SAMPLING SPECIAL SECTION

The classic publication on sampling and analysis costs in full-scale mining—Editor's summary

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Incorrect sampling operations cause huge economic losses to the mining industry, here illustrated by three industrial cases, which also show that when the Theory of Sampling (TOS) is applied correctly (ensuring unbiased sampling and analysis), considerable amounts of money can be saved.

Case 1

Sampling density influences the estimated value of mining plan alternatives

Before decisions regarding a US$640 M investment for a heap leaching facility in northern Chile, alternative spatial sampling grid densities for open pit mining of a low-grade oxide zone porphyry copper deposit (grids from $100 \times 100\,m^2$ down to $10 \times 5\,m^2$) result in markedly different Net Present Value (*NPV*) estimates spanning US$345–450 M as a function of the drilling pattern sizes. A difference between US$345 M and US$450 M, i.e. a **30 % increase** in estimated resource value, is solely due to increased diligence regarding the most appropriate sampling plan, which would not have been revealed without the TOS (and geostatistics). Carrasco *et al.* a.o. conclude that "improper drilling patterns result in misleading economic decisions, e.g. wrongly dismissing good business opportunities, faulty designs of milling capacity and overestimation of waste dump capacity.

The *hidden* value loss in Case 1 is **US$105 M**.

DOI: 10.1255/sew.2021.a32

Case 2

Consequences of installing a TOS-compliant sampler at a tailings discharge location

A US$0.5 M TOS-compliant sampling station was installed to monitor a tailings stream in a large copper operation in central Chile. The tailings were to be sold off to another reclaiming company, so both parties have a vested interest in introducing reliable grade estimation procedures. Before installation, traditional tailing copper grade had been *assumed* to be 0.15 % based on conventional metallurgical balance calculations in the preceding minerals processing pathway. The newly installed unbiased sampling station proved the earlier assumptions wrong—the actual grade turned out to be 0.20 % copper. While this may seem only a relatively small deviation (an underestimation of 0.05 % copper), the tailings flow rate is 96,000 tons per day, so large tonnages are involved here. But what could be worse, this underestimation had been taking place for 87 years! This difference, over this period of time, represents an accumulated loss of copper not accounted for in the company's accounts which had been assumed correct over this long period of mining business. To be fair and to count on improved technology gains a.o., it was decided to calculate the value of this loss for the last 20 years only. Based on contemporary copper prices and production costs, some 175,207 tons per year were unknowingly lost, which when calculated on an *NPV* basis amounts to a staggering **US$2207 M**.

Conclusion

Correct representative sampling practice and equipment discovered a hidden loss of a magnitude of more than **US$2 billion**. It does not take an economics degree to compare this with an investment of US$0.5 M.

Case 3

Economic consequences of a biased grade control system based on blast hole sampling

Blast hole sampling is inexpensive, efficient and often performed manually in many mining industries handling very large tonnages. This is recognised as being a major risk in the industry, but is nevertheless still often preferred from a narrow economics and logistics perspective. In Case 3 this was the established procedure in which a quickly acquired "sample" of 250 g was supposed to represent a lot of 2 tons. Amongst other things, this approach generates a huge Fundamental Sampling Error (FSE). This is a highly significant bias of unknown and inconstant magnitude amounting to ~70 % of the total observable grade variability. In other words, 2/3 of the analytical information with which mining planners are supposed to work, was in reality just… *noise*. An alternative procedure (diamond drilling) is more expensive but also more accurate and precise, so deciding on introducing this would obviously depend on a reliable estimate of the accumulated losses from the blast hole approach. The mining work procedures a.o. involved classifying ores vs waste, based on a so-called "cut-off grade" of 0.40 % (technical details are not relevant here, see the original publication[1]). Complicated geostatistical procedures were used to present relevant information. In terms of *PV* (present value): $PV = B^+ - B^-$ [B^+ *NPV* of wrongly sending ores to the waste dump; B^- *NPV* of, equally wrongly, sending waste to the processing mill]. Based on reliable yearly average costs and performance data, the economic calculations ultimately presented to management were as follows:

Total loss of revenue by misclassification due to blast hole sampling: $B^+ - B^-$ = **US$156 M**

Total loss of misclassification due to the alternative diamond drilling sampling: $B^{+}-B^{-}=$US\$22M

Again, no kudos for being able to reach a conclusion in a manner appreciated by upper management.

General conclusions

General conclusions from Carrasco *et al.*[1] include:

1) Improper (non-representative) sampling practices can produce monumental value losses.
2) For a single big mining company, amounts up to US\$2billion were lost over 20 years.
3) Incorrect sampling (including non-optimised analysis) not only leads to unnecessary economic inefficiency and contributes towards unsustainable exploitation of Earth's resources.
4) In the present context, focus must be on the TOS' ability to help reveal hidden value and economic losses otherwise not known to management—all realised by making sure that "…all sampling and analysis performed to produce decision making information is representative".
5) The most efficient way to discover hidden losses is to foster skill and the ability to understand the different sources of variability—and to understand that estimation is not identical to reality; there are always error effects and uncertainties. The only framework for guaranteed reduction (in optimal situations, elimination) of such adverse effects is by introducing and supporting TOS knowledge.

Read the original paper here

1. P. Carrasco, P. Carrasco and E. Jara, "The economic impact of correct sampling and analysis practices in the copper mining industry", in *Proceedings: First World Conference on Sampling and Blending (WCSB1)*, Ed by K.H. Esbensen and P. Minkkinen, *Chemometr. Intel. Lab. Syst.* **74(1)**, 209–213 (2004). https://doi.org/10.1016/j.chemolab.2004.04.013