Serious Questions about Radiation Measurements

A Technical Presentation

Health Physics Society Midyear Meeting
Austin, Texas

Presented

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by

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Serious Questions about Radiation Measurements

A 15 Minute Technical Paper Presentation for
HPS Midyear Meeting, Austin, TX February 3, 2016

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How often do we find ourselves interpreting data based on someone else's radiation measurements without really knowing if the data are valid? Do we know for sure that the data justify our decisions for radiation safety or possibly expensive actions? 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. People commonly take the written measurements as gospel and proceed to interpret the numbers as absolute values, as if they were real. 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. 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. 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. 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, DAAHP, CHP

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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, 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)
- DAAHP – Diplomate and 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, 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, CEL 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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My Dismay about Measurements

- My work involves providing training on radiation safety at facilities where they have not had such training before
- Workers are concerned for exposures to NORM, and have had no radiation 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

Once Numbers are Written Down by Someone Else

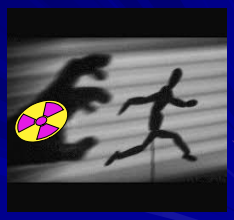
- We are asked to interpret the data without any idea if the numbers are valid
- How do we know if the data justify an expensive decision ?
- Defensible decisions should begin with good measurements
- Decisions may be based on measurements with great uncertainties,
  - either unknown or neglected

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

Measurements are Just Numbers

- Numbers have no meaning until they are interpreted
- Once interpreted, the numbers mean whatever people believe



–Often related to fears of radiation

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. Background, absorption, scattering
7. Wrong detector or probe, mR/Hr vs cpm
8. Geometry, relationship to the sources
9. Speed of probe movement
10. Operator fatigue and judgment

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

7

Randomness of Radiation

- Since radiation is random, all measurements, even with great care
  - Are only "best estimates" from a random distribution
- Reported uncertainties, usually, only account for randomness, $\sqrt{\frac{N}{T}}$

Radiation Safety Counseling Institute 8

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

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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

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Because of Radiation Fears

- Many will want to quickly implement safety decisions
  - Without confirming the measurements
- "Golden Rule"
  - Repeat measurements to confirm
  - Ideally, different instruments and people
  - Ask lots of questions

Radiation Safety Counseling Institute 11

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

Radiation Safety Counseling Institute 12

Questions ?

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13