ON THE TRAINING OF SPECIALISTS FOR NUCLEAR FACILITIES DECOMMISSIONING IN THE SAINT-PETERSBURG INSTITUTE OF TECHNOLOGY

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Article received on October 28, 2021

Adapted from the Report for the Third International Scientific and Practical Conference on the Environmental Protection and the Management of Radioactive Waste from Scientific and Industrial Centers, FSUE RADON, September 22—23, 2021.

The paper evaluates the scale and the specific aspects associated with nuclear decommissioning tasks, as well as the recruitment needs. It discusses the readiness of the Institute for the introduction of the discipline Organization, Technology and Economics of Nuclear Decommissioning with the focus placed on the availability of an adequate educational and methodical complex and a teaching staff with the required competence. It also briefly overviews the course, the tasks to master the discipline and its target audience.

Keywords: *nuclear and radiation hazardous facilities, decommissioning, radioactive waste, remediation of industrial sites, training of specialists.*

Decommissioning of nuclear and radiation hazardous facilities (hereinafter, referred to as nuclear decommissioning) in Russia is becoming a branch of a large-scale economic activity. To address the challenge of the so-called nuclear legacy (Table 1) alone, it may take from 40 (considering an intensive implementation scenario for the Federal Target Program Nuclear and Radiation Safety in 2016—2030) to 100 years. Moreover, scheduled decommissioning is required for NPP units, research and transport nuclear reactors, nuclear fuel cycle (NFC) facilities, installations of nuclear science, instruments and devices with radionuclide sources used for various purposes, storage facilities for radioactive and industrial technogenic waste with high content of natural radionuclides being at the final stages of their design life.

Table 1. Nuclear and radiation hazardous facilities that have been shut down or are to be shut down in the future [1]

Type of NRHF	Total number	Years				
		until 2008	2008—2015	2016—2025	2026—2035	after 2025
Nuclear facility	331	37	31	73	25	165
Storage facility	1,253	290	68	120	61	714
Radioactive source	479	24	41	34	25	355
Radioactively contaminated buildings and structures	44	9	4	8	11	12
Radioactively contaminated territories	22	-	-	-	-	-
Sites of peaceful nuclear explosions	80	-	-	-	-	-
Total	2,210	360	144	235	122	1,246

It is not a stretch to say that on a national scale, nuclear decommissioning is currently considered an urgent problem in Russia, and not only and not so much due to the technical aspects involved, but to a larger extent due to environmental, partly — political and to a greater extent — social aspects engaged. The State Policy Fundamentals in the Field of Nuclear and Radiation Safety of the Russian Federation declare nuclear decommissioning providing RW "neutralization" and restoration of the environmental quality at industrial sites a priority task for social and economic development promoting national safety.

Given this circumstance, as well as the absence of a reasonable alternative to the use of radionuclides and radiation in energy, medicine, industry, space technology, it is obvious that nuclear decommissioning, as a type of large-scale economic activity, is going to be highly-demanded throughout the life of many generations, and its success (including not only technical, but economic, environmental, institutional and social aspects) largely depends on the availability of sufficient and competent human resources.

Considering this perspective, we've embarked upon the development of a discipline called Management, Technology and Economics of Nuclear Decommissioning to be introduced to the curriculum of the Department for Engineering Radioecology and Radiochemical Technology (ERRT) of the St. Petersburg State Technological Institute (Technical University) (SPbSTI(TU)) within the framework of the specialty 18.05.02 Chemical Technology of Materials for Modern Energy.

This discipline is mastered to provide basic training of radiochemical engineers in research and the implementation of organizational and technical activities in the field of nuclear decommissioning contributing to the formation of an integrated, comprehensive perception of the problem, which, in turn, paves the way for the implementation of predominantly optimized procedures associated with the design development and implementation of nuclear decommissioning projects taking into account all the key features that can affect the final result. Therefore, the decisions made at a stage of the process would not exclude reasonable alternative options at subsequent stages of nuclear decommissioning.

To prove the need for introducing a new discipline to the training program for radiochemical engineers, emphasized was the fact that current needs in nuclear decommissioning stimulate R&D just as much as the "basic" technology. It would be suffice to mention:

- laser radiation, ultrasound, supercritical state of water, chemical nanocavitants used for decontamination purposes;
- GPS technologies and gamma detectors for engineering and radiation inspections at nuclear sites;
- computer 3D modeling for the cold testing of decommissioning processes;
- synthetic mineral-like materials and nanotubes for matrix isolation of long-lived radionuclides;
- chitosans, fullerenes and graphenes for deep waste processing.

These studies and developments are not always embodied in the industrial decommissioning practice, nevertheless, are considered as a driver providing active growth of innovative potential both in the nuclear industry and the industry in general. The same goes for the use of these innovations in the training process which undoubtedly broadens the horizons and increases the creative activity of graduates in radiochemical processing engineering.

The ERRT department was established in 1949 and the decision made on the introduction of the new discipline there emerged due the pronounced academic background in training the specialists of this kind and, most importantly, due to the active involvement of the teaching staff in research and development on a wide range of decommissioning challenges. Since early 1990s, the staff of the department has been engaged as invited Russian experts in coordination research projects, technical support programs and advisory groups of the International Atomic Energy Agency (IAEA) covering such aspects of nuclear decommissioning as policy and strategy [2, 3], regulation, management and organization [4—6], engineering and technology [7—10], safe waste management [11—14], social and economic impact [15]. In 2015, by the order of the St. Petersburg branch of the Technical Academy of Rosatom, the department developed an advanced nuclear decommissioning training program for employees of the nuclear industry. Specialists of the department are regularly involved in lecturing, seminars and laboratory workshops (including those held at ERRT department, which has a Rostekhnadzor's license).

Analytical reviews, technical reports and guidelines of IAEA developed with the engagement of ERRT stuff, as well as textbooks for universities developed in cooperation with the Radium Institute named after V. G. Khlopin, the Rosatom Technical Academy, the Ozersk branch of the National Research Nuclear University MEPhI, the Belgorod Technological University and with the engagement of the State Duma's subcommittee of the Federal Assembly of the Russian Federation on legislative support of atomic energy uses [16—19] form a balanced educational and methodological complex incorporating global trends and practices that can be used to train engineering stuff in the field of radiochemical

processing with competencies that are currently in demand at the final stage of NF life cycle.

The curriculum covers almost all fundamental stages and components of nuclear decommissioning:

- project management and planning;
- integrated engineering and radiological survey (KIRO) of facilities;
- dismantling and decontamination of process systems, equipment, buildings and structures at nuclear facilities;
- radioactive waste management;
- environmental quality restoration at industrial sites;
- social aspects;
- methods and tools for aggregate estimation of nuclear decommissioning costs.

The curriculum is quite moderate (400 hours, including laboratory and practical exercises) since it is intended for students with basic radiochemical and general engineering training, therefore, to master the discipline the students have to focus mainly on those processes and procedures that are supposed to be specific for the nuclear decommissioning.

For example, when decontamination methods are discussed, the emphasis is placed on "harsh" low-waste methods, which are normally avoided at the operation stage of nuclear facilities assuming the potential risk of an unacceptable change in the functional properties of structural materials. In RW management (the waste resulting both from operation and decommissioning of nuclear facilities), the technology and managerial aspects are considered in the light of requirements driven by the decommissioning strategy. Therefore, instead of the "process and store" paradigm considered predominant until recently, the decommissioning flowchart should be now driven by a concept suggesting that the "RW should be conditioned to meet waste acceptance criteria for disposal, packaged and ship away from the site", which radically changes the RW management flowchart at all stages of nuclear facility life cycle and is governed by the general logic of the decommissioning process, provisions of the Federal law 190-FZ On RW Management … and by-laws establishing the requirements for the final RW state (top-down reduction of controlled storage time at industrial sites followed by mandatory waste disposal).

It seems worth noting that introduction of a new discipline into the curriculum is not exclusively intended to train the personnel specialized in nuclear decommissioning. The decommissioning practice has convincingly demonstrated that the currently accepted technology applied to manage the waste from the operation of nuclear facilities should be upgraded [20]; the criteria applied to evaluate the design solutions for newly-developed nuclear facilities have changed (more precisely, should change); the proactive development of nuclear decommissioning concepts and programs has become a routine task for operating organizations; designs of new nuclear facilities are required to include information necessary for their decommissioning, including the preferred dismantling and decontamination methods, evaluated inventory of RW resulting from the decommissioning and its nature, etc.

In other words, competencies (knowledge, abilities, skills) in the field of nuclear decommissioning are now seen as a mandatory qualification requirement to the personnel of design, research, supervisory organizations and operated nuclear and radiation hazardous facilities. It was this challenge for the current development stage of nuclear science and technology that was taken into account during the development of the discipline Management, Technology and Economics of Nuclear Decommissioning and its introduction to the curriculum under the specialty Chemical Technology of Materials for Modern Energy. To summarize the above, the following points can be noted:

- The cleanup of so-called nuclear legacy facilities alone may take up to 100 years at an annual cost of several tens of billions of rubles. Thus, nuclear decommissioning efforts will be implemented throughout the life of many generations and the success of the decommissioning programs will largely depend on the competencies available in this area not only among the employees of specialized companies, but equally among the personnel of design and development, scientific and research, supervisory organizations and operated nuclear facilities. The latter should be certainly taken into account during the training of specialists in radiochemistry.
- In SPbSTI(TU), this task was addressed by introducing the discipline Management, Technology and Economics of Nuclear Decommissioning to the curriculum of the ERRT department. This discipline covers all fundamental stages of nuclear decommissioning, is intended for students with basic radiochemical and general engineering training and is focused mainly on those processes and procedures that are directly reflecting some specific features of nuclear decommissioning.

Educational experience of the ERRT Department established over 70 years ago (as part of the Engineering Physics and Chemistry Faculty by the Minister Council Decree of the USSR in 1948) and almost 30 years of experience gained by the teaching staff of the Department from its engagement in Russian and international nuclear decommissioning projects demonstrate its ability in providing high-quality training of the specialists.

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Bibliographic description

Akatov A. A., Nechaev A. F. On the Training of Specialists for Nuclear Facilities Decommissioning in the Saint-Petersburg Institute of Technology. *Radioactive Waste,* 2021, no. 4 (17), pp. 22—27. DOI: 10.25283/2587-9707-2021-4-22-27. (In Russian).