Decommissioning of Underground Storage Tanks of Liquid Radioactive Waste at the A1 NPP in Slovakia – 14252

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ABSTRACT

Decommissioning of the underground storage tanks of the Active water purification station was performed in the frame of the A-1 NPP Decommissioning project. The tanks had been used for storage of liquid RAW and sludge from operation of the A-1 NPP and later for storage of liquid waste from decommissioning activities.
The tanks are made of concrete and their inner surfaces are finished with waterproof mortal and lined with PESL (Glass fibre reinforced polyester). There are five tanks with diameter of 6 m, height of 4 m, and two tanks with diameter of 16 m, copula's height of 7,2 m.
Manipulator DENAR-41 was designed and delivered for decommissioning of tanks. It was used for cutting of internal pipes, pumping of bottom sediments from tanks and decontamination of internal surfaces of the tanks.
The overall volume of liquid RAW and sludge stored in the tanks was 213 m^3. The specific activity of Cs-137 ranges from 1.10^9 to 6.10^9 Bq/kg in dry residue of sludge. Aqueous phase was pumped from the tanks into the certified stainless tanks. Sludge and bottom sediments were conditioned into cement matrix directly at the places of their retrieval in the Movable cementation facility.
The PESL lining was removed manually. Adjacent soil around the tanks was excavated, the ceilings of the tanks were demolished and inner contaminated concrete layers were decontaminated.
Then, the final monitoring was performed and the release certificates were issued. Finally the tanks were backfilled with non-contaminated soil and the area was grassed over.

INTRODUCTION

The first NPP operated in Slovakia was the A1 NPP Jaslovske Bohunice. Its reactor was cooled by CO_2, moderated by heavy water and natural uranium was used as a fuel (HWGCR type). It was in operation since 1972 and was finally shutdown in 1977 after an accident (level 4 according to the International Nuclear Event Scale). The government decided about the final shutdown of the A1 NPP in 1979 on the bases of technical, economic and safety analyses.
During the transition period (1977-1999) all spent fuel from the A1 NPP was transported to the Russian Federation. Some auxiliary buildings were decommissioned to the green field. The part of the Turbine building was refurbished for processing and storage of radioactive waste. The A1 NPP Decommissioning project began in 1999. It is divided into five separate licenced stages. The aim of the first stage (1999 -2008) was to achieve radiation safe status of the NPP and therefore the main activities were focused on risk minimising of radioactivity spreading to the environment - amid others treatment of liquid and wet radioactive waste. The purpose of the second, on-going decommissioning stage (2008-2016), is decommissioning of outer active objects - their reconstruction for decommissioning purposes, reuse, demolition or their release

from the authority control. The subsequent individually licenced decommissioning stages (Stages III-V) are planned for period 2016-2033 with decommissioning of reactor itself by 2033.
The decommissioning of the underground storage tanks of the Waste water purification station has been one of the main priorities of the A1 NPP Decommissioning project, because the stored waste represented the direct threat to the environment.

UNDERGROUND TANKS

The underground storage tanks of the Active water purification station are located in the open area (garden) next to the station. The tanks were built in 1960s. They are made of concrete and their inner surfaces are finished with waterproof mortal and lined with PESL (Glass fibre reinforced polyester coating). The outside surface of the tanks is insulated by asphalt boards. There are five tanks with diameter of 6 m, flat ceiling, height of 4 m and volume 113 m^3. Three of them are divided into two separate tanks by partition walls (tanks No.: 1, 2, 3/1, 3/2, 4/1, 4/2). The other two tanks (tanks No.: 7/1and 7/2) have diameter of 16 m, monolithic arched ceiling with copula’s height of 7,2 m and volume 1 000 m^3. The dimensions of entrance chambers are 1600 x 1600 mm and height 3 300 mm and the dimensions of manholes on the bottom of the chambers are 575 x 575 mm (see Fig. 1).

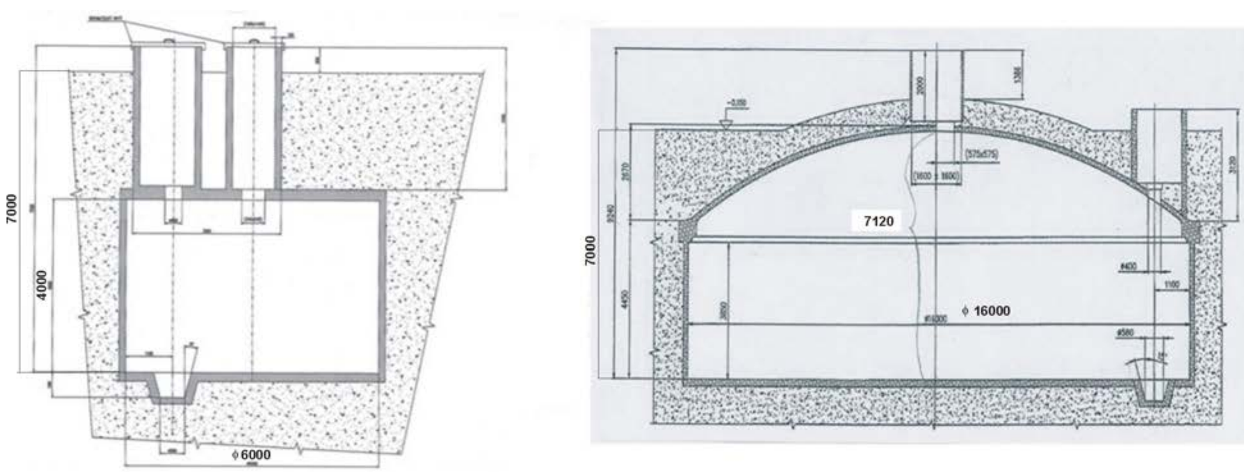

Fig. 1. The underground tanks

WASTE CHARACTERISATION

The tanks served for collection of waste water from operation of the A1 NPP - laundry water and mechanically contaminated water. Later they were used also for collection of water from decommissioning activities, when high active water was treated by means of potash ferrocyanide and copper sulphate.
The overall volume of liquid RAW and sludge stored in the tanks was 213 m^3. Samples have been several times taken and analysed in laboratories. The basic chemical and radionuclide composition has been estimated and physical and mechanical properties have been determined too. The results of analyses can be summarized as follows.
There is a dominant amount of iron and calcite, which are probably in the form of oxo – hydroxides. The solid phase consists of composition of magnesium, manganese, chrome,

aluminium and silicium. The amount of dry phase is about 10% of mass. Aqueous phase contains the sulphates, chlorides, phosphoresces, alkali nitrate and hydrogen carbons.
The results of distribution of particles showed that the predominant fraction of particles is from range 1 to 10 μm. Their density ranges from 2.0 to 2.9 g/cm^3. The concentration of solid particles is from 15% to 20% of mass. The dynamic viscosity of sludge with 15% concentration of dry residue reaches 9 mPas.
Sludge contains a significant amount of alpha nuclides. The activity of Pu-238, Pu-239,240 and Am-241 in dry residue ranges from 10^5 to 10^6 Bq/kg. The activity of Cs-137 ranges from 1.10^9 to 6.10^9 Bq/kg and the activity of Co-60 ranges from 3.10^6 to 2.10^8 Bq/kg in dry residue of sludge.
Generally sludge is non-homogenous, with very adhesive properties and with great specific activity.

APPLIED DECOMMISSIONING PROCEDURES AND TECHNIQUES

The decommissioning of the underground tanks started in 1999 during the 1st stage of the A-1 NPP Decommissioning project. The project of the decontamination of underground tanks was elaborated after radiation fields were monitored in the tanks and samples of liquid and sludge RAW were taken. The project defined the basic steps of decommission of the tanks and required tools, equipment and facilities. Then the individual decontamination programs were prepared for each individual tank on the bases of its radiation situation and content of RAW.

Overall Decommissioning Strategy

- Radiation monitoring and sampling in the tanks
- Aqueous phase of liquid RAW repumping into certified stainless tanks
- Radiation monitoring and sampling in the tanks
- Decontamination of walls and ceilings by high pressure water rinsing
- Retrieval and treatment of bottom sludge and sediments
- Decontamination of tanks' bottoms by high pressure water rinsing
- Ripping off PESL from inner surfaces of the tanks
- High pressure water rinsing of inner concrete surfaces of the tanks
- Radiation monitoring and core drilling of concrete samples in the tanks
- Digging away soil in the vicinity of the tanks up to -7.0 m under surrounding terrain
- Monitoring and sorting of contaminated soil
- Demolition of entrance chambers and ceilings of the tanks (up to -3.15 m under surrounding terrain
- Decontamination of inner surfaces of the tanks by scabbling
- Demonstration of achievement of radiological criteria for free release of concrete structures of the tanks
- Backfilling of the tanks with clean soil (soil with activity up to 200 Bq/kg)
- Remediation of terrain over the tanks

Pre-decommissioning Characterisation of Tanks and Waste

Radiation monitoring and sampling in the tanks was performed at the beginning of the decommissioning tanks during the 1st stage of the A1 NPP Decommissioning project. The fields of dose rate were measured by handle controlled mechanical arm inserted into tanks. The dose

rate was measured in different levels and radiuses. The dose rate ranges from 0.1 to 2 mGy/hour. The smearable samples from inner surfaces were taken also by mechanical arm inserted into tanks. Samples of liquid RAW, sludge and sediments were taken too. The most of activity was found in sludge and bottom sediments. The activity of Pu-238, Pu-239,240 and Am-241 in dry residue ranges from 10^5 to 10^6 Bq/kg. The activity of Cs-137 ranges from 1.10^9 to 6.10^9 Bq/kg and the activity of Co-60 ranges from 3.10^6 to 2.10^8 Bq/kg in dry residue of sludge.
The aqueous phase of liquid RAW stored in the tanks was repumped into certified stainless tanks and monitoring of dose rates was performed again. In some cases the measured dose rates were higher, because the overall activity was mostly contained in the sludge phase of waste and sediments on the bottoms of the tanks. Sludge and bottom sediments in the tanks were non homogenous, with very adhesive properties and with great specific activity.

Manipulator DENAR-41

The remained levels of dose rates in the tanks after repumping of aqueous phase of RAW were still very high - up to 1 mGy/hour. Therefore special manipulator DENAR-41 (Fig. 2) was designed [1], tested and delivered for cutting of tanks' inner structures (sucking tubes, measurement pipes), retrieval of bottom sediments and sludge from tanks (by sludge pump) and decontamination of tanks' inner surfaces by high pressure water rinsing.

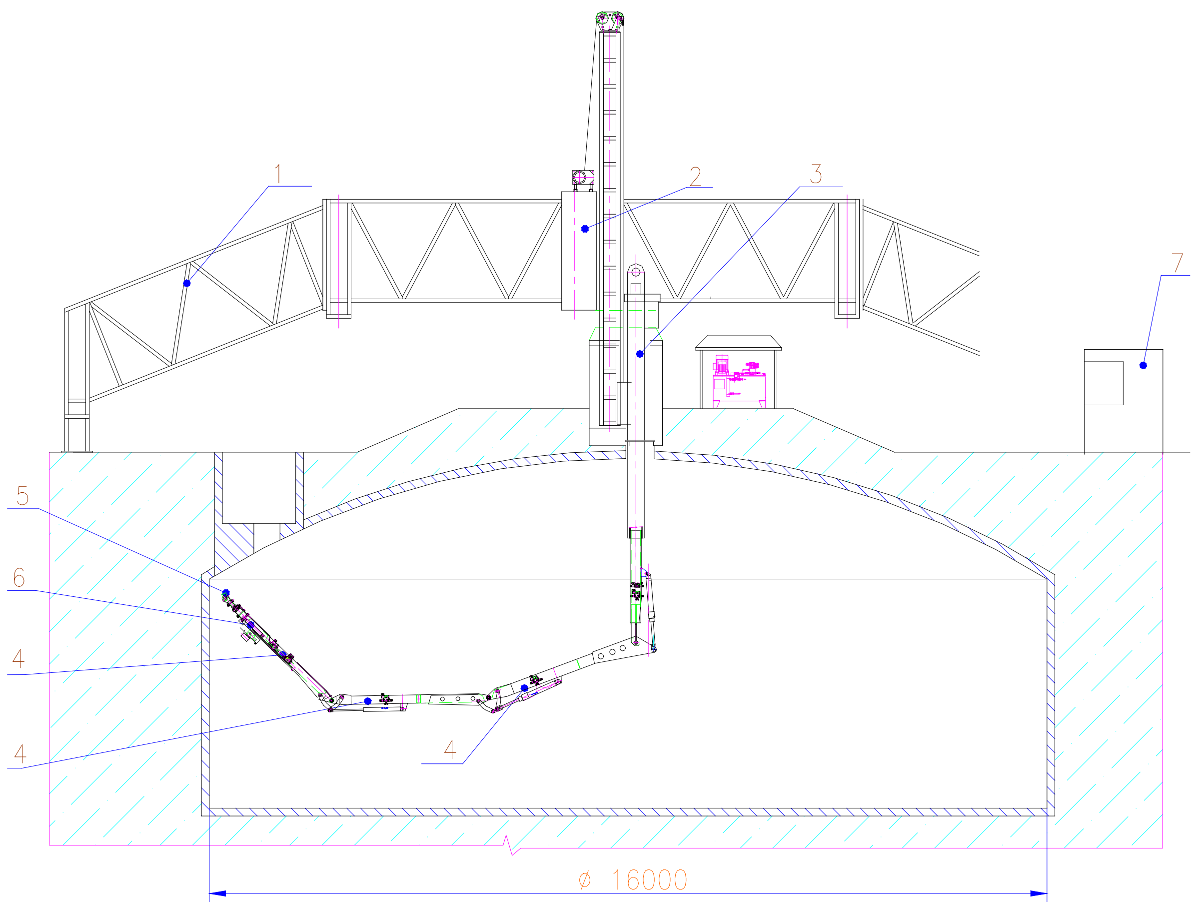

Fig. 2. Manipulator DENAR-41

DENAR-41 is long reach manipulator, which wrist can be equipped with different tools. It is long-reach hydraulic manipulator fixed to bearing construction. The bearing construction (1) is placed over tanks thus that its weight does not press on construction of tanks. The manipulator consists of vertical unit (2) with rotation column (3) and three tilting arms (4). The vertical unit is fixed to the bearing construction and the rotation column is inserted into tanks through entrance hole in inspection chamber. It rotates with arms around vertical axis (n x 360°). The tilting arms are attached to bottom part of the column and their kinematics allowed reaching any point on the internal surfaces of tanks. The arms are hydraulically actuated. The wrist (5) with tool is attached to the last arm (wrist yaw ± 90° and wrist pitch ± 30°).
The bearing construction and the tilting arms are modular type, because of different diameter of storage tanks (∅ 16 m and ∅ 6 m). In case of large tanks the reach of manipulator is 9 m and its payload at full extension is 35 kg. For smaller tanks the reach of manipulator is 6.15 m and its payload at full extension is 50 kg. In this case it is possible mounted manipulator MT-80 (autonomous remotely controlled dexterous manipulator) instead of the last tilting arm. This configuration is dedicated for decontamination of tanks with rather complicated geometry (e. g. tanks with partition flat walls). The wrist of manipulator can be equipped with necessary tools for decontamination and waste retrieval. Two cameras are mounted for in-tank views of the DENAR-41 operation and its maneuvering. One of them (6) is mounted to the forearm of the manipulator to watch operation of the tools.

Conditioning of Sludge and Bottom Sediments

Radioactive sludge and bottom sediments were conditioned into compact form directly at the places of their retrieval - next to the given tank. Movable cementation facility (ZFK) [2, 3] was designed and delivered for this task.
Radioactive sludge was fixed in a cement matrix directly in 200 l drums in batch operation mode. The formulation of cement grout was based on requirements for quality of final product and chemical and radiochemical composition of treated waste. The drums with conditioned waste were transported to the Bohunice RAW treatment centre for the final conditioning. The ZFK was designed for production of drums with overall activity up to 1.10^{11} Bq and dose rate on the drum's surface up to 30 mGy/hour. Apparatuses and equipment of the ZFK are mounted in four ISO containers and all operations are remotely controlled from control unit. The disposition of the Movable cementation facility is shown in Fig. No. 3.
The sludge to be treated was pumped from the underground tanks by the manipulator DENAR-41 to the ZFK through the pipe laid in the shielding concrete canal (4) to the sludge receiving tank (1a), which is placed in the first ISO container. The sludge operation tank (1b), the sludge weighting unit (2), the sludge and aqueous phase pumps, the sampling box and the decontamination solution tank (36) are placed in this container too.
The second container accommodates non-active apparatuses such as the bins for cement or other powder materials (34), the screw conveyors (5) for feeding of powders, two aqueous additive tanks (13, 17) and their dosing pumps and the compressor. The ventilation system with HEPA filter is placed on the top of the container.
The third and fourth containers are designed for processing of drums with waste. The roller conveyor (20), the dosing lid of the drums (10a), the powder material weighting unit (3), the homogenization unit (12), the vibration plate, the liquid additive weighing unit (22), the cement product sampling equipment (14), the mechanism for fixation of lids on drums (38) are placed there. The shielding along the roller conveyor (35) is made of lead plates. Furthermore, the containers are surrounded with concrete shielding panels (6).

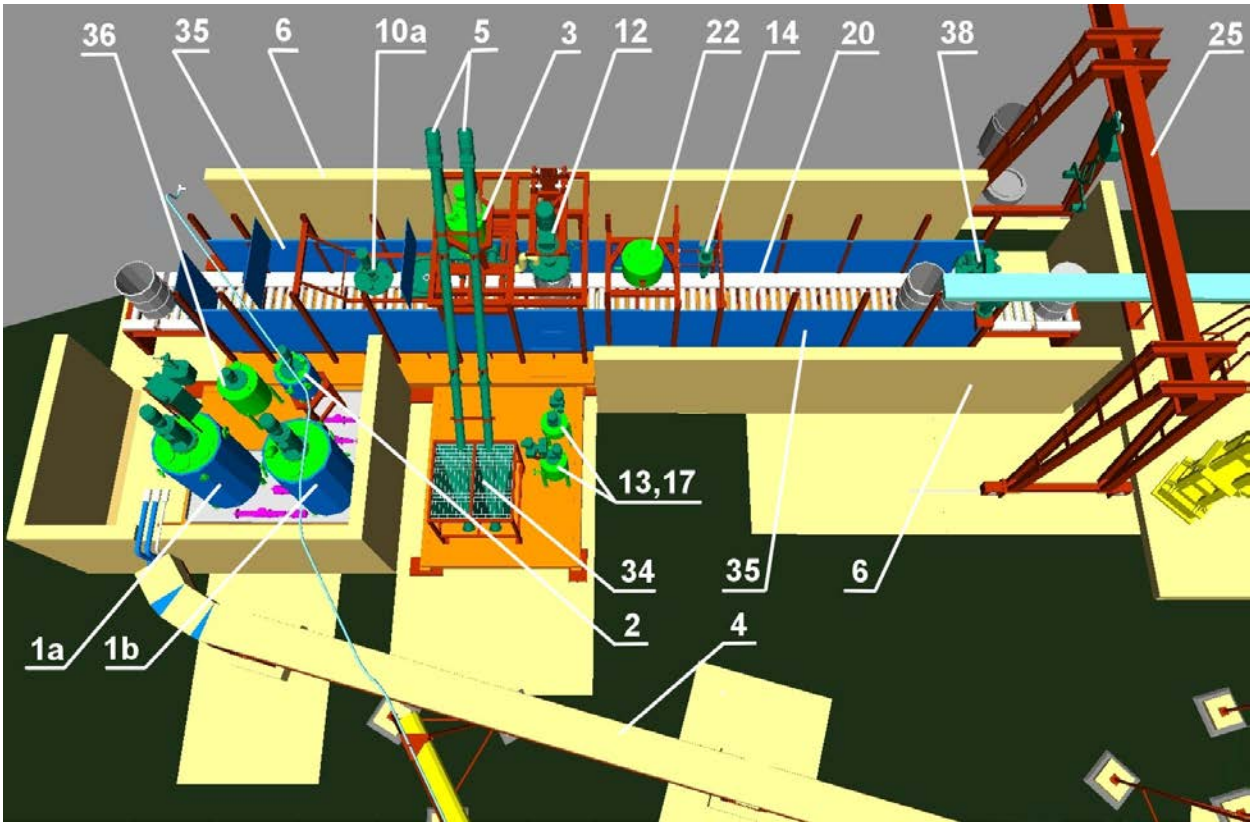

Fig. 3. Disposition of the main apparatuses of the Movable cementation facility

Decontamination of the Tanks

When the sludge and bottom sediments were retrieved from the tanks rinsing of the inner surfaces of the tanks was performed by the manipulator DENAR-41, which wrist was equipped with high pressure water jet.

The PESL lining of the bottom and walls of the thanks was removed manually during the 2nd stage of the A-1 NPP Decommissioning project. Removed lining was fragmented, loaded into 200 l drums and transported to the Bohunice RAW treatment centre for final conditioning.

Core samples were taken from the bottoms and walls of the tanks to check the depth of contamination in concrete as well as to prove that there were not leakages to surrounding soil.

Treatment of Surrounding Soil

There was concern that the tanks were overflowed during their operation or that some of them could have leaked. Therefore, contamination of soil in the vicinity of the tanks was checked by deep core drilling nearby the tanks and randomly in the whole area of the tanks location (garden). It was found that contamination was not significant, contaminated soil was found mainly near the inlet and outlet pipes of the tanks.

However, soil from the vicinity of the tanks (tanks No: 1, 2, 3/1, 3/2, 4/1, 4/2) was retrieved. Retrieving was done manually by excavation of soil layers in 0,3 m thick layers and continuous sampling and samples checking [4, 5].

Soil was sorted into three categories:

1. Soil with specific activity up to 200 Bq/kg - clean soil, which could be free released.
2. Soil with specific activity in range from 200 Bq/kg to 10^4Bq/kg, which was stored temporarily as Very low level waste.
3. Soil with specific activity more than 10^4 Bq/kg, which was loaded into drums as an RAW.

The special certified Facility for sorting of contaminated soils (PTKZ) [4] was designed tested and delivered for sorting of dug soil. Sorting of potentially contaminated soil is based on measurement of its activity by shielded twin LaBr detectors, which are mounted above moving belt, which transports specified layer of soil and continuous tensometric weighing of soil layer on the belt.
The facility (see Fig. 4) consist of the charging screw conveyor (1), the operation bin of soil (4), the belt conveyer with tensometric scale (3), detector unit (6) (two shielded LaBr detectors), the tree way flap (5), tree output screw conveyors (2), the specific activity evaluation unit (7) and switch board and control unit (8). The tree way flap switch output to the one of output conveyers on the bases of measured activity of soils and the given conveyer delivers it to the high capacity container placed next to the facility. All main equipment of the PTKZ is mounted in ISO container, which is divided to technological part and control part. The air conditioning keeps constant temperate necessary for precise measurement of soil activity. The capacity of the facility is approximately 10 t/shift.

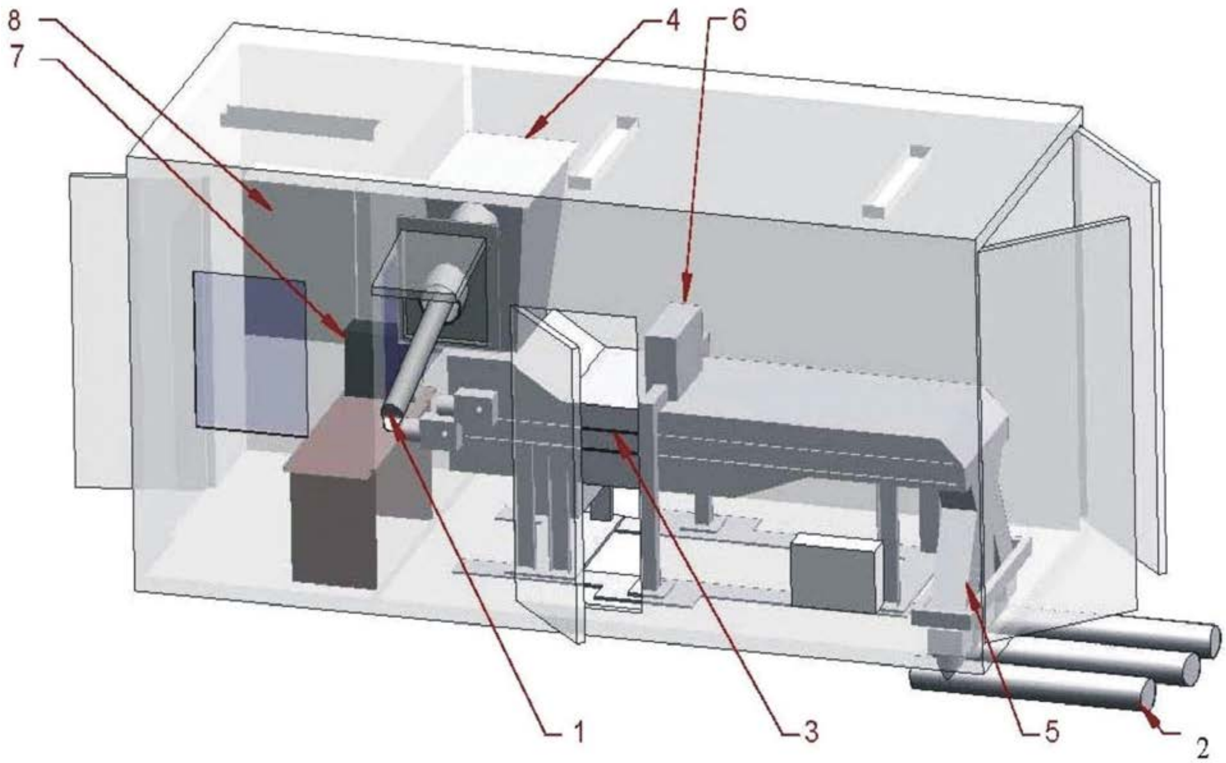

Fig. 4. Facility for sorting of contaminated soil (PTKZ)

The PTKZ facility can work in two operating modes:

1. It allows automatic sorting of soil into 3 adjustable categories: 200 Bq/kg < 200 Bq/kg to 10^4Bq/kg < 10^4 Bq/kg,
2. In certified mode it allows free release of potentially contaminated soils to the environment.

Dug soil with activity up to 200 Bq/kg was checked by the PTKZ and then clean soil was later used for backfilling of the tanks.

Treatment of Concrete Structure of the Tanks and Clearance Procedure

Concrete parts of tanks were demolished up to - 3,15 m under surrounding terrain level including ceilings of the tanks, entrance and sucking shafts. Concrete debris was loaded into 200 l drums or 600 l container and checked on Large Capacity Monitoring Post (LCMP) (see Fig. No. 5). LCMP consists of twin HPGe electrically cooled detectors (30% efficiency). Typical measurement time is 10 minutes with MDA at level of 10 Bq/kg for container geometry (Cs-137). Hard-to-Measure radionuclides (RN) are estimated according to the most conservative RN vector.
Concrete debris were treated as RAW or free released as conventional waste on the bases of monitoring. The concrete blocks of entrance and sucking shafts were decontaminated at the Facility for treatment of concrete (PNKB). Contaminated layers were removed from concrete blocks by grinding. Cleaned concrete blocks were crushed, loaded into 200 l drums and after checking on LCMP they were release and treated as conventional waste.

Fig. 5. Large Capacity Monitoring Post (LCMP)

Monitoring of remained concrete structures of the tanks was performed according to the EC recommendation RP-113. In situ LaBr gamma spectrometry was applied for dominant Cs-137 determination (100% covering) [6]. Other radionuclides including Hard to detect radionuclides were estimated on bases of known RN vectors. The squares of grid with dimension of 1 x 1 m were monitored and contaminated layers of mortal and concrete were removed by manual grinding and scabbling.
Then the clearance measurement of concrete surfaces was performed and release certificates were issued. Finally the tanks were backfilled with soil with specific activity up to 200 Bq/kg, soil was compacted and grassed over.

Fig. 6. Digging away soil in the vicinity of tank and scabbling its inner concrete surfaces

Conditioned Waste

The overall volume of liquid RAW and sludge stored in the tanks was 213 m^3. The aqueous phase of liquid RAW was repumped into certified stainless tanks. Sludge and bottom sediments were retrieved and fixed in the cement matrix directly in 200 l drums. It was retrieved 18 m^3 of sludge and sediments (1 720 kg of dry mass of sludge), which was cemented in 188 drums. The drums with fixed waste were transported to the Bohunice RAW treatment centre for final conditioning.
The PESL lining of the tanks was loaded into 200 l drums and transported to the Bohunice RAW treatment centre for final conditioning. There were produced 150 drums with PESL.
Up to submission of the paper, it was dig away 1 200 m3 of potentially contaminated soil from the vicinity of the tanks (tanks No.: 1, 2, 3/1, 3/2, 4/1, 4/2). Clean soil with specific activity up to 200 Bq/kg was used for backfilling of the tanks. Soil with specific activity in range from 200 Bq/kg to 10^4Bq/kg was temporarily stored as Very low level waste. Soil with specific activity more than 10^4 Bq/kg was loaded into drums and treated as Low level RAW.
Demolition of upper parts of the tanks generated 200 m^3 of concrete debris, which was loaded into 200 l drums and check on LCMP and then they were release as conventional waste or treated as RAW. The concrete blocks of entrance and sucking shafts were decontaminated at

the Facility for treatment of concrete. Contaminated layers were removed from concrete blocks by grinding, loaded into 200 l drums and transported to the Bohunice RAW treatment centre for final conditioning. Cleaned concrete blocks were crushed, loaded into 200 l drums and after checking on LCMP they were release and treated as conventional waste.

CURRENT STATUS OF DECOMMISSIONING

The tanks No.: 1, 2, 3/1, 3/2, 4/1 and 4/2 were completely decommissioned - liquid RAW was retrieved and conditioned, PESL was removed, upper parts of the tanks were demolished, surfaces of the tanks were decontaminated, and certificates for their free release were issued. The tanks were backfilled with clean soil.

The tanks No.: 6/1, 6/2, 7/1 and 7/2 were partly decommissioned - liquid RAW was retrieved and conditioned, PESL was removed and surfaces of the tanks were decontaminated by high pressure water rinsing. The soil in the vicinity of the tanks No.: 6/1 and 6/2 was dug away, the upper parts of the tanks were demolished and layers of contaminated inner surfaces were partly scabbled. Digging of soil in the vicinity of the tanks No.: 7/1 and 7/2 is being prepared for next year and completion of decommissioning of all tanks is planned in 2016.

CONCLUSION

Decommissioning of underground tanks represents complex set of different tasks - retrieval of liquid RAW, treatment and conditioning of sludge and bottom sediments from the tanks, digging and sorting of potentially contaminated soil, treatment with contaminated concrete, radiation monitoring and licenced monitoring for free release of different materials and structures.

During the decommissioning of the underground tanks of the Water purification station several tools, equipment, facilities, methods and procedures were developed tested and their performance was proved for above mentioned tasks. Some of them were unique and the other one can be easily used for other decommissioning tasks in the frame of the A1 NPP decommissioning projects.

Lack of above mentioned equipment, facilities, experience with procedures and methods and uncertainty regarding their specification and performance at the beginning of the tanks decommissioning causes lengthening of the whole project.

The unconditional release of underground tanks is being based on EC recommendation of RP-113 and generic radiological criteria valid in SR.

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