Conservatism, Nonconservatism and Uncertainty in Dose Calculations - Risk Informed Dose Calculations

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A note for all

The views I present today
are my own!

Risk-Informed, Performance-Based Regulations

In 1999, the US Nuclear Regulatory Commission issued a policy paper that described how risk-informed and performance-based concepts should apply to NRC's regulatory work. An important benchmark for radiological performance assessment

Risk-Informed, Performance-Based Regulations

(Kaplan and Garrick, 1981) provided the risk triplet.

What can go wrong?

How likely is it?

What are the consequences?

Risk-Informed, Performance-Based Regulations

Risk insights from assessments using these principles will highlight the contributors to risk and their significance.

There are a range of tools that will yield a range of results in understanding risk.

Tools for Risk Assessments Past and Present

- Extreme bounding analysis
- Bounding analysis
- Sensitivity studies
- “One-off” calculations and comparisons
- Probabilistic Risk Analysis

Applications

Risk-informed approaches work for all aspects of performance assessments

- Inventory
- Source term
- Released fractions of radionuclides from engineered systems
- Interactions in the near field
- Interactions in the far field
- Uptake and dosimetry estimates

Risk-Informed Dosimetry

Intake Rates

- Inhalation – Respiratory Tract
- Ingestion - GI Tract
- Inunction – Skin Absorption (mainly ^{3}H and wounds)

Risk-Informed Dosimetry

Inhalation

- - Aerosol science
  - Work place exposures have little substrate for radioactive material
  - Environmental exposures can involve significant amounts of substrates mixing and interacting with radioactive material

Risk-Informed Dosimetry

Inhalation

- - Aerosol & biological sciences

  Solubility, deposition, absorption and clearance kinetics can significantly influence doses

Risk-Informed Dosimetry

Inhalation

- – Physiology (Reference worker)

  Light work 0.54 m^3 h^{-1} respiration rate is 12 min^{-1}

  Light exercise 1.5 m^3 h^{-1} and respiration rate is 20 min^{-1}

  For both levels of activity all air enters through the nose.

Risk-Informed Dosimetry

Ingestion

-GI Tract Update (for workers!)

The selection of a GI tract uptake fraction is a scaling factor to dose

- *5.0 x 10^{-4} (moderate) unspecified compounds*
- *1.0 X 10^{-5} (slow) insoluble oxides*
- *Kocher and Ryan (1983) suggested ~10^{-3} for environmental assessments*

Risk-Informed Dosimetry

Inunction

- Introduction via wounds is a mainly workplace issue
- Absorption via skin (^3H) is considered in dose conversion factors – be careful which ones you use (^3H absorption is 50% of that inhaled)

^{129}I Isotopic Effects

- ^{129}I is soluble, mobile, and long-lived (1.57 x 10^7 y)
- relatively small inventory.
- Dilution of iodine in the diet can minimize potential doses from ^{129}I (~400 ugms/day)
- [Moeller and Ryan, 2004].
- But the story continues!!

^{129}I Isotopic Effects

- Reference used 400 µg d^{-1} as the average intake of stable iodine by adults in the United States [ATSDR 2001], which was based on a 1974 data
- More recent surveys Hollowell et al. 2001 had documented an average daily intake rate of 150 µg d^{-1}.
- Dose coefficient provided by the ICRP in Publication 72 is based on the Reference Man estimated daily intake of 200 µg

^{14}C Isotopic Effects

Varies by ~10^3 based on intake assumptions (food; food and water: models)

Key assumptions count!

(Moeller, Ryan, Sun & Cherry 2005)

Table 2. Comparison of annual dose estimates due to ingestion of ^{14}C, based on the several computational approaches.

Approach	Assumed conditions	Estimated dose
#1a	Application of Killough & Rohwer (1978) dose conversion formula assuming a daily stable carbon (drinking water) intake of 112 mg	7.45×10^{-2} μSv
#1b	Application of Killough & Rohwer (1978) dose conversion formula assuming a daily stable (total) carbon intake of 300 g	2.77×10^{-5} μSv
#2a	Application of FRG No. 11 dose coefficient without explicit regard to the daily stable carbon intake	3.05×10^{-5} μSv
#2b	Application of FRG No. 13 dose coefficient without explicit regard to the daily stable carbon intake	3.14×10^{-5} μSv

Exposure Scenarios

- 10 CCR 61 - Extreme bounding case
- Intruder probability of = 1
- Intrusion probability into Class C waste = 1
- Maximal exposure via all pathways!
- Extreme bounding scenario – can masks and over estimate realistic risks

Exposure Scenarios

- RESRAD – Bounding analysis (?) for groundwater using some site specific data
  - Realism of drinking leachate?
  - Depends on analysts choices.
  - Risks may be masked or overstated?
  - Important processes can be missed.

Exposure Scenarios

- MARSSIM D&D applications

- statistical approach (Wilcoxon rank sum) to residual contamination
- Different analysts will get similar results
- More rigorous approach to uncertainty analysis
- What is the relationship to risk?

Exposure Scenarios

10 CFR 63 - Stylized & prescribed scenario (63.322 Representative Volume)

- It is required by law
- Is it representative or conservative or non conservative?
- Does it address all sources of variability?
- It helps to understand risks by exploring conservatisms (positive or negative)

Conclusions

A broad spectrum of approaches to risk informing decision making (particularly the PA part) are used. The goal should be realism that presents best estimates and transparent assessment of risks.

- Challenge old wisdom
- Understand the foundations for all parameters
- Know the limits of established scenarios

Conclusions

- Extreme bounding analysis
- Bounding analysis
- Sensitivity studies
- On-off calculations and comparisons
- Probabilistic Risk Analysis

- All can play a role in dose calculations (risk-informed analysis).
- All have strengths and weaknesses.
- Some are better than others!