [99]. Arrangement of activities at the Pisky-1 site is shown in Fig. 6.3.

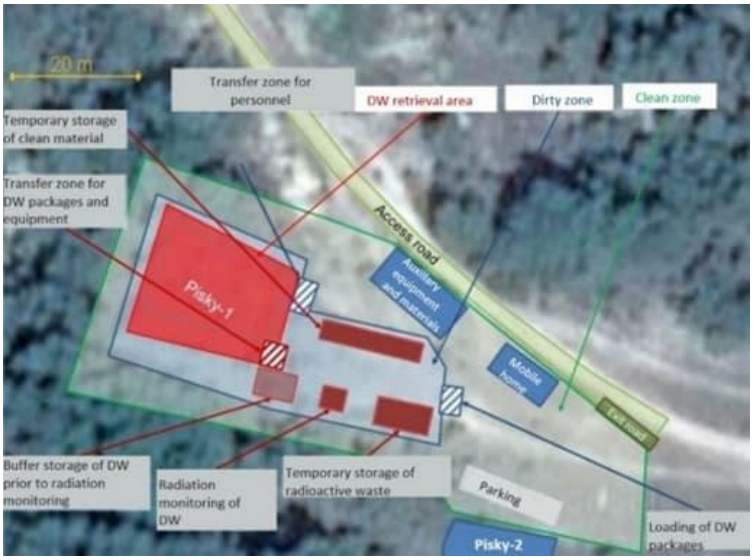


Fig. 6.3 Arrangement of activities at Pisky-1 site

8.1.3 Management of Radwaste of Military Facilities

Several former Soviet Union military facilities in Ukraine are associated with legacy radwaste and require liquidation, along with the remediation of their territories.

A pilot remediation project was implemented at the Vakulenchuk site with NATO support. Another remediation project was carried out at the Tsybuleve site, where three concrete cylindrical tanks (wells) were constructed. These wells contained disused radioactive sources (DRS). The placement of DRS in the wells began in 1966-1967, but systematic accounting (with very limited data) was conducted only from 1976 to 1987.

At the Vakulenchuk site, dismantling of the burial well was performed incrementally, with radwaste retrieved layer by layer. In contrast, the Tsybuleve wells were dismantled intact, without fragmenting the wells or retrieving radwaste from them.

8.1.4 Management of Non-Nuclear Radwaste Including Radwaste in Form of Disused Sealed Radiaoactive Sources

Non-nuclear radwaste is supplied by various producers, including medical, scientific, and industrial organizations, to the State Specialized Enterprise “Radon Association.” This enterprise operates five industrial sites located in Kyiv, Lviv, Odesa, Kharkiv, and Dnipro. Non-nuclear radwaste is temporarily stored in storage facilities at these industrial sites.

Most of these storage facilities have been in operation for more than 50 years, and some are closed storage facilities. The radwaste stored in these facilities generally consists of a mixture of solid waste and disused sealed radioactive sources, varying in origin, composition, properties, types of radioactive contamination, and activity levels. The storage facilities contain both packaged and unpackaged waste. This radwaste can be conventionally categorized into the following groups:

- **Disused sealed radioactive sources** with α-, β-, γ-emitting radionuclides, as well as neutron emitters;
- **Waste from radiation departments** of medical institutions and research laboratories;
- **Waste containing tritium** (primarily cemented);
- **Waste from production and research organizations**;
- **Decontamination waste**, such as contaminated soil, equipment, construction waste, wood waste, and individual protective equipment;
- **Waste with surface contamination**, including equipment, accessories, and tools;
- **Waste from locations of radiation accident mitigation**;
- **"Legacy" waste**, such as bulk radwaste, cemented radwaste, disused sealed radioactive sources encapsulated in cement, damaged disused sealed radioactive sources, disused sealed radioactive sources without biological protection, rags, static electricity neutralizers, and neutron sources;
- **Waste from the oil and gas industry**, including dry sludge, consolidated sludge, and tubing pipes;
- **Radioactive materials seized from illegal trafficking**.

Examples of solid radwaste storage facilities are shown in **Figure 6.4**.

Fig. 6.4 Examples of radwaste storage facilities at the State Specialized Enterprise "Radon Association"

Liquid radwaste is also stored at the sites of the State Specialized Enterprise "Radon Association."

The current state of underground engineering structures is unknown; however, available data on tritium migration from certain radioactive waste storage facilities indicate failures in engineering barriers and compromises to their stability. Key issues preventing the assurance of an appropriate safety level when handling radioactive waste at these sites include:

- Uncertainty regarding the physical condition of engineering components in radioactive waste treatment plants.
- Limited data on the current state of radioactive waste.
- Risks associated with the potential consequences of waste package and storage facility degradation.

As part of the INSC U4.01/14C Project, comprehensive safety assessments were conducted for the sites operated by the State Specialized Enterprise "Radon Association." These assessments evaluated the radiation impact on personnel, the public, and the environment during ongoing operations and in potential emergency or accident scenarios. The radioactive waste storage facilities were ranked based on their

hazard level and the feasibility of waste retrieval. There is an urgent need to establish infrastructure for the retrieval and further management of radioactive waste, particularly “legacy” waste, stored at these sites.

After the operational period of sealed radioactive sources (DRS) expires, Ukraine provides the following management options:

- **Reuse** after extending the DRS life span according to established procedures.
- **Return** to the supplier in accordance with contractual agreements.
- **Declare as radwaste** and transfer to a specialized radwaste management company for storage, decay, and/or disposal.

Ukraine has accumulated more than **660,000 DRS** declared as radwaste, with a total activity of **2.23×10^{16} Bq**.

Most of these DRS have been transferred to the Radon Association and placed in storage facilities at its sites. These DRS can be categorized as follows:

- **DRS with well-known characteristics**, stored separately from other radwaste.
- **“Legacy” DRS with unknown characteristics**, stored separately from other radwaste.
- **“Legacy” DRS mixed with other radwaste**, with some facilities containing cemented waste.
- **“Legacy” DRS stored in well-type storage facilities**, with some facilities containing cemented waste.

The Centralized Long-Term Storage Facility for DRS (CSDRS) is a key component of Ukraine’s DRS management system. The CSDRS is designed to ensure the centralized storage of most radwaste in the form of DRS of various types and designs. The facility’s technological process for managing DRS includes acceptance, identification, sorting, conditioning, and long-term storage (50 years).

In recent years, the State Specialized Enterprise “Central Radioactive Waste Management Enterprise” has been conducting comprehensive “hot” tests of the CSDRS and addressing identified deficiencies.

8.1.5 ChNPP Decommissioning and Radioactive Waste Management

ChNPP is conducting activities related to its decommissioning through the successive implementation of the following stages: termination of operation, final closure and shutdown, safe storage, and dismantling.

In 2015, ChNPP completed the operation termination stage, during which nuclear fuel was removed from the units, and obtained an SNRIU permit to proceed with the next decommissioning stage: final closure and shutdown.

ChNPP operates a liquid radwaste treatment plant and processes evaporation bottoms. Hot tests have been completed at the solid radwaste treatment plant. The intermediate storage facility for long-lived and high-level radioactive waste packages is authorized and operational. Additionally, the NSC-Shelter has been put into operation.

8.1.6 Radioactive Waste Disposal

The engineered near-surface disposal facility for solid radwaste (ENSDF) was authorized, constructed, and is now operational at the Vektor site in the Exclusion Zone. The facility has a design capacity of **50,210 m^3** for radwaste packages. The ENSDF consists of two parallel sections, each with 11 reinforced concrete

compartments (modules). The SNRIU license permits the filling of two symmetric ENSDF modules, **A1** and **D1**.

Two additional near-surface disposal facilities, **SRW-1** and **SRW-2**, for solid radwaste with a combined total capacity of **19,200 m³**, are in the final stage of commissioning at the Vektor site complex.

The construction of a geological disposal facility and a medium-depth disposal facility is at an initial stage in Ukraine. The first steps in developing conceptual disposal options, preliminary radwaste acceptability criteria for the proposed disposal concepts, and plans for a geological disposal facility for radioactive waste were taken as part of industrial projects of the European Commission:

- **INSC U4.01/09B**: *"Concept of Radioactive Waste Disposal in Ukraine"* [100].
- **U4.01/14B**: *"Development of a National Plan for Geological Disposal of Radioactive Waste in Ukraine and Its Implementation Schedule"* [101].

8.2 Development of Regulatory Framework on Radioactive Waste Management and Decommissioning

8.2.1 Ukrainian Laws and High-Level Regulations on Radioactive Waste Management

The Law of Ukraine *"On Amending Some Laws of Ukraine on Improving Legislation on Radioactive Waste Management"* [102] introduced amendments to the Law of Ukraine *"On Radioactive Waste Management"* concerning the disposal of radwaste in one of four types of disposal facilities (surface, near-surface, at medium depths, or geological repository) depending on the potential hazard level of the radwaste.

The law also established the classification of radwaste into the following categories based on the type of disposal facilities:

- **Very low-level waste (VLLW)**
- **Low-level waste (LLW)**
- **Intermediate-level waste (ILW)**
- **High-level waste (HLW)**

The Law of Ukraine [102] states that the assignment of radwaste to the appropriate type shall be carried out in accordance with nuclear and radiation safety (NRS) rules and standards. However, criteria for assigning radwaste to each class have not yet been established.

With DSA expert and financial support, the following was achieved under the **WASTE Project**:

- The **Regulation "General Safety Provisions for Predisposal Management of Radioactive Waste"** (NP 306.4.213-2017) [7] was developed and put into force. This regulation establishes the objectives, criteria, principles, and general requirements for nuclear and radiation safety at all stages of radwaste management prior to disposal.
- The **Regulation "General Safety Provisions for Disposal of Radioactive Waste"** (NP 306.4.219-2018) [9] was developed and put into force. This regulation defines the purpose, criteria, principles, and general requirements for nuclear and radiation safety during radwaste disposal.

Together, these two regulations form the top-level regulatory framework for radwaste management in Ukraine.

The compliance of Ukraine's regulatory framework for radwaste disposal with the WENRA reference safety levels has been confirmed by the results of a self-assessment conducted by the SNRIU and ratified by the WENRA Working Group on Radioactive Waste Management and Decommissioning.

8.2.2 Requirements for Radwaste Disposal Safety

The development of two guidelines to elaborate on the general provisions of **NP 306.4.213-2017** [7] and **NP 306.4.219-2018** [9] concerning the application of an integrated approach to radwaste management and classification for different purposes has been completed with support from the European Commission under the **INSC Project U3.01/14 & U3.01/15 (UK/TS/56)** [103]. These guidelines are:

- **"Guideline for Integrated Radwaste Management Prior to Disposal and Classification of Radwaste."**
- **"Guideline for Applying an Integrated Approach to the Disposal of Radwaste and Classification for the Purposes of Disposal."**

The Law of Ukraine [102] requires specific criteria to be established in NRS standards and rules for dividing radwaste into types for disposal in the four types of storage facilities. However, the current rules and standards do not yet specify criteria for classifying radwaste as **VLLW**, **LLW**, **ILW**, or **HLW** for disposal in the respective facility types.

The aforementioned guidelines provide general recommendations for establishing these criteria, including simplified criteria to serve as initial recommendations for the approximate division of radwaste into streams at the early stages of radwaste management, considering the final stage of disposal.

Regulatory requirements for waste classification and associated criteria will be detailed in a specific regulation, **"General Criteria for Radwaste Classification for Disposal in Different Types of Disposal Facilities,"** which is currently under development with expert and financial support from the DSA under the **CLASSIFICATION Project**.

As noted above, Ukrainian legislation now defines four types of radioactive waste disposal facilities, including those at medium depths and geological disposal facilities (previously, only geological disposal facilities were considered). Currently, general safety requirements for designing disposal facilities at medium depths and geological facilities have not been determined. Specific gaps include:

- Applicability of the defense-in-depth principle.
- Safety requirements for the overall efficiency of the disposal system, depending on the physical and chemical properties of radwaste, including heat output of radwaste packages.
- Consideration of geological, hydrogeological, and other site-specific conditions.

These general requirements are critical at the stages of selecting the disposal facility type, determining the concept for safe radwaste disposal, and siting the facility. Public acceptance must also be considered. If a local community does not accept the siting of a disposal facility in their area, the facility may need to be located on "the best available site," rather than "the best site," as determined by general safety requirements.

In such cases, safety requirements might need to be complemented by additional requirements for engineered barriers to achieve the overall efficiency of the disposal system. These additional requirements would significantly influence the waste acceptance criteria for a given facility, which are defined in the safety assessment and safety case.

Addressing these issues will require regulatory requirements. A viable solution to mitigate this threat is the development of a dedicated regulation.

8.2.3 Requirements for the Structure and Contents of Safety Analysis Reports on Radioactive Waste Management Facilities

The following regulations were developed and put into force with the support of the European Commission under the **INSC U3.01/12 (UK/TS/48)** Project [104]:

- **"Requirements for the Structure and Content of the Safety Analysis Report for Shallow and Near-Surface Radwaste Disposal Facilities"** (NP 306.4.223-2020) [105];
- **"Requirements for the Structure and Content of the Safety Analysis Report for Radwaste Treatment Facilities"** (NP 306.4.225-2020) [106].

The development of the regulation **"Requirements for the Structure and Content of the Safety Analysis Report for Long-Term Radioactive Waste Storage Facilities"** was started under the **INSC U3.01/14 & U3.01/15 (UK/TS/58)** Project [40], but due to the military aggression by the Russian Federation, **UK/TS/58** resources were redistributed to other urgent tasks to support the SNRIU, and the development of this regulatory document was halted.

In accordance with current regulatory requirements [9], safety assessments and justifications will be required at each stage of the life cycle for designing medium-depth disposal facilities and geological disposal facilities for ILW and HLW disposal. These assessments will support decisions such as the choice of disposal facility type, the definition of the safety concept for radwaste disposal, siting, etc. However, the requirements for the structure and content of the safety analysis report for such disposal facilities are currently missing and will need to be established, as discussed in Section 6.1.6.

The current requirements for the structure and content of safety analysis reports for radioactive waste treatment plants are not very useful for the development of safety analysis reports for treatment plants at the Radon Association sites due to the specific characteristics of these plants. This regulatory gap has become evident in recent years, particularly during the comprehensive safety assessment of the Radwaste Treatment Plants at the Radon Association and the preparation of safety analysis reports and other licensing documents for renewing licenses.

The specific features of safety assessments and analyses for installations at the Radon Association sites and activities on these sites are associated primarily with the following key factors:

- The presence of several different disposal facilities at each site (including closed "legacy" disposal facilities and those currently in operation with different types of structures).
- Insufficient data on the condition and characteristics of the radioactive waste, the condition of barriers in the disposal facilities, and the need to retrieve and process radioactive waste, taking into account the ranking of disposal facilities according to their safety state.

A possible solution to eliminate this threat is the development of a specific regulation.

8.2.4 Safety Requirements for Legacy and Accident-Origin Radioactive Waste Management

The **Guidelines** for safety assessment of radwaste treatment plants located in the Chornobyl Exclusion Zone were developed with the support of the European Commission under the **INSC U3.01/08** Project (UK/TS/39) [107], namely:

- **Guideline for Assessing the Common Impact of the Vektor Site with Multiple Facilities for Radioactive Waste Processing, Storage, and Disposal** [108];
- **Guideline for Safety Assessment of Accident-Origin Radioactive Waste Interim Confinement Sites in the Chornobyl Exclusion Zone** [109].

Following the **Guideline for Safety Assessment of Accident-Origin Radioactive Waste Interim Confinement Sites in the Chornobyl Exclusion Zone** [109], the industrial party performed a safety assessment of **RWDS** and **RICS** in the Chornobyl Exclusion Zone within the framework of the **INSC Project U4.01/10C+D+F** [110]. Based on the assessment, individual **RICS** were ranked according to their hazard degree, and recommendations on maintaining the **RICS** safety level and retrieving radwaste from individual **RICS** were defined. In addition, within the framework of the **INSC Project U4.01/10C+D+F** [110], the industrial party performed a comprehensive safety assessment of radwaste storage/disposal in the Chornobyl Exclusion Zone following the **Guideline for Assessing the Common Impact of the Vektor Site with Multiple Facilities for Radioactive Waste Processing, Storage, and Disposal** [108]. Therefore, safety assessments of radwaste facilities located in the Chornobyl Exclusion Zone are regulated by these specific **Guidelines**.

The **Guideline for safety assessment of facilities with legacy radwaste**, namely: the **Guideline for Safety Reassessment of the Existing Storage/Disposal Facilities and Decision-Making Criteria Concerning Subsequent Measures at These Facilities** [111], was developed with the support of the European Commission within the framework of the **INSC Project U3.01/08** (UK/TS/39) [107], which was used under the safety assessment of radwaste burials at the military sites of the former Soviet Union.

IAEA Safety Guide No. GSG-15 "Remediation Strategy and Process for Areas Affected by Past Activities or Events" [112] shows that the remediation process should be designed and implemented systematically, with each step and all decisions clearly documented. Also, criteria should be established for making decisions on whether remediation is required and to what extent.

The regulatory documents of Ukraine do not establish, but should define, the requirements and criteria for remediation of the facilities with accident-origin and legacy radwaste and the corresponding territories. In the decision-making process on radwaste retrieval from the **Pisky-1** site, which contains confined radwaste of Chornobyl origin located beyond the Exclusion Zone, and from the **Vakulenchuk** and **Tsybuleve** military sites of the former Soviet Union, separate regulatory decisions on remediation criteria were made. However, the requirements for the procedure of defining these criteria and the criteria themselves are not set in the regulations.

The development of a regulatory document with the requirements and criteria for remediation of the facilities with accident-origin and legacy radioactive waste and the corresponding territories is envisaged under the recently launched **INSC Project** [30] with the participation of the DSA.

8.2.5 Safety Requirements for Shelter Radioactive Waste Management

As part of the international **Shelter Implementation Plan**, measures have been taken to improve Shelter safety, and the NSC has been constructed. The SNRIU issued a license to operate the NSC-Shelter, considering the NSC-Shelter as a facility for the management of emergency radioactive waste. This facility is subject to the regulation [7] developed with DSA support as part of the **WASTE Project**.

Considering the uniqueness of the NSC-Shelter, based on this document, a regulation titled **"Safety Requirements for the NSC and the Shelter"** was developed, which establishes special requirements and safety rules for the NSC-Shelter and activities at this facility. This draft document was developed with the support of the European Bank for Reconstruction and Development within the framework of the Chornobyl Shelter Fund. This regulation is planned to be put into effect in early 2024.

8.2.6 Safety Requirements for Management of Disused Sealed Radioactive Sources

Regulatory control of the management and safety of radwaste in the form of DRS relies only on the regulations establishing the safety requirements for 'ordinary' radwaste management. There are no special requirements for the safe management of DRS. The CSDRS licensing experience has demonstrated the need for establishing special requirements. The high-level regulation **'General Safety Provisions for Predisposal Management of Radioactive Waste'** [7], developed with **DSA** support, also covers the management activities for **DRS** declared as radwaste. The development of the regulation that will establish the requirements and rules for the management of **DRS** declared as radwaste, based on these requirements, is nearing completion in the framework of the **ACCEPTANCE Project** with the support of the **DSA**.

8.2.7 Requirements for Safe Management Radwaste of Non-Nuclear Origin

The high-level requirements **"General Safety Provisions for Predisposal Management of Radioactive Waste"** [7] apply to non-nuclear radioactive waste management of non-nuclear origin. This document sets out general requirements only. At the same time, installations at the Radon Association and activities at the sites have a number of features.

The practice of regulating the management of non-nuclear radioactive waste of non-nuclear origin at the sites of the Radon Association, taking into account the existing uncertainties and risks and the current state of radioactive waste management facilities, has shown the need for establishing specific requirements and rules for:

- Arranging activities for radioactive waste management at the sites, taking into account the presence of various storage facilities on them;
- Taking technical measures to ensure and improve the safety level of radwaste management facilities;
- Implementing activities to manage the aging of the structures, systems, and equipment;
- Features of the implemented system for radiation dosimetric control and environmental monitoring;
- Planning, development, and implementation of measures for radioactive waste retrieval from the storage facilities and management of this radioactive waste (considering the ranking of storage facilities);
- Etc.

In addition, having considered a number of features of the storage facilities at each site of the Radon Association, a regular efficient dialogue between the licensees and the SNRIU, with the involvement of experts, should be ensured. Therefore, a possible way to mitigate this threat is to establish specific requirements and safety rules for the sites at the Radon Association and ensure a regular efficient dialogue between the licensees and the SNRIU with the involvement of an expert organization.

8.2.8 Requirements for Clearance of Radioactive Materials from Regulatory Control

In Ukraine, clearance of radioactive materials from regulatory control (radioactive material clearance) was regulated by the document **NP 306.4.159-2010** 'Procedure for Clearance of Radioactive Materials from Regulatory Control within Practices' [114]. The experience in using **NP 306.4.159-2010** [114] showed that this regulation had certain drawbacks, established insufficiently detailed requirements, and did not cover individual issues important to safety. In the framework of the **CLEARANCE Project** with DSA support, the development of a new document to replace **NP 306.4.159-2010** [114] with detailed requirements for the criteria and procedures for clearance of radioactive materials from regulatory control is under completion.

8.2.9 Safety Requirements for Decommissioning

The following regulations were developed and put into force with DSA support in the framework of the **DECOMMISSIONING Project**:

- **NP 306.2.230-2020** General Safety Provisions for Decommissioning of Nuclear Facilities [11];
- **NP 306.2.239-2023** Requirements for the Structure and Contents of the Operator's Documents for Licensing Application for Decommissioning of Nuclear Facilities [14].

The compliance of the regulatory framework of Ukraine for decommissioning with the WENRA safety reference levels, considering the implementation of these requirements, is confirmed by the SNRIU self-assessment results, ratified by the WENRA working group on radioactive waste management and decommissioning.

The regulation **'General Safety Provisions for Decommissioning of Nuclear Facilities'** [11] provides the high-level regulatory framework for decommissioning. One of the key provisions of this regulation defines the application of a graded approach during decommissioning, as set out, in particular, by the IAEA documents [115] and [116], and the WENRA reference levels for decommissioning [117]. At present, specific requirements for the application of the 'graded approach' in decommissioning are missing from the Ukrainian regulatory framework.

The implementation of the activity management system at the stage of decommissioning of nuclear installations has significant features, as their state and the types of activities and operations performed on them are constantly changing. **NP 306.2.230-2020** [11] does not establish separate requirements for the implementation of the activity management system during decommissioning of nuclear installations.

With the support of the DSA, within the framework of the **APPROACH Project**, regulatory documents are currently being developed, and their implementation will allow eliminating the mentioned gaps:

- "Requirements for the Implementation of Safety Measures During Decommissioning of Nuclear Installations Depending on Their Condition and the Types of Activities Performed on Them";
- "Requirements for the Implementation of the Activity Management System Related to the Decommissioning of Nuclear Installations".

8.2.10 Application of Safety Requirements for Nuclear and Radiation Facilities Located in the Chornobyl Exclusion Zone, which was Influenced by Military Operations

There are a number of nuclear and radiation facilities in the Chornobyl Exclusion Zone (ChEZ). In February and March 2022, these sites were beyond Ukrainian control due to military occupation by the Russian Federation. After the liberation of the ChEZ from the occupiers, an urgent task arose to renew control over the facilities in the ChEZ, in particular, the state safety regulation of these facilities. There is no global experience in regulating safety under such conditions.

The following recommendation documents were developed under the **ZONE Project** to support the safety regulation of nuclear and radiation facilities in the Chornobyl Exclusion Zone during the renewal of control over this territory by Ukraine, with DSA financial and technical support:

- **"Recommended Approach to the State Safety Regulation of Nuclear and Radiation Facilities in the Chornobyl Exclusion Zone Influenced by Military Operations."** This document establishes the recommended approach to the scope and features of application for different facility types (nuclear installations, radioactive waste treatment plants, decommissioned

Chornobyl NPP units, NSC-Shelter), particularly the principles, general provisions, and relevant safety requirements, licensing, and state oversight procedures.

- **"Recommended Procedure to Renew the Safety Level of Nuclear and Radiation Facilities in the Chornobyl Exclusion Zone Influenced by Military Operations."** This document establishes the recommended procedure for the following:
  - Checking the presence and condition of spent nuclear fuel, radioactive waste, and radioactive materials on the facilities; the state and possibilities for safe operation of the facilities; radiation monitoring conditions at the sites and on the facilities; and the ability of licensees to operate the facilities in accordance with safety requirements.
  - Identification of safety deficiencies, development, and implementation of measures to eliminate identified safety deficiencies.
  - Interaction between the licensees and the SNRIU.

These recommendatory documents were approved in August 2022 by the SNRIU Board Resolution and are used by the SNRIU and licensees operating in the field of nuclear energy use in the ChEZ during their practical activities to renew the safety level of the facilities and activities on them. They also served as the basis for the implementation of a regular and efficient dialogue between the licensees and the SNRIU. Thus, the immediate strengthening of safety regulation of nuclear and radiation facilities in the ChEZ and activities on these facilities was ensured after their de-occupation by the Armed Forces of Ukraine.

8.2.11 Regulation of the Safe Management of Non-Nuclear Naturally Occurring Radioactive Materials (NORM)

On 17 September 2023, the Law of Ukraine "On Amendments to Certain Laws of Ukraine on Human Protection Against Radiation Exposure" [127] was put into force, particularly amending the Law of Ukraine "On Human Protection Against Ionizing Radiation" [122]. Consequently, according to Article 9 of the Law of Ukraine "On Human Protection Against Ionizing Radiation" [122], the powers of the SNRIU include, particularly, the establishment and implementation of the state policy in the field of safe nuclear energy use and radiation safety in the handling of naturally-occurring radioactive materials (NORM), which are formed and/or produced as a result of activities not related to the use of nuclear energy.

The primary task of the SNRIU was the development of a regulatory framework for safety regulation in the management of NORM, which are formed and/or produced as a result of activities not related to nuclear energy, in accordance with the provisions of Article 23 of Council Directive 2013/59/EURATOM [15].

The following actions should be immediately performed as the first step to accomplish this task:

1. Analysis of current industrial activities in Ukraine that could potentially be classified as practices specified in Article 23 of Council Directive 2013/59/EURATOM [15]. The analysis should be carried out based on the list of industries related to natural radioactive materials specified in Annex VI of Council Directive 2013/59/EURATOM [15]. Based on the analysis results, it is necessary to determine specific industrial activities (specific enterprises, their products, etc.) that could potentially be attributed to the above practices;

2. Analysis of gaps in the regulatory framework of Ukraine to regulate the safe handling of naturally occurring radioactive materials not related to the use of nuclear energy. Based on the analysis results, it is necessary to determine the structure of the regulatory framework to be established and the sequence of developing the regulatory and legal acts.

Summarizing the information presented in this Section, it should be noted that the threats and challenges identified in the Reports [2]-[4] have been or are being mitigated within the framework of the bilateral cooperation projects between the SNRIU and DSA. In addition, the revealed threats to regulatory activities

in the field of radioactive waste management and decommissioning are being mitigated with the support of the European Commission (for more details, see Section 10 of this Report).

At the same time, based on the analysis results in the development of this Report, the following new threats and challenges have been identified, whose mitigation will improve the regulatory framework for safe radwaste management and decommissioning (for more details, see Section 9 of this Report):

- Absence of a regulatory system for the safe management of non-nuclear naturally-occurring radioactive materials (NORM);
- Absence of specific requirements and rules for the safe management of non-nuclear waste;
- Absence of requirements for the structure and content of the safety analysis reports on the management of non-nuclear radioactive waste;
- Absence of specific safety requirements for disposal facilities at medium depths and geological disposal facilities;
- Absence of requirements for the structure and content of the safety analysis reports of disposal facilities at medium depths and geological disposal facilities.

9 RADIATION PROTECTION

The Law of Ukraine “On Nuclear Energy Use and Radiation Safety” [27] establishes safety—including radiation safety, as well as human and environmental safety—as a priority in the field of nuclear energy use. The principles of radiation safety regulation in Ukraine are detailed in previous Reports [2], [3], [4]. During the current period, efforts to enhance the regulatory and legal framework in the NRS field have continued, aiming to ensure that the level of radiation safety in Ukraine aligns with the standards established in EU member states.

9.1 Regulation of Radiation Protection and Radiation Safety. Radiation Safety of Non-Nuclear Facilities

9.1.1 Regulation of Radiation Protection and Safety

In Ukraine, the implementation of the **Action Plan** [118], which was developed to implement the Association Agreement between Ukraine and the European Union to improve the system of state radiation safety regulation, continues. In view of this, the following key points should be noted:

One of the fundamental principles in state regulation involves the application of a **graded approach** to safety requirements depending on the potential nuclear and radiation hazards associated with specific activities and installations housing radiation sources. To improve the procedures involving the graded approach, the **Law of Ukraine “On Amendments to Certain Laws of Ukraine Regarding Improvement of Authorizing Activity in Nuclear Energy Use” No. 2755-IX** [120] of 16 November 2022 was adopted, which, in particular, provides for introducing the procedures for obtaining, by an entity in the field of nuclear energy use, a confirmation from the state nuclear regulatory authority on the conformity of radiation sources with the criteria according to which the activity involving the use of radiation sources is exempted from licensing [119], and the procedure for decision-making on the specified issue by the state nuclear regulatory authority. The relevant provisions were implemented by amending the **Law of Ukraine “On Authorizing Activities in Nuclear Energy”** [49].

The state regulation system was also improved by introducing the institute of **“radiation protection experts”** into activities related to nuclear energy use. The **Law of Ukraine “On Amendment of the Law of Ukraine on Nuclear Energy Use and Radiation Safety Regarding Radiation Protection Expert” No. 2758-IX** [121] of 16 November 2022 introduced the procedure for the recognition of the radiation protection expert. Currently, the draft document **“Provisions on Radiation Protection Expert,”** developed in the framework of the SNRIU and DSA cooperation (PROVISION Project), is in the process of being submitted by the SNRIU to the Cabinet of Ministers of Ukraine for review and agreement.

In order to fulfill Ukraine's international legal obligations in the field of European integration and European Union law, in particular **Directive 2013/59/Euratom** [15] and the **IAEA Standard GSR Part 3** [126], the **Law of Ukraine “On Amendments to Certain Laws of Ukraine on Human Protection Against Ionizing Radiation” No. 3344-IX** [127] of 23 August 2023 was adopted, which, in particular, provides for:

- Introduction of three exposure situations (planned, existing, and emergency);
- Establishment of effective and equivalent dose limits for occupational exposure, exposure of the public, as well as exposure of interns and students for the planned exposure situation;
- Introduction of reference levels for existing and emergency exposure situations;
- Introduction of reference levels for the average annual radon activity concentration in the air of premises for permanent residence of people and at workplaces;
- Determination of the main measures for justifying and optimizing protection and safety measures in case of medical exposure, etc.

Development and improvement of the safety regulation system in the field of medical radiation sources use continued. Development of two important regulatory documents in the framework of the SNRIU and DSA cooperation was initiated: on establishing radiation safety rules in interventional radiology (**FOLLOW-UP Project**) and on establishing acceptance criteria for medical X-ray diagnostic equipment (**CRITERIA Project**) as well as development of rules for the provision of services on acceptance, commissioning, periodic operational testing, and decommissioning of medical diagnostic radiological equipment (**CRITERIA II Project**). The main goal of both ongoing projects is to increase the safety of personnel, patients, and the public when using medical radiation technologies. The specified documents are being elaborated to further develop provisions of the regulation **"General Rules for Safety Assurance of the Radiation Sources Use in Medicine"** [6], which was also created under the SNRIU and DSA cooperation (MEDICINE Project).

To overcome the threats identified in the Reports [3], [4], and in view of the trends of expanding the use of linear accelerators in medical practice, the SNRIU is developing a regulation that establishes radiation safety rules for the use of electron accelerators in medicine.

The revision of one of the basic documents regarding the safety in the use of radiation sources, namely the **"Technical Specifications for Sealed Radioactive Sources"** [123], which required updating due to changes in the regulatory framework it refers to, is at the final stage.

It should be noted that certain gaps still remain in the field of radiation safety regulation of radiation sources. According to the outcomes of previous threat assessments [2], [3], [4], there were and currently remain outdated basic documents in the radiation protection and safety area, such as **"Radiation Safety Standards of Ukraine" (NRBU-97)** [66] and **"Basic Health and Radiation Safety Rules of Ukraine" (OSPU-2005)** [68]. Recommendations on the priority revision of these basic documents were provided both by DSA experts in the framework of the SNRIU and DSA cooperation, and by other international experts [125]. The development of the draft regulation **"Basic Radiation Safety Rules of Radiation Sources,"** which was a part of the SNRIU and DSA cooperation (SOURCE Project), was suspended by the SNRIU's decision until completion of the NRBU-97 [66] revision process, and it was proposed to extend the regulation, changing its title accordingly to **"General Requirements for Radiation Protection and Safety."**

Challenges regarding safety regulation in certain areas of radiation sources use remain. Primarily, it concerns medical sources. Currently, there are gaps in the regulatory documents for the use of nuclear medicine, the production of radiopharmaceuticals, and radon therapy (Radon therapy departments are currently functioning in Ukraine, but after the cancellation of Soviet health regulations, there are no relevant documents establishing requirements for radiation safety of personnel and patients during the design, construction, and operation of laboratories and radon therapy departments).

The licensing experience of medical radiation sources, namely conducting pre-licensing inspections of complex installations such as linear accelerators, demonstrated the need for a standard plan of a detailed radiological survey, which shall determine, in particular, the survey scope, modes of installation, hardware and methodological support for measurements, an algorithm for processing and interpreting measurement results, etc.

With regard to the technical maintenance of medical radiological equipment, it should be noted that the provision of an appropriate official authorization for mounting, technical or service maintenance of medical radiological equipment, taking into account training, professional development, and competence of service engineers and technicians, shall be considered when obtaining a license for the right to carry out activities involving the use of ionizing sources in terms of maintenance, namely in an individual document **"Rules for Provision of Maintenance Services of Radiation Sources and Equipment with Radiation Sources."**

9.1.2 Safety of Uranium Facilities

In Ukraine, uranium ore mining and enrichment are carried out by the State Enterprise "Eastern Mining and Enrichment Combine," located in the city of Zhovti Vody, Dnipropetrovsk region. Measures for activity termination, which include remediation and restoration activities on radioactively contaminated territories of the former Production Association "Prydniprovsky Chemical Plant" (PChP) in the city of Kamyanske, Dnipropetrovsk region, are conducted by the State Enterprise "Baryer" (Baryer).

It should be noted that in 2019, to implement the provisions of Directive 2013/59/Euratom [15], amendments to the **Law of Ukraine "On Mining and Processing Uranium Ore"** [124] were made regarding the extension of state regulation in the field of nuclear energy use to uranium ore mining activities. This made it possible to put into force the regulation **"General Radiation Safety Provisions for Uranium Ore Mining and Milling"** [12], the draft of which was developed within the framework of the SNRIU and DSA cooperation (URAN Project).

For the current period, in accordance with the SNRIU Order **"On Amending Some Regulations on Uranium Ore Mining and Milling Operations,"** the regulatory document **"Requirements for the Structure and Content of the Safety Analysis Report of Uranium Ore Mining and Milling Operations"** came into force in December 2022 (the regulation **"Requirements for the Safety Analysis Report of Uranium Ore Processing"** valid at that time was revised, taking into account relevant provisions on licensing uranium ore mining activities).

At the same time, a considerable domain of uranium facilities' activities remains unregulated, namely decommissioning, termination of operation, repurposing, and remediation of contaminated territories. The SNRIU approved the draft Cabinet Resolution **"On Concept Approval of the State Target Environmental Program 'Decommissioning of Uranium Facilities for 2022–2026.'"**

The introduction of the basic existing exposure situation provisions at the legislative level (**Law of Ukraine "On Amendments to Certain Laws of Ukraine on Human Protection against Ionizing Radiation" No. 3344-IX** [127] of 23 August 2023) provides an opportunity to eliminate several challenges in this area by developing the appropriate regulatory framework in the field of uranium facilities' safety.

9.1.3 Challenges in the field of radiation source use caused by the martial law

Special challenges in the field of radiation source use and their safety regulation, starting from February 2022, were caused by the war waged by the Russian Federation against Ukraine. As stated in the SNRIU Report on Nuclear and Radiation Safety in Ukraine for 2022 [134], under martial law conditions, ensuring radiation protection of personnel, the public, and the environment during the use and production of radiation sources remains a priority area of state nuclear and radiation safety regulation.

Parts of the Luhansk, Donetsk, Zaporizhzhia, Kherson, Kharkiv, and Sumy regions were occupied by the armed forces of the Russian Federation, including entities using radionuclide radiation sources of Categories 1–3.

Currently, there are risks regarding the loss of regulatory control over radiation sources belonging to entities located in the temporarily occupied territories. It should be emphasized that reliable information on the state of radiation sources in the occupied territories is missing. Only after the de-occupation of these territories will the entities be able to conduct extraordinary inventories, and based on their results, it will be possible to compile an accurate list of orphaned/destroyed radiation sources and take measures to restore regulatory control over them.

At present, there have been no cases of regulatory control loss over sources of Categories 1–3 in the de-occupied territory of the Kherson region. However, the SNRIU received reports from two entities (the National Scientific Center “Institute of Metrology” and the Sumy Customs Service of the State Customs Service) in the de-occupied territories of the Kharkiv and Sumy regions regarding the probable loss of regulatory control over radionuclide radiation sources, including those of Categories 1–3. Due to the minimum distance to the border with the Russian Federation, the threat of artillery shelling and missile attacks, mining of the territory, and limited access, staying in these specified territories remains dangerous for personnel. Accordingly, conducting a physical inventory of radiation sources, assessing damage, and determining quantitative losses of radiation sources is currently impossible and will be carried out once safe conditions are restored. These issues remain under the SNRIU’s control.

The war has caused considerable damage to the medical industry. A large amount of medical radiological equipment has been destroyed or damaged (see Fig. 7.1 and Fig. 7.2), and some undamaged radiological equipment has been removed from the temporarily occupied territories.

Fig. 7.1 – Destroyed medical institutions with medical radiological equipment

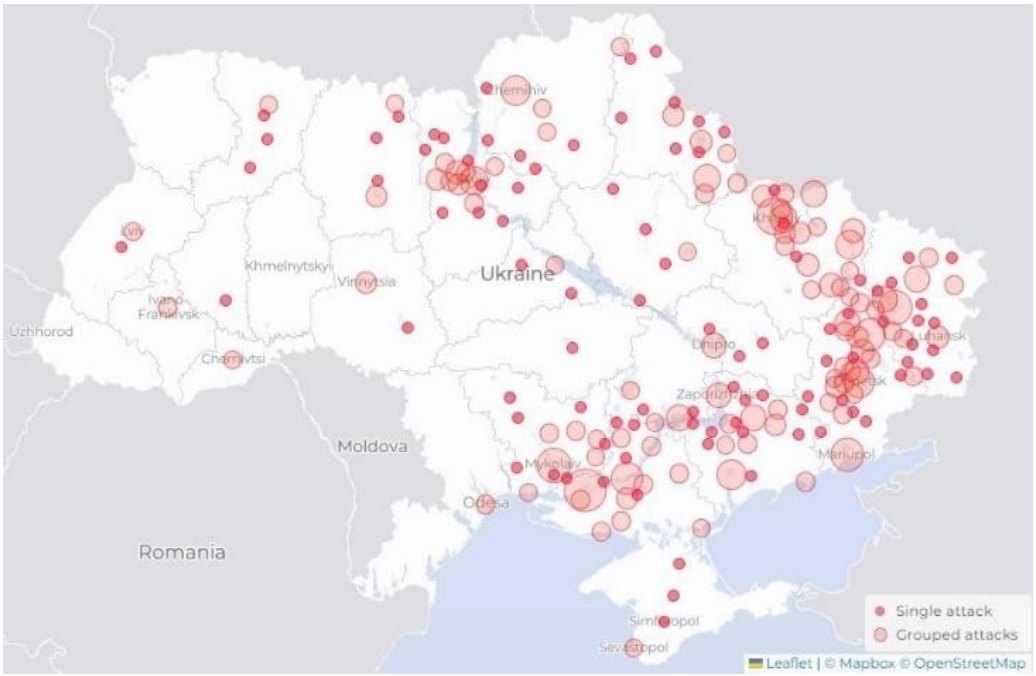


Fig. 7.2 – Map of attacks on medical institutions (24 February 2022 – 29 July 2023)

It can be ascertained that the loss of a significant amount of medical radiological equipment in the temporarily occupied territories, the damage or destruction of equipment and facilities in the war zone, the transfer of a large portion of the population to safer central and western regions of Ukraine, and the growing number of wounded military personnel and injured civilians during the war all create new challenges under the current martial law conditions in Ukraine. The urgent need to provide qualified medical care to military personnel and civilians requires the commissioning of high-tech diagnostic and therapeutic radiological equipment and installations in the shortest time possible. At the same time, ensuring an appropriate level of radiation protection for both medical personnel and patients is crucial, as it directly impacts the effectiveness of the necessary medical care. The use of interventional procedures is expanding significantly, which, on the one hand, greatly improves the quality of medical procedures, but on the other, requires heightened attention to radiation safety due to the specific nature of these procedures.

Thus, licensing activities involving the use of radiation sources amidst these challenges are among the primary tasks of the SNRIU. Supporting the SNRIU's licensing activities during wartime, including state NRS reviews (technical assessments) of design documentation (engineering designs) for the placement of medical radiation sources, is a priority task. This includes developing relevant recommendations that define the composition and content of the specified design documentation, depending on the type of equipment or installation and the technical condition of the facility where it will be located.

In 2022–2023, the European Commission provided Ukraine with appropriate support for conducting state NRS reviews (technical assessments) of design documentation (engineering designs) for the placement of medical radiation sources in state and municipal medical institutions. While the respective project has been completed, the urgent needs it addressed remain relevant. Therefore, to continue addressing this issue, the SUPPORT Project was recently launched within the framework of SNRIU and DSA cooperation.

One of the important tasks of the SNRIU after de-occupation will be assessing the radiation safety status of radiation sources in the de-occupied territories, providing regulatory support (including expert support) for activities aimed at bringing damaged and destroyed facilities with radioactive sources to a safe state, resuming inspection activities in these territories, and more.

These challenges form the basis for developing plans for SNRIU's rule-making activities and determining priorities for state regulation in this area. Consequently, the main rule-making activity areas of the SNRIU related to the use of radiation sources and uranium facilities for the coming years include:

- Continuing to align national basic rules and standards on radiation safety with up-to-date international basic safety standards and EU legislation;
- Continuing the development of a Unified State Accounting and Control System for Occupational Exposure Individual Doses;
- Initiating the development of a Unified State Accounting and Control System for Individual Patient Medical Exposure Doses;
- Developing safety rules for industrial production involving materials with natural NORM radionuclide content (e.g., iron ore, coal mines) and safety rules for aircraft crews;
- Implementing measures to reduce public exposure to radon and its decay products, including minimizing long-term risks from radon in residential and non-residential buildings, workplaces, and other sources such as soil, construction materials, and water;
- Developing radiation safety requirements and rules for radiation sources used for human imaging for non-medical purposes.

9.2 Radiation Safety of Nuclear Installations

The military aggression of the Russian Federation directly impacted Energoatom's activities, particularly due to damage to critical infrastructure, disruption of logistics, and a decrease in the workforce of contracting organizations caused by mobilization and forced evacuation. These factors led to a reduction in the scope of work performed within the framework of safety upgrades. The reduced scope of work, combined with the transfer of ZNPP units into a shutdown state (without performing repair activities), has also affected the radiation safety indicators for personnel.

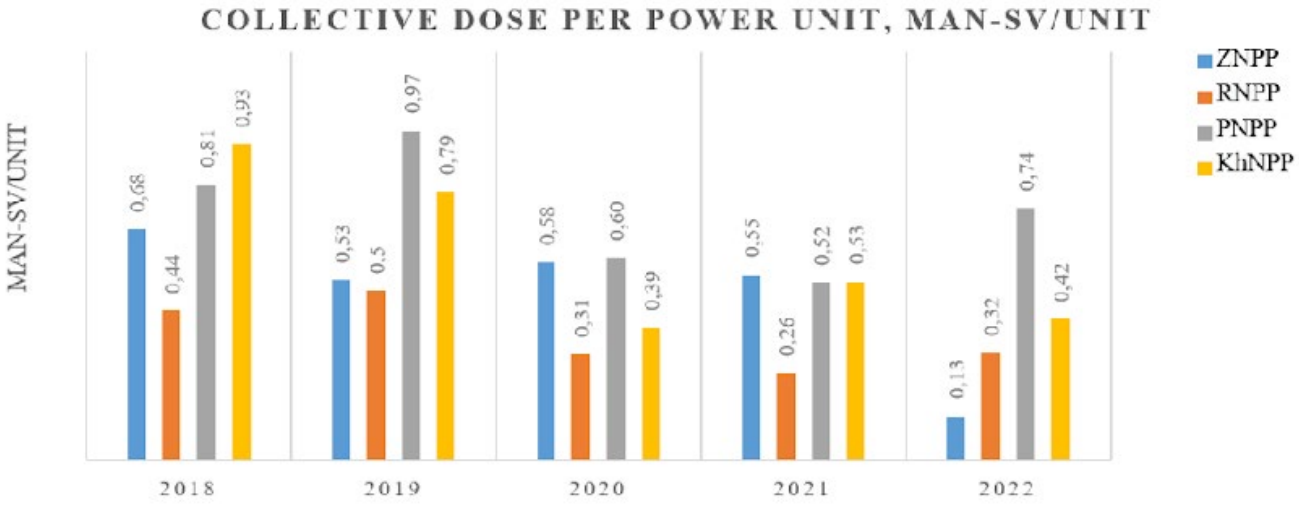


Fig. 7.3 – Annual collective exposure doses of NPP personnel (including personnel of external organizations) per power unit for 2018 – 2022.

As shown in Fig. 7.3, there is a moderate trend toward a decrease in the annual collective exposure dose indicator of NPP personnel per power unit. The indicator value is approaching the industry's long-term goal according to the WANO CRE indicator (collective radiation exposure dose of personnel), which is 0.7 man-Sv per power unit, and is below the average level for foreign NPPs with VVER-type reactors (three-year average collective dose for 2017–2019: 0.46 person-sievert per power unit).

The effectiveness of NPP radiation safety concerning the public is assessed using the following indicators:

- Gas-aerosol radionuclide releases and water discharges per 1000 MW of installed capacity;

- Indices of releases and discharges (Fig. 7.4) of radioactive substances into the environment, defined as the ratio of radionuclide and radionuclide group activities in releases and discharges to their permissible levels.

Fig. 7.4 - Dynamics of total indices of gas-aerosol releases and discharges of radioactive substances into the environment by Ukrainian NPPs in 2018-2022.

In 2022, the gas and aerosol releases of Ukrainian NPPs were registered at levels significantly below the release limits set for each individual NPP. The total indices of gas-aerosol releases into the environment, based on the main components of releases (inert radioactive gases, iodine radionuclides, and long-lived nuclides such as 137Cs, 134Cs, 60Co, 54Mn, 90Sr, 110mAg, 3H, and 14C), were as follows: ZNPP: 5.825%, RNPP: 0.618%, PNPP: 3.388%, and KhNPP: 0.140%.

There were no exceedances of reference levels or discharge limits for radioactive substances into external water reservoirs at any Ukrainian NPPs during the reporting period. Therefore, the radiation parameters characterizing the operation of Ukrainian NPPs did not exceed standard values. Radiation protection for personnel and the public was ensured at a sufficient level due to the organizational and technical measures implemented by the operator. However, it should be noted that these measures are implemented in accordance with outdated basic documents [66], [68]. The absence of regulatory requirements aligned with the recommendations of Council Directive 2013/59/Euratom [15] and IAEA standards [126] hinders consistency in this area.

The threats arising from the lack of regulatory requirements for monitoring public radiation safety in NPP influence areas are being addressed within the ongoing MONITORING Project under the cooperation between the DSA and SNRIU. The regulatory document developed under the MONITORING Project will establish requirements for radiation monitoring of releases and discharges from nuclear installations and environmental radiation monitoring to assess public doses in NPP influence areas. Introducing this document will enable the SNRIU to exercise its regulatory functions related to oversight of nuclear installations, pre-licensing assessment, and possible licensing of new nuclear installation designs concerning public radiation protection.

However, the existing gap in regulatory requirements for organizational and technical measures to ensure the radiation safety of nuclear facility personnel poses a threat to the SNRIU's ability to perform its main functions related to licensing new nuclear installations and overseeing the operation of existing ones. This gap must be addressed.

New challenges have emerged under the special martial law regime concerning radiation safety regulation:

- **Loss of regulatory control** over occupied facilities and territories and the need for restoration after de-occupation. Since the seizure of the ZNPP site by Russian troops on 4 March 2022, equipment, building structures, and piping have been damaged. Data transmission from the ZNPP automated radiation monitoring system, which serves as an early notification system, was

terminated. Violations of the integrity of systems and components, equipment degradation due to the lack of timely repairs and maintenance, and the loss of reliable communication with the regulatory authority have reduced the radiation safety level, necessitating inspections and restoration.

- **Integrity control of protective barriers** to limit the spread of radionuclides after enemy attacks and shelling. All Ukrainian nuclear installations, including the neutron source located at KIPT, have been subjected to bombardments and shelling by the aggressor country, resulting in varying levels of damage to protective barriers. Inspections and restoration of radiation protection and control systems at nuclear installations have become essential.

These challenges are addressed within the recently launched ZONE 2 and ZONE 3 Projects under the DSA-SNRIU cooperation framework (for more details, see Sections 9 and 10 of this Report).

In summary, the threats and challenges identified in Reports [2], [3], and [4], as well as those identified during the current assessment, are being addressed through DSA-SNRIU cooperation projects (see Section 10 for details):

- Support of the SNRIU in amending Ukrainian regulatory documents on radiation protection in medicine in accordance with the IAEA's International Safety Standards and Council Directive 2013/59/Euratom: **MEDICINE**;
- Development of the national regulatory document "General Radiation Safety Provisions for Uranium Ore Mining and Milling": **URAN**;
- Development of a national regulatory document on radiation safety in the use of radiation sources: **SOURCE**;
- Development of proposals/recommendations regarding the procedure and criteria for recognizing radiation protection experts in accordance with Council Directive 2013/59/Euratom and IAEA standards: **PROVISION**;
- Development of the regulatory document "Radiation Safety Rules in Interventional Radiology": **FOLLOW-UP**;
- Development of the regulatory document "Criteria for Acceptability of Medical Radiological Equipment Used in Diagnostic Radiology": **CRITERIA**;
- Development of the regulatory document "Rules for Provision of Services for Acceptance, Commissioning, Periodic Performance Testing, and Decommissioning of Medical Diagnostic Radiological Equipment": **CRITERIA II**;
- Development of the regulatory document on radiation monitoring in the influence area of nuclear installations: **MONITORING**;
- Support to the SNRIU in licensing medical radiation sources: **SUPPORT**.

Additionally, the threats identified in [2]-[4] are being addressed within the SNRIU-USNRC cooperation, which includes modernizing the State Register of Radiation Sources to establish a web-based version of the register.

However, based on the analysis conducted during the development of this Report, several new threats and challenges have been identified. Addressing these will further improve the regulatory framework for radiation protection activities (for details, see Section 9 of this Report):

- Lack of rules and standards on radiation safety in the medical field, including nuclear medicine, radiopharmaceutical production, and radiotherapy;
- Lack of rules and standards for the safety of uranium facilities, particularly for decommissioning and legacy facilities;
- Lack of specific requirements and rules for radiation safety of nuclear facility personnel;
- Need for requirements and rules for radiation safety of radiation sources used for human imaging for non-medical purposes;
- Lack of radiation safety rules for aircraft crews;
- Development of requirements for organizations involved in the maintenance of medical radiological equipment;

- Lack of recommendatory documents for calculating patient doses from medical diagnostic procedures using X-ray radiation.

10 NUCLEAR SECURITY

10.1 Nuclear Security Regulation in Ukraine: Challenges and Threats

The Reports [2] and [3] address the SNRIU's regulatory activities concerning the physical protection of nuclear installations, nuclear materials, radioactive waste, and other radiation sources, as well as the fulfillment of the requirements of the Amendment to the Convention on the Physical Protection of Nuclear Material [138] in Ukraine. It was established that compliance with the fundamental principles of physical protection outlined in the Amendment [138] was ensured. Specifically, through the creation of the State Physical Protection System (SPPS), the physical protection regime has been implemented and maintained in Ukraine at both the operator and state levels.

The Report [3] determined that the foundation for creating and maintaining the nuclear security regime is the development of the regulatory framework and systematic alignment with Euratom's regulatory requirements for nuclear safety and security, as well as IAEA recommendations. This effort aimed to strengthen the regulatory framework by implementing key nuclear security components and identifying areas for further activity in Ukraine. This objective became the focus of the FRAMEWORK Project [139], initiated under the DSA-SNRIU bilateral cooperation and implemented by the SSTC NRS in 2019–2020.

The Report [4] noted that the FRAMEWORK Project [139] serves as the foundation for the further development of SNRIU's regulatory activities in nuclear security and the implementation of the nuclear security regime in Ukraine. Based on the results of this project [138], subsequent projects named FUNDAMENTALS were initiated, dedicated to developing a series of regulatory acts to constitute the nuclear security framework, provide the legal basis for state regulation, and sustain the nuclear security regime. According to definitions in the Law [139], physical protection activities support nuclear security. Therefore, a comprehensive nuclear security regime incorporates the current physical protection regime as a fundamental element. An analysis was conducted to assess threats to nuclear security regulatory activities in the following areas:

Oversight Activities: State and Regular Inspections
In 2021, SNRIU inspectors conducted scheduled state inspections of the physical protection systems of the State Specialized Enterprise "Radon Association" and the ChNPP, as well as inspections of the Nuclear Research Institute of the National Academy of Sciences of Ukraine and State Enterprise "USIE IZOTOP." Additional inspections were carried out at Chornobyl NPP (ISF-1 and ISF-2). Eleven interaction plans in case of sabotage, physical protection plans, 24 Acts for determining physical protection levels, and 137 lists of positions requiring access clearance for special works were developed. Design-basis threats at the facility level were addressed and agreed upon. Twenty-two SNRIU inspectors and 19 managers of enterprises using radiation sources received permits to perform special activities.

In 2022, SNRIU specialists developed 9 Acts for determining physical protection levels and 63 lists of positions requiring access clearance. Permits to conduct special activities were issued to 24 SNRIU inspectors and 10 enterprise heads. However, state oversight of compliance with legislation on physical protection was restricted in 2022–2023 due to the imposition of martial law in Ukraine.

Rulemaking Activities
In 2021, five regulations related to nuclear security were developed or revised, followed by four in 2022. In 2023, three nuclear security regulations were under revision and update.

Authorizing Activities
In 2021, nine permits were issued for the use of land and water reservoirs within nuclear installation control areas, radioactive waste management facilities, and uranium facilities, with four additional permits issued in

2022. In 2021, as part of licensing activities for training and certifying specialists in physical protection, an inspection of the Chornobyl NPP was conducted, and one license was amended in 2022 to extend its validity.

State Physical Protection Review

In 2021, SNRIU conducted a state review of the design documentation for creating a CSFSF physical protection system. In 2022, reviews were completed for the technical re-equipment of the ZNPP Units 4–6 physical protection system and the reconstruction of KhNPP perimeter sections. In 2023, reviews addressed the reconstruction of KhNPP perimeter sections and physical protection arrangements at the ChNPP.

Radiation Source Security Improvement Project

In 2021, under the "Improving Security of Radiation Sources Used in Ukraine" project, modernization of physical protection systems at medical institutions and radioactive waste management facilities was carried out with U.S. Department of Energy support. Assessments of the Khmelnytskyi regional oncology dispensary were performed as part of these activities. Additionally, six special minibuses equipped with physical protection monitoring systems were delivered to the State Enterprise "USIE IZOTOP" to monitor radioactive material transportation.

In 2022, the scope of this project was expanded to address the restoration and enhancement of physical protection systems at facilities damaged by Russian aggression. A specific plan was developed with U.S. support to restore the physical protection system at the KIPT neutron source, enhance nuclear safety at "USIE IZOTOP," and create a central monitoring station for Radon Association sites.

Combatting Illicit Trafficking of Radioactive Materials

In 2021, 16 notifications of illicit trafficking incidents involving nuclear and radioactive materials in Ukraine were submitted to the IAEA. Notable incidents include the detection of Kr-85 sources in Zhytomyr, Sr-90 and H-3 sources in Luhansk, and a gamma relay unit with Cs-137 in Lviv. Additional cases involved Ra-226 contaminated items, such as aviation watches, detected at checkpoints and airports.

In 2022, five notifications of illicit trafficking incidents were submitted to the IAEA.

a) non-controlled R-22 switching arresters;

в) E-2M type gamma relay unit

c) shielding unit with Cs-137 radiation source

Fig. 8.1 – Cases of “legacy” sources detection in abandoned buildings and in soil

In February 2022, during a border crossing with the Republic of Poland, two military-purpose items were discovered in an international postal shipment: KI-11 aviation compasses containing Ra-226. The equivalent gamma radiation dose rate at a distance of 0.1 m was measured at 5.69 μSv/h.

On April 21, 2022, a local resident found an object in a forest near the village of Rudno (Lviv region). This object was handed over to representatives of the Security Service of Ukraine, who identified it as a shielding unit with a radiation source affected by corrosion, weighing 50 kg. The gamma radiation equivalent dose rate at a distance of 0.1 m was 6.3 μSv/h (preliminarily identified as a Cs-137 source, with three pieces).

On December 2, 2022, within the framework of the SURVEY Project (for details, see Section 10 of this Report), specialists from the SSTC NRS, as part of the mobile radiological laboratory RanidSONNI crew, conducted a radiation survey in the village of Myrcha (Kyiv region). During the survey, they discovered a DP-63A dosimeter containing Ra-226 in one of the utility rooms of a school. The gamma radiation equivalent dose rate on the surface of the object was recorded at 14.0 μSv/h.

All discovered items were identified and transferred to radioactive waste disposal sites managed by the State Specialized Enterprise “Radon Association.” Based on radiological examinations, it was concluded that all cases of radioactive material discoveries in illicit trafficking were relatively minor and not associated with significant attempts to cause malicious harm. Furthermore, the measures taken to address these events were demonstrated to be effective.

As observed from the above descriptions, all regulatory measures focused on physical protection. This focus is due to the fact that activities in this area of nuclear energy use are governed by sufficiently detailed and well-established rules, standards, and criteria. Consequently, it is possible to conduct state oversight of licensees, perform inspections and assessments of their activities, and require quality assurance self-assessments within the framework of the physical protection regime. At the same time, these functions and areas of activity, in accordance with IAEA recommendations [141], are components of the nuclear security regime. According to the Law of Ukraine [140], nuclear security is assessed by the conformity of the physical protection level with legal requirements. Therefore, the regulation of physical protection requirements is closely intertwined with the regulation of major aspects of nuclear security requirements.

10.2 Application of the Systematic Approach to Nuclear Security Regulation and Implementation of the Nuclear Security Regime

In Ukraine, two systems have been legislatively implemented at the state level to unify relevant central executive power bodies and ensure the functioning of two main nuclear security components: physical protection and the prevention of illicit trafficking.

State Physical Protection System (SPPS)
As demonstrated by the FRAMEWORK Project [139], the SPPS is crucial not only for ensuring physical protection at the state level but also as a foundation for implementing the broader nuclear security regime. According to Article 5-2 of the Law of Ukraine [140], the objective of the SPPS is to ensure the security of nuclear installations, nuclear materials, radioactive waste, and other radiation sources. This includes legal regulation, state oversight and control of physical protection, secure communication, and information exchange. The state system for training, professional development, and advanced training of physical protection specialists, along with the promotion of a security culture, is closely connected to the SPPS.

In 2021, as part of a project to create a training course on nuclear security for response forces, educational and training seminars were held for trainers of security police response forces at Kharkiv State University of Internal Affairs and Lviv State University of Internal Affairs.

From May 25 to 27, 2021, comprehensive anti-terrorist security training was conducted at the Chornobyl Nuclear Power Plant (ChNPP) and within the Exclusion Zone. Participants included personnel from the physical protection units of the ChNPP, radioactive waste and spent fuel storage facilities, as well as servicemen from the National Guard, the Special Operations Forces of the Armed Forces, and the State Border Guard Service.



Fig. 8.2 - Anti-terrorist security training in the Chornobyl Exclusion Zone, 25-27 May 2021 (materials from open sources: website of the Special Operations Forces of the Armed Forces of Ukraine)

On August 9-13, 2021, an international training course on computer (cyber) security of physical protection systems of radiation-hazardous facilities was held at PNPP.

In 2022, with the objective of increasing preparedness for response and countering potential threats of sabotage against NPPs and radioactive materials and unacceptable radiation consequences, the SNRIU developed a draft Cabinet Resolution [142]. To fulfill the tasks defined by the Resolution, the SNRIU established an Interdepartmental Working Group on design-basis threat determination for nuclear installations, nuclear materials, radioactive waste, and other radiation sources in Ukraine. The composition of this group was approved by the SNRIU Order No. 559 on September 16, 2022. The work to determine the design threat is underway, which will be approved by the relevant regulatory document.

Activities aimed at improving interaction and information exchange between the SPPS entities continued in 2023. In February of this year, a scientific and practical conference titled “Protection of Critical Infrastructure Facilities in the Energy Field” was held at the National Academy of the Security Service of Ukraine. The conference, the main objective of which was the security of nuclear facilities, was attended by representatives of the SNRIU, the National Academy of Sciences of Ukraine, scientific institutions of law enforcement authorities, other state physical protection system entities, as well as the Armed Forces of Ukraine.

Illicit Trafficking Prevention System

This system is implemented in the **Procedure [143]**. Its importance for maintaining the nuclear security regime was also considered in the FRAMEWORK Project [139]. The objective of this system is to ensure the interaction of central executive authorities and institutions whose powers include radiation protection, minimization of harm to the public and the environment due to radiation exposure, and law enforcement functions. Within the framework of this system, research, withdrawal, and return under regulatory control of radioactive material detected in illicit trafficking are carried out.

Transboundary Cooperation

Transboundary cooperation is also important since Ukraine is a transit country for radioactive material transportation and has international cooperation with a number of countries on these issues. Thus, in 2021, jointly with representatives of the IAEA Nuclear Security Division, a seminar was held in Sofia (Republic of Bulgaria) for representatives of Georgia, the Republic of Moldova, and Ukraine to discuss the next steps under the program to support national, bilateral, and regional response measures to events in the field of nuclear security and radioactive material detection in illicit trafficking.

SNRIU specialists of the Nuclear Security and Safeguards Directorate actively participate in online meetings and discussions of practical training opportunities aimed at combating the illicit trafficking of firearms, explosives, chemical, biological, nuclear, and radioactive materials across the Ukrainian-Moldovan state border with the support of the European Union Mission for the provision of border assistance to Ukraine and the Republic of Moldova (EUBAM).

In addition, in 2021, SNRIU representatives took part in a working meeting under the GEIGER Project (an analytical platform for collecting data from law enforcement agencies and other government authorities on incidents related to the investigation of terrorist and criminal acts involving radioactive materials) jointly with representatives of the National Police and the Security Service of Ukraine with the support of the Interpol General Secretariat, with the aim of developing international cooperation in the field of countering the illicit trafficking of radioactive materials.

On December 5-8, 2022, with the support of the Interpol General Secretariat in Istanbul, Republic of Turkey, jointly with representatives from the State Border Guard Service Administration and the Office of the Prosecutor General, the SNRIU representative participated in the 1st World Conference in the framework of the GEIGER Project. Expert discussions on radiological and nuclear safety during armed conflicts were held at the conference.

In the current year, an SSTC NRS representative took part in the IAEA Technical Meeting on developing and maintaining the Nuclear Security Events Detection Architecture. The meeting discussed the experience of the participating countries in the creation of national architectures and ways to overcome new challenges in the detection of radioactive material outside regulatory control.

Therefore, the application of state systems in physical protection and prevention of illicit trafficking enables ensuring interaction between the relevant executive power authorities, thus supporting the nuclear security regime in the state. In particular, joint training and professional development of personnel in special courses, participation in workshops, including with international support, proved to be efficient. However, at the same time, it is necessary to maintain the regulatory framework and update it in a timely manner.

A) IAEA seminar in Bulgaria on responding to events Ukraine in the nuclear security field, radioactive material detection in illicit trafficking;

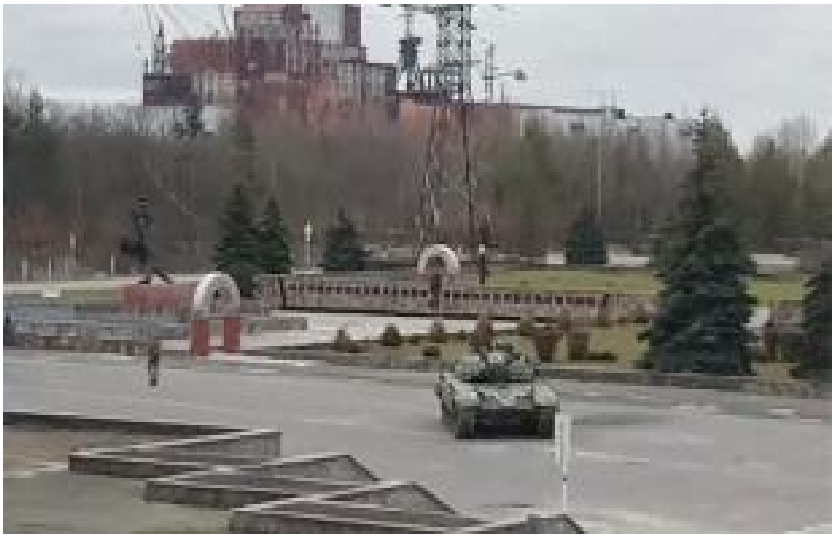
B) working meeting in the framework of the GEIGER Project in

C) 1st World Conference under the GEIGER Project

Fig. 8.3 - Participation of the SNRIU in international measures to support the prevention and radioactive material detection in illicit trafficking (A,B,C)

10.3 Escalation of Nuclear Security Threats

The full-scale armed aggression of the Russian Federation against Ukraine, which began on February 24, 2022, led not only to an increase in beyond-design-basis threats but also to direct crisis situations in nuclear security. Considering the continuation of military operations in the east and south of Ukraine, the SNRIU, jointly with the relevant ministries and authorities, continues activities to strengthen the physical protection of nuclear installations. At the same time, taking into account the regular missile attacks by the Russian Federation on the entire territory of Ukraine, the security of nuclear installations and materials, facilities designed for radioactive waste management, and other radiation sources in the context of hostilities remains a pressing issue and requires individual comprehensive consideration.



A) Russian tanks on the ChNPP site

B) heavy military vehicles of occupation forces on the ZNPP territory

C) looted nuclear ChNPP laboratory after liberation from occupying forces

Fig. 8.4 – Threats to security of nuclear installations (A,B,C)

10.4 Measures to Establish Regulatory Requirements for Nuclear Security and Regulatory Framework Development

In 2021, the SNRIU took several steps to improve nuclear security regulatory control. The SNRIU Order [145] was implemented, enabling the prompt resolution of several urgent issues in certain components of nuclear security:

- The text of the Rules [146] was amended to address countering acts of nuclear terrorism and sabotage, thereby eliminating inconsistencies with the requirements of the Law of Ukraine [140].
- The text of the SNRIU Order [147] was revised with respect to the requirements for checking personal information of individuals.
- The Order of the Ministry of Environmental Protection and Nuclear Safety of Ukraine was canceled [148]. As a result of the FRAMEWORK Project [139] implementation, the SNRIU established in 2020 that this regulatory document was outdated, did not meet the requirements of information legislation, and needed to be fundamentally revised or canceled.
- New requirements for the protection of confidential information related to nuclear security and determination of the physical protection level were introduced in Requirements [149].

In 2022, an SNRIU Order [150] was adopted, developed based on the IAEA recommendations on protecting computer networks at nuclear facilities and in accordance with the requirements of Ukrainian legislation on the cybersecurity of critical infrastructure facilities.

As mentioned above, the Cabinet of Ministers of Ukraine adopted a Resolution [142] in 2022, granting the SNRIU the authority to organize activities on assessing the nuclear security threat at the state level and developing the design-basis threat. Previously, this responsibility fell under the Security and Defense Council. This decision gives broader regulatory powers to the SNRIU as the competent body for the SPPS, but it also introduces a number of threats to regulatory activity. The procedure established by law for the interaction of central executive power authorities in providing information, assessing threats, and accepting the design-basis threat is in the process of changing. Based on the approved design-basis threat and in accordance with the legally established list of operating organizations, other licensees must develop facility-level design-basis threats. However, a regulatory document establishing requirements for such documents is currently missing.

Changes in the structure of central executive power authorities, particularly in their names and powers, have complicated the interaction of the SNRIU with the bodies responsible for creating a system to prevent the illicit trafficking of radioactive materials. Therefore, in 2023, the SNRIU developed a draft of amendments to the Procedure [143], which has been submitted to the Cabinet of Ministers of Ukraine for review.

In the current year, the SNRIU also developed a draft law on amendments to the Law of Ukraine [140]. These amendments establish clearer and more transparent standards for threat assessment, approval of the design-basis threat at the state level, and development of facility-level threats.

Thus, during 2021–2023, the SNRIU made significant steps to strengthen the nuclear security regulatory framework and its components. A number of existing requirements have been specified, and new ones have been implemented in the areas of physical protection, combating illicit trafficking, threat assessment, information security, and cybersecurity. However, considering that all current regulations were developed for peacetime, as well as the existence of gaps in the existing physical protection regulatory framework and the nuclear security regulatory framework being created based on it, there remain threats to nuclear security regulatory activity in Ukraine.

10.5 Measures to Develop the Nuclear Security Regulatory Framework

To overcome the threats identified in the Reports [3] and [4], as well as based on the outcomes of the FRAMEWORK Project [139] and with the objective of improving the national nuclear security regulatory framework, the cooperation program between DSA and the SNRIU for the period 2021–2025 envisaged the implementation of four projects focused on the development of regulatory documents, including:

- **"General Security Provisions for Nuclear Facilities, Nuclear Materials, Radioactive Waste, and Other Radiation Sources";**
- **"General Requirements for the Nuclear Security Regime for Nuclear Facilities and Facilities for Management of Radioactive Waste and Other Radiation Sources";**
- **"Requirements for Determination of the Facility-Level Design-Basis Threat";**
- **"Physical Protection Rules for Radioactive Waste and Other Radiation Sources."**

In November 2021, the implementation of the **FUNDAMENTALS I Project** began, under which the regulatory document **"General Security Provisions for Nuclear Facilities, Nuclear Materials, Radioactive Waste, and Other Radiation Sources"** is being developed (for details, see Section 10 of this Report). This document establishes the basic concepts of nuclear security and serves as a transitional framework for the conversion from a physical protection regime to a nuclear security regime.

The next step was intended to be the development of the draft regulation **"General Requirements for the Nuclear Security Regime,"** which is a logical continuation of the FUNDAMENTALS I Project. However, considering the military situation in the country and the emergence of new threats to nuclear security—particularly the loss of control over a significant number of radioactive waste and other radiation sources—and the corresponding shift in priorities, the SNRIU decided to focus on developing the draft regulation **"Physical Protection Rules for Radioactive Waste and Other Radiation Sources."** Consequently, in May 2023, in accordance with the submitted Project Proposal, the implementation of the **FUNDAMENTALS II Project** began.

In general, it should be noted that the threats and challenges identified in Reports [2]–[4], as well as during the current assessment, are currently being addressed through bilateral cooperation projects between the SNRIU and DSA. Thus, the SNRIU is taking significant steps to develop and implement requirements critical for nuclear security, enhancing the regulatory framework and establishing a robust nuclear security regime.

11 MAIN THREATS IDENTIFIED AND PROPOSALS FOR THEIR ELIMINATION

This section summarizes information on the status of the elimination or minimization of threats identified in the assessments in Sections 3–8 and highlights new threats compared to previous assessments [2]–[4]. Each unresolved threat, as of the beginning of 2023, is prioritized based on the extent of its negative impact on SNRIU activities in relevant areas, and proposed methods for its elimination are outlined.

11.1 Organization and General Principles for Activities of the Regulatory Authority

Based on the assessment results in this area, further support for SNRIU activities has been identified as necessary to harmonize national regulatory requirements for nuclear and radiation safety (NRS) with WENRA reference levels, EU directives, and IAEA Safety Standards. Significant progress has been made in this regard, with the Ukrainian regulatory framework already meeting WENRA reference levels in several areas (see Section 6 of this Report for more details). These achievements were primarily due to the implementation of bilateral cooperation projects between the SNRIU and DSA, which introduced a number of top-level regulatory requirements governing nuclear and radiation safety in relevant areas.

This challenge continues to be addressed through direct interaction between the SNRIU and the European Nuclear Safety Regulators Group (ENSREG), active participation of SNRIU representatives in WENRA working groups, and ongoing rulemaking carried out by the SNRIU with its own resources and with the involvement of the SSTC NRS. The primary source of international support in this area for the coming years is the collaboration with DSA under INSC Project U3.01/21 (UK/TS/59) Continued Alignment of the Ukrainian Regulatory Regime with the EU Acquis [30] (see Section 10 of this Report for more details).

A major overarching threat currently affecting the activities of the nuclear regulatory authority is the lack of global experience in addressing these challenges under military aggression. Global practices and internationally recognized safety guides (primarily IAEA guides) in this area are either underdeveloped or very limited. Consequently, the SNRIU must carry out its functions under these conditions and tackle challenges using its own resources and support from international partners.

Timely support from the DSA has enabled the SNRIU to develop and implement regulatory guidelines to ensure safety regulation while resuming control over nuclear-hazardous facilities and sites in the Chornobyl Exclusion Zone affected by hostilities in a very short time. Sections 2–7 of this Report provide several specific examples of ongoing SNRIU and DSA projects (ZONE 2, ZONE 3, CONVEYANCE Projects, and others) aimed at eliminating these complex threats, as well as addressing new challenges identified during the assessment, which require continued SNRIU support.

With the onset of full-scale aggression by Russia, the SNRIU has faced the need for daily and effective counteraction to attempts to manipulate public perception through disinformation, fake news, and hostile propaganda narratives about the nuclear sector and the level of nuclear, radiation safety, and nuclear security in Ukraine. To address this challenge, support critical thinking among experts and citizens, strengthen media literacy, and develop mechanisms for verifying information to ensure truthful and objective perceptions of nuclear events while preventing harmful manipulations, the SNRIU, with expert and financial support from the DSA, recently launched the COMMUNICATION Project (see Section 10 of this Report for more details). Expert support for implementing this project will also be provided by the Radiation and Nuclear Safety Authority in Finland (STUK).

11.1.1 Establishment and Implementation of Separate Platform (Website) on SNRIU and DSA Cooperation

The highest priority task for SNRIU and DSA cooperation should be the establishment of a dedicated platform (website) to provide comprehensive information about all implemented projects, their current status, and the results achieved. It is crucial that the content of this resource reflects not only the progress and dynamics of cooperation but also highlights the value and added benefits it brings to the broader context of effective nuclear and radiation safety regulation, both within Ukraine and internationally.

This platform should serve as an **information hub**, ensuring transparency and accessibility of cooperation-related information for all stakeholders. Additionally, it should become a central platform for **experience exchange, knowledge transfer**, and **strategic partnership building**. By showcasing the outcomes and benefits of joint projects, the platform would promote an understanding of the cooperation's role in enhancing safety and fostering innovation.

Moreover, the platform could act as a **driver for future initiatives**, facilitating the development and strengthening of interactions between SNRIU and DSA. It could support the planning and prioritization of new projects, highlight the impact of existing ones, and encourage broader engagement with other stakeholders in the nuclear safety field.

The establishment of this resource should be seen as a strategic step toward increasing efficiency and adopting best practices in nuclear regulation. It would also underscore the importance of international cooperation in addressing national needs and enhancing global safety standards. By reflecting the shared commitment to transparency, accountability, and mutual growth, the platform could significantly contribute to the long-term success and visibility of SNRIU and DSA collaboration efforts.

11.2 Safety of Nuclear Facilities

Threats and challenges in this area identified in Reports [2], [3], and [4] have been eliminated or are in the process of being eliminated through bilateral cooperation projects between the SNRIU and DSA, other completed or ongoing international cooperation projects (see Sections 3 and 10 of this Report for details), and the use of the SNRIU's own resources.

At the same time, during the current analysis, new threats were identified that cannot be addressed using the SNRIU's own resources alone and are critical due to the urgency of their elimination:

- **Development of a Program for Restoring State Safety Regulation for the Operation of Nuclear Facilities at the Zaporizhzhia NPP Affected by the Hostilities and Occupation by Russian Federation Troops**: This threat is being addressed within the recently launched ZONE 2 Project under DSA and SNRIU cooperation (see Section 10 of this Report for more details).
- **Assessment of Time Available for Operator Response under Total SBO at ZNPP Considering Reduced Decay Power after a Long-term Shutdown**: This threat is being addressed within the recently launched RECOVERY Project under DSA and SNRIU cooperation (see Section 10 of this Report for more details).
- **Development of an Action Plan to Renew and Complete Licensing of the Neutron Source at the Construction and Commissioning Life Stage, Considering Long-Term Shutdown and Damage Resulting from Shelling by Russian Federation Troops**: This threat is being addressed within the recently launched ZONE 3 Project under DSA and SNRIU cooperation (see Section 10 of this Report for more details).

STUK experts from Finland will provide technical support to the SNRIU by participating in the review of deliverables and results of the ZONE 2 and RECOVERY Projects.

Considering the above, based on the analysis results, no additional new threats requiring elimination were identified in the area of nuclear facility safety.

11.3 Radioactive Material Transport

Threats identified in Reports [2], [3], and [4] have been eliminated or are in the process of being eliminated through bilateral cooperation projects between the SNRIU and DSA. Additionally, regulatory activities in the area of safe radioactive material transport have been strengthened with support from the USNRC—see Sections 4 and 10 of this Report for more details.

At the same time, as a result of the Russian military aggression in Ukraine, a new challenge has arisen for the SNRIU to ensure safety regulation for the preparation and conveyance of radiation sources under military risks, given the lack of global experience in regulating these activities under such conditions. The recently launched **CONVEYANCE Project** within the framework of DSA and SNRIU cooperation is aimed at addressing this challenge. Expert support for this project will also be provided by STUK experts from Finland.

Based on the analysis results, no additional new threats requiring elimination were identified in the area of radioactive material transport.

11.4 Emergency Preparedness and Response

Threats and challenges in this area identified in Reports [2]-[4] have been eliminated or are in the process of being eliminated through bilateral cooperation projects between the SNRIU and DSA. Additionally, the threats identified in Reports [2]-[4] are being addressed through cooperation between the SNRIU and the USNRC (strengthening the SNRIU's emergency preparedness system by improving the regulatory framework governing IEC activities and forming a backup IEC on a virtual platform), as well as between the SNRIU and STUK (provision of measuring equipment to the SSTC NRS, launching the FURN Project—Finnish-Ukrainian Radiation and Nuclear Safety Cooperation Project—and providing expert support for the implementation of the **RESTORATION Project**). For more details, see Sections 5 and 10 of this Report.

Currently, the threat identified in assessment [4] regarding the formation of legal conditions for the full application of the IAEA INES User's Manual in Ukraine (beyond the classification of NPP operational events) remains unresolved. While this work remains relevant, priority has been given to addressing threats caused by the ongoing war.

During the present analysis, a critical threat was identified, necessitating urgent action to analyze and provide recommendations for assessing and optimizing the radiation exposure of Ukrainian Armed Forces military personnel during combat operations.

11.4.1 Analysis of Existing Practice on Radiation and Health Regulation of Exposure for Military Personnel during Combat Operations and Wartime

To adhere to the radiation protection principles for the Armed Forces of Ukraine, the SNRIU has decided to analyze the existing practices in radiation and health regulation of military personnel exposure during combat operations. This analysis will consider relevant experience acquired by NATO, the U.S., and

Canadian Armed Forces, among others, and will be conducted in accordance with the recommendations of the International Commission on Radiological Protection [93]. Based on this analysis, the SNRIU aims to propose approaches for addressing the issue of radiation monitoring for military personnel of the Armed Forces of Ukraine.

The expected outcome is the development of a report with recommendations to be utilized by relevant specialized institutions in establishing radiation and health standards for the Armed Forces of Ukraine in combat conditions. Conducting this analysis and formulating appropriate recommendations in cooperation with relevant institutions of the Ministry of Health is identified as a top-priority task.

11.5 Radioactive Waste Management and Decommissioning

The threats and challenges identified in Reports [2]-[4] have been or are being addressed through bilateral cooperation projects between the SNRIU and DSA, supported by the European Bank for Reconstruction and Development, and within ongoing and planned projects between the SNRIU and the European Commission. For further details, see sections 6.2.1–6.2.6 and 6.2.8–6.2.10 of this Report.

The analysis conducted during the preparation of this Report identified several new challenges. Two of these—developing safety requirements for the management of legacy and accident-origin radioactive waste and establishing requirements for the structure and contents of safety analysis reports on radioactive waste management facilities—are being or will be addressed as part of the recently launched INSC Project [30], which involves participation from the DSA (see sections 6.2.3–6.2.4 for more details). The remaining new challenges identified during the analysis are described below.

11.5.1 Lack of a Regulatory System for the Safety of Managing Materials with Increased Content of Naturally Occurring Radionuclides (NORM) of Non-nuclear Cycle

According to Article 9 of the updated Law of Ukraine “On Human Protection against Ionizing Radiation” [121], the powers of the state nuclear regulatory authority include, among other things, the development and implementation of state policy in the area of nuclear energy safety and radiation safety during the management of materials containing increased levels of naturally occurring radionuclides (NORM) arising from activities not related to nuclear energy use. The primary task of the SNRIU is to establish a regulatory framework for the safe management of NORM from such activities. Sections 6 and 7 of this Report outline the current status of the regulatory basis and identify threats and gaps concerning the safety of activities related to the management of NORM.

To address this task, the following steps must be undertaken as a first priority:

- **Analysis of Existing Industrial Activities**: An analysis should be conducted of existing industrial activities in Ukraine that could potentially be classified as practices indicated in Article 23 of Council Directive 2013/59/EURATOM. This analysis should be based on the list of industries associated with natural radioactive materials mentioned in Annex VI of Council Directive 2013/59/EURATOM. Based on the results of this analysis, specific industrial activities (including specific enterprises, their products, etc.) that could fall under these practices must be identified.
- **Gap Analysis of the Regulatory Framework**: A gap analysis of the Ukrainian regulatory framework for the safe management of materials containing increased levels of naturally occurring radionuclides not related to nuclear energy use should be conducted. Based on the results of this analysis, the structure of the regulatory framework to be established should be determined, along with the sequence for developing regulatory documents.

Eliminating this threat has the highest priority.

11.5.2 Lack of Specific Safety Requirements and Rules for Management of Non-nuclear Waste

Facilities and activities for non-nuclear radioactive waste management, primarily conducted at the Radon sites, possess unique characteristics (see para. 6.2.7 of this Report for further details). To address these specific needs, it is essential to develop a regulatory document with clear requirements and rules for:

- **Radioactive Waste Management at Sites**: Taking into account the diversity of storage facilities located on the Radon sites.
- **Technical Measures**: Ensuring and improving the safety of radioactive waste management facilities.
- **Aging Management**: Addressing the aging of structures, systems, and equipment at the sites.
- **Monitoring Systems**: Establishing specific features for radiation and dose monitoring systems, as well as environmental monitoring.
- **Planning for Radwaste Removal**: Developing and implementing plans for the removal of radioactive waste from storage facilities at the Radon sites, including management strategies based on the safety ranking of storage facilities.
- **Additional Considerations**: Addressing other relevant site-specific safety and operational factors.

Moreover, fostering a **regular, constructive dialogue** between licensees and the SNRIU, with the involvement of an expert organization, is essential to ensure compliance and continuous improvement.

Existing regulatory documents that establish requirements for the structure and contents of safety analysis reports for radioactive waste management facilities are largely inapplicable to the specific circumstances at the Radon sites. The unique safety assessments and analyses needed for these facilities are influenced by:

- **Diversity of Storage Facilities**: Each site typically contains several storage facilities, including closed legacy ones and operating facilities with different structures.
- **Insufficient Data**: Gaps in data regarding the condition and characteristics of radioactive waste, as well as the condition of facility barriers.
- **Radwaste Removal and Processing**: The need to remove and process radioactive waste, considering the safety ranking of storage facilities.

Developing a dedicated regulatory document to address these unique challenges is the most viable way to mitigate this threat. Eliminating this threat is a **highest-priority task**.

11.5.3 Lack of Specific Safety Requirements for Medium-Depth Disposal Facilities and Geological Repositories

The top-level regulatory requirements [9] recently introduced facility types for radwaste disposal at medium depths and in geological repositories (previously, only one type of disposal facility—geological—existed). However, specific requirements for medium-depth disposal facilities and geological repositories are still absent, particularly:

- **Defense in Depth**: Specific requirements for applying the defense-in-depth principle during the design of such disposal facilities are missing.
- **Design Requirements**: Other design-related requirements are also undefined, such as those that ensure the optimal integration of hydrogeological conditions and the physical and chemical properties of waste into facility design (see paras. 6.2.1, 6.2.2 of this Report for further details).

To ensure an optimized approach to the disposal of intermediate-level waste (ILW) and high-level waste (HLW), **specific safety requirements** must be developed for medium-depth disposal facilities and geological repositories, including:

- Disposal depth considerations.
- Hydrogeological site conditions.
- Waste physical and chemical properties.

Additionally, there are **no requirements** for the structure and content of safety analysis reports for medium-depth disposal facilities and geological repositories. These reports are critical as they must be submitted to the SNRIU during the licensing process across the life stages of these disposal facilities (see para. 6.2.3 of this Report for further details).

The urgency of establishing these requirements is underscored by the commencement of activities [99] aimed at constructing disposal facilities for ILW and HLW in Ukraine. Addressing this gap is a **high-priority task** to ensure the safe and effective disposal of radioactive waste and to support licensing and regulatory oversight.

11.6 Radiation Protection

Threats and challenges in this area identified in Reports [2]-[4] have been eliminated or are in the process of elimination through bilateral cooperation projects between the SNRIU and DSA. Additionally, threats highlighted in [2]-[4] are being addressed within SNRIU and USNRC cooperation efforts, including the modernization of the State Register of Radiation Sources to establish a web-based version of the register (see Sections 7, 10 for more details).

However, based on the analysis conducted during the development of this Report, the following new threats and challenges were identified. Addressing these will significantly enhance the regulatory framework for radiation protection safety. The resolution of these challenges is critical to strengthening safety regulations and ensuring effective radiation protection.

11.6.1 Need for Updating the Regulatory Framework with Regard to Establishing Licensing Conditions for the Use of Radiation Sources

The experience in licensing the use of radiation sources has highlighted an urgent need to update the regulatory framework that establishes licensing conditions and safety rules for such activities (see para. 7.1.1 of this Report). The current document [127] was developed over 20 years ago, with the last amendments made more than a decade ago. Although this document is one of the key components of the authorization system for activities involving the use of radiation sources, it no longer aligns with current regulatory needs.

To address this threat, the regulatory document **“Safety Requirements and Conditions (Licensing Conditions) for the Use of Radiation Sources”** [127] should be revised and updated. The revision should incorporate the following:

- **Experience acquired in licensing radiation sources,**
- **Provisions from up-to-date IAEA safety standards,**
- **Requirements of Council Directive 2013/59/Euratom [15],** and
- **Recent changes in the national regulatory framework.**

This update will ensure the regulatory framework remains robust, relevant, and aligned with international best practices and standards.

11.6.2 Lack of Radiation Safety Standards and Rules in Medical Area, with Regard to Nuclear Medicine, Production of Radiopharmaceuticals and Radon Therapy

In the area of using radiation sources, the largest segment involves **medical sources.** Their use stems from advancements in relevant radiation technologies, with the distinctive characteristic being their direct action on the patient. Consequently, the safety of such activities requires special attention.

A significant step toward establishing regulatory requirements for activities involving medical radiation sources has been made in previous years (see para. 7.1.1 of this Report for more details). However, certain activities involving medical radiation sources remain unregulated, each with its unique characteristics.

Eliminating this regulatory gap is a priority task for the SNRIU. It is essential to develop a comprehensive regulatory document that establishes specific requirements and criteria. This document should include the following:

- **Radiation safety rules in nuclear medicine,**
- **Radiation safety rules for the production of radiopharmaceuticals,** and
- **Radiation safety rules in radon therapy.**

Addressing these areas will ensure a more comprehensive regulatory framework, enhancing the safety of activities involving medical radiation sources and safeguarding both patients and personnel.

11.6.3 Lack of Safety Standards and Rules for Uranium Legacy Sites and Decommissioning of Uranium Sites

The presence of both **operating uranium sites** and **uranium legacy sites** in Ukraine necessitates the establishment of an appropriate regulatory framework (see para. 7.1.2 of this Report for more details). Such a framework will enable applicants (licensees) to conduct activities at these sites within established standards and criteria, while providing the regulatory authority with the tools to effectively oversee these activities.

Currently, existing regulatory documents only partially address safety issues for operating uranium sites (planned exposure situations). However, there are no established safety criteria or rules for legacy uranium sites (also planned exposure situations). This regulatory gap has posed a long-standing challenge for the regulation of these activities.

Eliminating this regulatory gap is a priority task for the SNRIU. It is essential to develop a comprehensive regulatory document that includes:

- **Safety requirements, criteria, and rules** for activities at uranium legacy sites, taking into account the specific characteristics of existing sites in Ukraine that fall under this definition.
- **Safety provisions for decommissioning uranium sites**, ensuring adherence to internationally recognized standards and best practices.

Addressing these areas will strengthen the regulatory oversight of uranium-related activities, improve environmental and public safety, and align Ukrainian practices with international norms.

11.6.4 Lack of Specific Requirements and Rules for Radiation Safety of Personnel at Nuclear Facilities

Ukraine continues to implement **Directive 2013/59/Euratom** [15] and **IAEA Standards** by amending its legislation, developing new safety standards, and improving the state regulatory system to ensure a radiation safety level that aligns with the standards established in EU member states. However, it should be noted that organizational and technical measures for radiation protection at nuclear power plants (NPPs) are currently being implemented based on the requirements of **outdated basic documents** in the area of radiation protection and safety.

In this regard, there is a clear need to develop a regulatory document titled **"Radiation Safety Rules for Personnel of Nuclear Facilities"** that corresponds to Directive 2013/59/Euratom [15] and IAEA Standards [125]. This document should address the following key aspects:

- **Radiation protection of personnel** at nuclear facilities.
- **Radiation monitoring** procedures to ensure comprehensive oversight.
- **Planning of radiation-hazardous activities** to minimize exposure risks.
- **Introducing optimization procedures** for managing occupational exposure of personnel, ensuring it is as low as reasonably achievable (ALARA).

Developing and implementing such a regulatory document will modernize the framework for radiation safety at NPPs and ensure compliance with international best practices and standards. For more details, see para. 7.2 of this Report.

11.6.5 Need for Developing Radiation Safety Requirements and Rules for Radiation Sources Used for Non-Medical Human Imaging

Non-medical human imaging using radiation sources includes various applications, such as imaging for professional activities and employment, periodic health evaluations during employment, legal, immigration, or emigration purposes, detection of drugs inside the human body, imaging for health insurance purposes, and more. Despite the growing demand for this practice, the use of radiation sources in such activities remains unregulated (see para. 7.1.1 of this Report).

To address this regulatory gap, it is necessary to develop **regulatory documents on radiation safety rules for radiation sources used in non-medical human imaging**, which should establish specific requirements and rules, including:

- **Application of the justification, protection optimization, and safety principles, as well as dose limits** to ensure the necessity and safety of imaging practices.
- **Elements of the radiation protection program** to provide a comprehensive framework for maintaining radiation safety.
- **Protection of personnel** performing non-medical human imaging procedures, ensuring they are not exposed to unnecessary radiation risks.
- **Protection of persons undergoing non-medical human imaging procedures** to safeguard their health and safety.
- **Protection of the public** to prevent unnecessary exposure during such practices.
- **Safety aspects of non-medical imaging devices**, including the design of the devices and the facilities where they are used.
- **Quality assurance programs** for ensuring the reliability and safety of imaging devices.
- **Investigation of incidents** to identify causes, implement corrective actions, and prevent recurrence.

Developing these regulatory documents is critical to ensuring the safe and justified use of radiation sources for non-medical human imaging while protecting the health and safety of all stakeholders involved.

11.6.6 Need for Developing Regulatory and Methodological Documents for the functioning of the State System of Accounting and Control of Individual Doses as part of the State Register

To ensure the functioning of the updated **State Register**, it is essential to modernize the hardware and software and simultaneously develop a series of **regulatory and methodological documents** as outlined in the **Plan of Measures for the Creation of a Unified State System of Accounting and Control of Individual Radiation Doses**. This initiative falls under the **Cabinet of Ministers Resolution No. 1141 of November 18, 2020, "Some Issues of Creation of the Unified State System of Accounting and Control of Individual Doses"** (see para. 7.1.1 of this Report).

Currently, the absence of these documents creates challenges for the full functionality of the **State Register**. To address this threat, the following documents need to be developed:

- **Forms for registration cards** for occupational exposure doses and doses of the population, along with the procedure for interaction between entities in the field of nuclear energy use.
- **Report forms** for entities in the field of nuclear energy use and the State Register, and the procedure for using the State Register.
- **Qualification requirements** for personnel of entities responsible for determining individual occupational exposure doses.
- **Requirements for quality control** of determination processes (including measurements and calculations) of individual exposure doses.
- **Criteria and requirements** for technical and organizational aspects of occupational exposure control, with an integrated approach to managing both external and internal occupational exposure.

Developing and implementing these documents is crucial to ensuring the **State Register** operates efficiently and effectively, thereby strengthening radiation protection and regulatory oversight.

11.6.7 Need to Develop Requirements for Organizations that Conduct of Intend to Conduct Maintenance of Medical Radiological Equipment

Developing requirements for organizations that conduct or intend to conduct maintenance of medical radiological equipment is essential for improving the quality and safety of medical diagnostic procedures. Effective maintenance and regular inspections ensure optimal equipment performance. Implementing such requirements will ensure effective equipment operation and the timely identification of any deviations that may affect the quality of diagnostic results and pose risks to patients and medical personnel.

Clearly defined requirements will help avoid potential errors and shortcomings in maintenance, which, in turn, will prevent challenges with diagnostic quality or premature failure of diagnostic equipment. Moreover, systematic maintenance and regular inspections carried out by competent organizations will allow timely identification of the need to repair or replace equipment components, thereby avoiding unnecessary expenses and ensuring the efficient use of resources. Eliminating this threat is of high priority.

11.6.8 Lack of Guidance Documents for Accounting Patient Dose from Medical Diagnostic Procedures Using X-ray

Patient dose monitoring measures during medical procedures in radiology should be based on the recommendations of the International Commission on Radiological Protection (ICRP) [93]. The primary objective of such a document is to ensure the accuracy and consistency of dose monitoring during diagnostic procedures and to minimize patient exposure during diagnostics. A standardized approach to

dose calculation, accounting for the specifics of various diagnostic procedures, types of equipment, and patient characteristics, will enable the most accurate assessment of exposure doses compared to national diagnostic reference levels and help optimize the effects of radiation on patient health.

The development of a document with methodological recommendations for recording patient doses from medical diagnostic procedures using X-rays is essential to minimize radiation risks to patients in accordance with international requirements. The introduction of patient reference dose levels into standard practice is common in developed countries and represents a significant step forward in optimizing diagnostic exposure doses for patients. Eliminating this threat is of high priority.

It should also be noted that the safety of activities in the field of NORM management is closely tied to radiation safety. To address all aspects of safety in such activities, proposals for eliminating gaps in this area are presented in Section 9.5, "Radioactive Waste Management and Decommissioning" (see para. 9.5.1).

11.7 Nuclear Security

Threats in this area identified in the roadmap of the FRAMEWORK Project [138] are being addressed through SNRIU and DSA cooperation projects:

- **FUNDAMENTALS I Project** (General Security Provisions for Nuclear Facilities, Nuclear Materials, Radioactive Waste, and Other Radiation Sources);
- **FUNDAMENTALS II Project** (Development of Draft Regulatory Document “Physical Protection Rules for Radioactive Waste and Other Radiation Sources”).

Upon completion of these projects, the SNRIU will continue advancing the regulatory framework for nuclear security in accordance with the areas identified in [138].

12 OVERVIEW OF STATUS OF INTERNATIONAL PROJECTS AND EFFORTS TO RESOLVE IDENTIFIED THREATS

This section presents an overview of the projects ongoing or planned for implementation as of 2023, which are aimed at addressing and mitigating the threats and challenges identified in the previous sections of this report.

12.1 Cooperation between SNRIU and DSA

According to the Agreement between the SNRIU and DSA on Cooperation [1], threats and challenges affecting the SNRIU's ability to perform its functions were assessed in 2015, 2017, and 2020. The results of these regulatory threat assessments are presented in Reports [2], [3], and [4], as well as in this Report. Based on these documents, a priority list of actions (projects) has been defined, implemented within the framework of cooperation, and aimed at eliminating or minimizing the consequences of identified threats. The implementation status of these projects, resolution of current issues, and planning of future activities are reviewed during working (coordination) meetings between the DSA and SNRIU, which are periodically organized and conducted in offline or online formats.

a) 31 May – 1 June 2023, Warsaw (Poland),

b) 27 – 29 November 2023, Drammen (Norway)

Fig. 10.1 – Overview meetings in 2023

The chronology of the implementation of these projects since the start of cooperation is shown in Fig. 10.2. Additionally, brief information on the technical content of the 21 completed projects and 20 ongoing projects (as of the beginning of 2024) is provided.

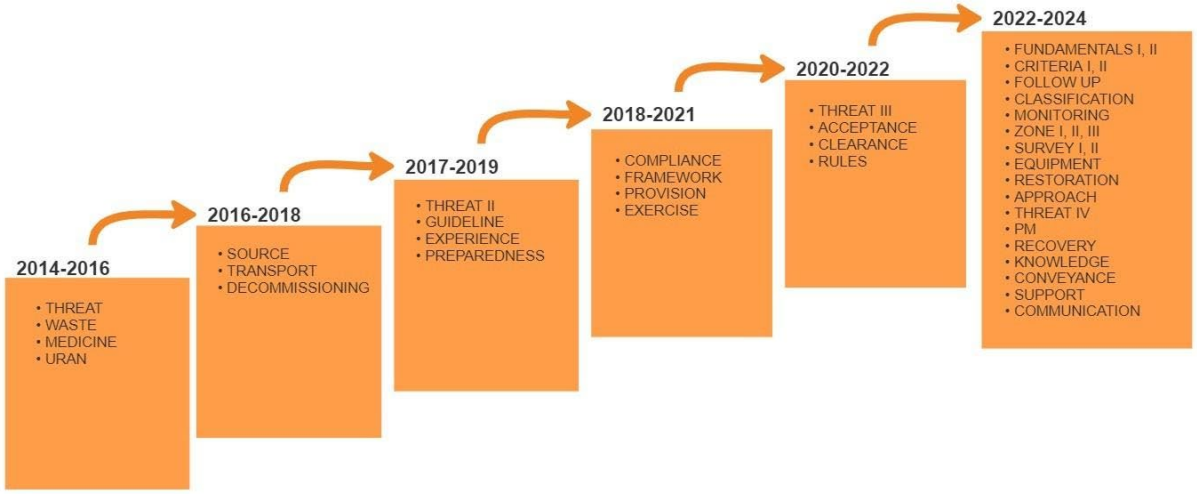


Fig. 10.2 – Projects of cooperation between the DSA and SNRIU (at the time of report writing, projects from 2014 to 2022 are completed, projects for the period 2022-2024 are at different stages of implementation).

12.1.1 THREAT, THREAT II, THREAT III Projects

The objective of these projects was to assess (as of 2015, 2017, 2021, and 2023) threats and challenges affecting the implementation by the SNRIU of its functions as a central executive body in the field of state NRS regulation. The main tasks of the indicated projects were as follows:

- Analysis of the situation, at the time of project implementation, in the field of NRS regulation within the competence of the SNRIU to identify the most significant threats and challenges requiring response.
- Assessment of progress in the regulatory activities of the SNRIU since the previous threat assessment.
- Identification of areas and tasks for joint efforts by the SNRIU and DSA to address the identified threats.

12.1.2 URAN, WASTE, MEDICINE Projects

The **URAN Project** (Support of the SNRIU in Amendment of Ukrainian Regulatory Documents on Radiation Protection in Uranium Industry in Accordance with IAEA Safety Standards and Council Directive 2013/59/EURATOM) aimed to enhance the regulatory framework for nuclear and radiation safety in the uranium industry. The project resulted in the development and implementation of two high-level regulations:

- **Requirements for Institutional Control of Uranium Sites within Restricted Clearance from Regulatory Control** [5], which established procedures for planning, conducting, revising, and terminating administrative control of uranium sites that, after termination of their operations by liquidation or conversion, are under restricted clearance from regulatory control.

- **General Radiation Safety Provisions for Uranium Ore Mining and Milling** [12], which established safety standards for uranium ore mining, milling, and termination of these operations, including designing, siting, construction, upgrading, operation, decommissioning, and temporary shutdown of uranium mining and milling facilities.

The **WASTE Project** (Development of General Safety Provisions for Radioactive Waste Management in Ukraine) focused on improving the regulatory framework for nuclear and radiation safety in radioactive waste management. Two high-level regulations were developed and implemented:

- **General Safety Provisions for Predisposal Management of Radioactive Waste** [7], which established safety criteria and main NRS safety requirements for all stages prior to radioactive waste disposal.
- **General Safety Provisions for Disposal of Radioactive Waste** [9], which set the main requirements for NRS assurance under radioactive waste disposal, protecting personnel, the population, and the environment from possible radiation impacts during the facility's operational period and for the long-term period after its closure.

The **MEDICINE Project** (Support of the SNRIU in the Amendment of Ukrainian Regulatory Documents on Radiation Protection in Medicine in Accordance with the IAEA's International Safety Standards and Council Directive 2013/59/EURATOM) sought to improve the regulatory framework for radiation safety in medicine. Two high-level regulations were developed and implemented:

- **General Safety Rules for Medical Radiation Sources** [6], which established safety criteria and requirements for all health care institutions that use radiation sources for medical purposes.
- **Radiation Safety Rules of Using Radiation Sources in Brachytherapy** [8], which defined safety principles and protection criteria for personnel and patients against radiation risks in brachytherapy.

12.1.3 SOURCE, TRANSPORT, DECOMMISSIONING Projects

The **SOURCE Project** (Development of a National Regulation on Radiation Protection in the Use of Radiation Sources) aimed to improve the national regulatory framework for radiation protection. During its implementation, the high-level document **"Basic Requirements for Assurance of Radiation Protection and Safety"** was developed. This regulation establishes systematic radiation safety requirements for the safe use of radiation sources (see Section 7 of this Report for details). The title and content of the document were revised to incorporate comments and recommendations from international experts, expanding its scope and aligning it with the provisions of Council Directive 2013/59/Euratom dated 5 December 2013. The document under development also reflects the updated [127] provisions of the Law **"On Human Protection against Ionizing Radiation"** [122] and the updated **Radiation Safety Standards of Ukraine (NRBU)**. After its registration with the Ministry of Justice of Ukraine and its entry into force, the final version of the regulation will be shared with the DSA.

The **TRANSPORT Project** (Revision of the Regulatory Document "Rules for Nuclear and Radiation Safety in Transport of Radioactive Materials") focused on establishing a modern basis for safety regulation in the transport of radioactive materials. This included all stages of the process, such as preparation, loading, transfer, transit storage, unloading, and final acceptance of radioactive materials and packages. The high-level regulation **"Rules for the Safe Transport of Radioactive Material"** [10] was developed and implemented as part of the project.

The **DECOMMISSIONING Project** (Development of High-Level Regulatory Documents for Decommissioning Safety of Nuclear Facilities) aimed to strengthen regulatory activities related to the decommissioning of nuclear facilities. Two high-level regulations were developed and implemented during the project:

- **General Safety Provisions for Decommissioning of Nuclear Facilities** [11], which established safety criteria and NRS requirements at all stages prior to facility decommissioning.
- **Requirements for the Structure and Contents of the Operator's Documents for Licensing Application for Activities at the Stage of Nuclear Facility Decommissioning** [14], which specified the format and content requirements for licensing documents.

12.1.4 GUIDELINE, EXPERIENCE, PREPAREDNESS Projects

The **GUIDELINE Project** (Development of General Regulatory Requirements for the Structure and Contents of NPP Emergency Documentation) aimed to develop a regulatory document establishing requirements for the development, use, review, and maintenance of emergency documentation, including regulatory ones, for Ukrainian NPP units. During the project implementation period, the regulation **"Requirements for the Structure and Contents of Emergency Documentation for NPPs"** was developed between 2017 and 2019 [13].

The **EXPERIENCE Project** (Development of Guideline for Assessment of Safety Culture and Human and Organizational Factors in Operating Experience Analysis) aimed to enhance the operational safety of Ukrainian NPPs by preventing operational events caused by human and organizational factors. The project resulted in the development of the **Guideline for Assessment of Safety Culture and Human and Organizational Factors in Operating Experience Analysis** for Ukrainian NPPs. This Guideline is an internal document of the SNRIU and is used by SSTC NRS experts as part of the operating experience system in the analysis of operational events.

The **PREPAREDNESS Project** (Enhancing Emergency Preparedness and Response in Ukraine) aimed to contribute to the harmonization of the national regulatory framework in the field of emergency preparedness and response with the up-to-date requirements of the IAEA and Euratom Directives. During the project implementation period, the **National Radiation Emergency Response Plan**, the main regulation defining emergency preparedness and response measures in Ukraine, was revised. The document was submitted to all interested parties for consideration and approval, after which it will be submitted to the Ministry of Justice of Ukraine for registration. It should be noted that the adoption of the **Law of Ukraine** [127] was one of the prerequisites for the approval of the **National Radiation Emergency Response Plan**. After its entry into force, the final version of the regulation will be provided to the DSA.

12.1.5 COMPLIANCE, FRAMEWORK, PROVISION, EXERCISE Projects

The **COMPLIANCE Project** (Improvement of the Regulatory Framework on the Safe Transport of Radioactive Materials) resulted in the following implementations:

- Revision of the regulation on the procedure for issuing certificates for the safe transport of radioactive materials;
- Development of the regulation **"Requirements for the Structure and Contents of Safety Analysis Reports for the Design of Radioactive Material or Packaging"**;
- Revision of the regulation **"Safety Requirements and Conditions (Licensing Conditions) for Carrying out Activities on Transport of Radioactive Materials"** (NP 306.6.095-2004) [58]; and
- Revision of the regulation **"Requirements for the Safety Analysis Report for Carrying out Activities on Transport of Radioactive Materials"** (NP 306.6.096-2004) [59].

All four documents are at different stages of approval in interested ministries and institutions. After their entry into force, the final versions of the regulations will be provided to the DSA.

The **FRAMEWORK Project** (Definition of Areas to Improve the Regulatory Framework for Nuclear Security) defined the areas and priority measures for further rule-making activities of the SNRIU in the area of nuclear security.

The **PROVISION Project** (Development of Proposals/Recommendations on Procedure and Criteria for the Recognition of Radiation Protection Experts According to Council Directive 2013/59/Euratom and IAEA Standards). The following tasks were performed within the project:

- Development of a recognition procedure to confirm the qualifications of experts in radiation protection (as part of the **Provisions on Radiation Protection Expert**);
- Development of a database of experts (database structure, software), which will be submitted (installed) to the SNRIU after the relevant regulatory framework is improved.

The SNRIU will send the **"Provisions on Radiation Protection Expert"** to the Cabinet of Ministers of Ukraine for approval. After its entry into force, the final version of the regulation will be provided to the DSA.

The **EXERCISE Project** (Strengthening Emergency Preparedness and Response in Ukraine) contributed to strengthening the capacities of the SNRIU in this area of regulatory activity. During the project implementation in 2019–2021, emergency exercises were carried out according to the developed scenarios:

- No. 1: "Conventional accident at an NPP on the territory of a third country with the transboundary impact threat";
- No. 2: "Conventional accident at a nuclear facility on the territory of Ukraine";
- No. 3: "Conventional accident with the loss of control over a radiation source on the territory of Ukraine/Norway".

12.1.6 ACCEPTANCE, CLEARANCE, RULES Projects

The **ACCEPTANCE Project** (Development of Regulatory Document on Requirements and Rules for Safe Management of Disused Sealed Radiation Sources Declared as Radioactive Waste) conducted activities to identify the needs for improving the regulatory framework on the safe management of disused sealed radiation sources, which are declared as radioactive waste. A draft structure and contents of the document were developed, and the development of the regulation is currently underway.

The **CLEARANCE Project** (Development of Regulatory Document on Clearance of Radioactive Materials from Regulatory Control) aims to revise the regulatory document NP 306.4.159-2010 **"Procedure for Clearance of Radioactive Materials from Regulatory Control within Practices"** [114]. Currently, revision 1 of the above regulation has been developed.

The **RULES Project** (Management and Compliance Assurance System for the Safe Transport of Radioactive Materials) resulted in the development of two draft regulations:

- **Requirements for the Management System for the Safe Transport of Radioactive Materials**;
- **Program for Compliance Assurance with the Rules for the Safe Transport of Radioactive Materials**.

These regulations are currently at different stages of approval in the interested ministries and institutions. After their entry into force, the final versions of the regulations will be provided to the DSA.

12.1.7 FUNDAMENTALS I, FUNDAMENTALS II, CRITERIA I, CRITERIA II, FOLLOW-UP, CLASSIFICATION, MONITORING, ZONE I, ZONE II, SURVEY I, SURVEY II, EQUIPMENT, RESTORATION, APPROACH, PROJECT MANAGEMENT Projects

The **ACCEPTANCE Project** (Development of Regulatory Document on Requirements and Rules for Safe Management of Disused Sealed Radiation Sources Declared as Radioactive Waste) conducted activities to identify the needs for improving the regulatory framework for the safe management of disused sealed radiation sources, which are declared as radioactive waste. A draft structure and content of the document was developed, and the regulation is currently under development.

The **CLEARANCE Project** (Development of Regulatory Document on Clearance of Radioactive Materials from Regulatory Control) aims to revise the regulatory document NP 306.4.159-2010 **"Procedure for Clearance of Radioactive Materials from Regulatory Control within Practices"** [114]. Revision 1 of this regulation has been developed.

The **RULES Project** (Management and Compliance Assurance System for the Safe Transport of Radioactive Materials) resulted in the development of two draft regulations:

- **Requirements for the Management System for the Safe Transport of Radioactive Materials**;
- **Program for Compliance Assurance with the Rules for the Safe Transport of Radioactive Materials**.

These regulations are currently at different stages of approval in the relevant ministries and institutions. Once they enter into force, the final versions will be provided to the DSA.

The **FUNDAMENTALS I Project** (General Security Provisions for Nuclear Facilities, Nuclear Materials, Radioactive Waste, and Other Radiation Sources) involved an in-depth analysis of EU and IAEA documents, and the final version of the regulation was developed. The title of the document remains the same as the project title.

The **FUNDAMENTALS II Project** (Development of Draft Regulatory Document "Physical Protection Rules for Radioactive Waste and Other Radiation Sources") will address the physical protection rules for radioactive waste and other radiation sources under SNRIU regulatory oversight. This will help improve the regulatory framework for nuclear security in accordance with EU and IAEA recommendations. EU and IAEA documents, as well as the national regulatory framework on nuclear security, including physical protection, have been analyzed.

The **CRITERIA I Project** (Development of Regulatory Document "Criteria for Acceptability of Medical Radiological Equipment Used in Diagnostic Radiology") is focused on eliminating significant gaps in the regulatory control on the acceptance criteria for X-ray diagnostic equipment. It also aims to harmonize the national regulatory framework on the safe use of medical radiation sources with international safety requirements. As of the end of 2023, gaps in the Ukrainian regulatory framework have been identified and analyzed, and revision 1 of the regulatory document has been developed.

The **CRITERIA II Project** (Rules for Provision of the Services of Acceptance, Commissioning, Periodic Performance Testing, and Decommissioning of Medical Diagnostic Radiological Equipment) is at the stage of analyzing international and Ukrainian experience, as well as the accreditation/certification system and relevant standards. These analyses will form the basis of the new regulatory document.

The **FOLLOW-UP Project** (Development of Regulatory Document "Radiation Safety Rules in Interventional Radiology") identified and analyzed gaps in the Ukrainian regulatory framework for radiation safety in

interventional radiology, comparing them with international standards and recommendations. The structure and content of the regulatory document have been developed, and revision 1 is being finalized.

The **CLASSIFICATION Project** (Development of Regulatory Document "Acceptability Criteria for the Disposal of Radioactive Waste in Disposal Facilities of Different Types") identified the needs for regulatory framework improvements regarding general criteria for radioactive waste classification for disposal in various types of facilities. Revision 1 of the structure and contents of the regulatory document has been developed, and revision 1 is being developed.

The **MONITORING Project** (Development of Regulation on Radiation Control of Nuclear Installations in Terms of Radiation Control of Releases and Discharges and Environmental Radiation Monitoring in the Impact Area of Nuclear Installations) analyzed gaps and identified needs for improving the regulatory framework on environmental radiation monitoring. Currently, a draft structure and content of the requirements for radiation control of nuclear installations is being developed.

The **ZONE Project** (Development of Priority Regulatory Documents to Ensure Safety Regulation of Nuclear-Hazardous Facilities in the Chornobyl Exclusion Zone after Restoring Ukraine's Control over its Territory following Temporary Seizure by Russian Federation Troops) developed recommendatory documents to eliminate gaps in the regulatory framework for Ukraine, focusing on restoring control over nuclear hazardous facilities impacted by hostilities:

- **Recommended approach to state regulation of the safety of nuclear and radiation facilities located in the Chornobyl exclusion zone, affected by hostilities**;
- **Recommended procedure for restoring the safety level of nuclear and radiation facilities located in the Chornobyl exclusion zone, affected by hostilities**.

The **ZONE II Project** (Development of a Program for Restoring State Safety Regulation for the Operation of Nuclear Facilities at the Zaporizhzhia NPP Affected by Hostilities and Occupation by Russian Federation Troops) will develop programs for the first time, based on existing international experience. The program will consider:

- Analysis of experience in restarting the Armenian NPP;
- Analysis of global experience in state regulation of nuclear and radiation safety during the COVID-19 pandemic;
- National experience gained after the de-occupation of ChNPP, and developments regarding the resumption of ZNPP operations.

Currently, activities are at the stage of multilateral analysis.

The **SURVEY I Project** (Radiation Survey of the Territories Affected by Hostile Military Occupation of Ukrainian Territory and War Peculiarities. Phase 1: Conducting Radiation Survey in Kyiv Region) carried out a radiation survey in the Kyiv region and collected sufficient data on the radiological situation for state authorities to implement necessary measures and inform the public. An **Analytical Report "Recommendations for Radiation Surveys under Hostilities"** was developed.

The **SURVEY II Project** (Radiation Survey of the Territories Affected by Hostile Military Occupation of Ukrainian Territory and War Peculiarities. Phase 2: Conducting Extended Radiation Survey in Kyiv Region) achieved the following results:

- An extended radiation survey of the Kyiv region was conducted;
- Sufficient data on the radiological situation were collected for state authorities to implement necessary measures and inform the public;
- Measures were taken to inform the relevant communities in occupied territories about radiological risks;

- Recommendations were developed for informing residents about wartime radiological risks.

The **EQUIPMENT Project** (Purchase of Gamma Spectrometer with CZT Detector Model Q4GR-001A-FG and Portable Gamma Spectrometer with HPGe detector model AEGIS-GC40-RDC) provided SSTC NRS with equipment for radiation monitoring. Two exercises were conducted in 2023 for SSTC NRS experts on using the provided equipment. The equipment was used in radiation surveys of territories affected by radiation risk, preliminary analysis of radionuclide content in food and water, and in the survey of locations where radioactive materials were found in illicit trafficking.

The **RESTORATION Project** (Restoration of Radiation Well-being in Ukraine in Territories Liberated from Occupation Troops and Nationwide, Phase 1: Strengthening the Technical Support Capabilities in Assessment of Doses to the Public Using Data from Independent Environmental Monitoring Stations) contributed to strengthening technical support for assessing radiological impact. An analytical report on recommended monitoring post locations and necessary data for forecast estimates was developed.

The **APPROACH Project** (Development of Regulatory Documents with Requirements for Implementation of General Safety Provisions for Decommissioning of Nuclear Facilities) is analyzing gaps in implementing general safety provisions for decommissioning of nuclear facilities in the Ukrainian regulatory framework, comparing them with international standards and recommendations.

The **PROJECT MANAGEMENT Project** (Support and Coordination of Activities under Joint DSA/SNRIU Projects) aims to form an effective system for monitoring and coordination of ongoing projects, including implementation monitoring, periodic reporting, and information exchange. This project will be implemented from 2023 to 2028.

12.1.8 CONVEYANCE, ZONE 3, KNOWLEDGE, RECOVERY, COMMUNICATION, SUPPORT Project

CONVEYANCE Project (Preparation and Conveyance of Radiation Sources under War Risk Conditions). The project will result in the analysis of the need to adapt current requirements for the safety of the preparation and conveyance of radiation sources under war risk conditions and the development of two regulatory documents:

- **State Safety Regulation in Preparation and Conveyance of Radiation Sources under War Risk Conditions**;
- **Procedure for Preparation and Conveyance of Radiation Sources under War Risk Conditions**.

Support will also be provided to the SNRIU in regulatory activities as part of the authorizing process for the conveyance of radiation sources under war risk conditions. Activities under the project are at the initial stage.

ZONE 3 Project (Development of an Action Plan to Renew and Complete Licensing of the Neutron Source at the Construction and Commissioning Life Stage Taking into Account Long-Term Shutdown and Damage Resulting from Shelling by the Russian Federation). The project's objective is to develop an Action Plan to Renew and Complete Licensing of the Neutron Source, taking into account the long-term shutdown and damage resulting from shelling by the Russian Federation, in order to support SNRIU licensing and supervisory activities. The project is at the initial stage of implementation.

KNOWLEDGE Project (Managing Knowledge Vital for Protection of the Personnel Involved in Military Operations, the Public, and the Environment during a Nuclear or Radiation Accident Caused by Hostilities). The project involves the development and presentation of a fully functional training platform containing a self-training course on the protection of the public, the environment, and personnel engaged in military

operations during a nuclear or radiation accident caused by hostilities. These materials will summarize SNRIU/SSTC NRS experience in the assessment of radiological consequences, radiation situations, forecasting exposure doses received by individuals and the public, as well as environmental sampling, processing, and measurement. They will be used by new SNRIU/SSTC NRS experts or personnel of the Armed Forces of Ukraine during relevant tasks. The project is at the initial stage of implementation.

RECOVERY Project (Assessment of Time Available for Operator Response under Total SBO at ZNPP Considering Reduced Decay Power after a Long-term Shutdown). The project's objective is to describe the development of accident scenarios, assess the time available until severe damage to nuclear fuel begins, and assess radiological consequences under total SBO of NPP and/or loss of the ultimate heat sink at ZNPP, taking into account the state of long-term shutdown. The project is at the initial stage of implementation.

COMMUNICATION Project (Raising Awareness of SNRIU/SSTC NRS Experts and Mass Media Experts in the Area of Risk and Crisis Communications during Events Related to Nuclear and Radiation Threats). The project is aimed at raising awareness among media representatives on nuclear and radiation threats and consequences, as well as training for cooperation mechanisms between government agencies in the area of nuclear safety and the media. Activities under the project are at the initial stage.

SUPPORT Project (Support to the SNRIU in Licensing of Medical Radiation Sources). The project will provide scientific and technical support to the SNRIU regarding the licensing of activities and facilities related to the use of medical radiation sources (under martial law and in the post-war period) to ensure the timely provision of emergency medical care to wounded military personnel, injured civilians, and the public in general. The project's implementation will contribute to ensuring, in the context of current challenges, an appropriate level of radiation safety during the use of medical radiation sources in accordance with national standards and regulations, Council Directive 2013/59/Euratom, and IAEA safety standards. The project is at the initial stage of implementation.

A key attribute of the majority of the projects listed in this paragraph is a gap analysis, which includes the systematization of the relevant Ukrainian regulatory framework and its comparison with the requirements of EU directives, provisions of IAEA safety standards, and other guidance documents relevant to the specific project. Another important attribute is the analysis of international experience and best regulatory practices associated with the main part of the project, which usually involves the development and implementation of new regulations in the Ukrainian regulatory environment. Each project also demonstrates how the results of the gap analysis and advanced international practices have been integrated into the main task to develop appropriate regulatory requirements or guidelines. Each project includes a series of meetings with stakeholders at different stages of the development and approval of the relevant regulatory document.

12.1.9 Expanding the Scope of Cooperation: International Collaboration and Capacity Building

Cooperation between the SNRIU and DSA is carried out not only within the above projects but also covers a number of other important activities. In 2023, at the invitation and with the assistance of the DSA and the US Department of State, two meetings of the international coordination group; Information Sharing Initiative (ISI) on Technical Assistance to Ukraine in the Area of Radiation and Nuclear Security, working closely with the G7 Initiative "Global Partnership against the Proliferation of Weapons and Materials of Mass Destruction," were held. The meetings were attended by representatives from Norway, the USA, Canada, Great Britain, Sweden, Finland, France, Denmark, Japan, and Ukraine, as well as colleagues from the IAEA, EBRD, EU, United Nations, and other international organizations. During the meetings, the Ukrainian delegation reported on the crimes committed by Russia in the nuclear energy sector during Russia's full-scale invasion of Ukraine, informed about existing nuclear risks and threats, presented the

results of current projects, and proposed new cooperation initiatives. New challenges and current needs for assistance arising from Russia's full-scale war against Ukraine were also discussed.

Fig. 10.3 – Participants of the Information Sharing Initiative meeting (ISI), 19-20 April 2023, Oslo, Norway

In June 2023, a workshop on establishing national technical support organizations for nuclear safety and security was held in Oslo, Norway. It was organized jointly by the DSA and IAEA. The workshop provided an opportunity for experience exchange on establishing national technical support organizations, considering the experiences of member states of the Technical Support Organizations Forum (TSOF) and the European and Central Asian Security Network (EuCAS). During the workshop, an SSTC NRS representative presented a report on the challenges associated with the war in Ukraine and the role of the TSO during this period. The results achieved within the SURVEY Project, implemented with DSA support, were also presented in detail. This project involved a radiation survey of the Kyiv region, which had been affected by the military occupation and hostilities. The DSA and OECD NEA organized and hosted the International Conference "Radiological Protection during Armed Conflict: Improving Regulatory Resilience and Operational Applications" (22-24 November 2023, Oslo, Norway) to address radiation safety and security issues. Based on the proposals of the NEA Committee on Radiological Protection and Public Health and the ongoing cooperation between the SNRIU and DSA, the conference aimed to address key issues related to radiological protection in the context of armed conflict, including potential radiological emergencies caused by damage to nuclear and radiation facilities. SNRIU and SSTC NRS representatives actively participated in the conference.

Fig. 10.4 – Participation of SSTC NRS and SNRIU in Conference "Radiological Protection during Armed Conflict: Improving Regulatory Resilience and Operational Applications" (22-24 November 2023, Oslo, Norway)

12.2 Cooperation between SNRIU and USNRC

Cooperation between the parties has been underway since 2000. The areas of cooperation for a given period are agreed upon during meetings between USNRC and SNRIU representatives and are reflected in the relevant Memorandums of Meetings (Memoranda), which contain a detailed list of tasks planned by the parties to accomplish. The current Memorandum for 2023-2024 [151] envisages cooperation in the following 11 areas:

- oversight and licensing activity;
- risk-informed regulatory activity;
- transport and interim storage of spent fuel;
- VVER reactor pressure vessel embrittlement;
- new fuel management;
- radioactive materials and waste management;
- emergency response and related capabilities;
- safety of uranium facilities;
- regulatory oversight of radioactive sources;
- nuclear security; and
- strengthening of the SNRIU infrastructure.

The tasks performed under USNRC support within the Memorandum [151] are aimed at eliminating a number of threats and responding to the challenges described in Sections 3-7 of this Report, and are as follows:

- define requirements for aging management and lifetime extension for control systems important to safety;

- define requirements for safety assessment with regard to external man-induced hazards;
- analyze operational events at Ukrainian NPPs for 2022–2023;
- strengthen the Ukrainian regulatory framework in the area of siting for NPPs, particularly SMRs;
- develop models for RELAP and TRACE codes to use them in licensing Westinghouse fuel for VVER-440;
- develop models for neutron fluence assessment to use them in licensing Westinghouse fuel for VVER-440;
- develop models for independent calculation of fuel cycles to use them in licensing Westinghouse fuel for VVER-440;
- develop and validate PWR fuel assembly models for MCNP and SCALE packages;
- analyze improved characteristics of PWR HALEU fuel to support decision-making on fuel safety;
- assess safety during the dismantling of the Shelter structures under the New Safe Confinement;
- assess the safety of packages for the transport of radioactive materials, including their buffer storage;
- optimize and strengthen the SNRIU Information and Emergency Center;
- study the experience of the USNRC in the regulation of uranium sites;
- study the possibility of using RAMP codes for the safety assessment of uranium sites;
- modernize the State Register of Radiation Sources.

When determining the cooperation content, the parties take into account the current situation in the area of regulation in Ukraine and the challenges faced by the SNRIU, as well as the results of activities during previous periods, the existing experience, and the professional potential of Ukrainian experts. Special attention is paid to avoiding duplication with activities carried out by the SNRIU with its other partners.

To this end, from the beginning of 2021 to August 2023, USNRC and SNRIU representatives held joint meetings both online and offline. On 20 May 2022, during an online working meeting with USNRC Chairman Christopher Hanson, the issues of eliminating the use of fuel produced by the Russian Federation at VVER-440 units of Ukrainian NPPs, regulation of nuclear and radiation safety under conditions of military operations, and future areas of bilateral cooperation were discussed. These included, in particular, the support of the Ukrainian regulator for further study of the experience in licensing advanced nuclear technologies implemented in the AP1000 and SMR unit designs.

Current and promising issues of bilateral cooperation were discussed during a meeting between SNRIU Chairman and Chief State Inspector for Nuclear and Radiation Safety of Ukraine Oleh Korikov and USNRC Chairman Christopher Hanson on 15 March 2023, as part of the 35th annual USNRC Information Conference (13-16 March 2023, Washington, DC, USA).

Fig. 10.5 – Meeting of the USNRC and SNRIU Chairmen, 15 March 2023

On 1 August 2023, the Chairmen of the SNRIU and USNRC signed an Agreement on the Exchange of Technical Information and Cooperation in the Area of Nuclear Safety. The agreement provides for the exchange of experience and interaction between the regulators of the two countries on the regulation and oversight of the safety and security of nuclear facilities and radioactive materials, the application of safeguards, and the impact on the environment.

Fig. 10.6 – Signing an Agreement on Exchange of Technical Information and Cooperation in the Area of Nuclear Safety between the SNRIU and USNRC, 1 August 2023

12.3 Ongoing INSC Projects for Strengthening SNRIU Capabilities

The EU continues to provide technical assistance to the SNRIU on a systematic basis under the Instrument for Nuclear Safety Cooperation (INSC) through the funding of national Annual Action Programs. During 2021-2023, these activities were conducted under Annual Action Programs 2014-2015 and 2018 in the framework of INSC projects [152] [153], implemented with DSA participation. Due to the full-scale armed aggression of the Russian Federation, in order to meet the priority needs of the SNRIU, in April 2022, the European Commission decided to expand the UK/TS/58 Project [152] with four additional tasks. As of the end of 2023, all the above projects and tasks were successfully completed, and the new Project INSC U3.01/21 (UK/TS/59) "Continued Alignment of the Ukrainian Regulatory Regime with the EU Acquis" [30], covering the following tasks, has started (with DSA participation):

Task 1: Support to the SNRIU in activities implemented in the framework of the ENSREG Topical Peer Reviews on Ageing Management and Fire Protection. The task includes the following two parts:

- Implement measures to improve ageing management practices for components and structures based on the first topical peer review performed in 2018; and
- Support the SNRIU in respective activities under the second TPR (in 2024), which is focused on the fire protection of nuclear installations situated in Ukraine. This task aims to eliminate the threats referred to in Section 3 of this Report.

Task 2: Introduction of graded and integrated approaches in regulating the safety of radioactive waste and radioactive material management. The support will be provided to the SNRIU in implementing the indicated approaches to regulating the safe management of radioactive waste and materials, including the following regulatory areas:

- Regulation of safety in integrated management of radioactive waste of various origins using the graded approach;
- Regulation of remediation safety with the application of the graded approach; and
- Regulation of safety in the clearance of radioactive materials with the application of the graded approach. This task aims to eliminate the threats referred to in Section 6 of this Report.

Task 3: Providing methodological unity in radiation monitoring through the development of guidance on radiation monitoring in planned, emergency, and existing exposure situations. This task is intended to ensure the development of programs for source monitoring and environmental monitoring, and that the results from the monitoring are recorded and made available. To unify monitoring programs, it is planned to develop methodological guidance for licensees on radiation monitoring in planned, emergency, and

existing exposure situations and for different stages of emergency response, including the period of transition to stabilization and resumption of normal activities. Task 3 aims to eliminate the threats referred to in Section 5 of this Report.

Task 4: Strengthening of SNRIU regulatory capabilities in licensing load-following modes for NPP units. This task is intended to support the SNRIU in licensing measures implemented by the operating organization aimed at introducing the daily power control mode for NPP units for power control per day within a range of 100-75-100% power level. To support the licensing process, it is necessary to enhance the national regulatory framework by establishing the procedure for regulatory review and independent technical assessments of the safety justifications for implementing load-following modes at Ukrainian NPPs. Task 4 aims to eliminate the threats referred to in Section 3 of this Report.

Task 5: Support to the SNRIU in developing and implementing the national strategy for harmonization of the nuclear regulatory framework with EURATOM Directives. This task is intended to support the SNRIU in developing and implementing provisions of the national strategy aimed at achieving full coordination and harmonization of Ukrainian regulatory documents on nuclear and radiation safety with the legislation of the European Union on nuclear energy (EURATOM Directives). This task aims to eliminate the threats described in Sections 2-8 of this Report.

Task 6: Strengthening regulatory capabilities in severe accident management to assess the possibility of implementing in-vessel melt retention for Ukrainian NPPs (VVER-440 and VVER-1000). This task is aimed at ensuring SNRIU support in the regulatory review of the operator's justifications for safety measures in accordance with the C(I)SIP [28] on the mitigation of severe accident consequences. The task provides for an in-depth study of certain severe accident phenomena and the assessment of implementing the Modernization Program as a whole. Special attention will be focused on studying the possibility of implementing in-vessel melt retention for Ukrainian NPPs (VVER-440 and VVER-1000). In addition, this task aims to eliminate the threats referred to in Section 2 of this Report.

12.4 Cooperation of SNRIU with the International Atomic Energy Agency

In compliance with Cabinet Resolution [154], the SNRIU is responsible for cooperation with the IAEA. Over the past years, a number of national projects for Ukraine have been ongoing under the IAEA Technical Cooperation Program, including:

- Development of Laboratory Capacities for Diagnosis, Monitoring, and Prevention of New Animal Diseases;
- Strengthening the Capabilities of Ukraine for the Production of Radiopharmaceuticals for Healthcare;
- Strengthening the Capabilities for Diagnostics and Treatment of Cancer;
- Strengthening Radiotherapy and Medical Imaging in Ukraine;
- Supporting Ukrainian Organizations in Decommissioning, Radioactive Waste, and Spent Nuclear Fuel Management, including Radio-Environmental Monitoring.

SSTC NRS experts also participated in 6 Coordinated Research Projects (CRP) under the relevant IAEA program, which covered areas such as probabilistic safety analysis for multi-unit/multi-reactor NPP sites; use of the mobile laboratory's measurement capabilities and decision support system in the event of a severe accident; in-vessel melt retention; assessment and optimization of hybrid energy systems with nuclear and renewable energy sources, etc.

As part of cooperation with the International Atomic Energy Agency (IAEA), the implementation of national projects within the Technical Cooperation Program for Ukraine was disrupted in 2022 due to the unprovoked armed aggression of the Russian Federation against Ukraine. In 2023, the projects were

gradually resumed. The IAEA's main focus within the Technical Cooperation Program is on medical projects for Ukraine and the provision of equipment for hospitals.

Currently, the IAEA adheres to the principal position of continuing to apply the IAEA safeguards to nuclear facilities and materials in Ukraine in accordance with international law and the Agency's Statute, based on the fact that the Autonomous Republic of Crimea and Ukrainian regions occupied by the Russian Federation are an integral part of Ukraine.

Within the IAEA Response and Assistance Network (RANET), partner countries have already provided and continue to provide equipment to organizations in Ukraine. This equipment is a necessary factor in restoring the capabilities of organizations affected during the occupation by Russian troops and will be used to overcome the negative consequences for nuclear and radiation safety caused by military operations on the territory of Ukraine.

Due to the full-scale unprovoked invasion of Ukrainian territory by the Russian Federation, the implementation of the Integrated Nuclear Security Support Plan (INSSP) for Ukraine was postponed.

Since September 2022, at the request of President of Ukraine Volodymyr Zelenskyi, permanent IAEA missions have been stationed at all Ukrainian NPPs, including the Zaporizhzhia NPP occupied by the Russian aggressor. The missions work in accordance with the Technical Tasks developed by central executive authorities and approved through exchanges of notes between Ukraine and the IAEA. Every week, Ukrainian institutions and organizations receive a report on the mission's activities, and the results of the week's activities are discussed with the Ukrainian party via video conference.

SNRIU and SSTC NRS experts are actively involved in the process of improving IAEA standards, participating in the work of three IAEA safety standards committees in the areas of nuclear safety (NUSSC), emergency preparedness and response (EPReSC), and safe transport of radioactive materials (TRANSSC). In addition, SSTC NRS, as the national coordinator from Ukraine, provides the operation of the Incident Reporting System for Research Reactors (IRSRR), the functioning of the International Reporting System for Operating Experience (IRS), and the International Nuclear and Radiological Event Scale (INES).

12.5 Other Areas of SNRIU International Cooperation

In addition to the SNRIU's international cooperation areas presented in the previous sections, the Ukrainian nuclear regulator has actively cooperated in recent years with regulators of other countries and international organizations, also under relevant bilateral agreements.

Grant Agreement No. 007 (Chornobyl Nuclear Safety Project) [155] between the SNRIU and the European Bank for Reconstruction and Development, which is discussed in Section 6 of this Report, has been successfully implemented.

In 2022, the SNRIU resumed bilateral cooperation with the Radiation and Nuclear Safety Authority in Finland (STUK). A Memorandum of Understanding was signed between the State Nuclear Regulatory Inspectorate of Ukraine and the Radiation and Nuclear Safety Authority of Finland (STUK) on cooperation and information exchange in the area of nuclear and radiation safety [156].

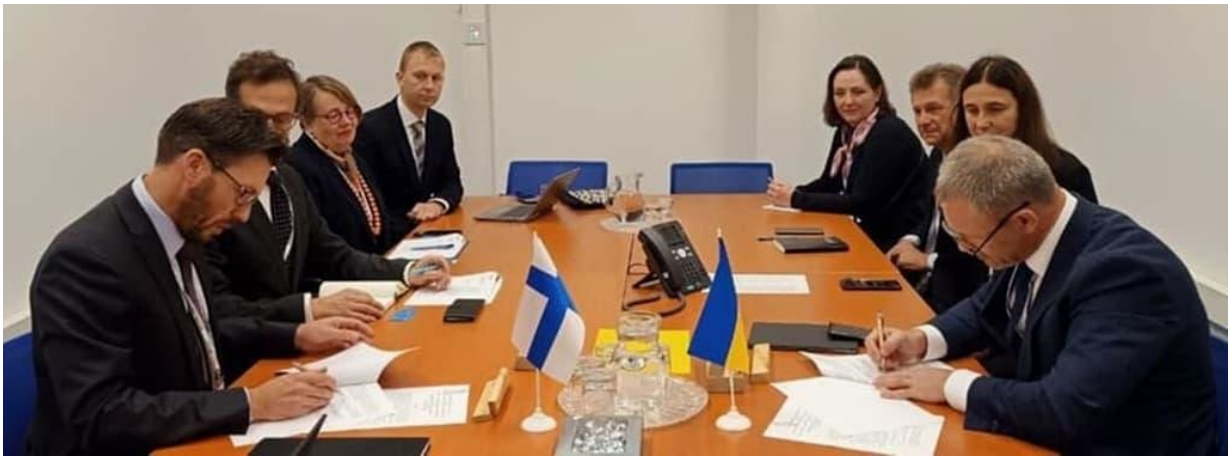


Fig. 10.7 – Signing a Memorandum of Understanding between the SNRIU and STUK, September 2022

The first significant example of cooperation between the two agencies is the activities under the new Finnish-Ukrainian Radiation and Nuclear Safety Cooperation Project – FURN, which includes two main tasks. The first is to further strengthen the development of the Ukrainian nuclear regulator and its TSO by reforming its working methods, improving personnel qualifications, and expanding its international cooperation. This task is planned to be accomplished, in particular, through STUK expert support in implementing the following recently launched SNRIU-DSA cooperation projects (a brief description of the projects is presented in Sections 10.1.7 and 10.1.8 of the Report):

- RESTORATION;
- RECOVERY;
- ZONE 2;
- CONVEYANCE;
- KNOWLEDGE;
- COMMUNICATION.

The second task involves providing the SSTC NRS with a new mobile radiation reconnaissance laboratory, NORDIM, the Nordic Radiation Detection and Identification Module. In addition to STUK, financial support for this task will be provided by the nuclear regulators of the northern countries: DSA, SSM (Sweden), and DEMA (Denmark). The project will last 2 years (starting in 2024), with the possibility of extension for another two years.

In 2023, the SNRIU started cooperation with the Canadian Nuclear Safety Commission (CNSC). In August, a Memorandum of Understanding was signed for cooperation and information exchange on nuclear regulation between the State Nuclear Regulatory Inspectorate of Ukraine and the Canadian Nuclear Safety Commission [157].

Fig. 10.8 – Signing of a Memorandum of Understanding between the SNRIU and CNSC, August 2023

According to the signed document, the priority issues for bilateral cooperation in the near future are related to regulatory experience exchange in the following technical areas:

- Pre-licensing technical assessment of nuclear facility design;
- Restoration of safe operation for nuclear facilities;
- Safety regulation for the remediation of uranium legacy;
- Safety of radioactive waste disposal.

On 28 September 2023, an Agreement on Information Exchange and Cooperation on the Safe Regulation of Peaceful Nuclear Energy Use was signed between the State Nuclear Regulatory Inspectorate of Ukraine and the Office for Nuclear Regulation of the United Kingdom of Great Britain and Northern Ireland. According to the agreement, cooperation between the parties will be implemented through mutual assistance in the training of scientific and technical personnel; personnel exchange (for information exchange or training on technical regulation); formation of joint working groups to implement specific cooperation measures on nuclear safety and related research; and exchange of information.

The parties may exchange information on nuclear safety, in particular: regulation of siting, construction, commissioning, operation, decommissioning of civil nuclear facilities and radioactive waste management facilities; regulation of the transport of radioactive materials; scientific research related to licensing and regulatory control of nuclear facilities; regulation of radioactive sources; regulatory interest regarding new reactor technologies; and inspections of nuclear and production facilities.

Fig. 10.9 – Signing a Memorandum of Cooperation between the SNRIU and ONR, September 2023

The information presented in Sections 10.1-10.5 of this Report provides a general overview of the status, main areas, and components of international support aimed at eliminating threats and challenges affecting SNRIU activities in the relevant areas. A list of such existing threats, identified as a result of the current assessment, for which no remedial action has been identified in the framework of international cooperation or planned activities using SNRIU's own resources, is provided in Section 9 of this Report.

13 CONCLUSIONS

The most recent assessment of regulatory threats [4] was completed in June 2021. Based on this assessment, the SNRIU and DSA initiated several new joint projects. However, the full-scale war waged by the Russian Federation against Ukraine introduced unprecedented challenges, causing immense harm to both the people and the state. Recent events have involved targeted attacks on critical infrastructure and energy facilities, including nuclear power plants. These unprecedented challenges to nuclear and radiation safety have created a need for urgent reassessment of regulatory risks and vulnerabilities. In response, DSA and SNRIU initiated an extraordinary evaluation of the current regulatory threats. The outcomes of this assessment are presented in this Report.

The primary identified threat, which significantly impacts the foundational principles of the nuclear regulatory authority, is the lack of global experience in carrying out regulatory activities amidst military aggression. Existing world practices and internationally recognized safety guidelines in this context are either absent or very limited. The complexity of this identified threat is reflected in the following key challenges:

- Ensuring regulatory stability and sustained functionality amidst an ongoing military threat with an indefinite duration.
- The need to restore regulatory control over nuclear and radiation-hazardous facilities that suffered impacts from hostilities and occupation, following prolonged periods of inactivity.
- The need for daily and efficient countermeasures against attempts to manipulate public perception through the dissemination of disinformation, fake news, and hostile propaganda within Ukraine's information space, particularly concerning the status of its nuclear sector and the level of nuclear and radiation safety and security.

Thanks to the timely and diversified support from DSA and other partners, the SNRIU has initiated, and in some cases already implemented, a number of priority projects addressing specific components of the identified threat. This report emphasizes the timeliness of the provided support and the importance of the activities completed or ongoing under these projects. Notably, certain initiatives have led to the development and implementation of unique regulatory guidelines and procedures, specifically designed to restore control over nuclear installations impacted by hostilities. Some of these projects have had a significant positive impact on the public, particularly due to the transparency and attention to each request during their implementation, such as conducting radiation measurements in territories affected by occupation.

The performed assessment revealed the need for additional projects aimed at overcoming this complex threat. These threats form the foundation for planning and are reflected in the Roadmap for Cooperation between the SNRIU and DSA for 2024–2028.

The collaboration between DSA and SNRIU will continue, maintaining an established project-oriented approach with a new emphasis on:

- Assessing the radiological impact on the public to implement the necessary protection actions and enhance public awareness of current and potential threats.
- Informing the public in territories affected by occupation on nuclear and radiation safety issues and raising the awareness of media representatives regarding nuclear and radiation threats.
- Improving dialogue with other authorized bodies and stakeholders, including adopting procedures and measures that enhance the coordination and efficiency of joint activities.
- Enhancing the visibility of cooperation between DSA and the SNRIU at both the national and international levels.

A systematic and transparent approach to the planning and implementation of bilateral measures was introduced from the beginning of the cooperation between the Norwegian and Ukrainian nuclear regulators. Reports on the assessment of regulatory threats [2]-[4], which have been developed since 2014, as well as this Report, demonstrate the coordinated and effective practice of joint actions by both parties to ensure successful implementation of the provisions of the Agreement [1].

When determining the objectives, tasks, and anticipated outcomes of new projects, both parties consistently pay special attention to the coordination of assistance provided by DSA to avoid duplication with other measures already being implemented or planned at the national and international levels by both DSA and the SNRIU. This approach has already proven its high efficiency and garnered international recognition. Other European nuclear regulators and technical support organizations are ready to join and contribute to the development of the ongoing cooperation between the SNRIU and the DSA, which undoubtedly enhances its significance in both national and global contexts.

The results of this cooperation are offered as a contribution to the efforts to develop guidelines and other measures to support nuclear and radiation safety during armed aggression, marking an important step in strengthening the resilience of nuclear safety and regulation in Ukraine amid unprecedented challenges.

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