## Interpretation of Radiation Measurements – Defensibility and Pitfalls

Health Physics Society
Professional Development School
Radiation Instruments –
New Technology and Developments
Baltimore, MD
July 11, 2014

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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**

## 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

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## 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

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## 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 ?
  - Possible litigation ?
  - Upset workers ? Union ? Management ?

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## 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

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## 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 ?
- How good does the measurement have to be for a defensible decision ?
- How much money are we willing to spend ?

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## 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

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## Uncertainty in Measurements

- Radiation is statistically random
- Decay constant – λ = 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 pCi / l (no indicator of uncertainty)

4.0 ± 0.5 pCi / l (uncertainty as std. dev.)

4.0 pCi / l ± 12% (uncertainty as CV)



## Significant Figures ?

| pCi / l | CV - % |
|---|---|
| 4 | 25% |
| 4.0 | 2.5% |
| 4.4 | 2.3 % |
| 11 | 10 % |
| 11.1 | 1% |
| 100 | $1 \times 10^2$ |
| 111 | $1 \times 10^2$ |
| 135 | $1 \times 10^2$ |



## 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

## 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 ?

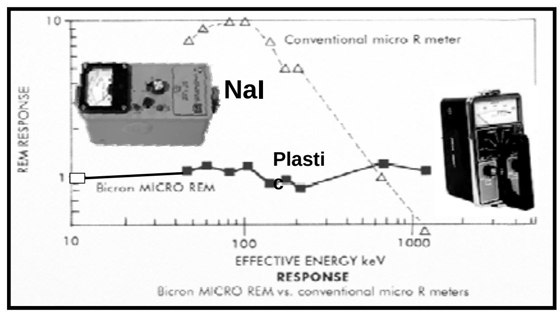


## 9 Factors Affecting Quality

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

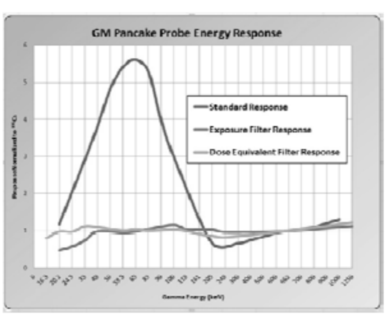


## NaI and Plastic Scintillator Response



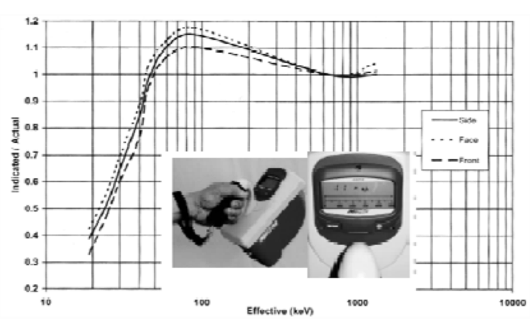



## Pan GM with Filter






## 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
- Geometry
- Uniformity of samples
- Sample location
- Sample selection bias
- Sample preparation
- Volume and weight errors

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## 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

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## 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

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## Summary

- Common assumptions
  - If its measurable - it must be bad
  - Written data are always good
  - Must take immediate action
- Common to make decisions (cry wolf)
  - Without verifying the measurement
- Stay calm
- As minimum – repeat at least once
  - For confirmation, with other instruments and people, if possible

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## 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 ?

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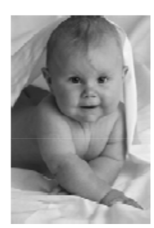
## Questions ?



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