Risk Assessment Perspectives on Air Dispersion Modeling

Stephen G. Zemba, Ph.D., P.E.
(Zemba@CambridgeEnvironmental.com)

Michael R. Ames, Sc.D.
(Ames@CambridgeEnvironmental.com)

Cambridge Environmental Inc
58 Charles Street Cambridge, Massachusetts 02141

www.CambridgeEnvironmental.com
617-225-0810 FAX:617-225-0813

Alternate Titles for the Talk

True Confessions of a Risk Assessor

The Devil is Definitely in the Details

A Risk Assessor's Letter to Santa

(How) Does a Risk Assessor Think?

Take Home Points

- Air toxics risk assessments may employ air dispersion models in applications for which the models were perhaps not specifically designed
- Receptor-specific deposition estimates are often the key factor in the subsequent risk multi-pathway (*i.e.*, foodchain) risk estimation
- Future model development should consider the needs of the risk assessment and risk management communities

Air Emissions Risk Assessment

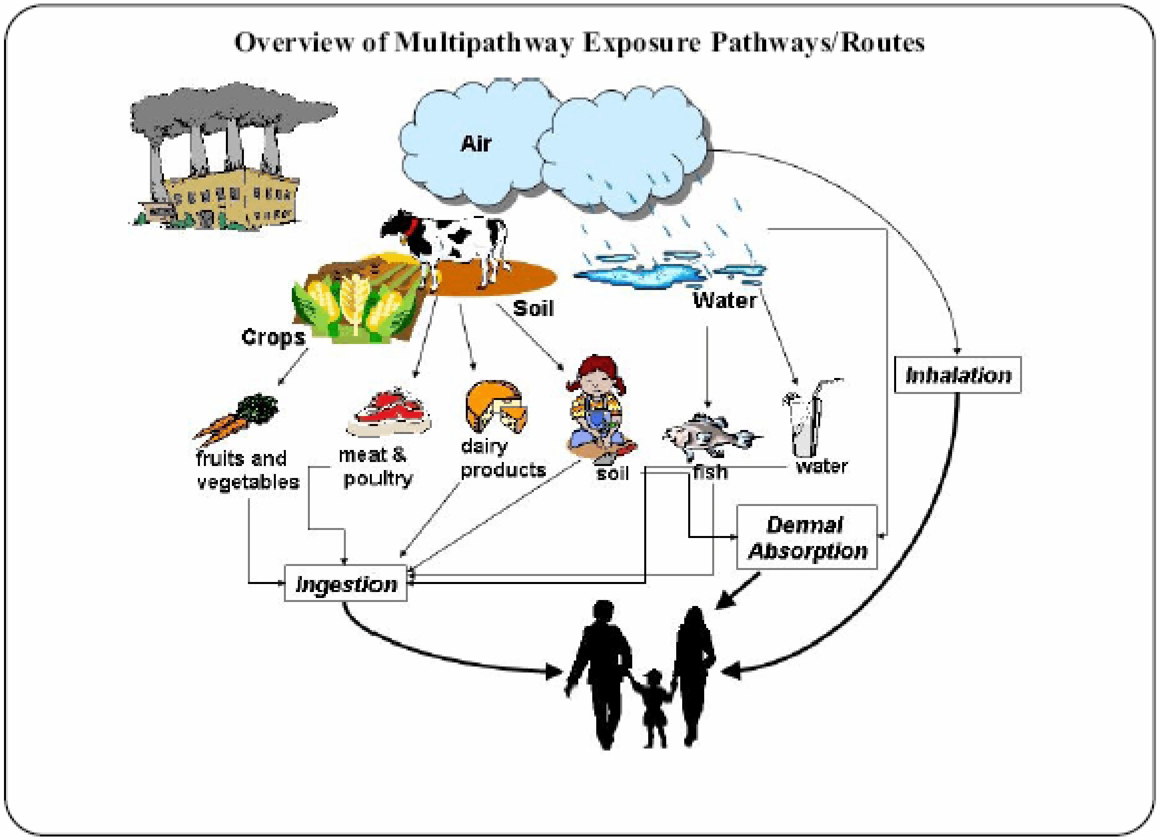


Figure from the OAQPS's *Air Toxics Risk Assessment Reference Library*

Modes of Deposition

- Particles (size distributions) and vapors (physicochemical properties)
- Wet processes
  - Occur vertically throughout the mixed layer
  - In-cloud *v.* below cloud
  - Scavenging coefficients
- Dry processes
  - Occur at ground-level
  - Deposition velocities

Deposition Modeling for Point Sources

A history based on personal observations

Mid-to-late 1980s	Run air dispersion model to predict airborne ground-level concentrations, apply post-hoc dry deposition velocity, ignore (?) wet deposition
~1990	COMPDEP
~1995	ISCST3
Present	AERMOD

AERMOD Deposition Algorithms

- Originally designed for ISCST3
- Wesely *et al*. (ANL, 2002) multi-resistance algorithms (aerodynamic, laminar, surface canopy)
- Covers wet and dry deposition, particles and gases – key parameters are particle size distributions and (gaseous) chemical properties
- Intrinsically tied to meteorological data processing & seasonal sector-specific surface characteristics (albedo, roughness length, & Bowen ratio)

Surface Profile Correction
An omission from AERMOD's algorithms?

- Dry deposition is calculated as the product of a concentration (usually at some near-ground reference height) and a deposition velocity
- ISCST3 includes a vertical *profile correction factor* to account for surface plume depletion; this factor does not appear to be in AERMOD's deposition algorithms – should it be there?
- All other things being equal, the lack of a profile correction factor leads AERMOD to predict higher dry deposition rates than ISCST3

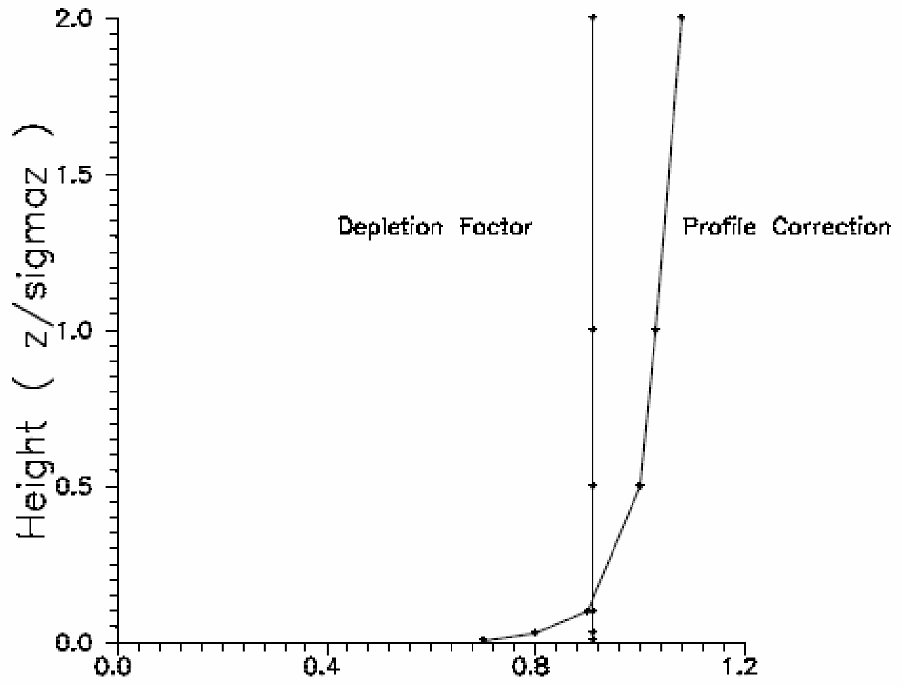


Figure 1-6 from the ISCST3 User's Manual, Vol. 2

Receptor-Specific Deposition

- AERMOD (through AERMET) characterizes land use and surface deposition parameters in a sector-specific (i.e., pie slice) manner
- Surface characteristics at a critical receptor may differ from those of the sector at large
- In many cases, land-use changes more significantly with distance than with direction (*e.g.*, a source in an urbanized area surrounded by suburban or rural land uses)
- Can, or should, models be designed to use receptor-specific deposition parameters to better estimate local deposition?

Aerosol-Vapor Interactions

- Some contaminants (*e.g.*, Polycyclic aromatic hydrocarbons [PAHs] and dioxin-like compounds) are present both as vapors and bound to particles
- Some contaminants are likely to change partitioning in the atmosphere
- Deposition characteristics of aerosols and vapors can differ
- Can/should these effects be incorporated into models such as AERMOD?

Multi-Pollutant Models?

- Should AERMOD and other models be designed to handle multiple pollutants simultaneously?
  - Deposition parameters may differ widely among pollutants, but many other model parameters do not
  - Currently, risk assessors must perform separate model runs for each pollutant
  - A multi-pollutant model (even without interactive chemistry) would offer significant computational and logistical efficiencies

Near-Field Models?

- Deposition of some pollutants is a potential concern at receptors close to emission sources
  - Mercury
  - Nitrogen (from NO_x and NH_3)
- Some sources, such as ground level fugitive dust, must be evaluated at very close-by receptors (*e.g.* at distances of tens of meters)
- Most models are verified for ambient concentrations for passive tracers at distances of a few kilometers and beyond; acid deposition verification far (> 50 km) downwind
- Reactive plume chemistry (including aerosols) and removal processes are key factors
  - Specialized models or adaptations of existing models?

Nested Models

- Source-specific modeling sometimes interacts in important ways with existing air quality
  - Background ammonia concentrations affect NO_x oxidation chemistry
  - A plume particle size distribution melds with the background distribution as dilution proceeds
- Would regional model simulations be useful in developing background conditions for local plume modeling?

Beyond the First Terrain Feature

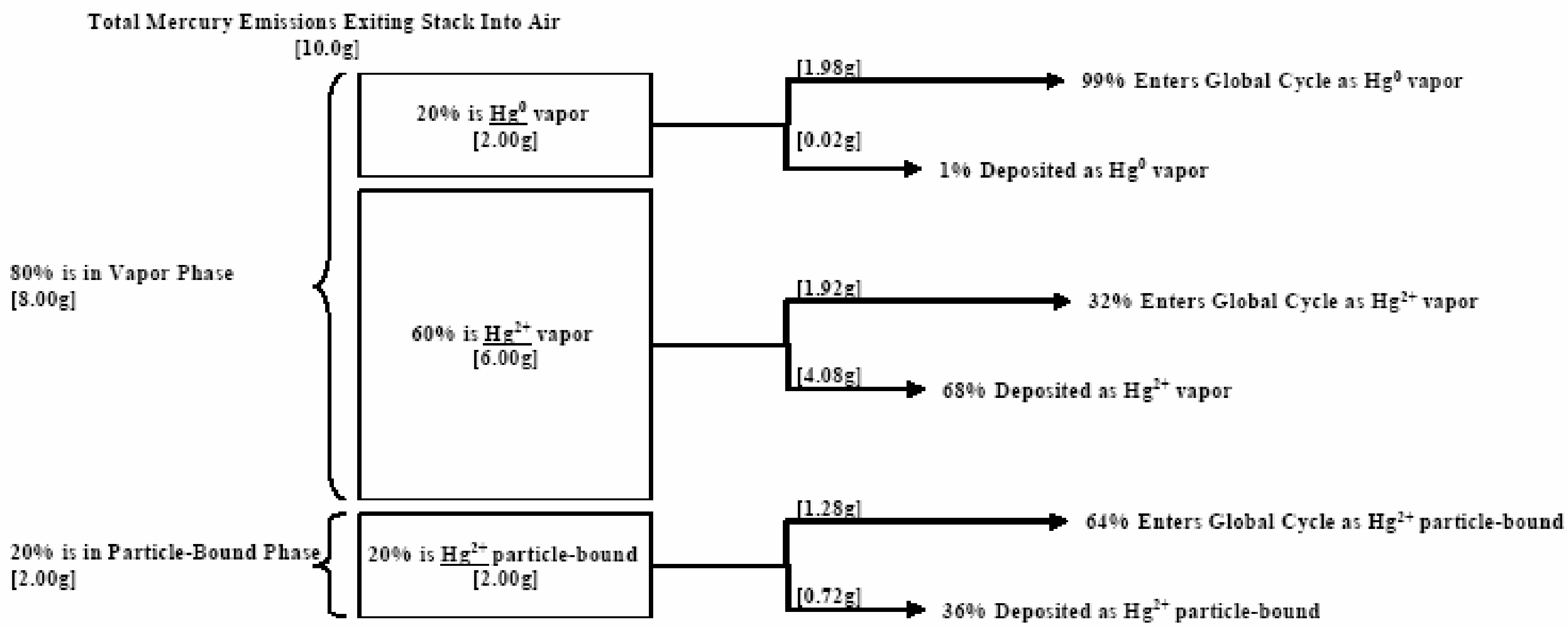
- Modeling has traditionally focused on the first complex terrain feature, with the knowledge that impacts at greater distances will be smaller
- Risk assessments often need to focus on receptors such as water bodies, farms, and receptors of special interest, beyond this first feature
- CALPUFF can examine truly complex terrain through 3-D wind fields, but is AERMOD designed for this purpose?
- What uncertainties do we introduce by applying models in highly complex terrain?
- Are risk assessors cognizant of modeling uncertainties introduced by complex terrain?

Mercury

- Mercury has been a pollutant of special concern to the public and risk assessors for at least 20 years
  - EPA believes typical exposures are at or near levels of concern
  - Natural and anthropogenic sources and cycles intermingle
  - Local, regional, and global concerns are influenced by different mixes of emissions and relevant atmospheric processes
- Methods to assess mercury remain highly uncertain

Mercury Deposition: Speciation

- EPA's *Human Health Risk Assessment Protocol* removes a significant amount of mercury emissions from consideration in the deposition modeling and places it into a global pool – does this make sense?



Risk Assessment Guidance Development 1.01

Step 1: A risk assessor examining a novel situation makes an assumption and applies a model based largely on professional judgment (and perhaps some data)

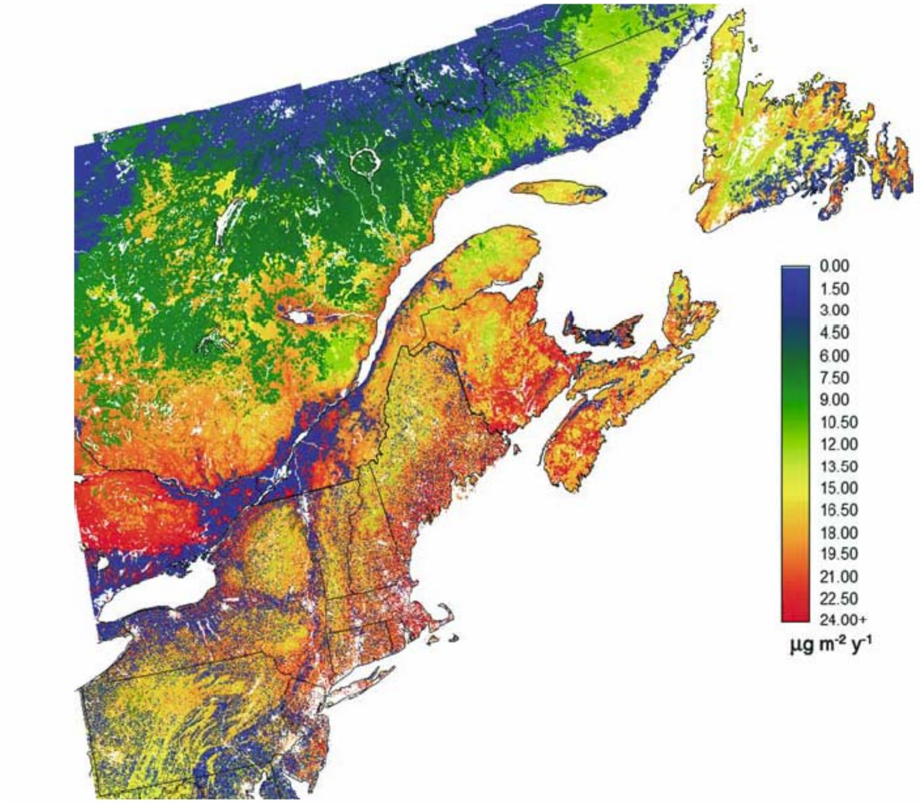
Step 2: A second risk assessor references the first one, repeating the uncertain assumption

Step 3: The assumption gets codified into official guidance and is then required to be used by subsequent risk assessors

Mercury Deposition Modeling
Dry deposition

- Dry deposition velocity = 2.9 cm/s for oxidized (+2) mercury species
  - Used in EPA's *Mercury Report to Congress*
- Based (in part) on an analogy with nitric acid
  - Empirical nitric acid deposition velocities vary from 0.06 to 4.5 cm/s (Seinfeld, 1986)
  - CASTNET deposition velocities for nitric acid typically range from 1 to 2 cm/s
- Uncertainties drive the tendency to bias deposition parameters to the high side

Land-Use Dependent Deposition
Dry deposition of mercury



- From Miller *et al.* (2005), Ecotoxicology **14** (1-2): 53-70

Summary

- Risk assessors use air dispersion models and their needs differ from Clean Air Act permitting analyses
- Contaminant deposition is often a key to risk assessment analyses
- Reliable tools for deposition analyses are not always available
- Model capabilities should be better tailored to risk assessment needs
- Attention to mercury modeling is welcomed
- More air dispersion modeling guidance is welcomed