Predicting exposure to soil Pb

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Overview

- Pb and its exposure pathways
- Tools for estimating exposure
  - SEGH model
  - CLEA model
  - IEUBK model
- Challenges for the Pb risk assessor

Pb and its exposure pathways

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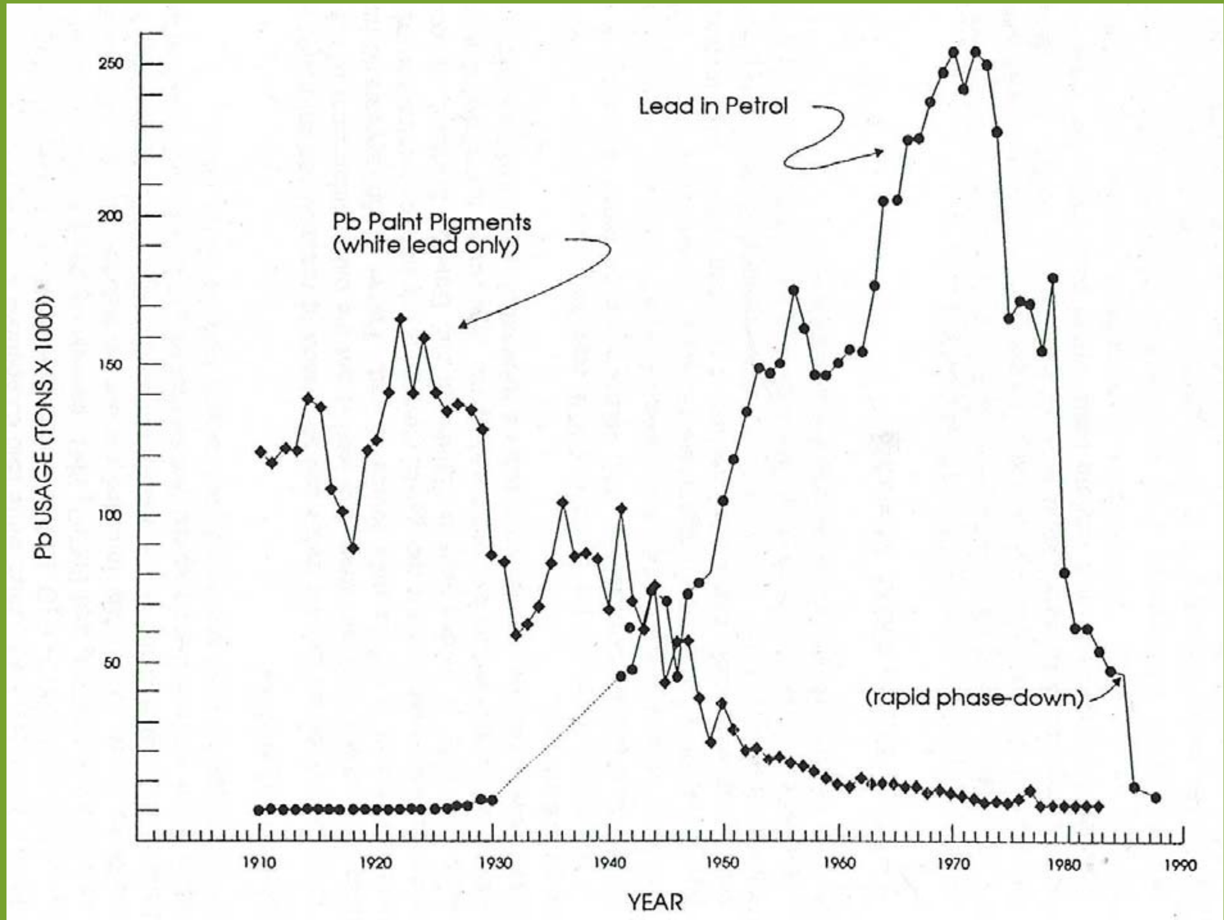
Pb in soils (sources)

- Key sources of soil Pb
  - Pb occurs naturally in soils, highly elevated in mineralised areas
  - Local and regional hot spots from mining and smelting
  - Urban diffuse pollution from Pb in petrol and paints

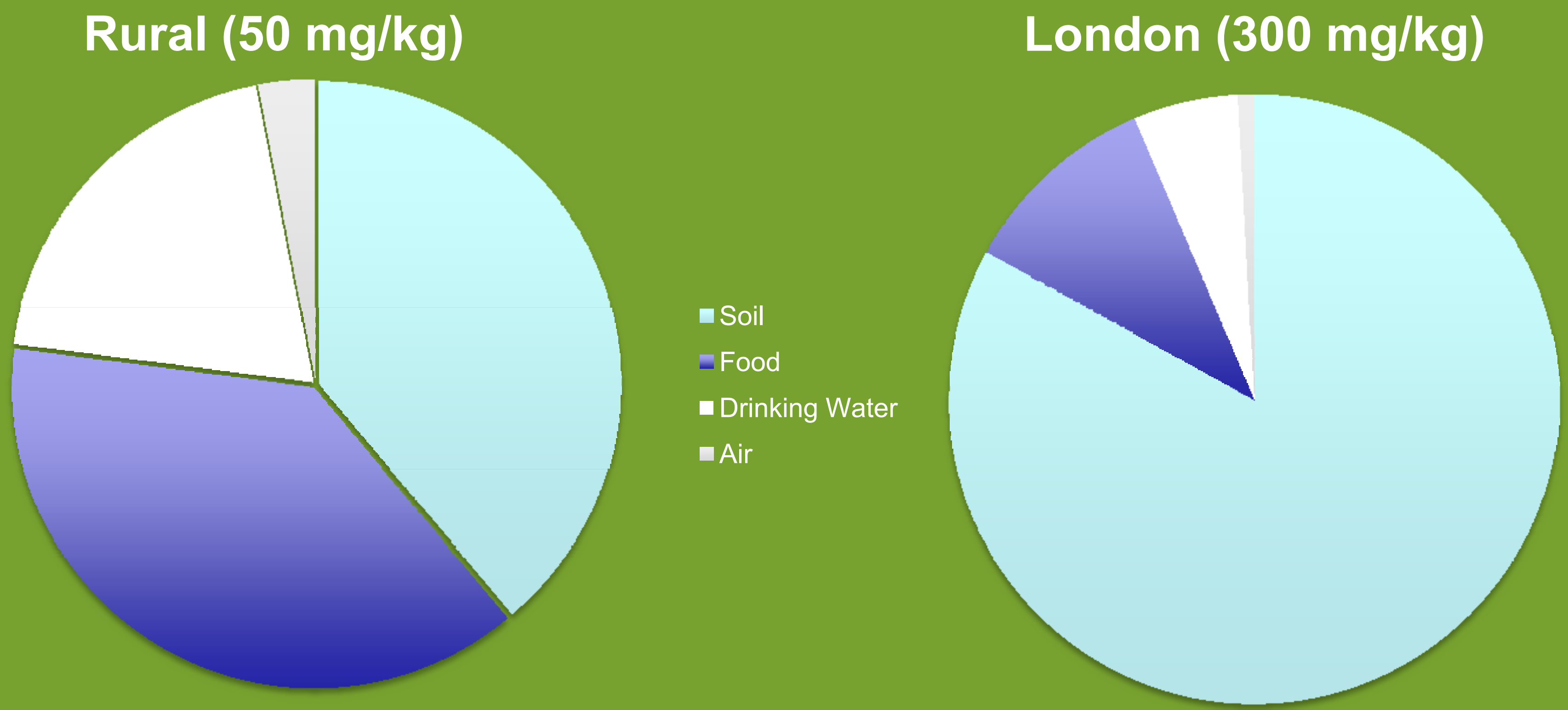


From SEGH (1993) *Lead in Soil* (eds. Wixson and Davies)

Pb in soils (speciation)

- Forms of Pb entering soil
  - Mining: sulphide (galena), and possibly sulphates and carbonates
  - Smelting: oxides, sulphates and possibly metallic
  - Combustion: oxides and halides
  - Paints: oxides, carbonates, sulphates, calcium plumbate, basic Pb silicate, Pb chromate, and Pb molybdate.
  - Firing ranges: metallic Pb
- Forms of Pb in soil
  - Weathered Pb: generally reduced solubility and availability
  - Largely adsorbed onto clays and organic matter and sparingly soluble
  - Metallic Pb will corrode over time to generally more soluble compounds , which later weather to largely insoluble salts
  - Decrease in pH will increase solubility

General exposure pathways



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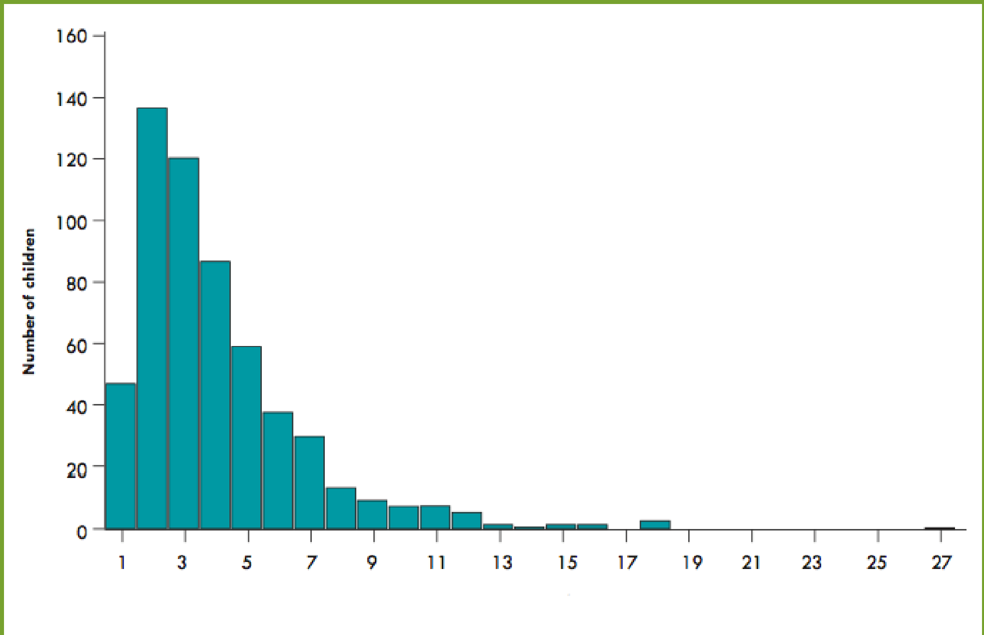
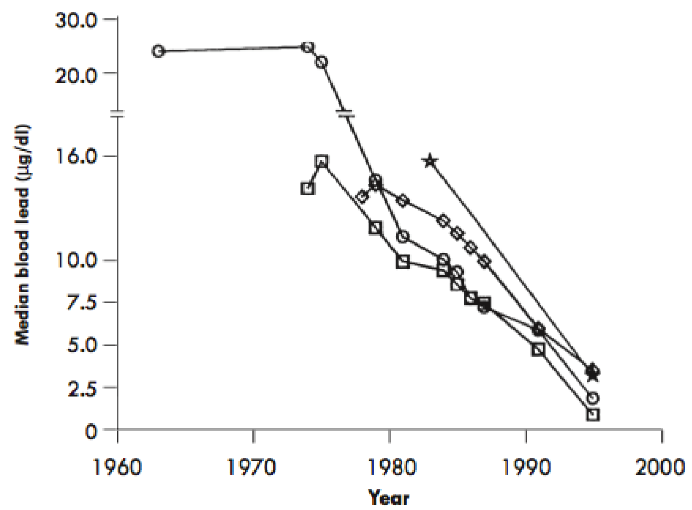
Blood Pb in children

Blood Pb levels of children in ALSPAC study



From IEH (1998) *Recent UK blood lead surveys,* Report R9

Median blood Pb levels in UK (1964 – 1995)



Children, ○ <16years; ★ <3 years; □ Adult females; ◇ Adult males

All analyses conducted by Great Ormond Street Hospital (1964–78) and Southampton General Hospital (1979–95). From Moncrieff *et al.* (1964); Elwood *et al.* (1977); Pocock *et al.* (1983); DoE (1981, 1983); Harvey *et al.* (1984); DoE (1990); Delves *et al.* (1996); and from the ALSPAC study (*Blood Lead Levels at Two and a Half Years,* Report to the DoE) and a study at a contaminated land site at Portsmouth, 1991

From IEH (1998) *Recent UK blood lead surveys,* Report R9

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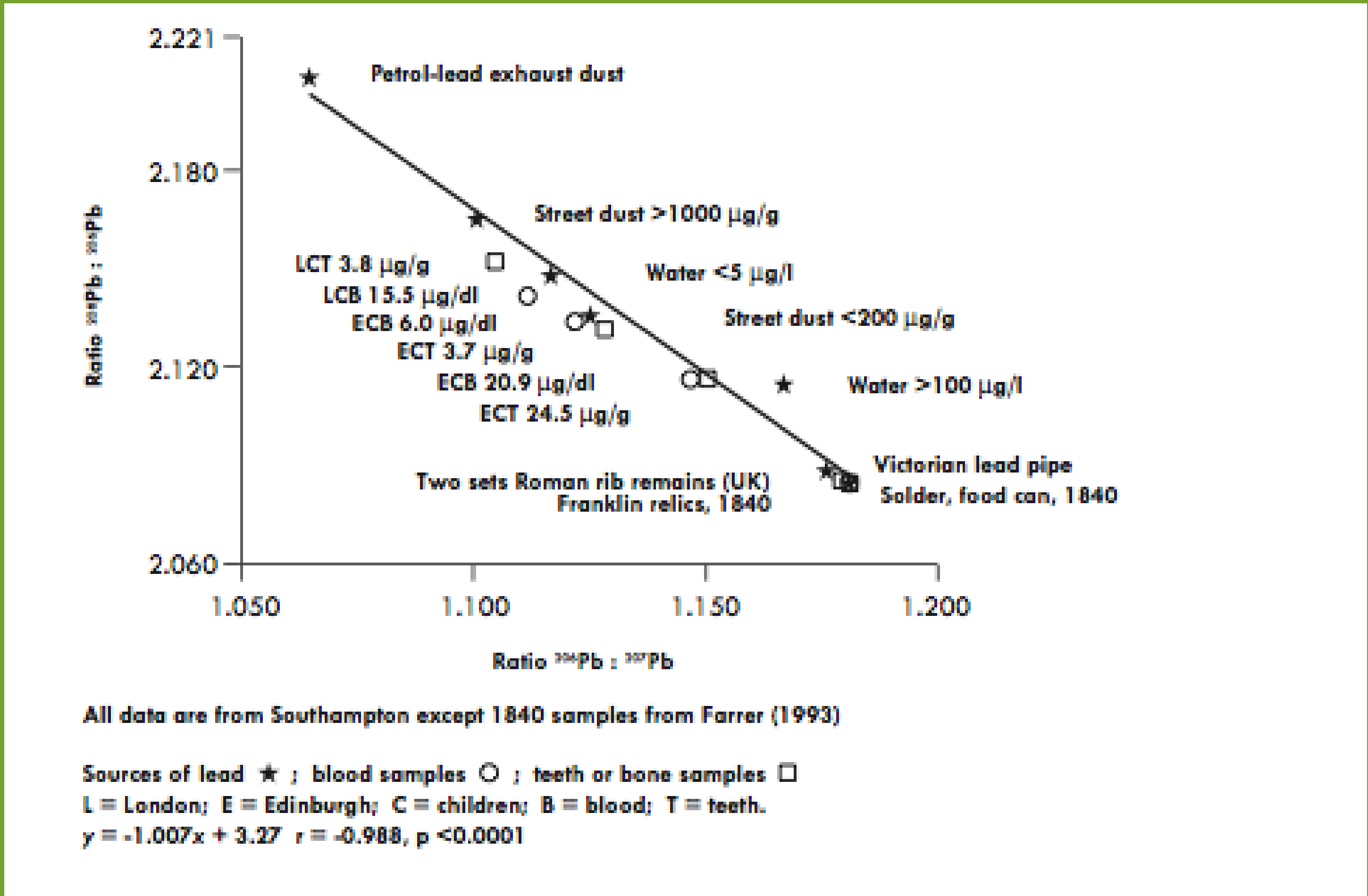
Pb isotope ratios

Stable Pb isotope ratios in body tissues and environmental sources of Pb



From IEH (1998) *Recent UK blood lead surveys,* Report R9

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Predicting soil Pb exposures

SEGH model

$$S = \frac{\frac{T}{G^{n}} - B}{\delta} \times 1{,}000$$

S is the soil or dust guideline (mg / kg)

T is the blood Pb target concentration (µg / dL) [10]

G is the GSD of blood Pb distribution [1.4]

B is background or baseline blood Pb level (µg / dL) [3.44]

n is the number of standard deviations corresponding to degree of protection required for the population at risk (-) [1.645]

δ is the slope or response of blood Pb versus soil and dust Pb relationship (µg / dL blood increase per 1000 µg / g of soil or dust Pb) [5]

SEGH model (empirical basis)

Study	Area	Soil/dust (µg/g)	Blood Pb (µg/dl)	Estimated δ
Bornschein *et al*. (1989)	Mining	172	6	2.2
Moffat (1989)	Mining	213 - 69,025	10 - 18	1.2
Phillips *et al*. (1989)	Mining	70 - 2,258	7 - 22	2.2
Rabinowitz and Bellinger (1988)	Urban	702	6	0.9
Laxen *et al*. (1987)	Urban	500 (d)	11	1.9
Milar and Mushak (1982)	Battery plant	250 - 3,000 (d)	18 - 44	9.0
Reeves *et al*. (1982)	Urban	24 - 842	12 - 19	5.0
Stark *et al*. (1982)	Urban	230 - 1,330	27	0.6, 2.0, 2.2
Roels *et al*. (1980)	Smelter	112 - 2,560 (d)	9 - 25	2.1, 3.5
Angle and McIntire (1979, 1982)	Urban	81 - 339	23 - 30	4.0, 6.8
Neri *et al*. (1978)	Smelter, Urban	225 - 1,800	19 - 29	7.6, 8.5
Schmitt *et al*. (1979)				4.6, 7.2
Watson *et al*. (1978)	Battery plant	718 - 2,239 (d)	21 - 32	6.8
Baker *et al*. (1977)	Smelter	500 - 5,500 (d)	22 - 68	8.6
Yankel *et al*. (1977)	Smelter	400 - 7,500	21 - 66	1.1
Barltrop *et al*. (1975)	Mining	420 - 13,970	21 - 29	2.3
Galke *et al*. (1975)	Urban	173 - 1,400	32 - 43	2.5
Shellstear *et al*. (1975)	Urban	150 - 1,950	18 - 25	3.9
Roberts *et al*. (1974)	Smelter, Urban	99 - 1,715	17 - 27	6.0

SEGH model (unpicking δ)

- Site-specific values require soil, dust and blood Pb data
- Qualitative factors for delta values are:

- Older children and well maintained vegetative cover
- Mine tailings (or chemical Pb forms with low bioavailability)
- Cleaner houses and more frequent hand washing
- Heavier textured soils

- Young children (1½ - 2 years old)
- Dusty conditions and bare soil
- Poor levels of hygiene
- Soluble Pb forms such as paint(or chemical Pb with high bioavailability)
- Light textured soils or those with low organic matter content

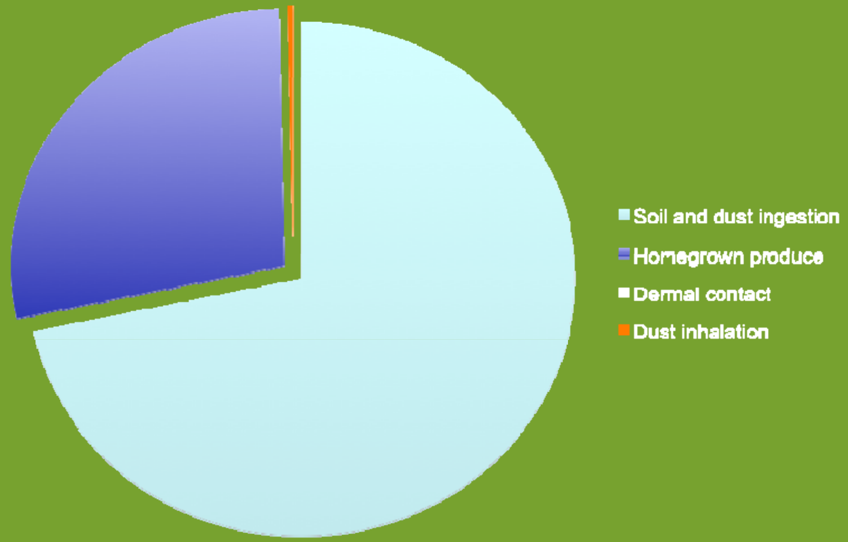
Comparative Summary

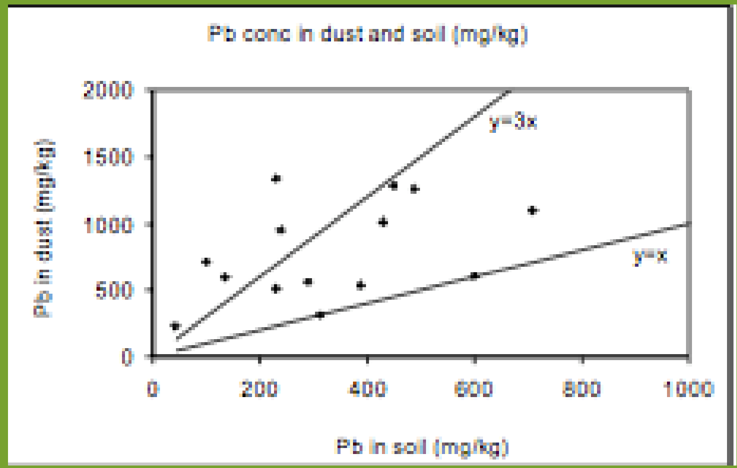
Factor	SEGH	CLEA	IEUBK
Easy to use	Y		
Uptake / intake	Uptake		
Exposure adjustments	N		
Bioavailability adjustments	N		
Uncertainty analysis	Y		

CLEA Software (v 1.06)

- Consistent with approach to other chemicals
- Many exposure assessment options (e.g. receptor sex / age, soil type, building type)
- Based primarily on estimated intake
- Limited ability to account for uptake

Estimated residential exposure

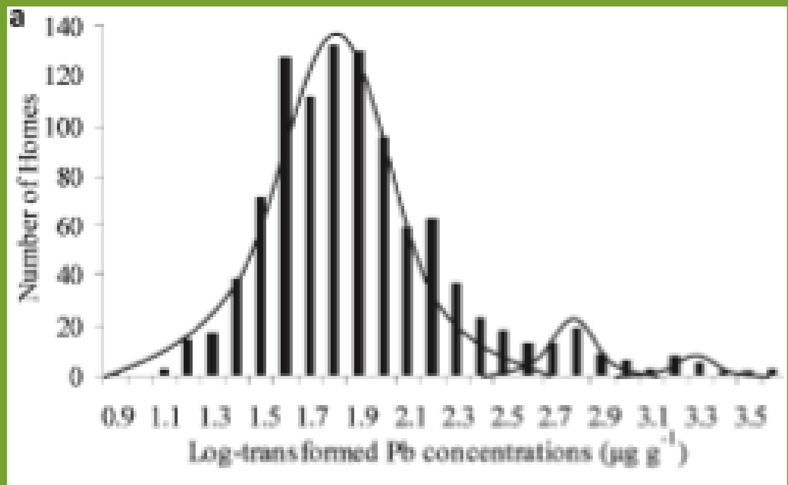




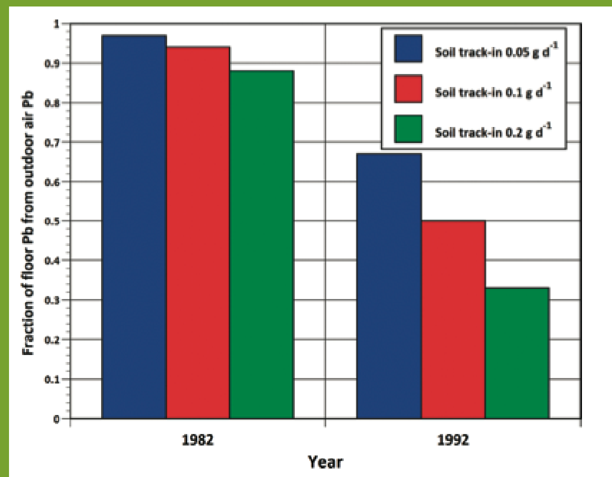
From Oomen and Lijzen (2004) *Relevancy of human exposure via house dust to contaminants lead and asbestos,* Report 711701037

Produce	GM CF (mg/kg FW per mg/kg DW)
Green veg	4.2×10^{-3} (371)
Root veg	4.0×10^{-3} (222)
Tuber veg	7.3×10^{-3} (41)
Herb fruit	7.5×10^{-4} (99)
Shrub fruit	2.0×10^{-4} (12)
Tree fruit	2.3×10^{-4} (19)

From EA (unpublished, 2009)



From Rasmussen *et al.* (2011) *Canadian house dust study: Lead bioaccessibility and speciation*



From Layton and Beamer (2009) *Migration of contaminated soil and airborne particulates to indoor dust.*

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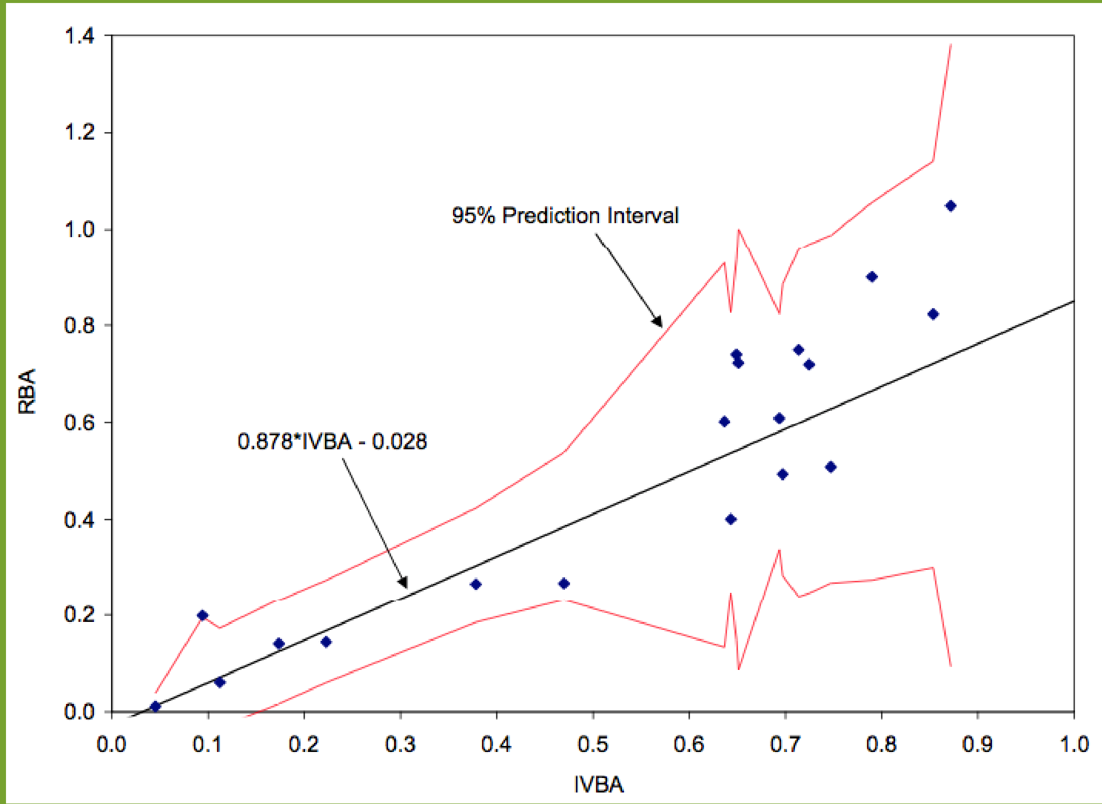
Bioavailability

- Relative Bioavailability (RBA) and bioaccessibility

$$RBA = \frac{ABA_{soil}}{ABA_{tox}}$$

$$RBA = \frac{F_B \times F_A \times F_H}{ABA_{tox}}$$



From US EPA (2007) *Estimation of relative bioavailability of lead in soil and soil-like materials using in vivo and in vitro methods*

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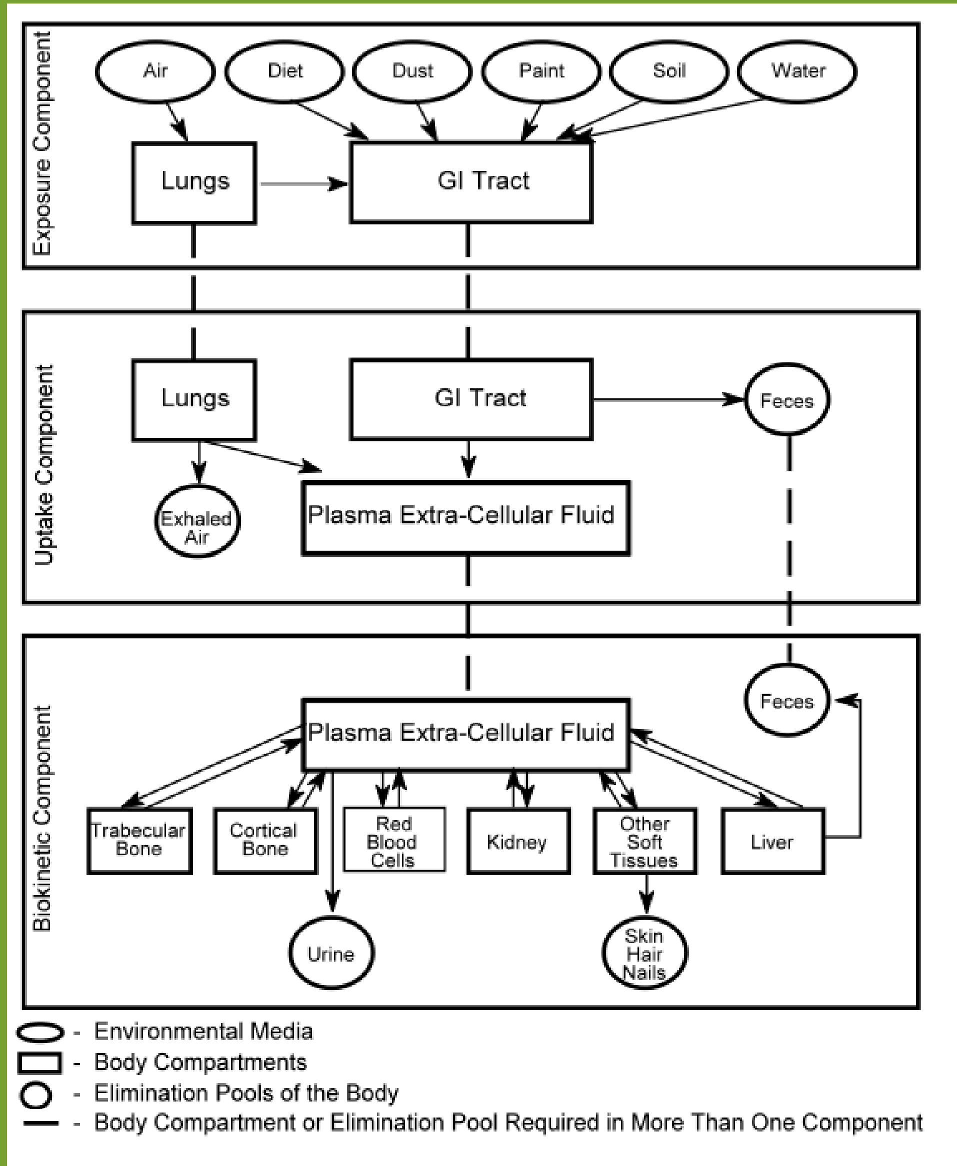
Comparative Summary

Factor	SEGH	CLEA	IEUBK
Easy to use	Y	N	
Uptake / intake	Uptake	Intake	
Exposure adjustments	N	Y	
Bioavailability adjustments	N	Y (limited)	
Uncertainty analysis	Y	N	

IEUBK model

- Most widely validated model for blood Pb in young children
- Multiple Pb sources considered via oral and inhalation routes
- Probabilistic model takes account of population blood Pb distributions



From US EPA (2007) *User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK)*

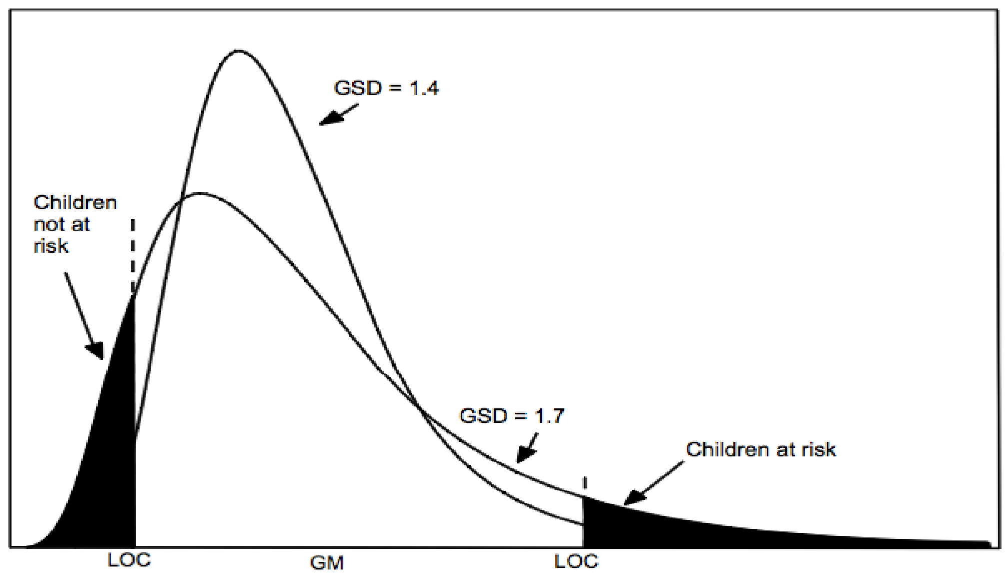
IEUBK model (parameters)

- More than 100 parameters, 46 may be changed by user
- Users are encouraged to enter site-specific Pb media concentrations
- Users are discouraged from changing other factors including mass fraction of soil to dust (MSD), bioavailability, geometric standard deviation, soil ingestion rates, and dietary data *unless* they have thorough understanding of the underlying methodologies

Parameter	IEUBK	CLEA
Body weight (kg)	14.6 (average)	13.3 (average)
Fraction of soil in indoor dust (-)	0.7	0.5
Soil and dust ingestion rate (mg/day)	113 (85 – 135)	100
Percent homegrown foods (%)	Site-specific	2 - 9
Pb levels in homegrown fruit and vegetables	Site-specific	Modeled or site-specific
ABA from diet / soil	50 / 30	-

IEUBK model (results and variability)

- Children with same contact with environmental Pb develop very different blood Pb levels
- Modelled as a log normal distribution



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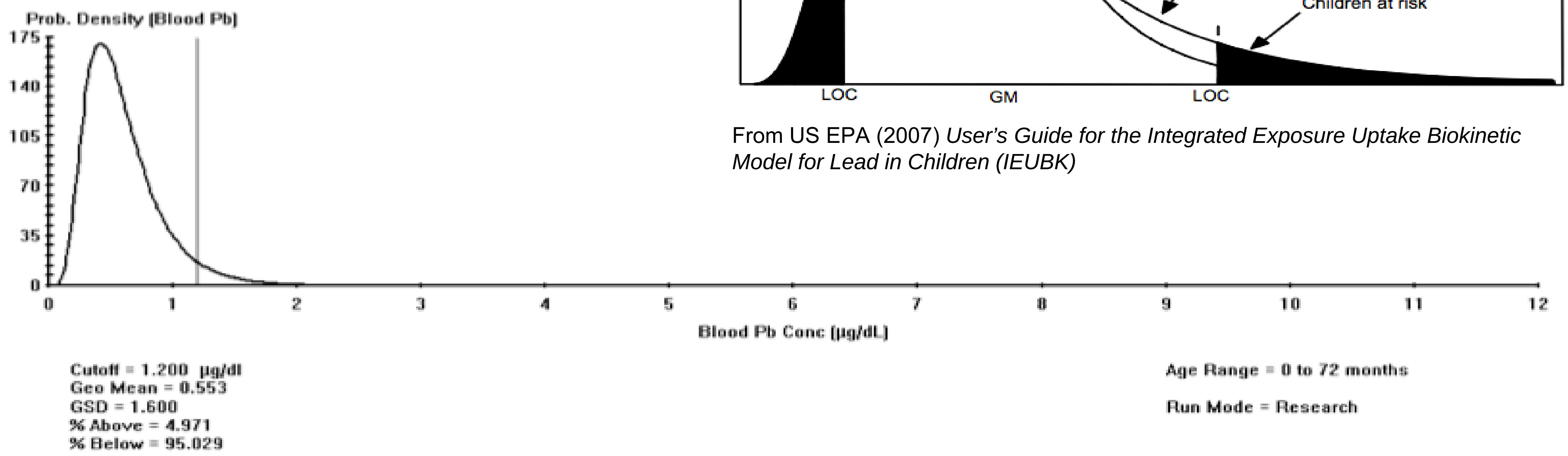

Comparative Summary

Factor	SEGH	CLEA	IEUBK
Easy to use	Y	N	N
Uptake / intake	Uptake	Intake	Uptake
Exposure adjustments	N	Y	Y (limited)
Bioavailability adjustments	N	Y (limited)	Y
Uncertainty analysis	Y	N	Y

Challenges for risk assessors

- Selecting an appropriate HCV
  - Uptake or intake based
  - Include or ignore background (non-soil sources)
  - Minimal risk level for IQ decrements
- Differentiating soil and indoor exposure components
- Communicating outcomes

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