PROSPECTS OF LARGE DIAMETER WELL CONSTRUCTION AT "RADON" SITES

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ABSTRACT

The main purpose of radioactive waste management is to develop methods of radioactive waste containment that will eliminate any negative influence on the public and the environment. Since 1997 MosNPO "Radon" has been testing large diameter wells (LDW) as low and intermediate level waste (LILW) repositories, a new technique for the "Radon" system. In the case of LDW applications for LILW storage, the wastes are removed from the scope of human activity into a stable geological medium. Wastes are placed below the frost zone where damage to engineered barriers due to climatic factors is practically impossible. Construction of the repository by means of drilling prevents large disturbances of the hosting rocks, as happens during excavation work. When LDW are used, the usage factor (ratio of repository surface area, protected with natural barrier, to total repository surface area) of the geological barrier (hosting rocks) is about 1, as almost all of the surface of the repository is protected with hosting rocks. This helps draw the conclusion that, even in the case of the total destruction of all engineered barriers, which is very unlikely, radionuclides will still be constrained in a small volume of the hosting rocks and their release to the human activity sphere is virtually impossible. The high degree of ecological safety of this new storage type allows considering it as a facility for a final low and intermediate level radioactive waste.

BACKGROUND

Application of radioactive substances in industry, medicine and scientific research leads to generation of radioactive wastes. The problem of improving reliability of isolation of the radioactive wastes is becoming more acute with each passing year, and requirements for ecological safety are getting more and more stringent.

Near surface repositories are considered to be acceptable for storage of wastes with low and intermediate levels of activity (LILW), which decay to safe levels in some hundreds of years. However, the experience with LILW isolation in the near surface facilities in Russia has shown that a lot of operational and natural factors impact on the engineered barriers and may cause failure of the isolation. In addition, the exploitation of the old repositories and construction of new ones require more area.

Significant increase in LILW isolation reliability and space saving may be achieved by wastes disposal/storage in large diameter wells (LDW), drilled in clayey sediments. To date MosNPO "Radon" specialists have been carrying out development of the LDW construction technology with the aim to use such wells for LILW isolation in moraine clays. The diameter of a LDW type repository may range from 1 to 5 or 6 m depending on drilling rig capabilities and performance parameters of the repository in whole. The depth of the wells depends on geological and hydro-geological conditions of the site.

A project for construction of a demonstration unit for LILW storage in large diameter wells at the MosNPO "Radon" disposal site near Sergiev Posad has been developed. The aim of the project is development of the technology of LDW repository construction and pilot operation of the new repository for 25-30 years.

The project provides for construction of 9 wells with diameters from 1.9 to 4 m and with depths from 40 to 50 m. The wells will be drilled in a 7.2 x 7.2 m grid. For radiation and geological monitoring 16 wells will be constructed.

The LDW construction is based on multibarrier criteria. The engineered barriers provided in LDW, have optimal shape and perform at stable conditions. For instance:

- The barriers have a closed ring configuration, which provides the ability to resist more load in comparison to open box shapes;
- The barriers have minimal contact with other barriers, decreasing negative impacts of one barrier on another.

However, the reliability of the engineered barriers does not reduce the role of the natural barrier, the hosting deposits. The post-closure long-term safety assessment and evaluation of likely radionuclide release to the environment in the case of engineered barrier failure credits the surrounding rocks with providing a medium that is able to constrain the contamination to remain within the site boundaries.

GEOLOGY OF THE TEST SITE

The upper geologic deposits in the area are Quaternary moraine clays between 0.0 and 62 m in depth. Below this layer a water-bearing Cretaceous horizon has been found. The aquifer is composed of sands and clays (in the top) and various grained sands (in the bottom). Water in the aquifer is artesian, and the water table is at the 41.8 m. depth. Between depths of 45.7 and 48.2 m, clays have local lenses of water-saturated sands.

Due to the hydro-geological conditions, the LDW depth was limited to 40 m.

During construction of the first wells it was discovered that the clayey deposits of the Moscow moraine, where the wells are placed, include local water-containing lenses and thin layers of sands and loamy sands, sometimes with gravel. Thickness of several sandy layers is 1-2 cm, seldom exceeding 5-10 cm. According to hydro-geological pump-down results, the hydraulic connection between the layers is absent or very slow.

Hydraulic conductivity (K_f) of:

- thin sand layers is 0.08-0.1 m/day,
- gravel loamy sands - 1.0 m/day,
- moraine deposits in average - 0.008 m/day.

Besides the sporadic underground water in the Moscow moraine stratum there is a water horizon in the clayey sands of the intermoraine fluvioglacial bed at the depth of 44.8 m. The clayey sand thickness is 1.6 m. The aquifer has a water head of 33 m (piezometric surface is at 11.4 m depth). The water has a bicarbonate-magnesium-calcium content and 0.4 g/dm^3 salinity. Hydraulic conductivity of the aquifer is 0.94 m/day.

Average sorption and filtration features of the Moscow moraine interbeds and the intermoraine fluvioglacial clayey sands are given in Table I.

Table I. Average sorption and filtration features of interbeds.

	Soils			
	loam prQ_{II}	loam $gQ_{II}ms$	loam $gQ_{II}dn$	loamy sand $flgQ_{II}dn\text{-}ms$
Average thickness, m	3.1	41.6	8,0	1.6
Plasticity index, %	16	9	11	-
Fraction content <0.005 mm, %	26	14	16	-
Colloid activity	0.61	0.68	0.70	-
^{90}Sr ?$_d$	78	27	26	24
^{137}Cs ?$_d$	3850	2300	2300	2260
K_f, m/day	0.0094	0.008	0.0013	0.94

As may be seen from Table I, sorption properties of the water-containing intermoraine clayey sands are close to the properties of the loams. Therefore, in the case of hypothetical radionuclide release to this aquifer, the contamination should not move too far because of the high sorption capacity and low permeability and hydraulic gradient (~0.001) of the horizon. Because of low water yield, the aquifer is not used for local water supply; nevertheless, it should be observed for possible radionuclide migration during the time of LDW site operation.

PILOT LDW SITE

In accordance with the project plan, two LDW repositories have been constructed at the MosNPO "Radon" Site. These are wells with 1.5m internal diameter and 40 m depth (Fig.1, a).

The wells were drilled with the A-50 drilling rig by means of rotary boring a 1.9 m diameter borehole, washed with clay mud. At completion, the well was cased with a steel pipe of 1.5 m diameter with a 16-20 mm wall thickness. After the casing string had been set, the drill string borehole annulus was filled with bentonite-cement mortar for providing isolation of the casing from surrounding rocks. When the bentonite-cement mortar solidified, clay drilling mud was pumped from the well.

In the dry well, containers of solidified radioactive wastes were set with a special lowering column. Metal 200-liter drums 0.6 m in diameter were used as containers.

It is worth noting that the wells may be used for both storage and disposal. In the first case the LILW containers are stored in a dry well and may be recovered at any time. In the second case, the void space between the containers and casing pipe is filled with bentonite-cement mortar and the wastes are not subject to recovery (Fig.1, b).

Control of near field rocks and leakproofness of the repository is provided by a monitoring system. The system consists of wells equipped with a set of high resolution seismic gages and radiometric equipment for monitoring any possible radionuclide release out of the repository boundaries.

A layout of the wells and special channels for monitoring of LDW repositories are shown in Fig.2.

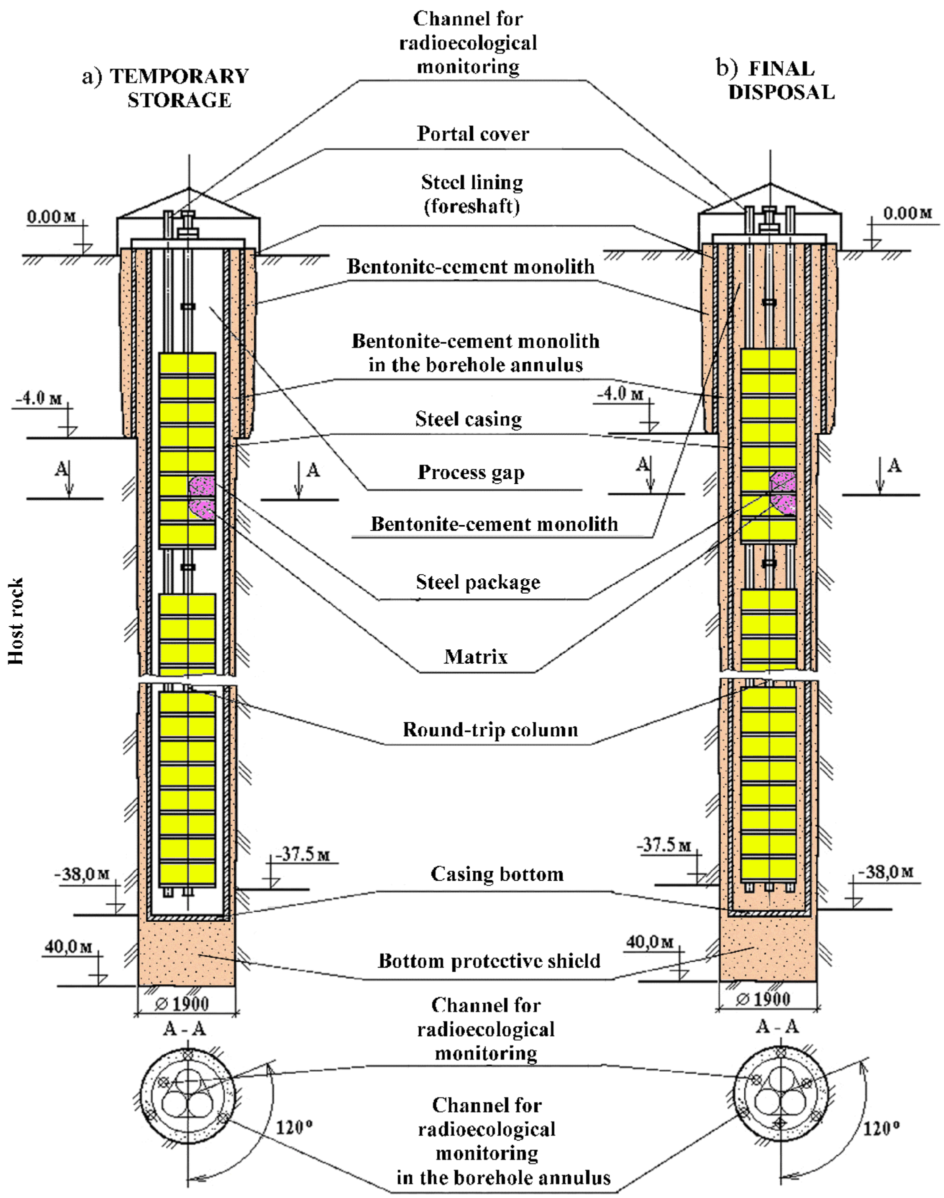

Fig.1. Large diameter wells applied as a LILW repository (a) and as a LILW disposal (b).

Geological monitoring wells are located between adjacent repositories. In geological monitoring wells, rock conditions during LDW drilling are observed. The results of stress deformation field observations will serve as a base for determination of a safe distance between LDW repositories from the point of view of rock stability. Radiation is controlled in the working zone of the repository, in the casing pipe annulus and in hosting rocks. The radiation monitoring results provide the basis for conclusions about isolation of LILW containers and the repository as a whole.

In the working zone radiation monitoring is performed by means of periodic gamma-logging in a work string. Using the same monitoring channel, possible water penetration into the repository is detected and controlled.

To control the isolation of a LDW repository, three metal perforated pipes as channels are set at the total depth of the repository in the casing string annulus. Within these channels gamma-logging is performed periodically and the hydrodynamic mode of underground water is controlled.

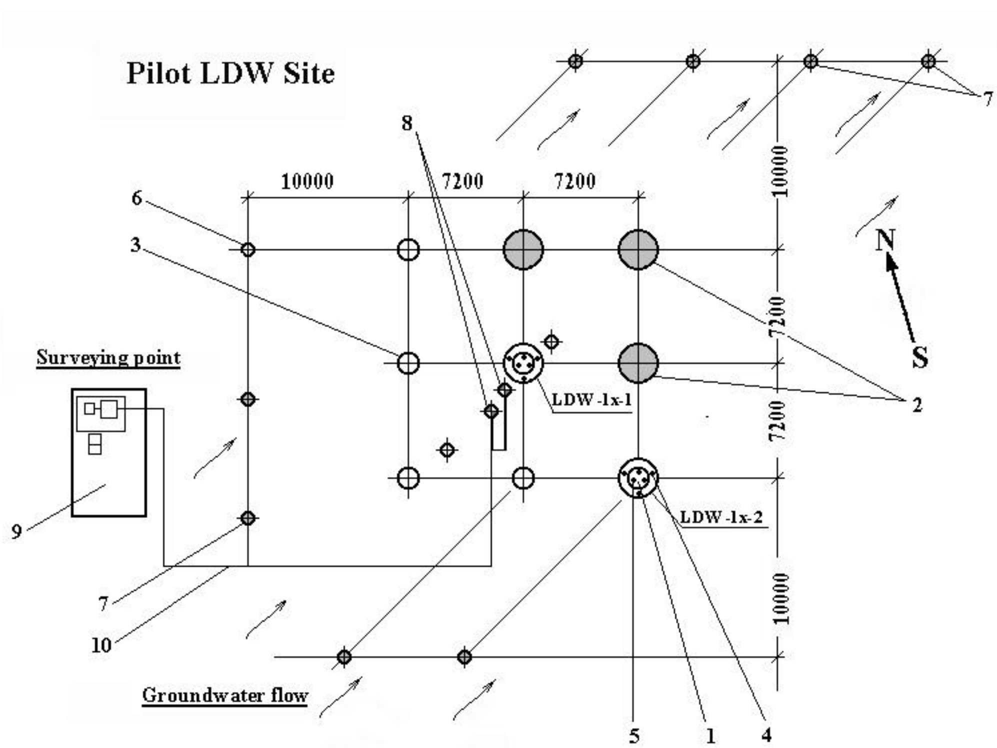

Fig.2. Pilot LDW site layout
1- LDW repository; 2- foreshafts, prepared for new LDW; 3- proposed LDW; 4,5- monitoring channels;
6- radiomonitoring boreholes; 7- projected radiomonitoring boreholes; 8- geomonitoring boreholes; 9- surveying point; 10- cable line.

Under certain conditions at the Sergiev Posad site, control of possible radionuclide releases from a repository in the hosting rocks can be performed using a well, located 2 m along the construction wall. The well opens into a water containing interbed, located at about 47 m depth and is situated along the flow path of underground water movement. Control of soil background radiation, hydrodynamic mode of the aquifer, and radionuclide content of underground water are determined using gamma-logging and water sampling methods.

The developed monitoring system allows controlling construction impermeability and surrounding rock stability with high level of reliability.

LDW ADVANTAGES

At the current time typical near surface repositories are widely used for long-term storage of conditioned low and intermediate level radioactive wastes (LILW) at "Radon" facility sites. But their essential disadvantage has been shownas a result of long operating experience and field monitoring at the sites [1]. This disadvantage is a decrease in LILW isolation reliability due to negative artificial and natural factors impact on the engineered protective barriers of the shallow ground repositories. In some cases there has been radionuclide migration into the near field, which leads to radioactive contamination of the ground around the storage facility. Decontamination of such ground results in generation of secondary wastes and in growth of storage costs.

Construction of new shallow ground repositories at the operating sites within the boundaries of the lease area is problematic because of the shortage of free area after 30-40 years of exploitation or for ecological safety reasons. Creation of new sites for LILW storage is difficult because of high costs of engineering surveys and construction works, long times required for obtaining regulatory authorization and license, and there is a strong negative public opinion about new repository construction for radioactive waste storage in Russian regions. These problems may be solved by increasing LILW repository reliability and by more effective use of existing sites.

In the case of large diameter wells (LDW) for LILW storage, the wastes are removed from the scope of human activity into a stable geological medium. Wastes are placed below the frost zone where engineered barrier damage because of climatic factors is practically impossible. Construction of the repository by means of drilling prevents large disturbances of the hosting rocks, as happens during excavation work. When LDW are used, the usage factor (ratio of repository surface area, protected with natural barrier, to total repository surface area) of the geological barrier (hosting rocks) is about 1, as almost all of the surface of the repository is protected with hosting rocks.
The construction of a LDW repository employs multibarrier protection of the environment from radioactive wastes. There are 6 barriers blocking likely radionuclide release, as follows:

1) the cement matrix;
2) the steel drum;
3) space between drums and the casing filled with bentonite-cement mixture in the case of disposal;
4) steel casing;
5) bentonite-cement stone around the casing column;
6) surrounding clayey soils. Shape and properties of the bentonite-cement stone protective barrier in a drilled borehole annulus depend on drilling technology and geology of surrounding strata.

The engineered barriers are made during the well construction. They have optimal shape and operate in stable conditions. At the expense of some increase in capital costs per m^3 of radioactive wastes [2], casing of a well with metal pipe with walls 10-22 mm in thickness, and grouting the bentonite-cement mortar into the space outside of the casing wall, the reliability of the LDW repositories is greatly increased.

Thus, the key differences between the LDW repositories and near surface ones are:

- there are a metal casing and bentonite-cement stone in the drill annulus, as additional protective barriers;
- the zone of hosting soils, broken during the drilling, becomes stronger after bentonite-cement mortar grouting;
- LDW depth may be up to 100 m, when depth of near surface repository bottoms is generally 3-4 m, not more than 10 m. Thus, the hosting soils play a more effective role in providing safety than in the case of typical near surface repositories.
- due to the depth, impact of climatic factors on LDW construction and waste leaching is minimal.
- These factors help lead to the conclusion that, even in the case of total destruction of all engineered barriers, which is very unlikely, radionuclides will be constrained in a small volume of the hosting rocks and their release to the human activity sphere is virtually impossible.

Thus, LILW storage in large diameter wells may be used to satisfy current requirements for long term radioactive waste storage. This type of repository appears to be promising for application at existing operational "Radon" sites.

CONCLUSION

Technologies used during LDW construction help make engineered barriers with desired parameters, which meet geological conditions of a given site. Such barriers will provide reliable isolation of radioactive wastes.

Monitoring systems will provide the possibility to control conditions during waste storage both inside the repository and outside, and allow remedial maintenance in case of an emergency. Hoisting mechanisms and charge-discharge systems allow removing waste packages at the end of the storage period or in the case of a need to retrieve the containers.

In spite of rather high storage costs, the LDW repositories guarantee more reliable radioactive waste isolation and, consequently, higher levels of safety for the public and the environment. The implementation of LDW repositories at operating sites for LILW storage, which are located in populous East-European regions of Russia, instead of typical near surface ones, will allow conservation of existing waste repository areas and help solve the problem of negative public opinion about new disposal sites construction. Therefore, consideration of the matter from every side, taking into account all social and economic issues, will allow acceptance of the decision to establish radioactive waste placement sites.

REFERENCES

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