

ECONOMIC ANALYSIS OF UNPLANNED DILUTION IN VENARCH MANGANESE UNDERGROUND STOPES

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Abstract: In underground stopes, unplanned dilution occurs due to the over-break and slough of walls and roof, consequently mixing the ore with wastes. This phenomenon not only leads to a reduction in the grade, but also imposes some costs due to the grade deficit, and wastes money and energy for extraction of wastes. Hence, measuring the over-break and slough of roof and walls of the stopes is considered critical in underground mining, in order to determine the unplanned dilution and the study of its economic side-effects. In this paper, the effects of unplanned dilution on grade reduction, mining costs increase, and profit reduction was investigated using the cavity monitoring system (CMS). The system was implemented on 24 stopes of Venarch manganese mines, defining the linear equivalent of over-break and slough (ELOS) for the dilution, which led to understand the relations between the over-break and dilution parameters and the economic parameters, including the equation for predicting the loss of profit. Results of data analysis indicated that the break-even of the over-break was 2.18 m that caused a dilution of 67.38%; any further over-break will be loss-making.

Keywords: Underground stope, cavity monitoring system, unplanned dilution, economic analysis.

INTRODUCTION

The mixing of the ore with waste rocks or materials with a grade lower than cut-off grade is referred to as dilution. In underground stoping methods, dilution happens as a result of falling roof or walls, cutting roof or floor, and loading of waste materials. In general categorization, dilution can be classified into two categories: planned (internal) dilution and unplanned (external) dilution. Planned dilution refers to a situation where some rock materials are removed from hanging wall or footwall, considering the deposit characteristics or in order to design the stope. Unplanned dilution, however, happens outside stope design premise, as a result of over-break of the hanging wall by undesired fractures. Final dilution can be defined as the sum of planned and unplanned dilutions (Ataei, 2015).

In mining projects, the objective is to economically exploit the ore while taking into account the safety of the work force and machineries. However, dilution drastically affects direct and indirect costs of mining (Luo et al 2008). Dilution significantly influences the costs of a stope and hence the profitability, because it not only increases associated costs, but also affects all other cost components incurred by exploitation, transportation, crushing, milling, and handling, as well as those operations to be performed on valueless wastes or low-grade rocks of insignificant value. Moreover, the extra time spent on cutting and filling large stopes developed as a result of wastes ends up with unplanned delays and renewal costs (Henning and Mitri, 2007).

Dilution economically affects different stages of mining. The effect begins at the stope where the exploitation of unwanted wastes forces mining machineries to take more time handling the exploited material. This extra time attributed to wastes, reducing the useful life of the machineries, which in turn increases the frequency of maintenance required for the machineries and equipment. This is followed by the generation of excessive dust within the stope, reducing

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workers' eyesight which can contribute to lower quality of products. Then, in the transportation phase, dilution imposes extra costs, particularly for the transportation operations in long distances. These costs affect the transportation operation either directly, or indirectly. More energy required to transport the ore along with the waste directly contributes to enhanced costs of mining. Reduced transportation capacity and increased depreciation (shorter useful life of transportation systems, such as conveyers) are amongst the direct effects of dilution on transportation cost. Moreover, addressing the points blocked by wastes, and controlling excessive dust inside the stope are amongst the sources of indirect costs at the transportation stage. At the primary crushing stage, which is commonly performed inside the mine site, dilution results in increased cost of crushing through, for example, it is associated excessive costs of more power consumption by machines, faster depreciation of machineries, and reduced operational capacity of crushers. Moreover, some more expenses are imposed during this stage, such as stacking wastes inside the mine site, and environmental costs. In mineral processing phase, associated costs with dilution are of more significant importance, especially when wastes exhibit similar processing properties to those of the valuable ore. At this stage, when exploited wastes are introduced into the processing facilities mixed with ore, higher costs of secondary crushing, handling, screening, concentrating, dewatering, and waste stacking are expected (Le Roux and Stacey, 2017).

METHODS

In this study, cavity monitoring system (CMS) was implemented on 24 underground stopes of Venarch manganese mines in order to investigate the effects of unplanned dilutions on, the economic parameters of mining projects. The relationship between the over-break and dilution was determined, defining the linear equivalent of over-break and slough (ELOS) for dilution. Then utilizing the regression analysis on dilution parameters (ELOS and current dilution) and economic parameters (incomes, costs and profits), the equations between them were determined.

FINDINGS AND ARGUMENT

The effect of unplanned dilution on the mining cycle includes direct and indirect costs. Direct costs are associated with the physical handling of the materials while indirect costs are related to the downstream effects of the instability. Direct Costs include mucking, hauling, crushing, hoisting and milling of the waste rock and the additional material needed for backfilling. The indirect costs of dilution include stope cycle delay, loss or damage of equipment, lower mill grade recovery, increased tailings, morale drops, sterilization of adjacent ore bodies, creation of rehabilitation requirements, loss of access and additional mining, reduction in mine efficiencies, and increased mucking and backfilling risks. In this paper, only direct costs of dilution were investigated and the indirect costs were not included. Obviously, considering these costs will reduce the amount of the break-even of ELOS. All the analyses were carried out at constant prices.

Conclusion

- Investigations on unplanned dilution in underground stopes of Venarch manganese mines showed there was a power relationship between the drop in grade and ELOS, and also between the profit reduction and dilution.
- The break-even ELOS accrued at 2.18 m, with a dilution of 67.38%, which reduced the product grade by 16 units; any further over-break would be loss-making.

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