Elaboration of strategies and criteria of environmental remediation and post-remediation control for radiation legacy facilities

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A considerable part of nuclear and radiation hazardous facilities (NRHF) in Russia are situated in densely populated areas. Research reactors can be with certainty placed among facilities, making serious radiation threats. Although they have much lesser amounts of stored radioactive materials, as compared to nuclear power generating units or plutonium production reactors, in Russia, as a rule, they are situated within or close to large cities. Quite often spent nuclear fuel (SNF) and radioactive waste (RW) depositories, hot research laboratories, etc. are also located nearby such facilities. Only within the Moscow city and the Moscow Region, in the city of St. Petersburg and Leningrad Region there are more than fifty facilities of such kind.

The total area of lands contaminated with radionuclides as a result of operation of enterprises of the former Minatom of Russia during the period from 1945 to 2000 is about 480 km², 15% of them having the exposure rate level exceeding 200 µR/h. From 1965 to 1988 more than 124 industrial nuclear explosions were set off in the USSR (81 of them on the territory of the Russian Federation). Some of them entailed accidental release of radioactive substances into the environment. Up to now elevated radiation exposure rate levels are observed around some of them. Former on-shore maintenance bases of the nuclear Navy on the Kola Peninsula and on the Pacific Ocean shore are also real sources of radiological threat to the public and the environment.

Besides that there are territories in Russia radioactively contaminated in result of prospecting, mining and processing of uranium and thorium ores, extraction and processing of other raw materials (rare earth metals, coal, oil and gas), inadequate RW management at early stages of nuclear research and nuclear industry coming-to-be in the country, etc.

Today the NRHF and adjacent radioactively contaminated sites pose a potential threat to the public and the biosphere. These facilities are related to radiation legacy of the USSR. They were built and operated in compliance with radiation safety standards of the former Soviet Union, which are essentially different from regulatory requirements applied now to civil NRHF in Russia.

Therefore special remedial actions aimed at potential threat mitigation or decrease are needed. Such measures should include decommissioning of the facilities, cleaning up and remediation of their sites, restoration of the environment and social support programs for the public, living around the facilities.

The main task of the remediation is reduction of the human exposure, creation of necessary conditions for efficient and safe economical activities.

Concrete objectives should be determined, as well as radiation protection principles and standards for conducting remediation works, and also – specifications for evaluation of the NRHF site condition prior to their remediation, criteria of decision-making, decommissioning and remediation planning, and recommendations for their future uses.
Remediation of NRHF sites should not only essentially decrease radiation risk to the public, but also open the possibility to use them for the societal interests, that would require bringing them to either “green-field” or “brown-field” condition. In this point, however, there is still a conceptual uncertainty.

Firstly, it is not clear what should be a level of residual radioactive contamination of the remediated sites after decommissioning and dismantling nuclear reactors, RW storage facilities, as well as various buildings, structures and equipment located on the NRHF sites.

Secondly, it is not clear how costly will be the remedial actions, to what extent should they be carried out, what will be the anticipated remediation effect and the degree of radiation risk reduction in every particulate case. In many cases by a number of reasons (economic, technological, safety-related) after cleanup a site cannot be brought to the state of “green-field”, i.e. a site that can be used without any restrictions.

So, it becomes obvious, that the post-decommissioning and post-remediation stages of a NRHF life cycle may represent a very serious problem. To manage the problem, it is necessary to find out solutions of the tasks as follows:

1. Elaboration and justification of the concept of post-remediation control as the final stage of radiation legacy facilities’ decommissioning and remediation, including
   a) working out conditions for termination a license of NRHF and full release of its site from regulatory control; or
   b) working out post-remediation stewardship methods and means for a site that after decommissioning and remediation cannot be completely released from regulatory control.

2. Elaboration and justification of requirements to end states of radiation legacy facility after their decommissioning and environmental remediation of its site.

3. Elaboration and justification of criteria of attaining certain end states for radiation legacy facility in result of environmental remediation of its site.

4. Development of methodology for demonstration compliance of the on-site conditions to the set criteria.

5. Development of methodology for selection of acceptable NRHF end states after their remediation and working out strategies for attaining the states.

As both the Russian and international experience show, in many cases radioactively contaminated sites cannot be cleaned up to such level of residual activity that would allow release them for unrestricted use in course of “exclusion-exemption-clearance” concept.

The residual contamination can remain after completing active restoration actions by a number of reasons, including

- technical limits;
- economic expediency;
- the personnel health and safety, or
- prevention of environmental side effects.

So an optimum is to be found between the social and economic factors, on the one hand, and the level of residual radiation risk, on the other.

Last time a new approach is evolving to the problem of reduction of the radiation risk from sites remained after NRHF decommissioning. It consists in giving up efforts of complete remediation of a site to the state of “green-field” and setting up long-term stewardship.
The long-term stewardship envisages a differential approach to arrangement of a system of measures on the management and institutional control of facility sites and surrounding territories after clean-up, including:

1. Administrative responsibility for the long-term (up to several hundred years) stewardship for the sources of radiation risk;
2. Creation and control of protection barriers;
3. Environmental (radiation inclusive) monitoring;
4. Providing the safety and security of the public.

Setting up the institutional control makes it possible to reduce sharply the level of radiological threat without resorting many-billion expenditures. Is also evident that as we deal with non-guarded or insufficiently secured sites containing radioactively contaminated land and buildings, to set up the long-term stewardship regime is quite necessary in order to prevent non-authorized access to such sites and eventual exposure of the public.

For the present some key problems of ensuring radiation safety in the process of the radiation legacy elimination still remain unsolved. Within the situation of management of the radiation legacy the exposure of the public and personnel involved includes, along with other, also the exposure from the global radionuclide fallout due to nuclear weapons tests, as well as existing exposure at contaminated sites of former military facilities, now coming under civilian regulatory control. The presence of those exposure components, which don’t come within the home normative framework and are not regulated, is a serious problem. The framework of radiation protection formulated in the new ICRP Recommendation could be the base for solving this problem.

In 2007 the new ICRP Recommendations (Publication 103) were issued, in 2-3 years new International basic safety standards are expected to appear. The standards are being developed by the IAEA in cooperation with co-sponsoring organizations and member-states. Implementation of the standards in member-states is supposed to be completed by 2015.

Let’s consider some probable approaches to solving problems of radiation protection in the process of planning and performing environmental remediation (and also in the post-remediation period) of the facility for spent nuclear fuel and radiation waste temporary storage in Gremikha (Gremikha TSF) on the northern seaboard of the Kola Peninsula. It is the example of radiation legacy facility being now at stage of decommissioning and planning remediation of its site.

To ensure the public and personnel radiation safety when carrying out the Gremikha TSF conversion and environmental remediation, an adequate strategy should be worked out. On the basis of the strategy it would be possible:
- to determine the radiation protection criteria for planning the remediation works;
- to determine the radiation protection criteria for the performing remediation works;
- to determine the particular radiation protection criteria at both the stage of performing the planned remediation works and after their completion.

One of the most important aspects of the 2007 Recommendations of the ICRP, which could have an essential effect on providing the radiation protection in the process of NRHF decommissioning and subsequent environmental remediation of its site, is marking out of three exposure situations, each of them requiring different approaches to ensuring the radiation protection and safety:
1. Planned exposure situations;
2. Emergency exposure situations;
3. Existing exposure situations.

Exposure situations in the process of Gremikha TSF conversion and implementation of strategies to change status of its site (remediation to the state of “brown-field”: a site for an industrial non-radiation-hazardous facility) can be attributed to two types:

1. Planned exposure situations, conditioned by:
   a) performing operations, concerned with conversion to restore regulatory control over hazardous nuclear and radioactive materials;
   b) the facility’s operation after the change of its status.
2. Existing exposure situations, conditioned by a residual radioactive contamination of site of either a new radiation-hazardous facility when implementing renovation strategy or an industrial (non-radiation-hazardous) facility when implementing termination strategy.

In accordance with ICRP, in order to plan the personnel radiation protection measures at the stage of the facilities conversion and remediation it is expedient to set the following boundary dose levels:

1. Not above 5 mSv per annum - in routine operations planning.
2. Not above 25 mSv per operation – in extraordinary situations.

The dose limits (contained in NRB-99 and preserved in 2007 Recommendations of the ICRP) for the exposure from man-made sources should be applied:

1. The personnel exposure from all radiation sources when performing routine operations on an industrial site – 20 mSv per year averaged over five successive years, but not above 50 mSv in any single year.
2. The public exposure from an industrial site related radiation sources – 1 mSv per year averaged over five successive years, but not above 5 mSv in any single year.

In accordance with the new ICRP Recommendations, the goals of a site remediation can be considered as achieved, if the exposure doses from residual contamination don’t exceed reference levels set by the National regulatory body. It is expedient to establish the reference level values, depending on the site end state after the Gremikha TSF remediation:

1. In case of implementing the Gremikha TSF activity status change strategy, supposing further use of the site and constructions for creation of a new radiation-hazardous facility, the following values of the reference levels (due to the residual contamination) are proposed:
   - group A personnel workplaces – 3 mSv per annum;
   - group B personnel workplaces - 1 mSv per annum;
   - public in the supervised area – 0.1 mSv per annum.
2. In case of implementing the Gremikha TSF elimination strategy, supposing further use of the site for an industrial facility, the following values of the reference levels (due to residual contamination) are proposed:
   - The facility’s personnel – 1 mSv per annum (0.9 mSv per annum due to work at the facility and 0.1 mSv per annum due to living in the supervised area);
   - public in the supervised area – 0.1 mSv per annum.
3. In case of implementing strategy of further Gremikha TSF use as a radiation-hazardous facility, the design of such an facility and its operation should be carried
out so that annual effective dose due to the facility’s operation should not exceed
the set dose constrains:

- 7 mSv per annum for the group A personnel;
- 1 mSv per annum for the group B personnel;
- 0.15 mSv per annum for the public in the supervised area.

At the stage of planning the works and radiation protection measures a final decision is to be
made, concerning the indicated reference levels and dose constrains. Stakeholders have to
take part in the decision-making process in accordance with home normative documents,
basing on the 2007 Recommendations of the ICRP and International basic safety standards.