Conceptual Site Modeling for Contaminated Site/Environmental and Occupational Health Exposure and Risk Assessment

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Exposure Definitions

- An exposure is an event when a person (receptor) comes in contact with a toxic material.
- This contact is a highly variable and dynamic changing from person to person, depending on job classification, personal behavior, location, lifestyle and from one toxic substance to another. It has both spatial and temporal aspects. Time and space are in fact key to its understanding.
Exposure Definitions

- The goal of exposure science is to identify and characterize “real world” contacts with and uptakes of toxic contaminants that can cause acute or chronic health endpoints.

- The results of exposure studies are vital for dose reconstruction, and reducing or preventing future exposures.
Characteristics of Exposure Science

- It is observational and historical in nature initially-akin to the medical history and physical.
- Performed in the field within normal living and working conditions. So that improper assumptions about who is exposed and why they are exposed are not made.
- Complex air, water, food, sediment tests for specific contaminants /carcinogens /toxins can be performed and related to exposure per 8 hr day or other useful time period.
What can we do with toxic material exposure information?

- Link it with health endpoints to produce exposure-response curves.
- Use the exposure information with existing dose-response curves (generally from laboratory toxicology work) to develop risk models.
- Use information in computer models to generalize to other populations.
Composition of an Exposure Pathway

- Source(s) (may be numerous)/Accidents (acute exposures).
- Magnitude and rate of environmental emissions (may change according to production needs).
- The transport pathways through environmental media (air/water/groundwater/soil/food/smoking)
- The uptake pathways associated with exposure of different population and sub-population groups (categories of workers/ages/gender/childbearing) linked to specific activities
- The dose that depends on the type, intensity, concentration and elimination rate of radionuclides and/or toxic substances to which these groups are exposed.
Figure 2. Possible approaches for analysis of air contaminant exposures (NRC, 1991).
What is a Conceptual Site Model?

- A written and/or pictorial representation of an environmental system and the biological, physical and chemical processes that determine the transport and fate of contaminants through environmental media to environmental receptors.
Definition of Environmental Media -

- Air
- Surface Water
- Groundwater-Confined or Unconfined Aquifers
- Sediment
- Soil
- Subsurface area-Vadose Zone
- Food Chain
Components of a Complete Conceptual Site Model for Site Decontamination

- Sources of contaminants (can be multiple sources as well as species on a site).
- Pathways of environmental transport.
- Indications of any barriers or remedies that exist or are proposed.
- Pathways to ecological and human receptors.
Why develop a Conceptual Site Model?

- Pull together technical data concerning a site from numerous sources (Sampling, hydrological and geological, population density and age distribution etc.).
- Support the selection of sampling locations to establish background concentrations of identified contaminants.
- Identify data needs and gaps.
- Describe and integrate the processes that determine contaminant release, migration and receptor exposure.
Why develop a Conceptual Site Model (continued)?

- Determine exposure routes (inhalation, ingestion and/or dermal absorption).
- Identify uncertainties in the model that need further study.
- Preliminarily evaluate the risk to human and ecological receptors (CERCLA NPL status is based on a significant risk to human health or the environment).
Why develop a Conceptual Site Model (continued)?

- Facilitate the selection of remedial alternatives and evaluate the effectiveness of remedial actions to reduce exposure.
- For use as a communication tool in the decision-making process involving experts from exposure assessment, human and ecological health, remediation engineers etc.
- As a risk communication tool for the public.
Because Peoples Lives Can Depend On A Conceptual Model

The Story of the Bruin Lagoon
Activities Associated with the Development of Conceptual Site Models (ASTM E 1689 – 95) - in order!

- Identification of potential contaminants.
- Identification and characterization of the source(s) of contaminants.
- Delineation of potential migration pathways through environmental media.
- Establishment of background areas of contaminants for each contaminated media (natural, other anthropogenic source, source dependant).
Activities Associated with the Development of Conceptual Site Models (ASTM E 1689 – 95)-in order!

- Identification and characterization of potential environmental receptors.
- Determination of the limits of the study area or system boundary.
Uptake Mechanisms from Failure of Engineering Controls at Nuclear Facilities

Vvas and Powers, 2005
CSM of Release of Liquid Radionuclides – Can Build This for Manhattan Project Contaminated Sites and Industrial/Power or Defense Plants Using Radionuclides


**Source**: Liquid release

- Cs137
- Sr90

**Contamination process**: Dispersion
- Water

**Contamination medium**: Water contamination

**Bioaccumulation**
- Fish
- Aquatic Receptors

**Mode of exposure**: Ingestion

**Habits**: Consumption rate

**Dose**: Internal Dose
- Pharmakokinetics
- Elimination Rate
- Toxicity and Damage

**Man**

- Time
- Shielding and Distance
Contaminants include U and Trichloroethene---TCE degrades into vinyl chloride, which causes angiosarcoma of the liver.

Vyas, Volz and Powers, 2005
Water Usage Projections and Conceptual Effects on the Transport of Radionuclides to New Populations

Vyas, Volz and Powers  2005
Legacy Iron and Steel Industry (ISI) Wastes

Cokemaking
- Polynuclear Aromatic Hydrocarbons
- Naphthalene, creosote, and tar
- Oils and grease
- Benzene and other aromatic hydrocarbons
- Cyanides and thiocyanides
- Phenolics
- Ammonia Liquor

Sinter Plants
- Oil and Grease
- Phenolics
- Metals including lead and zinc
- Aliphatic Hydrocarbons
- Ammonia and Related Compounds

Ironmaking
- Suspended solids
- Ammonia
- Cyanide
- Phenols
- Heavy metals including copper, lead, zinc, and arsenic
- Slag

Steelmaking
- Metal dusts including lead, zinc and arsenic
- Fluorides

Forming, Cleaning, De-scaling
- Oil and Grease
- Wastewater Sludge—contains manganese, nickel, cobalt copper, cadmium, chromium, and lead
- Wastewater containing zinc, lead, cadmium, and/or chromium
- Grindings containing chromium and zinc dross
- Spent pickle liquors including hydrochloric, sulfuric, nitric and hydrofluoride acid

Hot Coating
- Metals including zinc, lead, aluminum, cadmium, and chromium

Electroplating
- Zinc, tin, and chromium
- Oil and grease

Introduction
Evidence shows that legacy wastes from the Iron and Steel Industry (ISI) continue to contaminate human and ecological habitat in the Three Rivers Area (TRA) of Pittsburgh through: transport from contaminated surface soils, subsurface media, groundwater transport; and residual toxins deposited in river sediment. Conceptual Site Models (CSMs), used by the EPA and DOE, graphically depict sources, release, transport pathways, exposure routes and human and ecological receptors and possible blocks to each receptor to reduce risk. CSMs are a powerful tool to help public and environmental health officials understand and communicate regarding risk.

Conceptual Site Model to Understand Human and Ecological Risk from Legacy Iron and Steel Wastes in the Three Rivers Area of Pittsburgh

Conrad D. Volz, DrPH, MPH

CSM of bio-accumulation and bio-concentration of contaminants in water and sediment by lower trophic levels in the Three Rivers. These contaminants are bio-magnified as they move up the food chain through processes such as the concentration of organic pollutants in lipids and the binding of heavy metals to proteins. The resulting concentration of contaminants in piscivorous fish pose a health risk to human consumers of TRA caught fish (especially subsistence-style fishermen) and fish eating birds.
Figure 3.10. Expanded CSM for the Northern Pacific/Bering Sea ecosystem.
Conceptual Site Model of Radionuclide Transport from the Amchitka Nuclear Test Shot into Groundwater
CSM of Radionuclide Movement Through Subsurface Water Into the Marine Environment and Likely Receptors and Exposure Mechanisms

![Diagram showing the movement of radionuclides from subsurface water to various receptors through different mechanisms like dermal ingestion, gills, and food chain.]

<table>
<thead>
<tr>
<th>Receptors</th>
<th>Sessile plants and animals</th>
<th>Mobile marine birds, fish, mammals, invertebrates</th>
<th>Migratory marine birds, fish and mammals</th>
<th>Aleut Pribilof Island</th>
<th>Commercial Fisheries</th>
<th>On-site worker/resident</th>
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<tbody>
<tr>
<td>Intertidal Leakage</td>
<td>Dermal Ingestion Gills</td>
<td>Dermal Food Chain</td>
<td>Dermal Food Chain</td>
<td>Dermal Food Chain</td>
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<td>Ingestion, Food Chain</td>
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<tr>
<td>Subtidal Leakage</td>
<td>Dermal Ingestion Gills</td>
<td>Food Chain</td>
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<td>Ingestion, Food Chain</td>
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<tr>
<td>Benthic Leakage</td>
<td>Dermal Ingestion Gills</td>
<td>Gills, Dermal Ingestion, Food Chain</td>
<td>Ingestion, Food Chain</td>
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a. Where there are bottom-dwelling biota
b. Areas without benthic biota

Burger et al., 2005