Uncertainty in Ecological Risk Assessments

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PHC & Health Risk Assessment

- PHC authorities through Army Regulation 200-1 (2007):

  - review authority on all human health risk assessments (HHRA) and ecological risk assessments (ERA)

  - approval authority on all HHRAs

  - can set risk assessment policy

  - coordinate on decision documents
- Provides consultative services to the installations
- Produces *in-house* risk assessments

A brief review of ERA Guidance

- Ecological Risk Assessment Guidance for Superfund ("ERAGS"; U.S. Environmental Protection Agency, [U.S. EPA], 1997)
- Guidelines for Ecological Risk Assessment (U.S. EPA, 1998)
- Tri-Service Procedural Guidelines for Ecological Risk Assessment (1996)
- Tri-Service Remedial Project Manager's Handbook for Ecological Risk Assessment (2000)
- Office of Solid Waste and Emergency Response Dir. 9285.7-28P: Ecological Risk Assessment and Risk Management Principles for Superfund Sites (U.S. EPA 1999)

Much of the uncertainty associated with ERAs derives from the Hazard Quotient (HQ) -- the lone calculation used in assessments.

The ERA Hazard Quotient (HQ)

- The ERA HQ construct is isomorphic to the HQ for non-cancer hazard in HHRA. It is a simple ratio (of chemical doses for animals):

$$HQ = \frac{\text{estimated chemical intake (mg/kg/d)}}{\text{demonstrated safe dose (mg/kg/d)}}$$

(aka the 'Toxicity Reference Value'; TRV)

*** notable uncertainty: HQs evaluate chemicals one-at-a-time! But that's not at all how the eco receptor consumes them!**

A quick review of ERA HQs

- They are only computed for birds and mammals.
  (They are not computed for reptiles or amphibians.)
- They are only computed for the ingestion pathway.
  (They are not computed for the inhalation or dermal contact pathways.)

*** notable uncertainty: Although the inhalation and dermal contact pathways are not assessed, the pathways are nevertheless operative for birds and mammals!**

An ERA HQ ‘spot quiz’ . . .

Question #1:
A Hazard Quotient of 5 means:

a. There are 5 individuals in the population who should be demonstrating the toxicological effect.

b. There is a 5% chance that individuals will be affected.

c. Individuals onsite have 5 times as great a chance as those offsite of showing a toxicological effect.

d. There is a one-in-five chance (i.e., 20%) that onsite receptors will be toxicologically affected.

Correct Answer

e. None of the above!

Hazard quotients are not measures of risk.

In fact, in ERA, there is no measure of risk!

Most people don't realize this. Risk is the probability of a receptor developing a toxic endpoint. Importantly, HQs are only unitless ratios; they are not probabilities.

True or False:

Question #2.

A population with a HQ of 10 has twice as much risk as a population of the same species with a HQ of 5.

False

- First of all, HQ is not a measure of risk.
- But aside from that, HQs are not linearly scaled metrics.

True or False:

Question #3.

If a Red fox has a HQ of 10 and a Meadow vole has a HQ of 5, the Red fox is at twice the hazard level of the vole.

False

- HQs are not linearly scaled metrics.
- There is no basis for a comparison of the HQs of receptors of different species.

Ramifications of HQ limitations . . .

- A HQ >1.0 does not mean that there is unacceptable risk.
- A HQ >1.0 doesn't guarantee that there is even one site receptor bearing a toxicological effect of concern.
- A HQ >1.0 alone cannot justify a cleanup. Even if the HQ is very large, we don't know that anything is wrong ecologically at a site. And speaking of very large HQs . . .

Uncertainties with regard to HQ magnitude need to be considered

1. Not that you should ever compute HQs for site background, but if you did . . . you'd find that frequently enough they fail.

magnitude uncertainty, cont'd.

2. HQ's are frequently computed that are "unrealistically high and toxicologically impossible".

Example: You cannot have a HQ of 125. That would mean the receptor is consuming a chemical with toxic effects at 125 times the safe dose -- but no ecological receptor could survive such a dose.

Source: Tannenbaum, L.V., Johnson, M.S., and Bazar, M., 2003. Human and Ecological Risk Assessment, Volume 9 (1): 387-401.

Critical Ramifications of HQ use:

THE HQ IS ONLY A SCREENING TOOL!

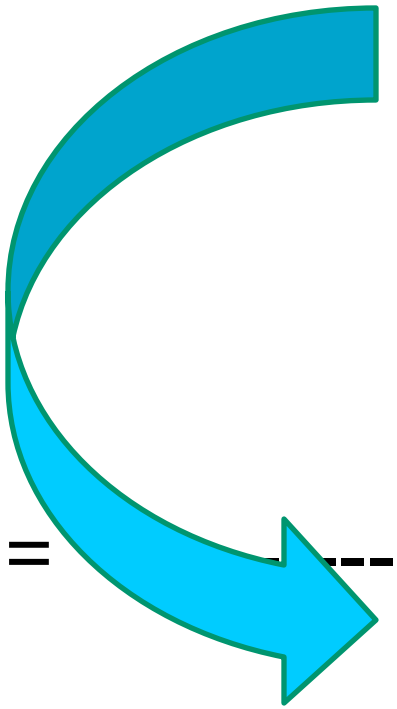
- A HQ < 1.0 means that, by our estimation, a receptor is ingesting a safe dose. A site can be closed out.
- A HQ > 1.0 means that by our estimation, a receptor is ingesting a chemical dose that is higher than the safe one. At best it can mean that additional analysis is needed. There are no grounds for remediating a site based on a HQ alone.

If you have a failing HQ . . .

Use 'HQ refinement' to reduce the uncertainty and the magnitude of the HQ estimate. Use more appropriate and realistic terms in the HQ's numerator and denominator, and maybe the HQ >1 will go away. Adjust:

exposure point concentration; body weight; ingestion rate; dietary composition; Area Use Factor; for the TRV use a Lowest Observed Adverse Effect Level (LOAEL) in place of a No Observed Adverse Effect Level.

$$HQ = \frac{\text{estimated intake}}{\text{NOAEL (safe dose)}}$$



$$HQ = \frac{\text{estimated intake}}{\text{LOAEL (effect level dose)}}$$

Example: antimony exposure to a fox (intake for chemical X is 0.100 mg/kg/day)

Mammalian TRV		HQ
NOAEL-based	0.025 mg/kg/day	$\frac{0.100}{0.025} = 4.0$
LOAEL-based	0.125 mg/kg/day	$\frac{0.100}{0.125} = 0.8$

Be cautious of the uncertainty associated with the HQ denominator (i.e., the TRV)

- Consider how the TRV's supporting study differs from the actual exposures at your site:
- The chemical forms may not match.
- The test species won't match your receptor of interest.
- Check the study's route-of-administration, duration, and toxicological endpoint.
- We want to assess wild-type animals, but inbred/ isogenic strains are used in lab studies.
- The natural environment is variable (temperature, lighting, terrain), but a lab environment is a fixed one.

Beyond the HQ . . .

- spatial scale / animal density: (Have you enough animals at your site to worry about anyway?)
- weight-of-evidence (What if the HQ fails, but the site looks fine?)
- cost/benefit consideration (A site cleanup might do more damage than good!)
- historical contamination / evidence of effects (Does it make sense to be doing an ERA so many years after the fact?)

Spatial scale realities . . .

species	home range
Red fox	> 3000 acres
Mink	0.62 - 3.7 miles long
Red-tailed hawk	> 3000 acres
Marsh wren	0.13 acres
American robin	0.61 acres

Spatial scale realities . . .

species	density (animals/acre)
Red fox	0.02/acre
Marsh wren	4 males/acre
American robin	2 pairs/acre
Woodcock	1.4 birds/acre

And how big did you say your site was again?

Risk Assessment & Risk Management What's the Difference?

- **Risk Assessment**

- A qualitative and/or quantitative appraisal of the actual or potential impact of contaminants on plants or animals

- A process for scientifically evaluating the adverse effects of contaminants on the environment

- Establishes whether a risk is present & defines a range or magnitude of the risk; it doesn't decide what gets cleaned up

Risk Assessment & Risk Management What's the Difference?

- **Risk Management**

- Combines risk assessment results with other considerations to make & justify a response decision

* Other considerations include: tradeoffs between human & ecological concerns; ecological impacts of remedial options; costs of the alternatives; available technology; implications of existing background considerations; and political pressures

Further reading

Tannenbaum, L.V. (2014) Alternative Ecological Risk Assessment: An Innovative Approach to Understanding Ecological Assessments for Contaminated Sites. Wiley-Blackwell, 2014