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Radiation Dosimetry as Part of an Integrated Radiation Protection Program

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Outline I

Introduction — What is “Likely to Receive”

External and Internal Dose Measurement Requirements

Implementation of Dosimetry Programs in the 21st Century

Integration of Dosimetry Programs with Operations

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The USNRC and the DOE have similar requirements for dose monitoring.

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USNRC

- Adults likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of the limits in §20.1201(a)
- Adults likely to receive, in 1 year, an intake in excess of 10 percent of the applicable ALI(s) in table 1, columns 1 and 2, of appendix B to §§20.1001-20.2402;

DOE

- Radiological workers who, under typical conditions, are likely to receive …An effective dose of 0.1 rem (0.001 Sv) or more in a year;
- Radiological workers who, under typical conditions, are likely to receive a committed effective dose of 0.1 rem (0.001 Sv) or more from all occupational radionuclide intakes in a year;

Is *likelihood* the same as *potential*?

- Few workers in the US nuclear industry are truly “likely” to exceed the monitoring level as a result of routine operations
- However, because of difficulties associated with determining likelihood, we tend to monitor workers who have a reasonable potential to exceed the monitoring level

Likelihood is defined in terms of dependencies.

- The likelihood of exceeding the monitoring level will depend on
  - the amount of radioactive material present and the radionuclides involved
  - the physical and chemical form of the radioactive material
  - the type of containment or shielding used
  - the operations performed
  - the general working conditions
  - past operating history
  - skill and training of workers
- However, little guidance is offered concerning how to actually determine the likelihood of exceeding the monitoring level

There are different approaches to inferring the likelihood.

Can you make an a priori estimate of likelihood?

- Is the radiological environment stable?
  - External dose fields
  - Airborne radioactivity levels
  - Contamination levels
- Is the work stable?
  - Expected duration of internal or external exposure periods
  - Expected exposure periods throughout the year
- Are the personnel stable?
  - What is the typical personnel turnover in the work environment?
  - Is there a reason why that might increase or decrease?

For example, can general air monitoring be used to determine likelihood?

Assumptions when using general (room) air monitoring.

1. Retrospective air monitors are representative.
   - Not 100% of the time, but generally true over a year.
2. Workers entering areas >0.1 DAC (2.4 DAC-hours per 24 hour day) wear respiratory protection.
3. Workers wearing respiratory protection are unlikely to exceed 0.1 rem.
4. Workers entering areas >0.1 DAC who do not wear respiratory protection are placed on a special bioassay program (they are likely to exceed 0.1 rem).

5. Any excursions in air activity that exceed 2.4 DAC-hours in a day and fall under assumptions 3 or 4 are not included in the assessment of likelihood.
6. Occupancy time is 1000 hours per year and the air samplers run around the clock (8760 hours per year).

The last assumption means that the occupancy factor is 8.76, which means that a room must exceed a fairly uniform annual exposure of

$$(8.76)(40 \text{ DAC-hours}) = 350 \text{ DAC-hours}$$

before a worker could be considered likely to exceed 100 mrem.

So when do we know “likely to receive?”

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In situations like…

- Routine production-type environment
- Job or series of jobs planned for the year with with known exposure potential
- Or…little or no exposure at all is expected.

This has led to the demise of *routine* dosimetry programs.

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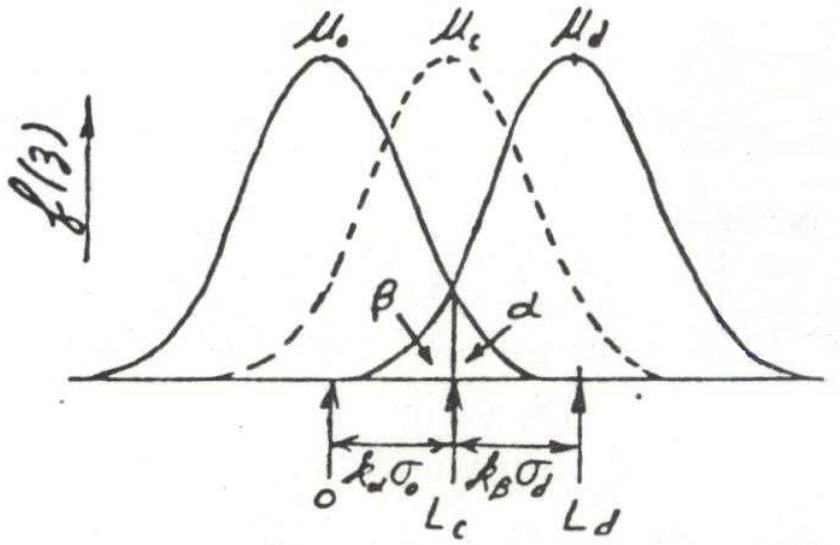
Statistics are used to determine the importance of a positive indication.



Definitions

- L_c: Critical Level
- L_d: Detection Limit
- σ_0: Standard deviation when sample count rate is zero
- σ_0: Standard deviation when sample count rate is L_d
- k_α: Number of standard deviations corresponding to a Type I error probability of α
- k_β: Number of standard deviations corresponding to a Type II error probability of ß

There are different action thresholds depending on whether the measurement is external or internal.

External doses are reported if they exceed the LLD

- LLD (lower limit of detection) is the detection limit signal from a dosimeter adjusted for dose.
- LLD is determined a priori by a type-testing study (see ANSI N13.11).

Internal doses are determined if the measurement exceeds the L_c.

- k_α is typically 1.645 representing $\alpha = 0.05$
- This means for each 100 samples analyzed, five will be a false positive.
- There is no requirement for a particular value of α.

What does it mean to use L_d instead of L_c?

$$L_d = L_c + k_\beta \sigma_d$$

$$L_c = k_\alpha \sigma_0$$

$$\sigma_d = \left[\frac{L_d + R_b}{T_{s+b}} + \frac{R_b}{T_b} \right]^{\frac{1}{2}}$$

$$L_d = \frac{\left(2k_\alpha \sigma_0 + \frac{k_\beta^2}{T_{s+b}} \right) \pm \sqrt{\left(2k_\alpha \sigma_0 + \frac{k_\beta^2}{T_{s+b}} \right)^2 - 4\left(k_\alpha^2 \sigma_b^2 - k_\beta^2 \sigma_0^2 \right)}}{2}$$

Using L_d effectively reduces the value of α.

$$R_b = \frac{30c}{m}$$

$$T_b = T_{s+b} = 30min$$

$$\sigma_b = \sqrt{\frac{30cpm}{30m}} = 1cpm$$

$$L_d = 4.356$$

$$k_\alpha = 3.111$$

$$\alpha = 0.002$$

Ramifications of this are:

- Reduces false positive rate for external dose to 0.2%
- Continues dichotomy between internal and external dose.
  - External is assumed worse.
  - (It's probably the other way around.)

Regulators also require accrediation where available.

10 CFR 20.1501(d)

1. …Holding current personnel dosimetry accreditation from…NVLAP…; and
2. …Approved…for the type of radiation or radiations included in the NVLAP program that most closely approximates the type of radiation or radiations for which the individual wearing the dosimeter is monitored.

10 CFR 835.402

- (b) External dose monitoring programs…shall be…(1) Accredited, or excepted from accreditation, in accordance with the [DOELAP] for Personnel Dosimetry
- (d) Internal dose monitoring programs…shall be…(1) Accredited, or excepted from accreditation, in accordance with the [DOELAP] for Radiobioassay

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This is not your grandparents' dosimetry program

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20th Century Dosimetry

- Internal and external dose had separate limits.
- Exposure limits for dosimetry were allowed (MPC-h).
- Some internal exposures were tracked by body burden.
- Routine programs were common due to chronic exposures.

21st Century Dosimetry

- Use of total effective dose (internal + external) required.
- Air monitoring not allowed in some cases (10CFR835)
- Determination of dose is required.
- ALARA requirements and associated engineering controls make occupational dose and routine programs less common.

Why should I expose myself to routine program requirements when my workers are not “Likely to Receive?”

- You shouldn’t.
- Most workplace environments do not qualify for dosimetry programs under the “likely to receive” requirements.
- This does not mean that you shouldn’t use dosimetry.
  - As a health physicist, you still have responsibility to your company and your workers.
  - It’s the right thing to do.
  - It just requires a different mindse

Confirmatory dosimetry programs are the wave of the future!

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External Dosimetry

- Once a dosimetry service is established, adding dosimeters is not expensive.
- Identify most likely candidates for unexpected exposures and monitor them at some frequency.

Internal Dosimetry

- Bioassay sample analysis can be procured under contract. In vivo measurement, not so much.
- Gamma spectrometry on urine, while not as desirable, can be used in lieu of in vivo monitoring.
- Identify candidates most likely to be contaminated accidentally.

Confirmatory dosimetry is a quality program.

- If your workplace controls are properly designed and implemented, you should have no dose results that are unexpected.
- The internal and external dose results provide the quality control measurements showing that the workplace controls are functioning properly.
- If you have a positive result, this could make life unpleasant.
  - As previously seen, the use of LLD for external dosimetry makes false positive results fairly unlikely.
  - This is not the case for internal dose. You will be tracking down the cause (or lack thereof) of 1 in 20 positive bioassay results.

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The demise of the routine dosimetry program has positive and negative ramifications.

Negative

- There is no safety net for unknown exposures.
- Positive results require follow-up.

Positive

- Right-sizing of dosimetry programs comes with a cost savings.
- Absence of routine monitoring forces early notification of dosimetry for failure of rad controls.
- Early notification means dosimetry organization can better provide proper response.

HP Operations must now work with dosimetry to ensure proper job monitoring occurs.

Operational dosimetry: dosimetry services provided for individuals participating on an operation where dose is expected.

- External dosimetry might include self-reading electronic dosimetry with or without integrating dosimeter (i.e., TLD or AlO)
- Internal dosimetry might include bioassay at the end of the job or periodically throughout depending on the length and dose potential.

HP Operations must now notify dosimetry for suspected exposures, and they work together for appropriate response.

Special dosimetry: retrospective measurement of dose following an unexpected exposure.

- Internal dosimetry is usually in the form of “special bioassay”, high frequency backing off to follow-up measurements.
- External dosimetry might be a re-creation of events to determine exposure including time-motion studies.

HP operations and dosimetry work together in developing the confirmatory monitoring program.

Confirmatory monitoring: quality control of workplace controls.

- Workplaces where unexpected exposure could occur.
- Operations with radiation fields or contamination of relatively higher risk.
- Likely a moving target — program should change with changing conditions.

Remember that the objective is worker protection.

- Feedback is important.
- Dosimetry must be timely.
  - However, missed dose must be considered.
- In some cases, dosimetry capability exceeds workplace monitoring (e.g., ^{3}H, ^{125}I)

Summary

- Operations requiring dosimetry under *Likely to Receive* are becoming uncommon.
- Internal and external dose measurement requirements and usage are different.
- In the absence of a dosimetry requirement, we have to do what is right for the worker and employer.
- Doing it right requires collaboration between HP operations and dosimetry.