

# TOS reflections: is there a third way? (to promote the Theory of Sampling)

Kim H. Esbensen

KHE Consulting, [kheconsult.com](http://kheconsult.com)



A standing discussion topic within the sampling community is: “What is the best way to promote the TOS—not only as a theory, but also as a tool to help customers?” The latter objective casts the question into a rather more direct format: “How to sell TOS-compliant equipment, sampling system solutions, consulting and audit services to customers with only little or no familiarity with the need for proper sampling?” These reflections address the two most dominant answers: i) the economic argument “You’ll lose a lot of money if you don’t...”; or ii) the technical argument: “You need to understand these critical aspects of the TOS, or else ...”. However, this is usually but a futile debate; obviously one should be able to wield a flexible tactics which best matches a specific marketing or application need with one, or both, of these approaches. But a recent event has tickled the imagination—is there possibly also a third way?

## Introduction

Recently KHE Consulting was asked to contribute to a one-day professional meeting within the context of environmental soil sampling: “Delighted to, no problem—but give me a day or two to find out the precise scope that will be most appropriate...”. However, this issue was thrown into a different context by the title of the contribution in the immediately preceding programme slot: “Which technical uncertainties can a lawyer live with?” That indeed got this author thinking...

Could there actually be a third way to promote interest in the TOS—a compelling third way?

## Historical background

Traditionally, there are two schools-of-thought regarding how best to promote the TOS and its application:

The **economic argument**: presenting easy-to-understand, compelling examples and case histories focusing on the adverse economic consequences of not invoking proper TOS, of the type (rather in-your-face): “This is how much money you lose by neglecting proper sampling in this particular situation”. This approach, it is claimed, will lead to a clearer understanding of *hidden causes* for loss of profit. After this argument has caught the attention of the stakeholder, the door is opened, it is hoped, to be allowed to present also the technical arguments—and the race is off.

Or, vice versa:

The **technical argument**: focus is here on making the stakeholder *understand* the concepts, principles, sampling errors etc. in the TOS. Specifically, this approach

aims at bringing about a full understanding of the devastating effects of *sampling bias*, if not properly eliminated. This approach is designed to lead to recognition of *understandable causes* for loss of profit. It is, however, (with very good experience) the dominant opinion that this approach is (much) more difficult for the stakeholders in question, e.g. company and corporation CEOs and other top management, who, while experts in business, will not necessarily also be experts in this subtle aspect of the TOS.

Where- and whenever two or more sampling practitioners and sampling experts have met in person, there has been no end to this evergreen debate. Understandably, this interaction has been exponentially expanded with the start and development of the WCSB fora.... While there would not appear to be a *clear* winner, it is fair to state that the overwhelming opinion is that it is the economic argument that works best—“It’s the economy, stupid!”

**A personal aside**: the present author has never been comfortable presenting the economic argument to members of top management in companies, corporations and/or organisations: “You stand to lose a lot of money, if you don’t listen to me about the TOS”. I cannot escape the feeling that this flies directly in the face of highly competent and experienced stakeholders. To put it bluntly, they do not like to be *told* about the business perspective of their work! To me this approach can easily appear a bit rude or lacking proper respect... But I may be wrong.

So, while there is only one way to sample—the TOS way—is there a third type of argument?



Figure 1. “There is only one way to sample—the TOS way!”. Messieurs Pitard, Esbensen and Francois-Bongarcon at the 1<sup>st</sup> International Conference on Mineral Sampling, Lima, 2018.

## The third way

The **third approach**. Focus is here not on the potential economic loss, nor on the more complex issues surrounding sampling errors and sampling bias, the third way takes its point of departure on interactions in which sampling plays the *crucial* role—i.e. trade agreements aiming at fairness and benefits for all parties, method transparency etc. This approach will require us to stray a bit outside the strictly scientific, technical and economic issues; in fact we shall call in the *lawyers*, with the legal point of view as concerns contractual obligations.

## A compelling case for the TOS in trade and commerce

**Case example:** raw materials or commodity trading; transport, e.g. via ship, train or truck; strong contractual emphasis on each party's right to independent control (loading, transport, off-loading, sampling, analysis). The material specifics in this example are not important—trade interaction is the focal issue, and sampling is the crucial success factor involved.

According to international trade traditions, contractual agreements and codes, disputes between buyer and seller are to be pre-empted by duplication (or triplication) of primary samples, of which one is analysed by the buyer, the other by the seller and a third sample is often archived to be used if disputes can only be resolved in a court of law. Sometimes, a third technical party is called for, which then analyses the archival sample or (although much less frequently) is asked to perform a completely new primary sampling + analysis.

Usually, however, only the two analytical results from the buyer and seller are available and compared. These should ideally fall *within* a commonly agreed upon uncertainty interval, which is specified in the contract; the simple average value is then often used for the pertinent business purposes.

The interesting case is, of course, when analytical differences exceed this acceptance interval, in which case trade codes most often mandate that the archival sample is forwarded to, and analysed by, a third *independent party*, whose analytical result is sometimes used directly *by fiat*. But if this is not acceptable to one or both parties, the dispute goes to arbitration in a court of law. The court will then, in most cases, dictate to use the average between the two *nearest* of the three analytical values, upon which to conduct the salient business transaction. This arbitration approach appears eminently logical and is easy to follow—and is never questioned further, likely because there is always a guaranteed *resolution* that appears intuitively fair to both parties.

**However, there is a hidden elephant in the room—a very big elephant!**

There are very rarely sufficient stipulations in the relevant contractual framework on **how** primary samples are to be extracted! Most often there is only a stony silence on this topic. When pointed out, the response most likely is: “Well, this is obviously a *technical issue* that will be taken care of by the relevant experts—this is not a legal matter”.

The crucial issue is that it is not recognised that the sampling method plays any role—the subsequent analysis is all that matters. This focus is overwhelmingly on the magnitude and the quality of the final analytical results' Total Analytical Error (TAE), which is the basis for establishing the acceptance interval in the first place. The Total Sampling Error (TSE), which unfortunately *dominates* the total uncertainty budget,<sup>1–4</sup> simply does not exist within the traditional legal framework from which trade contract traditions originate. The distinction between TAE and TSE is acknowledged, for example, in *metrology*,<sup>5</sup> but constitutes a fundamental lacuna within the legal area.

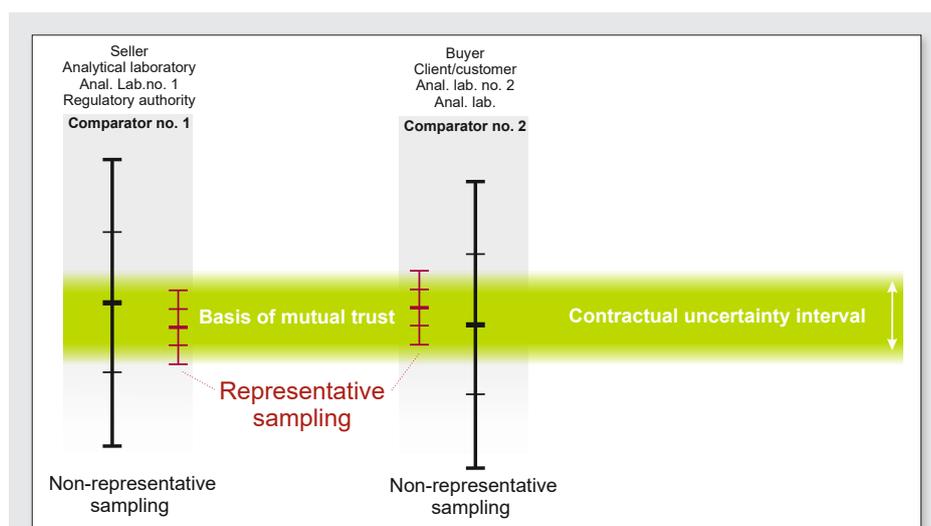
It is thus acceptable that the seller and the buyer perform sampling independently, typically the seller samples at the production site, or at the port of loading of a ship's cargo, while the buyer samples the same cargo but at the receiving port upon arrival. This is because every pair, or every triplicate set, of primary samples is tacitly *assumed* to be identically fully *representative* of the cargo in question; otherwise the above arbitration rules will fall apart and be invalid.

Thus, the crucial issue is that the dominating sampling error effects are *invisible* in the gamut of contractual stipulations—where it is all about the numerical values of the analytical results and about the *quality*

of the analytical determinations involved, the TAE. The focus is only on TAE, instead of TSE + TAE.

Sampling procedures for which the TOS demands elimination of all bias-generating errors (Incorrect Sampling Errors, ISE)<sup>1–4</sup> are not heeded, which unavoidably leads to *biased sampling*. This leaves everybody without control of the magnitude of the influence from the material heterogeneity. This will unavoidably lead to a significant *inflation* of the practical sampling variability, the more so with increasing lot heterogeneity [larger vertical bars (black) in Figure 2]. Biased sampling, whether recognised or not, is the prime reason behind inaccurate (non-representative) sampling, with the unavoidable consequence that the analytical results (even when under impeccable analytical control, i.e. with a minimum TAE) will also be non-representative—and by an unknown factor.<sup>1–4</sup> And it gets worse—there is no way non-representative samples, and ditto analytical results, can be corrected! (See References 1–4 and further references within.)

When the critical primary sampling procedures are but a free-for-all, optional, unregulated matter, i.e. when one, or both, parties in an analytical dispute are not in compliance with the prerequisites for representative sampling, the empirical sampling variability is highly likely to be much larger



**Figure 2.** The consequences of non-representative sampling are identical for buyer and seller—an inflated sampling variability (black, denoted “non-representative sampling”) making it very difficult to be able to satisfy the contractual uncertainty interval (green). Vertical bars show simplified distribution characteristics of repeated [sampling+analysis], a central average result with  $\pm 2$  standard deviation variability. Resolution of an analytical comparison impasse is only possible when all parties agree only to use representative sampling procedures (red, denoted as “Representative sampling”, see also text below and Chapter 20 in Reference 1. Reproduced from Reference 1; ©2020 IM Publications Open.

than the commonly agreed upon contractual uncertainty interval, Figure 2. This translates directly into a high probability that the analytical results from both parties cannot be resolved within the traditional legal framework, but will have to go to arbitration. This is the *status quo* for very many current international trade agreements, codes and contracts. The degree to which this scheme results in the need for arbitration is directly proportional to the inherent heterogeneity of the material involved, and to the degree of procedural deviation from the principles in the TOS that guarantee representative sampling. Lots and materials with low heterogeneity will only rarely experience a need for arbitration, but if/as heterogeneity goes up, so will the number of cases in which efforts to resolve different analytical results are structurally impossible.

The key feature here is that it is the degree of heterogeneity of the lot or material, as sampled by a specific procedure in use (representative or not), that is the *real determinant* w.r.t. the magnitude of the difference between analytical results—and most emphatically not the aptitude of the analytical laboratories involved as is invariably implied when TAE alone is the basis in the trade contract.

This is unfortunately all the more disingenuous since very nearly always analytical errors are very well under control (minimum TAE)—indeed these are often practically negligibly small compared to the dominant total sampling error effects (TSE). This all means that within this traditional context there will never be a *bona fide common basis* upon which to evaluate the magnitude and the significance of the difference between any two or three analytical results, no matter what resolution effort. As long as there is no agreement or contractual stipulation that legally *demand*s representative sampling, there will never be an objective basis nor a rational treatment of “analytical disputes”. There will never be a rational understanding of the reason behind the, completely unnecessary, inflated sampling variability, Figure 2.

TOS is a missing element in the legal contract arena. It is imperative that legal competence includes a full understanding of the distinction between TAE and [TSE + TAE].

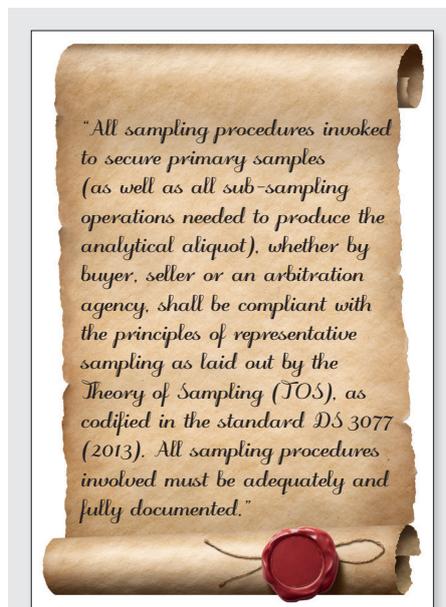
Only representative procedures are able to deliver the effective minimum sampling-and-analysis [TSE + TAE] uncertainty that is the only relevant basis for the contractual uncertainty interval. Things get really out of control if/when buyer and seller, and/or an arbitration agency, can freely choose their own sampling procedure.

The mind boggles when it is realised that a single paragraph is able to rectify the fatal quagmire outlined above, a paragraph that needs to be included in all contracts forthwith for cases that demonstrably involves sampling *before* analysis...

### The credo of contractually stipulated representative sampling

Imagine a world in which the following credo was universally accepted, and willingly complied with (Figure 3):

“All sampling procedures involved to secure primary samples (as well as all sampling operations needed to produce the analytical aliquot), whether by buyer, seller or an arbitration agency, shall be compliant with the principles of representative sampling as laid out by the Theory of Sampling



**Figure 3.** The sampling credo SCROLL. Reproduced from Reference 1, ©2020 IM Publications Open, scroll image: Shutterstock/Andrey\_Kuzmin.

(TOS) as codified in the standard *DS 3077* (2013). All sampling procedures shall be adequately and fully documented.”

In the words of Louis Armstrong: “What a wonderful world it would be”.

### First and last: the economy vs TOS competence

So, which is the best way to promote TOS: economic, technical or legal?

It stands to immediate reason that the current situation shown in Figure 2 will result in significant losses of profitability due to exacerbated dangers of making decisions relying on *hidden, unnecessarily* inflated sampling + analysis uncertainty, see, for example, Chapters 20–25 in Reference 1. This point of view *combines* the technical and the economic arguments.

Because of the need for universal acceptance of the sampling credo, there is here a compelling reason to make sure that sufficient TOS competence is available for all parties involved, either in-house (already existing or by training), or via external sampling expert consulting. It is, therefore, *necessary* that a minimum of TOS competence be inducted not only in technical departments but at legal, administrative and executive levels as well.

Thus, there are indeed three avenues to application of TOS, each arguable on their own merit: for technical reasons, for economic reasons **and** for legal reasons.

### References

1. K.H. Esbensen, *Introduction to the Theory and Practice of Sampling*. IM Publications Open (2020). <https://doi.org/10.1255/978-1-906715-29-8>
2. F.F. Pitard, *Theory of Sampling and Sampling Practice*, 3rd Edn. CRC Press, Taylor & Francis Group (2019). <https://doi.org/10.1201/9781351105934>
3. G.J. Lyman, *Theory and Practice of Particulate Sampling: An Engineering Approach*. Materials Sampling & Consulting (2020).
4. *DS3077, Representative sampling—Horizontal Standard*. Danish Standards (2013). <http://www.ds.dk>
5. K. Heydorn and K. Esbensen, “Sampling and metrology”, *Accredit. Qual. Assur.* **9(7)**, 391–396 (2004). <https://doi.org/10.1007/s00769-004-0808-z>