Environmental Lead in the UK:

Could biomonitoring help to decide the true scale of human health impacts?



SOBRA/RSC Current Issues in Contaminated Land Burlington House, Piccadilly, London

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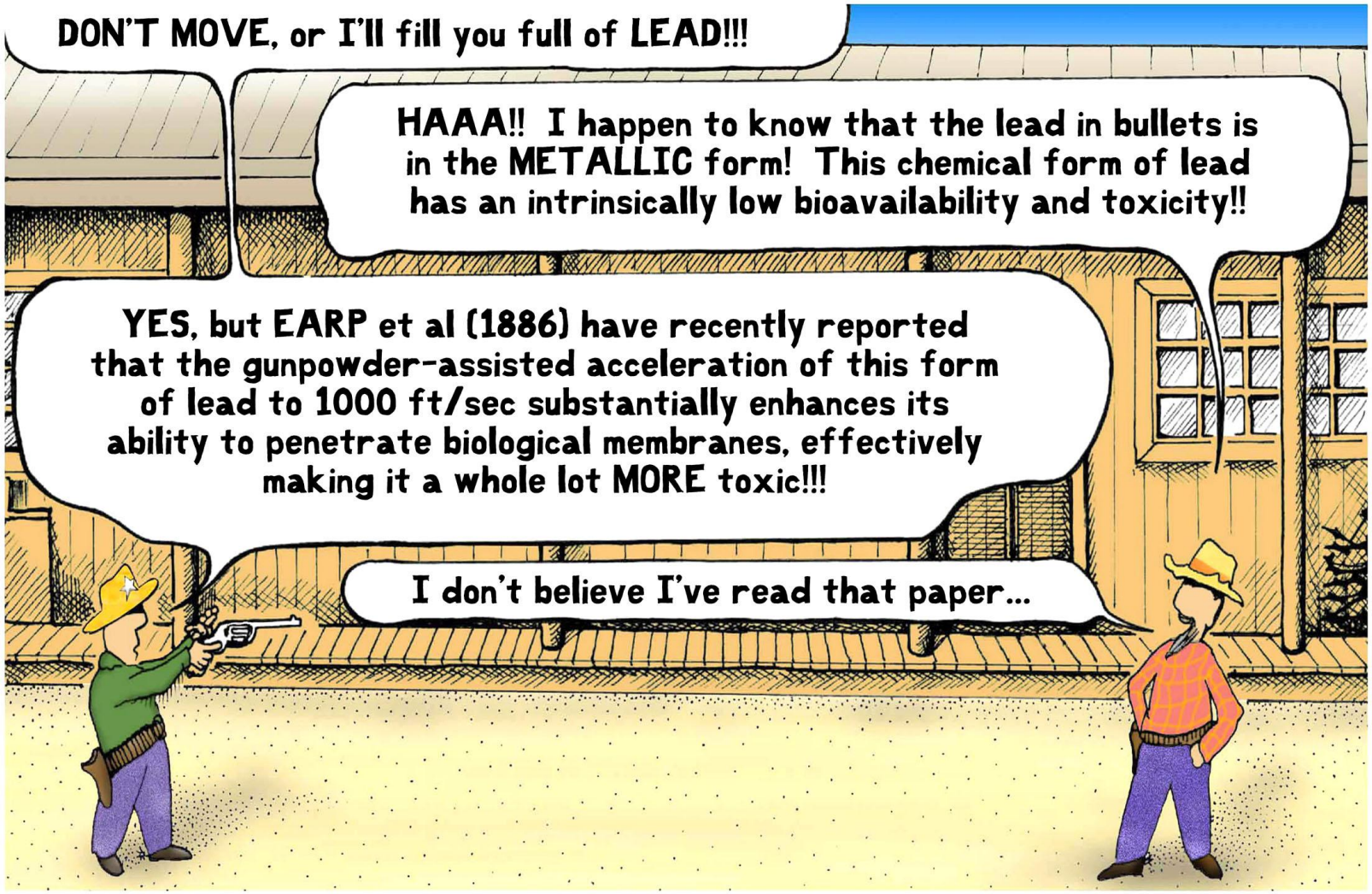
Health Concerns of Lead



ENVIRONMENTAL SCIENTISTS IN THE WILD WEST

Overview of Today's Talk

- Health concerns of lead
- What the health science tells us today?
- Potential sources of exposure to lead
- Modelling & uncertainty of Pb exposure
- A brief history of blood lead monitoring in the UK
- What are the options for the UK?

Recent Comprehensive Reviews of the Toxicology of Lead

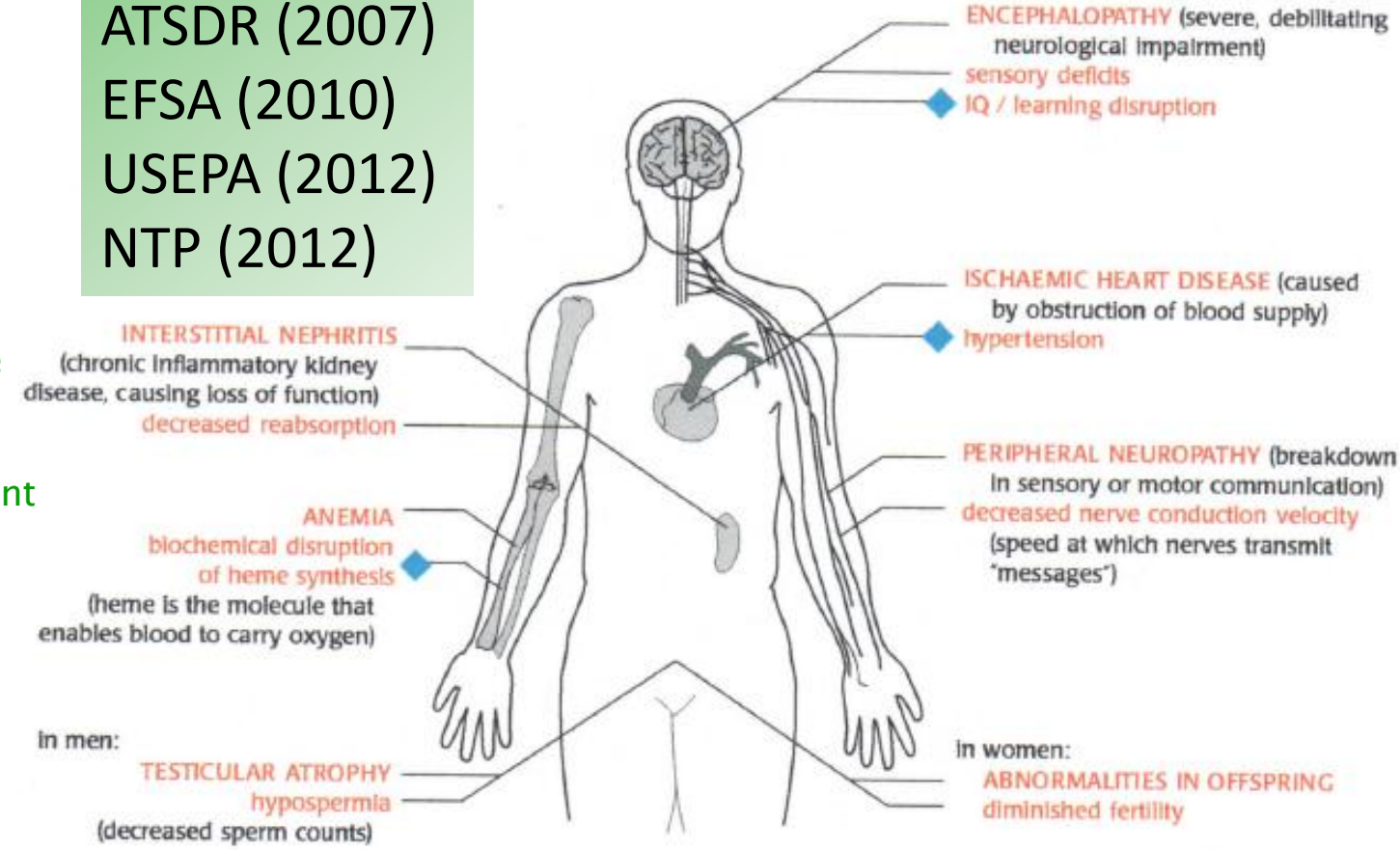
Acute Pb poisoning
>70 µg/dL blood

Chronic exposures
→ non-thresholded toxicity <10 µg/dL
no 'zero effect' dose

Children and pregnant women are sensitive subpopulations
- irreversible effects of exposure in the developing child

Detection of Pb in the blood & bone – health surveys e.g NHANES in USA; WHO in Europe

ATSDR (2007)
EFSA (2010)
USEPA (2012)
NTP (2012)



HIGHER DOSE – MORE SEVERE EFFECT
lower dose – less severe effect
◆ Extensive study shows NO evidence of 'threshold' or safe exposure

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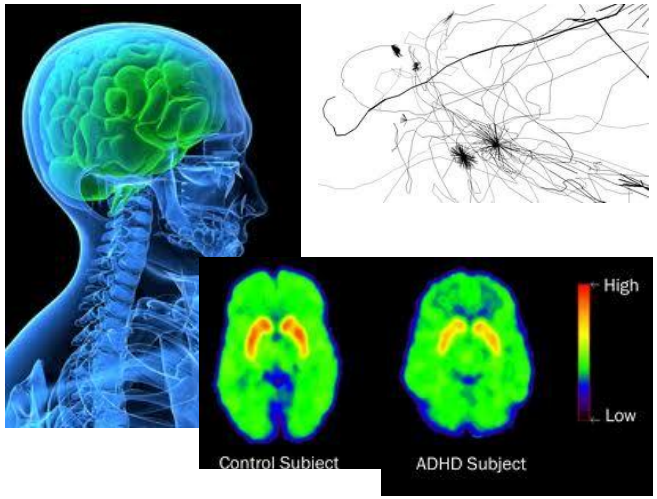
Benchmark Dose Modelling of the 3 most sensitive health concerns (as per EFSA 2010 modelling evaluations)

BMDL Value (µg/dL)	BMR	Effect	Human study/ Receptor
1.2	1 point reduction in IQ	Neurobehavioural	Child
1.5	10% increased incidence	Chronic kidney disease: glomerular filtration rates below 60 mL/min	Adult
3.6	1% increase above average 120 mm Hg systolic blood pressure	Cardiovascular	Adult

N.B. 3 key effects at similar blood Pb levels; BMDL – lowest 95% confidence limit

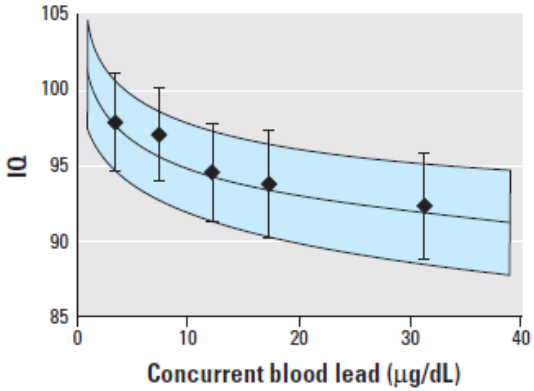
Health Concerns of Pb Exposure

- Neurobehavioural problems in children
  - is Pb exposure an under-the-radar issue in society?
  - can the effects of Pb exposure be de-convoluted from socio-economic factors leading to low IQ?

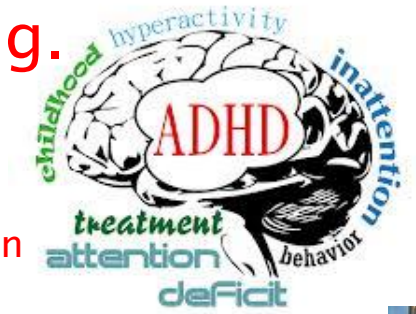


- Lanphear et al., 2005

Low-Level Environmental Lead Exposure and Children's Intellectual Function: An International Pooled Analysis. *Childrens Health*, 113, 894-899.



e.g.



Reductions in Intelligence Quotient (I.Q.)

"We conclude that environmental lead exposure in children who have maximal blood lead levels < 7.5 µg/dL is associated with intellectual deficits"

Lanphear et al., 2005

BMD modelling performed by Budtz-Jorgensen for EFSA

	BMR_{01} = a 1 point reduction in IQ on the full IQ scale		
Value	**Logarithmic model**	**Piecewise linear model**	**Linear model**
BMD_{01} (µg dL^{-1})	0.26	1.8	5.6
$BMDL_{01}$ (µg dL^{-1})	0.35	1.2	4.1
Fit			
All data	6563.4	6566.3	6571.6
Low dose data	3360.8	3362.4	3364.4

- **EFSA 2010 Opinion** **$BMDL_{01}$ = 1.2 µgPb/dL blood**

"chosen to account for the fact that a shift of the distribution of the IQ by 1 IQ point to lower values would have an impact on the socioeconomic status of the population and its productivity".

"a decrease of 1 IQ in children can be associated with a decrease of later productivity of about 2%" (Schwartz 1994; Grosse et al 2002).

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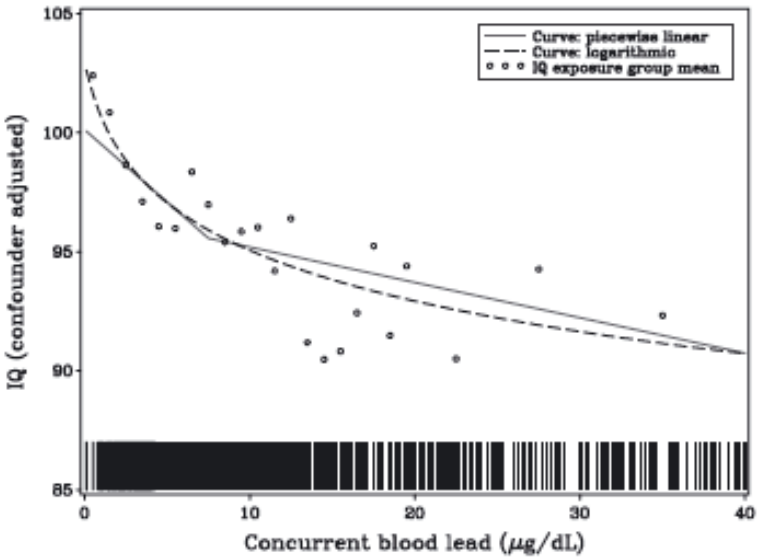
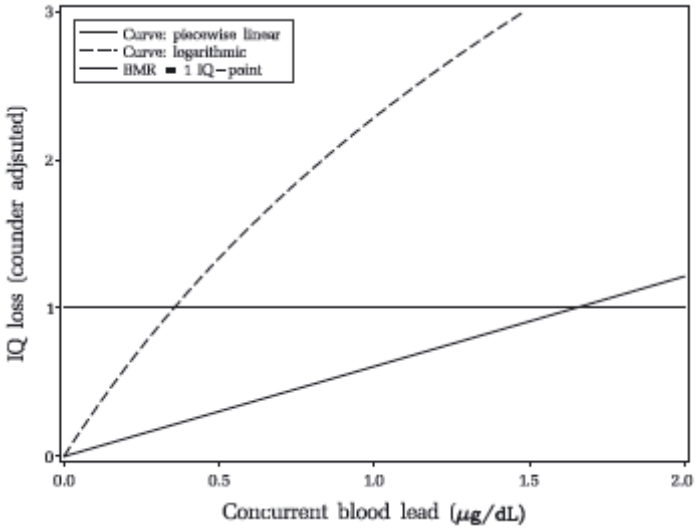
Budtz-Jorgensen et al., 2013

BMD modelling published and extended upon in
Budtz-Jorgensen et al., (2013) **An International Pooled Analysis for Obtaining a Benchmark Dose for Environmental Lead Exposure in Children.** *Risk Analysis, 33, 3.*





Further evidence of
no threshold effect

Lower confidence limits of about 0.1–1.0 µg/dL for the BPb exposure associated with a loss of one IQ point

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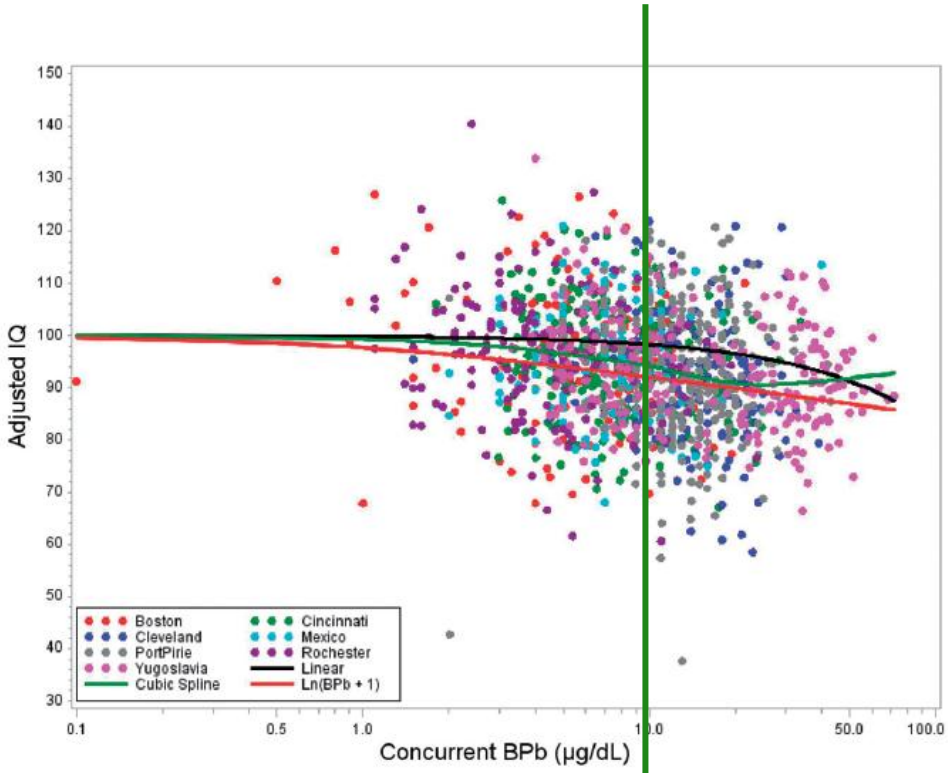
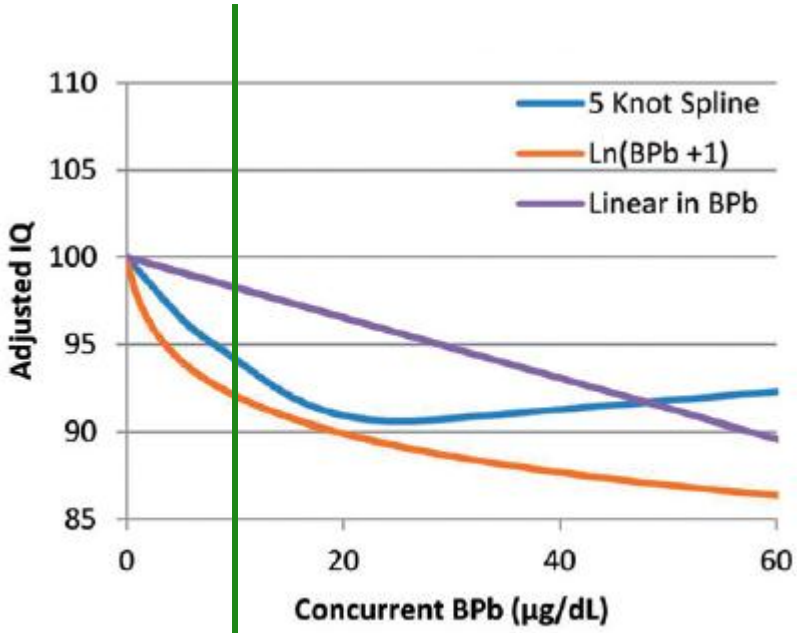
Crump et al., 2013 Crit Rev Toxicol, 2013; 43(9): 785–799.

A statistical re-evaluation of the data used in the Lanphear et al. (2005)





Withdrawn
2002 HCV 10 µg/dL

This work was conducted under contract awarded to ENVIRON International
by International Lead Zinc Research Organization (ILZRO)
Acknowledgement: Cynthia van Landingham (ENVIRON)

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Conclusions of Crump et al., 2013

- Confirms the major conclusions of Lanphear et al., 2005.

- Non-linear best statistical fit to data and no threshold of effect
  - higher impacts on IQ at lower doses

- Of the four Blood Pb measures
  (Concurrent, average lifetime, 24 hour, early stage)
  - only concurrent BPb showed a statistically significant BPb association with IQ

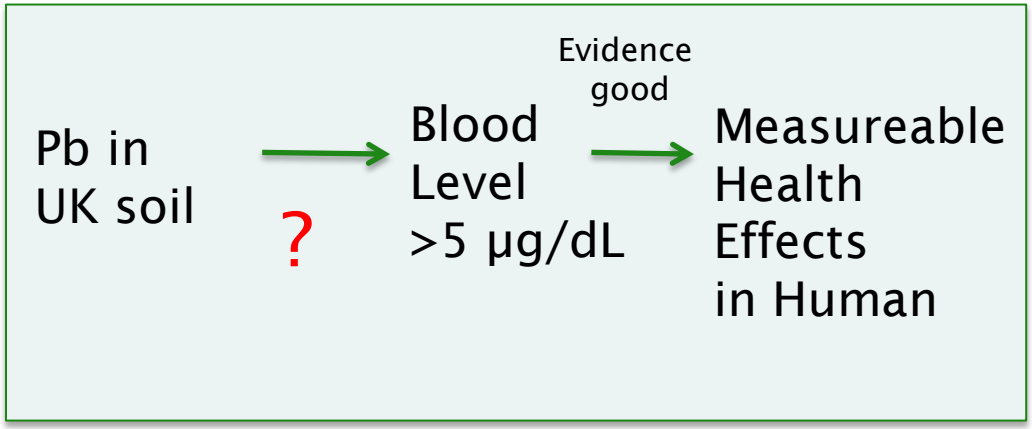
- Association between IQ reduction and Blood Pb
  - as low as 5 μg/dL concurrent

- The summary BPb data selected makes a considerable difference to the evidence for an association of BPb with IQ for low BPb levels (ie < 5 μg/dL)

What the health science tells us today

Toxicological quantitative evaluations for the three critical effects:

Neurobehavioural
Chronic kidney disease
Cardiovascular effects



suggests no threshold, and there could be real health concerns to be investigated further in populations of children and adults exposed chronically to blood lead levels higher than 5 µg dL^{-1}.

Potential Sources of Pb Exposure

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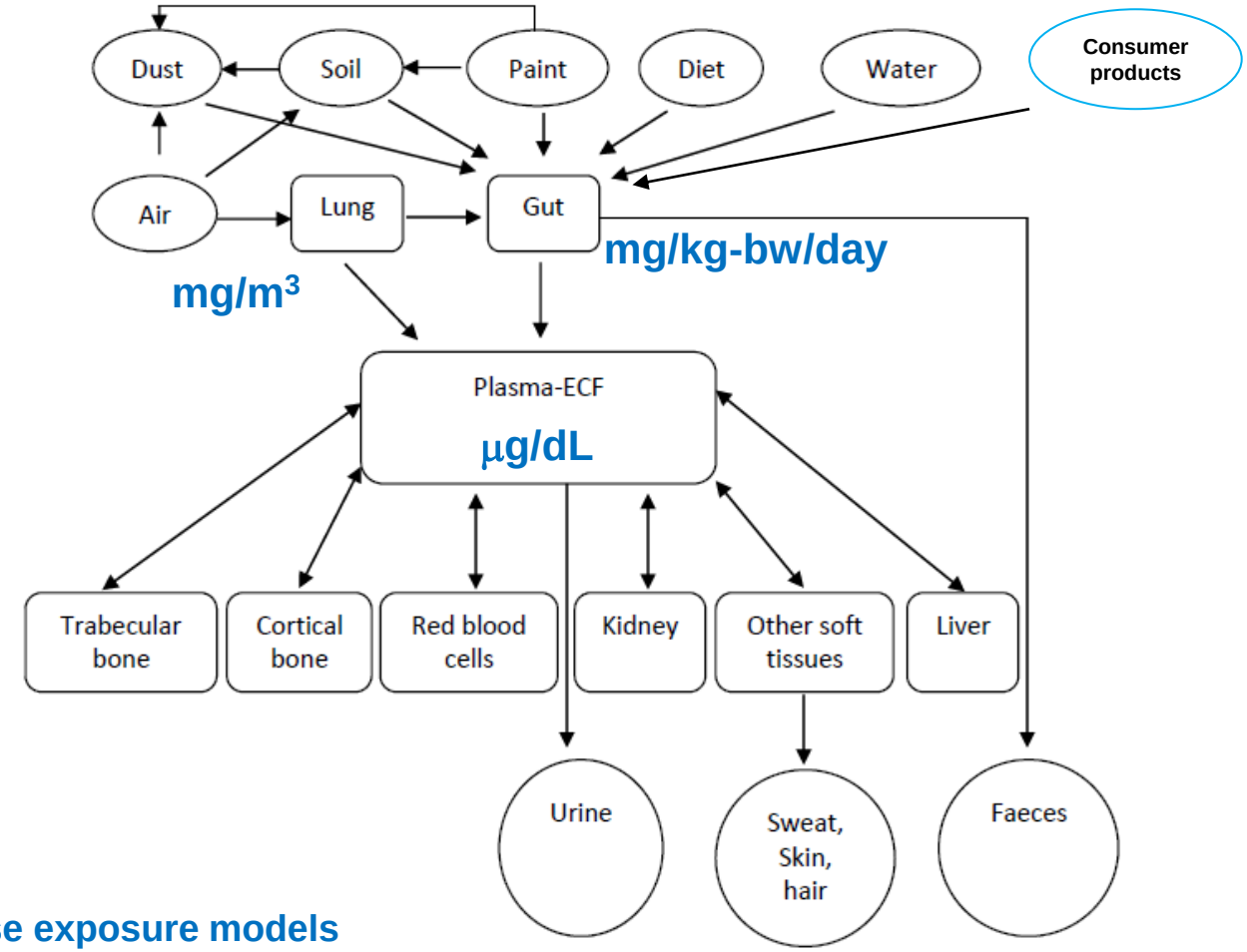
Potential Sources of Pb Exposure in Humans

Figure from White *et al.*, 1998, *Environmental Health Perspectives.* **106 (Suppl. 6):** 1513-1530

Cited in COT July 2013
'Statement on the potential risks from lead in the infant diet'

"…total exposure to lead is unlikely to pose a material risk to health in the large majority of UK infants. **However, there remains a concern that adverse effects could occur where concentrations of lead in water or soil are unusually high.**"



Use exposure models to obtain relevant metrics of human exposure

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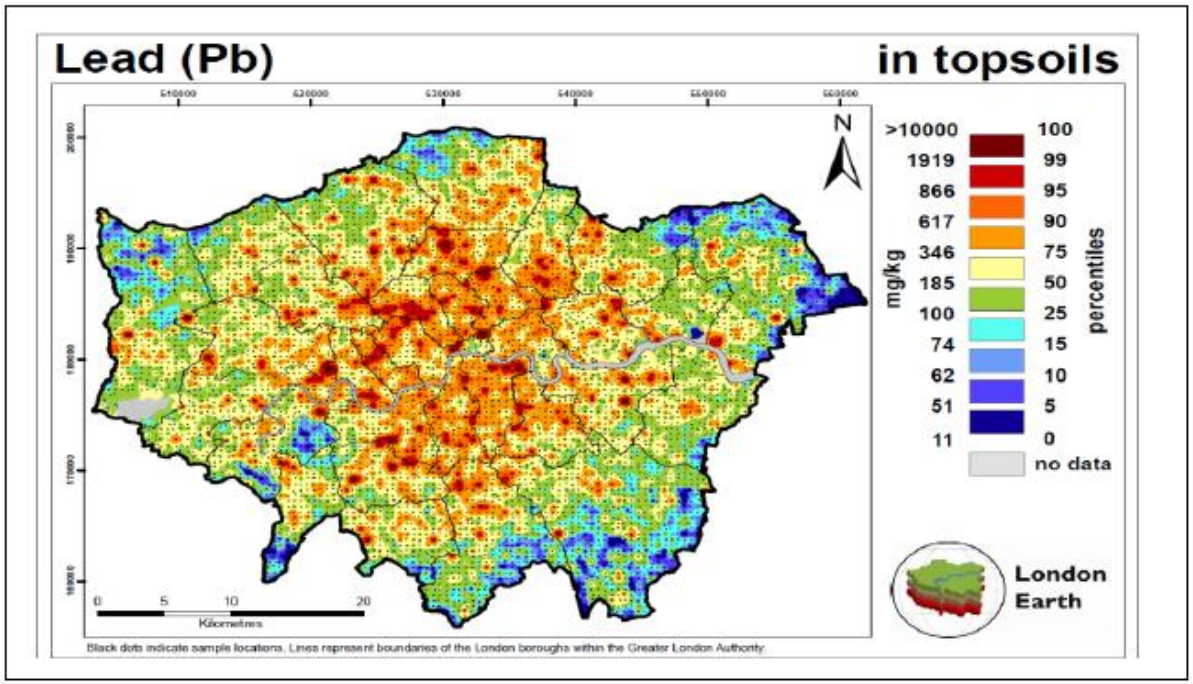
Pb in Urban London Soil – 2011 data

From page 8 of the SOBRA 2011 Lead workshop report

Table 6: Typical concentrations of lead in London soils

(all mg/kg)	No. Samples	Minimum	Median	Mean	Maximum
London	6288	11	185	301	>10,000



British Geological Survey (2011). London Earth: Lead in surface soils. G-BASE geochemical map, Keyworth, Nottingham, UK

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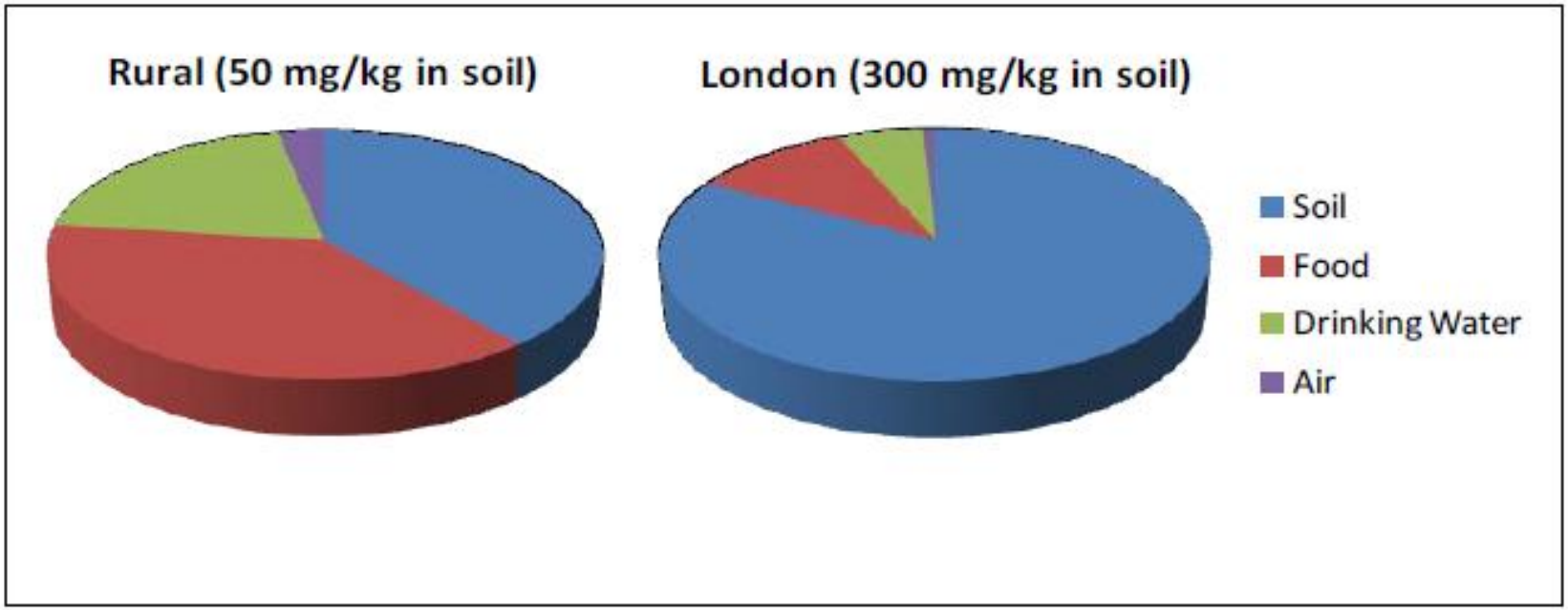
The relevance of source depending upon where you live

From page 19 of the SOBRA 2011 Lead workshop report relating to Ian Martin (EA) presentation

Box 9: Exposure contributions of lead in a rural vs an urban area



Multiple sources of exposure
Source-pathway-receptor link?

Modelling of Blood Lead Exposure

- IEUBK used to assess relationship between intake, uptake and blood lead for 0 to 7 yr old child
- Carlisle & Wade and USEPA Adult Lead Methodology (ALM) used to assess relationship between intake, uptake and blood lead for adult

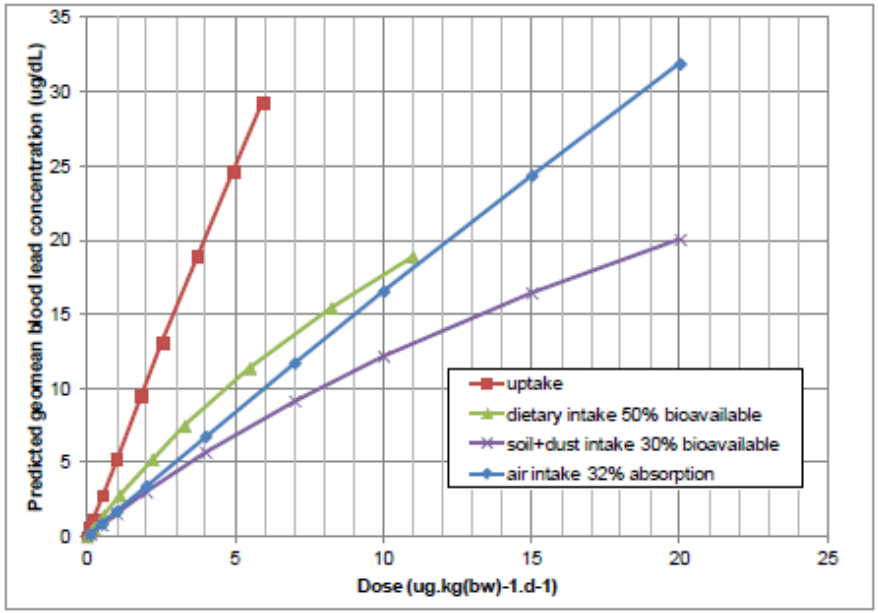


Figure from Defra C4SL project

Used to interconvert blood lead concentration and intake dose (mg/kg/day)

↓

CLEA model

Varying Degrees of Uncertainty in Models

Health criteria values – models of human studies at low dose

Multi-parametric exposure & kinetic models

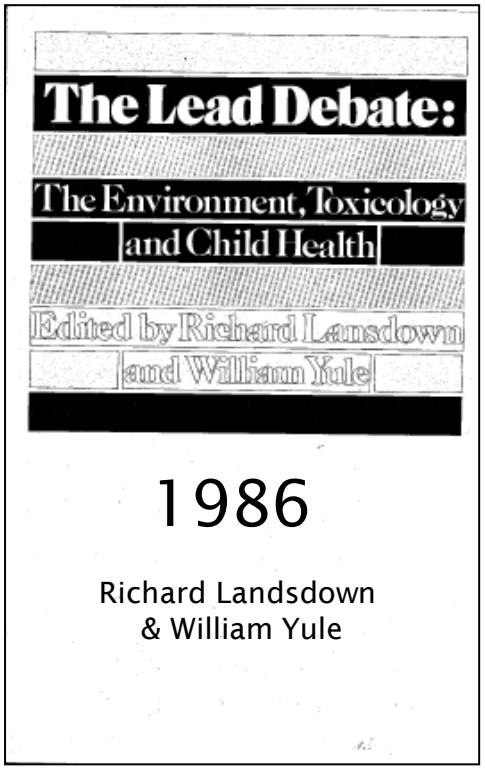
Assumptions about exposure scenarios → Model parameters

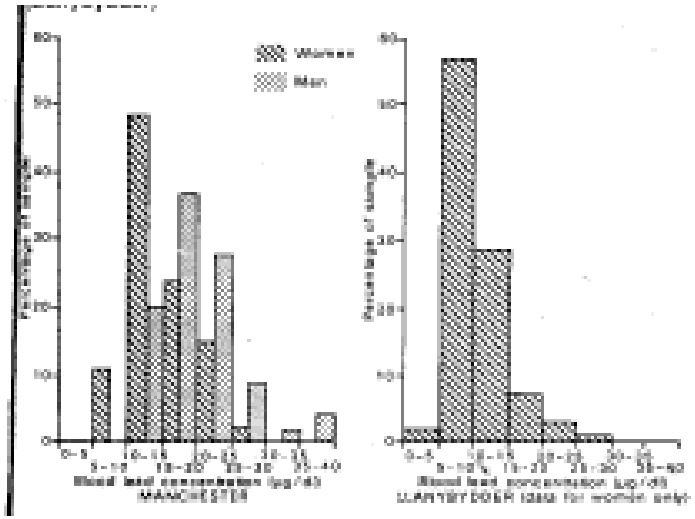
Assumptions on bioavailability/bioaccessibility

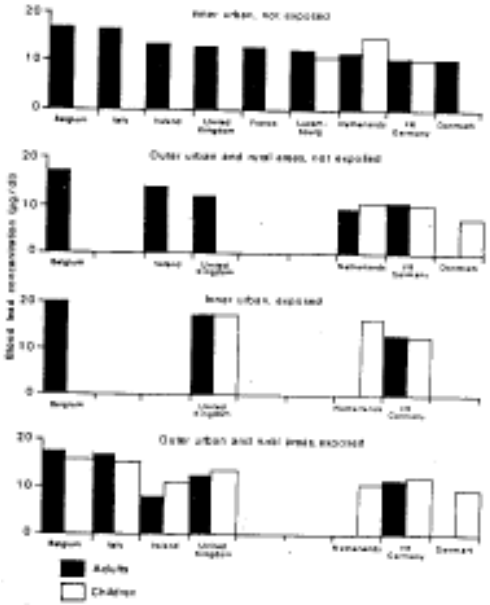
From the available science, the models and assumptions are the best we can do today

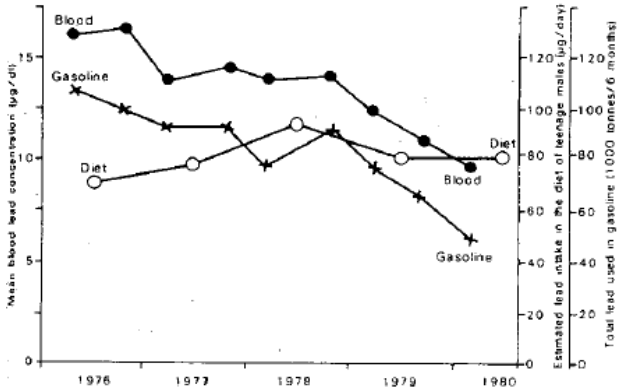
But predictive exposure models are not validated in terms of whether lead in soil transfers to UK children's blood in quantities predicted

A Brief History of UK Lead Monitoring









EEC Directive called for blood lead screening
UK studies in 1979 and 1981

UK Blood Lead Monitoring Programme 1984-1987
Dept of Environment – reduction of Pb in petrol

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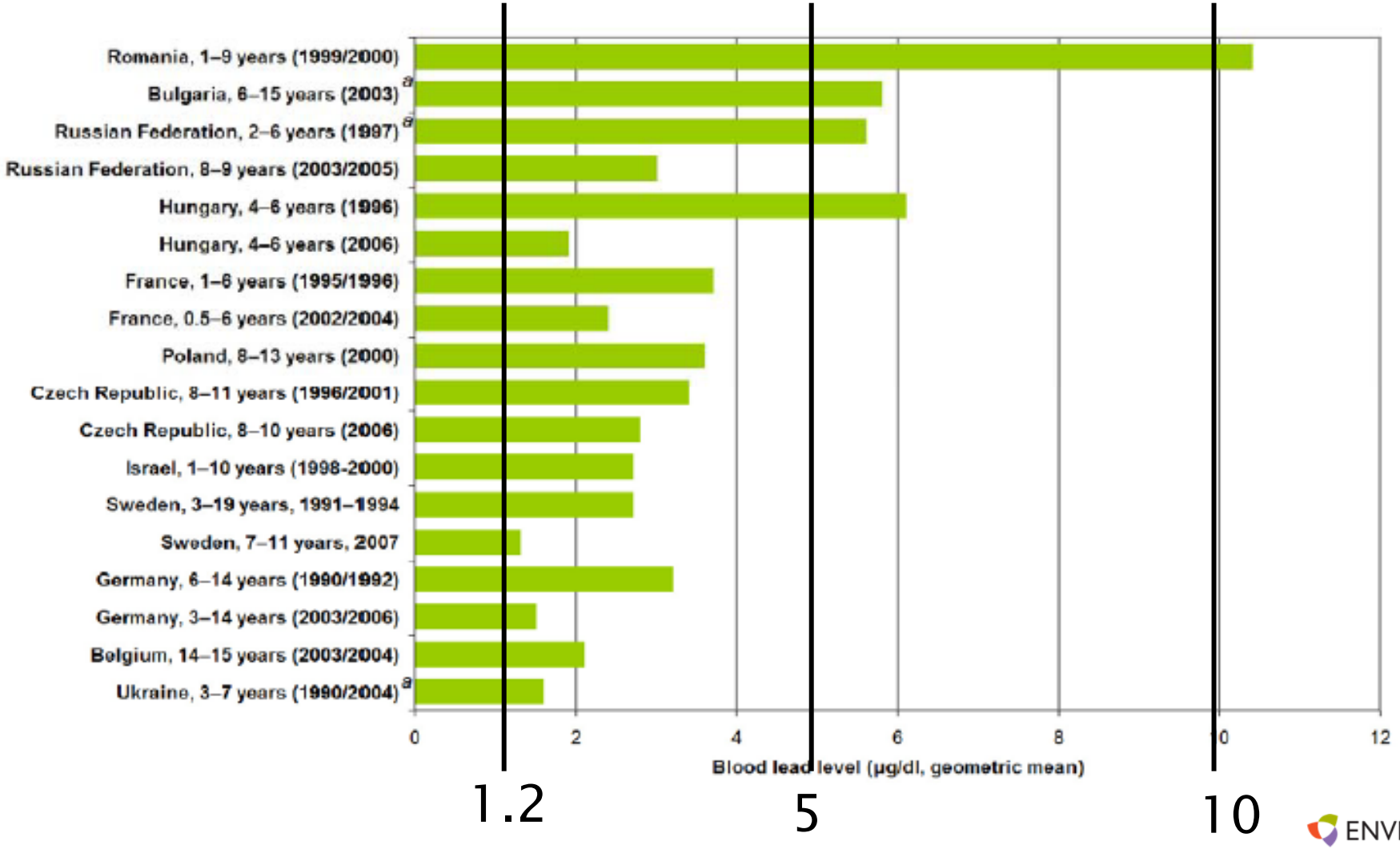
WHO/Europe December2009

LEVELS OF LEAD IN CHILDREN'S BLOOD. FACT SHEET 4.5

Fig. 1. Mean blood lead levels of children measured in areas without significant local sources of lead exposure in selected European countries, 1991–2006



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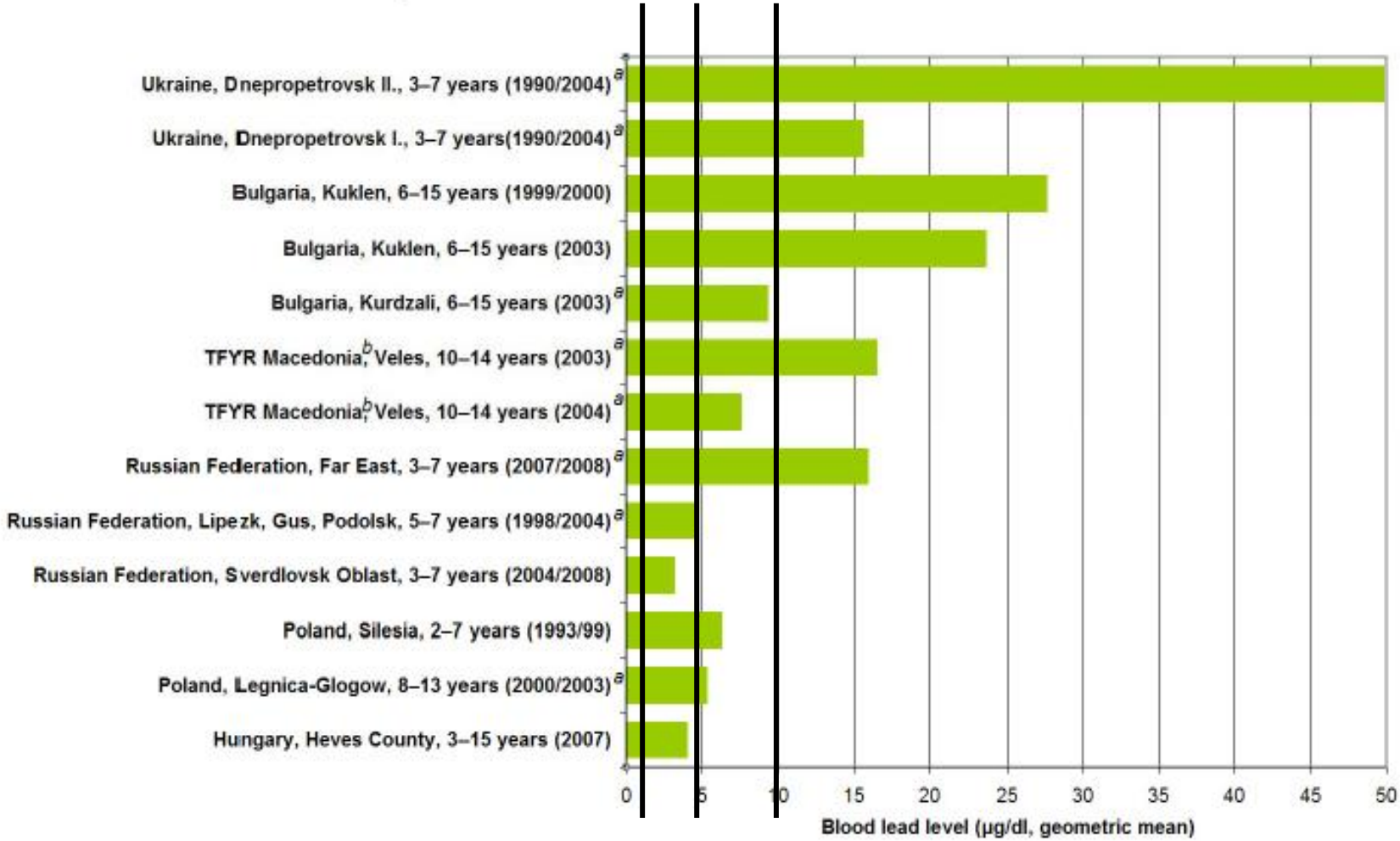
WHO/Europe December2009

LEVELS OF LEAD IN CHILDREN'S BLOOD. FACT SHEET 4.5

Fig. 2. Mean blood lead levels in children measured in selected areas with specific local sources of lead exposure



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LEVELS OF LEAD IN CHILDREN'S BLOOD. FACT SHEET 4.5

The Declaration of Brescia on Prevention of the Neurotoxicity of Metals. American Journal of Industrial Medicine, 2007, 50:709–711

"..supported the revision of lead exposure standards and promoted an immediate reduction of lead in children's blood to a level of 5 µg/dL worldwide."

Qu – if the UK adopted 5 µg/dL as a target level, what would it mean for Pb in soil?

Biomonitoring of children living in different areas - BPb levels > 5 µg/dL

Determine whether Pb in soil was causative of any elevated blood Pb

Likely to be reassured in general?

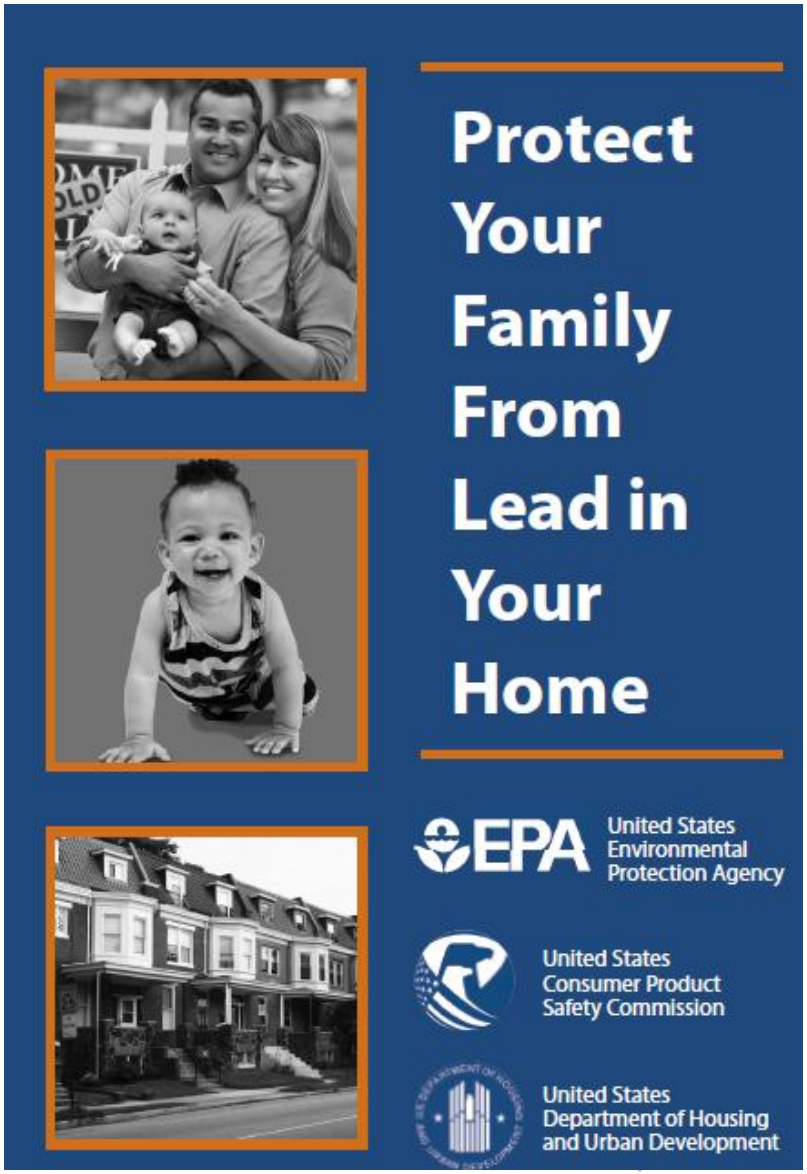
If a child's blood Pb is higher than 5 µg/dL and soil is a large contribution, what action could be taken?

What impact does the CDC Action level (5 ug/dL) have on US children?

Risk Management Strategies

- BLL is 5-9 µg/dL
  – parents receive some **educational materials**
  - discuss suspected sources of lead, the importance of household cleaning
  Re-test within 6 months.

- Roz Schoof (ENVIRON) will present a blood monitoring study at the Society of Toxicology March 2014
  - average BLLs of children in a mining community in Butte, USA have **declined by more than 50% from 2002 through 2011**, as a direct result of risk management strategies.



What are the Options for the UK?

Lead in the body

No safe level of lead in a child's body has been identified. Studies continue to document significant harm at far lower levels of exposure than previously known.

Blood-lead levels (µg/dL)* and their effect:

70+
Seizures, coma, possible death

45+
Chelation therapy recommended with medication that causes lead to be excreted in the urine

15+
Can trigger a home inspection by local health officials to identify lead source (level varies by department)

10
Previous CDC "level of concern" set in 1991

Less than 10
Decreased IQ, delayed puberty, reduced postnatal growth and decreased hearing

5**
New CDC action level

Less than 5
Decreased academic achievement, increased incidence of ADHD and problem behaviors

* µg/dL = micrograms per deciliter of blood.
** New action "level of concern" set in May, 2012.

Sources: CDC, National Toxicology Program, USA TODAY research

Not a question for science but for 'policy'

1970

Action levels

NHANES blood monitoring surveys in USA

1991 CDC USA/WHO 1995 (10 µg/dL action level)
2002 UK Environment Agency HCV (10 µg/dL)

May 2012 CDC USA (5 µg/dL action level)

2010 EFSA BMDL01 (1.2 µg/dL)
(0.3-4.1 – depending upon BMD model choice)

Defra C4SL Project
- we explored options between 1.2-5 µg/dL

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Provisional C4SLs Lead

Exposure parameters	LLTC		pC4SLs (mg.kg^{-1})					
			Residential		Allot-ments	Comm-ercial	POS_{resi}	POS_{park}
	ug. dL^{-1}	µg.kg^{-1} (bw) day^{-1}	With home grown prod.	Without home grown prod.				
Withdrawn SGV	10	N/A[1]	450	450	450	750	-	-
pC4SL with exposure parameters as SR3	1.6	0.6 (ch)[3]	82	130	30	-	-	-
		0.29 (ad)[4]	-	-	-	1100	-	-
		0.57 (ad)[5]	-	-	-	2160	-	-
	3.5	1.4 (ch)[3]	190	310	70	-	-	-
		0.63 (ad)[4]	-	-	-	2330	-	-
		1.3 (ad)[5]	-	-	-	4800	-	-
	5[6]	2.1 (ch)[3]	200[6]	300[6]	74[6]	-	-	-
		0.89 (ad)[4]	-	-	-	2690[6]	-	-
		1.8 (ad)[5]	-	-	-	6000[6]	-	-
pC4SL with changes in exposure[2]	1.6	0.6 (ch)[3]	86	130	34	-	270	580
		0.29 (ad)[4]	-	-	-	1100	-	-
		0.57 (ad)[5]	-	-	-	2160	-	-
	3.5	1.4 (ch)[3]	200	310	80	-	630	1300
		0.63 (ad)[4]	-	-	-	2330	-	-
		1.3 (ad)[5]	-	-	-	4800	-	-
	5[6]	2.1 (ch)[3]	210[6]	330[6]	84[6]	-	760[6]	1400[6]
		0.89 (ad)[4]	-	-	-	2690[6]	-	-
		1.8 (ad)[5]	-	-	-	6000[6]	-	-

Defra C4SL Research Project SP1010

Illustrate options

N.B. Non-threshold – risk management principle of ALARP applies

CL:AIRE

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Concluding remarks – personal view

- Good scientific evidence and international harmonisation to support a pragmatic 'low level of concern' of 5 µg/dL

- Too many uncertainties on whether current Pb in UK soil actually results in blood Pb levels of >5 µg/dL, >10 µg/dL etc

Is there an issue to address for Pb in UK soil?
→ We don't know

Calls for: A multi-disciplinary exercise on the design, benefits and risks of undertaking blood biomonitoring of Pb in UK populations

Health scientists, toxicologists, child health specialists, exposure modellers, biomonitoring scientists, policy makers, socio-economic analysts, statisticians etc.