Summary of Child Ingestion Rate Studies

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Exposure Factors Handbook
Recommended Ingestion Rates

Table 5-1. Recommended Values for Daily Soil, Dust, and Soil + Dust Ingestion (mg/day)								
	Soil[a]				Dust[b]		Soil + Dust	
			High End					
Age Group	General Population Central Tendency [c]	General Population Upper Percentile [d]	Soil-Pica[e]	Geophagy [f]	General Population Central Tendency [g]	General Population Upper Percentile [h]	General Population Central Tendency [c]	General Population Upper Percentile [h]
6 weeks to <1 year	30				30		60	
1 to <6 years	50		1,000	50,000	60		100[i]	
3 to <6 years		200				100		200
6 to <21 years	50		1,000	50,000	60		100[i]	
Adult	20[j]			50,000	30[j]		50	

[a] Includes soil and outdoor settled dust.
[b] Includes indoor settled dust only.
[c] Davis and Mirick (2006); Hogan et al. (1998); Davis et al. (1990); van Wijnen et al. (1990); Calabrese and Stanek (1995).
[d] Özkaynak et al. (2011); Stanek and Calabrese (1995b); rounded to one significant figure.
[e] ATSDR (2001); Stanek et al. (1998); Calabrese et al. (1997b; 1997a; 1991; 1989); Calabrese and Stanek (1993); Barnes (1990); Wong (1988); Vermeer and Frate (1979).
[f] Vermeer and Frate (1979).
[g] Hogan et al. (1998).
[h] Özkaynak et al. (2011); rounded to one significant figure.
[i] Total soil and dust ingestion rate is 110 mg/day; rounded to one significant figure it is 100 mg/day.
[j] Estimates of soil and dust were derived from the soil + dust and assuming 45% soil and 55% dust.

Study Methodologies

1. Tracer element-based, mass balance
2. Biokinetic modeling – lead (Pb) study
   - Integrated Exposure Uptake Biokinetic Model (IEUBK)
3. Activity pattern
   - EPA's probabilistic Stochastic Human Exposure Dose Simulation (SHEDS) model
   - Macroactivity model (Ozkaynak et al.)
4. Survey response

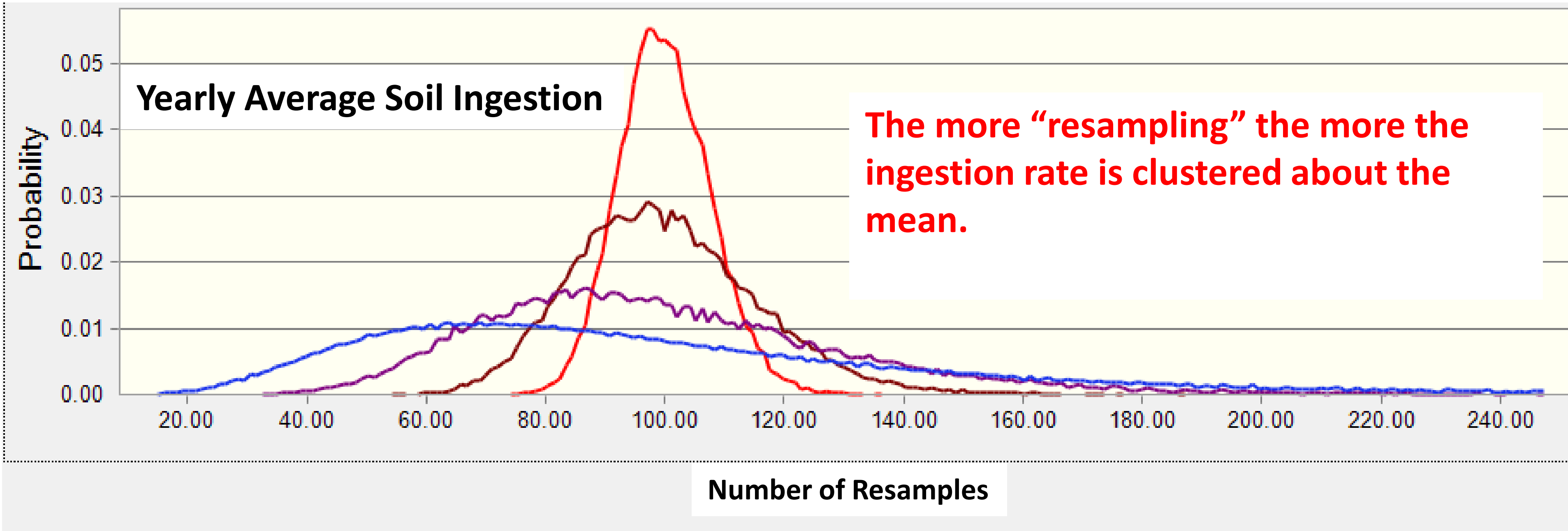
Tracer Element Studies

- Six key studies conducted
- Multiple tracer elements (e.g., Al, Si, Ti, Y, Zr, Ba, Mn, V)
  - Variability depending on the tracer(s)
- Mass balance approach
- Children aged ~ 6 months to 13 years of age
- Many underlying assumptions/issues
  - Metabolism, absorption, recovery timing, ingestion from other sources, short study duration, biased population

Ingestion Rate - Implementation

How do we extrapolate from a short-term study to estimate long-term ingestions rate?

- Many studies only follow subjects for 1 to 2 weeks
- Stanek and Calabrese caution that this can overestimate long-term rates.



Calabrese and Stanek, 1995 (reanalysis of four earlier studies): Best Tracer Method

- Non-soil sources of tracer elements
- BTM uses Food/Soil (F/S) tracer concentration ratios to correct for errors caused by misalignment of tracer input and outputs and ingestion of non-food/non-soil sources
- F/S ratio is the tracer concentration present in duplicate food and soil tracer concentration where children (or adults) spend their time.

Table 5-19. Distribution of Average (mean) Daily Soil Ingestion Estimates per Child for 64 Children[a] (mg/day)

Type of Estimate	Overall	Al	Ba	Mn	Si	Ti	V	Y	Zr
Number of Samples	64	64	33	19	63	56	52	61	62
Mean	179	122	655	1,053	139	271	112	165	23
25[th] Percentile	10	10	28	35	5	8	8	0	0
50[th] Percentile	45	19	65	121	32	31	47	15	15
75[th] Percentile	88	73	260	319	94	93	177	47	41
90[th] Percentile	186	131	470	478	206	154	340	105	87
95[th] Percentile	208	254	518	17,374	224	279	398	144	117
Maximum	7,703	4,692	17,991	17,374	4,975	12,055	845	8,976	208

[a] For each child, estimates of soil ingestion were formed on days 4–8 and the mean of these estimates was then evaluated for each child. The values in the column "overall" correspond to percentiles of the distribution of these means over the 64 children. When specific trace elements were not excluded via the relative standard deviation criteria, estimates of soil ingestion based on the specific trace element were formed for 108 days for each subject. The mean soil ingestion estimate was again evaluated. The distribution of these means for specific trace elements is shown.

Source: Stanek and Calabrese (1995a).

Source:

US EPA 2011, *Exposure Factors Handbook*

Ozkaynak et al. 2011 (SHEDS model)

Table II. Predicted Soil and Dust Ingestion Rates (mg/day)

Pathway	*n*	Mean	*SD*	p50	p75	p95
Dust ingestion from HM	1,000	19.80	36.54	8.39	21.29	73.74
Soil ingestion from HM	1,000	40.96	78.29	15.34	44.85	175.60
Dust ingestion from OM	1,000	6.85	14.41	2.41	7.43	27.23
Total ingestion	1,000	67.61	90.62	37.75	83.18	224.02

Note: HM is hand-to-mouth, OM is object-to-mouth.

Source: Modified from

Ozkaynak et al., 2011, *Modeled Estimates of Soil and Dust Ingestion Rates for Children*

1. Soil Ingestion Rates for Young Children. Our most recent study of soil ingestion rates in young children (Stanek and Calabrese, 2000) included several improvements over our prior studies. These included: 1) a relatively large study group (64 children); 2) improved particle size measurements that focused attention on soil of smaller particle size; 3) a longer study duration (365 days); 4) the use of a relevant age group (1 to 4 year old children); 5) use of a random sample of the population for that age group; and 6) better control for input/output error. The results of this study showed a 95th percentile soil ingestion rate of 106 mg/day (when evaluated over a year), a median (50th percentile) ingestion rate of 17 mg/day, and an arithmetic average ingestion rate of 31 mg/day. Based on these results, I recommend that the most appropriate soil ingestion rates to use for chronic exposures to young children would be an upper bound rate of 100 mg/day (based on the year-long 95th percentile value from our study) and a central tendency estimate of 20 mg/day (based on the median value from our study).

Letter from Dr. Calabrese to US EPA (Region 1) providing his recommendations for an update of ingestion rates for children.

Most recent study- Wilson et al., 2013

Table 5. Calculated arithmetic mean soil ingestion rates

Age (year)	Arithmetic (mean) ± SD (p95)
1 to 5	20 ± 26 (64)
5 to 11	23 ± 32 (75)
11 to 18	1.5 ± 2.6 (5.3)

Notes:

1. SD : standard deviation
2. p95 : 95th percentile

Source: Modified from

Wilson et al., 2013, *Revisiting Dust and Soil Ingestion Rates Based on Hand-to-Mouth Transfer*

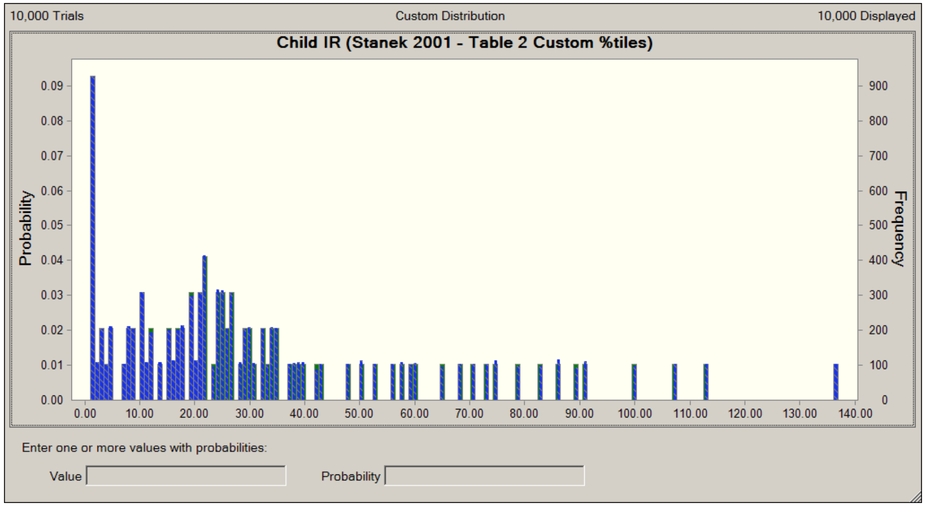
Ingestion Rate Alternatives

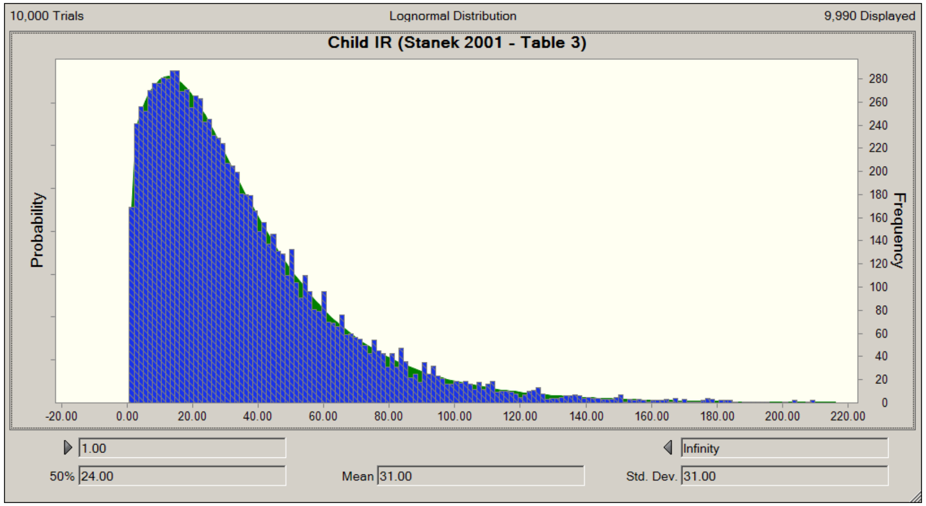
<u>Children</u>

Stanek et al. (2001) *Soil Ingestion Distributions for Monte Carlo Risk Assessment in Children*

BLUP – Best linear unbiased predictor

Child (mg/d): mean=31; median = 24; 95% = 91





What ingestion rate/distribution do we use?

How to extrapolate long-term exposure?

Deterministic Method SCTLs

$$\text{SCTL} = \frac{\overset{[1 \times 10^{-6}]}{[\text{Target Risk}]} \times \overset{[51.9\text{ kg}]}{[\text{Body Weight}]} \times [\text{Constants}]}{\underset{[120\text{ mg/day}]}{[\text{Soil Ingestion}]} \times \underset{[\text{EPA\#}]}{[\text{Toxicity}]} \times \underset{[350\text{ days/yr}]}{[\text{Exposure Freq}]} \times \underset{[30\text{ yrs}]}{[\text{Exposure Duration}]}}$$

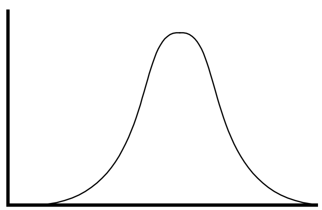
For each input a single value is selected such that the resulting risk estimate is the highest that is reasonably expected to occur (**R**easonably **M**aximum **E**xposure – **RME**).

In deterministic risk assessment the resulting output risk is a single value typically corresponding to a upper bound risk estimate.

2,3,7,8 TCDD – Residential SCTL = 0.000007 mg/kg soil
7 ng/kg (ppt)

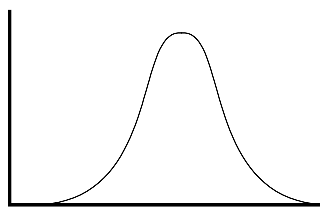
Probabilistic Risk Assessment

Rather than single value corresponding to conservative assumptions on exposure conditions - input assumptions are represented by a distribution of possible values.



distribution

x



distribution

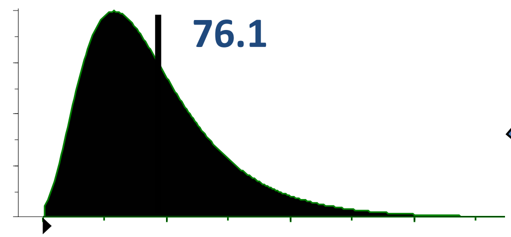
= **Distribution of Risks**

Note that 95%tile x 95%tile ≠ 95%tile

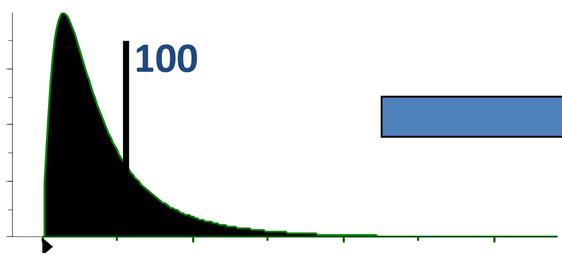
Monte Carlo Methods:
mathematically difficult or sometimes impossible to generate closed form analytical solutions

Probabilistic Risk Assessment

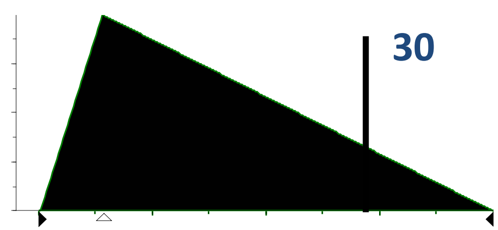
$$\text{SCTL} = \frac{[\text{Target Risk}] \times [\text{Body Weight}] \times [\text{Constants}]}{[\text{Soil Ingestion}] \times [\text{Toxicity}] \times [\text{Exposure Freq}] \times [\text{Exposure Duration}]}$$



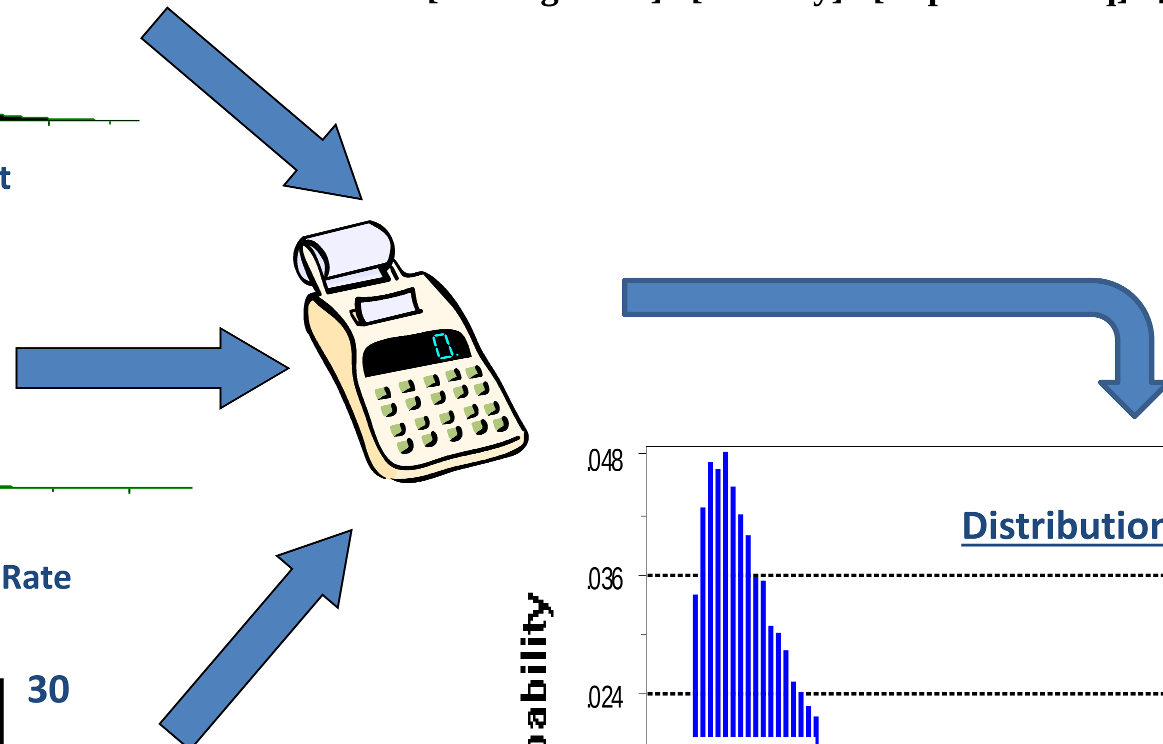
Body Weight

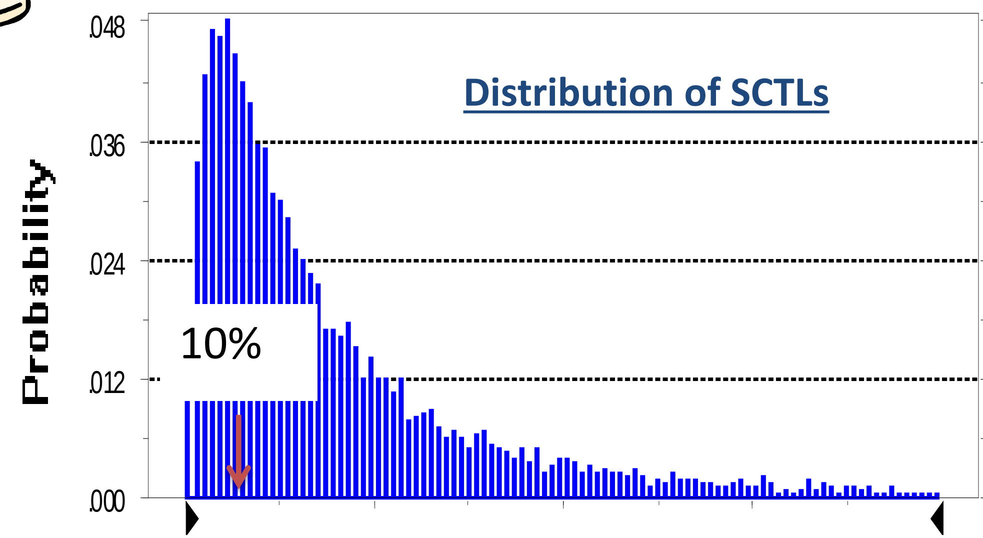


Soil Ingestion Rate



Exposure Duration





Back Calculation – Not Ideal for PRA

Deterministic is easy…

B x C = A ⟶ 2 x 3 = 6 ⟶ A / C = B

[Assume B = 2 and C = 3]

6 / 3 = 2

But assume B and C are ranges (simulates distributions)

B x C = A ⟶ (2 to 3) x (3 to 4) = (6 to 12)

Assume B = (2 to 3) and C = (3 to 4)

Rearrange and solve for B given A and C (above)…. Expect B = (2 to 3)

A / C = B ⟶ (6 to 12) / (3 to 4) = (6/4 to 12/3)

= (1.5 to 4)

~~2 to 3~~

can work around this by iterative forward calculations

Soil and Dust Ingestion: Children Central Tendency

- Hogan et al. 1998, *Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children: Empirical Comparisons with Epidemiologic Data*.
  - Used to derive recommended values for infant ingestion (< 12 months).
  - Used to derive recommended values for children ingestion (1 to 21 years).

Soil and Dust Ingestion: Children High End

- Ozkaynak et al., 2011, *Modeled Estimates of Soil and Dust Ingestion Rates for Children* and Calabrese and Stanek, 1995, *Resolving Intertracer Inconsistencies in Soil Ingestion Estimation*
  - Used to derive recommended values for infant ingestion (< 12 months).
  - Used to derive recommended values for children ingestion (1 to 21 years).

Soil and Dust Ingestion: Adults

- Davis and Mirick 2006, *Soil ingestion in children and adults in the same family study*
  - recommended central tendency value for soil + dust (note: there aren't any studies on adult ingestion of dust. Value was derived assuming 45% soil and 55% dust contribution)