Common Errors in NORM Measurements

Health Physics Society
Annual Meeting

Indianapolis, IN

An Invited Presentation for the
Special Session
on NORM

TPM-B.4 Tuesday, July 14, 2015

by

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Measurements for Naturally Occurring Radioactive Materials can be difficult for many reasons, including: 1) most radiation instruments in common use are calibrated in response to cesium-137 at 662 keV. The primary radioactive materials in NORM are part of the uranium-238 decay chain and potassium-40. These materials emit gamma energies from about 100 keV to about 1,500 keV. Instruments such as Geiger Counters (GM) and Sodium Iodide (NaI) scintillators do not respond well for this range of energies because of energy dependence. 2) Many of the radioactive isotopes in NORM also emit beta particles. Thus open window GM and ion chambers, as well as thin-window plastic or NaI scintillators, will over respond by as much as factor of 20 when taking readings of exposure in milliroentgen per hour (mR/hr) due to beta interference. This paper will show how a variety of common radiation instruments respond to several sources of NORM with and without a beta shield. The best measurements of NORM will use an instrument calibrated for radium-226 and all measurements for mR/hr should be sure to shield out beta particles. 3) Measurements for exposure are often made in contact with the source, such as a metal pipe, without consideration of the location of potentially exposed persons or occupancy time. Many people do not understand that readings in mR/hr have no meaning for assessing risks without knowing the hours of exposure. 4) Risk decisions are also made on the basis of count rate data without consideration of exposure pathways or radiation dose to people. There are over 20 sources of measurement errors which could result in radiation instruments not telling you what you think they are. Many people believe any reading on a GM counter automatically equates to radiation risks. We will review several case studies, where lack of understanding of measurement errors has led to excessive fears and expensive safety precautions for NORM

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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)
- 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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NORM Worker Concerns

- Workers handling materials from the ground may not know that everything coming from the ground contains NORM
- Workers may become alarmed when learning they have NORM in their workplace
- They are Not hired or trained to deal with radiation
- Easy to obtain a GM or NaI radiation meter and begin measurements without understanding the limitations of such meters

NORM Fears - Examples

- Paper Mill
  - Industrial worker saw GM meter go off scale
- Oil Field Workers
  - Classifying pipe as "radioactive"
- Granite counter tops
  - Misunderstanding measurements
- Screaming GM meter
  - Hard to ignore

Do You Really have a NORM Hazard ?

- Do you work with materials coming from the ground ?
  - Everything from the ground has NORM
- How do you measure NORM ?
- Do you have the right instrument ?
- Is it calibrated properly ?
- Are you using it properly ?
- What do the measurements mean ?
- How can your instruments mislead you ?

Reactions to Meausrements

- Our five senses do not tell us of radiation
- From lack of understanding, workers may react with alarm and make poor decisions for safety
- Interpretation of measurements is often a matter of responding to FEARS
- Hearing a Geiger counter may lead to the conclusion,

"If its measurable, it must be bad"

Is It Safe?

- To answer this question workers may obtain a GM meter and make measurements without knowing how the meter responds to NORM
- Radiation Instruments are often misused
- Measurements are often misunderstood
- Decisions are made on count rates or exposures measured in the wrong places

How to Answer "Is it Safe"

1. What are properties of radiation
   - α, β, γ, x-ray ? - Form and quantity ?
2. Where is it located - Inverse square law ?
3. How is it contained - Shielding ?
4. How will it move in the environment ?
5. What are the exposure conditions – mR / hr ?
6. What is the duration of the exposure – hr ?
7. How much energy is deposited in our body - mrem ?
8. How does this compare with limits or guidelines?

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Good Decisions for Radiation Safety

- We rely upon good measurements to tell us the type and amount of radiation
- Big questions ?
  - Why are you making measurements ?
  - Is your radiation instrument telling you what you think it is ?
  - What can go wrong ?
  - How good do the data need to be ?

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Steps for Defensible Measurements

1. Deciding what to measure ?
   Exposure (mR / hr) or activity (cpm) ?
2. Choosing the proper meter
3. Verifying meter performance
4. Deciding where to take measurements
5. Using the meter properly
   According to calibration ?
6. If you have been careful with the above steps,
   - You now have measurements to interpret
   - There are still countless pitfalls

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Choosing the Right Meter ?

- What is your need for data?
- Exposure or activity measurements?
- What decisions do you want to make?
- May have to rely on an available meter
- Could be marginal or totally inadequate

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Verifying Meter Operation

- How do you know if your meter is working properly ?
- Battery check ?
- Check source response ?
  - Appropriate source ?
- Possible probe or cable failure ?
- Current calibration ?

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Proper Instrument Usage

- Calibration conditions
  - Reproduce calibration conditions for defensible measurements
- Geometry conditions (Positioning)
  - How was meter calibrated ?
- Speed of probe movement

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Where to Take Measurements ?

- Common to take measurements in contact with a pipe surface
- OK for recycling decisions
- Not useful for determining worker exposures – mR / hr
- Better to measure exposure at locations actually occupied by workers
- Take into account occupancy time

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Interpretation of Radiation Measurements

- What do the measurements mean ?
- Interpretation may have as much to do with attitudes and perceptions as it does with technology
- Is interpretation based on fears ?
- Same measurements may have different meanings for others
- What decisions are warranted by the measurements ?

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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"

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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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Questions for Interpreting Radiation Measurements

- Radiation is a random event
  - Random in time and direction
- What does this mean for measurements ?
  - All measurements are "best estimates"
- 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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Quality of 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 calibrated properly ?
  - Is it used properly ?
  - How does instrument respond to different energies ?

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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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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, ideally with other people and other instruments
- 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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9 Factors Affecting Quality

1. Wrong detector or wrong probe
2. Calibration conditions – Cs-137 for mR / hr
3. Energy dependence - most NORM is lower energy
4. Misreading decade multiplier or full scale
5. Misreading mR / hr vs μR / hr
6. Including beta in mR / hr measurements
7. Geometry
8. Operator fatigue and judgments
9. Backscatter and self absorption

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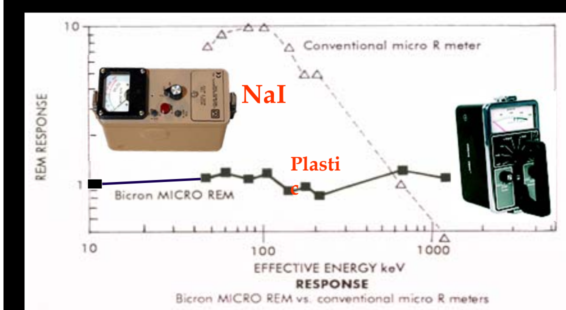
NaI and Plastic Scintillator Energy Response



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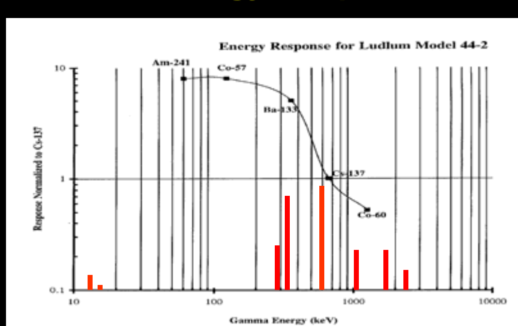
NaI Energy Response



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Effect of Energy Response

- NaI could read too high by factor of 1.5 to 2
- Thus, readings are conservative for safety
  - Would you want a meter that reads too high or too low ?
- The regulatory guideline is 2 mR in an hour
  - If your meter reads 1 mR / hr, then you are definitely below 2 mR / hr

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Operator Factors

- Operator Judgments
  - Choice of detector ?
    (what do you need to measure)?
  - How fast to move the probe?
  - How thorough to scan?
  - How close to the surface (geometry) ?
- Operator fatigue
  - What happens to judgments and quality of readings when operator becomes tired?

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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. Geometry
2. Uniformity of samples
3. Sample location
4. Sample selection bias
5. Sample preparation
6. Volume and weight errors

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Evaluation of Data ?

- Ask lots of questions
- How do you know if the data are any good ?
- Right instrument, working properly,
  used properly, calibration,
  energy dependence, geometry,
  operator factors ?
- Always repeat for confirmation,
  - Before reporting
    or making expensive decisions
- Compare with guidelines
  - 50 microR / hr or less for recycling
  - 2,000 microR / hr for public (or worker) exposures

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Have Workers Do Measurements

- Best answer to, "Is it Safe"
  - Have workers do their own measurements
  - Compare with background – 10 microR / hr
  - Compare with radioactive antiques
  - Compare with regulations
    - 2 mrem in an hour
    - 100 mrem in a year
- Best to enable workers to answer their own questions

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Summary

- Workers may react with alarm when hearing a Geiger counter
- Interpretation of measurements is as much about fears as technology
- Measurement is only one piece of information
  - Eight steps to answer, "Is it safe"
  - Most important –
    "exposure rate & duration"
- Encourage workers to make their own measurements

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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

- We rely on instruments to tell us of radiation
  - Choice of instrument, working properly,
  - Using it properly (according to calibration)
- Is our radiation meter telling us what we think it is ?
  - At least 20 sources of errors in readings
- Measurements are only numbers until interpreted – meaning is whatever is believed

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More Information

- MARSSIM – Multi Agency Radiation Survey and Site Investigation Manual
  http://www.epa.gov/rpdweb00/marssim/obtain.html
- Egidi, Phil. "Characteristics of Routine Radiation Safety Measures of NORM and TENORM Nuclides," (Chapter 5, 43 pages) In: Naturally Occurring Radioactive Materials (NORM) and Technologically Enhanced NORM (TENORM). P. Andrew Karam and Brian J. Vetter, Editors. A Textbook for the Health Physics Society Professional Development School, Minneapolis, MN July, 16-18, 2009. Medical Physics Publishing, Madison, WI (549 pages).

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More Information

- ANSI N323-B (2003)
  - Installed Radiation Protection Instrumentation Test and Calibration - Portable Survey Instruments for Near Background Operation
- Glenn F. Knoll (2010)
  - Radiation Detection and Measurement

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Questions ?

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