ASSESSMENT OF THICKENING TAILINGS AS A TOOL FOR ENVIRONMENTAL IMPROVEMENT.

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Abstract

Mining extraction by flotation generates huge amounts of liquid waste stored in large ponds. This is a reasonably safe, low cost storage which presents, however, a series of major issues. Firstly, it cannot recover all the water used in the process. In addition, tailing disposal involves a great environmental risk of dam failure, and water migration from the disposal site to water courses. Finally, this storage system does not prepare the mining for dismantling phase, requiring in the closing phase a major investment in pond drainage for subsequent repopulation.

Tailing thickening poses an alternative. The thickening up to concentrations of more than 65% of solids allows the improvement of water recovery, the reduction of storage site and facilitates the revegetation of deposit areas or mine refilling. It also removes the potential risk of dam failure.

The drawbacks come with the need for building specific installations, which involves a high cost and environmental impacts. It is convenient to assess the convenience of this treatment from an environmental perspective. This is only possible with a total Life Cycle Analysis of tailing treatments.

Keywords: Mining; Life Cycle Assessment; Waste Management; Tailings, Thickened; Paste

1. Introduction

The mineral extraction processes usually incorporate a foam flotation stage in which the gangue is separated from the ore by the addition of flocculants to water. The flotation has become the most competitive extraction method, since it provides a good ore-gangue separation, with very profitable energy cost. However, this process increases water consumption significantly, generating a significant amount of tailings (Gurdeep, 2005).

It was precisely the excessive water consumption during this flotation process that triggered the use of thickened tailings technologies and paste. Such thickening can remove a significant amount of the tailings water by gravity separation technique in a thickener tank. The denser solid particles naturally decant, accumulating at the bottom of the tank, which allows to remove a substantial amount of water through the top.
As untreated tailings, thickened tailings are dumped into a pond but, in this case, they form a consistent clay soil that dramatically reduces the pressure on the retaining wall. This achieves a more stable and smaller reservoir and a significant water saving (Verburg, 2001) (Newman, White & Cadden).

2. Objective

Given the apparent significant advantages from both environmental and safety points of view that the thickened tailings technique presents, the goal is to prove that such technique is a real sustainable alternative, which will be measured by the Life Cycle Assessment methodology.

This study presents the evaluation of this alternative compared to the traditional system of dumping unthickened tailings to determine if the thickening technique is profitable environmentally speaking.

3. Methodology used

To perform this study, the Life Cycle Assessment (LCA) is used, which is defined by the UNE-EN ISO 14.040 standard as: “a technique devised to assess the environmental aspects and potential impacts linked to a product through the recollection of an itemed list of a system’s relevant entries and withdrawals, the assessment of potential environmental impacts associated with such entries and withdrawals and the interpretation of results at the analysis and impact evaluation phases in accordance with the objectives of the study” (AENOR 2006).

As can be deduced by definition, the LCA is a tool that can be used to evaluate the environmental loads associated with a product, taking into account its full cycle. In this case,
it will make a comparison between two ways of managing mining waste. This comparative approach also alleviates some of the problems arising from the lack of information in specific stages, which will be diluted by its appearance in both processes.

A literature review has shown that, while there is extensive experience in the application of LCA in the mining field, this is restricted to the extraction and the industrial stage, forgetting waste management processes caused in obtaining the ore, as well as the closure of the mine and all the necessary care for monitoring after this final stage (Durucan, Korre & Munoz-Melendez, 2006).

However, there are several references to the validity of this tool for decision making, towards a sustainable use of natural resources and an optimal management of mine waste generated. (Kulczycka, 2008) (Reid et al., 2008) (Stewart & Petrie, 1999).

4. Definition of the analysis to be used

The Life Cycle Analysis starts defining system boundaries, functional unit and guidelines for data selection.

In this case, two different scenarios of an open-pit iron ore mine will be assessed. Stage 1 corresponds to the traditional tailings dumps and stage 2 with tailings thickening up to 70% before their final disposal. Even though one of the advantages of this technique is the possibility of filling the mine for its closure, in this case this option will not be considered as it will be evaluated as an open pit mine. In both cases, the facilities required along with their energy consumption will be taken into account.

All processes and facilities required for mineral extraction are beyond the system boundaries as they are common to both stages. The same applies to power supply facilities.

To enable comparison between stage 1 and 2, 1,000 m³ of tailings is taken as functional unit, with a density of 1,157 kg / m³ and 20% solid weight.

To prepare the inventory, bibliographic and manufacturers data have been mainly used, which have modelled the whole process using the Ecoinvent database (Classen et al., 2009).

5. Life Cycle Inventory

For the development of Life Cycle Inventories, a flow of 4,323 m³/h of iron ore tailings with a concentration of 20% in weight is taken as a starting point. These tailings are inert waste and accumulate during the exploitation lifetime, which is around 20 years.

5.1. Scenario 1

It corresponds to the reference scenario, which studies the impact generated by the traditional way of waste storage from the extractive mining.

The dumping of tailings or its final disposal on rafts, is the second major impact of mining activities, even for non-toxic waste such as extraction of iron ore.

In this stage, the residual material from the flotation stage for obtaining the ore is pumped to the discharge point. Even if there are examples of direct discharges into the river, there are specific recommendations to change this practice for less aggressive techniques. Therefore,
in this case, the environmental impacts associated with the discharge and storage in a reservoir will be studied.

The tailings have to be pumped into the storage pond located 10 km away from installation. To this purpose, there is a pipe of 80 cm diameter. An pumping efficiency of 70% and a total 50-meter vertical drop are considered. It is estimated that 450 kWh per 1,000 m³ transported should be used. A non-Newtonian fluid with laminar flow has been considered. (Diaz & Hechavarria, 1999), to 7200 operating hours per year during a 20 years lifetime (BOE, 2004).

This volume of tailings transported during 7200 h per year for 20 years, which is the estimated operating time for the installation, requires a raft with a maximum extension of 8.64 m³

Generally, the walls in this kind of ponds are built with tailings by successive flooding by layers and compaction. The unthickened tailings ponds suffer greater buoyancy from the fluid, therefore the walls of the dams have to be thicker, requiring a land sealing process of the raft to prevent infiltration of leachate and acid water underground, both for environmental reasons and to prevent damage to the foundations.

The lifetime of pumps and pipes considered for the Life Cycle Assessment is of 20 years, and 50 years for the raft. This latter value depends on the type of closure that is planned for the mine, because if it is not drained for subsequent seal and reforestation or rehabilitation, the land would still be held indefinitely (BOE, 2004).

5.2. Scenario 2

This stage evaluates the treatment of tailings by thickening, which starts at the output of the flotation tank and is performed in 4 stages. This pumping, which continues along 8 km of distance with a difference in level of 50m, supposes an energy cost of 298 kWh by 1,000 m³. It is considered a speed of 2.4 m / s, a pipe diameter of 80 cm and a transport efficiency of 70% (Peck, 2007) (Jewel & Fourie, 2011). Wes Tech Engineering, 2011).

Once the tailings are in the thickener tank, a flocculant is added to improve the aggregation of solid particles, which form conglomerates that decant naturally and deposit at the bottom of the tank. The choice of the flocculant depends mainly on the initial percentage of solids, the final concentration desired, the pH of the process and residence time. The percentage of solids at the input is usually up to 20%, reaching output levels of 70%. After the residence time, the thickened tailings are discharged through the bottom and clean water is extracted from the top (Wesh Tech Engineering, 2011).

There are several types of thickeners, but the most common is a mechanism of moving rakes which favours decantation and reduce the residence time of the sludge in the tank. This system represents a power consumption of 12 kWh per 1,000 m³ of tailing at the tank intake (Wes Tech Engineering, 2011). For its installation, it is necessary to make a foundation which involves the excavation of 6,725 m³ and 1,691 t of concrete. The thickener is recorded as 124,356 kg of steel with a useful life of 20 years.

The third stage refers to the pumping of thickened tailings into the raft with a length of 3 km and a height difference of 40 m, requiring 273 kWh per functional unit. Two pumping units are required. It is considered a transport speed of 2.5 m / s, a pipe diameter of 25 cm and a 50% efficiency (Weir Minerals, 2007).
The fourth stage is the dumping of fluid on the raft. This dumping is determined by the type of reservoir selected, choosing the most appropriate depending on the terrain, the total amount to be deposited, the weather conditions (rainfall, evapotranspiration and wind speed) and geology and seismicity of the location. The reservoirs are usually cone-shaped with central dumping and upstream dumping slope. 16 kWh is considered to boost paste on the raft and 18 kWh for return pumping of recovered water, always by functional unit.

**Figure 2. Thickened Tailings Dam Slope type**

![Diagram of Thickened Tailings Dam Slope type]

**Figure 3. Thickened Tailings Cone type.**

![Diagram of Thickened Tailings Cone type]

For this scenario, the cone-shaped reservoir is selected as it presents more stability, since to avoid avalanches tailings cone slope is limited to only 5% (Jewell & Fourie, 2006). The final surface of the reservoir is 3.68 million m². As in stage 1, it is considered a useful life of 50 years (BOE, 2004), although in this case it could be reduced to 25, since after the closure of the mine, it is possible to repopulate the land restoring its forest land category.

### 6. Life Cycle impact assessment

For Impact Assessment it has been selected the Eco-Indicator 99, an assessment method of final points which allows us to group into three damage categories: human health damage extent of disability life years, damage to ecosystem quality expressed as the percentage of extinct species in a particular area due to environmental load and resource usage expressed as the increase in energy needed to offset the increased difficulty in obtaining the same resources (Goedkoop, Effting, Collignon, 2009).

#### 6.1. Assessment of scenario 1 impact

In the analysis of the final damage categories in this scenario, it clearly shows the strong impact of land use in the final category of ecosystem quality. This transformation and land use due to the reservoir prolonged use for over 50 years is heavily penalized in Ecoindicator 99.
6.2. Assessment of scenario 2 impact

Unlike scenario 1, in the case of the tailings thickening technique, the overall impact is balanced between the three final damage categories. This is due to the strong electric consumption which is necessary for boosting the thickened tailings, resulting in a higher score in the human health category. The value of the category of resource use is also directly linked to energy demand, since it has been estimated as a source of electricity an energy mix which the different forms of energy production are represented in, including power plants. In addition, the thickener used in this scenario means the demand of mineral resources, contributing to increase the score of the final category of resource use.
6.3. Comparative evaluation between scenarios

Figure 6 shows the thickened tailings as best environmental solution, as its global impact is significantly less. However, the question is what would happen if it were a highly degraded environment, where the land had no value and there was no shortage of water (although in this case, it is not the savings in water what is being evaluated by using EI99, it rather penalizes the tailings thickening for requiring water pumping). It would be necessary to change the weighting of the land of use category, which would reduce dramatically the impact of ecosystem quality category. Given this scenario, Scenario 2 would clearly worse for the environment, since the benefits granted by the smaller size of the reservoir and its subsequent revegetation and recirculation of water into the production process would not compensate the energy or materials expenses that aggravate the human health and quality of natural resources categories (Gunson et al., 2012).
7. Conclusions

Once the environmental impact assessment of both scenarios is evaluated, the study concludes that the tailings thickening technique improves sustainability in extractive mining, even if requires an increase demand in energy consumption and materials (Franks et al., 2011)

Tailings thickening would only be penalized if the use of soil and water shortages is not a problem. However, even in that circumstance, the traditional tailings storage system would remain unfavorable if there was a failure of the reservoir that would have a huge impact in the life cycle inventory. This impact would be much higher in the case of pyrite tailings, as in the case of Aznalcóllar or aluminum, as occurred in Hungary more recently. In the event that a failure occurs in the thickened tailings reservoir, the risk of catastrophe would be much smaller, since it is expected to behave as a solid. In addition, its texture allows a quick and easy revegetation, ensuring a stable land (Böhm et al., 2005). However, these aspects are not covered by ACV technique so that it can be concluded that to obtain a real assessment of environmental sustainability, it would require using both methodologies of Life Cycle Analysis and Risk Assessment simultaneously (Kizil & Muller, 2011).

8. References


Safety of Tailings Facilities TAILSAFE. University of Miskolc, Faculty of Earth Science and Engineering.


Wes Tech Engineering, Inc. (2011). Equipment: Item A, One (1) 40 m dia x 8 m sidewall hidensity paste thickener; Item B, One (1) 40 m dia anchor channel tank.

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