Is Your RadiationInstrument Telling You What You Think it Is ?

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Good Decisions for Radiation Safety

Since our body gives no signal for radiation, we have to rely upon good measurements to tell us the type and amount of radiation

Big question ?

Is your instrument telling you

– what you think it is ?

What can go wrong ?

– How good do the data need to be ?

My Dismay about Measurements

– My work involves providing counseling and training on radiation safety at facilities where they have not had such training before

Workers are concerned for exposures to radiation, and have had no training

They buy a radiation detector and

1) Proceed to take measurements with the wrong instrument, 2) in the wrong places, and then 3) misinterpret the data

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

Common Aspect of Scenarios

"If its measurable, it must be bad !"

Interpretation of measurements is often a matter of responding to fears

One person's answer for defending conservative decision, Precautionary Principle, "Why take chances ?"

"Better to be safe than sorry"

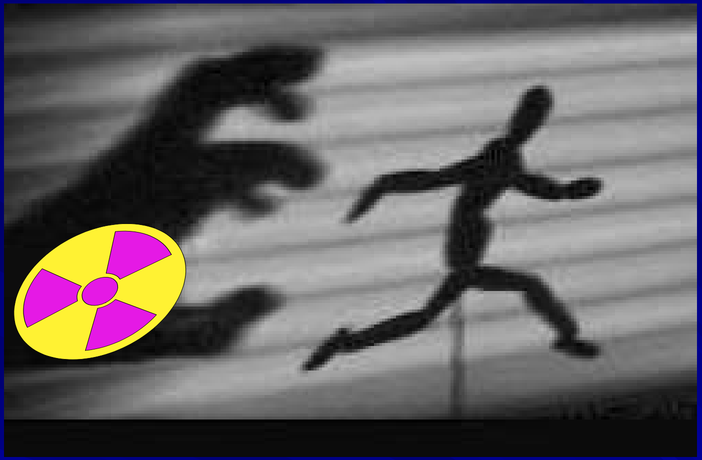
Common mindset
Measurement = "Deadly Radiation"

Risks of NOT taking action

Fears, criticism, responsibilities
– Making a mistake

Measurements are Just Numbers

Measurements have no meaning until they are interpreted



Measurements only have a meaning in terms of how they are interpreted

The meaning is whatever people believe

Often related to fears of radiation

– All measurements have uncertainty

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 quality of 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**

Once Numbers are Written Down by Someone Else

- Written numbers are considered reliable
- We are asked to interpret the data without any idea if the numbers are valid
- Measurements may have great uncertainties,
  - – either unknown or neglected
- How do we know if the data justify an expensive decision ?

Written Measurements

Take on a life of their own

They are treated as gospel

Interpreted as absolute values, as if the numbers are real

All uncertainties are lost

May not ask questions about uncertainties

Especially, if the numbers are above an action level

Steps for Defensible Measurements

1. Deciding what to measure ?

   Exposure or contamination ?

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

Choosing Right Instrument ?

What is your need for data?

Exposure or activity measurements?

What decisions do you want to make?

You 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

– All measurements are made by comparison, i.e. calibration

– Reproduce calibration conditions for best quality measurements

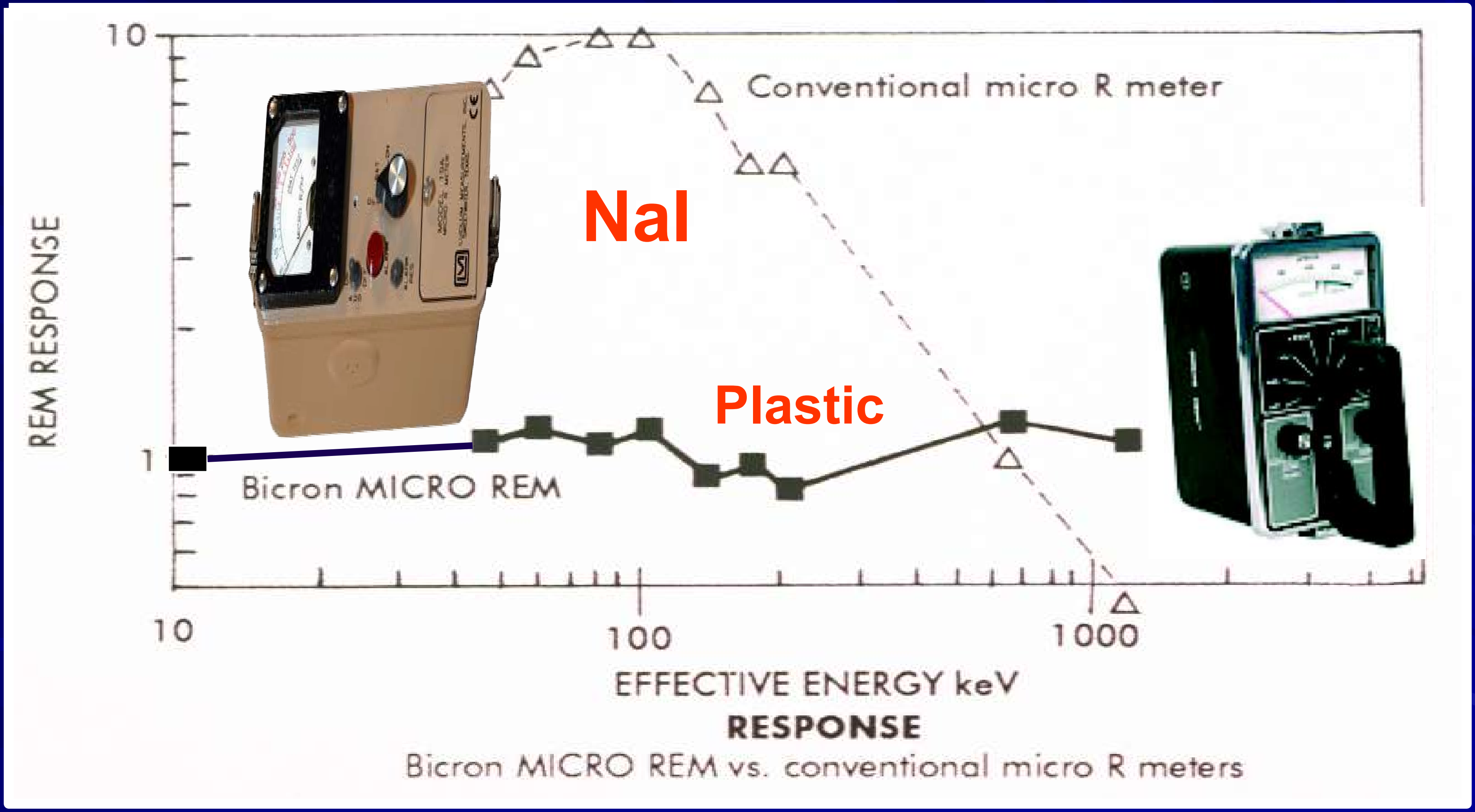
– Geometry conditions, relation of source to detector

How was meter calibrated ?

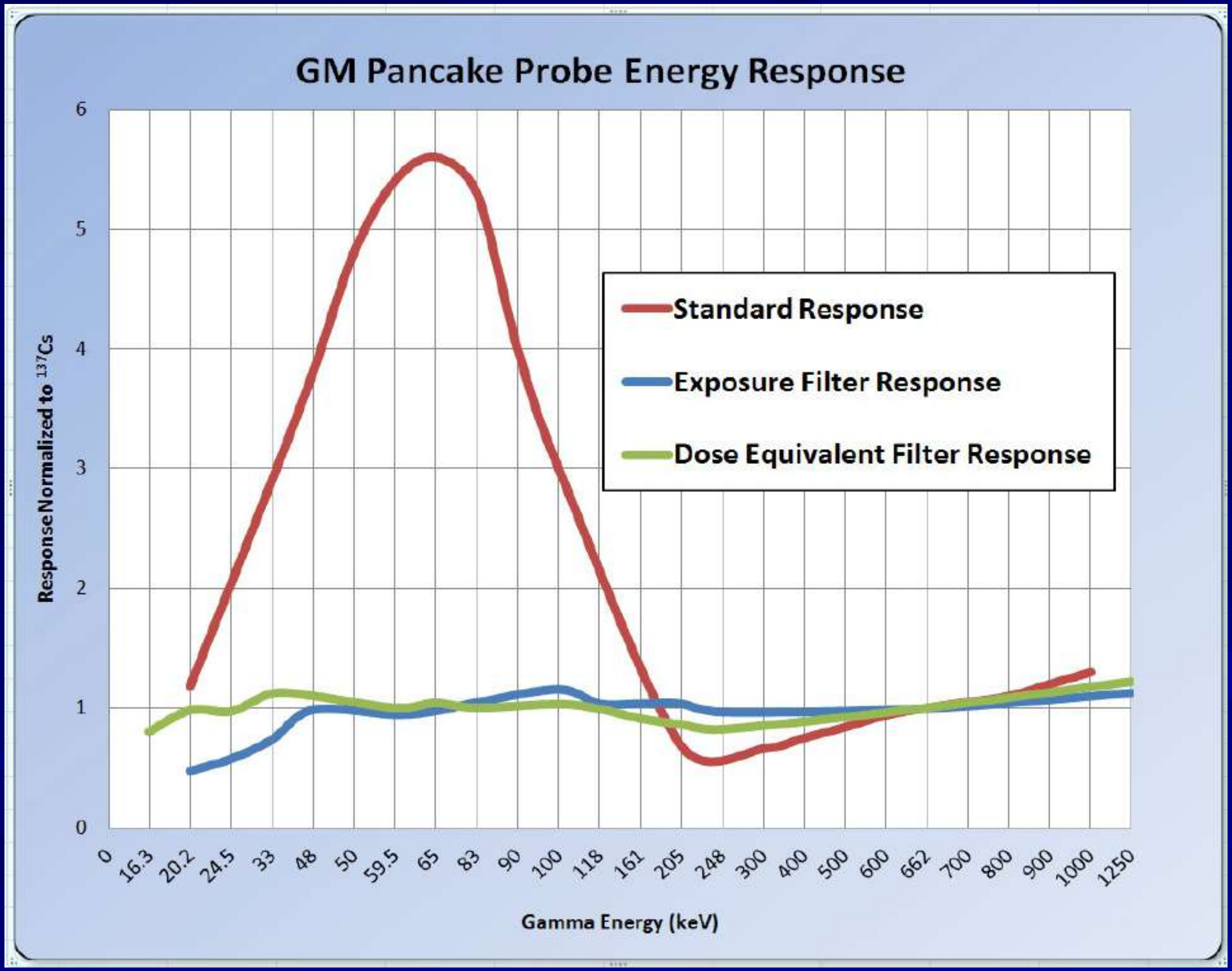
More than 20 Sources of Errors

1. Ion chambers, slow and erratic
2. GM detectors, window and thickness
3. NaI detectors, very energy dependent
4. Calibration conditions, Cesium - 137
5. Energy dependence, reference to Cs-137
6. Signal absorption, scattering
7. Wrong detector or probe, mR/Hr vs cpm
8. Geometry, relationship to the source
9. Speed of probe movement
10. Operator fatigue and judgment

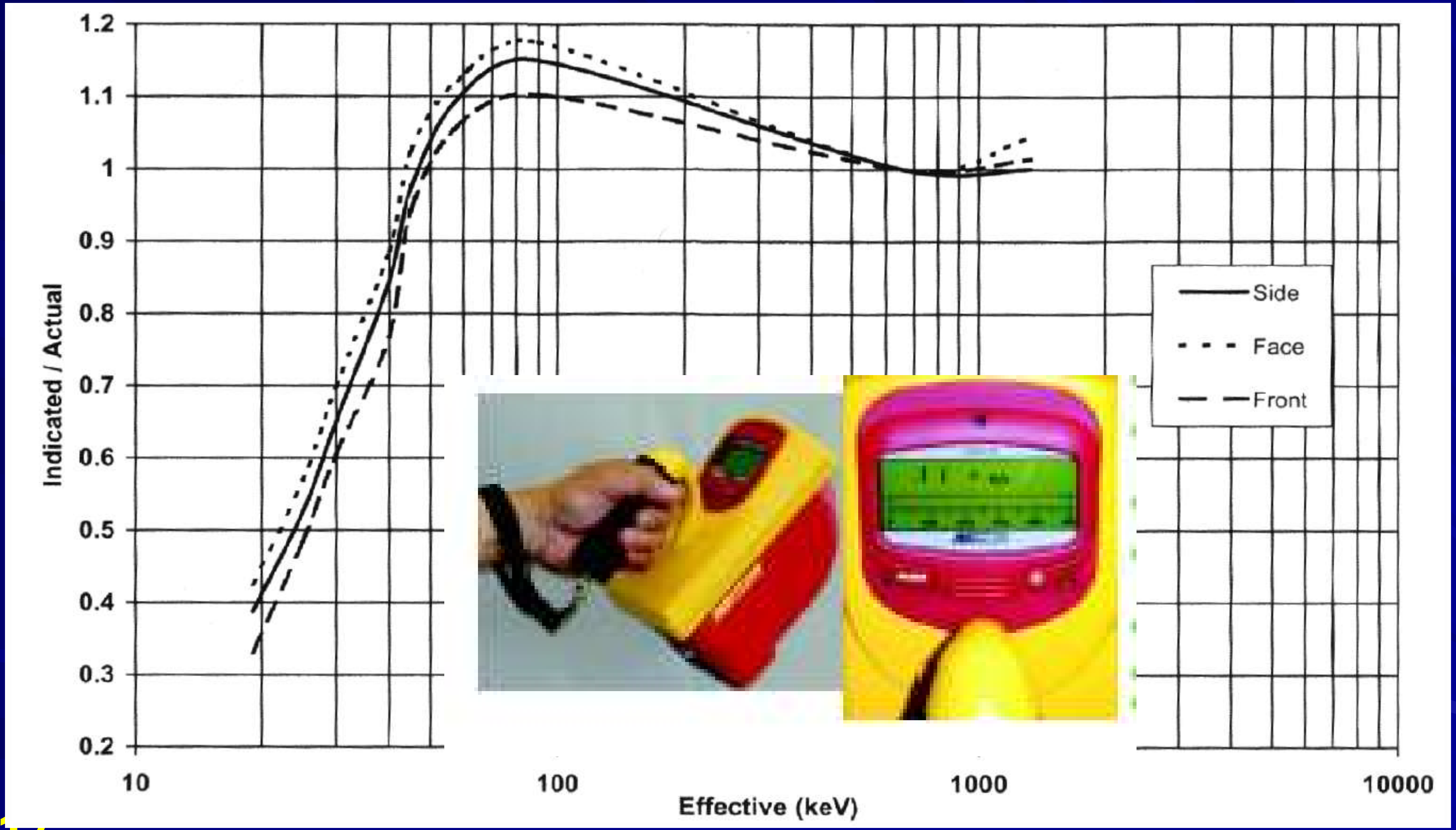
Energy Dependence
NaI vs Plastic Scintillator Response



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
- Reading wrong scale
- Wrong multiplier
- Uniformity of samples
- Sample location
- Sample selection bias
- Sample preparation
- Volume and weight errors

Uncertainties not Included

Calibration error, typically +/- 10%

Energy dependence, factors of 2 - 100

Operator judgements

- Right instrument or probe
- Use according to calibration
- Geometry
- Speed of probe
- Thoroughness of coverage
- Location of measurement

Other Errors

- Measuring in contact with the source
  - Without considering location of people and occupancy time
- Measurements for gamma without considering the accompanying beta
  - Exposure in mR / hr not defined for beta
- Switch setting may be a multiplier or full scale
- Digital confusion of μR / hr vs mR / hr

Questions for Interpretation ?

What do the numbers mean ?
Are the measurements defensible ?
What decision do you want to make ?
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 ?

Because of Radiation Fears

When a number is above an action level

- Many will want to quickly implement safety decisions
- Without confirming the measurements

"Golden Rule"

- Repeat measurements to confirm
- Ideally, with different instruments and people
- Ask lots of questions

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

Quality for Portable Instruments

Rule-of-thumb, + / - 20 %

Calibrations may be within + / - 10 %

NIST standard may be within + / - 5 %

Allowance for uncertainty affected by:

- **Choosing right instrument ?**
- **Is it working properly ?**
- **Is it used properly ?**
- **How does instrument respond ?**

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	1×10^2
111	1×10^2
125	1×10^2

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

- Measurements when written down are interpreted as absolute values
- Interpretation is whatever people believe
- Over 20 sources of uncertainty
  - Usually unknown or neglected
- Randomness means all measurements are only “best estimates”
- Measurements may lead to fears, which then drive the interpretation

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, ideally with other instruments and people, if possible

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
- Of making a mistake
- Is your interpretation defensible ?

What are you willing to commit ?

Is your meter telling you what you think it is ?

Questions ?

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