Khazar Iodine Production Plant Site Remediation in Turkmenistan. NORM Contaminated Waste Repository Establishment - 12398

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ABSTRACT

Radiation safety provisions for NORM contaminated areas are in use in a number of the former Soviet republics. Some of these areas were formed by absorbed radionuclides at the iodine and bromine extraction sites. As a rule, there are not any plant radiation monitoring systems nor appropriate services to ensure personnel, population and environmental radiation safety. The most hazardous sites are those which are situated in the Caspian Sea coastal zone. The bulk of the accumulated waste is represented by a loose mixture of sand and charcoal, which was basically used as the iodine extraction sorbent. The amounts of these wastes were estimated to be approximately 20,000 metric tons. The waste contamination is mainly composed of Ra-226 (U-238 decay series) and Ra-224, Ra-228 (Th-232 decay series).

In 2009, the "ECOMET-S", a Closed Joint-Stock Company from St. Petersburg, Russian Federation, was authorized by the Turkmenistan government to launch the rehabilitation project. The project includes D&D activities, contaminated areas remediation, collected wastes safe transportation to the repository and its disposal following repository closure.

The work at the Khazar chemical plant started in September, 2010. Comprehensive radiological surveys to estimate the waste quantities were carried out in advance. In course of the rehabilitation work at the site of the Khazar chemical plant additional waste quantities (5,000 MT, 10,000 m^3) were discovered after the sludge was dumped and drained. Disposal volumes for this waste wasn't provided initially. The additional volume of the construction wastes was required in order to accommodate all the waste to be disposed. For the larger disposal volume the project design enterprise VNIPIET, offered to erect a second wall outside the existing one and this solution was adopted.

As of May, 2011, 40,575 m^3 of contaminated waste were collected and disposed safely. This volume represents 96.6% of the initial repository volume. Now work is underway to erect the second repository wall, which will allow housing of the additional 16,800m^3 The Khazar chemical plant territory restoration work is underway as well.

INTRODUCTION

The radioactive safety provision for NORM contaminated territories (including former iodine, bromine and other elemental extraction sites) is being applied in some of the former Soviet republics. The USSR legacy plants were stopped years ago owing to equipment wear and out-of-date technologies. Many sites have no radiation monitoring systems or any organizations to provide personnel, population and environmental radiation safety and control. Iodine extraction plants which are situated in Turkmenistan on the Caspian Sea constitute the highest ecological danger. Continuous extraction of Iodine, Bromine and other substances from underground mineral waters at the Khazar chemical and Balkanabat Iodine plants resulted in the formation of significant quantities of the NORM contaminated industrial waste including a few very contaminated spots. The bulk of the wastes are the sand, soil and charcoal or mixtures thereof. Charcoal was originally used as feed material for Iodine adsorption units. The waste quantity was initially estimated at about 20,000 MT (40,000 m^3). The main contaminants are Radium isotopes Ra-226 (U- 238 series), Ra-224 and Ra-228 (Th-232 series).

Under decree from the President of Turkmenistan remediation activities have been started on the mentioned sites in order to provide ecological and radiological safety and security. The tender for the project contractor was announced and later won by the “ECOMET-S JSC” (St. Petersburg, Russian Federation). In 2009 JSC ECOMET-S started to execute the project. The project name is “Balkanabat Iodine and Khazar chemical plants TENORM waste safe transportation and disposal”. The “Turkmenchem” State Corporation was appointed by the President as the Turkmenian Party contract holder. The Design and Research Institute “VNIPIET” (St. Petersburg, Russian Federation) was awarded the design contract. Federal radiological centre NIIRG from the same city became the subcontractor for the design.

The work scope is the demolition of the adsorption shops buildings and structures, site remediation, waste conditioning and transportation to the repository and disposal.
The main results of completed works at the Balkanabat iodine plant have been presented in a report [1].

The results of the work performed at the adsorption site at the Khazar chemical plant follow, including building dismantling, site rehabilitation, waste collection, its packaging and transportation to the repository. Work at the site of the Khazar chemical plant began in September, 2010.

THE KHAZAR CHEMICAL PLANT SITE REHABILITATION

The initial state of the charcoal adsorption site

Extraction of Iodine, bromine and other elements from underground mineral water by the adsorption method is accompanied by the accumulation of naturally occurring radionuclides (NORM) in sorption media (charcoal). During the adsorbent replacement, the repair, maintenance and cleaning the NORM accumulation in the production waste occurs, and the accumulated NORM dispersion through the environment begins.
Long-term adsorption technology utilization, inadequate and uncontrolled waste storage materials at the open sites have led to widespread contamination of buildings and adjacent territories of the Khazar chemical plant. The levels and the extent of the contaminated territory of the Khazar chemical plant were much higher than the ones at Balkanabat Iodine plant. The main building of the adsorption shop of the Khazar chemical plant consists of four blocks. Two of them contain absorbers (88 pieces in total). The absorbers’ design is similar to the design of those installed at the Balkanabat Iodine plant. Rinsing, separation, crystallization and pressing

departments, pumping station, warehouse, main switchboard and control rooms, laboratory, offices and ventilation chamber were situated in the other two buildings.
The 4,000 m^2 spent charcoal dump was situated behind the adsorption shop building. The spent charcoal quantity was estimated at the level of 18,000 m^3 with the depth of burial at about 5 m. Beyond the dump the artificial lake with the processed mineral water was situated. It was divided by the dam. By the time of the survey, the shop had not been in operation for more than 20 years. Partial destruction of building structures and equipment occurred after the shop shut down and the production transferred to the new buildings. The shop state at the moment of the survey is shown at the Fig. 1.

Fig.1. The shop state at the moment of the survey.

The first step in the project was the radiological survey. The NIIRG personnel carried out the gamma-radiation survey at the former coal adsorption shop and the current plant production site in 2009. The shop and the whole plant surveyed territories were 35,000 and 350,000 m^2, respectively. The work objective was to discover and mark the areas and spots with contaminated waste which were subject to excavation and disposal. The survey discovered 31 significantly contaminated spots with surfaces from a few to 16 thousand m^2 and depths in the range of 4-5 m. The natural nuclides' effective specific activity and the waste category were determined for the all anomalies, mentioned above. The waste categories were specified in accordance with the existing Russian Federation sanitary rules [2]:

Table I. NORM contaminated industrial waste categories.

Waste category	Effective specific activity (SA_E), kBq/kg	Dose capacity (DC), µrem/hour
I	≤ 1,5	≤ 70
II	1,5 < … ≤ 10,0	70 <…≤ 450
III	> 10,0	> 450

According to the survey estimates the following wastes were subjected for excavation and disposal:

Table II. Waste estimates.

Waste physical form	Effective specific activity, Bq/kg	Categ ory	Quantity, cu. m.
Charcoal & sand (soil) loose mixture	1,500-10,000	II	14,000-17,000 cu. m.
Charcoal & sand (soil) loose mixture	>10,000	III	18,000-25,000 cu. m.
Timber staff from the production cycle	1,500-10,000	II	About 500 cu. m.
Metal fragments	1,500-10,000	II	About 100 MT

The volume of the other industrial waste, including category I waste, hasn't been determined. The disposal of the surface contaminated buildings and structures fragments (concrete blocks, slabs, etc.) was considered inappropriate. These structures have to be decontaminated in place. The gamma radiation dose rates within the adsorption shop (6 anomalies, 29 measuring points), ranged from .40-.50 to 53.80 – 58.60 µSv /hour according to the radiation survey. The specific activity maximum within the radiation anomalies is 129 kBq / kg.
The gamma radiation dose rates within the other plant sites (25 anomalies, 111 measuring points) ranged from .90-.12 to 35.60 – 36.20 µSv /hour according to the radiation survey. The specific activity maximum within the radiation anomalies is 2.44 - 2.96 kBq / kg.

Technical solutions and the results of the works performed

The contaminated territories rehabilitation criteria were defined before the work started. Criteria selection was based on the need for further use for the new production buildings and facilities construction. The radiation safety performance parameters were identified in accordance with the existing norms:

Table III. Characterization of residual radioactive contamination of the plant after rehabilitation

The radiation safety parameters of the territory after the rehabilitation	Acceptable level
The NORM effective specific activity in the surface layers of soil and rock	1,500 Bq / kg
The specific activity of 226Ra in the surface layers of soil and rock	1,000 Bq / kg
The dose rate of gamma radiation	0.60 mSv / h

The complete dismantling (liquidation) of the shop was chosen as the 1st stage of the remediation project. The resulting waste, related to II and III categories, has to be collected, packed and shipped to the repository.
The work at the Khazar chemical plant site started in September, 2010 following the completion of work at the Balkanabat site. In the process of the project implementation the following work has been carried out:

-Various radiation measurements;
- Structures and process equipment dismantling and fragmentation;
-Waste segregation depending on physical nature and contamination levels;
-Waste collection and its packing into soft containers;
-Soft containers packing into the shipping containers;
-Waste transportation to the repository and its disposal.

The main waste volume (fragments of concrete, bricks, gravel, sand, charcoal and their mixture) has been moved by the front loaders. Then the waste was packed into Big Bag type soft containers (1 m^3 volume, 1500 kg payload) at the conveyor belt packing station. The VacTrailer S-4 vacuum suction unit was also used for spent charcoal collection [1].
The dismantling work at the adsorption site of the Khazar chemical plant was completed in February 2011. The site appearance after the dismantling campaign completion is shown on Fig. 2.

Fig. 2. Site appearance after the dismantling campaign completion.

In the course of the rehabilitation work additional waste amounts were discovered after sludge dump draining. The extra quantity of waste to be disposed was estimated at the 5,000 MT level (about 10,000 m^3). This waste was missed during initial survey because of its deeper bedding. Summary data for the rehabilitation of the territory of the Khazar chemical plant are shown in Table IV.

Table IV. The rehabilitation results of the territory of the Khazar chemical plant.

Indicator	Value
The initial gamma radiation rates: - adsorption shop site -operating plant	 0.23-56.55 µSv/hour 0.50-19.22 µSv/hour
Residual levels of the gamma radiation dose rates	0.20-0.25 µSv/hour
The initial effective specific activity of the NORM within the radiation anomalies: -adsorption shop site -operating plant	 0.3-129 kBq/kg 2.44-2.96 kBq / kg
The effective specific activity of the NORM in the surface layers (sand, soil) after the rehabilitation works and the waste removal	0.22-0.35 Bq/g
The specific activity of the 226Ra in the surface layers (sand, soil) after the rehabilitation works and the waste removal	0.15-0.23 Bq/g
The rehabilitated area: -adsorption shop site -operating plant	 31,000 m^2. 12,000 m^2
The disposed II category waste	4,733 m^3(474 20" containers)
The disposed III category waste	42,724 m^3(4,273 20" containers)
The total activity disposed	1.347 x 10^{12} Bq
Personnel individual exposure dose (for 1 year)	2-3.5 mSv

The total weight of the removed waste was 65,320 MT. Additionally, 6.5 m^3 (10.9 MT) of concrete with a total activity 5.92 x 10^7 Bq and 31 m^3 (25.5 MT) of ash after contaminated timber incineration (total activity of 4.24 x 10^7 Bq) have been collected and disposed.
A post-remediation survey has shown that the effective specific activity in the soil surface layers did not exceed 350 Bq/kg. The specific activity of 226-Ra in the surface layers of soil was 230 Bq/kg. The average gamma radiation dose rate is at 0.25 µSv / hour level. Thus the levels reached are significantly lower than the rehabilitation criteria values. The subsequent effective dose for all workers in the production area will not exceed 1 mSv per year, which corresponds to the dose limit prescribed for the general population.

REPOSITORY

The TENORM repository was built in a desert, in a 6-8 m deep natural hollow near Aligul` borough, about 9 km from the plant. The distances from the Balkanabat Iodine and the Khazar chemical plant are 120 and 9 km respectively. The distance from the Caspian sea is 7 km. The nearest settlement is Azizbekovo township, which is situated 5 km to the west of the repository. There are no open water sources or ponds in this area. Seismicity is magnitude 9.

A reinforced-concrete bowl is used as the storage facility. Its dimensions are 81.8 x106.8 m. The depth ranges from 5.44 to 11.44 m. Cell bottom dimensions are 80.0 x 105.0 m. The bottom surface is 8.400m^2. The storage volume is 42000m^3.
During radiation survey it was found that the TENORM repository and its surroundings out to 100 m distance have rather stable 10 – 22 µrem/hour radiation background. Dose capacities range from 0.09 to 0.13 µSv/hour. NORM effective specific activity (SAE) of the repository structures, neighboring territories and soils is about 120-190 Bq/kg. Most feasible level is about 150 Bq/kg. There are not any other surface and near-surface spots that are significantly contaminated within 100 m distance. The technical inspection has shown that the repository could be used for waste disposal after some repairs and additional equipment.

Repository filling and closure engineering solutions

The design and engineering documents have been worked out in accordance with the existing regulations of the Russian Federation and Turkmenistan. Safe waste storage in the repository for at least 100 years is a criterion that has been adopted. The repository bowl should be divided into cells by the double stacked used ISO containers. This option was designed to provide more effective filling and to prevent contamination migration. These containers are to be filled with full Big Bags directly in the repository.

Initially 20” 1CC containers have been designed. Later they were changed for the 40” (1AA) containers with cut off roofs. Containers should be strong enough to be double stacked. Deep and trough corrosion was not permitted. Six cells were formed in total.

The six cells are being filled with:
- Big Bag containers. These containers by themselves are being filled with contaminated media (charcoal. charcoal / sand mixture. soil. reinforced concrete and brick fragments).
- 3m^3. steel containers with contaminated metal.
- 200L barrels with incinerator ash.
- bulk fragments (reinforced-concrete. metal).

The cell cavities are being filled with the I category sand / soil. The leveling coating follows the cell filling. Cavity filling and leveling are carried out using Big Bags with the bottom discharge. After the coating has been done Big Bags containing charcoal are compacted by vibroplate in order to provide fire and explosion safety during the storage. Adsorbent charcoal is not self flammable and is heat and chemical burn retardant. Thus it can be stored in any way without the danger of the ignition. Figure 3 is a schematic cross section of the repository.

After all the sections are filled, leveled and compacted an upper protective shield has to be emplaced.
The repository’s shielding coating represents several layers of the different purposes:

- 0.5 m thick sand layer is to be placed over the waste. and into repository up to the height of the walls.
- 3-5 mm thick bentonite layer is laid over the sand as the waterproof media. The bentonite layer is overlapped to prevent moisture penetration. Also it will totally coat the repository outside walls.
- The basin pockets are filled up with the sand.
- Again 0.5 m sand layer is to be placed over bentonite.
- Geotextile 6 mm thick film should be placed over as a separating. filtering and protective media.
- The clay loam comes over. Its thickness should be at least 1 m over the repository ends. Because of the slopes the coating in the repository center has to be increased also.

Top altitude of storage is 28.5 m. Slopes batters are specified by laid coating stability conditions and designed to provide ground stability. Sand layer is being placed over bentonite coat step-by-step during repository filling. The sand layers and the bentonite coat also serve as a protection barrier against radon. The repository is equipped with an appropriate drainage system for water collection during filling, shielding and after closure. According to the safety norms 6 wells will be provided for potential radionuclide migration detection. Radiochemical analysis sample collection and ground water level monitoring will be performed.
The organizational and engineering measures, as well as the decisions on coal adsorption sites remediation, repository design, placement and filling ensure technical, radiation and ecological safety for the population and the environment.

Logistic solutions for the repository

A 45MT capacity mobile crane is used for the container loading and placement operations.
The waste from the Balkanabat and Khazar sites is delivered to the repository in the ISO 1CC containers, adopted for radioactive waste transportation [3]. After inspection, the truck brings container UKTN-24000 to the transshipment area, where containers are moved by the crane for the further unloading. The unloading is performed by 2MT diesel forklift.
Then the mobile crane places the packages with the waste to the cells formed by the 40" containers. The placement continues until the higher level of the second stack is achieved. Arising cavities are filled with I category waste (sand / soil) from reversible Big Bags with bottom discharge.

Dealing with the problem

As it was stated earlier, more than 10,000 m3 of waste has been discovered in the course of the work. It required the repository capacity to be increased to accommodate the additional waste. To expand the repository volume, the design enterprise VNIPIET designed an additional concrete wall around the perimeter of the existing repository walls. The height of the wall is 1.6 m (scheme is shown on the Fig.3):

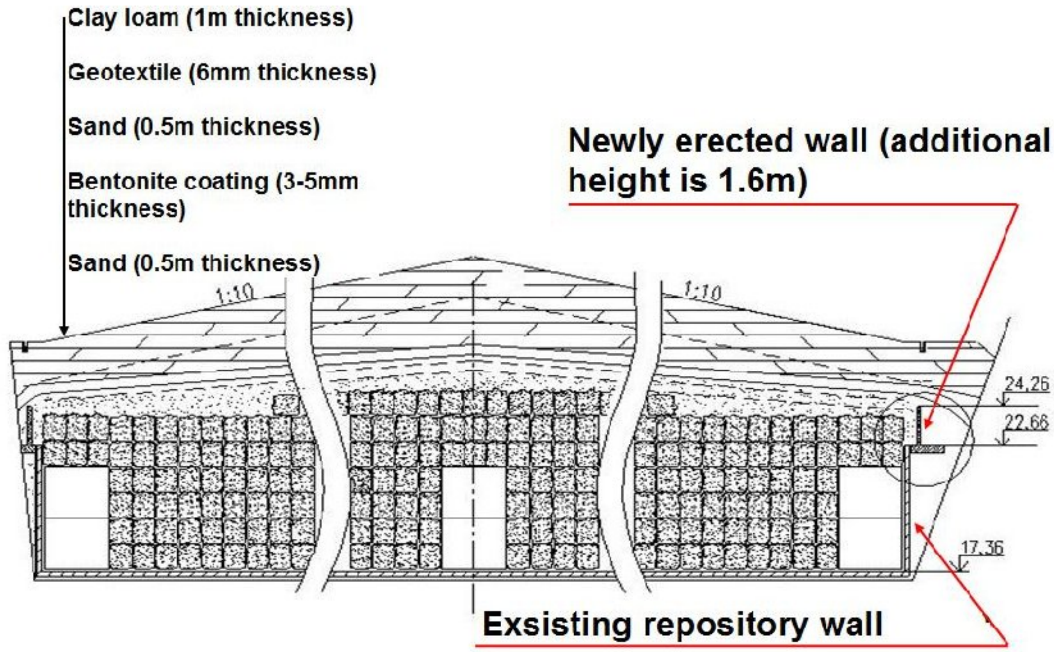

Fig. 3. Repository scheme with the additional wall.

The additional wall was erected in the July tthrough August, 2011 timeframe.
Its construction around the repository provided an opportunity to accommodate the additional 16 800 m^3 of the newly discovered waste.

WORK PERFORMED AND REPOSITORY STATE AS OF 20.10.2012

Before remediation started, a few preparatory actions were undertaken. Specifically, a radiological survey was conducted, project documents and remediation criteria were developed and approved, "ECOMET-S" JSC local branch was established and registered, infrastructure was created and equipment was purchased. Before the repository filling campaign, the following work had been performed:

- Hydro isolation repair;
- Controlled access area establishment.
- Drain system construction.
- Inner cells formation.

The project implementation phase started in 2009. By September, 2010 demolition and remediation work at Balkanabat site was finished. Altogether 3898 Big Bags (4415 m^3) of II category waste and 10 Big Bags with adsorbent charcoal of the III category (15 m^3.) have been filled and sent for the further disposal. Disposed waste total weight was 5,466 MT. Total activity was 1.063 x 10^{10} Bq.
The disposal campaign at the Khazar site started in September, 2010. The total disposed waste from the both sites is represented in the table below:

Table V. The disposed waste as of 20/10/2011.

Waste category	**Big Bags, piecs.**	**Volume, m^3**	**Weight, MT**	**Activity, Bq x 10^{10}**
II	8573	9076	11085	4.97
III	33743	42739	59691	130.83
Total	46316	51815	62776	135.8

Disposed waste total weight is 38.110 MT. Total activity is 1.112 x 10^{13}Bq. As of the beginning of May 2011 40.575 m^3 of the waste were transported and disposed amounting to 96.6 % of the repository total present capacity.

Fig. 4. Repository is filled with more than 90% of the wasre.

In the course of the work at the Khazar site it was discovered that the initial waste quantity was underestimated. That means it was necessary to remove and place an additional volume of at least 1.000 $m^3$of II and III category waste in the repository. Following the requirement for additional capacity, additional reinforced-concrete external cells around the main perimeter were designed. This solution will allow increased repository capacity of 16.800 m Because of the additional amount of work the project completion was re-scheduled for December. 2011.

FINAL STATEMENT

Project practical implementation phase has shown that the chosen organizational and technical approaches, as well as major decisions on the remediation, repository placement and filling provide technical, radiological and environmental safety to environment, personnel and population. The project implementation will prepare the former contaminated areas for industrial use, improve the ecology and provide future secure operations for running facilities.

Experience obtained during this project can be used for TENORM repositories design, filling and closure.

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