Review of Environmental Analysis of the Uranium Fuel Cycle

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Background

- SNL performed a review of
  - Title 40 CFR Part 190
  - EPA's environmental analysis of nuclear fuel reprocessing (EPA 1 520-9-73-003-D)
- Part of this review involved
  - Understanding EPA's treatment of doses and health effects
  - Verification of the doses and health effects
  - Comparison with current methods

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Overview

- EPA methods
- Verification of EPA results
- Independent assessment of I-129 doses
- Summary

EPA Methods for Estimating Doses

- **Standard methods for estimating atmospheric transport and dispersion**
  - **Dose to maximally exposed individual (MEI) at site boundary (3 km)**
  - **Regional (80-km circular area) population dose**
  - **US population beyond the 80-km zone**
  - **Worldwide population**
- **Five isotopes**
  - **H-3 (12 years)**
  - **Kr-85 (11 years)**
  - **I-129 (16 million years)**
  - **I-131 (8 days)**
  - **Actinides (18 to 2 million years)**
- **Cooling time chosen to be 150 days**

EPA Methods for Estimating Doses

- **Simplifying assumptions for dose pathways**
  - **Exposure to H-3 by ingestion of water**
  - **Exposure to Kr-85 by immersion**
  - **Exposure to I-129 and I-131 by ingestion of milk**
  - **Exposure to actinides by inhalation of resuspended aerosols**
- **Simplifying assumptions for worldwide dose estimates**
  - **Uniform dilution of Kr-85 throughout atmosphere**
  - **Dilution of H-3 in circulating waters of northern hemisphere**
- **Assumptions for decontamination factors**
  - **No decontamination (DF = 1) for H-3 and Kr-85**
  - **DF = 1000 for iodines**
  - **DF = 10^9 for actinides**

Verification of EPA's Dose Values

Average Individual and Population Doses from One-Year Release for 1980 Startup								
		MEI	Regional		US		World	
Radio-nuclide	Organ	mrem /yr	μrem/ yr	person-rem/yr	μrem/ yr	person-rem/yr	μrem/ yr	person-rem/yr
Kr-85	Effective	0.37	10	24	2	560	2	7,900
	Lung	0.75	21	47	5	1,100	4	16,000
	Skin	12	350	790	79	19,000	60	260,000
	Gonads	0.44	12	14	3	330	2	4,600
H-3	Effective	3.2	89	200	16	3,900	0.2	1,000
	Gonads	3.2	44	100	17	2,000	0.2	500
I-129	Thyroid Infant	1.4	40					
	Thyroid Adult	0.4	12					

SNL Comments on EPA's Dose Values

- **Doses to MEI and region**
  - **Atmospheric transport estimates are reasonable**
  - **Doses from ingestion of I-129 appear to be very conservative (more later)**
- **US doses**
  - **Atmospheric transport estimates are reasonable**
  - **Minor conservatisms**
- **Worldwide doses**
  - **Doses from ingestion of H-3 appear to be conservative because dilution is into a small fraction (1.8%) of surface waters**

EPA Methods for Estimating Health Effects

- Health effects are assumed to be proportional to population doses
- Health effects are estimated for 40 years of plant operation
- SNL confirmed EPA health effect predictions to within 3%

Verification of EPA's Health Effect Values

Radio-nuclide	Organ	Estimated Health Effects from 40 Years of Operation				
		3 km	Regional	US	World	Total
Kr-85	Effective	6.0E-6	0.38	9.0	130	140
	Lung	1.5E-6	0.094	2.2	30	32
	Skin	1.5E-6	0.095	2.3	30	32
	Gonads	5.2E-6	0.17	4.0	55	59
H-3	Effective	5.2E-5	3.2	62	16	82
	Gonads	3.9E-5	1.2	24	6	31
I-129	Thyroid Infant	8.6E-6				
	Thyroid Adult	8.7E-8				

Motivation for an Independent Evaluation of Iodine-129 Doses Using MACCS2

- **Iodine-129 appeared to be the limiting isotope in terms of regulation**
  - **A DF of 1000 would be difficult to achieve**
- **Iodine-129 dose estimates in the EPA report seemed larger than expected**
- **Some of the assumptions associated with the food-chain pathway were difficult to reconstruct and evaluate**
- **Some of the assumptions seemed very conservative**

Comparison of I-129 Ingestion Assumptions

EPA assumptions

- Annual release is continuous
- Exposure is by consumption of milk
  - 0.76 l/dy for infants
  - 0.5 l/dy for adults
- Deposition velocity is 0.5 cm/s
- I-129 in thyroid is based on lower than average level of stable iodine in environment
- Milk is produced where it is consumed
- No remediation or limits on ingestion doses are considered

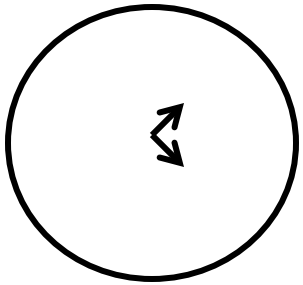
MACCS2 assumptions

- Annual release occurs in 1 hr
- Exposure is by consumption of milk and other foodstuffs
  - Typical food basket
  - 0.27 l/dy milk for adults
- Deposition velocity is 0.5 cm/s
- I-129 in thyroid is based on metabolic model used in ICRP-72 and FGR-13
- Milk and other food are produced where they are consumed
- No remediation or limits on ingestion doses are treated

Averaging Over Annual Weather Data Is Equivalent to a Continuous, Annual Release

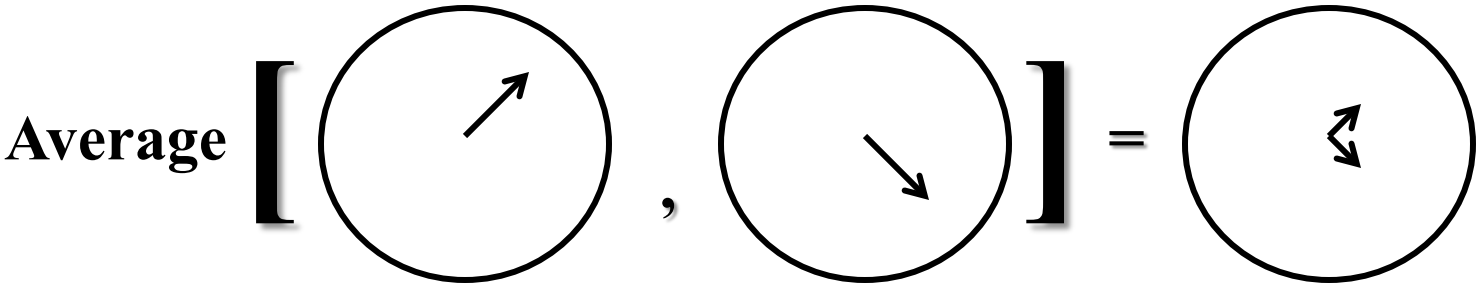
Continuous Release (EPA)

- Fraction of annual release travels in a direction (based on wind rose)



1-Hour Release (MACCS2)

- Entire annual release travels in a direction in a single weather trial
- Fraction of the weather trials travel in a direction (based on wind rose)
- Average is the same for any result that behaves linearly



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Other MACCS2 Assumptions

- **Calculations based on recycling plant collocated with Sequoyah NPP**
  - **Weather data**
  - **Population (about 1 million within 80 km)**
  - **Other site information (30% of land used for farming, etc.)**
- **Standard choices for**
  - **Atmospheric transport and dispersion**
  - **Resuspension of deposited aerosols**
  - **Food chain parameters**

Food Basket Assumptions

Food Type	Consumption Rate (kg/yr) EPA	MACCS2
Milk	188	100
Grains		69
Leafy Vegetables		11
Roots		26
Fruits		46
Legumes		26
Beef		59
Poultry		9
Other Meat		10

- **EPA analysis only considers doses from milk**
- **MACCS2 normally considers a typical food basket**
  - **Based on typical diet at the time of NUREG-1150**

Population Dose Comparison

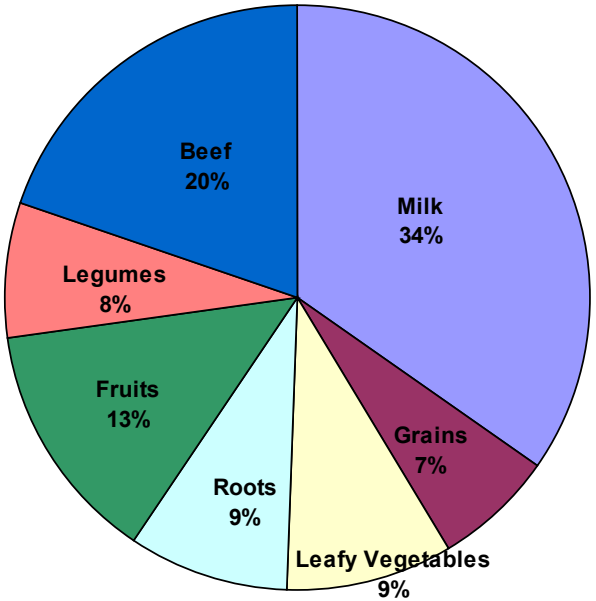
Dose Pathway	Annual Dose (Person-rem) EPA Effective	EPA Thyroid	MACCS2 without Ingestion Limits Effective	MACCS2 without Ingestion Limits Thyroid
Direct Inhalation			9	179
Groundshine			36	42
Resuspension Inhalation			12	236
Ingestion		27000	562	11194
Milk		27000	194	3873
Grains			38	765
Leafy Vegetables			51	1026
Roots			50	1002
Fruits			74	1467
Legumes			42	842
Beef			111	2216
Poultry			0	3
Other Meat			1	0

- Table compares EPA and MACCS2 population doses assuming iodine DF = 1
- Compared with the EPA analysis
  - Milk dose is a factor of 8 lower
  - Ingestion dose is a factor of 2.5 lower

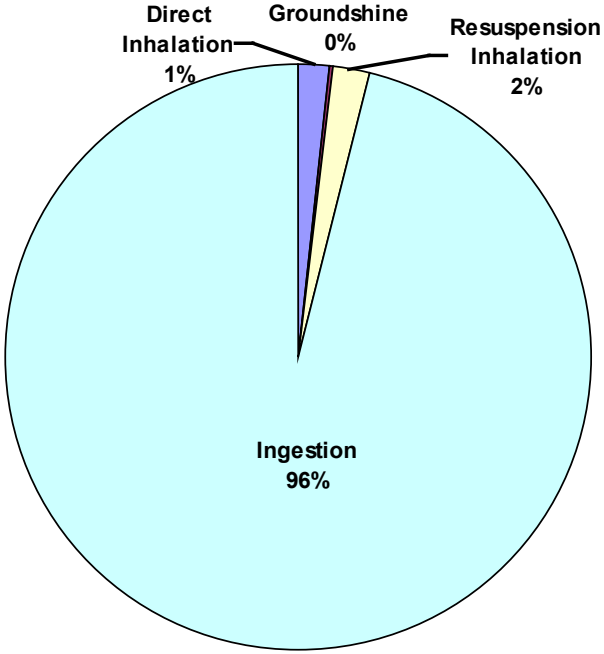
Evaluation of Dose Pathways

- Ingestion dominates the thyroid dose pathways
- Milk comprises about one-third of the ingestion dose

Relative Contribution From Food Types

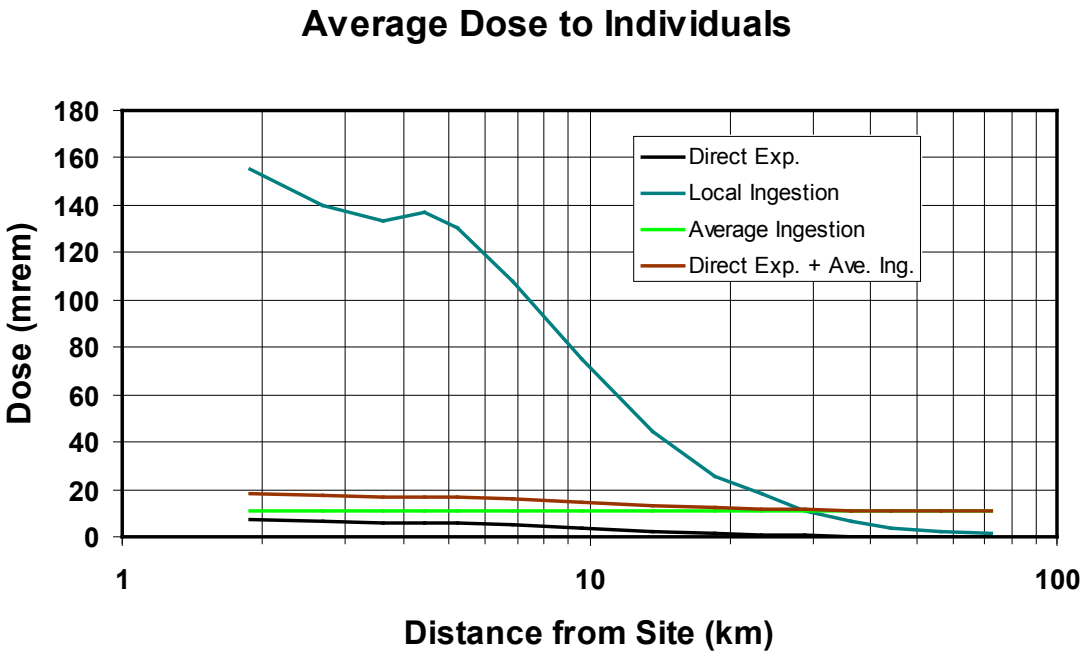


Relative Contribution From Dose Pathways



Dose at Site Boundary

- **MACCS2 ingestion dose at site boundary**
  - **140 mrem if food is grown at site boundary**
  - **11 mrem if food is grown within 80 km**



Adult Thyroid Dose at Site Boundary	*Dose (mrem/yr)*
EPA	400
MACCS2 Direct Exposure	6
MACCS2 Local Ingestion	140
MACCS2 Average Ingestion	11
MACCS2 Dir. Exp. Plus Ave. Ing.	17

Summary

- Sandia has reassessed and confirmed EPA analysis
- Some EPA assumptions are conservative
- EPA estimates of I-129 regional doses
  - Reasonable for population dose
  - Conservative at site boundary because food is assumed to be produced there
- EPA restrictions on site boundary dose (25 mrem/yr) could be achieved with DF =1 for I-129