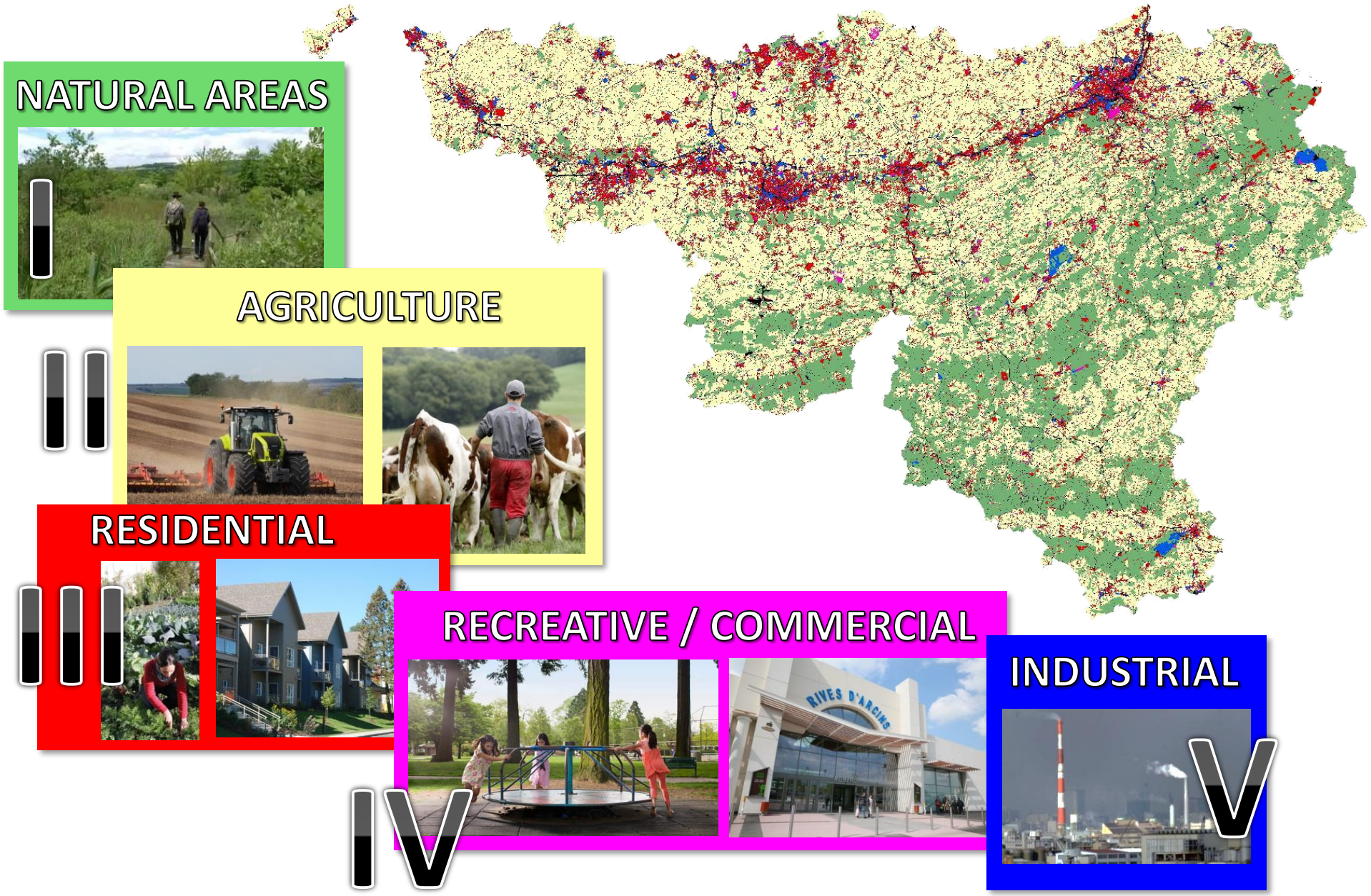
Development of sustainable health risk-based soils standards for lead, using probabilistic & toxicokinetic models

Getting a grip on lead in Soil - Problems and Solutions

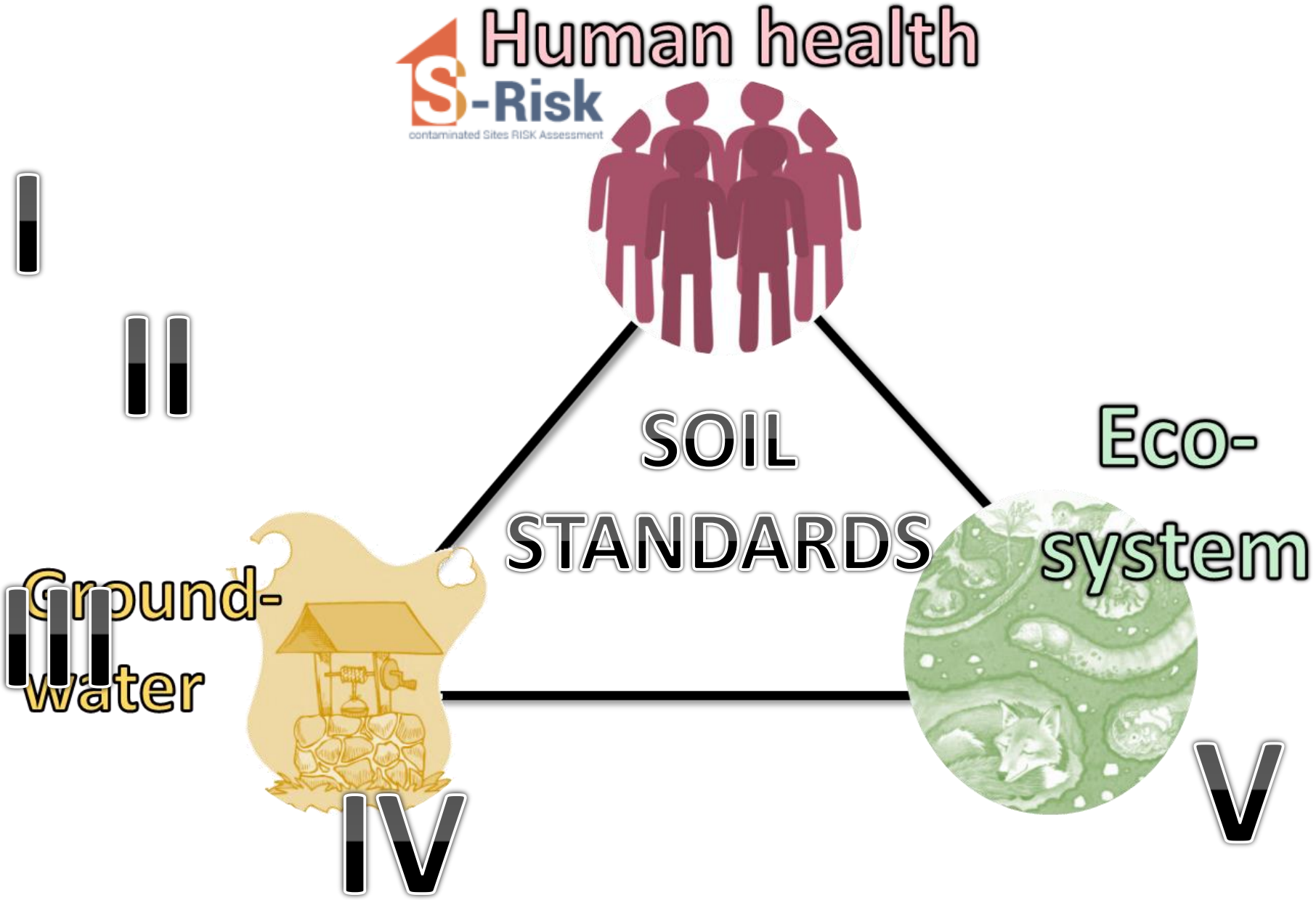
25th November 14.00 hrs - 17.30 hrs (Zoom)

Dr Jérôme C.J Petit
https://jcjpetit.wixsite.com/jcjpetit
CellulEnvironnementSanté

Legal soils standards – dependence with soil use



Legal soils standards = Triple protection



Soil standards for Pb - former Soil decree

Risk-based Pb concentrations in soils (mg/kg)

↓ Risk component / Soil use →	I	II	III	IV	V
Human Health	408	13	196	408	3090
Groundwater	581	2492	2077	2077	1837
Ecosystem	124	192	279	279	386
SOIL STANDARDS (2008)	120	200	200	280	385

«provisionnal tolerable weekly intake»
3,57 $\mu g_{Pb}/kg_{bw}/d$
(OMS 1993).

Organisation mondiale de la santé

Soil standards for Pb - Revision of Human health component

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Organisation mondiale de la santé

Update of reference toxicological values derived from BMDL for neurodev. (12 µg/L, children) & nephrotox. (15 µg/L, adults) effects from EFSA (2009)

efsa
European Food Safety Authority

0,063 *(ad.) and* ***0,050*** *(ch.)* ***$\mu g_{Pb}/kg_{bw}/d$*** *(EFSA, 2009)*

Soil standards for Pb - Revision of Human health component

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Human Health	37,3	0,37	1,41	37,3	204

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0,063 *(ad.) and* ***0,050*** *(ch.)* ***$\mu g_{Pb}/kg_{bw}/d$*** *(EFSA, 2009)*

- Health Risk based SS **not sustainable** (below LOQ's and below natural Pb concentration range in soils).
- Legal SS not **heath protective**, based on EFSA (2009) and multimedia model

Soil standards for Pb - Revision of Human health component

Risk-based Pb concentrations in soils (mg/kg)

↓ Risk component / Soil use →	I	II	III	IV	V
Human Health	408	13	196	408	3090
Groundwater	581	2492	2077	2077	1837
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«provisionnal tolerable weekly intake» ***3,57 $\mu g_{Pb}/kg_{bw}/d$*** *(OMS 1993).*

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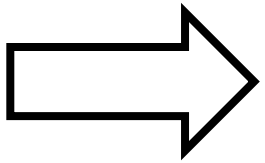
0,063 *(ad.) and* ***0,050*** *(ch.)* ***$\mu g_{Pb}/kg_{bw}/d$*** *(EFSA, 2009)*

Way around the problem…. Assuming an average natural background of 25 mg/kg (and a bioacessibility of 0,74) for soil use II (most sensitive exposure scenario) is acceptable (RI=7,7)

Human Health (RI=7,7, BA =0,74)	389	25	46	389	2212
SOIL STANDARDS (2018)	120	200	200	389	1837

Soil standards for Pb - CAN WE DO BETTER?

	I	II	III	IV	V
SOIL STANDARDS (2018)	120	200	200	389	1837



✓OK FOR SOIL MANAGEMENT

✖ NOT HEALTH PROTECTIVE (on the basis of dose/rfd model endorsed by the soil decree)

✖ ASSUMED TO MITIGATE HEALTH RISKS

✖ LACK OF CONSISTENCE and NOT BASED ON A FORMAL, COMMON HHRA MODEL

Environmental data
-Concentrations
- Behaviour in soils
-Bioaccessibility

Toxicity
-Bioavailability
-Toxicokinetic's
-…

Blood lead level
-In the general population
-In populations exposed to soils contaminations

Soil standards for Pb - CAN WE DO BETTER?

DE GRUYTER Clin Chem Lab Med 2020; aop

Perrine Hoet*, Chantal Jacquerye, Gladys Deumer, Dominique Lison and Vincent Haufroid

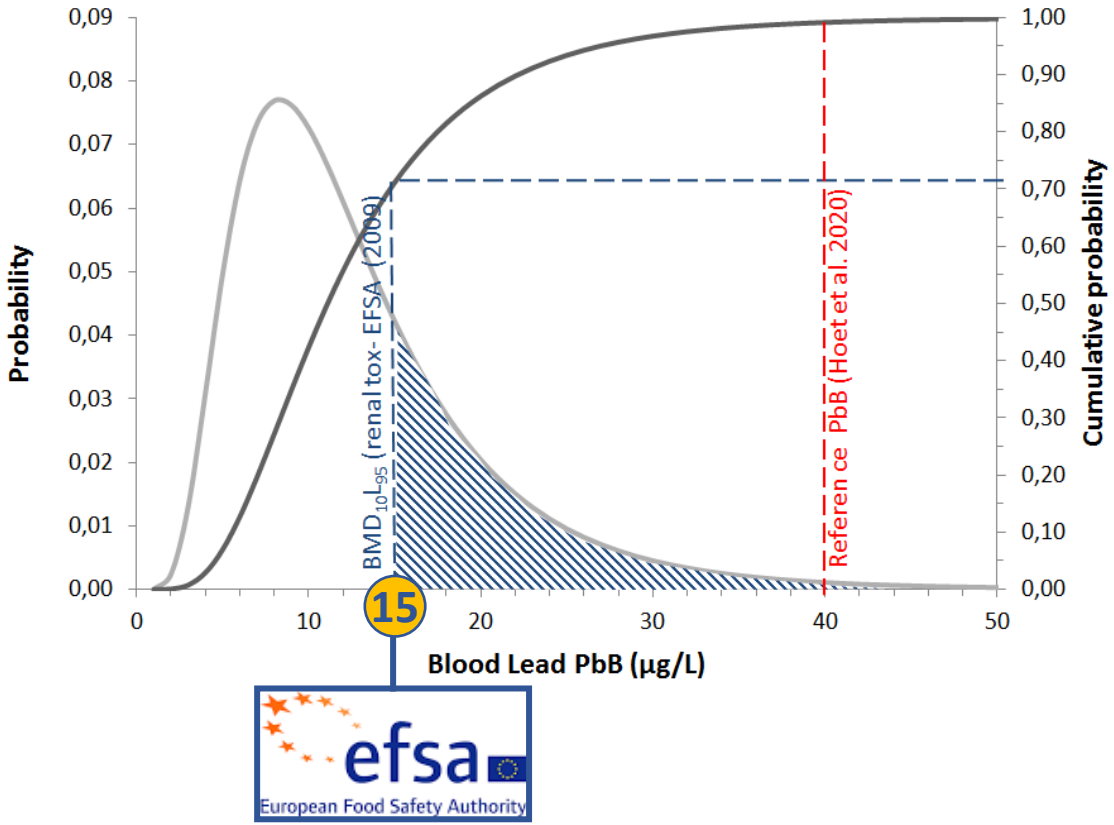
Reference values of trace elements in blood and/ or plasma in adults living in Belgium

Today, nearly 30% of adults are at risk with respect to renal toxicity for Pb (!)

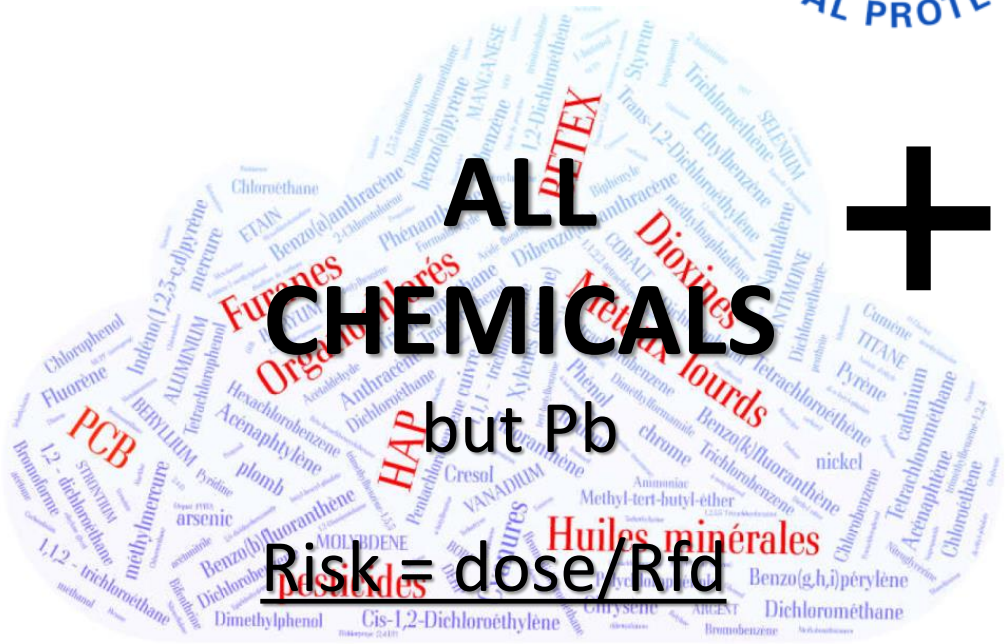
- Pb exposure in the general population remain a health issue for adults (and children).
- Relying on EFSA's BMDL's is not sustainable in terms of Health.
- Use of population PbB reference value instead to manage health risks.

⇨ Other model needed

PbB distribution for the general population (Hoet et al. 2020)



Soil standards for Pb - CAN WE DO BETTER?



ALL CHEMICALS but Pb

Risk = dose/Rfd

+

Pb

ALM

Adult, occupational

Integrated Exposure Uptake Biokinetic Model for Lead in Children

Windows® version 1.1 Build11

IEUBK

WORKGROUP

Developed for the U.S. Environmental Protection Agency by Syracuse Research Corporation

Children, residential

ADULT LEAD MODEL (EPA 2003, last update 2017)

Use of **median estimates** for exposure parameters, instead of worst case values

Baseline PbB = GMean of the general adult population

Pb soil concentration

Ingestion rate for soil&dust

Pb absorption factor for soil&dust

Exposure frequency

$$PbB_{central} = PbB_0 + BKSF * Pb_S * IR_{S+D} * AF_{S,D} * \frac{EF_S}{365}$$

Baseline PbB_0 instrinsically includes all Pb exposure sources and exposure history.

Biokinetic slope factor [µg/dl.(µg/j)$^{-1}$]

Intake [µg/j]

Soil & soil derived dust considered as an additionnal exposure source.

PbB increment due to local soil/sources

$$PbB_{0.975} = PbB_{central} * GSD_{adult}^{1,96}$$

97.5th percentile of PbB distribution

Geometric standard deviation

GSD accounts for population variabilities related to physiology and exposure.

ADULT LEAD MODEL with reference PbB distribution

Reference PbB for adults = **40 µg/L**

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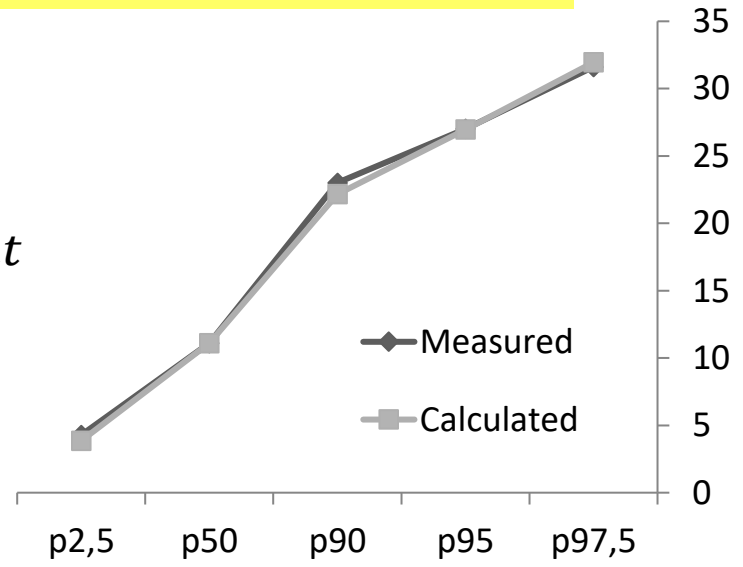
Reference values of trace elements in blood and/or plasma in adults living in Belgium

$$PbB_{central} = PbB_0 + BKSF * Pb_S * IR_{S+D} * AF_{S,D} * \frac{EF_S}{365}$$

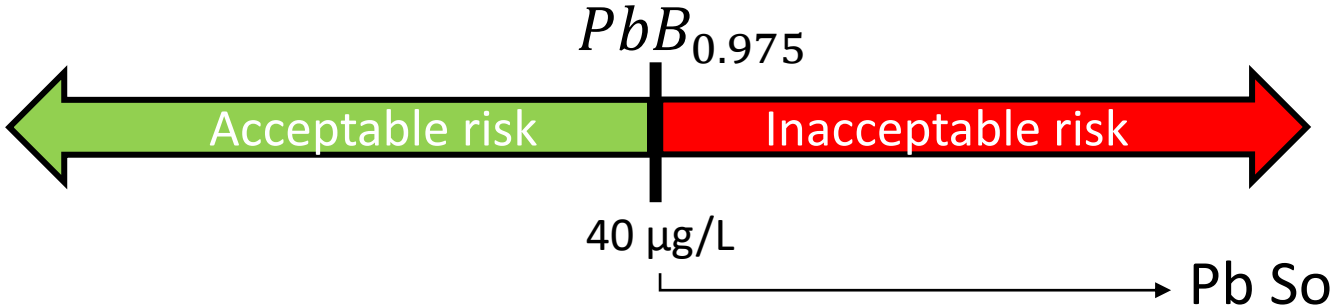
11 µg/L
(GM, Hoet et al. 2020)

1,715 derived from Hoet et al. 2020 data, assuming a lognormal distribution

$$PbB_{0.975} = PbB_{central} * GSD_{adult}^{1,96}$$



ADULT LEAD MODEL with reference PbB distribution



Pb Soil standard :

Variable	Description of Variable	References	Units	original model*
PbS	Soil lead concentration		µg/g or ppm	194
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	EPA (2017) et al. 2019	g/d	0,030
$AF_{S,\ D}$	Absorption fraction (same for soil and dust)	EPA (2003)	--	0,12
$EF_{S,\ o}$	Exposure frequency outside	Table 4	days/yr	365
$AT_{S,\ D}$	Averaging time (same for soil and dust)	EPA (2003)	days/yr	365
BKSF	Biokinetic Slope Factor	EPA (2003)	µg/dL per µg/day	0,4
GSD_i	Geometric standard deviation PbB	voir section 4	--	1,715
PbB_0	Baseline PbB, Geometric mean	Hoet et al. (2020), voir section 4	µg/dL	1,1
$PbB_{adult,\ central}$	PbB of adult, geometric mean		µg/dL	1,389
$PbB_{adult,\ 0.975}$	97,5th percentile PbB among adults		µg/dL	4,0
PbB_t	Target PbB level of concern	URL - Hoet et al. 2020	µg/dL	**4,0**
$P(PbB_{adult} > PbB_t)$	**Probability that adult PbB exceeds target PbB, assuming lognormal distribution**		**%**	**2,50%**

Pb soil concentration not giving rise to more than 2,5% chance for an adult, to have a PbB level above the reference value of **40 µg/L.**

194 mg/kg is close to 200 mg/kg for residential soil use.

ADULT LEAD MODEL General eqs. (EPA 2003)

$$PbB_{central} = PbB_0 + BKSF * Pb_S * IR_{S+D} * AF_{S,D} * \frac{EF_S}{AT}$$

$$PbB_{central} = PbB_0 + BKSF * \left[\left(Pb_S * W_S * IR_{S+D} * AF_S * \frac{EF_{S,o}}{AT}\right) + \left(\boldsymbol{K_{SD}} * Pb_S * (\mathbf{1} - \boldsymbol{W_S}) * IR_{S+D} * AF_S * \frac{EF_{D,i}}{AT}\right)\right]$$

Ratio of indoor dust Lead concentration to soil lead concentration

Fraction of total soil and dust that is directly ingested as soil

Exposure to soil, outside

Exposure to dust, inside

ADULT LEAD MODEL General eqs. (EPA 2003)

$$PbB_{central} = PbB_0 + BKSF * Pb_S * IR_{S+D} * AF_{S,D} * \frac{EF_S}{AT}$$

$$PbB_{central} = PbB_0 + BKSF * \left[\left(Pb_S * W_S * IR_{S+D} * AF_S * \frac{EF_{S,o}}{AT} \right) + \left(K_{SD} * Pb_S * (1 - W_S) * IR_{S+D} * AF_S * \frac{EF_{D,i}}{AT} \right) \right]$$

Ratio of indoor dust Lead concentration to soil lead concentration

Fraction of total soil and dust that is directly ingested as soil

Exposure to soil, outside

Exposure to dust, inside

Changes in parameter values only ….still consistent with the general equations from ALM (EPA, 2003).

S-Risk contaminated Sites RISK Assessment

6/8 Scenario-dependent parameters

1) Residential without garden
2) Residential with ornemental garden
3) Recreative outside
4) Recreative inside
5) Industrial outside
6) Industrial inside

Examples of scenario-depenent parameter values

S-Risk
contaminated Sites RISK Assessment

Activity patterns/ time use

Table 37: Time-use for landuse type residential with garden (RES)

Age	Sleeping (t_{sleep})	Awake inside (t_{in})	Outside (t_{out})	Total* on site	EF_{week}	EF_{year}
	h/day	h/day	h/day	h/day	d/week	weeks/year
1 - < 3 year	12	11.5	0.5	24	7	52
3 - < 6 year	11	9.7	1.38	22.08	7	52
6 - < 10 year	10	8.7	1.57	20.27	7	52
10 - < 15 year	9	10.6	1.12	20.72	7	52
15 - < 21 year	8	8.5	0.4	16.9	7	52
21 - < 31 year	8	9.0	0.4	17.4	7	52
31 - < 41 year	8	11.5	0.7	20.2	7	52
41 - < 51 year	8	11.5	1.0	20.5	7	52
51 - < 61 year	8	11.5	1.3	20.8	7	52
≥ 61 years	8	11.5	1.0	20.5	7	52

* sum of hours 'sleeping'. 'awake' and 'outside'

Table 44: Daily soil and dust ingestion rates and fraction of soil contributing

Age	AGR / RES-veg / RES		RES-ng		IND-l		IND-h	
	$IR_{soil/dust\_daily}$ (mg/d)	F_{oral_soil} (-)	$IR_{soil/dust\_daily}$ (mg/d)	F_{oral_soil} (-)	$IR_{soil/dust\_daily}$ (mg/d)	F_{oral_soil} (-)	$IR_{soil/dust\_daily}$ (mg/d)	F_{oral_soil} (-)
1 - < 3 year	106	0.45	87	0.32	0.0	0.0	0.0	0.0
3 - < 6 year	85	0.45	69	0.32	0.0	0.0	0.0	0.0
6 - < 10 year	69	0.45	54	0.25	0.0	0.0	0.0	0.0
10 - < 15 year	68	0.45	51	0.23	0.0	0.0	0.0	0.0
15 - < 21 year	67	0.45	49	0.20	23	0.20	33	0.8
21 - < 31 year	66	0.45	45	0.20	23	0.20	33	0.8
31 - < 41 year	66	0.45	45	0.20	23	0.20	33	0.8
41 - < 51 year	66	0.45	45	0.20	23	0.20	33	0.8
51 - < 61 year	66	0.45	45	0.20	23	0.20	33	0.8
≥ 61 years	66	0.45	45	0.20	23	0.20	33	0.8

Ingestion rates for soil & dust

ADULT LEAD MODEL -WAL

$$PbB_{central} = PbB_0 + BKSF$$

$$* \left[\left(\underbrace{Pb_S * W_S * IR_{S+D} * AF_S * \frac{EF_{S,o}}{AT}}_{\text{Exposure to soil, outside}} \right) + \left(\underbrace{K_{SD} * Pb_S * (1 - W_S) * IR_{S+D} * AF_S * \frac{EF_{D,i}}{AT}}_{\text{Exposure to dust, inside}} \right) \right]$$

$$+ BKSF * \underbrace{\left[AF_F * \sum_{i=1}^{50} Q_i * Pb_{V,i} * f_i \right]}_{\text{Intake from local food}}$$

- Q_i: *Mass of veg. « i » in diet*
- AF_F: *Autoconsumption rate*
- $Pb_{V,i}$: *Pb concentration in veg. « i » from soil-plant transfert equations*

Update of exposure parameters and soil-plant transfer equations based on SANISOL research results

× SANISOL

8 Scenario-dependent parameters

7) *Residential with vegetable garden*
8) *Agricultural use (= worst case residential exposure)*

ADULT LEAD MODEL -WAL

$$PbB_{central} = PbB_0 + BKSF$$

$$* \left[\left(\underbrace{Pb_S * W_S * IR_{S+D} * AF_S * \frac{EF_{S,o}}{AT}}_{\text{Exposure to soil, outside}} \right) + \left(\underbrace{K_{SD} * Pb_S * (1 - W_S) * IR_{S+D} * AF_S * \frac{EF_{D,i}}{AT}}_{\text{Exposure to dust, inside}} \right) \right]$$

$$+ BKSF * \underbrace{\left[AF_F * \sum_{i=1}^{50} Q_i * Pb_{V,i} * f_i \right]}_{\text{Intake from local food}} - Y$$

Y: Term accounting for the intake of vegetables that are substituted by those grown on soils

Update of exposure parameters and soil-plant transfer equations based on SANISOL research results

× SANISOL

8 Scenario-dependent parameters

7) *Residential with vegetable garden*
8) *Agricultural use (= worst case residential exposure)*

ADULT LEAD MODEL -WAL

$$PbB_{central} = PbB_0 + BKSF * \left[\left(Pb_S * W_S * IR_{S+D} * AF_S * \frac{EF_{S,o}}{AT}\right) + \right.$$

$$\left.\left(K_{SD} * Pb_S * (1 - W_S) * IR_{S+D} * AF_S * \frac{EF_{D,i}}{AT}\right)\right] + BKSF * \left[AF_F * \right.$$

$$\left.\sum_{i=1}^{50} Q_i * Pb_{V,i} * f_i\right]\text{-Y}$$

$$PbB_{0.975} = PbB_{central} * GSD_{adult}^{1,96}$$

ADULT LEAD MODEL -WAL

ALM-WAL model (Blood Lead Concentrations (PbBs) and Risk for S-RISK exposure scenarios)
ALM generalised equations U.S. EPA Technical Review Workgroup for Lead (2003)
Exposure parameters from S-RISK
Diet and soil plant transfert equation from SANISOL
Updated blood Lead distribution from Hoet et al. 2020.

Variable	Description of Variable	References	Units	original model*	original generalised model**	AGRI	RESVEG	RES	RESNG	Heavy Ind.	Light Ind.	RECOUT	RECIN
PbS	**Soil lead concentration**		**µg/g or ppm**	**194**	**194**	**51**	**159**	**286,5**	**602**	**387**	**1370**	**2380**	**9100**
EFsoil/settled_dust$	Enrichment factor from soil to settled indoor dust	Cornelis et al. (2017)			1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Fsoil/settled_dust$	Fraction of soil in indoor settled dust	Cornelis et al. 2017 & Table 5	--	--	1,000	0,500	0,500	0,500	0,250	0,250	0,250	0,250	0,250
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	Table 4, derived from Cornelis et al. 2019	g/d	0,030	0,030	0,066	0,066	0,066	0,045	0,033	0,023	0,033	0,023
W_S	fraction of IR_{S+D} ingested as outdoor soil (Foralsoil dans S-RISK)	EPA (2003); Cornelis et al.(2017)	--	--	1,000	0,450	0,450	0,450	0,200	0,800	0,200	1,000	0,000
$AF_{S, D}$	Absorption fraction (same for soil and dust)	EPA (2003)	--	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12
$EF_{S, o}$	Exposure frequency outside	Table 4	days/yr	365	365	33,215	33,215	20,05	16,835	205,625	29,375	27,06	0
$EF_{D, i}$	Exposure frequency inside	Table 4	days/yr		0	250,25	250,25	250,25	250,25	29,375	205,625	0	27,06
$AT_{S, D}$	Averaging time (same for soil and dust)	EPA (2003)	days/yr	365	365	365	365	365	365	365	365	365	365
$\Sigma qi*Pb_{Vi}*f_i$	Intake from local food	Table 6	µgPb/d	0	0	4,78	2,28	0	0	0	0	0	0
AF_F	absorption factor for food	EPA (2003); ATDSR (2010)		0	0	0,2	0,2	0	0	0	0	0	0
X	fraction of food contributiong to Pb0	Table 6		0	0	0,14	0,06	0	0	0	0	0	0
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	EPA(2003) - 1 for adults	--	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
BKSF	Biokinetic Slope Factor	EPA (2003)	µg/dL per µg/day	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
GSD_i	Geometric standard deviation PbB	voir section 4	--	1,715	1,715	1,715	1,715	1,715	1,715	1,715	1,715	1,715	1,715
PbB_0	Baseline PbB, Geometric mean	Hoet et al. (2020), voir section 4	µg/dL	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
$PbB_{adult, central}$	PbB of adult, geometric mean		µg/dL	1,389	1,389	1,389	1,389	1,389	1,389	1,390	1,390	1,389	1,389
$PbB_{adult, 0.975}$	97,5th percentile PbB among adults		µg/dL	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
PbB_t	Target PbB level of concern	URL - Hoet et al. 2020	µg/dL	**4,0**	**4,0**	**4,0**	**4,0**	**4,0**	**4,0**	**4,0**	**4,0**	**4,0**	**4,0**
$P(PbB_{adult} > PbB_t)$	**Probability that adult PbB exceeds target PbB, assuming lognormal distribution**		**%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**

* : basic ALM model with no distinction for soil & dust. Use of Hoet et al. (2020) distriubtion and URL value and US-EPA(2017) ingestion rate
** : Generalised ALM model with parameter changes for ingestion of 100% soils (Fsoil/settled_dust=1; Ws=1, EFD,i =0), same as basic ALM model.
$: Ksd=EFsoil/settled_dust * Fsoil/settled_dust, see section 5

Version date 03/09/2021, author : Jérôme C.J. Petit

ADULT LEAD MODEL -WAL

ALM-WAL model (Blood Lead Concentrations (PbBs) and Risk for S-RISK exposure scenarios)
ALM generalised equations U.S. EPA Technical Review Workgroup for Lead (2003)
Exposure parameters from S-RISK
Diet and soil plant transfert equation from SANISOL
Updated blood Lead distribution from Hoet et al. 2020.

Variable	Description of Variable	References	Units	original model*	original generalised model**	AGRI	RESVEG	RES	RESNG	Heavy Ind.	Light Ind.	RECOUT	RECIN
PbS	Soil lead concentration		µg/g or ppm	194	194	51	159	286,5	602	387	1370	2380	9100
X	fraction of food contributiong to Pb0	Table 6		0	0	0,14	0,06						
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	EPA(2003) - 1 for adults	--	1,0	1,0	1,0	1,0						
BKSF	Biokinetic Slope Factor	EPA (2003)	µg/dL per µg/day	0,4	0,4	0,4	0,4						
GSD_i	Geometric standard deviation PbB	voir section 4	--	1,715	1,715	1,715	1,715						
PbB_0	Baseline PbB, Geometric mean	Hoet et al. (2020), voir section 4	µg/dL	1,1	1,1	1,1	1,1						
$PbB_{adult, central}$	PbB of adult, geometric mean		µg/dL	1,389	1,389	1,389	1,389						
$PbB_{adult, 0.975}$	97,5th percentile PbB among adults		µg/dL	4,0	4,0	4,0	4,0						
PbB_t	Target PbB level of concern	URL - Hoet et al. 2020	µg/dL	4,0	4,0	4,0	4,0						
$P(PbB_{adult} > PbB_t)$	Probability that adult PbB exceeds target PbB, assuming lognormal distribution		%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%

Pb

Comparison of Soil standards from S-RISK (adult & children) and Soil standards from ALM-WAL (adults only) – mg/kg

	AGRI	RESVEG	RES	RESNG	INDH	INDL	RECOUT	RECIN
S-RISK WAL	0,37	1,4	6,7	12	390	527	37	1130
ALM WAL	51	159	287	602	387	1370	2380	9100

Sustainable Pb soil standards for all 8 scenarios behind RA in Wallonia are determined from a unique model, based on EPA Adult Lead Model

* : basic ALM model with no distinction for soil & dust. Use of Hoet et al. (2020) distriubtion and URL value and US-EPA(2017) ingestion rate
** : Generalised ALM model with parameter changes for ingestion of 100% soils (Fsoil/settled_dust=1; Ws=1, EFD,i =0), same as basic ALM model.
$: Ksd=EFsoil/settled_dust * Fsoil/settled_dust, see section 5

Version date 03/09/2021, author : Jérôme C.J. Petit

ADULT LEAD MODEL -WAL

ALM-WAL model (Blood Lead Concentrations (PbBs) and Risk for S-RISK exposure scenarios)
ALM generalised equations U.S. EPA Technical Review Workgroup for Lead (2003)
Exposure parameters from S-RISK
Diet and soil plant transfert equation from SANISOL
Updated blood Lead distribution from Hoet et al. 2020.

Variable	Description of Variable	References	Units	original model*	original generalised model**	AGRI	RESVEG	RES	RESNG	Heavy Ind.	Light Ind.	RECOUT	RECIN
PbS	Soil lead concentration		µg/g or ppm	194	194	51	159	286,5	602	387	1370	2380	9100
$P(PbB_{adult} > PbB_t)$	Probability that adult PbB exceeds target PbB, assuming lognormal distribution		%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%

Pb

Comparison of Soil standards from S-RISK (adult & children) and Soil standards from ALM-WAL (adults only) – mg/kg

	AGRI	RESVEG	RES	RESNG	INDH	INDL	RECOUT	RECIN
S-RISK WAL	0,37	1,4	6,7	12	390	527	37	1130
ALM WAL	51	159	287	602	387	1370	2380	9100

Twice the average value for natural background

Range of values allowing various real estate projects in residential setting

Sustainable Pb soil standards for all 8 scenarios behind RA in Wallonia are determined from a unique HHRA model, based on EPA Adult Lead Model

* : basic ALM model with no distinction for soil & dust. Use of Hoet et al. (2020) distriubtion and URL value and US-EPA(2017) ingestion rate
** : Generalised ALM model with parameter changes for ingestion of 100% soils (Fsoil/settled_dust=1; Ws=1, EFD,i =0), same as basic ALM model.
$: Ksd=EFsoil/settled_dust * Fsoil/settled_dust, see section 5

Version date 03/09/2021, author : Jérôme C.J. Petit

ADULT LEAD MODEL -WAL

ALM-WAL model (Blood Lead Concentrations (PbBs) and Risk for S-RISK exposure scenarios)
ALM generalised equations U.S. EPA Technical Review Workgroup for Lead (2003)
Exposure parameters from S-RISK
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Variable	Description of Variable	References	Units	original model*	original generalised model**	AGRI	RESVEG	RES	RESNG	Heavy Ind.	Light Ind.	RECOUT	RECIN
PbS	Soil lead concentration		µg/g or ppm	194	194	51	159	286,5	602	387	1370	2380	9100
$EF_{soil/settled_dust}$$	Enrichment factor from soil to settled	Cornelis et al. (2017)				1,5	1,5						
AF_{soil}	Absorption factor for soil					0,500	0,500						
AF_{dust}	Absorption factor for dust					0,066	0,066						
IR_{soil}	Soil ingestion rate					0,450	0,450						
IR_{dust}	Dust ingestion rate					0,12	0,12						
IR_{food}	Food ingestion rate					33,215	33,215						
BW_{adult}	Adult bodyweight					250,25	250,25						
AT_{adult}	Averaging time adult					365	365						
IR_{air}	Inhalation rate adult					2,28	2,28						
EF_{adult}	Exposure frequency adult					0,2	0,2						
X	fraction of food contributiong to Pb0	Table 6		0	0	0,14	0,06						
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	EPA(2003) - 1 for adults	--	1,0	1,0	1,0	1,0						
BKSF	Biokinetic Slope Factor	EPA (2003)	µg/dL per µg/day	0,4	0,4	0,4	0,4						
GSD_i	Geometric standard deviation PbB	voir section 4	--	1,715	1,715	1,715	1,715						
PbB_0	Baseline PbB, Geometric mean	Hoet et al. (2020), voir section 4	µg/dL	1,1	1,1	1,1	1,1						
$PbB_{adult,\ central}$	PbB of adult, geometric mean		µg/dL	1,389	1,389	1,389	1,389						
$PbB_{adult,\ 0.975}$	97,5th percentile PbB among adults		µg/dL	4,0	4,0	4,0	4,0						
PbB_t	Target PbB level of concern	URL - Hoet et al. 2020	µg/dL	4,0	4,0	4,0	4,0						
$P(PbB_{adult} > PbB_t)$	**Probability that adult PbB exceeds target PbB, assuming lognormal distribution**		**%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**	**2,50%**

Pb

Comparison of Soil standards from S-RISK (adult & children) and Soil standards from ALM-WAL (adults only) – mg/kg

	AGRI	RESVEG	RES	RESNG	INDH	INDL	RECOUT	RECIN
S-RISK WAL	0,37	1,4	6,7	12	390	527	37	1130
ALM WAL	51	159	287	602	387	1370	2380	9100

Soils standards based on health risk assesment

* : basic ALM model with no distinction for soil & dust. Use of Hoet et al. (2020) distriubtion and URL value and US-EPA(2017) ingestion rate
** : Generalised ALM model with parameter changes for ingestion of 100% soils (Fsoil/settled_dust=1; Ws=1, EFD,i =0), same as basic ALM model.
$: Ksd=EFsoil/settled_dust * Fsoil/settled_dust, see section 5

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ADULT LEAD MODEL -WAL

ALM-WAL model (Blood Lead Concentrations (PbBs) and Risk for S-RISK exposure scenarios)
ALM generalised equations U.S. EPA Technical Review Workgroup for Lead (2003)
Exposure parameters from S-RISK
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Variable	Description of Variable	References	Units	original model*	original generalised model**	AGRI	RESVEG	RES	RESNG	Heavy Ind.	Light Ind.	RECOUT	RECIN
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$R_{fetal/maternal}$	Fetal/maternal PbB ratio	EPA(2003) - 1 for adults	--	--	1,0	1,0	1,0						
BKSF	Biokinetic Slope Factor	EPA (2003)	µg/dL per µg/day	0,4	0,4	0,4	0,4						
GSD_i	Geometric standard deviation PbB	voir section 4	--	1,715	1,715	1,715	1,715						
PbB_0	Baseline PbB, Geometric mean	Hoet et al. (2020), voir section 4	µg/dL	1,1	1,1	1,1	1,1						
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$PbB_{adult, 0.975}$	97,5th percentile PbB among adults		µg/dL	4,0	4,0	4,0	4,0						
PbB_t	Target PbB level of concern	URL - Hoet et al. 2020	µg/dL	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
$P(PbB_{adult} > PbB_t)$	Probability that adult PbB exceeds target PbB, assuming lognormal distribution		%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%	2,50%

Comparison of Soil standards from S-RISK (adult & children) and Soil standards from ALM-WAL (adults only) – mg/kg

Pb	AGRI	RESVEG	RES	RESNG	INDH	INDL	RECOUT	RECIN
S-RISK WAL	0,37	1,4	6,7	12	390	527	37	1130
ALM WAL	51	159	287	602	387	1370	2380	9100

Soils standards based on ~~health risk assesment~~ health risk management approach

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$: Ksd=EFsoil/settled_dust * Fsoil/settled_dust, see section 5
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Conclusions and take home mesages

ALM-WAL model (Blood Lead Concentrations (PbBs) and Risk for S-RISK exposure scenarios)
ALM generalised equations U.S. EPA Technical Review Workgroup for Lead (2003)
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ISSeP Institut scientifique de service public

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Pb	AGRI	RESVEG	RES	RESNG	INDH	INDL	RECOUT	RECIN
S-RISK WAL	0,37	1,4	6,7	12	390	527	37	1130
ALM WAL	51	159	287	602	387	1370	2380	9100

Comparison of Soil standards from S-RISK (adult & children) and Soil standards from ALM-WAL (adults only) – mg/kg

Since the general population is already at risk due to Pb,

it is acceptable to rely on PbB reference values rather than rfd's or BMDL's.

* : basic ALM model with no distinction for soil & dust. Use of Hoet et al. (2020) distriubtion and URL value and US-EPA(2017) ingestion rate
** : Generalised ALM model with parameter changes for ingestion of 100% soils (Fsoil/settled_dust=1; Ws=1, EFD,i =0), same as basic ALM model.
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Conclusions and take home mesages

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							0,500						
							0,066						
							0,450						
							0,12						
							33,215						
							250,25						
							365						
							2,28						
							0,2						
X	fraction of food contributiong to Pb0	Table 6		0	0	0,14	0,06						
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Pb	Comparison of Soil standards from S-RISK (adult & children) and Soil standards from ALM-WAL (adults only) – mg/kg							
	AGRI	RESVEG	RES	RESNG	INDH	INDL	RECOUT	RECIN
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Thanks for your attention

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ORIGINAL PAPER

Sustainable health-based soil standards for arsenic using epidemiological data and toxicokinetic/probabilistic modelling

Jérôme C. J. Petit · Marie Peeters · Suzanne Remy

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Dr Jérôme C.J Petit
https://jcjpetit.wixsite.com/jcjpetit
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