Proceedings Tailings and Mine Waste 2015

Vancouver, BC, October 26 to 28, 2015

Efficient and environmentally sustainable tailings treatment and storage by geosynthetic dewatering tubes: working principles and talvivaara case study

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ABSTRACT

The most common management practice for mining residuals (e.g. tailings, contaminated process byproducts, etc.) is pond storage (Zinck, 2013). Alternatively, mine slurries can be managed by geosynthetic dewatering tubes. This treatment option combines several process phases. By pumping the conditioned slurry into a geosynthetic element the liquid and solids are separated. Due to the permeable dewatering fabric the water is able to drain through the system while the solid particles are retained.

In comparison to other dewatering techniques the higher process capacity and the lower investment and maintenance costs are remarkable. Furthermore the dewatered material can be permanently stored within the tube which could create operational advantages.

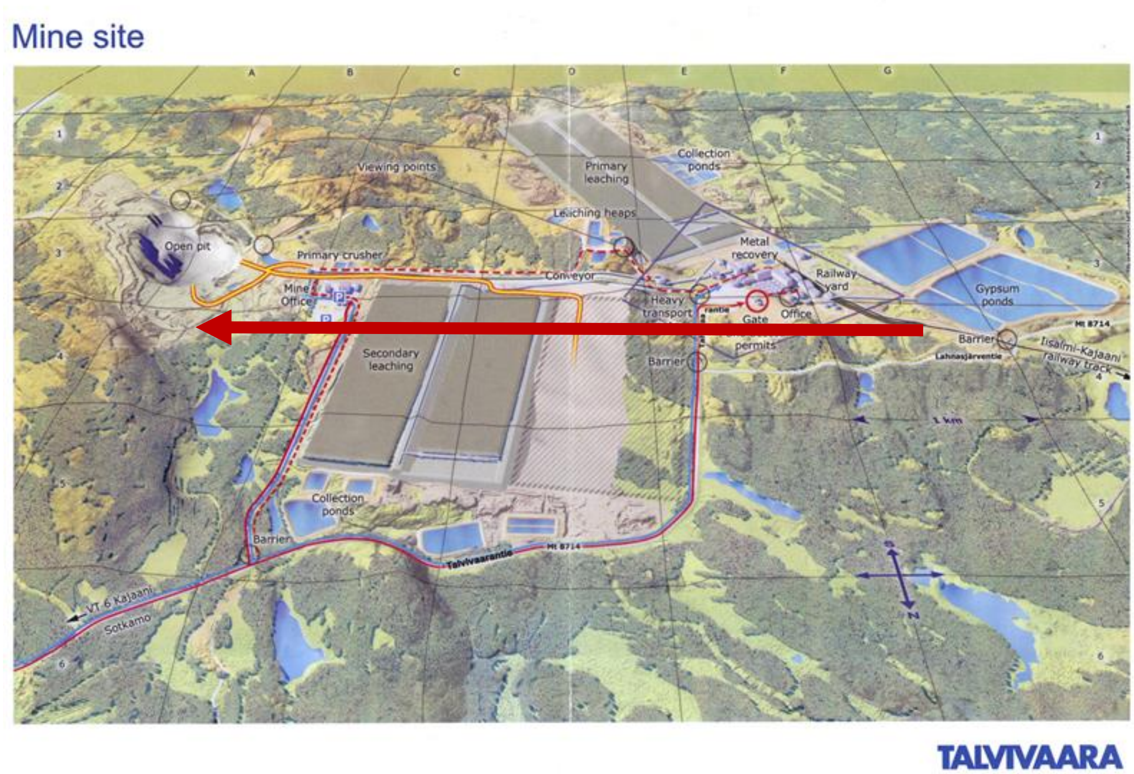
The paper is intended to illustrate the basic working principles of the geosynthetic dewatering tube system in general. Moreover it will show the environmentally sustainable and efficient implementation of the previously described system to the water balance and management system of the Talvivaara Mine in Finland. As Europe’s largest nickel mine Talvivaara produces a large volume of gypsum slurry as process byproduct. This originates from the bio-heap leaching method used for metal recovery.

Keywords: solid liquid separation, geotextile

1. INTRODUCTION

The Talvivaara Mine is considered to be the largest opencast nickel & zinc mine in Europe withlife of mine estimated at 46 years, the mine consists of two deposits 3 km apart, Kuusilampi and Kolmisoppi and has an annual production capacity of over 10 million tons of ore and produces large volumes of gypsum waste product per annum. The Talvivaara mine is the first mine to produce nickel through bioleaching. Bioleaching is preferred as it is a natural, cost-effective and environmentally friendly process utilizing the catalytic action of iron and sulfur oxidizing bacteria. Key process parameters include particle size, aeration, irrigation and acid consumption. The bioleaching process at the Talvivaara mine runs in two stages 1.) Primary leaching cycle for 15-18 months with an expected nickel recovery of approximately 80% and 2.) A secondary bioleaching cycle for an additional 3.5 years with a total expected nickel recovery of >90%. The Talvivaara mine produces ~13,000 tons of nickel and ~26,000 tons of zinc sulphides per annum.

Figure 1. Talvivaara Mine site layout



In November 2012 the mine experienced a leak in their gypsum ponds which was quickly located. As an emergency response the remaining gypsum from the gypsum ponds and gypsum produced from the process plant were pumped into the open pit. In early 2013 trials commenced to investigate and prove the suitability of the use of geosynthetic dewatering tubes as a remediation solution to provide environmentally sustainable storage of the gypsum material to be dredged from the open pit. The trial and subsequent dewatering operations was so successful that Talvivaara decided to not only utilize geosynthetic dewatering tubes for the permanent storage of the gypsum being pumped out of the open pit, but to use the technology as the gypsum storage solution for all the waste gypsum product going forward.

2. THE DEWATERING TUBE SYSTEM

For treatment the processed sludge is pumped into the geosynthetic dewatering tube. Within this geotextile containment and dewatering element the solid-liquid separation takes place. Due to the particle retaining ability of the fabric, the solids deposit inside the tube and the water is able to drain as a result of the fabric permeability. Initially the process is mainly a suspension filtration. During this period small amounts of fines might escape the tube. After the initial startup phase of tube operation a natural filter cake develops on the inner side of the tube shell. This significantly increases the degree of separation.

The influence of flocculation aids on the filtration efficiency and their working principles are explained in greater detail in chapter 3.1.2.

Practically, dewatering by means of geosynthetic tubes comprises a cyclical process, schematically shown in Figure 2. During the first filling cycle the dewatering tube is filled to the given maximum initial design height, and the filling is stopped. The static drainage of the sludge commences as soon as the filling process is halted and following a degree of dewatering the tube can be re-filled. During this cycle the water within the sludge is extracted, therefore the volume is reduced and the solids concentration of the residual dewatered material is increased.

The principal process is repeated until the tube is completely filled. If the tube stays in place for an additional period of time, a subsequent consolidation and further desiccation occurs.

Finally the tube can be opened and the dewatered material with a solid state can be re-used or disposed.

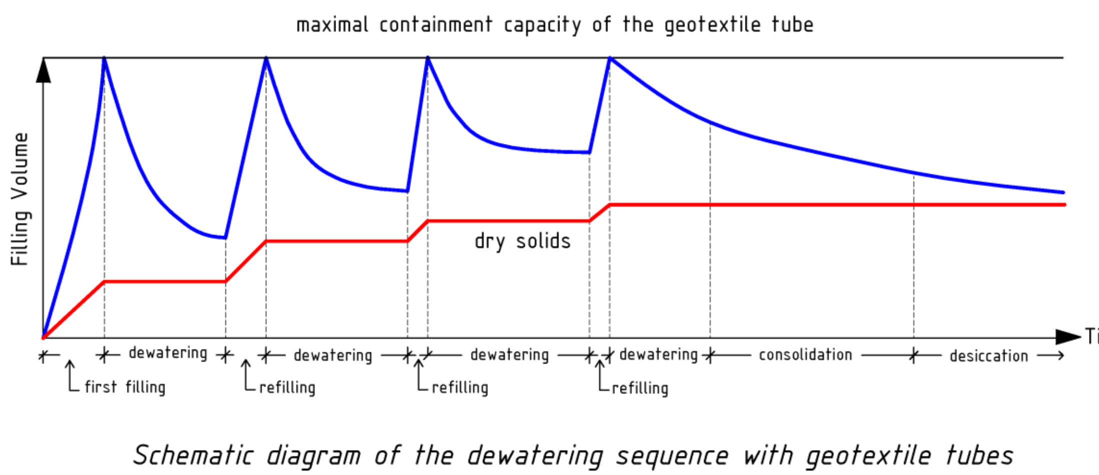


Figure 2. Schematic dewatering cycle by use of geosynthetic tubes (adapted and modified from Lawson (2008)).

A substantial advantage of the dewatering tube system is the stacking availability. By arranging the single tubes in a pyramidal stacked group pattern with several layers the footprint can be effectively reduced and the storage volume increased.

2.1 System components

The main system components required for operation are briefly explained.

2.1.1 Dewatering tubes

After filling dewatering tubes are almost elliptically shaped long geotextile containment elements designed with a dewatering and storage function. By use of high strength seams for connecting the specifically developed filter fabric sheets, this tubular element is formed. Dewatering tubes are available with standard dimensions but can also be customized with adopted tube dimensions for specific project requirements. The standard dimensions vary from small tubes with 30m³ storage volume up to 65m long elements with a containment capacity of approximately 1,600m³ per unit.

Normally dewatering tubes are furnished with inlets, distributed along the longitudinal axis of the tube. The tube filling is undertaken through these nozzle inlets with the processed slurry.

2.1.2 Flocculation aids

There are several ways to agglomerate fine suspended solids in order to increase the water release capacity and enhance the dewatering performance of slurries. Two basic physical bonding or agglomeration principles exist: coagulation and flocculation. Flocculation, which to date has been most commonly used in conjunction with geotextile dewatering tubes, will be briefly explained.

The flocculation is the step where destabilized colloidal particles are assembled into aggregates and can then be efficiently separated from the water medium. Flocculants clarify water by combining with suspended solids, in such a way as to enable these particles to be quickly and easily separated from the water. The basic phenomena is based on the opposite charge of the suspended solids and the admixed flocculation aid. Because of this the destabilized particles in combination with the flocculation aid form stable flocs. Flocculation aids can be produced from different raw materials like polyacrylamides, starch, chitin and minerals. Widely used and currently most common are flocculation aids on polyacrylamide base. Depending on the particle characteristics (size, charge, etc.) and the sludge properties (pH, concentration of suspended solids) an appropriate flocculation aid can be selected. For all dewatering operations the blending of a flocculation aid is necessary (exception: very coarse mineral sludge; comparable to a medium sand) in order to facilitate/enable sufficient and relatively rapid dewatering.

2.1.3 Dewatering area

The dewatering tubes have to be placed on a prepared area which is capable of bearing the expected loads. Additionally, the dewatering area has to allow for sufficient drainage capacity of the effluent water. Normally the dewatering pad consists of a containment bund, a flexible membrane liner and a gravel drainage layer (rounded gravel e.g. 16/32 is preferable). The protective gravel layer is optional and is beneficial if the prepared area is going to be used for several dewatering tube cycles.

The set-up of the dewatering field can be adapted to specific project requirements. Nevertheless, some points always have to be taken into account:

- The lining system design has to be adjusted to the degree of contamination of the sludge.
- The area on which the dewatering tubes will be placed has to be erosion-resistant. Otherwise the effluent water may erode the surface.
- The area has to be horizontally levelled (slope perpendicular to the longitudinal axis of the tubes $\leq$ 0.1 %; slope in direction of the longitudinal axis of the tube $\leq$ 1.0 %).

Proper laydown area preparation is essential for the subsequent dewatering tube operation.

3. IMPLEMENTATION OF THE DEWATERING TUBE SYSTEM AT THE TALVIVAARA MINE

3.1 Talvivaara gypsum slurry characteristics

The sieve size analysis curve of the gypsum residual is shown in Figure 3. A d_{50} of 0.02 to 0.03 was determined. The grain density is given at 2.84g/cm³ to 2.72g/cm³. The pH value is in the range of 6.6 to 8.8 after neutralization.

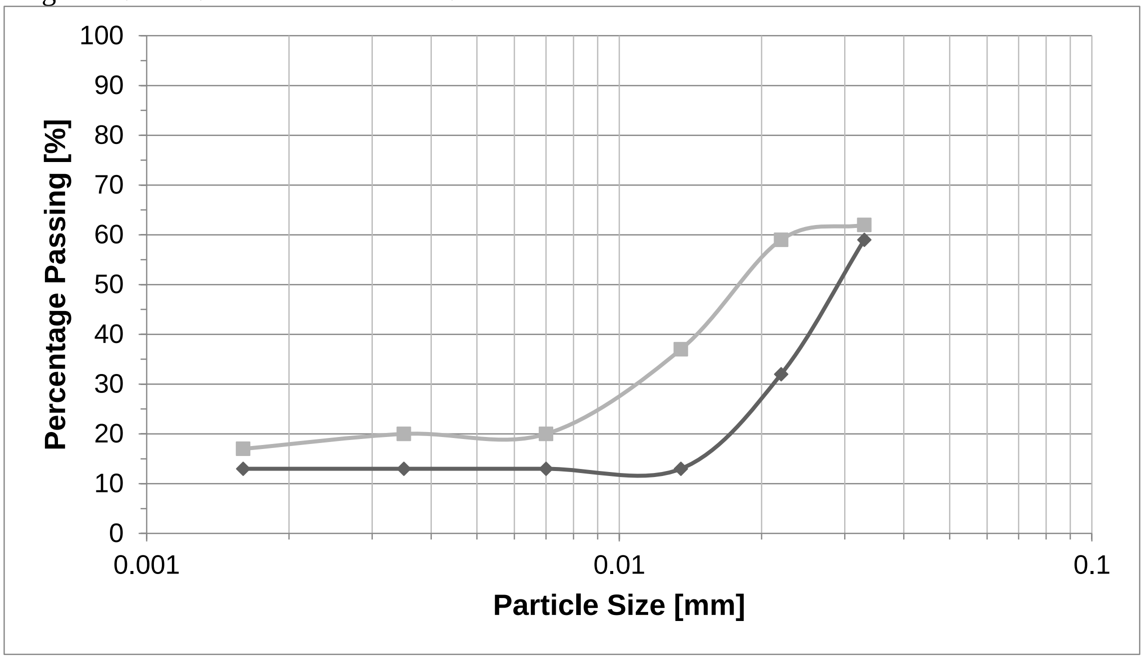


Figure 3. Sieve sizes analysis of the gypsum slurry.

The friction angle and the cohesion have been determined for two dry solid (DS) contents of the slurry (c_w40 with a DS content of 40% and c_w50 with a DS content of 50%). The results are shown in Table 1.

Table 1. Results of the cohesion and angle of repose analysis.

Sample	Cohesion [kPa]	Angle of internal friction [°]
c_w40	4.8	31.2
c_w50	11.7	34.7

3.2 Dewatering area construction and tube layout

The designated tube laydown areas are lined with a 1.5mm to 2.0mm thick HDPE geomembrane. The recommended maximum slope inclination was taken into account. For discharge of the filtrate a lined drainage trench was incorporated into the field. Apart from one field the standard dewatering area geometry is rectangular.

Figure 4 shows an overview of a typical layout pattern for a standard dewatering field.

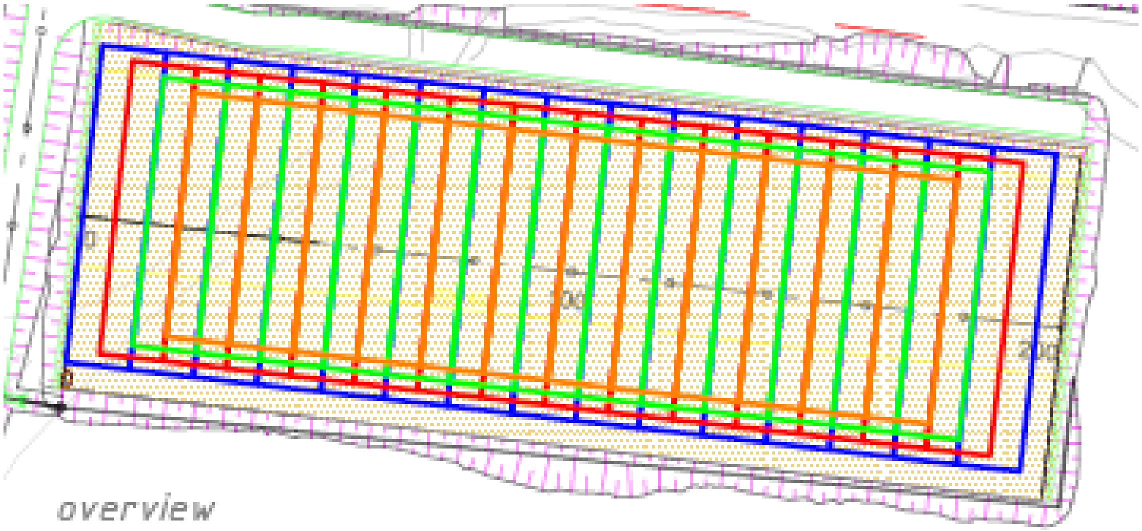


Figure 4. Typical pyramidal stacking pattern top view: First layer (blue), second layer (red), third layer (green), fourth layer (orange).

In order to be able to place a tube layer on top of the lower layer, the top layer tubes are shortened by at least 5m in order to avoid so called "overhead sliding".

3.3 Dewatering tube operation

As previously described for the dewatering acceleration the gypsum slurry was mixed with a flocculation aid. Figure 5 illustrates the working efficiency.

Figure 5. Influence of polymer admixture: Not properly treated slurry (left hand side); Proper flocculated sludge (right hand side).

The sludge is transported into the dewatering tubes on the dewatering area by a manifold system. The flow can be diverted in a controlled manner to every tube by use of several valves. Due to preventing measures the whole system can also be operated during winter time (see Figure 6).

Figure 6. Operation of the additional placed fifth tube layer during winter; the four tube layers below are completely covered by snow and ice.

Figure 7. Completed dewatering field with fifth tube layer.

4. DISCUSSION

The common way of mining residual treatment is primarily through the reduction of the water content (thickening/dewatering) before it is further processed. Typically the tailings are stored in Tailings Storage Facilities (TSF) which require large prepared areas for storage and have an increased risk of unplanned tailings escape. Alternatively, dewatering can be undertaken by mechanical devices, such as belt filter presses, chamber filter presses or centrifuges. These processes require large amounts of energy and are limited by the small volume which can be processed.

The geosynthetic dewatering tube system has been successfully implemented at the Talvivaara Mine in Finland. In comparison to the other options the following points were the decisive factors for choosing the alternative dewatering tube solution:

- Higher process capacity and lower investment and maintenance costs.
- Increased storage flexibility by adding an additional tube layer or additional tubes.
- Demobilization of the tailings by water extraction.
- Encapsulation and permanent storage of the dewatered material inside the tube.
- As a result of the tailings being stored in a solid state the risk of environmentally detrimental spillage is drastically reduced.
- Research (Wilke, 2016) has shown that rain does not affect the moisture content inside the tubes after dewatering. The material stays dry.
- Tube operation is possible to be performed during winter.
- Tube drainage water can be rapidly recycled and re-used in the mine process.

Through practical experience it has been shown that making use of geotextile dewatering tubes the volume of tailings to be stored can be reduced by up to 40%, through rapid water extraction and the corresponding volume reduction.

5. REFERENCES

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