Remediation of an Uranium Mining Waste Rock Dump in Slovenia

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Abstract Uranium mining in Slovenia conducted by the state owned company RŽV started relatively late compared to other Eastern European countries. During the short time of the production activities in the Žirovski Vrh Mountains from 1982 to 1990 a total of 452 t of U_3O_8 have been produced. A major mine waste dump and various smaller dumps resulted from this mining activity. After 1990 an extensive remediation program started in spite of the fact that the company had already paid considerable attention to protect the environment during the production phase. Nevertheless some of the implemented measures failed to fully achieve the design objectives, resulting in subsequent environmental impacts which have to be addressed by remediation measures. The paper outlines the strategy followed for the remediation of the Jazbec waste rock dump taking into account the hydrogeological, geochemical and geotechnical conditions at the site. Material from the smaller dumps was relocated to the central mine waste rock dump to reduce the footprint of the mining legacies. For the cover design the expected contaminant release, as well as radiological aspects, were traded off against the estimated costs. This allowed the constructrion of a multi-layer cover using conditioned material from a local source. The results of the environmental monitoring show that the prescribed limits of the seepage waters are met, and consequently treatment of these waters will not be necessary.

Key Words uranium mining, remediation, waste rock dump, Slovenia

Introduction

The Žirovski Vrh Uranium Mine is situated 45 km west from Ljubljana, the capital of the Republic of Slovenia. Uranium mineralization was found in 1960, ore exploitation started in 1982, and yellow cake production in 1984. In 1990 production ceased without prior remediation planning. About 610,000 t of sandstone with 0.7 kg U/t were processed and 452 t of yellow cake were produced. A total of 3.31 Mt of rock was mined with 630,000 ine waste (Paul et al. 2008).

The Jazbec waste rock dump was constructed by backfilling the former Jazbec brook ravine with the mine waste rock. Surface waters from the Jazbec brook, smaller springs and swampy areas were captured in polyethylene pipes which were connected to a concrete culvert (329 m long) constructed along the former valley bottom (Gantar et al. 2004).

Apart from mine waste rock, filter residues from water treatment and ore processing, so called "red mud", were dumped at the Jazbec dump, forming the most problematic material from a radiological point of view due to their high Thorium content. The main components of the red mud are calcium, gypsum, iron hydroxide, uranium (0,5 Bq /g), Ra-226 (0.2 Bq/g) and Th-230 (62 Bq/g). Compared to the processed rocks Th-230 shows an 8 times higher enrichment compared to the Ra-226 concentrations in the mud. During the remediation of the uranium mining legacies, construction debris and other contaminated material were also disposed of at the waste rock dump. The 2008 material balance showed that about 1.91 Mt of material was contained in the dump with a surface area of about 7 ha.

Local meteorological conditions are characterized by an annual mean temperature of 8.6 °C. Precipitation shows a long term average of approximately 1800 mm per year ranging between 1215 and 2072 mm/a in the past 10 years. Rainfalls might have torrential characteristics.

Land use in the surrounding area is dominated by forestry and farmland. Close to the dump there are scattered farms. The closest settlement, Gorenja Dobrava, is about 1 km from the dump.

Remediation concept

An evaluation of the water balance of the dump before remediation, including the results from ground and seepage water monitoring, revealed that apart from infiltration the dump is also influenced by inflow of groundwater from the upstream catchment. Furthermore, seepage water also leaks into a karstic aquifer that is hydraulically connected to a part of the waste rock dump. The remaining seepage water is collected in the drainage system at the bottom of the dump and discharged through the culvert. Due to subsidence and horizontal displacement, the drainage system at the bottom of the dump was partly destroyed and therefore not capable to drain all waters entering the dump. The outflow from the culvert is discharged in a channel to the 200 m distant Brebovščica river, with an average dilution factor of 1 in 200.

Seepage water collected in the Jazbec culvert had an annual average uranium concentration between 250 and 500 µg/L (2000 to 2010) while the prescribed discharge limit is 600 µg/L. There are no elevated concentrations of heavy metals in the seepage water, and the average sulphate concentrations, ranging between 200 and 300 mg/L, show that no acid generation occurs in the waste rock. A significant deterioration of the seepage water quality is not expected. So the contaminant release will be dominated by flushing of pore waters.

It was in the scope of remediation to relocate all waste rock from smaller remote dumps to the Jazbec dump, limiting radioactive exposures to the environment due to radon exhalation, seepage water release and dusting. Based on the given conditions the main tasks for remediation of the Jazbec waste rock dump were identified as follows: (1) regulation of surface water discharge, (2) reduction of surface water inflow from the upstream catchment to the dump area, (3) stabilisation and closure of the culvert to ensure long-term stability and reduce the radon emissions and (4) stabilization and encapsulation of the waste rock by reshaping and covering. In addition to water balance effects the cover should also ensure that unauthorised access to the dumped radioactive materials can be prevented. Due to the water balance results calculated for the whole dump it was decided that a complex cover system aimed at maximum reduction of infiltration is not reasonable, because leakage from the dump could not be stopped by covering alone. Therefore, a cover design had to be derived ensuring a reasonable reduction of infiltration taking into account economic factors and the local conditions. It was decided that locally available soil material should be used.

The cover material was prepared in a borrow pit of weathered Carnian sandstone situated in the vicinity on a property of RŽV. It was shown in laboratory and field tests that the material fulfills the geotechnical requirements needed for the use as cover material, taking into account selective winning and processing. Material with a high portion of fine grains was used for the sealing layer, for which a hydraulic conductivity of less than $5 \cdot 10^{-9}$ m/s was required.

Remediation works

Reshaping and covering of the mine waste rock dump was realised between 2006 and 2008. Trial covering conducted prior to full-scale application showed that the planned cover could be realised even on the steeper slopes. This test also allowed a decision on a proper construction technology taking into account the given site conditions. Internal limitations to contouring of the Jazbec dump were posed (1) by the presence of the "red mud" buried in the upper parts and in the mantle zone of the dump and (2) the limited space at the dump toe not allowing a dump contour extension. Cutting into the red mud had to be avoided mainly for radiological reasons. Therefore, any major excavation during contouring was carefully avoided in the final contour design.

The reshaped slope inclination is about 20° (ratio ≈ 1 : 2.8) with slope lengths between 25 m and a maximum of 40 m. Vehicle accessible berms were constructed to allow future maintenance of the object. Because of the restricted space at the toe area the lower three slopes are partially steeper with an inclinations of up to 34°. These parts are covered with large stones called 'rock lining' to ensure sufficient erosion protection (Fig. 1).

Stability analyses showed that a full saturation of the cover layers has to be avoided. Therefore, much attention was paid to the fact that a sufficient drainage of the cover has to be ensured even under the given meteorological conditions. In addition to the short slope length chosen, at the toe of each individual slope gabions were buried to support the drainage of the lateral flow in the cover layers. These gabions are hydraulically connected to the surface water discharge channels at the berms allowing the discharge of the collected interflow.

The cover was constructed from locally available material. Different functional layers were prepared by selective winning and application of different compaction rates. A 0.4 m thick sealing layer was built using more fine-grained material compacted to greater than 95 % standard proctor density. The layers on top of the sealing layer, with a total thickness of 1.3 m, should protect the sealing layer and offer sufficient water holding capacity to support the vegetation and to reduce direct infiltration. On top of the cover a 0.25 m thick vegetation layer was placed to offer optimum conditions for the development of the vegetation.

Figure 1 *Eastern slope of the mine waste rock dump Jazbec prior to (2005) and during remediation (2008).*

At the same time the surface water discharge structures around the dump were reconstructed. Due to the hydrological and meteorological conditions considerable amounts of surface water pass the dump site during heavy rainfalls. Measures were taken to reduce the size of the catchment of the dump. In the upstream catchment a certain part of the surface water is now diverted into a neighbouring valley by an open channel. At the three points where surface water enters the dump site the existing inflow receiving structures were enforced and stilling basins were constructed. From these basins the surface water of the upstream catchment is discharged through the two main dewatering channels at the northern and southern rim of the waste rock dump. These dewatering channels also receive the surface water run-off from the covered dump area.

Prior to remediation the surface waters were directed into the culvert at the bottom of the dump. Since this is not sustainable over the long-term the connections to the culvert were closed. Apart from diversion of the water this led to a reduction of the ventilation of the culvert resulting in a reduction of the radon exhalation from the culvert. The culvert was partially backfilled to avoid a later structural collapse. An air door was built close to the entrance with water discharged through a siphon.

Conclusions and lessons learned

Designing remediation activities such as covering of a waste rock dump requires a sound understanding of the hydraulical, geochemical and geotechnical conditions of the object and its interaction with the surroundings. Design requirements for a soil cover must take into account the expected effects of the covering compared to the total contaminant release. In case of the Jazbec site a highly engineered cover system would not have stopped the seepage water release from the dump due to the groundwater inflow from the upstream catchment. This allowed the adjustment of the design approach to use locally available material for the cover construction.

Before starting to dump mine waste rock material at the Jazbec site a drainage system had been implemented at the bottom of the valley which would have been essential to avoid groundwater inflow to the dump. However, this system was destroyed during dumping of the waste rock due to load induced movements and subsidence. It can be concluded that the solution chosen inherits a relatively high risk of failure, and the repair of such a system would require tremendous economical effort and is therefore in most cases not feasible.

The construction of test areas proved to be an important measure to show the applicability of the designed technical solution. Furthermore the tests allow the sampling and analysis the cover material under as-built conditions before full-scale cover construction starts. This is of advantage in preparation and adjustment of the quality control program for the construction. Relevant parameters could be indentified. Any correlation found between parameters might give the opportunity to reduce the quality control effort in a justified manner.

Given the restrictions in space, appropriately steep slopes had to be constructed. Effort needs to be undertaken to drain the interflow within single cover layers at steeper slopes. To ensure long-term stability even under the given meteorological conditions with torrential rainfalls, short slope length, additional drainage elements and also the use of rock linings were required by the design. The collection of surface run-off is provided by ditches on each berm ensuring short flow lengths at the dump surface reducing the risk of erosion. These ditches are connected to the main dewatering channels running along the contour of the dump discharging the surface water from the dump but also the catchment area outside the dump.

The management of surface waters is essential for such sites as Jazbec. Special attention was paid to the reduction of the surface water catchment area with a water diversion system constructed outside the dump site. The remaining surface water inflow is collected and discharged at the rim of the dump.

Because the mine waste rock dump contains radioactive materials a long-term monitoring and maintenance will be necessary. This requires sufficient funding as well as the conservation of the existing site knowledge with appropriate means.

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