Composite sampling II: lot dimensionality transformation

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We have learned that grab sampling never works—instead composite sampling rules! In the previous columns we met with many examples of lots made up a different materials with widely different heterogeneities, lots at all scales: and, for all, the Fundamental Sampling Principle forces the active sampler painstakingly to "cover" the entire lot volume with an appropriate number of increments (Q). While easy to understand, it must also be acknowledged that the practicality of reaching every corner of every lot imaginable is a daunting task, especially if the lot is a three-dimensional (3-D) body larger than what can easily be manipulated on the laboratory bench. Of course, this is not possible for the range of the primary sampling stage, where the sampler meets with all manner of lot sizes from handy to large (to enormous) from which to take a primary sample, a composite sample. Is there an easier way to do the right thing, easier that just to "dig in"? Luckily there is! First, we will appreciate how easy to it is to carry out composite sampling on a one-dimensional (1-D) lot. And the whole world will suddenly get a lot easier—in fact we will be able fully to appreciate how representative sampling has arrived on the scene!

1-D lots: elongated lots

The principal characteristic of all 1-D lots is that the transverse dimensions (width, thickness) are so small (and reasonably constant in absolute magnitude) that all increments will be able to "cover" these two dimensions, hopefully with no adverse problems. This is the essential point. Unfortunately the real world does not always comply. Figures 1 and 2 illustrate this issue clearly.

A 1-D lot can either be a stationary lot or it may be a dynamic, i.e. moving, lot. The latter is the archetypal "moving stream of matter", which may be made up as a one-, two- or even a three-phase system. For the present illustration we focus on aggregate streams of matter but the arguments to be presented are valid for all types of compositional systems *on the move* or strung out as a stationary 1-D lot.

Figure 2 shows how the adverse sampling bias can be produced by inappropriate sampling. But there is hope; especially if the sampler invests but a trifling effort, based on TOS' principles.

Process sampling

Figure 3 gives two examples of 3-D lots that, at some point in their life, actually

Figure 1. (a) Archetypal moving 1-D lots, the pipeline (left) and the conveyor belt (right), with potential sampling station locations indicated by red arrows. (b) The folly of grab sampling in the process domain. Manual process grab sampling attempts to cover the full transverse dimensions of the flow (width/height) but with clear dangers of being insufficient—grossly so in two of the examples shown. A sampling bias has been introduced, which will haunt the reliability all the way to analysis. "IDE, IME" represents a sneak preview of the type of sampling error that can be produced by the sampling process itself (a matter for later columns).

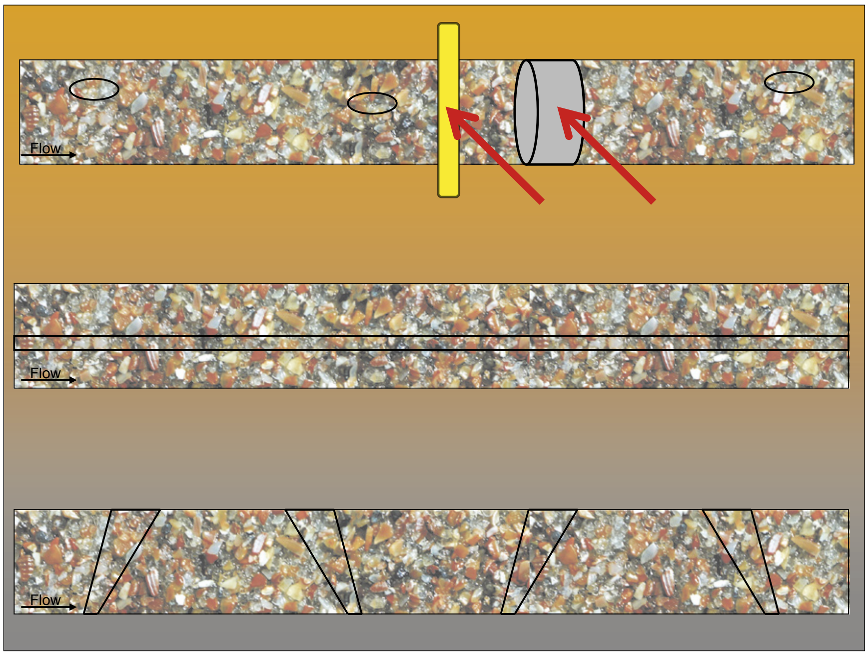


Figure 2. Increments can be extracted from 1-D lots in a variety of ways, but only one is correct (representative): a complete slice of the stream/flow defined by parallel boundaries (shown in yellow). All other increment delineations shown are incorrect and will give rise to a sampling bias. For process sampling, e.g. a pipeline, the correct increment delineation is also a planar–parallel slice of the flow, i.e. a cyindrical cut (shown in grey).

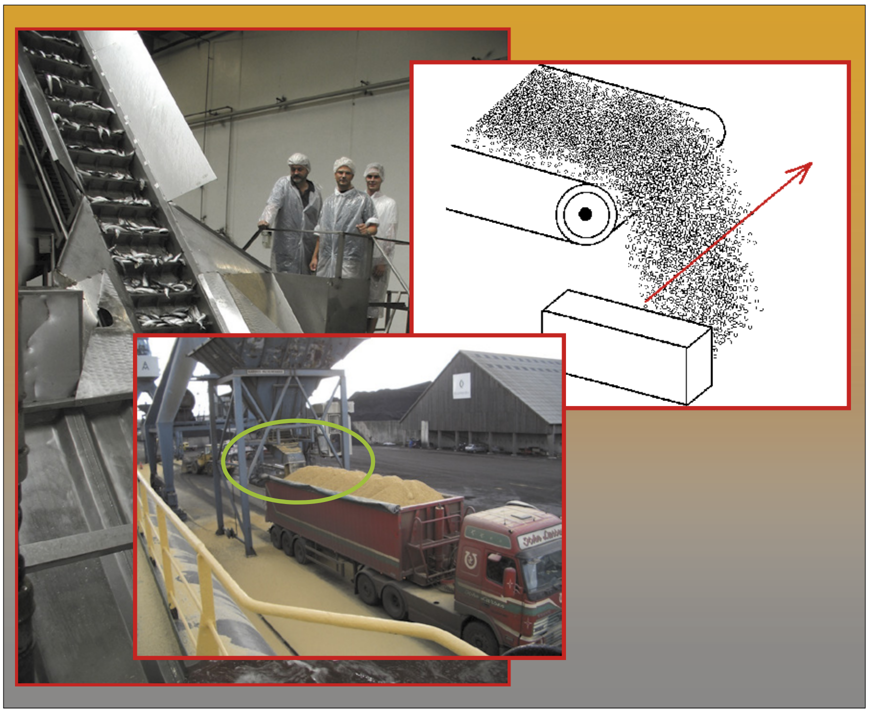


Figure 3. Often an "impossible-to-sample 3-D lot" will at some point be in a state of transportation—which then constitutes a 1-D lot, a stream-of-matter or a flow, that can be intercepted by incremental sampling. The top illustration shows a surprising parallel between a cross-stream sampler and a moving fish elevator (transported from the cargo hold of a trawler). While representative sampling from the full trawler cargo hold is impossible, the fish elevator constitutes a perfect location for incremental sampling able to "cover" the entire lot (cargo hold) as it passes by.

manifest themselves as moving 1-D lots. The fish elevator example is explained in the figure caption; the grain trucks example is but the terminal end of a much bigger off-loading process from a 30,000-ton cargo ship carrying feed soy beans. The entire nine-cargo-hold soy bean lot is off-loaded by one-ton grabs being deposited in the hopper shown. Each truckload, 10 tons, is then driven to the warehouse shown in the background, where the complex 3-D ship cargo is now again turned into a massive 3-D storage lot. The interesting element in this process is the temporary existence as a moving 1-D lot: the green ellipse focuses attention on a stream-of-matter originating from/through a 1×0.2-m opening at the bottom of the hopper, gradually emptying the load of 10×1 ton soy bean. The entire ship's cargo will flow through this orifice. While the ship's cargo is rightfully characterised as an "impossible-to-sample" 3-D lot, the hopper outflow makes it quite different. Imagine that a "cross-stream cutter" (illustrated by the sketch in Figure 3) can be implemented at this location? This cutter will be able to cut correct, representative slices of this temporary stream, i.e. correct increments. The only remaining question would actually now be: how many increments are needed in order to characterise the entire ship's cargo?

Process sampling generalised

The scene is now set for a revelation. As soon as one has decided on always honouring the transverse coverage demand for every increment extracted, it is clear that one can always also cover the elongated dimension (the defining 1-D dimension). It is simply a matter of covering the entire extension of the lot, whether by walking up the full length of the stationary lot, or if the dynamic lot, conveniently, streams past your sampling location. Where one is always at liberty to choose, there is no doubt which situation would be preferred—it is indeed a very convenient situation, simply repeating the correctly covering increment sampling Q times. This type of sampling is much the easiest if automated, giving absolute sampling powers over all forms of flowing streams of matter, Figure 4.

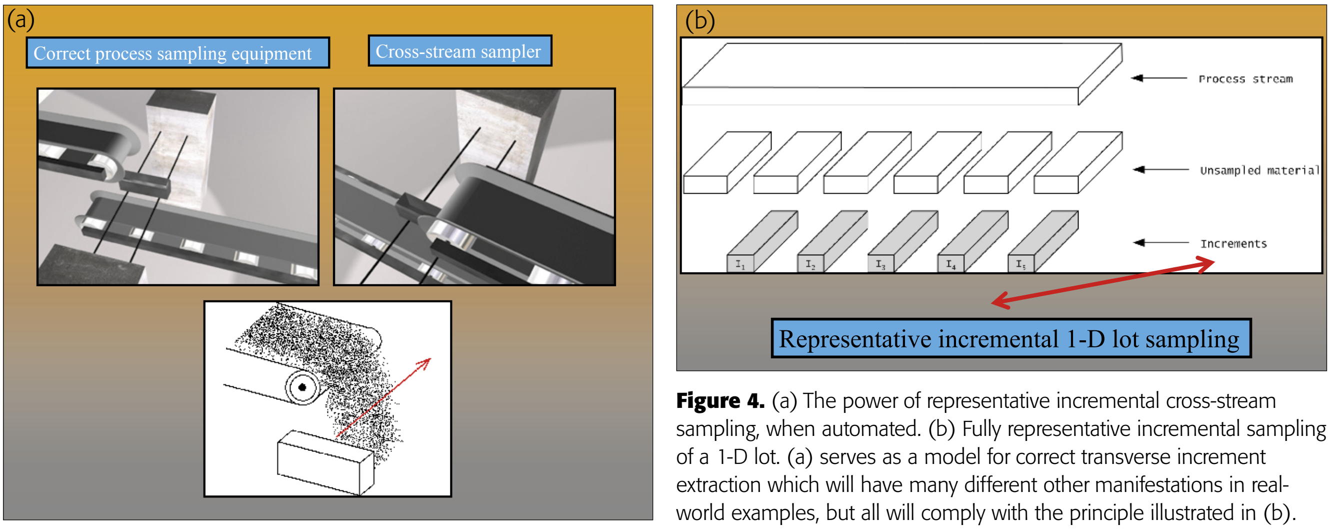


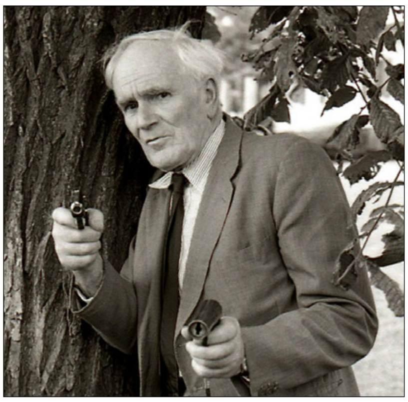
Figure 4. (a) The power of representative incremental cross-stream sampling, when automated. (b) Fully representative incremental sampling of a 1-D lot. (a) serves as a model for correct transverse increment extraction which will have many different other manifestations in real-world examples, but all will comply with the principle illustrated in (b).

Q

If the objective of the sampling is to produce a representative analytical value pertaining to the whole lot, we observe that after *Q* increments extracted in this fashion we have indeed covered all three dimensions of the original lot, which may well have been a completely impossible-to-sample 3-D lot. All that was needed was to intercept the lot while it was in a moving state (1-D).

Upon reflection there are but few lots (if any) that are created in a finished state as 3-D lots; it is rather the case that these "big, impossible-to-sample 3-D lots" are created by a process meticulously laying up the lot in question by a series of incremental units, for example units being delivered at the terminal end of a conveyor belt, or units delivered through a pipeline or otherwise. Imagine how easy the job would be for the sampler, if one were able to install a relevant variant of a cross-stream sampler at the sampling station chosen, e.g. after the terminal end of a conveyor belt intercepting the collimated falling stream of matter that is slowly building up the 3-D lot-to-be (or similar). This situation is rightly often seen as the prototype sampling procedure that can be turned into any composite sampling scheme desired—and always at the sampler's leisure: How many increments to accumulate? *Q*!

It goes without saying that TOS owes the sampler an answer to the fair question: "HOW DO I ESTIMATE *Q*?" And an answer will be given, but in a later column. The pre-requisite for enjoying this answer is simply a decision to never relinquish the composite sampling imperative (Figure 4). An example from a complicated system is given in Figure 5.



Q: The actor Desmond Llewelyn.
Credit: Wikipedia/Towpilot.

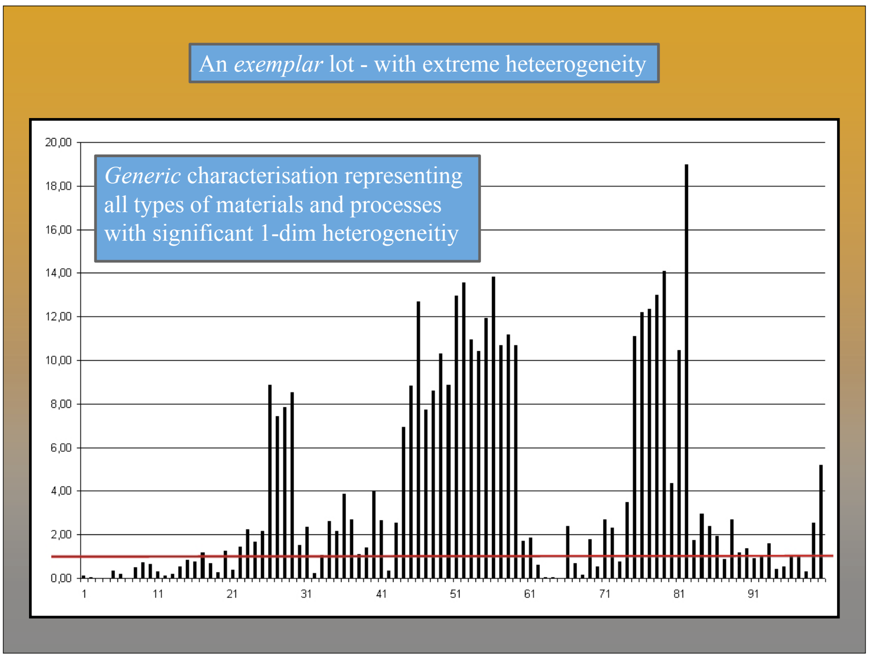


Figure 5. Representative extraction [*cf.* Figure 4(b)] of 100 increments of a 1-D process stream reveal a pressing need for an effective composite sampling scheme if one is to be able to state with any reliability an average concentration of the 100 individual analytical results presented. It turns out (see later columns) that the pertinent *Q* for this difficult task is *Q*=42. [For the reader who cannot wait, this example derives from the famous KeLDA study (see Literature).]

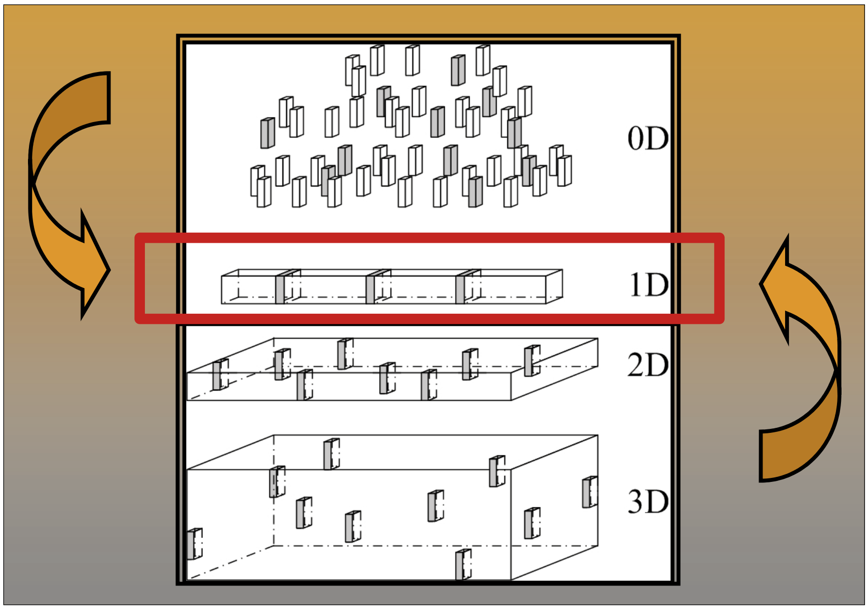


Figure 6. TOS' Governing Principle: "Lot Dimensionality Transformation (LDT)".

The present column is a first illustration of the framework in which composite sampling can be implemented without undue problems or issues; it is all about the practicality of installing an appropriate cross-stream sampler, perhaps also the costs involved. Although the latter must never be allowed to take over—for the crucial primary sample, representativity is the only legitimate incentive!

Lot dimensionality transformation (LDT)

All of the above serve to illustrate why the composite sampling imperative, together with a natural wish to conduct sampling in as easy a manner as possible (what else?), has led to a universal desire to locate all or as many as possible situations in which lots are in a similar state of 1-D transportation; or can be forced into such a situation (Figure 6). Why? Simply because of the immensely easier sampling that can be achieved from a 1-D lot. Later we shall also see why this is actually the situation in which the most effective sampling can be achieved, especially with respect to the critical possibilities of eliminating the adverse sampling bias.

This situation has in fact been codified as one of the six Governing Principles of TOS: "Lot Dimensionality Transformation (LDT)", which plays a fundamental role in the primary sampling arena.

Literature

K.H. Esbensen, C. Paoletti and P. Minkkinen, "Representative sampling of large kernel lots – I. Theory of Sampling and variographic analysis", *Trends Anal. Chem.* **32,** 154–165 (2012). doi: http://dx.doi.org/10.1016/j. trac.2011.09.008

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