UDC 621.039.009

ON THE ISSUE OF GENERATION AND MANAGEMENT OF RADIOACTIVE WASTE FROM REMEDIATION OF CONTAMINATED TERRITORIES

Abalkina I. L., Linge I. I., Panchenko S. V.

Nuclear Safety Institute RAS, Moscow

Submitted on February 6, 2018

No regulations concerning the remediation of radioactively contaminated territories exist in Russia. This paper discusses the management of waste generated from such remediation and focuses on further development of the Unified State System for Radioactive Waste Management. The paper considers some practices for contaminated soil management, stresses the necessity of increasing the availability of disposal options for very low-level waste.

Key words: *remediation, radioactive waste, management of radioactive waste, contaminated material, decontamination, final state.*

Further development of the Unified State System for Radioactive Waste Management (USS RW) greatly depends on how this task was initially set. More specifically, we have to answer the following question: "What is exactly that we want to do and how fast it should happen?" In other words, what are the radioactive waste (RW) amounts intended to be managed under this system. This paper overviews only one RW stream and the particular features of its generation — waste from the remediation of radioactively contaminated territories. We are convinced that this waste stream should be of very small amount.

Based on such parameters as the strictness of disposal requirements, tariff rates and container costs, we can firmly state that all the necessary prerequisites are in place for USS RW successful development currently being a very expensive and weakly differentiated system as regards the management of different RW types. So far, this point has been absolutely true for RW generated from remediation — these are "expensive" wastes, and in some cases their generation has been unreasonably stimulated.

This paper provides a clear overview of two case studies and presents relevant practical conclusions. Firstly, the decision regarding the activities to be performed during the remediation and the retrieval of soils followed by their designation as RW shall be made very carefully. Therefore, such designation places heavy commitments both on the land owner coordinating relevant activities and the executor performing the cleanup itself. After being designated as RW, the waste shall be physically isolated in a disposal facility with relevant costs to be covered. Secondly, USS RW shall provide for a separate class of low hazard level waste intended to cover the major portion of RW from remediation if such waste is generated. It was initially supposed that this class would cover very low-level waste (VLLW). However, with no particular tariff set for this class to date, its presence produced no visible effect.

A key practical conclusion that can be made in this regard is that for disposal purposes a clearer differentiation shall be made between RW classes. Fig. 1 shows this approach with the tariffs set for RW classes rather tentatively matched up with boundary activity levels and the deemed radiobiological effects of exposure. To quantify the latter, considered are the effects associated with week-long exposure from one cubic meter of RW pertaining to a relevant class. The effects vary in a quite wide range — from those being not detected in radiation and epidemiological investigations to deterministic and even lethal. As regards the correlation between the effects and relevant disposal tariffs, it should be noted that the cost of 0.5 — 1 mln RUB per cubic meter of waste seems quite reasonable for RW with the highest level of potential hazard.

The translation is done by N. S. Cebakovskaya

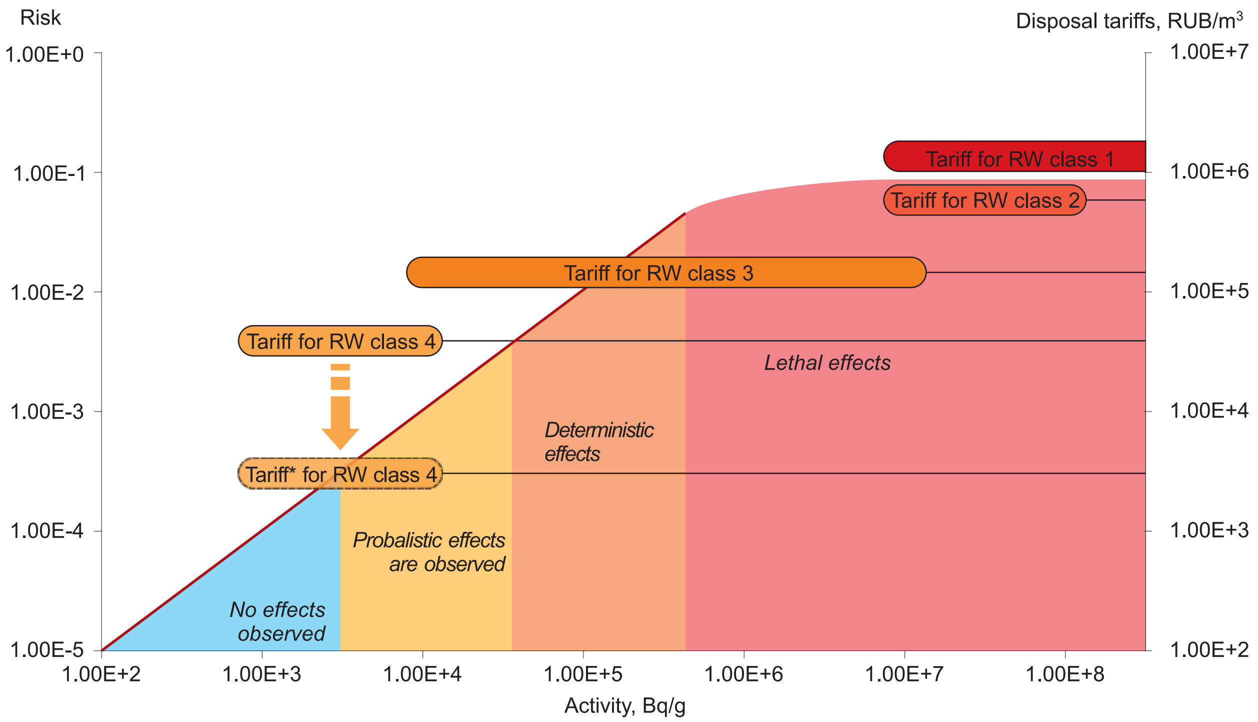

Fig. 1. Disposal tariffs for 1 cubic meter of RW and relevant hazard levels

However, for RW the potential hazard of which is equal to the level of undetectable effects the cost shall be not overestimated and shall not result in a several fold exceedances of socially significant values, for example, the minimum wage or living wage, etc. In other words, the cost of hazard elimination would be more reasonable if, within the range of low concentrations, it is over ten-fold lower. This will enable to accommodate the interests of not only the future generations, but also of the current generation as well as to eliminate unjustified expenditures. It should be noted that the example presented is illustrative in its nature as for any RW disposal option the public exposure doses shall not exceed 10 µSv/year.

Development of definition framework and methodological approaches

Law stipulates that "radioactive waste are materials and substances for which no future use is foreseen...". The major feature of the waste deemed to be radioactive is, in the first place, that it is seen as materials, substances, equipment and tools for which "no future use is foreseen", whereas the second feature — radionuclide content, is of second importance. In other words, material with a similar radionuclide content can be designated either as a radioactive substance if some future uses are foreseen, otherwise, it should be assigned to the RW category. Article 21, of the RW law provides for a special procedure enabling to extend the due date of decision making on the use of materials containing radioactive substances: *"Organizations...shall 1) on a yearly basis, identify if the future use of materials, substances, equipment, tools generated by them is possible ...and designate them as radioactive waste if their future use is considered to be impossible"*. This regulation also provides for the RW minimization principle with the waste being considered as unrecyclable end product. This approach is stated in the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. Article 11, discusses the liabilities of States concerning RW minimization, whereas, RW are defined as *radioactive material for which no future use is foreseen*. Basic international safety regulations specify that the generation of any RW shall be kept as low as reasonably achievable both as regards the activity level and its volume [1]. It should be noted that materials not being designated as RW shall be managed in a proper way in compliance with radiation safety requirements specified in current national standards.

It should be also pointed out that RW are generated solely as a result of a specific activity. Thus, this principle is applied to all production and consumption waste — these are generated as a result of certain production activities, operations, execution of services or originate from consumption [2]. Lands of any State, regardless of how contaminated they are for human and the environment, can not be designated as waste — these are contaminated territories and their status renders it impossible to apply relevant waste designation criteria in such cases.

No definition framework addressing remediation is available in Russian legislation. However, the wording "remediation" has been widely used in different regulations, including the title of a federal law on special environmental programs. Remediation of radioactively contaminated sites is listed as a key focus area of the state nuclear and radiation safety policy [3]. It is also viewed as a target indicator for currently executed federal target program on nuclear and radiation safety for 2016—2030.

Classical definition for "remediation" was given in IAEA glossary — *"any measures that may be carried out to reduce the radiation exposure due to existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to people"* [4] (it should be noted that the wording given in the official Russian translation of this paper is considered to be quite unfortunate [5]). Moreover, the Glossary has a note telling that *"complete removal of the contamination is not implied"*. Thus, remediation covers any activities reducing the exposure and not always providing for the relocation of radioactive material. It is not correct to consider remediation only as decontamination (for example, excavation of contaminated soils).

As regards the use of the wording "remediation" it should be pointed out that according to IAEA it is associated with an existing contamination situation. The actions that are required to be taken to achieve the end state of the site during its decommissioning should not be considered as remediation [6]. However, in some way the performed operations can be quite similar, for example: decontamination, removal of contaminated soil and etc. On the whole, the key difference is that under normal operation and planned decommissioning of a nuclear facility no plans regarding its "remediation" can be developed ahead and it should be eliminated. That is exactly why the wording "remediation" is not used in federal rules and regulations in the field of atomic energy use. The situation is different for nuclear legacy facilities contaminated due to past activities. And in this context, it seems quite reasonable to use the wording "remediation" and its use in the literature and regulations is absolutely appropriate.

However, yet another key wording is missing in the law — "end state" which is the physical state of an area (site) after the remediation is completed (Rostechnadzor has already put this wording in place for decommissioning purposes). The end state is basically described using remediation criteria, i.e. quantitative (measurable and calculated) indicators. This gap shall be filled as it is the state of the site defined in the designs that is viewed as the goal of remediation.

Certain achievements have been made in this area. Thus, [7] discusses different scenarios describing the use of lands with residual radioactive contamination (permanent residence, temporary stay) and justifies the radiological release criteria based on dose approach. Another paper [8] suggests remediation criteria for facilities holding non-retrievable waste.

We believe that relevant definitions shall be further elaborated but what is also very important is that scientific approaches and techniques for remediation shall be developed and compiled in the form of institutional guidelines or technical guides. The end state can be described in a number of ways (such as unrestricted use, restricted use or use for certain purposes, and etc.). However, the key point is to identify this state in the designs describing the remediation of a particular site, as its achievement is viewed as the result of the project implementation. It should be noted that the requirements regarding the content of document portfolio (sections of design documentation) are specified in relevant regulations, whereas no regulations are currently available to specify the requirements for relevant justifications and the decision-making process aimed at the selection of a remedial option.

We believe that for these purposes technical guidelines would be quite useful so that they could focus on such key aspects as the goal and the nature of the future land-use at the considered site, remediation criteria, the decision-making process enabling to select the remedial option (based on the comparison of different options including the "no-action" option), the procedure enabling to check the compliance with the predefined "end state", post-remedial monitoring procedure (if necessary). The recommendations should list the factors that are to be taken into account when the options are compared. Based on national and international experience, such factors can be exemplified as follows: the cost of remedial operations, technical complexity/feasibility, personnel exposure does received during the execution of remedial operations, the amount of radioactive and other waste, the sustainability of results achieved, the decrease of potential migration of radionuclides and other chemical components.

Typical situations and remediation options

The regulatory framework should be developed with due account of particular features of remedial goals and methods used in specific situations. In fact, when it comes to remediation there are three typical cases that we have to deal with and particular decisions to be made to address them.

The first one-surface contamination of large territories (East-Urals Radioactive Trace (EURT), Chernobyl region). The monograph [9] overviews practical experience gained during the remedial actions performed following large-scale radiation accidents and is mostly focused on the agricultural sector. As for this type of contamination, the current state of affairs in Russia and in the world suggests that from the radiological point of view remedial actions are not considered to be feasible. Moreover, at the smallest areas with the highest level of contamination almost no people are residing [10]. For such cases social aspects and motivation are crucial. This is also the case of large-scale remedial actions performed at the territories contaminated due to the Fukushima accident.

The second one-nuclear sites with RW storage facilities, as well as other facilities and the adjacent territories. At these territories there are some areas contaminated due to the release of radioactive substances from engineered safety barriers resulted from their degradation or accidents. The surface area of these sites is relatively small if the EURT areas are not accounted for. In these cases, we have to deal with essentially different situation both considering the nature of the contamination itself (radionuclide content, specific activities, depth, migration and etc.), as well as relevant risks and addressed issues. The rate of setting the remediation tasks for such sites directly depends on the existing perspectives for further site development and implementation of national nuclear legacy programs.

Finally, the third type covers the situations with no currently available operating organization with the contamination resulted from past operations. For example, peaceful nuclear explosions — the owner is absent as well as the facility as it is. However, insignificant surface contamination exists and very high-level contamination at the depth of the explosion chamber is present. Some other sites with contamination resulting from past storage of waste containing radioactive substances or orphan disused sealed radionuclide sources are being occasionally revealed.

On the whole, if no operations involving contaminated materials (contaminated soils in our case) take place, there no RW is generated. The situation becomes different when we launch remediation efforts. In this case, regardless of the contamination origin, several options or their combinations are available (fig. 2).

What is important for us, is that the first option suggests that there aren't any reasons for RW generation. When it comes to agricultural land-use, the methods used are well developed and elaborated (deep plowing, chemicalization and etc.). As for production sites, a striking example of such remediation is the backfilling of a contaminated site or its capping with certain material (asphalting for example). In this case we don't have to elaborate

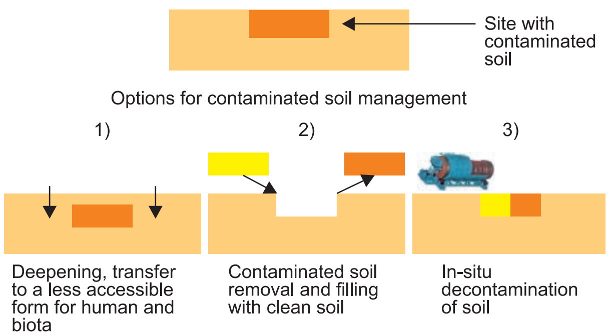

Fig. 2. Options for contaminated soil management during site remediation

which amount of soil may comply with RW designation criteria according to its radionuclide content, as the material (soil) is used in accordance with its immediate purpose. Moreover, the radioactive substances contained therein are subject to radioactive decay.

The second option provides for soil excavation. In this case, three options are available: use of contaminated soils to perform various land planning operations or its disposal in landfills for industrial waste (including the waste with increased radionuclide content). It should be noted that this option is considered to be effective and preferred if it can be implemented under the effective sanitary rules, and the landfills are situated close enough to the remediated sites. Another point to note, is that separate facility-level decisions considered feasible according to radiation safety criteria can be made. The second scenario suggests direct assignment of the soil to the RW category. The third one involves soil cleanup resulting in a small amount of secondary waste. On the whole the third option is seen as the preferred one when it comes to small amounts of soil and in some cases appears to be the only one possible if the site is located inside a settlement with newly detected or accident contamination. In this case, public concerns may play the key role in the decision making.

The third option suggests in-situ treatment of contaminated soil and is considered to be the preferred option for industrial sites, including decommissioning. Categorization of secondary waste shall be made in full compliance with RW designation criteria.

Waste management practice during remediation

The way the remedial activities are executed greatly depend on the volume of waste generation, so that the economic feasibility directly depends on the waste management costs. Moreover, economically feasible RW management approach suggests that the situations when the regulatory framework or the existing practice results in excessive actions incommensurable with relevant hazards should be eliminated. Such actions may be exemplified as ill-judged decisions on remedial actions resulting in big amounts of waste, as well as the attempts of using RW designation criteria beyond the scope of their application, for example with respect to contaminated soils [11]. Absence of relevant provisions in the regulatory framework [6] is also viewed as a potential reason for ineffective planning, including the categorization of waste resulting from remediation and their management.

As for the volume of waste generation and the management costs, remediation is quite similar to decommissioning practice for which the overall amount of waste generated (RW and other) impact both the contamination levels of equipment and structures, as well as the decisions on concepts and technologies to be applied. For example, a frequently used decommissioning option provides for surface contamination removal followed by the release of the building from regulatory control and its demolition as a "common" building.

When speaking of the international experience in this field, it should be noted that a few decades ago the main trend in contaminated sites cleanup was the decontamination involving the removal of the surface layer (complete removal or its return after treatment). Now days a quite wide range of different methods is being applied including separation (washing, filtration, ion exchange, chemical dissolution, biological sorption), containment (construction of barriers preventing radionuclide migration) and immobilization (reducing the mobility by in-situ or ex-situ cementation or chemical immobilization). Paper [9] presents some examples of remedial costs and generated waste volumes for some remedial strategies implemented abroad. The study of different remedial methods and their costs performed in the United Kingdom in 2010 [12] has shown that no general conclusions regarding the cost advantage of in-situ or ex-situ methods can be drawn. However, the use of some technologies result in lower costs when applied to big waste amounts.

As for old sites with RW storage facilities, remedial issues are of secondary importance when compared to the decision making on RW retrieval, as RW isolation should be of a primary importance. However, organizations have recently started to draw more attention to the issue of new RW generation resulting from storage facility demolition (in particular such estimates were performed by JSC AECC [13]). These assessments are used as an additional argument during the feasibility study of solutions on the accumulated RW inventory.

On the other hand, the issue of contaminated material (soil and etc.) seems to be quite controversial when it comes to the remediation of contaminated areas not being part of industrial sites. During the remedial actions taken following large-scale accidents (the South Urals in 1957 and at Chernobyl NPP in 1986), management of contaminated soils was performed in a quite rational and cost-effective way. It was a common practice to establish waste landfills in the immediate vicinity of the sites where remedial actions were taking place. For example, in the Bryansk region buildings were demolished and some part of surface soils was removed from the territories of resettled villages and in a number of inhabited settlements. The waste generated (soils and debris), not considered as RW at this time, were disposed of in keeping with special recommendations of June 12, 1986 "On the Storage Facilities for Soils with Low-level and Intermediate-level Contamination Removed due to Decontamination of Settlements". The soils were disposed of in tranches backfilled with clean soil. Later studies have shown that the average specific activity of the disposed waste for ^{137}Cs in different points ranges from 0.7 to 8 Bq/g as for the measurement date. The calculations show that by the time the remediation had been performed, most part of waste had a specific activity of over 10 Bq/g (ranging from 0.9 to 11 Bq/g). To date, not accounting for radionuclide migration from the storage facility (the estimates show that this migration is very insignificant), ^{137}Cs concentration values in the decontamination waste fall within the range of 0.5—5 Bq/g. In keeping with solid RW designation criteria these values allow to categorized these facilities as RW disposal facilities (10 Bq/g is the specific activity limit for ^{137}Cs).

The lessons learned from post-accidental remediation are not exactly applicable to existing exposure situations and those projects that have been recently implemented. However, some practical conclusions should be accounted for even in these situations. It should be noted that once the contaminated soil is to be managed as RW, the cost of activities increases (in some cases by several orders of magnitude) and relevant RW management costs may become the major part of total expenses. For example, in 2001, cleanup was performed at two small sites with a total area of 26 m^2 in Malyi Koretniy Street (Moscow) involving the removal of a total of 980 kg of the uppermost soil layer. According to IBRAE RAN estimates based on the financial statements of State Unitary Enterprise Radon, the remediation cost totaled 637,000 RUB in the current prices (21,900 USD $ given the Central Bank course) including 60 % spent on waste transportation and 30 % — on RW processing and storage.

RW factor was of key importance resulting in high specific cost of activities and remedial projects during the last years. It should be noted that in a number of projects, some definitions were confused at the time the tasks were set. For example, in 2017 the remediation of Solovyov gulley (Ulyanovsk) were directly identified as a set of actions on retrieval, transportation and intermediate storage of RW and industrial waste with elevated radionuclide content. Whereas before the remediation was started, relevant technical specifications stated that the contaminated soil at the site has to be categorized as retrievable RW of class 4.

The remediation project of 2016 on the elimination of radiation abnormalities implemented in the Moscow Region was aimed at the remediation of an area of over 658 m^2 involving over 443 m^3 of contaminated soils. Further on, these soils were treated and the RW generated from this treatment — subject to conditioning. It should be stressed that the limitation of RW is certainly viewed as a correct task. However, the remediation goal measured in soil amounts seems to be quite arguable.

We believe that during the remediation it is based on the future land use and the existing regulations should the end state of a site determined. Whereas the methods and the technologies used to achieve this end state are technical issues and conditions that can't be seen as goal on its own. Possible remedial cases, such as a small-area contamination inside city boundaries, site release from regulatory control during the facility elimination and remediation of a site with a facility holding non-retrievable RW may be essentially different as regards remediation goals, relevant criteria and methods. It should be noted that the best remediation practices are not limited to the technologies considered. In the first place, these are managerial decisions enabling to state a correct goal and to provide an optimized way for its achievement given the existing financial, social and other limitations.

Conclusions

We believe that effective management of waste from remediation activities may be promoted in several ways. The first one involves the upgrading of the regulatory framework; thus, the following conclusions can be drawn.

Conclusion 1. Remediation (and decommissioning) goals require either to have more disposal facilities available (especially in those cases when remediation activities result in a big amount of waste) or the interim decay storage of very low-level waste with a particular disposal tariff set for very low-level waste in a range of 100—1,000 RUB per cubic meter (depending on more specific criteria).

Conclusion 2. Development of regulatory and methodological remediation framework involving formal definitions for "remediation", "end state" and quantitative criteria for these wordings will enable a uniform understanding of this terminology and of relevant requirements by organizations, acting as either as customers or contractors, and to expend the notion of remediation that is quite oftentimes confused with activities solely covering the retrieval of the term source.

Conclusion 3. A most important point to be identified when remediation activities are planned or ordered are the requirements to relevant goals and results. These requirements have to address the state of the site in question. When contaminated soils are required to be excavated and shipped, a requirement should be in place for their subsequent treatment or other actions to be implemented eliminating in a definitive way any manipulations with the clean soil amounts.

The second one suggests that the best practices covering managerial aspects and remediation activities shall be followed. Land owners willing to remediate the sites on their own expenses can choose and implement any projects consistent with the tasks set by organization (release from regulatory control and cession of rights for the site, construction of a new facility at the remediated site and etc.). Situations when the state funding is used to implement ineffective projects when the money is literally "buried in the ground" or "the soil is converted into RW" shall be avoided via regulatory and methodological documents and managerial decisions.

References

1. IAEA — Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. No GSR Part 3. – Vienna, IAEA, 2014. – 436 p.
2. Federal'nyi zakon «Ob Otkhodah Proizvodstva i Potrebleniya» ot 24 iyunya 1998 g. № 89-FZ. (In Russian).
3. Osnovy Gosudarstvennoi Politiki v Oblasti Obespecheniya Yadernoi i Radiatzionnoi Bezopasnosti Rossiiskoi Federatzii na Period do 2025 goda. Utv. prikazom Prezidenta RF ot 01.03.2012 № Pr-539. (In Russian).
4. IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection: 2016 Edition URL: http://www-ns.iaea.org/downloads/standards/glossary/iaea-safety-glossary-rev2016.pdf.
5. Glossariy MAGATE po Voprosam Bezopasnosti. Terminologiya, Ispol'zuemaya v Oblasti Yadernoi Bezopasnosti i Radiarzionnoi Zashity. MAGATE, Vena, 2007.
6. *Bolshov L. A., Arutyunyan R. V., Linge I. I., Abalkina I. L.* Nuclear Accidents: Consequences for Human, Society and Energy Sector. Radiatsionnaya Gygiena, 2016, vol. 9, no 3, pp 43—52. (In Russian).
7. *Golikov V. Y., Romanovich I. K.* Justification for the Radiological Criteria for the Use of Areas with Residual Radioactive Contamination Based on the Dose Approach. Radiatsionnaya Gygiena, 2017, vol.10, no 4, pp 6—22. (In Russian).
8. *Abalkina I. L., Panchenko S. V., Savkin M. N., Vedernikova M. V., Kryshev I. I.* Sozial'no i Ekologicheski Priemlemye Kriterii Reabilitatzii Zagryaznennykh Territoryi Punktov Razmesheniya Osobykh Radioactivnykh Otkhodov. Voprosy Radiatzionnoi Bezopasnosti, 2016, no 3(87), pp 46—53. (In Russian).
9. Problemy Yadernogo Naslediya i Puti Ikh Resheniya. T. 2. Razvitie Systemy Obrashcheniya s Radioaktivnymi Otkhodami v Rossii. Pod Obshchei Redakciej Bol'shova L. A., Laverova N. P., Linge I. I. Moskva, 2013, 392 p. (In Russian).
10. Atlas Sovremennogo Sostoyaniya i Prognoznykh Aspektov Posledstvyi Avarii na Chernobyl'skoi AES na postrdavshikh territoriyakh Rossii I Belarusi (ASPA Rossiya-Belarus'). Pod Red. Yu. A. Izraelya i I. M. Bogdevicha. 2009, 138 p. (In Russian).
11. *Dorofeev A. N., Linge I. I., Samoylov A. A., Sharafutdinov R. B.* Feasibility study on enhancing the efficiency of uss rw regulatory framework. Radioactive Waste, 2017, no 1, pp 22—31. (In Russian).
12. Contaminated Land: Applications in Real Environments (CL: AIRE). Environment Agency, Defra Research Project SP1001. — London, UK. — 2011. — 120 p.
13. *Bocharov K. G., Micheev S. V., Vedernikova M. V.* Prospects of works on accumulated RW in the organizations o the Fuel Company JTC «TVEL». Radioactive Waste, 2017, no 1, pp 85—92. (In Russian).

Information about the authors

Abalkina Irina Leonidovna, PhD, Head of Laboratory, Nuclear Safety Institute of RAS (52, Bolshaya Tulskaya st., Moscow, Russia, 115191), e-mail: abalkina@ibrae.ac.ru

Linge Igor Innokentevich, Doctor of Technical Sciences, Deputy Director, Nuclear Safety Institute of RAS (52, Bolshaya Tulskaya st., Moscow, Russia, 115191), e-mail: linge@ibrae.ac.ru

Panchenko Sergei Vladimirovich, senior researcher, Nuclear Safety Institute of RAS (52, Bolshaya Tulskaya st., Moscow, Russia, 115191), e-mail: panch@ibrae.ac.ru

Bibliographic description

Abalkina I. L., Linge I. I., Panchenko S. V. On the Issue of Generation and Management of Radioactive Waste from Remediation of Contaminated Territories. Radioactive Waste, 2018, no 1 (2), pp. 5—11.