Recent initiatives in reducing dilution at Konkola Mine, Zambia

by D.M. Mubita*

Synopsis

Dilution reduction is one of the areas that offer metal mines an opportunity to increase revenue and reduce costs, resulting in enhanced profits. Effective dilution control programmes require interaction on a multi-disciplinary level. This paper outlines recent initiatives undertaken at Konkola Mine to reduce dilution and increase revenue. The increase in revenue arising from reduced dilution and high factors between in situ and delivered to mill grades were quantified and amount to close to US$ 1.0 million per one per cent improvement in grade factor at a 75c/lb copper price. Sources of dilution from open and in-stope mining methods practised at the mine were identified and a multi-disciplinary dilution control forum set up to control these.

Among the major achievements were the introduction of low dilution in-stope mining methods; the introduction of Gemcom geological and mining planning software to replace traditional pencil and paper methods, leading to better in situ estimation and production planning; enhanced control in open stopes through dilution awareness among mining production personnel; location of critical secondary development ends in correct positions; enhanced blast hole control; tracking of development waste by metal tracers and monthly tally; implementation of a cavity monitoring system to check over-breaks in open stopes; and setting up of a stope history database.

The results from the cavity monitoring system showed that stopes with over-breaks of 5 metres or less could be controlled to break along the hangingwall contact.

Introduction

Dilution control has progressively become a central activity in mining operations at Konkola Mine. It is closely associated with elimination of waste from reporting to ore stream, optimization of extraction of the mineral resource and optimization of feed to mill.

Konkola Mine is situated on the extreme north of the Zambian Copperbelt and only a few kilometers from the border with the Democratic Republic of Congo. The mine extracts copper mineralisation hosted within the Oreshale formation of the Lower Roan Group, which belongs to the Katanga Super Group. This is a 3 to 20 m thick laminated calcareous siltstone with dolomitic interbeds. It is defined on a 1% in situ total copper grade cut-off defined from evaluation drill holes and/or chip samples in cross-cuts. It has a very weak footwall locally called the ‘A’ Zone and a generally good but variable hangingwall, which may be in the Oreshale formation or in the overlying hangingwall quartzite formation.

The method of extraction is mainly through sub-level open stopes, which was previously the only mining method employed at the mine, and in-stope mining methods, namely post pillar cut and fill (PPCF), overcut and bench (OCB), longitudinal room and pillar (LRP) and drift and fill (DAF).

The objective of reducing dilution is to maximize revenue through efficient designs, good mining practices, efficient monitoring and efficient control. These, however, require interaction on a multi-disciplinary level involving geologists, mine planning engineers, geotechnical engineers, surveyors and mine production engineers.

This has led to the formation of a multi-disciplinary dilution control team, which meets on a regular basis to initiate and address issues related to dilution reduction at the mine.

General causes of dilution

In general, the main causes of excessive dilution are:

➤ Incompetent ground conditions arising from variable stope rock wall competencies associated with fault and leached zones
➤ Inappropriate mining methods
➤ Poor mining practices due to:
  ➤ poor blasting resulting in over-break of the stope boundaries
  ➤ dilution due to inconsistencies in stope boundaries
  ➤ poor mining discipline associated with a lack of or poor draw control procedures.


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Sources of dilution at Konkola Mine

Sources of dilution at Konkola Mine can be subdivided into two broad mining methods employed at the mine, namely, conventional sub-level open stopes where dilution ranges between 20 and 70 per cent and in stope cut and fill methods where dilution ranges between 5 and 15 per cent.

Conventional sub-level open stopes

➤ Footwall dilution—at the base of the Oreshale is the A unit, which consists of a weak, poorly consolidated sandy layer ranging from 0.5 m to 2.0 m thick. In areas where it is unmineralized the A unit causes dilution as the weak unit peels on its own during stoping, especially in gravity stopes. Footwall dilution may also be induced during coning operations to attain running angles at the start of the stope.

➤ Hangingwall dilution—when the hangingwall plane is breached by over-drilling or poor secondary development, peeling is induced, especially towards the end life of the stope as the opened up span increases. In seismically active areas to the south, the hangingwall tends to peel excessively. To reduce the effect of HW dilution, a 1 m skin is normally left unblasted below the AHW. The stope is usually kept full so that broken ground in the stope supports the hangingwall.

➤ Stope life-end/pillar breach dilution—towards the life-end of a stope when the rib and crown pillars are wrecked or if there is premature pillar breach, dilution comes from old adjacent stopes on top as well as along strike. The material coming from old stopes mixes with ore. The time it takes to tram from the stope until a 1% cut-off grade is reached can introduce a lot of waste, especially in high grade areas. This has been a big problem as seen from graphs of stope history parameters.

➤ Poor ore/waste segregation dilution—there are cases when ground from waste development ends is not segregated due to non-availability of separate ore and waste tips.

➤ Tramming from closed stopes—during severe shortage of ground there have been cases of old closed stopes being trammed at marginal grades to make up for the shortfall.

In-stope cut and fill methods

➤ Footwall dilution—at the base of the Oreshale is the A unit, which consists of a weak, poorly consolidated sandy layer ranging from 0.5 m to 2.0 m thick. In areas where it is unmineralized the A unit causes dilution as the weak unit may be taken during mucking operations, poor control of footwall excavations and poor bench drilling control.

➤ Hangingwall dilution—poor control of hangingwall excavations and poor breasting control operations.

➤ Poor ore/waste segregation dilution—this occurs mainly during breakaway for Overcuts. In order to avoid sharp bull noses breakaways from hangingwall and footwall access excavations may end up getting into waste before re-entering the orebody. Sometimes the sections in waste are not segregated. This is being overcome by breaking overcuts to only one side where they will be within the orebody.

Revenue from dilution control

Revenue from dilution control is derived from two main sources:

➤ Improving the quality of the ore so that contained metal is maximized

➤ Reduction in the cost involved by handling the waste that finds its way into the ore stream.

Table 1 gives an example of revenue that could be realized at Konkola based on actual production figures for 2002 and based on improvement of grade factor by 1% and cost of handling waste at 35 cc/ton.

The table shows that close to U$1.0 million can be realized for each % increment in grade factor and that U$11.3 million is spent each year on handling waste in ore stream from which no return is realized.

This emphasizes the need to enhance dilution control measures at the mine.

Factors affecting grade of ore delivered to mill

The following factors usually affect the grade of ore delivered to mill:

➤ Geological—estimation of in situ grades if not accurate will affect the grade of ore delivered to mill.

<table>
<thead>
<tr>
<th>Revenue from dilution control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Using actual production for 2002 grade</strong></td>
</tr>
<tr>
<td>Shaft</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Diluting T cost</td>
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At current grade factor
At improvement of 1% in current grade factor
At current grade factor
At improvement of 1% in current grade factor
At improvement of 1% in current grade factor over the mine
overcome this problem, Gemcom mining and geological software was introduced at the mine starting in the year 2001. The new Gemcom model has greatly improved the estimation on a stope-by-stope basis.

➤ Planning—planned production from given areas is not achieved due to delayed development for various reasons, leading to other areas producing tonnages more than budget to offset losses. This is compounded if such areas have significantly lower grades. The Gemcom-based mine planning system has led to improved and more flexible planning programmes.

➤ Production
- Dilution resulting from any of the sources described above
- Departure from scheduled production plan leading to poor blending
- Over-extraction from old stopes due to late preparation of replacement stopes and erratic or irregular blasting to generate fresh ground
- Development waste arising from poor excavation control and waste segregation finds its way into the ore stream.

Measurement of dilution

Before the advent of the cavity monitoring system, there was no direct measure of dilution in the stopes. Dilution on the mine was monitored in an indirect way using factors. Grade factor, described as grade of rock received at mill divided by grade of depleted reserves by mining and unrecoverable.

Dilution factor is calculated by dividing the total waste tons received at mill by tons ore received at mill and can also be expressed as:

\[(\frac{1}{GF} - 1) \times 100.\]

The cavity monitoring system (CMS) at Konkola Mine was purchased in the last quarter of 2002 to survey the shape of open stopes to determine the amount of overbreak and underbreak in order to assess the magnitude of dilution and poor ore extraction problems. This works in conjunction with Gemcom mine planning software, which was implemented as an integration platform to combine geology, mine planning and survey information in a dynamic 3-D graphic environment. In grade control and mining operations, the two systems provide useful inputs to minimize and control stope dilution.

The CMS surveys are conducted by the Survey Department and the results are imported into Gemcom where stope excavation solids are created. The solids are accessed and displayed in 2-D sections together with the orebody contacts to determine the stope overbreaks and underbreaks. The orebody contacts in Gemcom are compared with manual orebody contacts by superimposing the two at the same section positions.

Initially CMS surveys showed that major overbreaks were occurring in both the hangingwall and footwall of open stopes. Corrective actions through the Mine dilution committee were put in place. This resulted in much better performance of stopes. However, while the hangingwall overbreak was largely controlled, the footwall dilution from the weak basal A zone continued and confirmed that it could only be minimized through change of mining method where such methods were more cost-effective. It nevertheless enhanced the planning process as this was now accepted as planned dilution in open stopes making projections to the mill more realistic.

Figures 1(a) to (d) are CMS pictures showing successive improvements in hangingwall overbreak. 800 mN had an overbreak of more than 5 metres prior to dilution initiatives but 900 mN, 1000 mN and 1986 mN stopes show much improvement. Figures 2(a) to (b) are stope history graphs.

Major milestones in dilution control

Major milestones achieved in reducing dilution at Konkola Mine through an integrated interdisciplinary approach may be cited as:
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![Figure 1c](image1)
![Figure 1d](image2)

1417 mN stope-block, daily and progressive grade

![Figure 2a](image3)

6777 mS stope-block, daily and progressive grades

![Figure 2b](image4)
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- Successful implementation of the Gemcom geological and mining software. This continues to be enhanced through ongoing training and increased utilization of the system by geologists, mine planning engineers, geotechnical engineers, and surveyors.
- Successful implementation of post pillar cut and fill, overcut and bench, drift and fill in-stope mining methods.
- Enhanced control in open stopes through:
  - Dilution awareness among mining production personnel such as shift bosses and loader operators.
  - Location of critical secondary development ends in correct positions.
  - Enhanced blast-hole control through stope checkers' reports and regular blasting to generate fresh ground in open stopes.
  - Tracking of development waste generated and its destination through use of metal tracers and monthly tally of blasted waste, stowed waste and hoisted waste.
  - Successful implementation of cavity monitoring system, hence enhanced monitoring in open stopes.
  - Setting up of a stope history database.

Results

Figures 3a to d show historical performance at each shaft and total mine for 2003 by month and annually for the last 10 years.
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In general there is a consistent improvement in grade factor for each of the shafts and total mine, though slightly obscured by varying relative contribution from sub-level open stopes and in-stope cut and fill stopes. Cavity monitoring system surveys, however, assert major improvements in dilution control at Konkola Mine.

The improvement at No. 3 Shaft is mainly due to change in mining methods from sub-level open stopes to in-stope cut and fill methods and enhanced grade control, while the improvement at No. 1 Shaft is mainly due to enhanced grade control.

**Discussion and conclusion**

Recent initiatives in reducing dilution at Konkola Mine have offered an opportunity to increase revenue and reduce costs. A multi-disciplinary approach has enhanced grade control management at the mine. However, despite the achievements made so far, a lot remains to be done. Among the challenges that lie ahead are mining methods compounded by variable dip, thickness and ground conditions over approximately 10 kilometres of orebody strike. These should be overcome through an inter-disciplinary approach, enhanced dilution awareness in mining operations and new technology such as orebody modeling techniques, a cavity monitoring system and a most importantly, continued search for low-dilution mining methods.

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**Figure 3c**

**Konkola Mine factors—10 year period**

![Graph showing percentage of dilution from 1994 to 2003 for 1 Shaft, 3 Shaft, and Total Mine](image1)

**Figure 3d**

**2003 Konkola Mine factors**

![Graph showing percentage of dilution from January to December 2003 for 1 Shaft, 3 Shaft, and Total Mine](image2)