Comparison of operational costs and Net Present Value (NPV) of project investment between thickened tailings disposal and conventional lean tailings disposal

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ABSTRACT

A European producer of copper required a new solution for their tailings storage as their existing facility was approaching its maximum capacity. Increasing the height of the dam on the existing tailings facility was not feasible. The plant was operating a conventional lean slurry disposal system that included centrifugal pumps in series to transport the slurry to the storage facility. It was decided to construct a new tailings storage facility, but instead of selecting a conventional lean system, a Thickened Tailings Disposal (TTD) system was selected. Through the TTD a sloped and stable disposal area can be formed as the majority of liquid evaporates from the slurry. In addition, the amount of liquid required for transportation is reduced; power consumption per dry tonne of deposited tailings is decreased and environmental risks are minimised.

This paper compares two alternative tailings disposal systems, TTD and conventional, with a focus on financial impacts. Included in the financial comparison is the complete tailings system, including thickener, pumping system and disposal area. Centrifugal pumps in a series were considered for the conventional system, while Piston Diaphragm (PD) pumps were evaluated for the TTD system. Although the concept of TTD requires a higher investment for slurry preparation and pumping equipment when compared to conventional, the net cost per dry tonne of deposited tailings proved to be substantially lower for TTD. The financial analysis demonstrated a payback time of 1.9 years justifying the initial higher investment for a project with a 15 year life. Factors such as mine closure, rehabilitation and long-term liability have not been included in the financial analysis as presented, but it is believed that including these aspects would create an even stronger case for the TTD approach.

INTRODUCTION

The customer's copper tailings were handled by a conventional lean slurry disposal system and deposited into a tailings storage facility approximately 1,750m from the processing plant. Due to an increase in production, the maximum storage capacity of approximately 3.5 million m3 was reached ahead of predictions and the plant needed to come up with a solution to secure future disposal of the process tailings. As an expansion of the existing containment by increasing the dam height was not possible, the plant needed to build a new containment approximately 1000m further from the processing plant, totalling a pumping distance of

2,775m. In addition, this new containment would be located at an elevation 270m higher than the tailings processing area. The requirement to pump the tailings slurry to this new containment also required a new pumping system.

For this new system two alternatives were considered: a conventional lean system or a TTD system, operating at higher densities. While a conventional system normally operates centrifugal pumps, a TTD system typically requires positive displacement pumps. The customer compared the two alternatives while reviewing the investment and operating costs of both systems for this project.

THE EXISTING SITUATION: CONVENTIONAL TAILINGS DISPOSAL

In the existing application, the containment consisted of a conventional tailings disposal system, relatively close to the process plant at a distance of 1,750m and at the same altitude. The plant was operating a concentration of approximately 35% by mass. Fresh water usage was minimised by a water recycling system. The pumping system consisted of three centrifugal pumps in a series arrangement. There was no standby capacity, therefore if a pump failure occurred, the existing pumping system had to be stopped and repaired, or pumps replaced. Due to the series arrangement of the pumps and the absence of standby capacity, reliability of the system was an issue.

THE FUTURE SITUATION: STUDY OF TWO ALTERNATIVE SOLUTIONS

A location for the new tailings containment was found at a distance of approximately 2,775m and at an altitude of 270m higher from the tailings processing plant. As such, the pumping pressures for a conventional system were considerably higher than in the previous situation. Using a centrifugal pump system would require a multistage arrangement of eight centrifugal pumps in series. As for the TTD, the pressure requirement would increase beyond these values and the use of PD pumps was considered. The customer conducted a study comparing these two alternatives: a conventional slurry system running on a lower solids concentration using centrifugal pumps, and a TTD system using PD pumps. In addition to the investment and operational cost aspect, other important considerations for the new tailings disposal system were reliability and flexibility. With an expected lifetime of seven to eight years for the containment, and a remaining life of mine of fifteen years, the disposal system needed the flexibility to accommodate any future system layout changes. Additionally, environmental aspects including reduction of power, water usage and safety also played an important role.

THICKENED TAILINGS DISPOSAL (TTD)

A modern method for mine tailings management is the handling of slurries at higher solid concentrations, often referred to as thickened tailings or paste. The advantages compared to conventional lean slurry handling are significant. Due to the high solids content, less water is required, subsequently providing improvements to operational costs and benefits to the environment. Furthermore, thanks to the low water content of the thickened tailings, a stable disposal area can be created. After discharge onto the disposal area, the small amount of water contained in the slurry evaporates, resulting in a sloped and stable tailings disposal. The

remaining tailings substance is dry enough to be walked on within a number of days after discharge.

It is important to find the optimum solids concentration of the slurry to obtain a suitable angle of repose of the dried-up substance. Owing to the sloped shape of the tailings disposal, rain will run off and has no or little effect on the dried tailings. The increased geotechnical and geochemical stability of the tailings storage substantially decreases risks and reduces the environmental footprint. This means that these solutions often enable a smoother permit approval process and subsequent start-up of operations.

By using thickened tailings, dam breaches and spillages of wet mine tailings can be prevented. An additional advantage is that the disposal area can contain more tailings on the same footprint, making it more cost efficient than the conventional lean variant. Rehabilitation of a TTD area after mine closure is significantly easier and less costly.

COMPARISON BETWEEN CONVENTIONAL AND TTD

The differences between the tailings management approaches discussed above: conventional lean and TTD, have a major impact on equipment selection. This causes differences in the cost structure for capital (CAPEX), as well as operational expenditure (OPEX). In cooperation with the customer, a case study was conducted to compare the costs between both systems taking investment, maintenance, water and energy costs into account. Other factors such as costs related to regulation, the environment, mine closure and rehabilitation, legal requirements and financing are excluded from this study.

The primary differences in equipment scope between the two alternatives will be described. The designs are based on the process parameters as shown in the table 1.

Item	**Value / description**
Slurry type	Mine copper tailings
System duty	265 t/h
Specific weight of dry material	3,752 kg/m3
Required system availability	95% = 8,322 hours per year
Distance process plant - disposal area	2755 m
Altitude difference process plant - disposal area	270 m

Table 1: process design parameters of the new copper tailings disposal system

CONVENTIONAL LEAN SLURRY USING CENTRIFUGAL PUMPS

Generally, in most conventional tailings disposal systems centrifugal pumps are used. Tailings from the process plant are collected in a tank where it is then transported to the disposal area at a distance of approximately 2775 m over a height of +270 m. The system was designed to handle slurry with maximum solids content of 40% (by mass).

In order to deliver the required (static and frictional) pumping pressure of approximately 46 bar, a pump train of eight centrifugal pumps is required in a series arrangement. For the standby capacity, an additional eight centrifugal pumps in a multistage arrangement is required. A 12" pipeline to the disposal area is envisaged. The excess process water is returned back to the plant by means of four centrifugal return water pumps. This includes rain water and flush water.

The new tailings containment design complies with the latest environmental technology and legislation. The capacity is 3.5 million m3.

The entire system includes: one pump station including 16 main 200 kW centrifugal pumps (eight operational – eight standby), one gland water pump system, 2x 12" pipeline and a disposal area which includes the containment and return water system, including 4 x 90 kW centrifugal pumps and pipeline back to the process plant.

THICKENED TAILINGS DISPOSAL USING PISTON DIAPHRAGM PUMPS

The tailings are first treated in a thickener and then fed to the PD pump. The slurry is thickened to a solids percentage of 72% (design value). The required pumping pressure for this application is 110 bars, which can be handled by one PD pump. Standby capacity is achieved with an additional pump, connected in parallel to the same pipeline. The PD pump is fed by a small centrifugal pump in order to provide the required suction pressure of approximately 2.5 bars.

The slurry is pumped through an 8" pipeline. Rain water and flush water is pumped from the containment to the plant by means of two small centrifugal pumps.

This new tailings containment design is compliant to the latest environmental technology and legislation. The capacity is 3.5 million m3.

The TTD system includes: thickener including flocculant dosing system, one pump station including two PD pumps (one operational – one standby), strainers, feed pumps, gland water pump system, 2x 8"pipeline and a disposal area include containment and rain water pumps 2 x 30 kW pumps and pipeline to the plant.

TECHNICAL CONSIDERATIONS

System availability:

For the customer, system reliability and availability was an important criterion during the equipment selection. Based on an assumed availability of 97% for a single centrifugal pump, the total series multistage pump system of eight centrifugal pumps will have an availability of $(0.97)^8$, which equals 78%. Compared to the PD pump alternative, the availability is around 98%. Although the availability will be increased with the respective standby system, the availability of a system using PD pumps will be substantially higher.

Tailings storage capacity:

The basis for this comparison is the settled situation at mine closure, expected in approximately 15 years from today. The in-situ solids content of the settled tailings in the containment is estimated at an approximated 65% for the conventional lean, and 85% for the TTD alternative (solids concentrations by mass). For the new containment of 3.5 million m3, a storage capacity of 6.7 million dry tonnes tailings is required for conventional and 9.3 million dry tonnes for the TTD alternative. This represents a capacity increase of 39%, or a lifetime increase of 1.5 years at a constant plant tailings disposal rate. In this calculation, storage above dam crest, as common for TTD, is not included. The additional storage capacity on the same footprint is an advantage of the TTD approach.

BASIS OF COST ANALYSIS

The investment costs related to a PD pump solution are often higher than for a centrifugal pump solution. However, in most cases the operational costs including electric power and maintenance are lower. Over a period of time, in most cases, the Total Cost of Ownership (TCO) is lower for a PD solution, as illustrated by this case study.

For this tailings disposal system a study was conducted to compare the costs between the two options. The following was considered:

- Investment costs, including:
    - Thickening equipment
    - Slurry control system
    - Complete pump station including pump system, control system including civil, mechanical and electrical works
    - Pipelines from pump station to disposal area
    - Return water system (water recycling)
    - Tailings disposal area (containment)
- Operational costs, including:
    - Maintenance, including wear parts and labor
    - Electricity costs
    - Water cost
    - Flocculants cost

Costs related to factors such as regulation, environment, mine closure, rehabilitation, legal and financing have been excluded from this study.

The financial comparison of both alternatives is based on a period of 15 years, which is the estimated remaining lifetime of the mine. The calculation is based on an electricity rate of €0.062 /kWh, a water rate of €0.774 /m3 and a discount rate of 10% (rates provided by customer).

In addition to the total investment (CAPEX) and operational costs (OPEX) for both options, the cost per dry tonne, as well as the Net Present Value (NPV) and the payback time, has been calculated. The results are presented in the following table. The currency is Euro.

The NPV is calculated by applying the differences in annual cash flow of both alternatives. For the calculation of the NPV, the following formula is used:

$$NPV = \sum_{t=1}^{N} \frac{R_t}{(1+i)^t} - R_0 \qquad (1)$$

Where

R_t is the net cash flow at time t
(i.e. the difference in operational costs between HCSD and LCSD, per year)

N is the number of years

i is the discount rate

R_0 is the total initial investment

RESULTS

COST COMPARISON

Thickened Tailings disopsal versus Lean Slurry Disposal

Project:	**Case study**
Slurry description:	**Copper tailings**
Date:	**March 2016**

	Thickened Tailings	Conventioanl Lean	Comparison	
Capital investment costs (CAPEX) incl thickener, pump system and disposal area	**€ 13,043,774**	**€ 11,665,058**	**€ 1,378,716**	TTD more expensive
Operational costs per year (OPEX) incl energy, wear parts, labor, flocculants and water	**€ 471,674**	**€ 1,181,673**	**-€ 709,998**	TTD less expensive
Total costs per dry metric ton incl CAPEX and OPEX	**€ 0.61**	**€ 0.71**	**-€ 0.10**	TTD less expensive
Net Present Value (NPV)	**-€ 15,605,766**	**-€ 18,083,548**	**€ 2,477,782**	
Pay back time [in years]			**1.9**	for the TTD option compared to Lean

Remarks:
- NPV calculation based on period of 15 years (expected remaining life of mine)
- Due to the fact that a tailings disposal does not generate income, the NPV's for both alternatives are negative

Table 2: cost comparison and financial analysis

The results of the financial comparison, as presented in table 2 above, demonstrate that the investment costs for the TTD alternative are higher. However, this is compensated by the operational cost savings, including energy, maintenance and water costs:

- Energy usage is lower for the TTD alternative due to the higher power efficiency of PD pumps, typically 96%, compared to the power efficiency of centrifugal pumps, in this calculation set at 78%
- Maintenance costs are lower for the TTD alternative, in this case because a single PD pump can handle the flow and pressure, compared to a series of eight centrifugal pumps for the conventional lean option
- Water usage is lower for the TTD option

The NPV demonstrates that from a financial viewpoint, the payback time of 1.9 years justified the initial higher investment for a project with a 15 year life.

CONCLUSION

TTD is increasingly being adopted in operations around the world to improve the stability and safety of tailings storage facilities and to minimise the potential for environmental impacts. The benefits of thickened tailings handling and disposal covers all aspects involved in mining operation including safety, environmental, regulations, legal and financial. Correct implementation of a TTD system substantially decreases risks at the disposal area, such as dam breaches, and reduces the overall environmental footprint. In many cases this will also enable a smoother permit approval process and startup operations. Mine closure and rehabilitation of a TTD tailings area are also significantly easier and less costly.

Important selection criteria for the customer, while comparing the two alternatives, for their new tailings handling solution, were system reliability and flexibility, environmental and financial. As the TTD solution typically utilises PD pumps for the handling of the thickened tailings, it increases reliability and lower operating costs. Energy, maintenance and water usage are considerably lower for the TTD alternative.

This paper demonstrates that a thickened tailings solution is the best alternative for the customer's new tailings handling system. Although the initial investment is higher for a TTD solution, the operational costs are substantially lower, resulting in lower Total Cost of Ownership. Comparing the two alternatives, the paper demonstrates a payback time of 1.9 years.

Aspects such mine closure, rehabilitation and long-term liability have not been included in the financial analysis as presented. It is however believed that including these would create an even stronger case for the TTD approach.