Storm Drain Pond Dose Assessment

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What are the Possible Exposure Pathways?

- Limited Set of Exposure Pathways In RG 1.109
  - Inhalation
  - Ground Plane
  - Vegetation Consumption
  - Milk/Meat Consumption
- Focuses On:
  - Local Agriculture
  - Human Food Chain

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Other Possible Exposure Pathways?

- Other Pathways of Potential Significance Are Not Addressed in 1.109.
  - Significant if it contributes > 10% to total dose
- Must be Considered on a Site-By-Site Bases
  - May Be Different Transport Mechanism
  - May Be Different Exposure Pathways
  - May Be Different Critical Receptor

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CGS Site Characteristics – High Desert

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CGS Site Characteristics – Local Agriculture

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Soil Resuspension Driven By Meteorology

- No Vegetative Cover in Immediate Area
- Loose Surface Soil
- Dust Storms Are Common

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Soil Resuspension Driven Human Activities

- Excavation
- Farming

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Soil Resuspension Dose

- Inhalation Dose
  - Due to Deposition in Lungs
- Ingestion Dose
  - Direct Oral Ingestion
    - Accidental
    - Deliberate (Soil Pica)
  - Indirect Ingestion via Inhalation
    - Particles Inhaled and Subsequently Swallowed

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Soil Resuspension Models

- Resuspension Factor (m^{-1})
  - Ratio of the air concentration to the surface deposition.
- Resuspension Rate (sec^{-1})
  - Fraction of material resuspended per unit time.
- Resuspension Velocity (m/sec)
  - Similar to the deposition velocity used in determining D/Q.
- Mass Loading Factor (kg-soil/m^3-air)

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Preferred Approach

- Mass Loading Factor (kg-soil/m^3-air)
  - Approach used by EPA and RESRAD
  - 100 mg/m^3 - Value Readily Available
    - RESRAD User Manual
    - NCRP Report 76
  - Conservative

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Source Term for Soil

- Highest Observed Activity Assigned to Each Nuclide
- Assumed Homogeneous Distribution
- Assumed Soil Readily Resuspended

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Source Term for Dose Assessment

- Airborne Concentration
  - Resuspended Concentrations Determined by Mass Loading Factor
- Release Rate
  - Assumed Constant Airborne Concentration
    - Storm Drain Pond is Continuous Release Source
  - This Equates to a Release Rate of 1 m^3/sec

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Source Term Constructed From Highest Activity for Each Nuclide

SDP Source Term			
Nuclide	Highest Activity (pCi/kg-soil)	Release Rate (pCi/sec)	SDP Location
Mn-54	130	1.30E-05	B
Co-58	57	5.70E-06	B
Co-60	6260	6.26E-04	K
Zn-65	670	6.70E-02	B
Cs-134	41.3	4.13E-06	B
Cs-137	193	1.93E-05	I
Fe-55	824	8.24E-05	J
Ni-63	168	1.68E-05	B
Sr-90	21.1	2.11E-06	A

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Receptors?

- Location (Onsite/Offsite)
- Duration of Exposure
- Onsite Age Group
  - Teen
  - No Public Access to Storm Drain Pond
- Offsite
  - Infant (Direct and Indirect Soil Ingestion)
  - Teen (Vegetation)
  - Adult (Cow Meat)

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Exposure Time, Pathways and Assumed Age Groups

Onsite Location	Hours per Year	Ground Plane	Inhalation	Indirect Soil Ingestion	Direct Soil Ingestion	Vegetation	Cow Meat
Tour Visitors	8	Teen	Teen	Teen	Teen		
Firing Range	8	Teen	Teen	Teen	Teen		
DOE Site 618-11	380	Teen	Teen	Teen	Teen		
WNP-4 Warehouse 2-4	2600	Teen	Teen	Teen	Teen		
WNP-1 Bldg 121	2600	Teen	Teen	Teen	Teen		
Ash Substation	2080	Teen	Teen	Teen	Teen		
DOE Train	8	Teen	Teen	Teen	Teen		
Nat Guard at 0.5 mi N	8760	Teen	Teen	Teen	Teen		
Nat Guard at 0.5 mi S	8760	Teen	Teen	Teen	Teen		
Offsite Location	Hours per Year	Ground Plane	Inhalation	Indirect Soil Ingestion	Direct Soil Ingestion	Vegetation	Cow Meat
Residence at 4.95 mi ENE	8760	Any	Teen	Infant	Infant	Teen	Adult

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Dose Pathway to be Calculated

- Onsite Dose Pathways
  - Ground Plane
  - Inhalation
  - Indirect Soil Ingestion
  - Direct Soil Ingestion
- Offsite
  - All Pathways Listed Above
  - Vegetation Ingestion
  - Meat Ingestion

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Dose Pathway Methodologies

- Reg Guide 1.109 or NUREG 0133
  - Ground Plane
  - Inhalation
  - Vegetation Ingestion
  - Meat Ingestion
- Resuspension
  - RESRAD Users Manual
  - NUERG 3332
  - IAEA Safety Report Series No.19
  - NCRP Report 76

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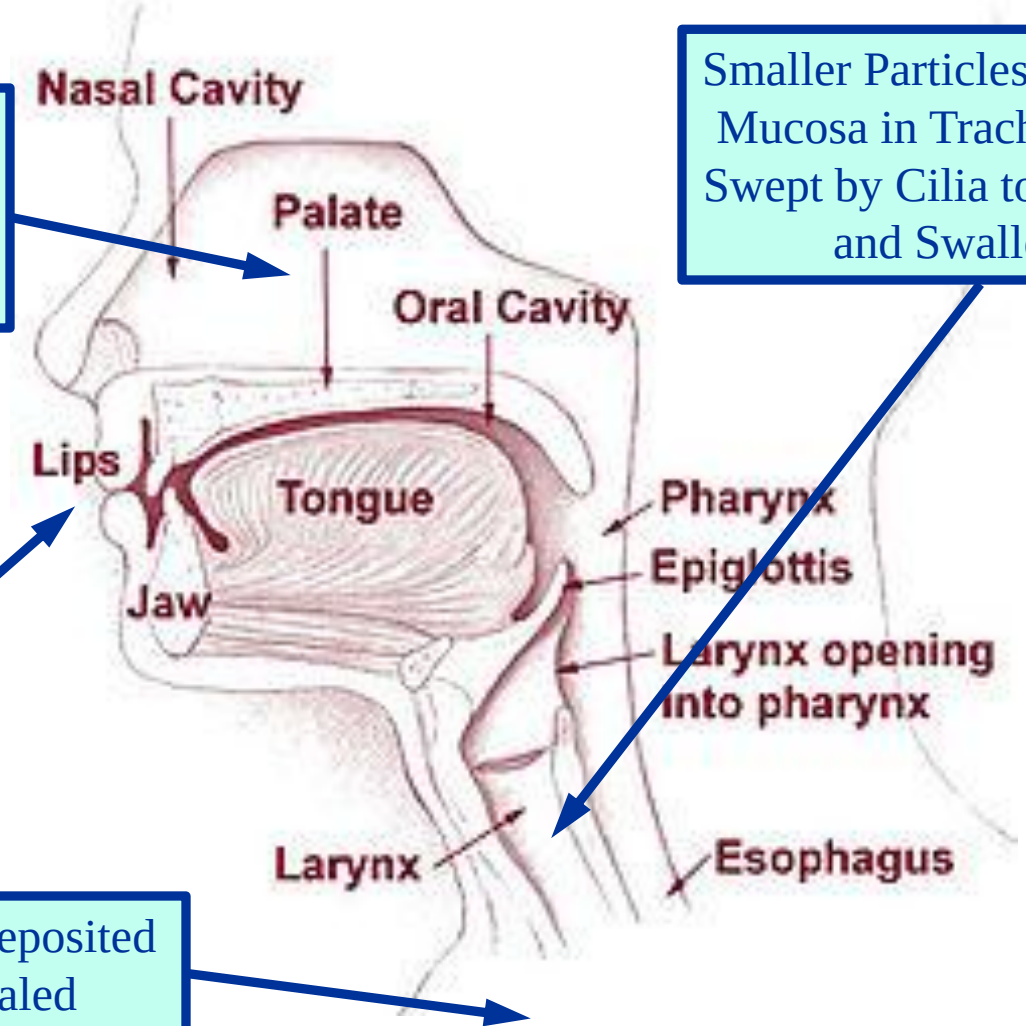
Dust Pathways into the Body

Large Particles Trapped and Blown, Sneezed or Swallowed

Smaller Particles Trapped by Mucosa in Trachea and Are Swept by Cilia to Esophagus and Swallowed



Direct Ingestion

Smallest Particles Deposited in Lungs or Exhaled

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Airborne Exposure Pathways

- Transient Exposure Pathways
  - Direct Function of Atmospheric Concentration
  - Dose Generated Only As Long as Release Is Taking Place
    - Inhalation
  - Use Dispersion – X/Q
- Integrating Exposure Pathways
  - Direct Function of Total Activity Released
  - Dose Continues to be Generated Due to Persistence in Environment
    - Ground Plane
  - Use Deposition – D/Q

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Soil Inhalation Dose

$$D^{IN}_{aij} = \chi/Q\ C_i\ P^{air}\ R^{air}\ BR_a\ \ DFA_{aij}$$

χ/Q	Dispersion (sec/m^3)
C_i	Concentration (pCi/kg)
P^{air}	Mass Loading Factor (kg-soil/m^3-air)
R^{air}	Release Rate (m^3/sec)
BR_a	Breathing Rate (m^3/yr)
DFA_{aij}	Inhalation Dose Factor (mrem/pCi)

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Indirect Soil Ingestion Dose

- Inhalation and Subsequent Ingestion
- Occurs in Environments of High Airborne Soil
  - Natural Processes
  - Agricultural Tillage
  - Soil Excavation
- Indirect Ingestion Rate
  - 200 mg/da (EPA EFH 2011 - upper percentile)
  - 480 mg/da for unusually high airborne soil concentration (EPA EFH 1997)

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Indirect Soil Ingestion Dose

$$D^{II}_{aij} = \chi/Q\ C_i\ (P^{air}/\ \rho^{soil})\ R^{air}\ U^{soil}_a\ DFI_{aij}$$

χ/Q	Dispersion (sec/m^3)
C_i	Concentration (pCi/kg)
P^{air}	Mass Loading Factor (kg-soil/m^3-air)
ρ^{soil}	Bulk Soil Density (kg/m^3)
R^{air}	Release Rate (m^3/sec)
U^{soil}	Soil Ingestion Rate (kg/yr)
DFA_{aij}	Inhalation Dose Factor (mrem/pCi)

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Direct Soil Ingestion

- Unintentional Consumption
  - Adhesion to Fruits, Vegetables, Hands, etc.
- Deliberate Ingestion
  - Soil Pica
    - Common Occurrence in Children
    - 1,000 to 5,000 mg/da for short periods of time.
  - Geophagy
    - Very high consumption of soil – 50,000 mg/da for short periods of time.
    - Associated with cultural practices.
    - Surface soil is not the consumed substance.

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Direct Soil Ingestion

- Considered only pica.
  - 5,000 mg/da ~ 1.8 kg/yr
- Did not consider dilution of deposited material by local soil.
- Source of ingested material is ground itself.
  - Must consider both deposition and buildup of transported soil.

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Direct Soil Ingestion Dose

$$D_{aij}^{DI} = D/Q\ C_i\ P^{air} R^{air} \left[\frac{\left(1 - \exp(-\lambda_i t)\right)}{\lambda_i} \right] \left[\frac{U_a}{\rho^{soil}\ T^{soil}} \right] DFI_{aij}$$

D/Q	Deposition ($1/m^2$)
U_a	Soil Ingestion Rate (kg/yr)
λ_i	Nuclide Decay Constant (sec^{-1})
t	Exposure Time (sec)
T^{soil}	Thickness of top layer of soil available for ingestion (m).

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Dose to Individual Due to Onsite Activities

Onsite Location	Max (mrem)	Max Organ
Tour Visitors	8.87E-08	Lung
Firing Range	1.64E-08	Bone
DOE Site 618-11	1.80E-07	Bone
WNP-4 Warehouse 2-4	2.87E-06	Bone
WNP-1 Bldg 121	5.74E-06	Bone
Ash Substation	8.98E-06	Bone
DOE Train	2.84E-08	Bone
Nat Guard at 0.5 mi N	3.78E-05	Bone
Nat Guard at 0.5 mi S	3.11E-05	Bone

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Dose to Individuals in the Unrestricted Area (mrem)

Pathway	Bone	Liver	TBody	Thyroid	Kidney	Lung	GI-LLI	Skin
Ground Plane (Any)	2.75E-09	2.75E-09	2.75E-09	2.75E-09	2.75E-09	2.75E-09	2.75E-09	3.23E-09
Inhalation (Teen)	1.60E-08	2.65E-09	2.47E-09	0.00E+00	8.29E-10	3.49E-07	1.05E-08	0.00E+00
Indirect Ingestion (Infant)	4.68E-15	4.68E-15	4.68E-15	4.68E-15	4.68E-15	4.68E-15	4.68E-15	0.00E+00
Direct Ingestion (Infant)	5.05E-07	1.35E-07	1.50E-07	0.00E+00	2.81E-08	1.17E-08	6.45E-08	0.00E+00
Vegetation (Teen)	4.05E-10	1.19E-10	1.76E-10	0.00E+00	3.34E-11	1.04E-11	4.07E-10	0.00E+00
Cow – Meat (Adult)	7.80E-11	3.64E-11	3.42E-11	0.00E+00	1.16E-11	2.40E-12	1.81E-10	0.00E+00
Total Dose	**5.24E-07**	**1.41E-07**	**1.56E-07**	**2.75E-09**	**3.17E-08**	**3.63E-07**	**7.84E-08**	**3.23E-09**

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