NORMALIZATION OF RECOVERY AND YIELD OF GEOMETALLURGICAL CONCENTRATION TESTS

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INTRODUCTION

In general, geometallurgy projects include geometallurgical grinding and concentration tests that aim to determine the geometallurgical variables, whether it is the yield, the recovery of the phases of interest and the levels of contaminants in the concentrate/final product. Invariably, the product that is generated in the processing plants has to meet strict specifications to be considered saleable, and the main objective of the geometallurgical test is to determine whether a georeferenced sample can be categorized as ore, i.e., it meets all the specifications required for the product, or whether the sample should be categorized as overburden, that is, the final concentrate from these samples does not meet the requirements provided for in the contract for saleable product. There is also the possibility of defining marginal samples which would generate products close to specification and which could consequently be mixed with samples classified as ore to achieve the desired specification. Once the samples are properly categorized, a second objective is to estimate the recovery of the stages of interest and the product yield. Recovery is important for reserve estimates, while yield is the basis for mine planning. It is important to emphasize that these estimates are not independent since the content of the georeferenced sample is known and the content of the final concentrate is a content to be reached in processing. With this, for a given yield, the recovery can be calculated and vice versa.

However, in the geometallurgical test, the content of the phase of interest in the final concentrate is not necessarily the same as the content specified for the product since there are many process variables that determine a higher or lower concentration efficiency, in addition to the quality of the ore itself. In fact, each and every ore sample produces whole recovery x grade curves across the entire spectrum of possible grades, starting from the feed grade that corresponds to a 100% recovery, through the desired grade in the product to the maximum theoretical grade which is the phase grade in the mineral of interest. This fact is illustrated in Figure 1.

Each combination of operating conditions results in a point on the curve, with the most selective condition generating the rightmost point on the curve, with the P2O5 content at 38% and a corresponding recovery of 25%. By contrast, the leftmost point represents the least selective condition of the assay, with 27% P2O5 and a corresponding recovery of 69%. This serves well to illustrate that a geometallurgical test will generate a result around the recovery x content curve of the sample being tested, but the content of the final concentrate of the test is not necessarily equal to the desired content in the concentrate for several reasons.

OBJECTIVES

As a standard product cannot be generated in the tests, the results will inevitably contain a lot of noise and this makes geometallurgical modeling and, in general, recovery and yield estimates difficult. The goal here is to make recovery and yield estimates for a constant product quality.

METHODOLOGY

There are at least three methodologies that can be used to calculate recoveries and yields from geometallurgical tests for a common product quality base. A methodology requires at least two concentration tests, one with quality above and one with quality below specification, and the yield and recovery corresponding to the specified quality can be obtained by interpolation. This method is widely used in Apatite concentration operations.

A second method, dilution, consists of concentrating the ore, in the laboratory, to a higher grade relative to the product specification. In most cases this can be achieved by using shorter flotation times or lower concentration of the collector, among other strategies. Higher concentrate grade than specification implies that the yield and recovery are below the actual potential of the sample. In this case, the concentrate can be diluted with the tailings to obtain a concentrate with the exact specification. The calculation requires the following definitions:

Y = measured concentrate yield
R = recovery of the phase of interest in the concentrate
g_c = grade of the phase of interest in the concentrate
g_f = grade of the phase of interest in the feed
g_t = grade of the phase of interest in the tailings
g_c^p = grade of the phase of interest required in the commercial product
Y^p = adjusted yield for the required commercial product
R^p = recovery of the phase of interest adjusted for the required commercial product

If the concentrate grade of the geomet test is higher than that of the specified product, it is possible to dilute the concentrate with a x fraction of tailing to obtain the exact product grade

$$\boldsymbol{g_c^p = \frac{g_c Y + g_t x}{Y + x}}$$

Solving for x:

$$\boldsymbol{x = Y\,\frac{(g_c - g_c^p)}{(g_c^p - g_t)}}$$

$$\boldsymbol{Y^p = Y + x}$$

$$\boldsymbol{R^p = Y^p\,\frac{g_c^p}{g_f}}$$

A third method, constant efficiency, also based on obtaining a concentrate above specification, assumes that the test waste can be concentrated/floated with the same efficiency as the original test and, thus, obtain a second concentrate of lower quality that, mixed with the original concentrate, generates a concentrate with the exact specification. Assay efficiency is defined as the ratio of the yield obtained to the maximum yield that could be obtained for a 100% recovery. Additional definitions are required here:

Eff = Efficiency of the geomet test
Y_{max} = Maximum yield that could be obtained in the geomet test
Y_{max}^p = Maximum yield for the product with standard concentrate grade

By definition, the maximum yield is obtained when the recovery of the phase of interest in the concentrate is 100% for the feed and product grades that are specified:

$$Y_{max} = 100\frac{g_f}{g_c}$$

And the efficiency may be calculated as the ratio between the measured yield and the maximum yield:

$$Eff = \frac{Y}{Y_{max}}$$

It follows:

$$Y^p_{max} = 100\frac{g_f}{g^p_c}$$

$$Y^p = Eff \times Y^p_{max}$$

$$R^p = Y^p\frac{g^p_c}{g_f}$$

RESULTS

The results of methodologies that involve estimates from dilution and constant efficiency can be evaluated by simulation, where real concentration tests, with results above specification, are adjusted and compared with the yield to be obtained in the exact specification. These results are shown in Figure 2.

CONCLUSION

Of course, the method of correction assuming constant efficiency seems to be much more accurate than the method by dilution. In any case, the two methods produce results that are standardized in terms of product quality and, consequently, eliminate noise that arises in the formulation of geometallurgical models and in the spatialization of yields and recoveries. This practice also improves reserve/resource estimates since the values, in these cases, are always adjusted upwards. Of course, if possible, it is recommended to use interpolation, thus avoiding errors associated with estimates based on assumed behaviors.

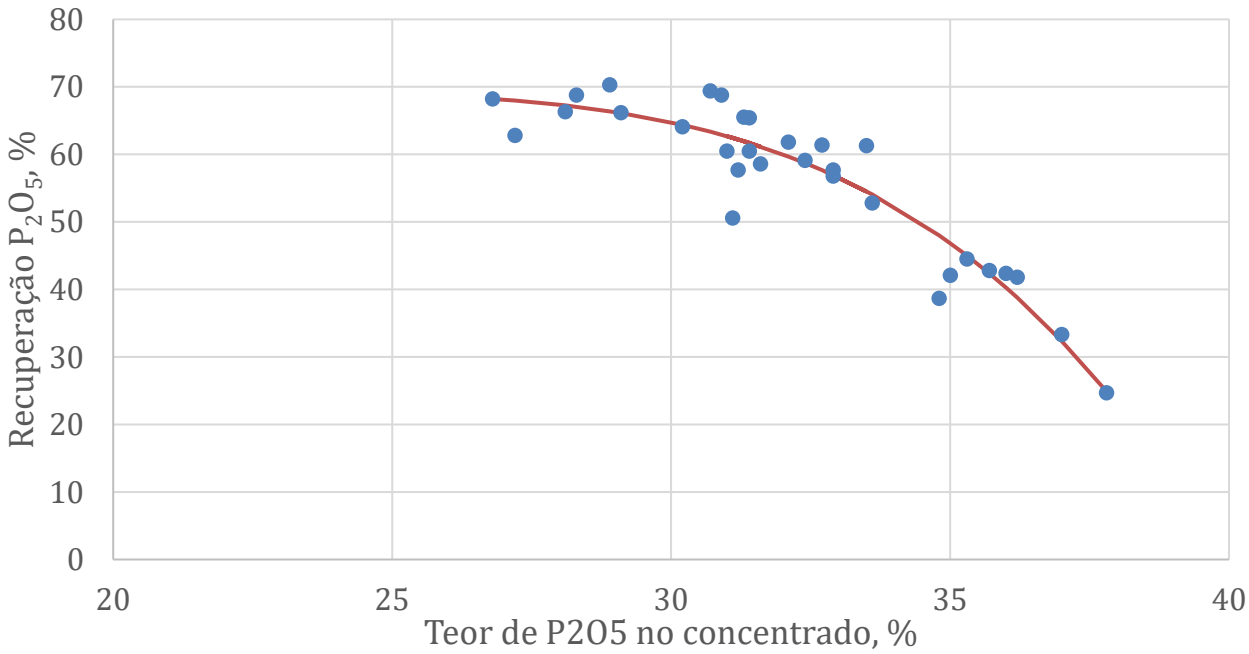

Figure 1: Recovery x Grade curve for a sample of Phosphorus ore. (Matiolo et al, 2017)

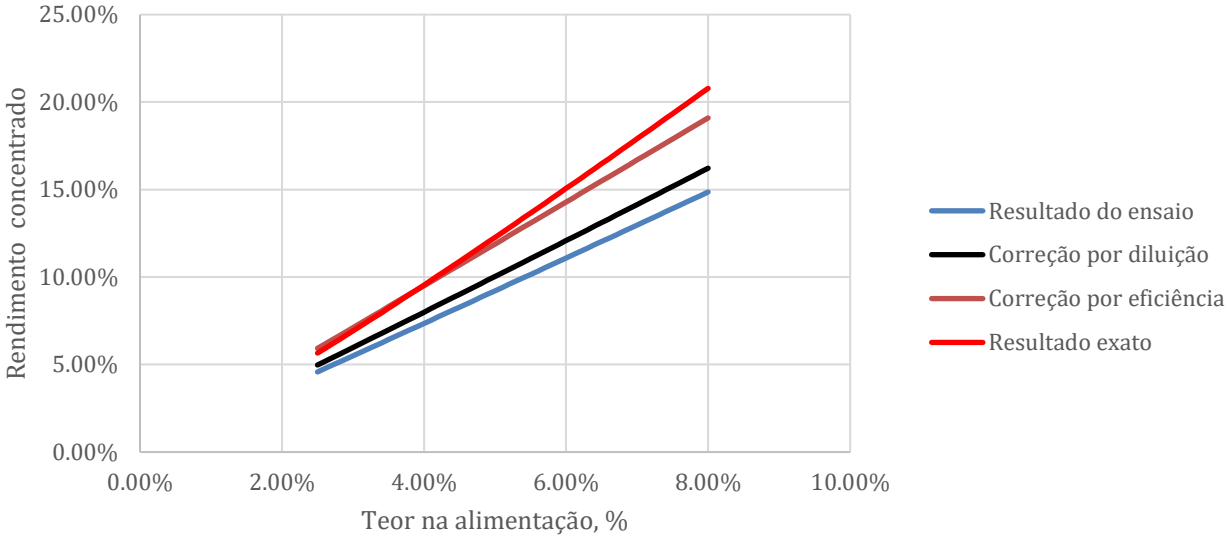

Figure 2: Test yields, dilution-corrected yields, concentration-efficiency-corrected yields and exact yields for the specified quality