HYDROGEOLOGICAL CONDITIONS FOR LEACHATE PRODUCTION CONTROL IN A SULFIDE MINE TAILING

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ABSTRACT

Leachate of contaminated water from sulfide mine residual products is a great environmental problem in Sweden. This paper summarizes an investigation carried out in order to minimize the leachate production from the residual products by means of covering the deposits with natural soil materials. The study shows that natural soil types have such a high infiltration capacity, that no significant sealing effects are obtained. It is only possible to reduce the infiltration at periods with intense precipitation or rapid melting of snow, and then only the peaks in the leachate production are affected. Nevertheless, the sealing and covering layers on the top of a deposit are of great importance as water reservoirs and thus increasing the evapotranspiration losses.

INTRODUCTION

Minimization of the amount of contaminated water discharging from the residual products sulfide mining is an essential demand on the disposal procedure. This is the case concerning both the protection of the environment and for the reduction of total mining costs. In Sweden, where most of the leachate production emanates from infiltration of precipitation water, a covering of the tailings with natural soils is a planned effort in order to reduce the amount of leachate. Field tests have been carried out at different sites in Sweden in order to evaluate the sealing effects of different covering materials. In these tests the demand on the material was that it should be locally available to a low cost. The following materials were tested:

- Glacial till
- Clay
- Sand mixed with bentonite (5 %)
- Till mixed with bentonite (10 %)

In general the thickness of the tested layers was 0.25-0.40 m. This paper presents the major results with a special consideration to the possibility of generalization.

LEACHATE PRODUCTION PROCESSES

The leachate production fluctuates widely with time and space, due to the variation in the amount of water avaliable for infiltration. As an example, the amount of leachate produced by a 1 sq. km tailing may be considered. If this site is located in an area with an annual precipitation of 600 mm and an evapotranspiration of 400 mm, the total amount of leachate water may be as much as 200 000 m a year. Thus, a considerable amount of contaminated water is being produced.

The leachate production is governed by three independent processes:

* Precipitation and evapotranspiration which determines the amount of water available for infiltration.

* Infiltration which is governed by the infiltration capacity of the covering material.

* Lateral water transportation determined by the hydraulic conductivity of the tailing products and the gradients.

HYDROMETEOROLOGICAL CONDITIONS

The hydrometeorological conditions are of great importance, and as the climatic prerequisities varies between different areas, the amount of leachate water will vary accordingly.

An important parameter to consider is the variation with time of the available precipitation. In the northern parts of Sweden, the precipitation during winter is accumulated as snow cover, which results in a delay of it's availability. In the southern parts, on the other hand, the winter precipitation is available almost directly. To illustrate the effect of the geographical location, water budget studies have been carried out in three regions - south, middle and north of Sweden. The calculations were made for three cases as regards the status of the mine residual products:

1. Uncovered residual products.

2. Residual products covered with a layer of fine-grained soil.

3. Residual products covered with a sealing layer and vegetation.

The calculated water budgets for the cases 1 and 3 are given in Figure 1.

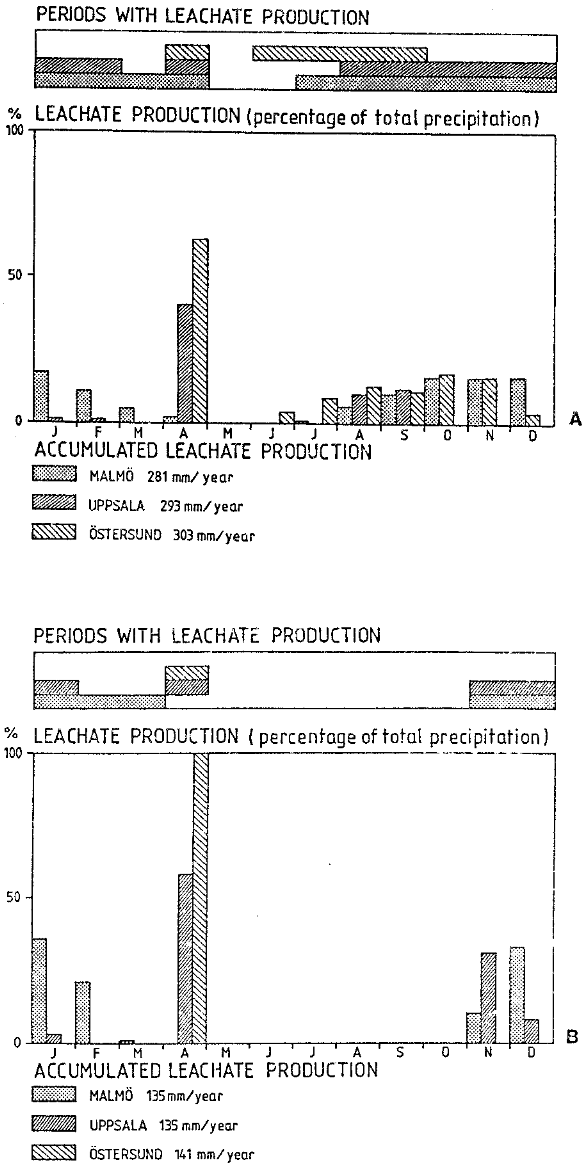

Figure 1. Water budget for an uncovered (A) and a covered and vegetated (B) deposit of residual products, calculated for three regions in Sweden: south (Malmö), middle (Uppsala) and north (Östersund).

The leachate production in the north of Sweden is restricted to a single period during the snow melt season, while data from the south shows a surplus of water during all winter months. These regional differences make it possible to divide the country into different regions, based on the availability of water for infiltration. A proposed regionalization is given in Figure 2, which shows three regions, each characterized by a graph which represent the leachate production during a calendar year.

As regards the variation in surface condition it can be seen that the evapotranspiration is low in the case of an uncovered deposit and consequently the leachate production may be high. A layer of till or clay (0.2 - 0.3 m) increases the evapotranspiration and reduces the infiltration. When a growing plant community has been established, the transpiration increases the water losses even more. The water budget for the middle part of Sweden shows that the leachate production is reduced from 290 mm per year for an uncovered deposit to 135 mm per year for a deposit covered with vegetation (Karlqvist and Olsson, 1983).

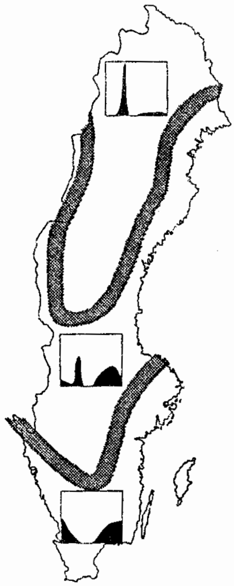

Figure 2. Different regions in Sweden with different availability of water for leachate production. Each box illustrates the variations in leachate production during a calendar year.

INFILTRATION CAPACITY OF THE SEALING LAYER

The amount of water that may be transported through a sealing layer depends on a number of parameters, such as:

* Water content of the layer
* Grain size and grain size distribution
* Grain shape
* Compaction

The infiltration rate is proportional to the fourth power of the effective pore-diameter. Consequently, the coarser pore-system or other coarse discontinuities governs the rate of infiltration. An open root-chanel of 1 mm diameter is able to transport 10 000 times more water during the same time than a pore diameter of 0.1 mm.

Karlqvist and Olsson (1982) presented a compilation of results from a great number of infiltration capacity determinations in natural soils carried out in Sweden, Figure 3.

A striking feature of Figure 3 is that the infiltration conductivity is not comparable to the hydraulic conductivity. It is therefore not wise only to use the hydraulic conductivity values when selecting cover material and calculating the leachate production.

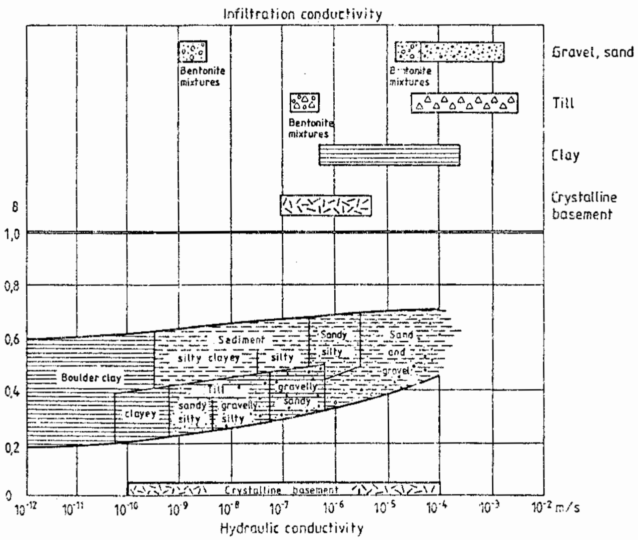

Figure 3. Compilation of data on the hydraulic conductivity and infiltration conductivity of different soil types.

The reasons for the discrepancy between the infiltration conductivity and the hydraulic conductivity may be due to a number of factors, such as:

* Biological activity near the surface
* Influence of the climate
* Weathering processes
* Differences in physical properties
* Different testing techniques

An important conclusion is that even a sealing material which normally should be regarded as impervious, i.e clay, has such a high infiltration capacity that almost all available precipitation is able to infiltrate. Sealing with such a cover layer is therefore only effective in reducing leachate production peaks.

WATER BALANCE OF A DEPOSIT

The water balance of a deposit is influenced by the design of the deposit and the hydraulic properties of the deposit and the underlying formation.

Leachate production varies within wide limits, when the lateral transport is considered. Compared to the available precipitation and expected values of the conductivity of the sealing layers, the lateral water flow may determine the leachate production under certain circumstances. This is the case for deposits of fine grained material and for low and widespread deposits. In these cases, the leachate head will reach the surface of the deposit, after which no further infiltrarion can take place. The water excess is then discharged from the surface layer.

At those deposits where the lateral flow is without significance as a determinator of the leachate production, the infiltration will be determined almost exclusively by the availability of water. Hence, the sealing efforts may be effective in cutting the peaks in the production process and thus, reducing the total amount of leachate.

FIELD TESTS OF COVERING MATERIALS

Field tests in Sweden indicate how different natural soils influence on the leachate production. An example of a test is given in Figure 4 where the leachate production is given in terms of per cent of the precipitation. The clays show a variable result, which was expected. These materials also give rise to great seasonal variations as their efficiency is strongly dependent on the water content. This effect also applies to

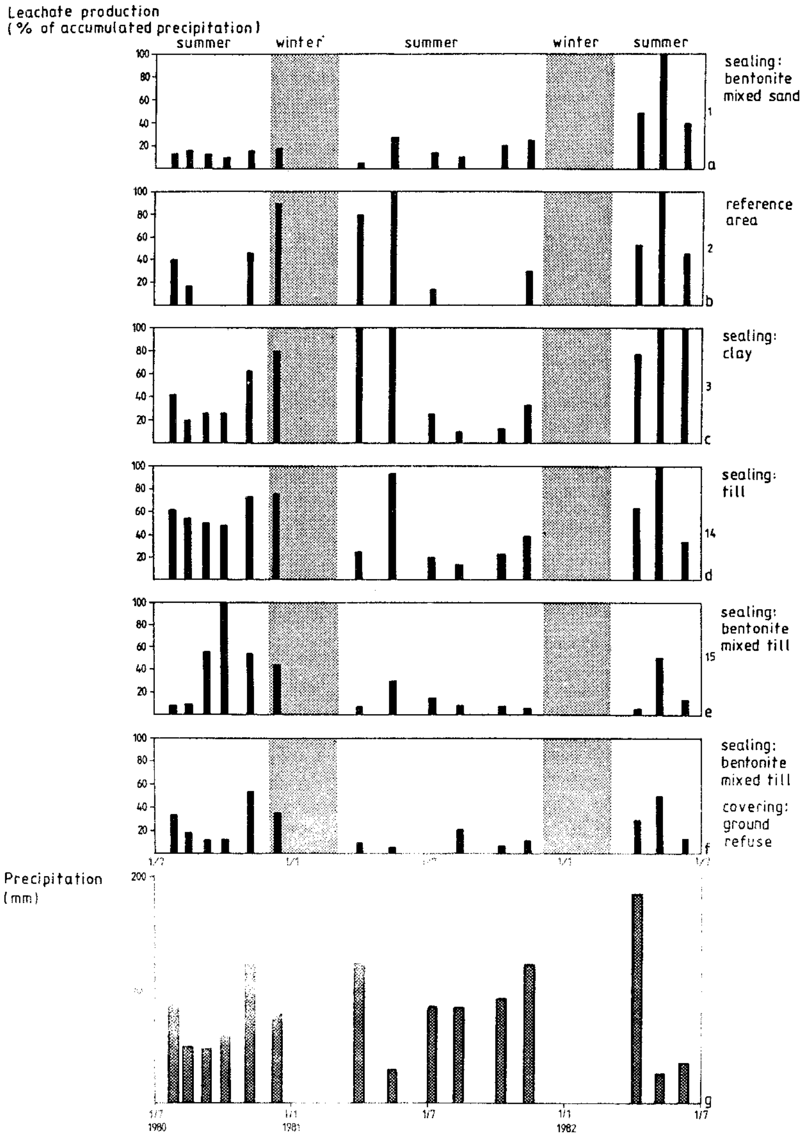

Figure 4. Measured leachate production for six different types of covering materials. The histograms represent the leachate production during a period since last measuring occassion. The accumulated total precipitation is given for the same time periods.

soils mixed with bentonite (sand and till). In the case of sand, the washing-out effect is of crucial importance, but it may be supressed by using a different mixture, e.g. a filler, to stabilize the material. As regards the till mixed with bentonite, this seems to provide the most effective sealing layers. The result shows that they clearly reduce the leachate production, mainly by cutting the peaks of the infiltration. The test shows that sealing layers of pure till are inefficient and without any sealing capacity.

DISCUSSION

This paper wish to stress that the infiltration conductivity varies from one point to an other, which generally reduces the mean value over a certain area. This may be shown in the following example: Consider a deposit of residual products sealed with clay which is assumed to have a hydraulic conductivity of E-9 m/s. The sealing layer has a few damaged zones where the conductivity is E-5 m/s. Together, these zones cover an area of 1 per cent of the total area. This gives a mean value for the area of E-7 m/s, i.e. 100 times greater than the assumed value.

These conditions clearly illustrate the importance of a proper validation of measured results. The calculations are misleading if the choice of parameters is made carelessly and without concideration.

The conductivity in a soil profile decreases with increasing depth. This means that the in-situ conductivity values obtained for a natural soil, normally at fairly great depths, are not representative for the infiltration conductivity of thin covering layers. The similarity between the hydraulic and infiltration conductivity increases when the deposit is covered with thick layers (one metre or more). For these layers, the discontinuities are of minor importance and the layer properties resamble those of the in-situ soil.

Although the sealing layers may be of less importance as a proper sealing, they are of great importance as a soil water reservoir from which the water evaporates. This effect is even more pronounced when strongly growing plants have been established and increases the evapotranspiration considerably.

References

Karlqvist, L. and Olsson, T., 1982: Infiltration-conductivity determinations from non-steady-tests. Bull. Geol. Inst. Univ. Uppsala, 9, 67 -75.

Karlqvist, L. and Olsson, T., 1983: Hydrogeologiska förutsättningar för reduktion av lakvattenbildningen vid avfallsupplag. National Environment Protection Board, PM, 1647. 76 pp. Stockholm.