Lecture 2, Conceptual Site Models - Methodologies to Depict and Evaluate Important Exposure Modes, from Source - to Media - to Receptor

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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 and their most likely exposure modes.
Definition of Environmental Media -

- Air
- Surface Water
- Groundwater
- Sediment
- Soil
- Subsurface area - Vadose Zone
- Food Chain
Components of a Complete Conceptual Site Model

- 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. (Refer to ASTM Handout page 8).
Why develop a Conceptual Site Model?

• Pull together technical data concerning a site from numerous sources.
• 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 a 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.
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.
Examples of Conceptual Site Models

- Simplistic Models
- Radionuclide Liquid Release Model
- Expanded CSM’s – Amchitka Island the Pacific Ocean and Bering Sea (Russia and the US and Commercial Fisheries)
Uptake Mechanisms from Failure of Engineering Controls at Nuclear Facilities

Post-remediation failure → Activity → Uptake Pathway

- Dietary
- Inhalation/Non-Dietary/Dermal
- Inhalation/Dermal

Vvas and Powers, 2005
CSM of Release of Liquid Radionuclides – Can Build This for Contaminated Sites and Industrial/Power or Defense Plants Using Radionuclides
The New Pittsburgh Region?
Fishing on the Mon
Legacy Contamination Mechanisms

- Air Emissions to Soil and Water - associated transport to subsoil, groundwater and river sediments.
- Leaking Pipes, Pits, Sumps to Soil and Water - associated transport to subsoil, groundwater and river sediments.
- Effluent Release to Streams and Rivers - associated transport to groundwater and river sediments.
- Waste depot transport to soil-subsoil-groundwater and surface water-sediments.
Environmental Protection Agency (EPA) indicated in 1995 that the ISI was the largest industrial source of toxic environmental contamination in the United States. (EPA 1995)

This figure did not include industrial codes for foundries or machine tooling plants, which have historically been associated with the ISI in the Tri-State Area (TSA) and have waste streams associated with metals, organic solvents, cutting oils and isocyanates.
Are the Exposures Gone?

Who might be exposed?
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.

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
- Phenol
- 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

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

CSM of the movement of legacy waste in the TRA through environmental media and uptake mechanisms by human and ecological receptors is presented.

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 poses a health risk to human consumers of TRA caught fish (especially subsistence-style fisherman) and fish eating birds.

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More information

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What is Missing?
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
CRESP Amchitka Expedition: Use of Conceptual Site Models to Generate Informed Hypothesis for Exposure Assessment
Underground Nuclear Tests on Amchitka Island

- 1965—Long Shot
  80 Kilotons

- 1969—Milrow
  1 Megaton

- 1971—Cannikin
  5-8 Megatons

Largest USA underground test

Nuclear Tests on Amchitka Account for 16% of all United States Nuclear Test Explosion Energy.
Amchitka Island Transport of Radionuclides to Marine Areas

Ocean surface → Cannikin Lake → Saltwater layer → Intertidal/subtidal benthic transport → Ocean surface

Possible chimney transport → Deep water benthic

Collapsed chimney → Test shot

Freshwater lens

 Leakage transport
Conceptual Site Model of Radionuclide Transport from the Amchitka Nuclear Test Shot into Groundwater

Burger et al.
CSM of Radionuclide Movement Through Subsurface Water Into the Marine Environment and Likely Receptors and Exposure Mechanisms

Burger et al., 2005
Figure 3.10. Expanded CSM for the Northern Pacific/Bering Sea ecosystem.