Serious Questions about Radiation Measurements

A 20-minute technical presentation

Podium Session 104

at the Annual Meeting of

the American Industrial Hygiene Association

Baltimore, MD

May 23, 2016

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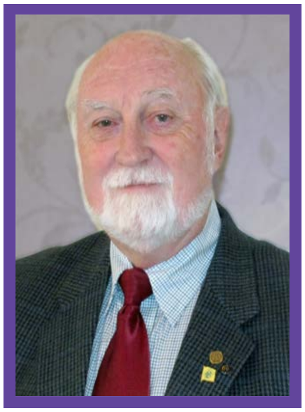
Situation Problem: How often do we find ourselves interpreting data based on someone else's radiation measurements without really knowing if the data are valid? Defensible decisions for radiation safety should begin with good radiation measurements. Unfortunately, many safety decisions are based on measurements with great uncertainties which are either unknown or neglected. Once a measurement is written down it seems to take on a life of its own and all uncertainties are lost. We may not ask questions to verify the data, especially if the number is above an action level. 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.

Resolution: Before making expensive decisions for radiation safety people need to understand that radiation is a random phenomenon, thus 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. Ideally they would include uncertainties due to calibration, energy response, and numerous operator judgment factors (geometry, location of measurement, speed of probe movement, etc.). Measurements should not be made in contact with a source without taking into account the location of potentially exposed people and occupancy time. Measurements made for gamma ray exposure should also consider a possible beta component. Also, care needs to be taken when reading the scale multiplier.

Results: Many expensive decisions for radiation safety may be avoided by careful evaluation of the quality of radiation measurements. However, because of fears of consequences, people may want to quickly implement radiation 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.

Lessons Learned: The golden rule for measurements should be to repeat the sample and measurement for confirmation, ideally with different people and instruments, before making an expensive decision. By asking serious questions about radiation measurements, IHs may avoid making expensive decisions that are not warranted by poor quality radiation measurements.



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- 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, Nuclear and Radiochemistry, 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 Health Physics Society, Past President, Secretary, Treasurer (2000)
- DAAHP – Diplomate and Past President, American Academy of Health Physics (2015)
- HPS Founders Award and Honorary HPS Life Membership (2016)
- 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, NORM, 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 analyses 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	EPA program manager and 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. Conducted doctoral research.

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); 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). Chair, Professional Development School Cmte (2014-Pres.), Academic Dean for HPS Professional Development School on Radiation Risk Communication (2010) and Radiation Instruments School (2014). PEP and CEL Lecturer, and Journal Reviewer. AAHP Instructor; Treasurer, AAHP (2009 – 2012). 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 (1983-1989), 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.), Taught 3,500 RSO students since 1985. Studied H.P. communication styles and presented Myers-Briggs seminars to over 4,000 H.P.s since 1984. Over 35 professional society awards. Licensed Professional Engineer since 1965. Certified Health Physicist since 1983.

Publications

Authored over 600 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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AIHce 2016 Inner Harbor, Baltimore

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Situation - My Dismay about Measurements

- My work involves providing training on radiation safety at facilities where they have not had such training before
- I find workers are concerned for exposures
- They buy a radiation detector and
  1) Proceed to take measurements with the wrong instrument,
  2) Fail to use the instrument properly,
  2) Measure in the wrong places, and then
  3) Misinterpret the data

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How do we Interpret Other's Data ?

- We may be asked to interpret other's data without any idea if the measurements are valid
- How do we know if the data justify expensive decisions for radiation safety ?
- Defensible decisions should begin with good measurements
- However, decisions may be based on measurements with great uncertainties, either unknown or neglected

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Good Decisions for Radiation Safety

- We rely upon good measurements for type and amount of radiation.
- Big questions for safety decisions ?
  – Is our instrument telling us what we think it is ?
  – What can go wrong ?
  – How good do the data need to be ?
  – Are the measurements defensible ?

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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
- We may not ask questions about uncertainties
  – Especially, if the numbers are above an action level

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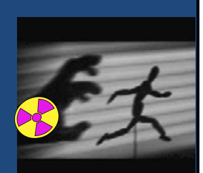
Measurements are Just Numbers



- Numbers have no meaning until they are interpreted
- Once interpreted, the numbers mean whatever people believe
- Interpretation is often related to fears of radiation
  – Interpretation may have as much to do with attitudes and perceptions as it does with technology

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More than 20 Sources of Errors

1. Ion chambers, slow, erratic, not very sensitive
2. GM detectors, window and thickness, beta counter
3. NaI Detectors, very energy dependent
4. Calibration conditions, comparison with Cesium - 137
5. Energy dependence, reference to Cesium - 137
6. Background interference, absorption, scattering
7. Wrong detector or probe, mR / hr vs cpm
8. Geometry, relationship of detector to the source
9. Speed of probe movement,
10. Operator fatigue and judgment

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Other Factors Affecting Uncertainty in Radiation Measurements

1. Radiation is random
2. Variation in standards
3. Sensitivity of instruments
4. Counting time
5. Amount of radiation
6. Background and variations

1. Reading wrong scale
2. Wrong multiplier
3. Uniformity of samples
4. Sample location
5. Sample selection bias
6. Sample preparation
7. Volume and weight errors

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Other Common 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

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Wrong Probe or Detector

- What do you want to measure?
- Use Ion Chamber when you know the source of radiation and want to measure exposure in mR / hr
- Use GM, NaI, Plastic, ZnS for measuring activity, cpm
  - Use to find source

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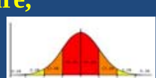
Resolution – Need to Understand Randomness of Radiation

- Since radiation is random – all measurements, even when taken with great care,
  - Are only "Best Estimates" from a random distribution



- Reported uncertainties usually only account for randomness of radiation

$$\sigma = \sqrt{n / t}$$

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Ideally, Interpretation Should Include,

- Calibration error, typically +/- 10%
- Energy dependence, factors of 2 - 100
- Operator judgements
  - Right instrument or probe
  - Use according to calibration
  - Geometry, relation of detector to source
  - Speed of probe movement
  - Thoroughness of coverage
  - Location of measurement

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Results – Case Studies

– NORM – oil field measurements

– Worker saw GM meter go off scale

– Granite counter tops

– Firemen observing twice background

– Screaming GM meter

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Common Aspects of Case Studies

- 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?" Precautionary Principle
- Common mindset
  Measurement = "Deadly Radiation"
- Risks of NOT taking action
  - Fears of consequences, 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 making 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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Other Factors for Safety Decisions

- Radiation safety decisions depend on many other factors, such as:
  - The type of radiation,
  - The proximity to people,
  - The duration of exposure,
  - The actual dose received.
- Radiation instrument readings are only one piece of information which specialists would use for making radiation safety decisions.

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Defending Results - Review

- 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 (more than 1 - not defensible)
- Always repeat for confirmation,
  - Before reporting or making expensive decisions

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Lessons Learned

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

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Summary

- Radiation safety decisions should be based on a good understanding of radiation measurements taken with a quality appropriate for defensible decisions.
- When measurements are written down, people interpret the data as reality
- Many do not know there are over 20 sources of errors which can affect quality of radiation measurements
- Radiation is random, thus all measurements are best estimates

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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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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

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Questions ?

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