Experience with Decommissioning of the Underground Reservoirs of Object No.41 at NPP A1 Site (Bohunice, Slovakia) - 15110

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ABSTRACT

A new concept of measurement procedures for clearance of building have been developed and implemented at NPP A1 (Bohunice). They are based on measurements of total RN activity per unit of surface area at the erected building according to EU Recommendation RP-113 (pure Cs-137 limit - 10 Bq/cm^2). However, as a priority the requirements of national legislation had to be complied, which, in the case of concrete structures, limits the massic activity of the concrete bulk material to be rose from the building demolition (300 Bq/kg for pure Cs-137) and surface activity of (0,3 Bq/cm^2 for pure Cs-137). Advantage of the new concept is that it avoids costly whole volume measurement of building rubble (e.g. 200 L drum monitor) and potentially decreases amount of produced radioactive waste. Whole volume measurement has been replaced by whole surface monitoring of surface contamination of the walls by portable devices in 1 x 1 m grid. The methodology was implemented on underground tanks as well, whose clearance is one of the primary goals of 2nd stage of the NPP A1 decommissioning project. The measurements proved that contamination on the outer side is rarely present and it is caused by overflowing or leak of contaminated water from reservoir. The most expensive clearance activities were: soil excavation around the reservoir, dry decontamination of concrete, as well as whole volume measurement of crushed concrete ruble from the top of reservoir by drum monitor. A lot of obstacles had to be overcome because of lack of experience with methodology (procedures were implemented as a pilot project), measurement and sampling techniques. During the pilot project rose other difficulties which had to be overcome.

INTRODUCTION

Characterization monitoring and decontamination of buildings surfaces precedes the clearance and free release of the building. In 2009 a new conception of building clearance was proposed within the decommissioning project of Bohunice NPP A1, Slovakia - [1], [2], [3]. The conception is based on recommendation of European Commission - RP113 [4, 5]. Its basis is that clearance measurements are performed in the erected building before the demolition. The main advantage of this approach is that the measured contamination of buildings structures is located in a very close distance (to the detector - thin self-absorption layer) during the measurement carried out. One of important parameter for contaminated concrete structures, depth of contamination, was experimentally investigated within the project. It was found that the penetration of contaminants (Cs-137) after about 30 years is rarely bigger than 1-2 centimeters.

CHARACTERIZATION OF UNDERGROUND TANKS

Historical Data

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 lined with PESL (Glass fiber reinforced polyester coating). The outside surface of the tanks is insulated by asphalt. There are five tanks with diameter of 6 m, flat ceiling, height of 4 m and volume 113 m^3. Three of them (tanks No.: 1, 2, 3/1, 3/2, 4/1, 4/2) are divided into two separate tanks by partition walls (see Fig. 1).The underground tanks are monolithic concrete structures of cylindrical shape (diameter 6m, height 4m) with concrete thickness approximately (20 -25) cm. Each tank had two entrances and inspection shafts [6].

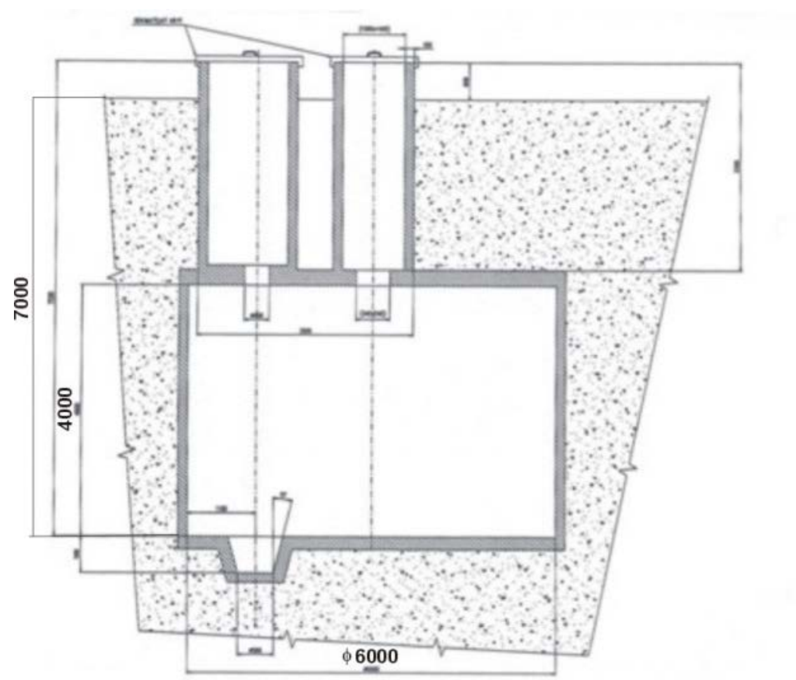

Fig. 1. The underground tanks

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. 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.

There is lack of detailed records of some incidents, in case of NPP A1. It is well known that some incidents occurred around the underground tanks, but information from various witnesses were contrary to each other, so could not rely on any information. This is very typical for old designed nuclear facilities that there is lack of detailed records, especially in case of NPP after accidents where some incidents occurred. Many of witnesses of the incidents are retired or they are scared to talk about. Nevertheless, concerning the underground tanks it is well known that land around the tanks has been flooded. There is also information that some of the tanks have been overfilled and therefore a contamination of soils can be found in the close surroundings and the soil must be treated and conditioned during clearance of the tanks.

Measurements - Conception of Buildings Clearance

It is proposed to use limits for total activity per unit surface area, which are specific for radionuclides according to RP113 [4], [5] (e.g. 10 Bq/cm^2 for Cs-137). For building rubble it was shown that after demolition of a typical concrete object (average thickness of walls is about 50 cm) the total surface activity limits according to RP-113 comply with the mass activity criteria (assuming that contamination is concentrated only in the surface 1-2cm layer, rest of concrete is without contamination) given in Slovak legislation [7], 300 Bq/kg for Cs-137 (radionuclides in the 1st class of radio-toxicity). Measurements of total surface contamination of radionuclides by properly calibrated devices for measurement of gross beta activity by large surface scintillation detectors and depth of contamination determination for dominant Cs-137 by semiconductor detectors were proposed within the prepared concept.

The concept of building clearance consists of 3 stages [1], [2], [3]:

- Pre- decontamination
- Post- decontamination and characterization
- Clearance

Measurements within pre- decontamination stage are performed mainly by devices for measurement of surface contamination where total surface activity of Cs-137 is measured. Many surfaces are contaminated in very limited depth and therefore it is suggested to remove the surface layer (1-2 cm) of surfaces with large potential of contamination before the measurements. From experiences it’s known that with this layer 75 - 90 % of total activity will be removed.

The primary purpose of the post- decontamination stage is to verify that decontamination of the surface is sufficient. In ideal case the measured values gained within this stage could be used for clearance. It means that 100 % of the surface should be measured. The same method of measurement is used as in previous stage. Otherwise detailed grid has to be used (20 x 50) cm. Within the characterization stage all necessary radiological data should be gained (hard to measure RN, surface contamination in corners, piping, etc.).

Clearance Stage

Final survey is performed by independent organization to confirm the measured data. Monitoring grid should be different in this stage (results should be independent on origin of the grid). After confirmation of measured values, the building can be demolished. Authorities can require additional confirmation measurement of the building rubble by drum monitor, which is licensed for clearance / free release measurements [9], [10].

Results of the measurements from all stages of building clearance are continuously recorded in particular Database of Contaminated Concretes (DBCC) [11], [12], [13]. The database ensures quality assurance of measured data and complementary requirements of Slovak authority.

The DBCC is effective tool for continuous filling in with new data, presentation of characterization and clearance measurements, and decommissioning status of building structures. The DBCC is important part of the new conception of building clearance and enables effective communication with experts and the authority but also it serves for confidence with the public.

Scaling Factors

During the pre- decontamination stage samples of concrete core drill samples are taken. The samples are cut to slides and each one is analyzed individually by gamma spectrometry. Today, only dominant Cs-137 can be identified in the underground tanks concrete walls (more than 35 years after shut down) and therefore it is the only key radionuclide. Afterwards the most active samples are selected and analyzed by radiochemistry or by portable spectrometer (Sr-90 only) [13] developed at Kurchatov Institute [14]. There are four hard to measure RNs, which are important in conditions of NPP A1 - Sr-90, ^{241}Am-241, Pu-238 and Pu-239,240. Other radionuclides are not radiologically significant considering their specific activity.

Due to known average activities of hard to measure RNs and key RN in the samples, it is possible to create a scaling factor for given material in given room and building. This scaling factor is used for estimation of hard-to measure RN and for determination of derived clearance levels.

DECONTAMINATION

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. 2). 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) [9]. Hard-to-Measure RN are estimated according to the most conservative RN vector.

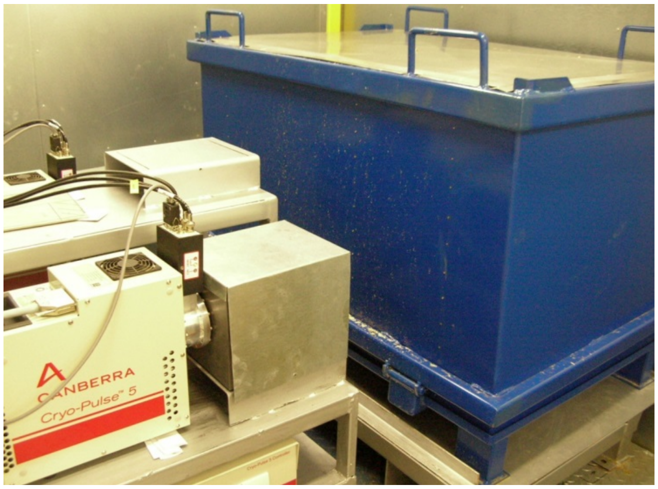

Fig. 2. Large Capacity Monitoring Post (LCMP)

Concrete debris were treated as RAW or free released as conventional waste on the basis 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 released and treated as conventional waste [6].

Decontamination of remained concrete structures of the tanks was performed on the basis of monitoring results. The squares of grid with dimension of 1 x 1 m were monitored and contaminated layers of concrete were removed by manual grinding, scabbing and hammering. After decontamination had been successfully finished, the tanks were backfilled by non-contaminated soil. Success and effectiveness of decontamination was proved by independent measurements.

Fig. 3 Hammering of the inner concrete surfaces

OBSTACLES AND LESSONS LEARNED

The most expensive clearance activities were: soil digging around the reservoir, dry decontamination, as well as whole volume measurement of crushed concrete ruble from the top of reservoir by drum monitor.

Soil digging was defined by space limits in the garden of obj. 41. Excavated soil had to be stored in the garden and therefore only limited place for manipulation was available. All soil has to be monitored but all monitoring devices were fully busy for characterization and clearance of another waste streams. A particular device - “spoon / bucklet” monitor has been developed for speed up of monitoring [16], [17], [18], scheme of which is on Fig.4.

Weather conditions were one of the limiting factor for sorting of the contaminated soil. During rainy weather it was not possible to continue with the activity, because terrain became dangerous for workers and mechanism was not possible to use in excavation hole. Nowadays it is clear that using a tent over the excavation hole would rapidly speed up digging out of soil. Next benefit of the tent would be risk reduction for contamination spreading by particles from soil treatment and from decontamination of concrete structures.

Fig. 4 Spoon soil sorting monitor

A lot of obstacles had to be overcome because of lack of experience with methodology (procedures were implemented as a pilot project), measurement and sampling techniques. During the pilot project of underground tanks decontamination rose other difficulties which could not or were not expected at the beginning and can be summarized as follows:

- Change of conception during the project: firstly was primary checked total RN activity per unit of surface area and later surface sum beta activity.
- Personal changes in decontamination group
- Change for decontamination technique
- Low quality of concrete at some places
- Presence of contamination in some place in deep structures.

- Presence of intensive interfering sources which disabled to perform direct measurements of surface activity.

Change of Conception

The conception of building clearance and measurement procedures has been consulted and approved by authorities. Conception of building clearance was based on recommendation of European Commission RP-113, it means, that total activity per unit of surface area (TAUSA) had to be monitored as the primary criteria. Mass activity was declared according to measured TAUSA. Besides of this surface activity was monitored as well (fortunately) to demonstrate that both criteria for surface and mass activity are met. First three of five underground tanks have been released by this methodology.

The purpose of originally proposed methodology of TAUSA measurement was to monitor Cs-137 in deeper layers, contrary to gross beta-gamma measurement required in Slovak legislation. After previous positive relation and acceptation of the TAUSA limit conception, the above mentioned conception was at last not approved by the health authority as a primary criterion for tanks clearance, and measurement of surface gross activity was chosen as the primary criteria. Except of surface activity it was necessary to monitor contamination in deep structures of concrete. This monitoring is fulfilled by monitoring of TAUSA on 100% of tank surface, because it is measured by scintillation detector (gamma radiation has much larger penetration that beta radiation) and therefore it is possible to see if any contamination is present in deep structures. Concrete core samples have been taken besides of TAUSA measurement.

Personal Changes and Change of Decontamination

A new decontamination technique has been procured during the project progress - after the first three underground tanks have been decontaminated and released. Only hammering was used for decontamination of the first three tanks. A specialized group of workers was set for manipulation with the new technique (scabbing, shaving, etc.). Aim of the bought technique was to speed up the decontamination process. Advantage of the new decontamination technique was eliminated by lack of historical data knowledge and experience of specialized team in field of decontamination practices.

Change of working group occurred during the lasting of the project and within this decision schedule of project and lasting of individual procedures was not taken into account and consequences was in prolonging of the project, because it was necessary to perform several cycles of decontamination. One of the main reasons of duration extension originated from unexperienced decontamination working group. Worker's primary goal was to produce as low amount of radioactive waste as possible, but after cost - benefit analysis it was clear, that this approach was not effective. Decontamination - measurement cycles took much more time as in case of previous tanks. Because of workers were focused on minimization of radioactive waste, only thin layer (up to 4 mm) was removed per one cycle of decontamination.

In the past hammering was used to remove roof of the tank. It means that from the side of the tank was concrete crushed and roof of the tank was lifted by crane. Specialized group cut hexagon from the top of the tank by saw so parts of the roof structure were not removed and remained at their place. In the past the tanks were overflowed and so as a result, significant contamination was not removed. It was decided to remove the contamination from inner side of the tank by hammering but it was shown to be not successful. Therefore it was decided to use previous method for roof removal -roof hammering from outer side and lifting of the roof as a whole.

At the end of year 2013 due to delay of the project it was at last decided to employ for decontamination and conventional hammering technique for decontamination the well experienced original experienced workers group for decontamination and to use originally approved decontamination technique. This group successfully finished the decontamination of the last two tanks within half year of 2014 using optimized working procedures.

Quality of the Concrete and Presence of Contamination in Deep Structures

According to our experience from the past and mainly from characterization of lower contaminated tanks it has been assumed that concrete of the same quality was used for construction of the last underground tank 6/2. It means that if any contamination has been identified in building structures, it was present only in very thin surface layer - not more then 2-3 cm and no further contamination was ever identified in deeper structures. During sampling (core drills) in the higher half of tanks cylinder tube, it was evident that cooling water outflew not from sampling point but from nearby cracks in concrete. This led to opinion that concrete is of low quality in this case and sampling in given point does not represent an average and representative value. Characterization by in situ measurements of the tank 6/2 was complicated by presence of interfering external source of ionizing radiation and therefore it was decided to remove upper half of the tank.

Interfering Sources of Radiation

The last underground tank (tank No.6/2) was adjacent to tank 7/1, which is the most contaminated concrete structure in the garden of the obj.No.41. Measured dose rates between tanks 7/1 and 6/2 were at level 0,1 - 0,3 mSv/h. Points of direct in-situ measurements on tank external surfaces lying on the tank's bottom half were well shielded by concrete structures (ambient dose rate up to 0,3 µSv/h). However, in the upper half of the tank was the situation more different. Dose rates in these places were too high in order to allow performance of direct measurements (few µSv/h) and on the other hand it was not possible to distinguish between contribution from measured surfaces of the tank 6/2 and nearby tank 7/1.

Distinguishing between the two tanks would need concrete sampling but this would increase the cost of decontamination and prolonging of the project and as it was described above, results of sampling would be unreliable. As the optimal variant it was finally decided to destruct the upper half of tank. Concrete structures of the upper half of tank 6/2 were crushed to rubble, which was subsequently measured on metrologically certified device and free released into the environment or treated as radioactive waste (VLLW/LLW).

CONCLUSIONS

A new conception of Building clearance was proposed based on recommendation of European Commission RP113 [1]. The conception uses clearance levels for total activity in the structure per unit of surface area at level of 10 Bq/cm^2, which is in agreement with indirectly derived mass contamination clearance level stated in national legislation [7]. Later, it was decided to use criteria exactly stated in national legislation for proving that materials can be cleared and free released into the environment. It means that measurement of surface contamination was the primary criterion and TAUSA measurement serves as confirmation that no contamination is expected in deeper concrete layers.

During the project a lot of changes has been implemented which influenced at least duration of the project. Changing of group of workers and working procedures was one of the crucial reasons for project delay. It was shown that using of unexperienced workers can be very risky (risk could be probably eliminated or decreased if only part of workers would be changed). Changing of decontamination procedures (technique) with working group was not convenient in this case. To speed up the project it has been decided to continue with previous approved and verified procedures.

Clearance of the underground tanks was the pilot project of this kind and according to the previous experience it was not expected that the cracks would be identified. Nowadays it is clear that quality of the concrete has to be well examined. In this case we were forced to demolish the corrupted part due to interfering ionizing radiation and impossibility to perform any direct measurements and therefore obstacle with quality of the concrete has been overcome.

It is very good to start with almost not contaminated parts to learn procedure but from point of view of clearance measurements it is better if no intense interference radiation is present. This is not always possible to do and for future application will be necessary to use a technology with shielding if external source will be impossible to remove.

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