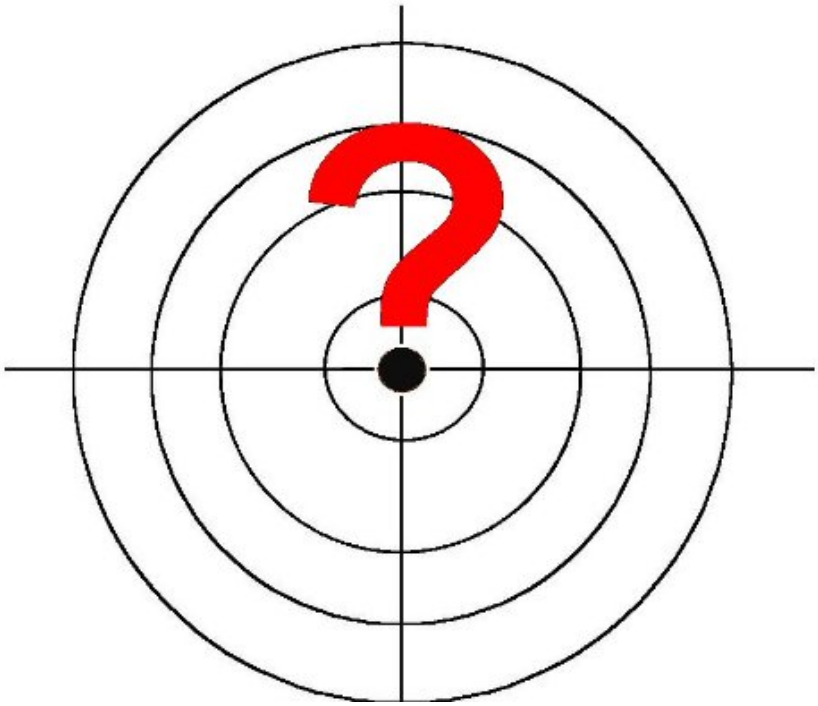
HYPOTHESIS TESTING in DQOs
LinkedIn Article
April 7, 2016

Caoimhín P. Connell
Forensic Industrial Hygienist



Industrial Hygiene is the recognition, evaluation, *anticipation*, and control of human stressors. All too often the anticipatory aspect of Industrial Hygiene, which inherently deals with uncertainty, is overlooked in the development of sampling strategies.

Thus when performing occupational exposure assessments we have already anticipated the compounds present, since as part of our sampling strategy, we have determined the materials being used, and therefore what is to be included in the assessment.

We have already determined probable concentrations from chemophysical properties of the materials, employee proxemics and exposure times.

We have begun to characterize random sampling error from the topography of the study area, employee duties, number of employees present vs. the budget available.

We have begun to characterize systematic error from the *a priori* decision thresholds (often regulatory thresholds) and the sampling/estimation methods ultimately selected.

We then begin to place those considerations into framing an appropriate question within the context of data quality objectives (DQOs) and their primary PARCC components:

- Precision
- Accuracy
- Representativeness
- Comparability
- Completeness

Before we go there, we must first ask a question - literally.

Before we collect a sample as part of the sampling protocol, we need to define a question that can be answered within the limitations of the PARCC parameters.

Thus, if we are looking at noise exposures, don't just ask "Why?," ask "Where?" ask "Whom?" and ask "When?" We probably don't really care about the noise of an operation so much as the sound exposure within the context of anticipating control. Therefore, the location, the operator, time of day, processes line, etc, all come into play.

When looking at airborne chemical exposures, we already know the geometric standard deviation of interday and intraday airborne concentrations are large and are probably between 1.2 and 2.5 geometric standard deviations.[1] Therefore, the question we must form already incorporates the inherent uncertainty and limitations of the sampling/analysis protocols.

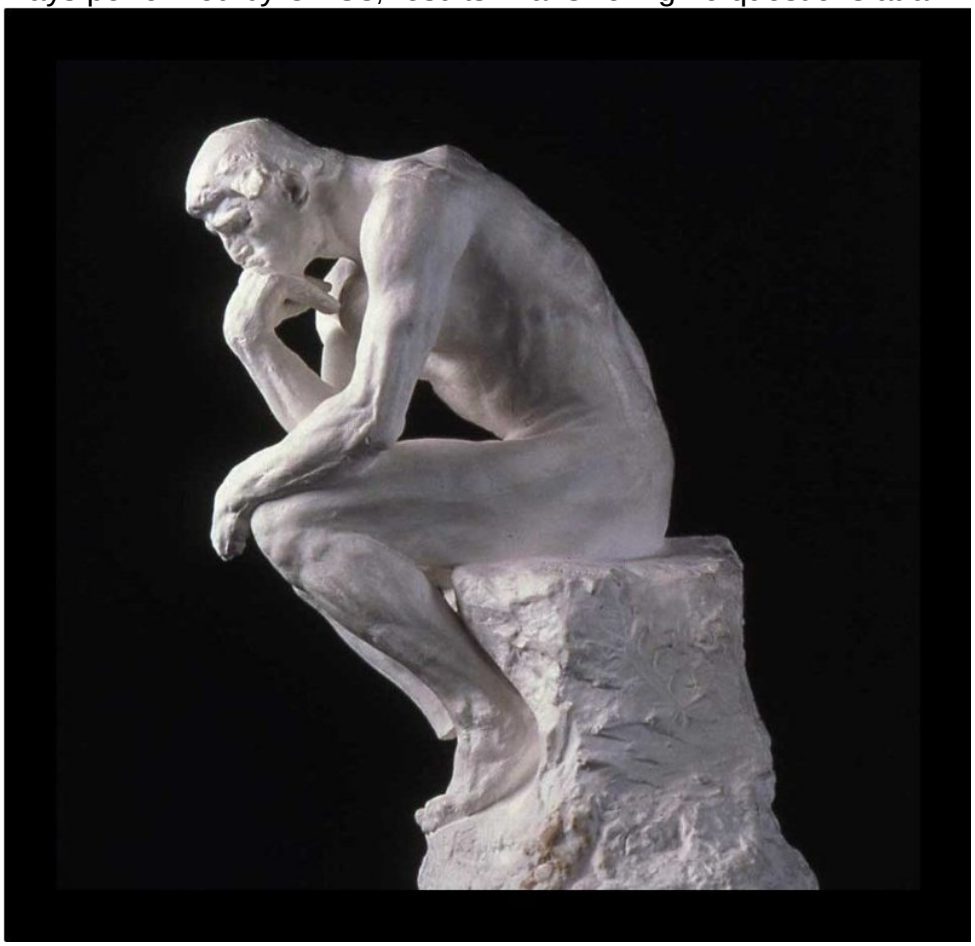
I often get phone calls from homeowners who want me to "test for mould" in their house – they are astonished when I tell them, "There is mould in your house, and it is present by the BILLIONS of mould spores." So they change their sampling objective: *"Well I want to find out if it's the BAD kind of mould."* So I asked them "OK… what IS the bad kind of mould?" So they again change their sampling objective: *"I want to find out if I*

[1] NIOSH Occupational Exposure Sampling Strategy Manual, HEW Publication Number 77-173 (1977)

have BLACK mould in my house." They are once again astonished when I tell them "There IS black mould in your house, and it is there by the billions of spores."

Ultimately, I allow the caller to take themselves down a decision making tree and figure out for themselves they don't really want "testing" or "sampling," rather, they usually want to know if a particular little spot of colonization or a particular water loss incident has resulted in a safety issue due to mould. In about 90% of those phone calls, the caller realizes they have been unnecessarily frightened by a "certified mould goober" (CMG) who usually works for a "mould remediation" company (certified, of course).

Therefore, "sampling" ultimately is "answering a question." Well defined questions, tend to be matched with well defined sampling protocols. Willy-nilly sampling, such as that virtually always performed by CMGs, results in answering no questions at all.



Classic sampling texts often discus "hypothesis testing" which is a bit over board for this brief discussion, so here, let's just think of "hypothesis testing" as simply being able to

ask the correct question our sample results are suppose to answer (in legitimate statistical hypothesis testing, we would find that the ability to reject the null hypothesis may be cost prohibitive due to the large sampling error we probably will encounter).

So, at the heart of *any* sampling is a question that is to be answered. Such a question must be the underpinning rationale regardless of whether one is sampling noise, dosimetry, manufacturing control, surveys, environmental contamination, etc.

Failure to pose the right question may well result in data that can support dozens of alternative explanations, and otherwise cannot be used to answer the intended question even when armed with legitimate sampling and legitimate laboratory analyses and otherwise excellent laboratory reports.

So, before performing sampling, one needs to know 1) the question, and 2) if the sample and results are capable of answering the question. Here are a couple real life examples from my files where this was not done:

Scenario 1

A railroad worker was in the vicinity where trona was being transloaded. The wind blew fine trona dust toward the employee, reportedly engulfing the employee. The employee did not know the identity of the dust and, perhaps not unreasonably panicked, and reportedly experienced respiratory distress. The employee was transported to the E.R. where he was diagnosed with an unrelated disorder.

The employee sued the rail carrier and the trona mining operation for his alleged injuries.

Attorneys had preserved the worker's shirt, and submitted the shirt for analysis. The law firm told the lab: "We need an elemental analysis of this shirt." Therefore, unwittingly, the question became "What elements comprise this shirt?"

The laboratory obliged and performed testing on the shirt and produced a very fine (and very large, expensive) report that contained the elemental analysis of the shirt as requested. The law firm provided the lab report to me, and I told them "thanks," but the lab report was useless. The lab analysis provided no defendable "data" and answered no questions germane to the case.

The question that should have been asked was very simple: "Is there trona on this shirt, and if so, how much?" Unfortunately, the lab no longer had any of the sample, and now, we had no evidence to play with and an expensive lab report we couldn't use.

Nobody asked the right question. (Nobody established a conceptual hypothesis).

Scenario 2

A large vault door in the basement of an old building was being removed by cutting the massive door into sections with torches. Due to the noise and engineering controls involved, the work was scheduled to be completed after-hours during a weekend.

During the sectioning process, a large piece of the door broke away and unexpectedly crashed to the floor with such force that it was heard on the third floor of the building. Although the building was supposed to be unoccupied, an occupant working on the third floor reported she experienced the "explosion" and was instantly enveloped in a choking white smoke that was so thick, she barely made it out of the building alive.

The following Monday morning, the building superintendant received complaints from the occupants of the third floor that there was a mysterious red dust settled on some surfaces. The City Health Department responded and collected samples of the dust and submitted the samples for laboratory analysis. The question they asked was "What was the metal content of the red dust?" The lab analyzed the samples via NIOSH 7300 and answered the question "predominantly lead, with minor constituents of tin, silver, and cadmium."

The occupant of the third floor filed a toxic tort suit against the construction company whom she blamed for her host of alleged health effects as a result of the exposure caused by the defendant.

For the next seven years, not one "expert" on the case actually looked at the analysis reports; everyone (including the defendant's experts) presumed the laboratory report damned the defendant. For seven years, no one looked at the question that was asked when the City Health Department analyzed the mysterious red dust on the third floor. The defendant's legal team accepted responsibility and entered negotiations for a settlement.

When I was hired, I started by looking at the lab report, and the tacit hypothesis challenged by the Health Department. I concluded that the question that *should* have asked was "Is the dust identified on the third floor the same composition as the materials being generated by the defendant, and, are there any similar contaminants anywhere else in the building?" The defendant had a good occupational exposure program, and I had access to OSHA air monitoring samples that had been collected from the demolition crew during the cutting operation.

I dropped a bomb on the case when I pointed out that the steel door that was being removed was predominantly iron with traces of nickel and chrome and contained virtually no lead. The mysterious red dust was predominantly lead with no measureable iron or nickel. The construction worker's personal monitoring results were consistent with the composition of the door. That is, the mysterious dust (that only appeared in a limited area on the third floor) was not even the same material as being generated by the construction company.

The Defendant's legal team had accepted responsibility for an event of which they had no culpability.

Nobody asked the right question. Nobody established an hypothesis. Everyone presumed the legitimate laboratory report answered questions that weren't asked.

Scenario 3

A homeowner noticed a massive bloom of fluffy white mould in her crawlspace and she hired a certified mould goober (CMG) to assess the situation. The CMG visually confirmed a large field of fluffy white tufts spreading extensively on the earthen floor of the crawlspace and, being an hammer, the CMG looked for a nail and collected a spore-trap air sample in the crawlspace.

The AIHA accredited laboratory who analyzed the sample identified the presence of the mould in the sample. (No kidding).

Armed with a REAL laboratory report from a REAL laboratory, the CMG announced the house was contaminated with "toxic mould" and advised an immediate evacuation of the residence and complete decontamination of the woman's chattels.

I was called in by the homebuilder and I met the client and the terrified homeowner at the house, wherein, I immediately pointed out that no one had asked the right question. The right question was "What's all that fluffy white stuff?"

Asked and answered

I explained that the fluffy white stuff was just a large field of (very beautiful) crystals comprised of dissolved salts that formed on the earthen floor as the crawlspace had slowly dried. "The fluffy white material," I announced confidently, "is just salts."

The homeowner was incredulous: "How can you say that without a laboratory analysis?" (*c.f*. The CSI Effect). After all, she protested, the CMG collected a "scientific sample" and he had a REAL laboratory report!

I explained that no lab analysis was needed and the CMG performed useless sampling and analysis that would have had the same meaningfulness regardless of which crawlspace in the neighborhood he collected his sample.

I asked the homeowner to bring me warm tap water in a clear glass. I told the client and homeowner that mould doesn't dissolve in water. I established the "hypothesis" that I was going to test:

Mould doesn't dissolve in water. If the material dissolves in water, it cannot be mould."

(Notice the alternative hypothesis doesn't actually identify what the material is, since if the fluffy white crystals were, say, hoar-frost, that too would dissolve in warm water).

I dumped a scoopful of the fluffy white stuff in the water and, presto-chango, the material instantly dissolved! Therefore, the hypothesis was supported and, ergo, the white stuff could not be mould.

"Perfectly safe," I announced again. To which the homeowner replied "Prove it." I immediately drank the water and smiled at the homeowner who shrieked with terror.

Conclusion

Even a Judge on the 6th Circuit Court of Appeals can be taught **how** to collect a "scientific sample." However the collection of an intelligible sample designed to answer an intelligent question is considerably more in depth, and may not be within the realm of the "certified environmental specialist" you have hired.

(I once got involved in a project where a mine hired a Home Inspector to perform radiological exposure monitoring in a mine – They hired a Home Inspector because he was a "Certified Radon Tester" so obviously he knew all about radiation, right?)

Asking the right question, and being able to present the question in the form of a specific challenge that will allow the rejection or failure to reject a specific hypothesis with specificity is at the heart of sampling. Narrowing the question down such that the test has fewer and fewer alternative explanations makes the sample more and more useful.

For regulatory sampling, an hypothesis is usually tacitly found in the assessment methods designed for regulatory compliance – but not always, for example in the latest regulations in Colorado for 6 CCR 1014-3, the state intentionally removed the sampling objectives because the existing objectives were "too complicated" and prevented fraudulent consultants from performing illegal work (I wish I was kidding).

Otherwise, for non regulatory sampling, the investigator will have to begin their investigation by ensuring they are asking the right question. Then, if they decide to perform “sampling” or “testing” that sampling or testing should be capable of either rejecting or supporting a stated hypothesis with specificity.

In the next installment, we are going to start putting our question into the context of “precision.” And explore why “precision” may lead one to not collect any samples at all, and why high precision can be more useful than accuracy.

Ref:
NIOSH Occupational Exposure Sampling Strategy Manual, HEW Publication Number 77-173 (1977)