# Common Errors in Radiation Measurements and Safety Decisions

**A Presentation for the**

## Health Physics Society
## Annual Meeting

## Indianapolis, IN

**THAM-B.3**

**Thursday, 9 AM,**
**July 16, 2015**

**by**


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# Abstract

Defensible decisions for radiation safety should begin with good radiation measurements. Unfortunately, many safety decisions are based on measurements with great uncertainties which are either unknown or neglected. Once a measurement is recorded it seems to take on a life of its own and all uncertainties are lost. People commonly take the written measurements as gospel and proceed to interpret the numbers as absolute values. However, before measurements are interpreted, they are just numbers. Once interpreted the numbers mean whatever people believe, often related to their fears of radiation. There are over 20 errors which can result in measurements that do not represent the real world. Since radiation is a random phenomenon, even with great care, radiation measurements are only "best estimates" from a random distribution. When uncertainties are reported for measurements, in most cases they only account for the randomness of radiation. They do not include uncertainties due to calibration, energy response, and numerous operator judgment factors (geometry, location of measurement, speed of probe movement, etc.). Measurements are often made in contact with a source without taking into account the location of potentially exposed people and occupancy time. Measurements are made for gamma ray exposure without knowing that most gamma ray sources will also have a beta component and exposure in mR/hr is not defined for beta particles. Other common errors include reading the wrong scale multiplier. For some analog instruments the switch setting is a multiplier and for others it is to choose a full scale reading. Errors have been made with digital instruments where people do not understand the symbol for micro. Because of fears of consequences, people may want to quickly implement safety decisions without confirming the initial measurements. We will review several case studies where protective actions were implemented based on erroneous measurements that would not justify the safety decisions.

# Raymond H. Johnson, MS, PSE, PE, FHPS, CHP

Director, Radiation Safety Counseling Institute 301-370-8573

- BS - Civil Engineering, University of Vermont (1961)
- MS - Sanitary Engineering, Massachusetts Institute of Technology (MIT) (1963)
- PSE - Professional Sanitary Engineer Degree, MIT and Harvard University (1963)
- PE – Licensed Professional Engineer, Vermont (1965 – present)
- PhD Studies, Radio and Nuclear Chemistry, Rensselaer Polytechnic Institute (1966–1972)
- Greater Washington Institute for Transactional Analysis – Counseling (1977–1980)
- CHP – Certified Health Physicist, American Board of Health Physics (1983–present)
- Johns Hopkins Fellow, Organizational Systems and Communications (1984–1985)
- FHPS - Fellow of the Health Physics Society and Past President (2000)
- Past President, American Academy of Health Physics (2015)
- Commissioned Stephen Minister – Counselor, United Methodist Church (2003–present)

### *Experience*

| | |
|---|---|
| 2010 – pres. | Director, Radiation Safety Counseling Institute. Workshops, training, and counseling for individuals, companies, universities, or government agencies with concerns or questions about radiation and x-ray safety. Specialist in helping people understand radiation, what is safe, risk communication, worker counseling, psychology of radiation safety, and dealing with fears of radiation and nuclear terrorism for homeland security. |
| 2007 – pres. | VP, Training Programs and consultant to Dade Moeller Radiation Safety Academy, training and consulting in x-ray and radiation safety, safety program audits, radiation instruments, and regulatory requirements. |
| 1984 - 2007 | Director, Radiation Safety Academy. Providing x-ray and radiation safety training, audits, and consulting to industry (nuclear gauges and x-ray), universities, research facilities, and professional organizations. |
| 1988 - 2006 | Manager and Contractor to National Institutes of Health (NIH) for radiation safety audits of 3,500 research laboratories and 2,500 instrument calibrations a year, along with environmental monitoring, hot lab and analytic lab operations, and inspections of three accelerators and over 100 x-ray machines. |
| 1990 - 2005 | President of Key Technology, Inc. a manufacturer and primary laboratory for radon analysis with over 1,500,000 measurements since 1985. Primary instructor at Rutgers University for radon, radon measurements, radiation risks, radiation instruments, and radon risk communication courses (1990-1998). |
| 1986 - 1988 | Laboratory Director, RSO, Inc. Directed analytical programs and Quality Assurance for samples from NIH, Aberdeen Proving Ground, radiopharmaceutical companies, and the nuclear industry. |
| 1970 - 1985 | Chief, Radiation Surveillance Branch, EPA, Office of Radiation Programs. Directed studies of radiation exposures from all sources of radiation in the US, coordinated 7 Federal agencies for nuclear fallout events, QA officer 8 years. Head of US delegations to I.A.E.A and N.E.A. on radioactive waste disposal. ANSI N-13 delegate (1975-1985). Retired as PHS Commissioned Officer (0-6) in 1985 with 29 years of service. |
| 1963 - 1970 | U.S.P.H.S. Directed development of radiation monitoring techniques at DOE National Labs, nuclear plants, and shipyards in the US and Chalk River Nuclear Laboratory in Canada. |

### *Health Physics and Professional Activities*

Health Physics Society (HPS) plenary member 1966; President-elect, President, Past President (1998-2001), Fellow (2000), Treasurer (1995-1998); Secretary (1992-1995); Executive Cmte. (1992-2001), Chair, Finance Cmte. (1996-1998); Head of U.S. delegation to IRPA X (2000). RSO Section Founder and Secretary/Treasurer (1997-2000); Co-founder and President, Radon Section (1995-1996). Co-Chair Local Arrangements Cmte. Annual Meeting in DC (1991); Public Info. Cmte. (1985-1988); Summer School Co-Chair (2004); Chair, President's Emeritus, Cmte (2006); Chair, Awards Cmte. (2002); Chair, History Cmte. (2005-2012); Historian (2012-Pres.) Continuing Education Cmte. (2005-2012). Academic Dean for HPS Professional Development School on Radiation Risk Communication (2010) and Radiation Instruments School (2014). PEP, CEL and Journal Reviewer. AAHP Instructor; Treasurer, AAHP (2008 – 2011). AAHP President-elect, President, Past President (2012-2015). Baltimore-Washington Chapter: President (1990-1991) and Honorary Life Member; Newsletter Editor (1983-2005); Public Info. Chair (1983-1991), Science Teacher Workshop Leader (1995 – Pres.). New England Chapter HPS, Newsletter Editor, Board of Directors, Education Chair (1968-1972). President, American Association of Radon Scientists and Technologists (1995-1998) and Honorary Life Member, Charter Member; Board of Directors; Newsletter Editor (1990-1993). Founder and first President, National Radon Safety Board (NRSB) (1997-1999). Member of American Industrial Hygiene Association (1997-Pres.) (Secretary, Vice Chair, Chair, Ionizing Radiation Committee, 2009-2012), Conference of Radiation Control Program Directors (1997-Pres.), Studied H.P. communication styles and presented Myers-Briggs seminars to over 3500 H.P.s since 1984. Over 35 professional society awards. Licensed Professional Engineer since 1965. Certified Health Physicist since 1983.

### *Publications*

Authored over 500 book chapters, articles, professional papers, training manuals, technical reports, and presentations on radiation safety. Author of monthly column, "Insights in Communication" HPS Newsletter 1984 – 1989, 1994 -2001, and 2012- 2013.

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## A few Decision Scenarios

- West Palm Beach, Florida - GM reading of twice background led to evacuation
- Paper Mill - Worker saw GM meter go off scale
- California Oil Field – Recycler rejected scrap pipe at 25 microR / hr and workers decided this meant pipe was a radiation risk and required special precautions for handling



## Defensible Decisions for Safety

- Should begin with good measurements
- Many decisions are based on poor data with great uncertainties
  - Either unknown or ignored
- Once a measurement is recorded
  - It takes on a life of its own and all uncertainties are lost
- People interpret written numbers as gospel and treat them as absolute values



## 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 - Often related to fears of radiation



## Questions for Interpretation ?

- What decision do you want to make ?
- Are you using the proper instrument ?
- 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 ?



## 10 Factors Affecting Quality

1. Wrong detector or wrong probe
2. Calibration conditions
3. Energy dependence
4. Factors affecting Ion Chambers
5. Factors affecting GM detectors
6. Background interference
7. Backscatter and self absorption
8. Reading the wrong scale and mR / hr for beta
9. Minimum detectable activity (MDA)
10. Operator factors: fatigue, speed of probe, thoroughness of scan

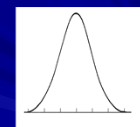
## Other Factors Affecting Uncertainty in Radiation Measurements

- 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



## Uncertainty in Measurements

- Radiation is statistically random
- Decay constant – $\lambda$ = $0.693 / T_{1/2}$
  - 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

- 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



## Measurement Errors

- Usually only account for randomness
- Do not account for uncertainties due to calibration, energy response, etc.
- Measurements are made in the wrong places – contact with source
- Do not account for occupancy location or time
- If its measurable, it must be "BAD"
- Requires immediate 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



## 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

# Common Errors in Radiation Measurements and Safety Decisions

## 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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## 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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## Review

- 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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## 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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## Questions ?

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