

Radioactive Waste Management at the New Conversion Facility of 'TVEL'® Fuel Company – 13474

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ABSTRACT

The project on the new conversion facility construction is being implemented by Joint Stock Company (JSC) “Siberian Group of Chemical Enterprises” (SGChE) within TVEL® Fuel Company. The objective is to construct the up-to-date facility ensuring the industrial and environmental safety with the reduced impact on the community and environment in compliance with the Russian new regulatory framework on radioactive waste (RW) management. The history of the SGChE development, as well as the concepts and approaches to RW management implemented by now are shown. The SGChE future image is outlined, together with its objectives and concept on RW management in compliance with the new act “On radioactive waste management” adopted in Russia in 2011. Possible areas of cooperation with international companies are discussed in the field of RW management with the purpose of deploying the best Russian and world practices on RW management at the new conversion facility.

INTRODUCTION

SGChE is located in the closed city of Seversk, Tomsk region. It is currently incorporated into TVEL which is part of the State Corporation for Atomic Energy of the Russian Federation (ROSATOM®) [<http://www.tvel.ru/wps/wcm/connect/tvel/tvelsite.eng/>]. Today TVEL incorporates productive and scientific assets in the fields of nuclear fuel manufacturing, separation-and-conversion complex, as well as production of gas centrifuges and associated equipment. TVEL was established to build an optimal management structure of the nuclear fuel cycle enterprises and enhance their performance and competitiveness in the world market.

SGChE was established in March 1949. The milestones of its development are shown in Fig.1. Starting from its establishment and almost until early 1970s, the SGChE main function was manufacturing of HEU and plutonium-based nuclear weapon components. Starting in 1967, SGChE gradually became involved in nuclear power complex activities, such as generation of electric and heat energy at power production uranium-graphite reactors operated at that period for the community needs; 1992 was beginning of reprocessed uranium treatment to uranium hexafluoride (UF₆) under international contracts; and starting in 1994 after the weapon-grade plutonium production program closure, SGChE completely converted its nuclear materials production to the peaceful nuclear power engineering only. Since 2000, SGChE has been a complex of nuclear fuel cycle production facilities comprising the refining of all types of natural and reprocessed feed uranium, UF₆ production and its enrichment.

Today the SGChE production core consists of the following plants [<http://www.atomsib.ru/sci/struktura.html>]:

- Enrichment plant which is involved in the production of enriched uranium for nuclear engineering and manufacturing of stable isotopes.

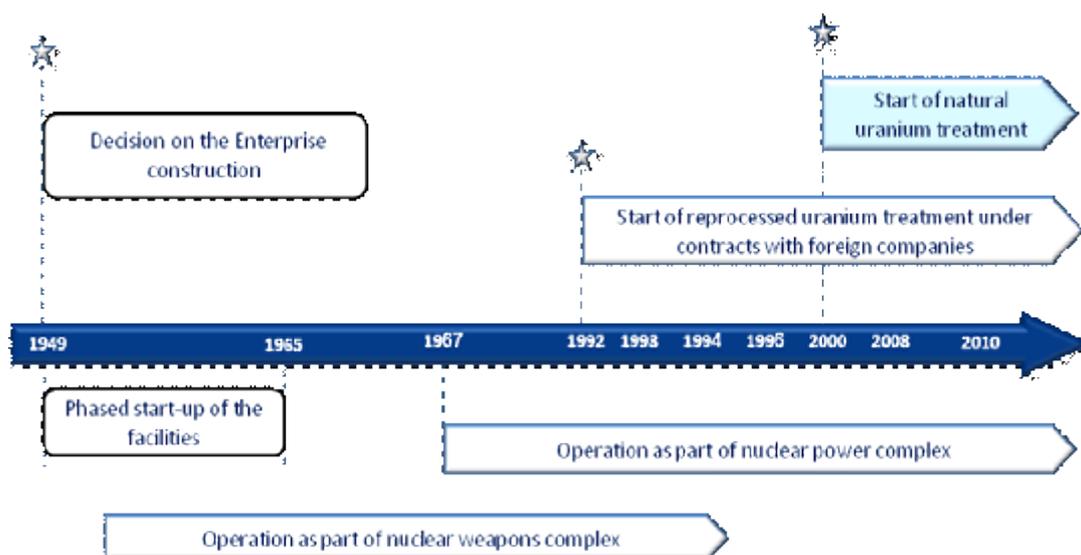


Fig.1. The milestones in SGChE's historical development.

- Conversion plant which specializes in the production of uranium oxides and hexafluoride. Both natural and reprocessed uranium purified at Radiochemical plant are used as a feedstock.
- Radiochemical plant which performs fine purification of uranium feedstock from radioactive and stable impurities. It also processes the feed uranium to uranium oxides meant for Conversion plant. The plant is also involved in the liquid radioactive waste (RW) ground disposal and closing-down surface RW storage facilities for the improvement of regional environmental situations.

DISCUSSION

The selection of the RW management technique during the SGChE establishment in the 1950s was guided by the world's geopolitical situation and necessity to start-up the weapon-grade plutonium production and raise it to the design capacity at the earliest possible date. For the period of 1958 to 1971, seven surface storage facilities were commissioned for liquid RW to be collected, held, and stored.

Storage facilities were classified depending on waste chemical composition and their activity level. High-salt LLW were collected in the slurry repositories, whereas low-salt waste was transferred to the ponds, followed by the purification up to the regulatory levels allowing its disposal to the open water system. Other ponds were used for collection and storage of ILW with different chemical composition. This approach was not safe and per se was a deferred decision on RW final disposal.

For the period of 1963 to 1967 the underground RW disposal system was commissioned for liquid ILW and LLW. This led to almost complete elimination of ILW disposition and accumulation in surface storage facilities and significant reduction of LLW accumulation amount.

The sites for in-depth liquid RW underground disposal are natural geological reservoirs ensuring RW confinement. Its operational principle is based on the waste location in deep (up to 300 meters) geological formations. The role of safety barriers preventing radionuclide dissemination is performed by sandy and clay rock which is poorly penetrable for liquid RW and acts as natural sorbents and magnets for radionuclides. In order to prevent the above-level impact on the geological environment and forecast the aftermath of underground disposal site operation, a continuous geo-monitoring system is applied. The monitoring is conducted by hydrodynamic, hydrochemical and geophysical methods covering the area of technogenic impact of the site and its adjacent territory. The monitoring network consists of 143 inspection wells at the disposal site and 91 observation wells beyond the site boundaries (Fig.2) [<http://www.atomic-energy.ru/articles/2012/02/20/31086>].

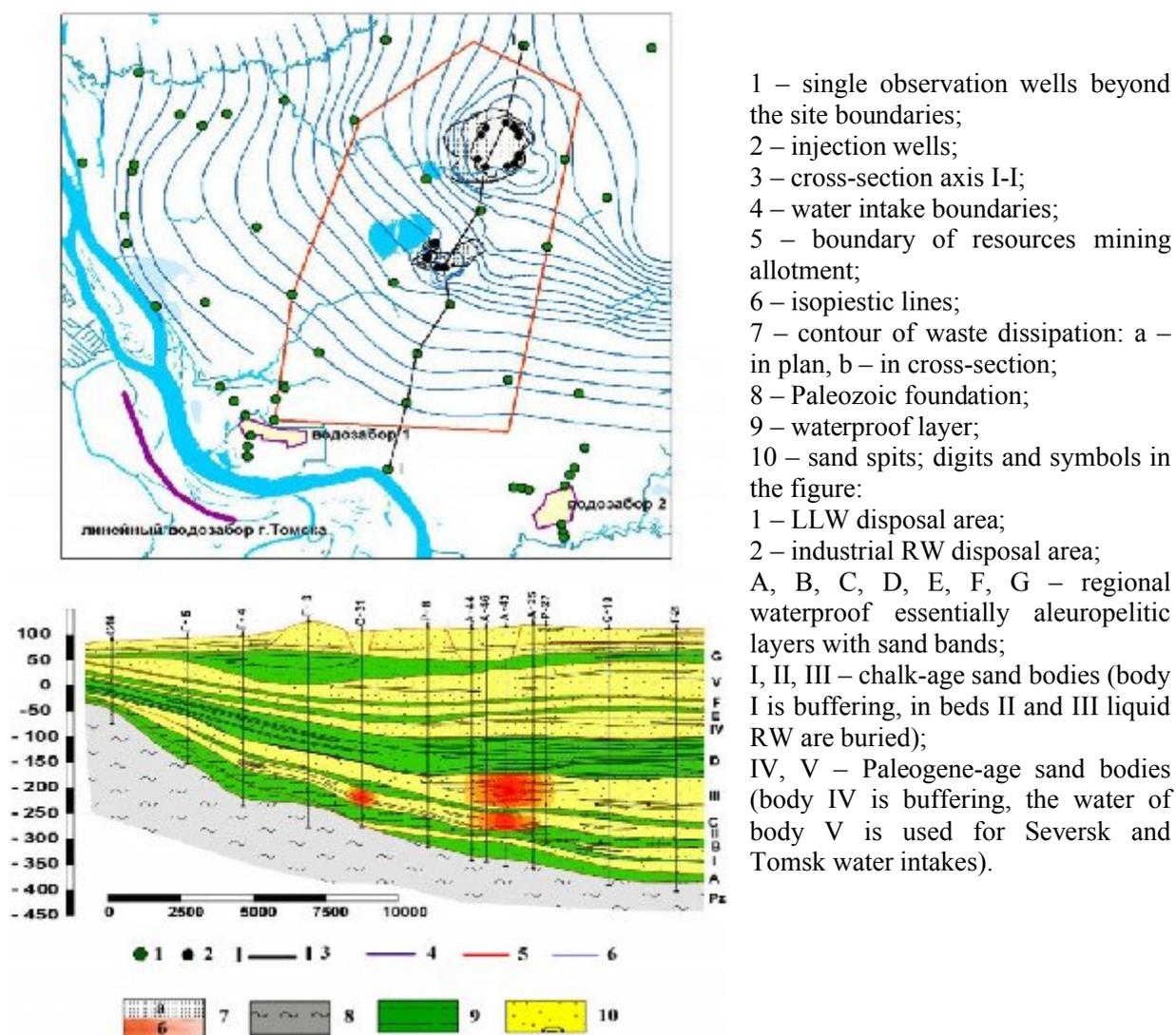


Fig. 2. General arrangement of geotechnological monitoring of subsurface resources condition

The monitoring is conducted by the SGChE dedicated department – Laboratory of Geotechnological Monitoring, as well as by Federal State Unitary Enterprise “Hydrospecial

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geology” and Closed JSC “Geospecial ecology” with the involvement of the Russian Academy of Sciences top institutes, followed by joint review of the obtained results for timely development and implementation of environmental measures.

Monitoring is conducted with the use of a set of techniques: temperature logging, gamma-ray logging, resistivity metering, acoustic cement bond logging, electromagnetic flaw detection-thickness gauging, flow meter survey, groundwater level measurement and its dynamics throughout the well network, and reservoir fluid sampling from observation wells. Another technique used for monitoring the radionuclides migration is tritium content determination (reservoir water contains almost no tritium and the lower detection limit in the applied measurement methods is 0.007 Becquerel per litre [Bq/l]). In terms of the site operational safety assessment, the great importance is placed on detecting the long-lived radionuclide occurrence form in the reservoir bed liquid phase.

The application of liquid RW underground disposal method allowed SGChE to sustain the favorable radiation and sanitary environment in the area of the Enterprise location throughout the period of its activity up to the present.

In spite of the long-term safe operation of RW disposal sites, SGChE continues to implement the set of measures reducing the negative impact of the operating facilities, such as:

- adoption and implementation of the SGChE Environmental Policy which implies the Administration and personnel being in charge of the Enterprise sustainable development with the maximum mitigation of negative environmental impact;
- introduction of new technological solutions to reduce the amount of formed RW; and
- certification of the existing environmental management system to comply with the requirements of international standard ISO 14001:2004.

Alongside with that, efforts are made to resolve the issue of “military programs legacy”, such as the decommissioning and closure of surface storage facilities. The RW repositories decommissioning is funded under the State Program on account of the federal budget, as well as by means of ROSATOM® State Corporation reserves. As of today, one ILW storage was closed and another pond closure is being completed. The efforts on the closure of high-salt RW accumulation and storage facilities will be completed by 2020. Due to the dedication of ROSATOM® State Corporation to the task of SGChE contaminated areas restoration, the amount of investments allocated for RW storage facilities close-out and remediation of adjacent territories is annually increasing. For instance, in 2010 the amount of cash investments in this field amounted to about 463 million rubles, whereas in 2011 it was about 592 million rubles.

There are three enterprises in Russia now involved in the uranium feed conversion to UF₆: JSC “Chepetsky Mechanical Plant” (JSC “ChMP”) [<http://www.chmz.net/site2>], JSC “Angarsk Electrochemical Combine” (JSC “AECC”) [<http://www.aecc.ru/>], and SGChE. They are all incorporated into ROSATOM®’s TVEL® Fuel Company. The production capacities of these enterprises were constructed in 1950-1960s and to a significant extent are out-of-date. After the cost-performance ratios review for different options of the new conversion facility location, the decision was made in 2011 to consolidate all capacities of TVEL on UF₆ production from natural and reprocessed feedstock to be located at SGChE site.

To this end, a modern, environmentally safe facility capable of processing different uranium feedstock is scheduled to be constructed by 2016 (Fig.3). The new facility is not only to meet all demands of TVEL in feed uranium conversion, but also to retrieve uranium from waste uranium products generated during nuclear fuel manufacturing at other TVEL enterprises. Once the new facility is constructed, the uranium processing capacities at JSC “ChMP” and JSC “AECC” are going to be decommissioned.

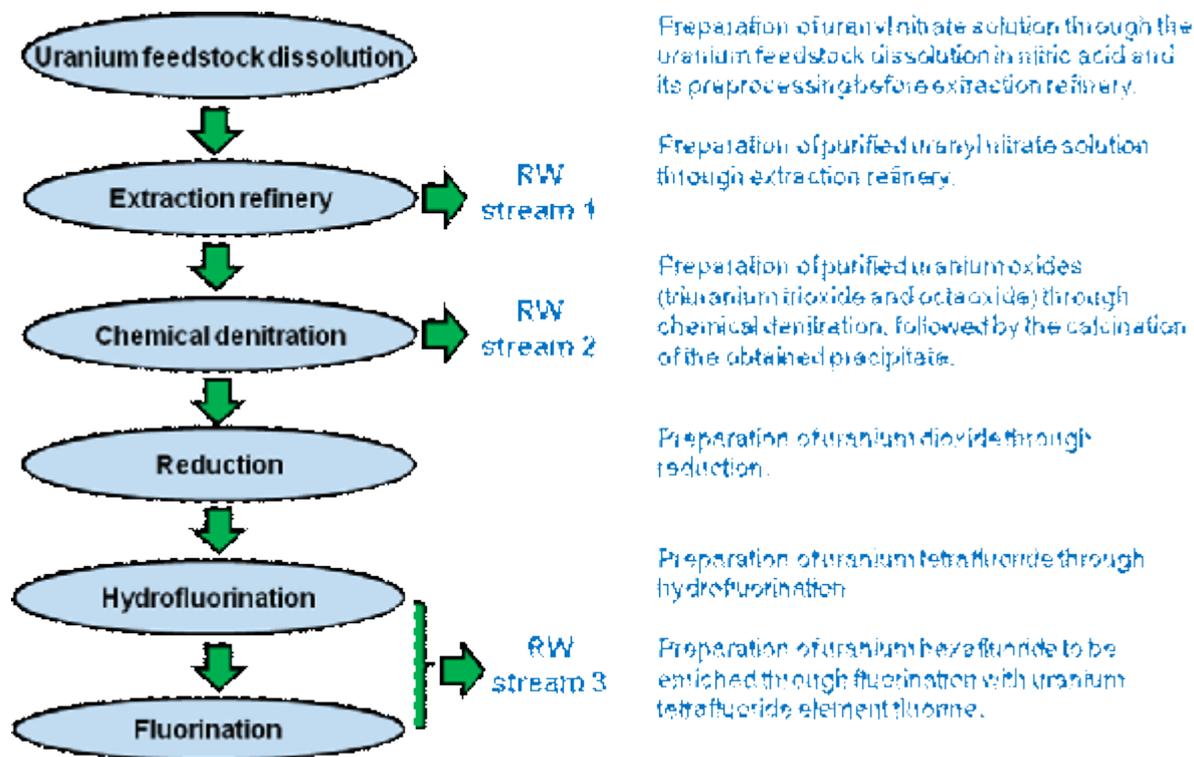


Fig. 3. Conceptual diagram of the new conversion facility

The implementation of the new RW management concept was also triggered by the new act “On RW management” adopted in Russia in 2011. It imposed tight constraints on liquid RW disposal and set forth new classification and management criteria.

The Act on RW management is a specific exhibition of the new state policy on ensuring radiological safety. Before the Act came into force, there existed a RW incomplete life cycle from the regulatory, technological and infrastructure standpoint, which resulted in enterprises not having any motivation to process RW and no conditions for its transfer to disposal. This contributed to the construction of RW storage facilities having great potential hazard for environment and community. The new act has set new requirements providing for the establishment of the complete RW management life cycle in Russia, including its processing, pre-disposal preparation, and disposal payment. “Pay-and-forget” concept is implemented for manufacturers. However, for it to be applied, RW should be converted into the condition which is suitable for disposal. It is the national operator that is going to deal with the disposal. Its major tasks are to establish the system of disposal sites, accept RW to be disposed, and ensure long-

term safety at RW disposal sites. The Act also imposes tight constraints on liquid RW disposal procedures by almost completely ban its burial. The RW ground disposal is allowed only at the sites that obtained operational permit before the Act came into force, with the number of such sites being quite few in Russia.

According to the new requirements, radionuclide-containing waste is classified as solid, liquid and gaseous radioactive waste, if the sum of ratios between specific (for solid and liquid waste) or volumetric (for gaseous waste) activities of radionuclides in the waste and their ultimate values exceeds 1 (as per Supplement published in the RF Government decree No.1069 dated October 19, 2012).

The disposable RW is classified into 6 categories:

1. Taking into account the technological features of its management, the disposable RW is classified as category 1 if it meets the following criteria:
 - a) it is solid RW represented by further unusable material, equipment, wares, solidified liquid RW;
 - b) it falls in the category of HLW containing radionuclides with the specific activity:
 - over 10^{11} Bq/g – for tritium-containing RW;
 - over 10^7 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - over 10^6 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - over 10^5 Bq/g – for RW containing TRU-radionuclides;
 - c) according to the acceptability criteria specified by the federal rules and regulations on it RW management, it is subject to deep underground disposal in RW repositories with prior holding for heat generation decrease.
2. Taking into account the technological features of its management, the disposable RW is classified as category 2 if it meets the following criteria:
 - a) it is solid RW represented by further unusable material, equipment, wares, ground, solidified liquid RW, spent sealed ionization radiation sources of classes of hazard 1 and 2, specified by the federal rules and regulations on the nuclear energy use;
 - b) it belongs to one of the following types of waste:
 - HLW containing radionuclides with the specific activity:
 - over 10^{11} Bq/g – for tritium-containing RW;
 - over 10^7 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - over 10^6 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - over 10^5 Bq/g – for RW containing TRU-radionuclides;
 - long-lived ILW containing radionuclides with the half-life period over 30 years and specific activity:
 - from 10^8 to 10^{11} Bq/g – for tritium-containing RW;
 - from 10^4 to 10^7 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - from 10^3 to 10^6 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - from 10^2 to 10^5 Bq/g – for RW containing TRU-radionuclides;
 - c) according to the acceptability criteria specified by the federal rules and regulations on RW management, it is subject to deep underground disposal in RW repositories without prior holding for heat generation decrease.

3. Taking into account the technological features of its management, the disposable RW is classified as category 3 if it meets the following criteria:
 - a) it is solid RW represented by further unusable material, equipment, wares, ground, solidified liquid RW, spent sealed ionization radiation sources of class of hazard 3, specified by the federal rules and regulations on the nuclear energy use;
 - b) it belongs to one of the following types of waste:
 - ILW containing radionuclides with the specific activity:
 - from 10^8 to 10^{11} Bq/g – for tritium-containing RW;
 - from 10^4 to 10^7 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - from 10^3 to 10^6 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - from 10^2 to 10^5 Bq/g – for RW containing TRU-radionuclides;
 - long-lived LLW containing radionuclides with the half-life period over 30 years and specific activity:
 - from 10^7 to 10^8 Bq/g – for tritium-containing RW;
 - from 10^3 to 10^4 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - from 10^2 to 10^3 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - from 10^1 to 10^2 Bq/g – for RW containing TRU-radionuclides;
 - c) according to the acceptability criteria specified by the federal rules and regulations on RW management, it is subject to near-surface ground disposal in RW repositories placed at the depth of up to 100 m.

4. Taking into account the technological features of its management, the disposable RW is classified as category 4 if it meets the following criteria:
 - a) it is solid RW represented by further unusable material, equipment, wares, biological objects, ground, solidified liquid RW, spent sealed ionization radiation sources of classes of hazard 4 and 5, specified by the federal rules and regulations on the nuclear energy use;
 - b) it belongs to one of the following types of waste:
 - LLW containing radionuclides with the specific activity:
 - from 10^7 to 10^8 Bq/g – for tritium-containing RW;
 - from 10^3 to 10^4 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - from 10^2 to 10^3 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - from 10^1 to 10^2 Bq/g – for RW containing TRU-radionuclides;
 - RW of very low activity containing radionuclides with the specific activity:
 - below 10^7 Bq/g – for tritium-containing RW;
 - below 10^3 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - below 10^2 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - below 10^1 Bq/g – for RW containing TRU-radionuclides;
 - c) according to the acceptability criteria specified by the federal rules and regulations on RW management, it is subject to near-surface ground disposal in RW repositories placed at the ground surface level.

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5. Taking into account the technological features of its management, the disposable RW is classified as category 5 if it meets the following criteria:
 - a) it is liquid RW represented by further unusable organic and inorganic liquids, slurry, and sludge;
 - b) it belongs to one of the following types of waste:
 - ILW containing radionuclides with the specific activity:
 - from 10^4 to 10^8 Bq/g – for tritium-containing RW;
 - from 10^3 to 10^7 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - from 10^2 to 10^6 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - from 10^1 to 10^5 Bq/g – for RW containing TRU-radionuclides;
 - LLW containing radionuclides with specific activity:
 - below 10^4 Bq/g – for tritium-containing RW;
 - below 10^3 Bq/g – for RW containing beta-emitting radionuclides (except tritium);
 - below 10^2 Bq/g – for RW containing alpha-emitting radionuclides (except TRU);
 - below 10^1 Bq/g – for RW containing TRU-radionuclides;
 - c) according to the acceptability criteria specified by the federal rules and regulations on RW management, it is subject to deep underground disposal in RW repositories constructed and operated as of the date of entry into force of Federal Law “On radioactive waste management and introduction of amendments in separate legislative acts of the Russian Federation”.

6. Taking into account the technological features of its management, the disposable RW is classified as category 6 if it meets the following criteria:
 - a) it is RW generated during the uranium ores mining and processing, as well as during activities unrelated to the nuclear energy use, on mining and processing of mineral and organic feedstock with the increased content of naturally occurring radionuclides;
 - b) according to the acceptability criteria specified by the federal rules and regulations on RW management, it is subject to near-surface ground disposal in RW repositories.

The RW classification will determine the choice of management technique and cost according to its potential hazard.

Within the new conversion facility the following main liquid RW streams will be formed:

- Stream 1 – nitric-acid solutions after uranium extraction (raffinates).ILW and LLW with macro-amounts of stable impurities (base - Fe, Al, Si, Ca, Na, HF, H₂SO₄);
- Stream 2 – solutions after chemical denitration of uranium re-extracts.LLW with macro-amount of NH₄NO₃; and
- Stream 3 – fluorine-containing solutions formed during UF₆ production.LLW with macro-amount of NaF and NaNO₃.

At present SGChE and Russian R&D institutes are exploring the following technological processes on the disposal of these main liquid RW streams:

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- Stream 1 – evaporation up to solid product and its transfer for recycling at the uranium mining enterprise, return of nitric acid to the process flow;
- Stream 2 – catalytic decomposition of ammonium nitrate with the gaseous phase conversion into nitric acid and its return to the process flow; and
- Stream 3 – neutralization of fluorine-containing solutions with the production of synthetic calcium fluoride and its reutilization in the hydrogen fluoride production.

However, these technological solutions on the improvement of RW management system are not ultimate yet with regard to the new conversion facility.

CONCLUSIONS

The history of the SGChE development shows that during 1950s the choice of the most potentially hazardous RW management techniques at the construction stage were imposed not by the concern about the mitigation of RW impact on environment and community, but by the necessity to commission the whole facility complex as fast as possible. This was caused by the world's geopolitical situation and unavailability of explored and proven RW management technologies. The evolution of the world's political environment and the aspiration of Russian and industry leadership for enhancing the environmental safety at operating facilities and establishing up-to-date and safe production altogether resulted in the drastic change of approaches to RW management. The revisions of the Russian legislation brought about the necessity to employ the safest and competitive technologies on RW management at newly-constructed facilities. In particular, this applies to the implementation of the project on new conversion facility construction. There are several options reviewed with regard to the RW management systems, for the best one to be selected and implemented within the project. Hence, the search for the world's up-to-date and proven technologies and equipment for RW management which allow eliminating liquid waste burial is a promising line of cooperation.

On the basis of the above-stated, the possible areas of cooperation within the framework of the project "Construction of the new conversion facility" are the following aspects of comprehensive engineering in RW management:

- conditioning of liquid ILW and LLW containing mineral acids (HNO_3 , H_2SO_4 and HF) and macro-amounts of stable impurities;
- manufacturing of containers suitable for solid RW ground disposal;
- compacting solid RW;
- technological solutions and materials for RW immobilization.