CE3502. Environmental Measurements, Monitoring & Data Analysis

Precision and Accuracy (Bias)

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Spring

Lab Reports

• 1rst lab – use MEMO format (short)
• 1rst report will not be graded but will be critiqued;
• First report due on day of lab, 1/21 or 1/22, by the start of your lab period;
• Report must be sent to me (nurban@mtu.edu) electronically.
Presentations

- Groups 1, 2, 5 and 9 will present next Friday (1/22) on Lab 1;
- Presentations should be ~10 minutes;
- Use PowerPoint; send the file to me electronically (nurban@mtu.edu) before 10:30 a.m. on day of presentation;
- First presentations are graded but lowest mark of 3 is not counted;

Accuracy (bias)

**DEFINITION:**
"Correctness" of measured value or nearness to "true" value.

**MOTIVATION:**
It is important to know if instruments or techniques make "systematic" errors that influence all measurements that are made.
**Theory**

Bias = \( \bar{x} - A \)

where A = “true value”
or A = \( \eta \), population mean

\[ \bar{x} = \frac{1}{n} \sum x_i \quad n = \text{number of observations (measurements) } x_i \]

\[ \eta = \frac{1}{N} \sum x_i \quad N = \text{total number of observations possible or population size} \]

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**Snowball Throw 2010**

![Graph of Snowball Throw 2010]
Example: Accuracy

The results of 2008 snowball throw are summarized in the figure below.

The average and standard deviation are indicated by the square with error bars.

How accurate was the throwing? Was there a systematic bias?
Example 2: Accuracy (Bias)

A balance is used to weigh a 10.0 g standard; the following results are obtained.

<table>
<thead>
<tr>
<th>Observation</th>
<th>Measured weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.05</td>
</tr>
<tr>
<td>2</td>
<td>9.98</td>
</tr>
<tr>
<td>3</td>
<td>10.12</td>
</tr>
<tr>
<td>4</td>
<td>10.02</td>
</tr>
<tr>
<td>5</td>
<td>10.08</td>
</tr>
</tbody>
</table>

What is the bias of this balance?

Mean = 10.05

Bias = Mean – “true”
Bias = 10.05 – 10.0
Bias = 0.05 g
Analysis: Accuracy

How do we know if our measurements are biased?

- We need to be able to compare a "true" value with our measurements

How can we minimize bias in measurements?

- Identify presence of bias;
- Calibrate the instrument after measurement of a standard

PRECISION

DEFINITION:
A measure of scatter in data caused by random errors

MOTIVATION:
The reliability of a method or the confidence we place in a result depends on whether repeated measurements of the same sample yield the same result.
Theory: Precision

Measures of precision include:
Variance ($s^2$), standard deviation ($s$), confidence intervals (CI), coefficient of variation, (COV)

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

In Excel: Stdev(range)

What is the difference between $s$ and $\sigma$? In Excel: stdevp(range)

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{N}}$$

Example: Precision

What is the precision of the following measurements?

<table>
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</table>

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

$S = 0.054$

Units?
Example 2: Precision

Are men or women better shots?

Which group was more accurate?

Which group had better precision?
Analysis: Precision

How can we maximize the precision of measurements?

• Careful technique;
• Make multiple measurements;

Which group would you rather have on your team in a snowball fight?
Which lab group would you choose for a softball team?

Quality Assurance/Quality Control

Data quality implies our confidence or certainty in the data. The error in data may involve both accuracy and precision (i.e., systematic and random errors). Both are equally important. It is easier to make corrections for systematic errors. For quality assurance, both systematic and random errors must be measured.

\[(\text{Total Error})^2 = (\text{Systematic error})^2 + (\text{Random error})^2\]
Application: Significant digits

Compare:  

\[
10.2541 \pm 0.15 \quad 10.2 \pm 0.15 \\
1 \pm 100 \quad 1,800 \pm 100 \\
90 \pm 100 
\]

Which numbers make sense?

The precision of a result determines how many digits are significant. Only significant digits should be reported.
Significant Digits: the Rule

The precision of a result determines how many digits are significant. Only significant digits should be reported.

The smallest digit that is significant is the largest digit of the “uncertainty”, or error.

10.2541 ± 0.15 → 10.2 ± 0.15

Summary: Items to know

- Accuracy
- Precision
- Random error
- Systematic error
- Total error
- Significant number
Wastewater treatment

Employment prospects
Infrastructure upgrades needed
New paradigms needed
Biological Treatment Modules

- Activated Sludge
- Trickling filters
- Rotating Biological Contactors
- Lagoons
- Packed bed reactors
- Wetlands (artificial or natural)

Activated Sludge Unit