Ten years experience of a multi-layer cover system for uranium mill tailings in Ranstad Sweden

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Abstract

A plant in Ranstad was operated from 1965 to 1969 for production of uranium. The uranium was extracted from low-grade alum shale (300 g/t). A total amount of 1,5 Mtons of alum shale was excavated and leached. The processing resulted in mill tailings covering an area of 250 000 m^2. Polluted water from the mill tailings has, since the 1960s, been treated in a plant before it has been released into the recipient.

Planning for the remediation started in the late 1980s to find out a sustainable solution for the environmental problems in the Ranstad area. A multi-layer cover system was proposed for reduction of infiltration of precipitation and diffusion of oxygen into the mill tailings. The chosen cover system consists of a sealing layer on top of the tailings, a drainage layer, a protective layer and finally a topsoil horizon. Two summer seasons, years 1991 and 1992, was required to cover the whole area. The surrounding water system was reconstructed for dewatering the mill tailings. This resulted in a release of about 50 000 m^3 polluted drainage water during the first year of remediation.

The infiltration through the sealing layer has been estimated to be about 10 % of the precipitation. The oxygen content below the sealing layer is about 5 % of the oxygen content in the free air.

The covering of the mill tailings has resulted in a decrease of the metal content in leakage water. The reduction is in the order of 75 to 85 % for metals as manganese, iron, nickel and uranium.

Even if the metal content has decreased to low levels, the water still has to be treated to reach the environmental goals.

Background

The open-pit uranium mine at Ranstad in south-western Sweden (see Figure 1) was developed as a part of the Swedish Nuclear Power Program. Uranium was extracted by percolation leaching with sulphuric acid from alum shale, which has a grade of about 300 g/t [1]. The plant was operated from 1965 to 1969. A total of 1.5 million tons of alum shale was excavated, and 215 tons of uranium was produced. The waste in the form of mill tailings consisted of about 1 million m^3 containing less than 100 tons of uranium and about 5×10^{12} Bq of radium-226. The tailings cover an area of about 250 000 m^2.

Remediation

The mill tailings were leaching considerable amounts of pollutants as e.g. uranium. It is obvious from figure 2 that very high concentrations were observed in the mid 1970's. Different studies were performed during the 1970's and 1980's s to find effective ways for reducing the leaching processes. The aim of the investigations was to find methods for reducing the infiltration of rainwater and entrance of oxygen into the tailings. Among other things a test pile, consisting of 15 000 tons of the mill tailings, was constructed in 1972 for studying the effect of different cover systems. The mill tailings were partly covered with a shallow layer of moraine.

In 1985 the planning of the restoration started with general planning and investigations including collection of available information and completion concerning maps, geology, hydrology and water quality. A detailed plan for the restoration was submitted to the County Administration in October 1988. After reviewing, the authorities granted permission for the project to be started in January 1990.

Remediation technique

The establishment of a tight cover on the leaching residues and additional mill tailings

was the most complicated part of the restoration, considering the County administration's requirement of a hydraulic conductivity less than $5 \cdot 10^{-9}$ m/s. Also such factors as availability of material, the long-term stability and the experience from using the material had to be considered in the design of the covering system. The preferred solution is shown in Figure 3. A layer of crushed limestone above the sealing layer works as a drainage layer. Furthermore a protective layer of moraine with a thickness of about 1,5 meter was placed on top of the other layers.

Moraine is a reliable, natural material, having been used in many Swedish hydro-power dam constructions. Within the disposal site at Ranstad a sufficient quantity (abut 50 000 m^3) of an especially favourable type of moraine was found, containing a fine fraction of clay shale particles. This material proved to given the required low permeability without the anticipated mixing with bentonit. For the larger moraine quantities necessary for the protection layer, there was good supply both within the disposal area and in the open pit.
On top of the covering, vegetation (mainly birch and spruce) was planted.

Environmental goals
No environmental goals for the remediation of the mill tailings were proposed when the restoration work began. As mentioned, demands for the hydraulic conductivity of the sealing layer were authorized. However in 1997 water quality goals were proposed for downstream values, in lake Blackesjön, for ten different metals.

Results of the remediation
The main findings from the remediation are summarized below. The multi-cover system used for the remediation of the mill tailings has reduced the infiltration. The recent infiltration rate is about 10 per cent of precipitation. The cover also reduces the oxygen diffusion into the tailings. The oxygen content below the sealing layer is about 5 per cent of the content in the free air. Furthermore the calculated oxygen diffusion is about $3 \cdot 10^{-11}$ m^2/s.
The pH in the leakage water from the mill tailings has increased from values below 5 to about 7 in the leakage water. This fact, in connection, with the reduced sulphate content indicates that the pyrite weathering has decreased.
The reduction of the metal concentrations in the leakage water after remediation is presented in figure 4. Most of the metals are reduced with a factor about 4 to 5 except arsenic. The reduction, if the former remediation in the 1970's is included, as high as a factor of about 100 for uranium, see figure 2. The uranium concentration indicate that the reduction has occurred in two steps. The first step took place in the end of 1970's and the next one in the 1990's after the primary respectively final remediation.

The environmental goals for the remediation were achieved in year 2000 for the lake Blackesjön, see figure 5.

Conclusions
Ten years after the final remediation of the mill tailings of Ranstad it can be concluded that,

- The requirements from the authorities have been fulfilled concerning the function of the cover system.
- The environmental goals concerning the water quality downstream the mill tailings have been achieved.
- Treatment of the leakage water still has to be performed in a purification plant.
- Studies for alternatives of a purification plant are proceeding.

Acknowledgement
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Figures

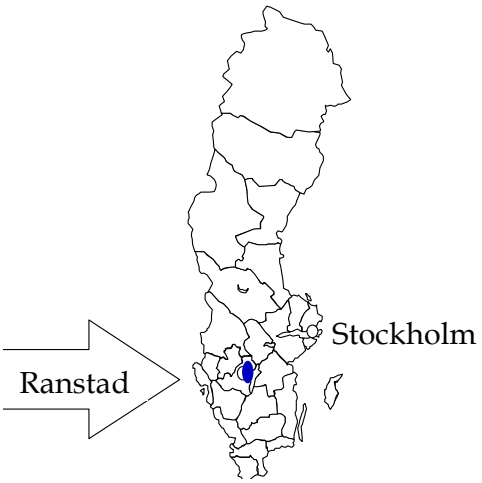

Figure 1 The Ranstad site, Sweden

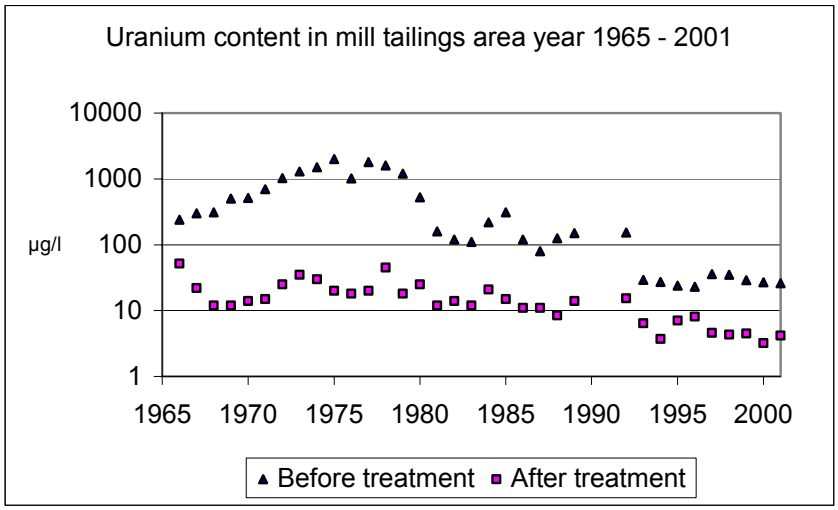

Figure 2 The uranium concentrations in leakage water before respectively after treatment year 1965 to 2001

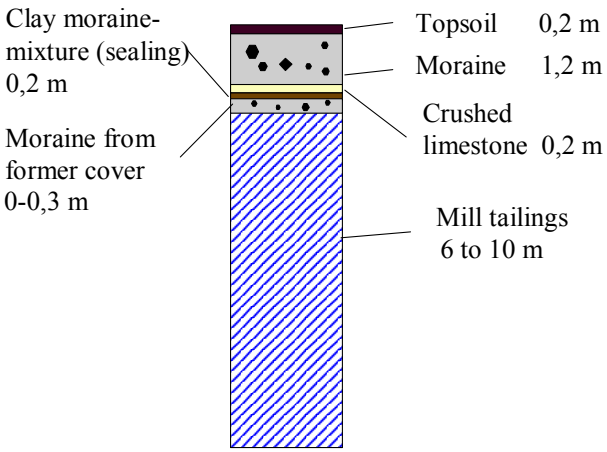

Figure 3 The cover system of the mill tailings depository in Ranstad

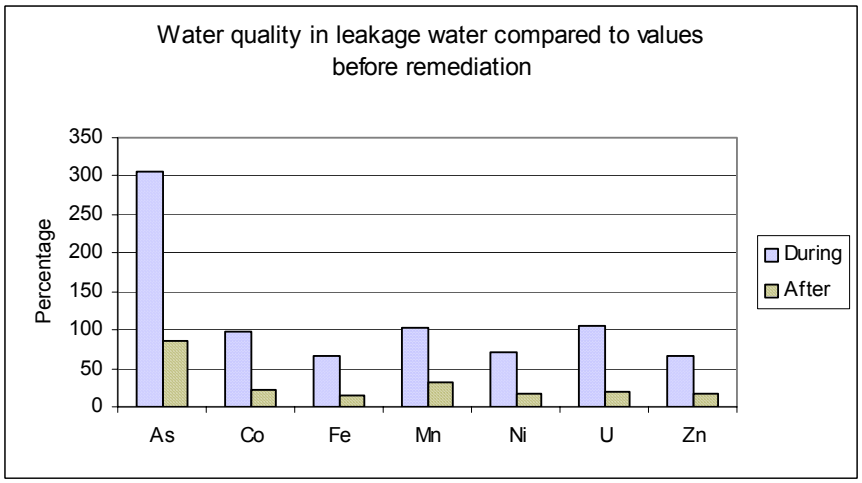

Figure 4 Water quality in leakage water during and after the remediation compared to the pre- remediation conditions

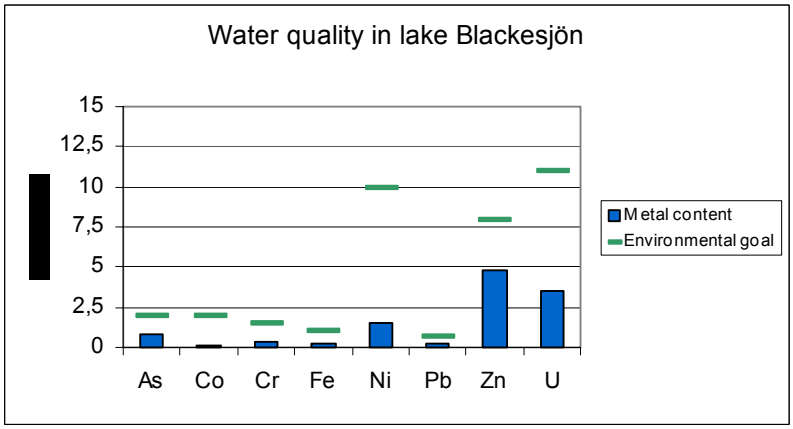

Figure 5 The water quality in lake Blackesjön during year 2001 compared to the environmental goals