The Problem With Precision

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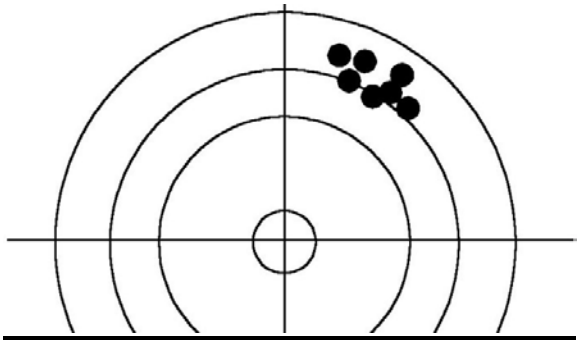


In this installment regarding Data Quality Objectives, we address the "P" of PARCC: -- Precision.

Once an investigator has identified the fundamental question to be asked (see DQO-Hypothesis), the investigator now needs to consider the necessary precision that must be met to answer that question.

Watch This
Imagine you have a choice between two wrist watches:

The Red Watch is absolutely accurate, but never precise.

The Blue Watch is never, ever, ever accurate, but is absolutely precise.

Which watch would you choose?

Before you answer the question, consider this: What is your starting "hypothesis" (objective)? If your objective is "*At all times, I need to know the time of day very accurately*." … then it may surprise you that the watch of choice is not the accurate Red Watch but the precise Blue Watch.

To explain why, know the Red Watch has stopped. The Red Watch stopped at 1:23 and 19 seconds. Twice each day, the Red Watch will be 100% accurate; it will be

accurate at 01:23:19 in the morning, and it will be accurate at 13:23:19 in the afternoon. Therefore, the watch is accurate twice per day, but it will be utterly useless for meeting your objective, which is to know the time of day with confidence.

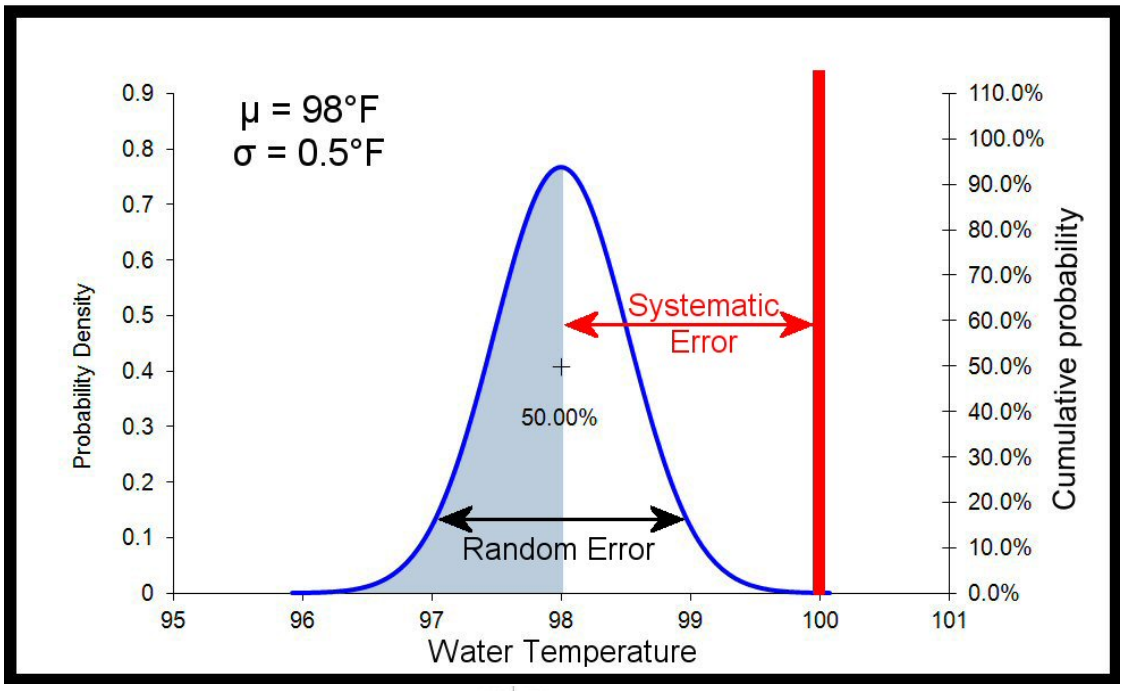
Now consider the Blue Watch: The Blue Watch is slow by exactly 20 minutes and 20 seconds - **always**. The Blue Watch will NEVER be accurate – however, the Blue Watch will meet your DQO since you will be able to apply a correction factor and add 20 minutes and 20 seconds to the displayed time and always know the time of day with confidence. In this case, the Blue Watch is exhibiting a type of precision error known as "systematic bias."

Hot Water

From a practical perspective, imagine we have purchased a thermometer for our hot-tub. We know if the rheostat on the hot-tub is kept at a setting of "4," the water in the hot-tub is exactly 100°F. But what if the rheostat is set to "5" or "6" – and we want to measure the water temperature? Is the thermometer up for the job?

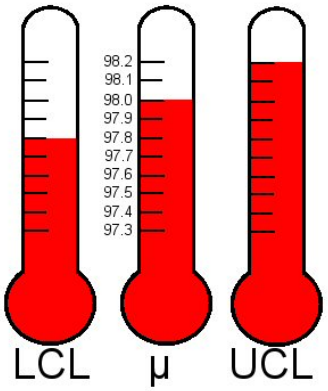
We begin by taking 20 readings using the new thermometer with the rheostat set at "4" and find the average reading (μ) is 98°F and 95% of the readings deviate (2σ) about the average by 0.5°F.

If we plot the readings, we find the familiar bell-shape curve indicating a Gaussian distribution. The shape of the curve, tells us about the random error and the distance of the mean from the known value tells us about the bias, or system error:



Now we know when we turn the rheostat up to “5,” and use the thermometer to sample the temperature, we apply a correction factor and add 2°F, and 95% of the time our sample will be correct, plus or minus half a degree.

We can now show this graphically by taking any sample reading and expressing the sample as it’s two confidence intervals, the Lower Confidence Level (LCL) and the Upper Confidence Level (UCL):



Probable Results

And so it is with a laboratory report. When we get a laboratory result back, the reported value on the lab report is a *probable* value; the true value will have a 95% probability of being between two limits – the LCL and the UCL:

Very typically, the LCL and UCL are within reasonable limits that make the data easy to compare to decision thresholds with confidence. The confidence intervals may be estimated from experimentation (as described with the thermometer above) and/or from validated methods. For example, if we look at NIOSH Method 1457 (Ethyl acetate), we see the validation data summarized on the cover:

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ETHYL ACETATE

1457

$CH_3COOC_2H_5$ MW: 88.10 CAS: 141-78-6 RTECS: AH5425000

METHOD: 1457, Issue 1 **EVALUATION: FULL** **Issue 1: 15 August 1994**

SAMPLING		MEASUREMENT	
ACCURACY		**MAKEUP GAS:**	N_2, 30 mL/min
RANGE STUDIED:	704 to 2950 mg/m^3 [2] (6-L samples)	**CALIBRATION:**	standard solutions of ethyl acetate in CS_2
BIAS:	-2.1%	**RANGE:**	1.5 to 1,000 µg per sample [1]
OVERALL PRECISION ($\hat{S}_{rT}$):	0.058 [2]	**ESTIMATED LOD:**	0.5 µg per sample [1]
ACCURACY:	±11.8%	**PRECISION ($\bar{S}_r$):**	0.019 @ 40.5 to 810 µg per sample [1]

From this, or other sources, we can calculate the confidence intervals. So let's do it using up-to-date data from IRSST, for ethyl acetate. If an Industrial Hygienist collected a full shift air sample from a workplace and received a lab report indicating a result of 550 ppm, we get a LCL of 509 ppm and a UCL of 592 ppm.

The OSHA PEL (decision threshold) for ethyl acetate is 400 ppm. Since the LCL is greater than the PEL, we know with confidence the data indicate a probable over exposure, and the data can be used to answer our question and decision making. If the UCL was below the PEL, then we can say with confidence an overexposure was improbable.

But what if the control level falls in between the LCL and UCL? (I will address this in a later installment).

For most analytes of interest, these limits are relatively close and the data are therefore useful. However, for some methods, such as spore traps in air samples, the sampling error alone is so **enormous** as to make any statement of confidence in the sampling meaningless and renders the results completely useless.

For example, let's take a look at a real life example: here are typical spore counts for a property in Denver, Colorado, whose "average" is 550 spores/m3 of air.(1) All sampling parameters for each sample were exactly the same, except the time of day.

Time	Spores/m3
09:00	97
10:45	2016
12:15	129
13:45	807
15:00	353
17:00	129

In this very typical example, we see the data are lognormally distributed as expected, and when we calculate the LCL and UCL based on the reported value of 550 spores/m3 on the lab report, we see the following:

This is to say that if an air sample collected from the residence is analyzed and the lab result came back as "550 spores/m3," there is a 95% chance any such air sample collected from the residence will be somewhere between 270 spores/m3 and 9,030 spores/m3. Well, any fool could tell an homeowner "*Well, gosh, I think the spore count*

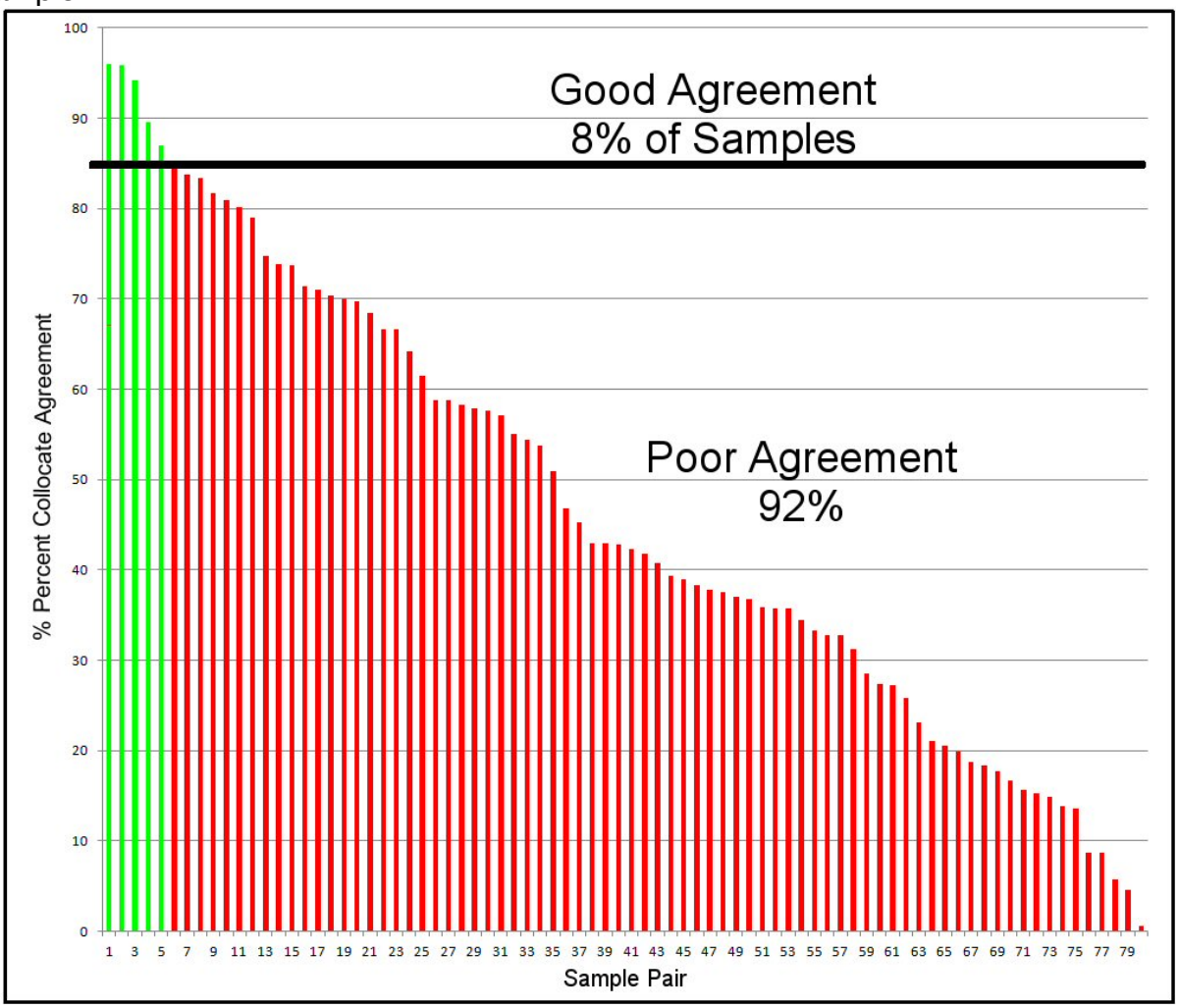
in your house is somewhere between 270 spores/m3 and 9,030 spores/m3." So what utility is the "data"? Answer, there isn't any.

The error here stems from the fact that from minute to minute, spore counts vary enormously – two samples taken only three minutes apart will have completely different results. The overwhelming vast majority of "consultants" running around collecting such "air samples" are "certified" mould inspectors who somehow think the spore concentrations in the air are both static and homogenous – neither assumption is even remotely valid.

Furthermore, spatial distances of just a few inches result in enormously different spore concentrations. If an investigator places two identical spore traps next to each other, separated by only 20 inches (about 50 cm) and simultaneously collects two samples, the results will be completely different from each other. That is, one cannot even get two spore trap samples collected from the same space and the same time to agree – let alone pretending that one is comparing an indoor sample with an outdoor sample.

Consider the following experimental setup – three simultaneous spore traps – two for total and one for culturables. All three devices are activated simultaneously and operated for the exact same time. "Certified" mould inspectors claim they can compare two samples from two separate locations within a structure, or inside locations to outdoor samples.

Yet, when we look at the data, (below) we find that it is impossible to get two simultaneous spore traps from the same room to agree. In the graphic below, I have compared 80 such simultaneous data sets. What we find is that virtually always (92% of the time), one spore trap sample collected can be contradicted by another spore trap sample.



As such, since the "certified mould inspector" has no idea what the spore count is for an area they have sampled, it is a scam when they declare they have compared two different locations or claim they have compared an indoor sample to an outdoor sample. Using the techniques of the "certified mould inspector," it is impossible to compare samples taken from the same room at the same time, let alone different locations at different times.

Virtually every sample collected by the "certified" mould inspector is this unreliable; but the bailiwick of the "certified" mould inspector is to deceive their victim and tell them

they have measured the spore count. In reality, the con-artist has only accomplished one thing – they have taken their victim's money and given them nothing in return but bamboozled their victim with a fancy (and very real) laboratory report containing meaningless numbers that make their "sampling" look very scientific.

This is not new information; and these enormous errors have been discussed in Industrial Hygiene literature for over half a century – but, for the "certified" mould inspector, ignoring science is a must for making money and perpetrating their scams.

It is for this reason (and many others like it to be discussed in an up coming discussion) the US Centers for Disease Control recognized the frivolity of mould sampling as performed during mould assessments when it stated: (2)

> *Other than in a controlled, limited, research setting, sampling for biological agents in the environment cannot be meaningfully interpreted and would not significantly affect relevant decisions regarding remediation, reoccupancy, handling or disposal of waste and debris, worker protection or safety, or public health.*

And:

> *Building consultants often recommend and perform "clearance" air sampling after remediation work has been completed in an attempt to demonstrate that the building is safe for occupants. However, NIOSH does **not** recommend this practice, **as there is no scientific basis for the use of air sampling for this purpose**.(3)*

In the next installment on DQOs dealing with "Accuracy" we are going to see that the errors associated with spore traps is actually much larger than even presented here!

CONCLUSION

When reviewing laboratory reports it is important to remember that one has collected a sample with inherent limitations and the results must be interpreted within the context of those limitations.

Before even collecting the sample, the investigator must know the precision of the method and analysis, and be able to state with confidence that the decision criteria are larger than the errors of the sampling method (a concept I will cover in an upcoming discussion on "Comparability.")

Remember, when reporting data, if an investigator presents their data as the gospel "truth" then they probably think they are this person: (3)

TV's Favorite Scientist, Abby Sciuto – NCIS (4)

If so… one should be very, very afraid if that work goes to court, because they may have to face a real scientist who may show that work for what it is -- a scam.

References:

1) Air-O-Cell data - In this case, as in virtually all cases of spores counts, the variations are HUGE, and typically exhibit a lognormal distribution. For the data set presented here, the MVUE is 549. The Shapiro-Wilks one-tail percentage point is 0.7880; Gaussian distribution is rejected (0.7434 <0.7880) and lognormal is not rejected (0.8904>0.7880). The LCL and UCL are therefore Land's 95% LCL and Land's 95% UCL

2) The CDC Mold Work Group, National Center for Environmental Health, National Center for Infectious Diseases, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, October 2005

3) US Centers for Disease Control *Preventing Occupational Respiratory Disease from Exposures caused by Dampness in Office Buildings, Schools, and Other Nonindustrial Buildings*, March 30, 2011

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