EXPERIENCE OF FSUE "RADON" ON THE DECOMMISSIONING OF RADIATION AND NUCLEAR HAZARDOUS FACILITIES AND REMEDIATION

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For many years FSUE "RADON" has been dealing with nuclear decommissioning s, comprehensive engineering and radiation surveys, remediation of territories contaminated with radionuclides due to industrial or scientific activities or radiation accidents. Extensive knowhow and knowledge have been accumulated in this field to date, typical problems hindering proper execution of these activities have been identified. This article summarizes the experience of FSUE "RADON" in the field of decommissioning and remediation with typical problems analyzed and relevant measures proposed to address them.

Keywords: *radioactive waste, decommissioning, nuclear facility, remediation, comprehensive engineering and radiation survey*

For over 60 years, Federal State Unitary Enterprise "RADON" has been implementing measures to provide the radiation safety in the city of Moscow, the Moscow Region and ten surrounding areas with more than 40 million residents and over 2,500 organizations that are currently using or were using radioactive substances and sources of ionizing radiation for their practical needs.

The enterprise was primarily established to ensure the safe management of radioactive waste resulting from the operation of medical, scientific and industrial organizations addressing existing issues in nuclear power sector associated with the use of radioactive materials. Over time, FSUE "RADON" started providing services on radiation monitoring, remediation of territories, scientific and technological support for the development of RW management technologies. In recent years, decommissioning of nuclear and radiation hazardous facilities (NRHF) have become a most relevant area of its activities.

Years of active research on the practical aspects of fissile and radioactive material applications prompted the establishment of a large number of laboratories, facilities, institutes and factories that are currently considered as morally and technically obsolete and can be no longer used for the original purposes. In these cases, decommissioning is viewed as a logical solution providing compliance with financial, environmental and radiation safety aspects.

Over the past two decades, FSUE "RADON" has accumulated considerable experience on NPP decommissioning, remediation of contaminated territories, including those contaminated due to radiation accidents.

In 2001—2002, decommissioning of production unit No. 14 belonging to OJSC Kolchugtsvetmet (Vladimir Region) was completed.

The structure was built and put into operation in early 1950s to produce permanent luminescent compounds (PLC) based on soluble ^{226}Ra bromide.

During production operations, radioactive substances were kept either in solid or dissolved state. Some operations resulted in dust and waste generation. No closed water circulation system was available in the unit. Washings and drains via floor traps were fed into the sewer and were discharged with no proper treatment.

In late 1980s, PLC production was discontinued and the unit was mothballed.

Radiation-ecological examination identified 2 sites and 31 sources of radioactive contamination with a total area of 208.25 m^2, an equivalent dose rate of gamma radiation of 45 to 28,000 μR/h and a flux density of α-emitters of up to 17,700 ppm/cm^2.

Based on the survey, efforts were performed to decontaminate the structures, to dismantle the buildings, remediate the territory and to manage the resulting radioactive waste.

In June 2013 — April 2014, as part of a nuclear decommissioning project, FSUE "RADON" performed a comprehensive engineering and radiation survey (KIRO) of the Sosna repository operated by FSUE "Combine "Elektrohimpribor", its buildings and structures located within the site boundaries and in its sanitary protection zone. Findings on the radioactive waste inventory accumulated at the site were used in the development of a decommissioning program for this facility.

Under the KIRO, the following activities were performed by FSUE "RADON":

1. KIRO program was developed and agreed.

2. A survey of the building structures constituting to SRW and LRW storage facility located at the site was performed.

3. A comprehensive survey of the storage facility was carried out, including measurements of gamma and neutron radiation in its premises and compartments, surface contamination with alpha- and beta-emitting radionuclides, specific activity of ^{222}Rn, sampling and analysis (radiometric, spectrometric, chemical) of LRW and liquids from SRW compartments; evaluation of RW held in the storage facility, namely of its quantitative and qualitative characteristics.

4. Industrial site and its adjacent areas were explored: gamma radiation dose rates on the surface were measured, exploration wells were drilled and their gamma-ray logging was performed, core was sampled which was followed by gamma-spectrometric analysis, boundaries of the radioactive contamination plume were identified, the volume and activity of radioactively contaminated soil was identified.

5. Possible scenarios of radionuclide spread into the environment were considered and the environmental impact of the RW held in the storage facility and at the stie was evaluated.

6. Engineering solutions on SRW retrieval from the engineering part of the storage facility were developed.

In 2016—2018, FSUE "RADON" completed the decommissioning of a radiobiological laboratory (building No. 73) of FSI "12 Central Research Institute" of the Russian Ministry of Defense. The operations were performed under a Project on the Decommissioning of the Radiobiological Laboratory (Building 73) Run by the Federal State Treasury Institution "12 Central Research Institute" of the Defense Ministry of Russia.

The radiobiological laboratory (RBL) was built in Priozersk (Leningrad Region) in 1970. A two-storey building with a total floor area of 1,518.2 m^2 was used for research focused on radioactive substances under stationary conditions and RW disposal. Open radioactive sources (radioactive substances) were involved in its activities as well.

By the time the decommissioning was started, RBL was in satisfactory condition and was connected to all utilities (water and electricity, heating). Radioactively contaminated stationary equipment could be found in its work premises: most of the painted surfaces, plastic, concrete, tile and stationary steel structures in the premises got radioactive contamination.

RBL decommissioning was performed in several stages.

1. Summarized and evaluated was the available information on the radionuclide composition and contamination levels of the RBL building relevant engineering data; KIRO program was developed.

2. Activities performed under KIRO involved:

- radiation survey of RBL structure, including: measurements of gamma radiation ambient dose rate equivalent; density measurements of alpha and beta emitters flux from the floor and wall surfaces inside the premises; density measurement of alpha and beta emitters flux from external and internal surfaces of the equipment; smears collected from the surface and samples collected from points with identified contamination followed by laboratory testing to determine the total alpha and beta activity, as well as gamma spectrometry to determine the radionuclide composition of the contamination; core sampling and laboratory research on the content of technogenic radionuclides to identify the maximum depth of concrete walling contamination;
- radiation survey of the adjacent territory, including: visual inspection to search for wells and identify the layout of the sewage system; pedestrian gamma shooting of the territory in a search mode; density measurements of alpha and beta emitter flux from the surface; soil and well sampling

for laboratory analysis; borehole drilling along the detected and marked sewerage pipelines to a depth that would be not less than the depth of the pipelines themselves with gamma-ray logging and soil sampling to identify possible leaks;

- radiation inspection of LRW storage tanks, including: measurement of surface EDR in a search mode; measurement of EDR over open hatches of tanks and a silo used for RW storage purposes; flux density measurements of alpha and beta emitters from the earth surface and accessible tank surfaces; sampling of water and bottom sediments from LRW reservoir tanks followed by the evaluation of their specific activity by laboratory methods;
- engineering survey of RBL's technical state, including: the review of available reports and findings of previous surveys; visual inspection of load-bearing and enclosing structures (visual inspection of the facility; identification of matches between the available design documentation and actually implemented engineering solutions; assessment of temperature and humidity conditions that evolved in the building structures during operation; identification of typical failures and damages in the building structures and their components; identification of potential causes resulting in such failures and damages; recording the identified structure failures; selection of structures and their components requiring instrumental examination; penetration and sampling; analysis of the visual inspection results and drawing up preliminary conclusions); instrumental examination of building structures (evaluation of concrete and masonry strength on the 1st and 2nd floor of the RBL, the strength of restricted access area structures, laboratory animal housing and LRW collector tanks with the use of non-destructive and destructive methods to develop relevant durability forecasts; measuring).

3. Draft document Terms of References for RBL Decommissioning Designs Development was issued. Its provisions were agreed upon with the operating organization (FSI "12 Central Research Institute" of the Russian Defense Ministry) and approved by the State Atomic Energy Corporation "Rosatom". RBL decommissioning designs were developed by JSC "Central Design and Engineering Institute".

4. Materials supporting the review and evaluation of the design documentation in accordance with the requirements of Order No. 1/1052-P of November 3, 2015 were drafted. A positive statement was issued on the design documentation.

5. Action Plan on RBL (building 73) Decommissioning was developed and agreed upon with the operating organization.

6. Necessary infrastructure was established, radioactively contaminated RBL equipment and systems were dismantled, RBL building structures were decontaminated. All these operations were performed by LLC "Kvant". FSUE "RADON" performed relevant operations on waste shipment enabling further processing, conditioning and temporary storage of RW that had resulted from the decommissioning.

7. To judge the completeness and quality of operations on the decontamination of RBL building and its adjacent territory and the readiness of the building for demolition, a radiation survey was performed. During the survey, the radiation state of the building, building structures, premises, structures, equipment of utilities, LRW collector tanks, and adjacent territories was evaluated. The radiation survey also involved the following activities: measurements of ambient gamma radiation dose rate equivalent in a search mode at a distance of 0.1 m from the walls and floor surface of the premises and the surrounding area to identify possible residual pollution; direct measurements of alpha and/or beta emitter flux density from the surface of enclosing structures along a 1 × 1 m grid on the floor and walls of the premises; sampling of cores, building materials (concrete, brick, tile) and soils for further laboratory evaluations. A report was compiled based on the radiation survey: its provisions were agreed upon with the operating organization ("12 Central Research Institute" of the RF Defense Ministry) and approved by the customer (SC "Rosatom"). Based on the survey report, a statement on the radiation safety of the RBL building was issued.

8. RBL building structures not subjected to radioactive contamination were dismantled by Razmakh LLC. The operations also involved the dismantlement of building foundations and site remediation. Radiation monitoring during these operations was provided by the Federal State Unitary Enterprise "RADON".

9. Control radiation survey was completed. A statement was issued enabling to withdraw site restrictions considering the radiation factor.

10. RW generated during RBL decommissioning were conditioned to meet waste acceptance criteria and handed over to FSUE "NO RAO" for disposal.

In 2017, under the Action Plan on the Safety of Radiation Hazardous Facilities (Building No. 46 and Building No. 3) Operated by FSI "12 Central Scientific Research Institute" of the Russian Defense Ministry, FSUE "RADON" performed a comprehensive engineering and radiation survey of the indicated building No. 46, a four-story brick structure built in the late 1950s. Until late 1960s, its premises were used to perform operations involving radioactive substances. Subsequently it has never been used for the original purpose.

Following building No. 46 decommissioning, its operator planned to use it for administrative purposes, thus, some arrangements had to be done to meet the requirements of sanitary standards given the new intended purpose.

KIRO was carried out to determine the state of building structures, systems (elements) of ventilation, sewage, electricity and to assess the feasibility of their further operation; radiation situation in the premises was characterized with proposals being developed on their upgrading to ensure the radiation safety; the amount, radionuclide composition, activity and aggregation state of RW that could be possibly generated during such upgrading activities was identified; areas contaminated with metallic mercury were identified; concentration of air-borne mercury vapor was measured.

The following task were accomplished:

1. Available information on the radionuclide composition and contamination levels of building No. 46 was summarized and evaluated along with available technical information on the building. Comprehensive engineering and radiation survey program was developed;

2. KIRO activities involved:

- mercury-environmental survey;
- radiation inspection of building No. 46: radiation parameters were measured, namely, EDR of γ-radiation in premises with relevant inspections of enclosing surfaces (floor, walls, ceiling) and equipment located in them; evaluation of air contamination in the building premises by technogenic radionuclides; measurement of α- and β-emitter flux density from the inspected surfaces of the premises and the equipment by a direct method (radiometry by portable devices); smears were collected from the building structure and equipment surfaces, followed by laboratory analysis (radiometry using stationary devices, α-, β-, γ-spectrometry); sampling of building materials (spalling of paint and varnish, plaster layer, drilling of samples with their layered separation) followed by a laboratory analysis (radiometry using stationary devices, α-, β-, γ-spectrometry) to evaluate radioactive contamination inside the building structures in premises and their in-depth distribution;
- engineering survey of building structures and engineering systems of building No. 46, including: evaluation of indoor temperature and humidity conditions; identification of operational violations; identification of typical failures and damages in the building structures and their components; recording the identified structure failures; evaluation of concrete and masonry strength by non-destructive methods with relevant forecasts of its durability (residual life), measurement drawings.

3. Based on the KIRO results, a report on the evaluated technical and radiation state of building No. 46 was developed providing recommendations and offering some engineering solutions on building No. 46 upgrading to ensure its radiation safety. The report was approved by FSI "12 Central Research Institute" of the Russian Defense Ministry and the State Atomic Energy Corporation Rosatom.

Tendering process identified another contractor who was selected to perform the decommissioning operations. The volume of RW generated due to decontamination was almost exactly consistent with FSUE expert evaluations.

Based on comprehensive engineering and radiation survey conducted by the operator in 2016, a decision was made on Building No. 3 decommissioning: immediate dismantlement option was chosen providing for building demolition.

Two-storey brick building No. 3 was built in late 1950s according to the designs developed by a Specialized Design Bureau. Until late 1960s, its premises were used to perform operations with radioactive substances. After that it has been never used for its intended purpose. The building was abandoned with some unmounted laboratory equipment (fume hoods, manipulator cells), active ventilation and sewage systems. The latter ones were not used, pumping equipment was partially dismantled, air ducts were damaged.

Under a state contract, the following activities were performed:

1. Action Program on the decontamination of equipment and building structures of building No. 3 of FSI "12 Central Research Institute" of the Russian Defense Ministry was developed and agreed with the operating organization.

2. A sanitary zone was established in the back of the building, bounded by a sectional welded wire mesh fence. Several sites (work areas) were fitted inside its perimeter: a site for temporary storage of RW containers; a site for empty containers; mobile sanitary inspection room for personnel leaving the sanitary zone; radiation control zone for transport containers and vehicles.

3. Decontamination areas (dismantlement, segregation, fragmentation, packaging) were arranged immediately within the premises where radioactive contamination exceeding the established limits was detected (the work area was warded-up by a signal tape, temporary protective fence was mounted, additional portable lighting, dust suppression equipment, segregation trays were installed, temporary

sanitary gateway was arranged at the entrance (exit), dosimetric control station was arranged).

4. Contaminated equipment, elements of the active ventilation and sewage systems were dismantled.

5. Areas with identified radioactive contamination of building No. 3 structures were decontaminated.

6. Radioactively contaminated elements of dismantled equipment, ducts and pipelines, construction waste generated during decontamination were wrapped into plastic film and loaded into containers at an adjacent site. After the containers were filled, preliminary inspection of prepared packages was performed. The containers were sealed, each RW batch was provided by an acceptance and transfer certificate. Radioactive waste was shipped to the industrial site of FSUE "RADON" for further processing (conditioning) and temporary storage until its further transfer to the national operator.

7. Final radiation inspection of the deactivated premises inside building No. 3 was performed. Radiation Inspection Statement on the Deactivated Premises of Building No. 3 Operated by FSI "12 Central Research Institute" of the Russian Defense Ministry was issued and agreed upon with the operating organization. Based on the survey report, a statement on the radiation safety of Building No. 3 was issued.

8. Work program on the dismantlement of building No. 3 was developed and agreed upon with the operator.

9. Razmakh LLC performed all operations associated with the dismantlement of building structures not subjected to radioactive contamination up to the level of –4.020, shipment of waste to industrial waste landfill and site remediation. All operations associated with building No. 3 dismantlement and industrial waste shipment were carried out under constant dosimetric monitoring implemented by FSUE "RADON".

10. Control radiation survey of the site was performed and the site was handed over to the operating organization with an issued statement confirming the completion of operations enabling to ensure the radiation safety of facilities operated by FSI "12 Central Research Institute" of the Russian Defense Ministry.

In 2017, a decision was made on the decommissioning of radiation sources (RI) of JSC "NIKIMT-Atomstroy", namely, of buildings 20 and 21, including RW storage facilities.

To reduce the decommissioning costs, as well as given the radiation monitoring data, a decision was made to eliminate the nuclear facility (immediate dismantling) without demolishing the building itself.

The following operations were performed by JSC "NIKIMT-Atomstroy" to address this task:

1. Pre-decommissioning stage involved the removal of sealed radionuclide sources from the RXM-gamma-20 installation and shipment of the spent sources from the site of "NIKIMT-Atomstroy" to "FSUE Radon". RW was received, conditioned and emplaced into a temporary storage facility pending its subsequent transfer for disposal. JSC RADIY MF implemented all operation associated with the removal of open and sealed radiation sources in keeping with design provision agreed with the Interregional Administration No. 1 of the FMBA of Russia.

2. RXM-gamma-20 installation was dismantled.

3. Accumulated RW was shipped from JSC "NIKIMT-Atomstroy" site to FSUE "RADON" with prior radiation control of the packages. RW was received, conditioned and emplaced into a temporary storage facility pending its subsequent transfer for disposal.

4. To specify the radiation state of building, building structures, premises, utility systems, a radiation survey was performed in buildings 20 and 21: radiation parameters were measured, namely, EDR of γ-radiation in premises, enclosing surfaces (floor, walls, ceiling) and equipment located in the premises were inspected; measured was α- and β-emitter flux density from the inspected surfaces in the premises and the equipment by a direct method (radiometry by portable devices); smears were collected from the building structure and equipment surfaces, followed by laboratory analysis (radiometry using stationary devices, α-, β-, γ-spectrometry); construction materials were sampled (spalling of paint and varnish, plaster layer, drilling of samples with their layered separation) and subjected to a laboratory analysis (radiometry using stationary devices, α, β-, γ-spectrometry) to evaluate the radioactive contamination inside the building structures in premises and their in-depth distribution. Based on the radiation survey, information was obtained on the required scope of decontamination and the amounts, types and radionuclide composition of the generated decommissioning RW.

5. Based on the radiation survey, the following documentation was developed: a work program on radiation source decommissioning; action plan on the protection of personnel in the event of accidents during RS decommissioning; quality assurance program during decommissioning; fire protection measures during RS decommissioning; safety analysis report. Action plan on the protection of personnel in the event accidents during RS decommissioning was agreed upon with the Interregional Department No. 1 of FMBA of Russia.

6. To provide radiation safety during work execution, the facility was zoned into the following areas:

free access zone; controlled access zone; area of radiation hazardous operations. Access from one zone to another was provided by means of arranging a temporary sanitary gateway and a sanitary inspection room.

7. Contaminated equipment, elements of active ventilation and sewage systems in building 21 were dismantled. Equipment from heavy exhaust boxes was dismantled and fragmented.

8. Mechanical decontamination of premises inside building 21 was completed. Dry mechanical decontamination of the work area was preceded by dust suppressant spraying. Contaminated sections of plastics and linoleum, concrete floor, paintwork, plaster were dismantled. During the decontamination of the premises, a film-forming composition was sprayed, if necessary. After the decontamination of building structures in each premise was completed, a control radiation survey and sealing of relevant premises was performed.

9. Following the decontamination efforts, the compliance of building 21 with the desired criteria was recognized. A decontamination certificate for building 21 was drawn up and agreed with the operating organization. Decontamination of building 20 was not required.

10. RW resulted from the decontamination was shipped to FSUE "RADON". The waste was received, conditioned and emplaced into a temporary storage facility pending its further transfer to FSUE "NO RAO" for disposal.

11. Final radiation survey was performed. Based on the radiation monitoring protocols, a report was drawn on the final radiation survey of JSC "NIKIMT-Atomstroy's" buildings 20 and 21.

In 2018, providing the implementation of a Program on the Remediation of the Second Restricted Access Area of FSI "12 Central Scientific Research Institute" of the Russian Defense Ministry (Sergiev Posad, Moscow Region), FSUE "RADON" performed necessary efforts on the remediation of radioactively contaminated areas indicated under the Program.

The site had woody vegetation; the upper soil layer was covered by grass, moss, fallen leaves, branches and deadwood. A site area of 46,144 m^2 bounded by an isoline of 0.3 μSv/h featured five sections affected by radioactive contamination (SRC) and two local focal contamination areas. The contamination plume has spread in the surface layer of soils to a depth of 0.1—1.4 m.

The following efforts were implemented to remediate the site:

1. Developed and agreed with the operating organization was a work plan on the Remediation of a Radioactively Contaminated Site Located within the Second Restricted Access Area of FSI "12 Central Research Institute" of the Russian Defense Ministry supporting the implementation of a corresponding Program (Sergiev Posad, Moscow region).

2. A Quality Assurance Program (site specific) has been developed.

3. A radiation survey was performed: boundaries of SRC with γ-radiation EDR of more than 0.6 μSv/h, as well as of those with a β-particles flux of more than 500 ppm/(cm^2·min) were identified.

4. Necessary pre-remediation activities were performed (establishment of necessary infrastructure): temporary inventory fencing around the work area and areas with dangerous and harmful factors was mounted to avoid unauthorized access; radiation inspection involving the specification of SRC boundaries with γ-radiation EDR of more than 0.6 μSv/h, as well as of those with a β-particles flux of more than 500 ppm/(cm^2·min); the site was cleared from bulky garbage, trees, shrubs, light forests; temporary trackways for special vehicles and RW transportation were arranged; temporary highway for vehicles was constructed within the work area; necessary units were arranged within the work area (temporary sites for radioactive and non-radioactive waste storage, sanitary and household premises).

5. Contaminated trees and shrubs collected from an area of 7,992 m^2 were processed (fragmentation, packaging into kraft bags with subsequent emplacement into containers and transportation to the industrial site of FSUE "RADON" for further processing (conditioning) of the generated waste).

6. Radioactively contaminated soil assigned to the RW category was collected, segregated, emplaced into containers and transported to the industrial site of FSUE "RADON" for further conditioning.

7. Tree-shrub vegetation that had not been subjected to radioactive contamination was removed from an area of 38,152 m^2.

8. RW was conditioned. The produced RW packages were handed over to FSUE "NO RAO" for disposal.

9. After RW retrieval, an area of 46,144 m^2 was remediated and landscaped (backfilling with clay loam, leveling the area with loam layer (over 100 mm thick); leveling the area with a vegetation soil layer (over 100 mm thick); grass sowing).

10. When the logging operations were completed, contaminated soil was excavated and the site was backfilled with soil, a control radiation survey was performed in keeping with relevant provisions of TI Rad 09-2008 Guidelines on Radiation Survey of Contaminated Areas. Since the remediated area was mainly contaminated by ^{137}Cs and ^{90}Sr, the radiation survey was directly implemented via a pedestrian gamma-ray survey in a search mode at a distance of 0.1 m from the surface with the results recorded in

5 × 5 m grid nodes and points of detected radiation anomalies: beta-emitter flux density was measured using DKS-96 dosimeter-radiometer fitted with BDZB-99 detection unit by direct measurement of surface contamination levels. Following the radiation survey, no RW was found at the site after its decontamination.

11. Based on the findings of the control radiation survey, relevant Statement summarizing its results was drawn up and agreed with the operating organization. Review statement was issued by the Core Center for State Sanitary and Epidemiological Surveillance (Special Purpose) of the Russian Defense Ministry on the site compliance with the requirements of SanPiN 2.6.1.2523-09 Radiation Safety Standards (NRB 99/2009) and SP 2.6.1.2612-10 Basic sanitary rules for radiation safety (OSPORB-99/2010).

The quality of comprehensive engineering and radiation surveys is believed to play a vital role in planning and implementing the nuclear decommissioning efforts. Thus, KIRO findings are used to evaluated the costs required for the management of the resulting radioactive waste that can potentially account for the major part of the nuclear decommissioning costs. KIRO findings are also used to specify the work flow for the decontamination activities providing minimum amounts of secondary RW generation and the radiation safety of personnel. A high-quality engineering survey performed under the KIRO allows making correct decisions on the decommissioning strategy and take timely measures to ensure the safety of personnel, such as reinforcing the walls and floors, timely design development and mounting of necessary engineering systems, etc.

The experience gained shows that the entities often do not possess the required documentation on the site, including design, construction documentation for buildings and structures, operational documentation, etc.: either the records could have been lost or damaged or a large part of the decommissioned facilities was used for different purposes and their departmental affiliation has changed.

Development of automated systems for decommissioning database management as prescribed by NP-091-14, NP-007-17, NP-012-16, NP-028-16, NP-057-17, NP-097-16 is viewed as a possible solution allowing to mitigate the setbacks associated with the unavailability of necessary documents. FSUE RADON is currently addressing this task.

Unavailability of necessary documentation, including information on operations with radioactive substances carried out at the facility, as well as inadequate competence level of personnel engaged in KIRO, can result in an underestimated of RW inventory generated during decommissioning. Thus, the case study of building No. 3 operated by FSI “12 Central Research Institute” of the Russian Defense Ministry showed that actual RW inventory had exceeded the estimated one based on KIRO performed by another organization by almost 20 times (46.8 m^3 versus 2.5 m^3). Such an underestimation can be explained by the fact that, unlike nuclear power plants, the radionuclide composition and the nature of contaminant spread at such facilities commonly operated for scientific, research or pilot-industrial purposes, can vary greatly.

In this case, the problem can be only addressed by engaging experienced personnel in such KIRO having enough knowledge and skills to reconstruct possible contamination scenarios based on some fragmentary data and select adequate measurement methods to detect all possible sources of RW generation during decontamination.

Sites involved in decommissioning activities performed by FSUE “RADON” were mostly contaminated with hard-to-detect radionuclides, including plutonium isotopes and other transuranic elements, uranium, strontium-90 isotopes. The radioactive decay of these radionuclides neither does result in sufficiently high levels of gamma radiation exposure nor the emitted gamma radiation is characterized by relatively low energy making them hard to detect.

To address this issue, empirical methods allowing to measure hard-to-detect radionuclides by indirect methods, including field gamma spectrometry method were developed by FSUE “RADON”.

Operations were performed using portable scintillation spectrometers. To identify the specific activity of the radionuclides contained in the items subject to measurement, more than 200 efficiency calibrations for different measured items were developed and verified using supplementary calculation programs. If it appeared no possible to measure the specific activity of the radionuclides contained in the item, a spectrometer was used to evaluate its radionuclide composition. Over two years of operation, more than 2,000 spectra were recorded and processed.

Application of spectrometric measurements during KIRO saves time needed to identify the waste class for different facilities, equipment and building structures considered and allows to specify the nature of the identified SRC.

The activities performed showed that spectrometric measurements are necessary to process radiometric in-situ measurements.

Difficulties in spectra processing resulting from the lack of specialists and desired reduction of the measurement time, can be optimized by engaging only one processor for several spectrometric installations.

Ill-preparedness of facilities for decommissioning is seen as an important factor impeding high-quality KIRO. During KIRO, direct access to enclosing structures of the buildings is required to allow for direct radiation measurements, inspection, specification of their actual state and sampling. At the same time, the premises should be cleared from inappropriate items, garbage, furniture not being part of the stationary equipment used to perform operations with radioactive substances (for example, fume hoods or glove boxes). Actually, most of the premises inspected by FSUE "RADON" employees was cluttered to various extents, which either does not allow the implementation of the entire set of necessary measurements or necessitates some additional efforts to clear up the premises (see Figure 1), which had not been accounted for in KIRO cost calculations.

Figure 1. Typical setup in decommissioned premises

This problem could be addressed by imposing certain restrictions under relevant regulations on the state of premises constituting to a facility being prepared for decommissioning. In this case, the responsibility for ensuring the compliance of the premises with the requirements should be assigned to the operating organization. Moreover, under the decommissioning designs a separate stage could be introduced providing for facility preparation for KIRO, carried out under a separate agreement or as a separate stage under a general agreement.

Extremely tight deadlines specified in the contract and terms of reference are viewed as another factor contributing to inadequate quality of KIRO and decommissioning activities. Given the setup associated with the procurement of necessary materials based exclusively on competitive procedures, the time left for work execution is judged as unacceptably short.

Unfortunately, for a long-time no fully fledged framework covering the regulation of KIRO activities not related to nuclear power plants was available in the Russian Federation. Only in late 2019, did appear the two regulations, namely, RB-159-19 Recommendations for a Comprehensive Engineering and Radiation Survey of Nuclear Power Facilities and RB-160-19 Recommendations on the Contents of a Comprehensive Engineering and Radiation Survey of Nuclear Power Facilities. These documents provide necessary guidelines on KIRO activities, the list of identified parameters and state the need of a preliminary survey enabling the development of an adequate KIRO program and the advisability of performing pre-KIRO activities involving preliminary decontamination, removal of garbage and some items of equipment.

Compliance with the above guides will increase the timing and the costs associated with this phase of decommissioning, however, these costs will enable more accurate evaluations of the costs required for RW management and safety assurance, ultimately yielding an optimized nuclear decommissioning flow chart.

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