

Estimating Radiological Health Impacts from In Situ Recovery Operations using MILDOS

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MILDOS 4.21

- **Computer code**

- Based on U.S. Nuclear Regulatory Commission (NRC) regulations and guidance
- Origin dates back to 1979

- **Estimates radiological impacts from airborne emissions**

- Uranium mining and milling facilities
- Uranium-238 and thorium-232 decay chains including radon
- Conventional uranium ore operations & in situ recovery facilities
- Human exposure from contaminated ground, air, and food

- **Licensing tool**

- Applicants and licensees
- NRC staff

Primary Basis for MILDOS Models

■ NRC Regulatory Guides

- 3.51 – Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations (1982)
- 3.59 – Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations (1987)

■ NRC Reports

- Compliance Determination Procedures for Environmental Radiation Protection Standards for Uranium Recovery Facilities 40 CFR Part 190 [NUREG-0859 (1982)]
- Standard Review Plan for In Situ Leach Uranium Extraction License Applications [NUREG-1569 (2003)]

■ NRC Interim Staff Guidance

- DUWP-ISG-001, Evaluations of Uranium Recovery Facility Surveys of Radon and Radon Progeny in Air and Demonstrations of Compliance with 10 CFR 20.1301, Final Report (2019)

All MILDOS documentation available at mildos.evs.anl.gov



Program Scope

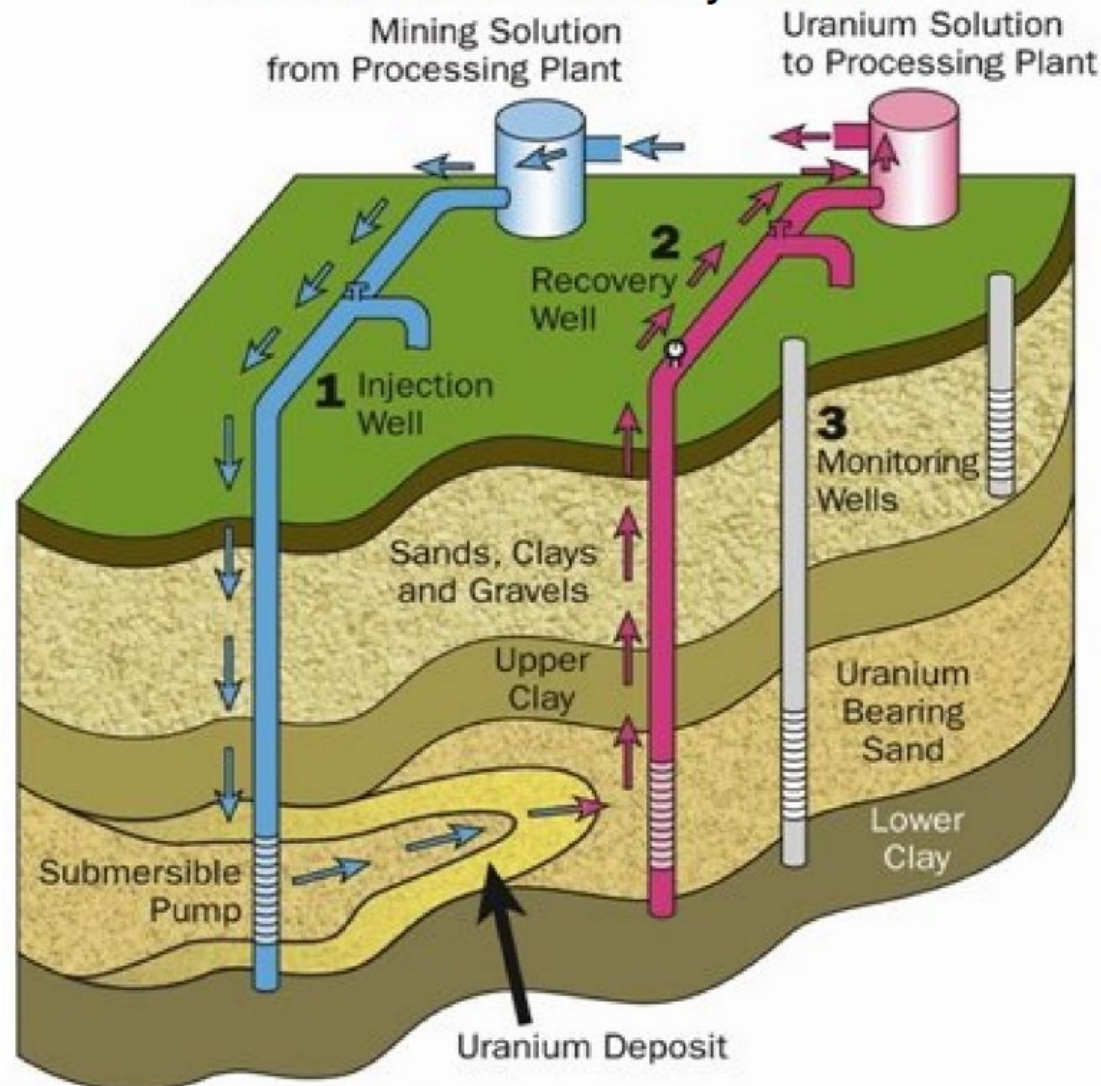
- **Impact estimation from radioactive emissions from uranium milling facilities (traditional ore and in-situ recovery)**
 - Dose commitments to individuals and regional population
 - Air, ground, and food concentrations
 - Different processes occur at different times in the facility's operational lifetime
 - For example: well drilling, operations, storage, restoration
- **Only radioactive emissions from airborne release**
 - Uses sector averaged plume model
 - Includes deposition, resuspension, accumulation, weathering, decay & ingrowth
 - No release to surface water or groundwater
- **Exposure pathways include**
 - External from groundshine and cloudshine
 - Inhalation
 - Ingestion of meat, milk, and vegetables





In Situ Recovery

The In Situ Uranium Recovery Process



Source: U.S. Nuclear Regulatory Commission.



In Situ Recovery



New Well Field Development



Well Fields



***Drying and
Packaging of
Yellowcake***



***Purge/Bleed and
Land Application***



Ion Exchange

New Well Field

- **Particulates: No release**
 - During drilling, a bentonite slurry flows out of the drill head and through the borehole
- **Radon: released from the cuttings that are temporarily stored in the “mud” pits**
 - average mass of cutting that are temporarily stored in the slurry pits
 - Number of mud pits generated per year
 - Average mass of cutting in a mud pit
 - Storage time of cuttings in mud pit



MILDOS 4.21

Area Source Name	x (m)	y (m)	z (m)	Disp. Coeff.
New Well Field	700	-50	0	Pasquill-Gifford

Area Source Type

☐ Generic Area ☒ New ISR Well Field
☐ Land Application ☐ ISR Well Field

Area Source Type / Dimensions

☐ Circular Radius (m) 100
☒ Rectangle Length (m) 10 Width (m) 10
Rotation (0 - < 90) 0
☐ Polygon

Source Total Area
100 m²

Uranium Ore (Rn-222)
Emanation Fraction 0.25
Ra-226 Concentration in Ore (pCi/g) 300

Thorium Ore (Rn-220)
Emanation Fraction 0.15
Ra-224 Concentration in Ore (pCi/g) 10

Mud Pits
Number of Mud Pits (1/yr) 42
Storage Time in Pit (days) 10
Ore Material Into Pit (g/yr) 4750000

Done

‘Production’ Well Field

- **Particulates: No release**

- Closed loop from the production well through the ion exchange column to the injection well

- **Radon: Released from the ore body into the process water**

- Radon circulates and builds up in the process water – released in 3 ways:
 - Purge: From process water that is purged
 - » Production well extracts more fluid than is pumped in through the injection well to maintain a cone of depression to prevent migration of mining solutions out of the ore in the production area
 - Resin Unloading: From the process water that is discharged during resin unloading from the ion exchange columns
 - Venting: From pipes and valves



‘Restoration’ Well Field

- **Pump and treat with fresh water injection. Similar to production well.**
- **Particulates: No release**
 - There is a closed loop from the well through to the injection well
- **Radon: Released from the ore body into the process water**
 - Radon circulates and builds up in the process water – released in 2 ways:
 - Purge: From process water that is purged
 - » Well extracts more fluid than is pumped in through the injection well to maintain a cone of depression to prevent migration of mining solutions out of the ore in the production area
 - Venting: From pipes and valves



Drying and Packaging

■ Particulates:

- Stack release from thermal dryers
 - Use a fraction of the production based on information from facilities that are operational
 - Progeny releases are a fraction of the uranium releases
- No release from vacuum dryers under normal operating conditions

■ U-238 series only

- Purified yellowcake (no Rn or Th-series)



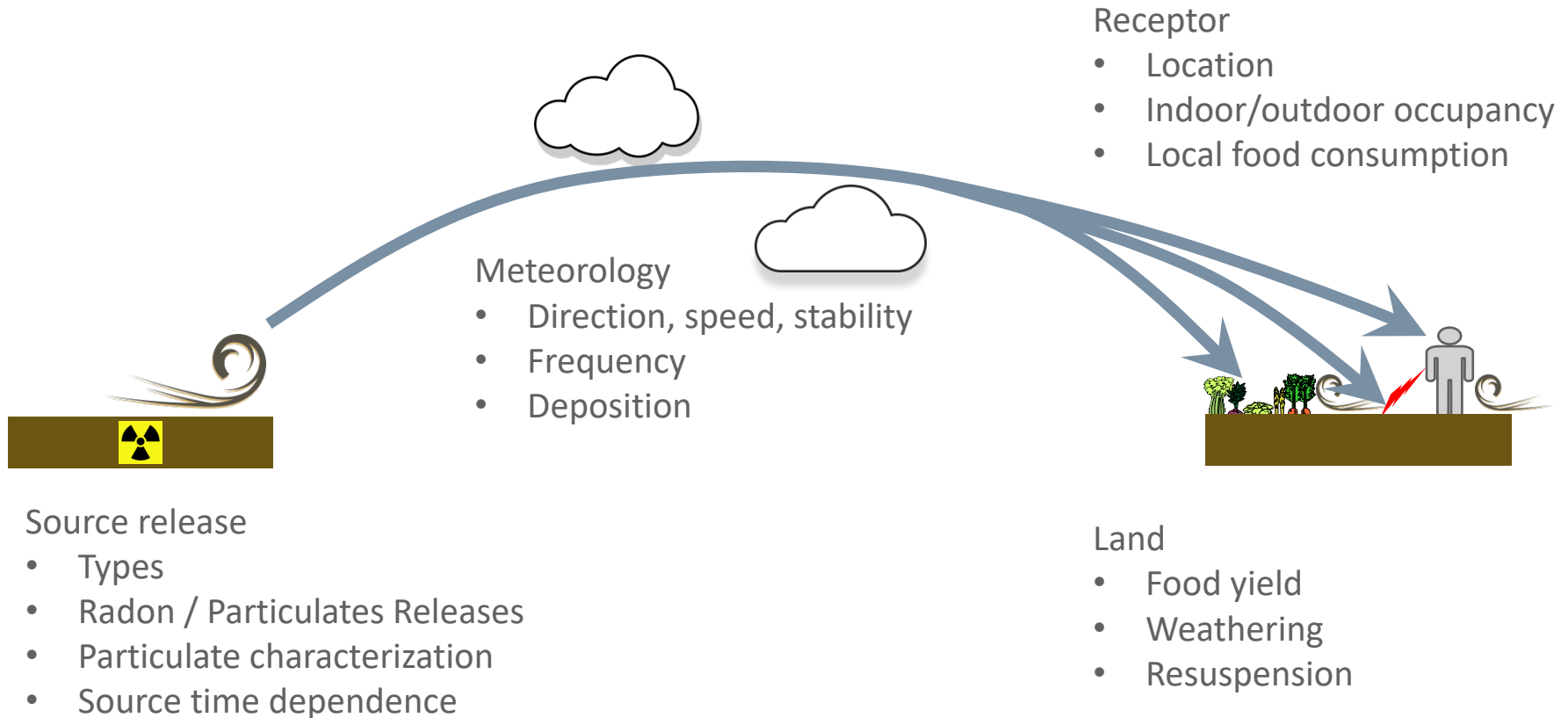
Land Application Area

■ Release of particulates

- Surface soil is contaminated
 - Purge water from production wells and waste water from well field restoration are treated to unrestricted release levels and disposed of by irrigating the land
- Uniform contamination over a specified depth
- Equilibrium adsorption of nuclide between soil and the applied irrigation
- Release from the area source



Input Components



Customizable Table and Graph Output Options

- **Impacts**
 - Normalized Air Conc. (χ/Q)
 - Media Concentrations
 - Doses
- **Receptors**
- **Sources**
- **Radionuclide**
 - U-238 / Th-232 decay chains
- **Particle Size**
 - Gas, 1.5, 3, 7.7, or 54 μm
- **Time Step**
- **Media**
 - Air / ground / 7 food stuffs
- **Organ**
 - Effective, bone, lung, liver, kidney
- **Pathway**
 - Inhalation and ingestion (plant, meat, milk)
 - Ground or cloud shine
- **Format**
 - Single table or graph; Series (e.g., dose for each time step); or Set (e.g., conc. for each nuclide by media type)

In Situ Recovery Example Demo

- **Follows well field development, production, and restoration**
 - For a given well field
 - New well field source – area source
 - Well field source (production vent) – area source
 - Well field source (production purge) – point source
 - Well field source (restoration vent) – area source
 - Well field source (restoration purge) – point source
 - Area sources are given the same location by the user
 - Point sources can be in a different location

More Information

- **Web sites**

mildos.evs.anl.gov

ramp.nrc-gateway.gov

- **Contacts**



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