Interpretation of Radiation Measurements – Defensibility and Pitfalls

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Two Aspects for Interpreting Radiation Measurements

- Understanding radiation instruments
  - How they work?
  - What they measure?
  - What are the pitfalls?

- Psychology of interpretation
  - What do the measurements mean?
  - How will the measurements be used for safety decisions?

Good Decisions for Radiation Safety

- We rely upon good measurements to tell us the type and amount of radiation

- Big questions?
  - Is your instrument telling you what you think it is?
  - What can go wrong?
  - What do the numbers mean?

Steps for Defensible Measurements

1. Deciding what to measure?
   - Exposure (mR/hr) or activity (cpm)?
2. Choosing the proper instrument
3. Verifying instrument performance
4. Using the instrument properly
   - According to calibration?
   - If you have been careful with above steps,
     - There are still countless pitfalls
     - You now have measurements to interpret

Goals for Measurements

- Improvements in quality
- May not consider how good the data need to be
  - What will data be used for?
- Measurements take on a life of their own
- Samples may be collected haphazardly
- Quality of measurement may exceed quality of sample
  - Example - swipes, wipes, or smears

Two Axioms on Measurements

1) “Measurement results have no meaning until interpreted for a particular purpose”
   They are just numbers

2) “Measurements only have a meaning in terms of how they are interpreted”
   The meaning is whatever people believe
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Psychology of Radiation Measurements
- Interpretation may have as much
to do with attitudes and perceptions
as it does with technology
- Same measurements may have
different meanings for others
- Examples:
  - Technician at nuclear plant,
    “We got a hot one here!”
  - Industrial worker saw
    GM meter go off scale
  - Granite counter tops
  - Firemen observing twice background
  - Screaming GM meter

Questions for Interpretation?
- What decision do you want to make?
- How good do the measurements need to be?
- What do the numbers mean?
- Are the measurements defensible?
- How much resources are you
  willing to commit on the
  basis of these measurements?
- What is the risk of making a mistake?
  - What if you act or do not act?
  - How will you be held accountable?
  - Upset workers? Union? Management?

Making Good Decisions
- How to avoid decisions that may not be
  warranted by the data, false positives
  - Be skeptical,
  - Ask lots of questions before decisions
- Repeat measurements for
  confirmation, with other people
  and other instruments ideally
- Typical when finding
  actionable levels
  - Most want to take immediate action
- No one wants to be criticized
  - For not taking action

Dealing with Uncertainty
- Most people do not want to deal with
  uncertainty, they want absolute values
- They typically do not ask questions
to evaluate the data or
to determine if the data
are defensible
- Tendency is to assume all data
  are of high quality and
  suitable for making decisions
  - When the number is
    written down, it becomes reliable

Radiation is a random event
- Random in time and direction
- What does this mean for measurements?
- How do we determine the quality or
  uncertainty of a measurement?
- How good does the measurement
  have to be for a defensible decision?
- How much money are we willing to spend?

Common Aspect of Scenarios
- If its measureable, it must be bad!
- Interpretation of measurements is often
  a matter of responding to fears
- One person’s answer for defending
  conservative decisions,
  “Why take chances?”
- Common mindset
  Measurement = “Deadly Radiation”
- Risks of NOT taking action
  - Fears, criticism, responsibilities
  - Making a mistake

Uncertainty of Radiation Measurements
- Radiation is a random event
  - Random in time and direction
- What does this mean for measurements?
- How do we determine the quality or
  uncertainty of a measurement?
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  have to be for a defensible decision?
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Uncertainty in Measurements

- Radiation is statistically random
- Decay constant – \( \lambda = \frac{0.693}{T_{1/2}} \)
  - probability per unit of time that a decay will occur
- There are no absolute measurements of radiation
- No measurement is a single value
- All are “best estimates”
- What is the best quality standard available from NIST?
  - Since all measurements are made by comparison, we can never be better than the standard

Portable Instruments

- NIST standard may be within +/ - 5 %
- Calibrations may be within +/ - 10 %
- Rule-of-thumb, +/ - 20 %
- Allowance for uncertainty affected by:
  - Choosing right instrument
  - Is it working properly
  - Is it used properly
  - How does instrument respond

How Do We Quantify Uncertainty

Estimates based on variations of sample count rates and background

Standard Deviation = \[ \sigma = \sqrt{\frac{N_{s+b}}{T_s} + \frac{N_b}{T_b}} \]

- \( N_{s+b} \) = cpm of sample + background
- \( N_b \) = cpm of background
- \( T_s \) = sample counting time
- \( T_b \) = background counting time

Reporting Conventions

- \( 4.0 \text{ pCi/l} \) (no indicator of uncertainty)
- \( 4.0 \pm 0.5 \text{ pCi/l} \) (uncertainty as std. dev.)
- \( 4.0 \text{ pCi/l} \pm 12\% \) (uncertainty as CV)

Choosing Right Instrument

- What is your need for data?
- Exposure or activity measurements?
- What decisions do you want to make?
- May have to rely on available meter
- Could be marginal or totally inadequate

Significant Figures?

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<th>CV - %</th>
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<tr>
<td>135</td>
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Verifying Instrument Operation
- How do you know if your instrument is working properly?
- Battery check
- Check source response
  - Appropriate source?
- Possible probe or cable failure?

Proper Instrument Usage
- Calibration conditions
  - Reproduce calibration conditions
- Geometry conditions
  - How was meter calibrated?

9 Factors Affecting Quality
1. Wrong detector or wrong probe
2. Calibration conditions
3. Energy dependence
4. Reading the wrong scale
5. Reading mR/hr for a beta signal
6. Background interference
7. Backscatter and self absorption
8. Minimum detectable activity
9. Operator factors: fatigue, speed of probe, thoroughness of scan

Nal and Plastic Scintillator Response

Pan GM with Filter

Pressurized Ion Chamber Response
More Factors Affecting Uncertainty in Radiation Measurements
- Radiation is random
- Variation in standards
- Sensitivity of instruments
- Counting time
- Amount of radiation
- Background and variations

Quality of Radiation Measurements
- No measurement is a single value
  - If repeated, result will be different
- No absolute measurements
- Radiation quantities are determined by comparisons
- Quality control
  - Spikes, blanks, duplicates
  - Single / double blinds
  - Control charts

Defending Results
- Ask lots of questions
- How do you know if the data are any good?
- Right instrument, working properly, used properly, calibration, energy dependence, geometry?
- Report results with estimates of all sources of uncertainty,
  - Be careful of significant figures
- Always repeat for confirmation,
  - Before reporting
    - or making expensive decisions

Summary
- What do the numbers mean?
- Measurements only have meaning in terms of interpretation
- Data interpretation may be driven by fears
  - Of radiation
  - Of consequences, health risks, liabilities
  - Making a mistake
- Is your interpretation defensible?
- What are you willing to commit?

Questions?
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