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JUNIA ISA



Feedback on the contribution and consideration of the oral bioaccessibility of lead in a pilot area

Intersol

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Context and issues

- Ile-de-France soils are heavily contaminated with Pb in some places
- It is the result of a combination of activities, including an important industrial past, sludge spreading in the 19th century, the Notre-Dame fire in 2019 and leaded gasoline vehicles
- Pb is of particular concern because of the many health problems it can cause

Problem:

The management of contaminated sites is often very expensive, but necessary to ensure the safety of populations and public health



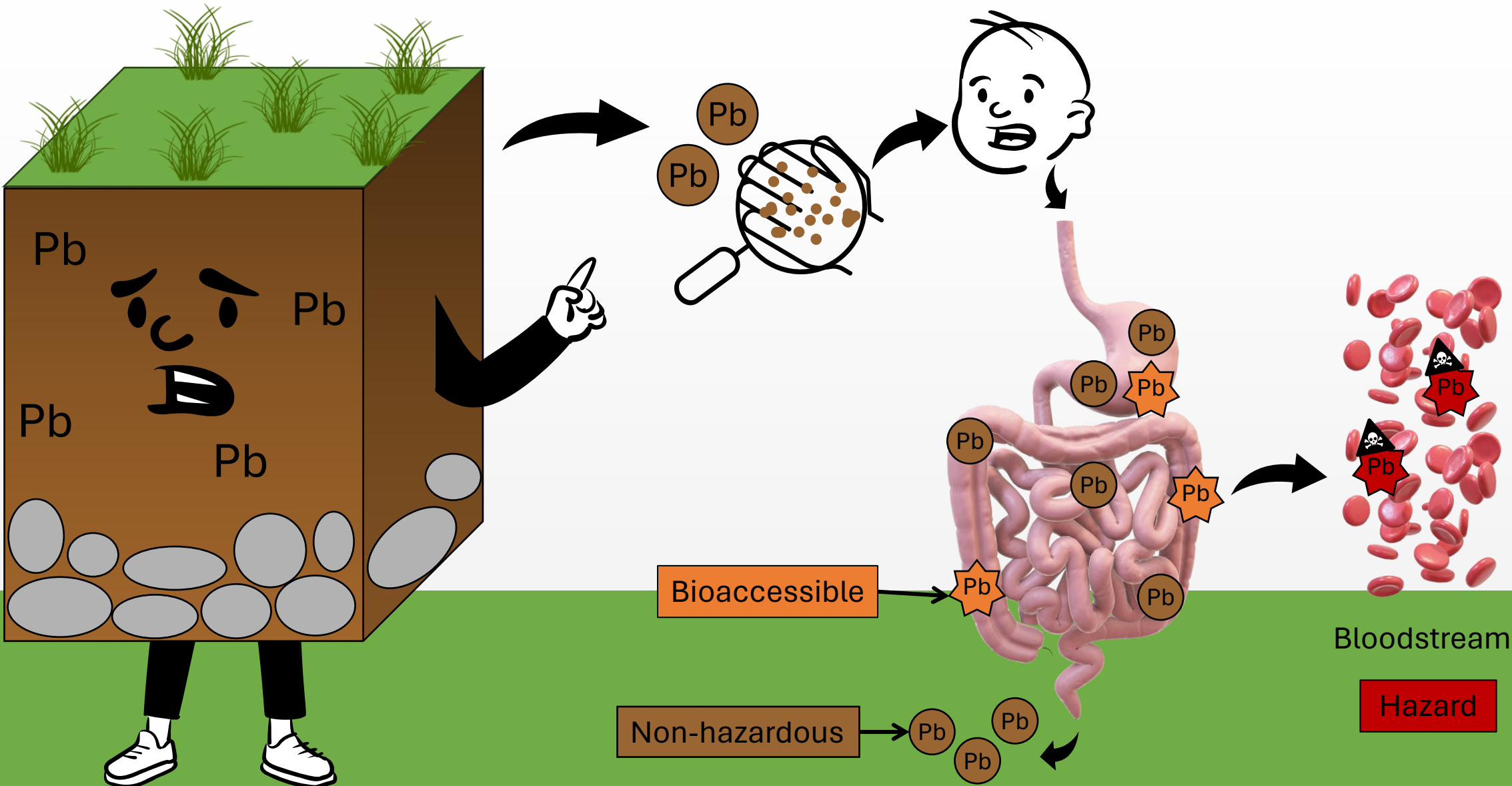
ACTUALITÉ
**Paris présente son plan
d'actions contre le plomb**

Mise à jour le 04/12/2019

www.paris.fr

Context and issues

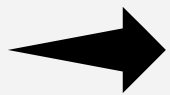
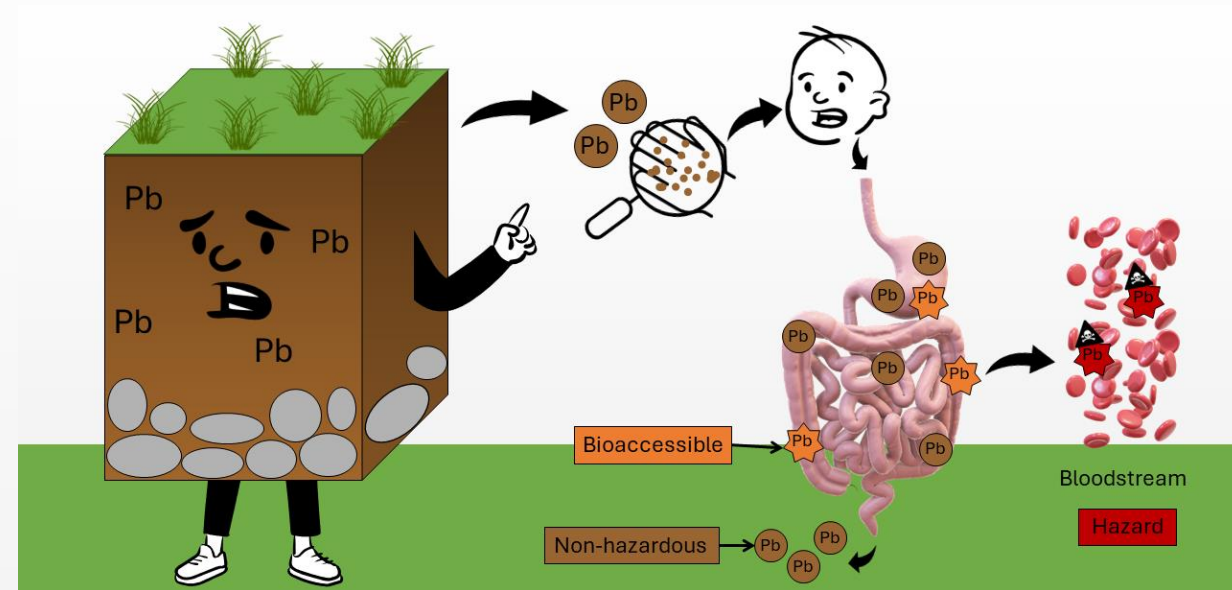
Contaminated soils: what's the real risk?



Context and issues

Contaminated soils: what's the real risk?

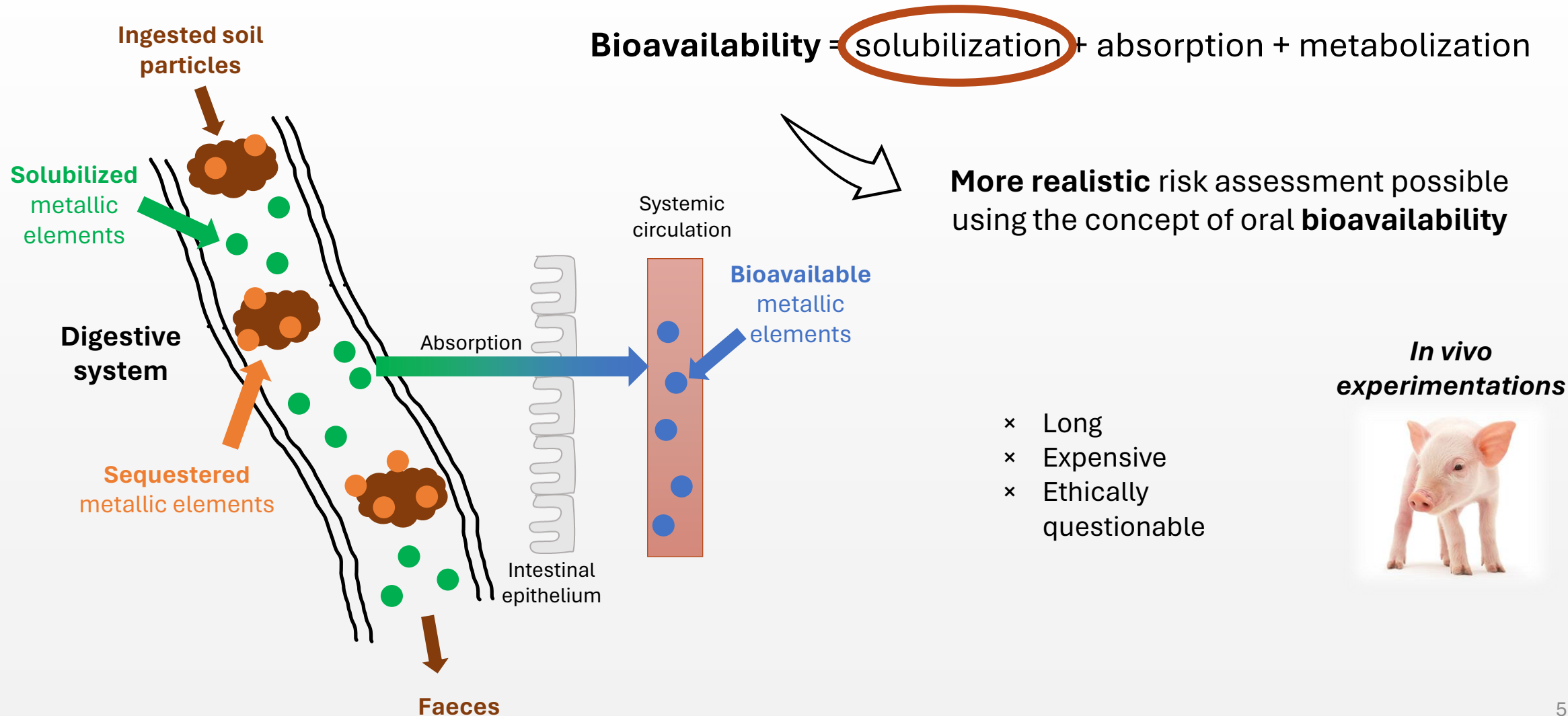
- Significant gap between estimated exposures (i.e. total pollutant concentrations in soil) and actual population exposures
- Need to develop tools and methods to improve the representativeness of human exposure characterization



**Bioavailability and
bioaccessibility**

Context and issues

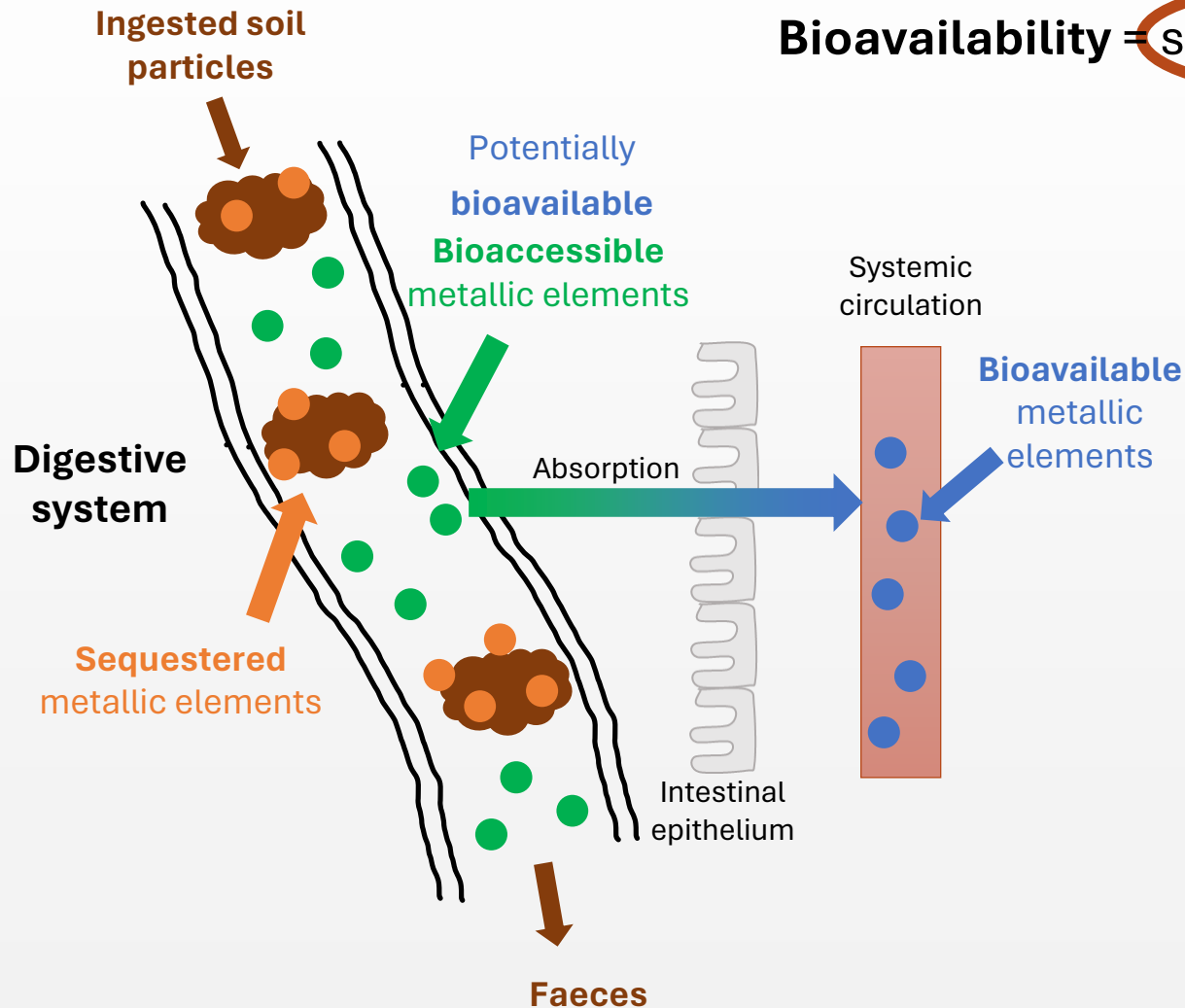
Bioavailability vs bioaccessibility



Context and issues

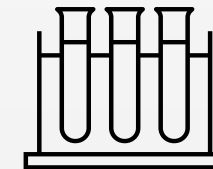
Bioavailability vs bioaccessibility

Bioavailability = solubilization + absorption + metabolization



Bioaccessibility: fraction of a substance in soil that is liberated in (human) gastrointestinal juices and thus available for absorption

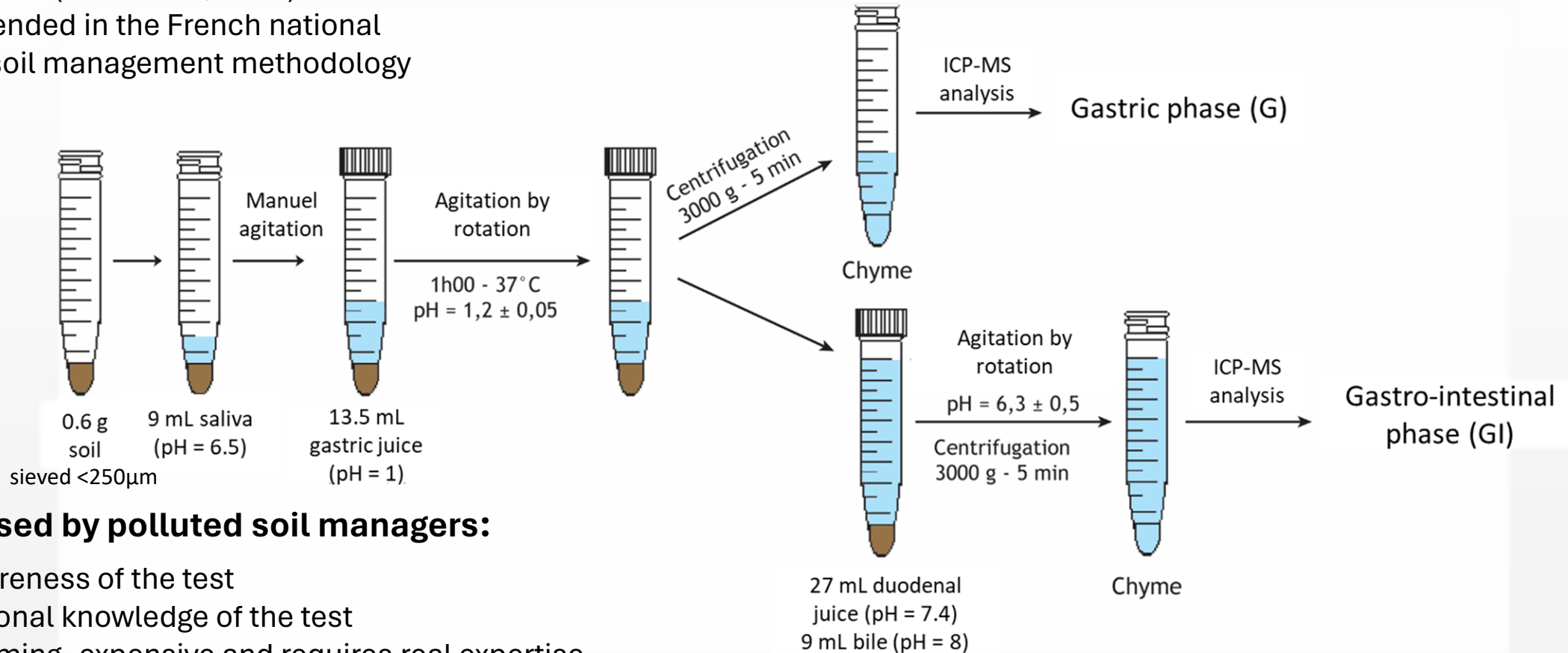
In vitro tests



Context and issues

UBM: Reference method in France

- ✓ Validated / in vivo model (As, Cd and Pb)
- ✓ Standardized (ISO 17924, 2019)
- ✓ Recommended in the French national polluted soil management methodology



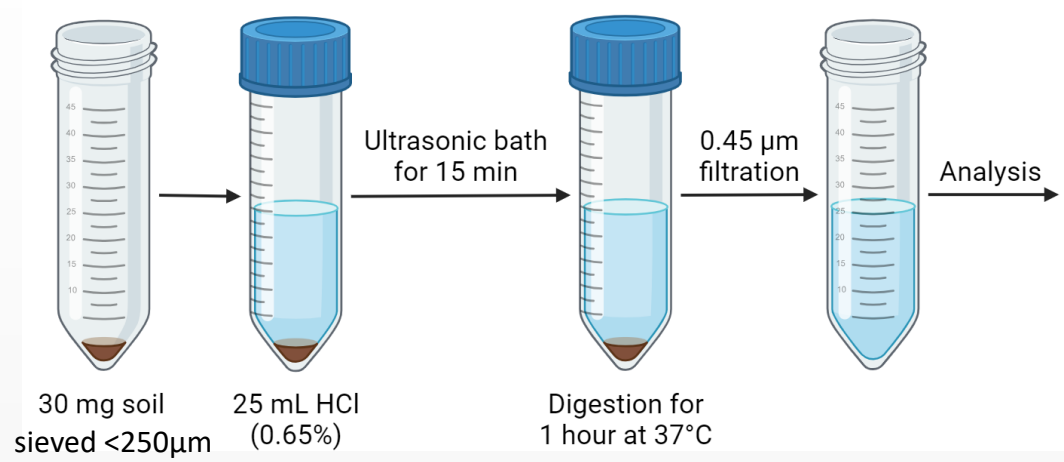
Not or little used by polluted soil managers:

- × Lack of awareness of the test
- × Lack of national knowledge of the test
- × Time consuming, expensive and requires real expertise
- × Test only valid for As, Cd and Pb
- × Operational difficulties to take into account bioaccessibility

Context and issues

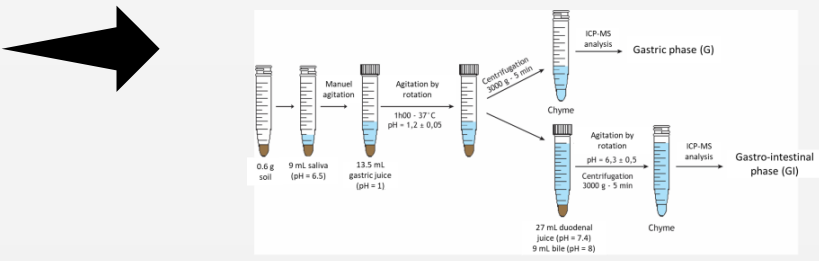
HCl test: simplified method

- ✓ Very good correlation with UBM test (As, Cd and Pb)
- ✓ ISO standardization in progress
- ✓ Can be used as a screening method on a large number of samples as decision-making tool



Element	Field of application	Phase	Equation
As	1.9–228 mg kg ⁻¹	G	$\log_{10}[\text{As}]_{\text{BA predicted}} = 0.83 \times \log_{10}[\text{As}]_{\text{HCl}} + 0.16$
		GI	$\log_{10}[\text{As}]_{\text{BA predicted}} = 0.80 \times \log_{10}[\text{As}]_{\text{HCl}} + 0.13$
Cd	0.1–483 mg kg ⁻¹	G	$\log_{10}[\text{Cd}]_{\text{BA predicted}} = 1.00 \times \log_{10}[\text{Cd}]_{\text{HCl}} - 0.01$
		GI	$\log_{10}[\text{Cd}]_{\text{BA predicted}} = 1.03 \times \log_{10}[\text{Cd}]_{\text{HCl}} - 0.41$
Pb	9–12,300 mg kg ⁻¹	G	$\log_{10}[\text{Pb}]_{\text{BA predicted}} = 1.01 \times \log_{10}[\text{Pb}]_{\text{HCl}} - 0.06$
		GI	$\log_{10}[\text{Pb}]_{\text{BA predicted}} = 1.11 \times \log_{10}[\text{Cd}]_{\text{HCl}} - 1.28$

Predicted UBM bioaccessibility



Context and issues

Operational difficulties to take into account bioaccessibility



Need to clarify how bioaccessibility should be taken into account when assessing health risks

Enhance the use of the simplified test

- Comparaison of UBM and HCl test

Strengthen the validity of the HCl test for predicting Pb bioaccessibility

Disparities between sample preparation method

- UBM method (NF ISO 17924): soil sieved <250µm
- French recommendation for total concentration (NF ISO 11464): sieved < 2mm then crushed <250µm

Investigate the influence of sample preparation methods on total concentration measurements

Bioaccessibility integration method in exposition and risk calculation

- Choice of phase
- Choice of method

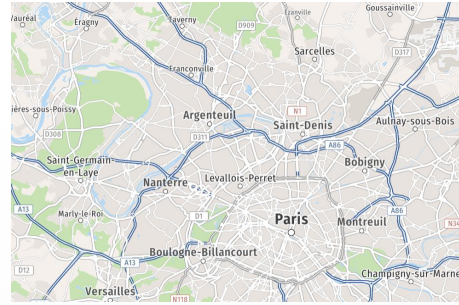
Method for integrating bioaccessibility into risk calculations



The aim is to give an idea of the contribution of oral bioaccessibility in Ile-de-France soils and to clarify its application

Methodology

Experimental design

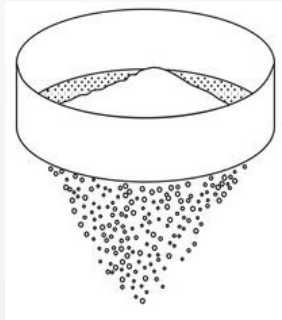
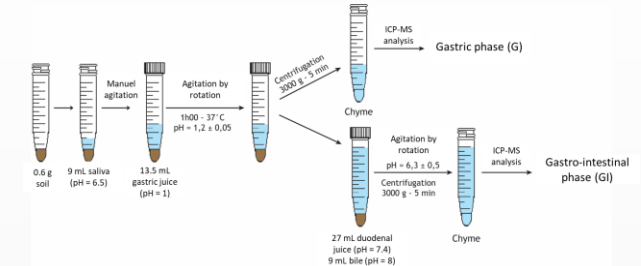


Collection of 45 Pb contaminated soil samples in Ile-de-France region

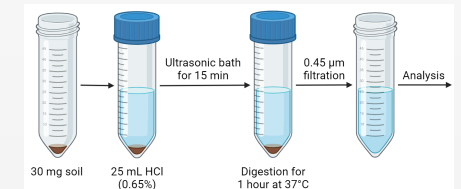
Pseudototal concentrations

Physico-chemical parameters

UBM & HCl tests



Operational framework for the use of bioaccessibility in risk assessment

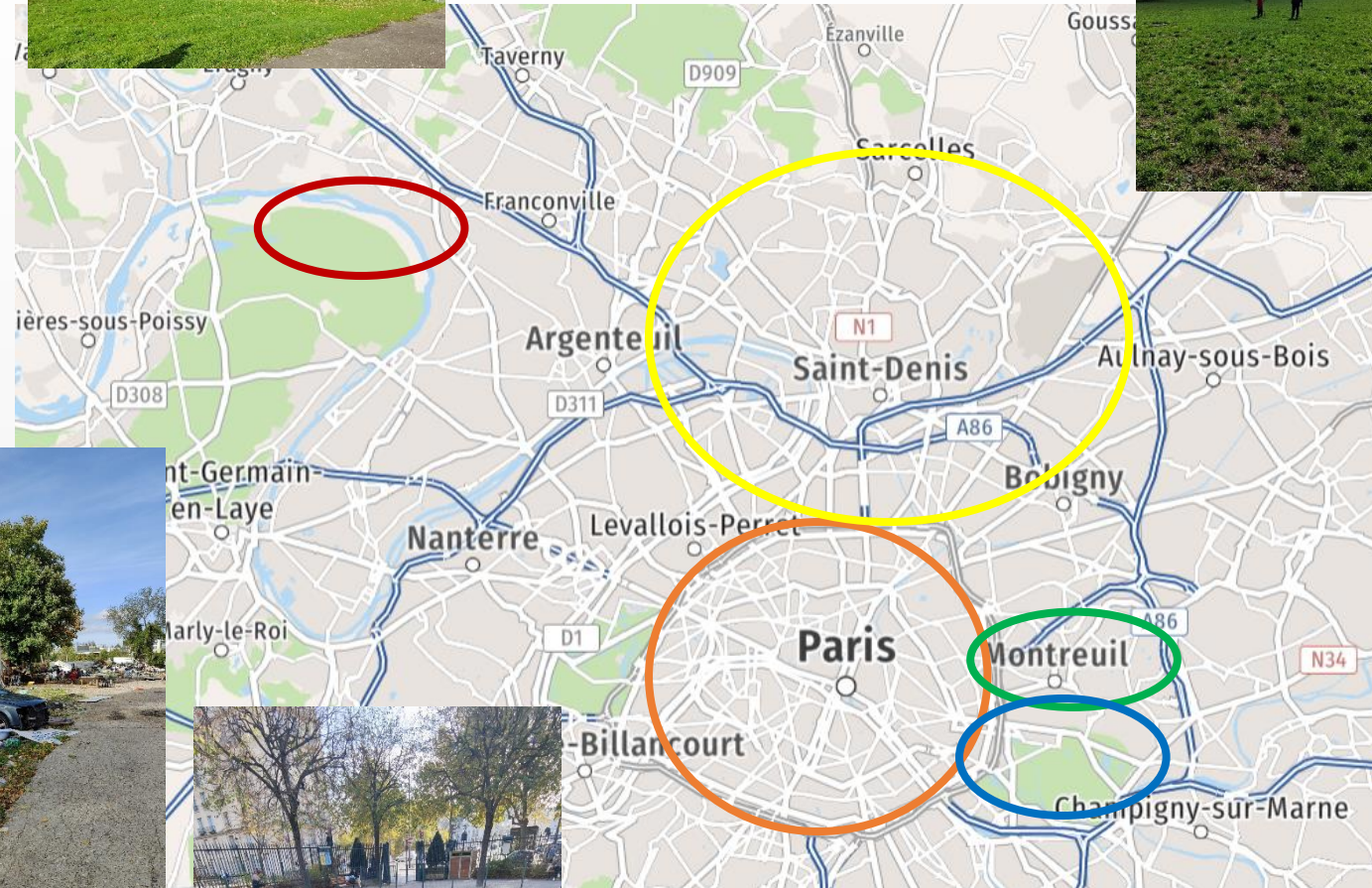


Results

Soil sample collection

Code	Nbr spl	Uses
ACH1	2	Agricultural soil / orchard
VIN1	1	Lawn in the public garden near the vegetable garden
MON1	2	Mound: deep soil / lawn near play area
MON2	1	Shared gardens
MON3	2	Meadow/undergrowth
MON4	1	Wasteland
MON5	1	Lawn public garden
MON6	1	Wooded area
PAR1	1	Garden courtyard
PAR2	1	Lawn public garden
PAR3	1	Lawn public garden
PAR4	4	Lawn public garden
PAR5	4	Lawn public garden
PAR6	2	Lawn public garden
PAR7	2	Lawn public garden
PAR8	5	Lawn public garden
PAR9	2	Lawn public garden
PAR10	1	Lawn public garden
PAR11	2	Lawn public garden
PAR12	3	Lawn public garden
PAR13	1	Lawn, building garden
PAR14	2	Lawn public garden
SSD1	3	Revegetated wasteland/flower beds

45 samples from 23 sites



Results

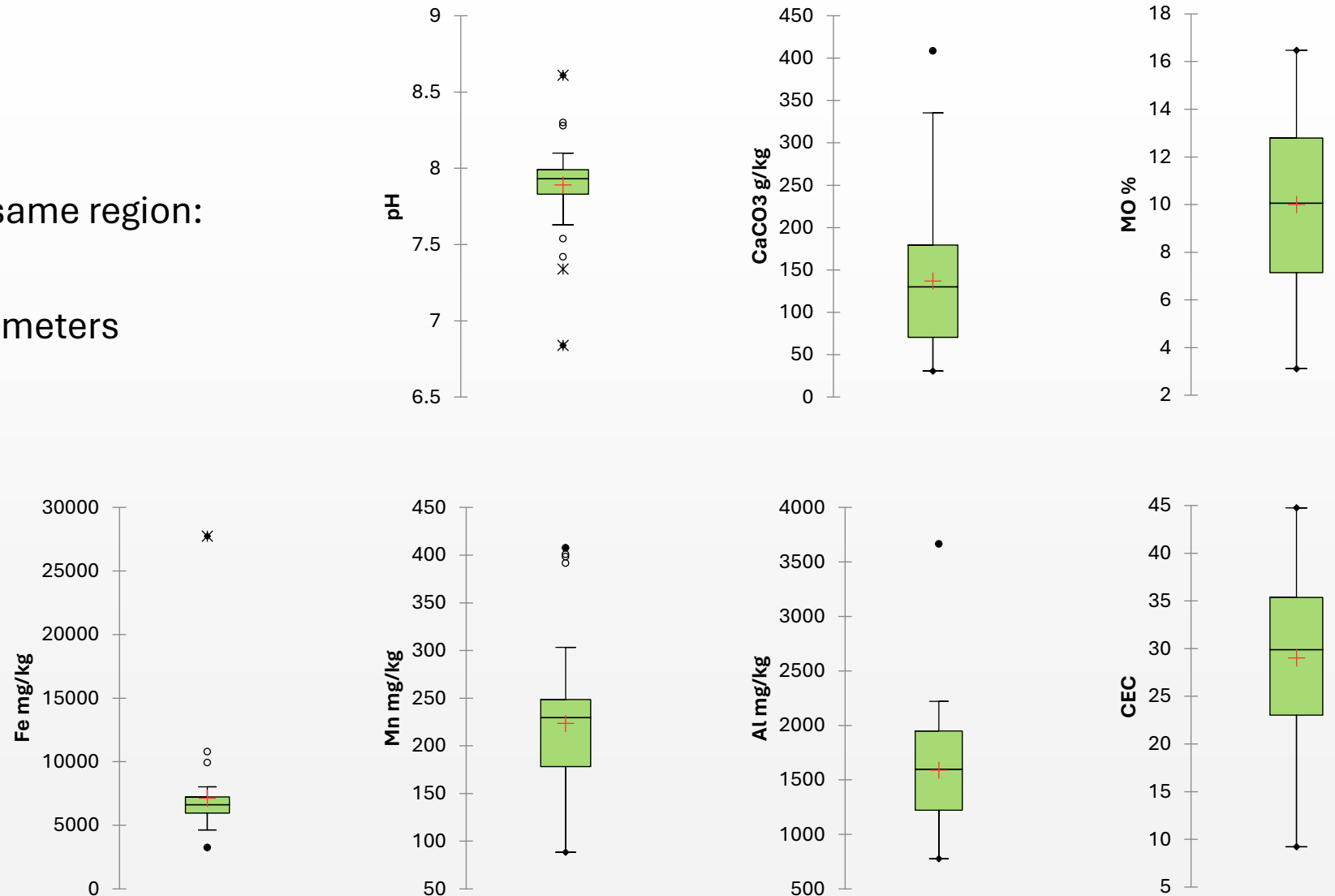
Soil physico-chemical characteristics

All soils are coming from the same region:
Ile-de-France

Little variability for some parameters
→ Soil pH mostly 7.7-8.2

Spearman correlation test

***No key parameter
influencing bioaccessibility
could be identified***



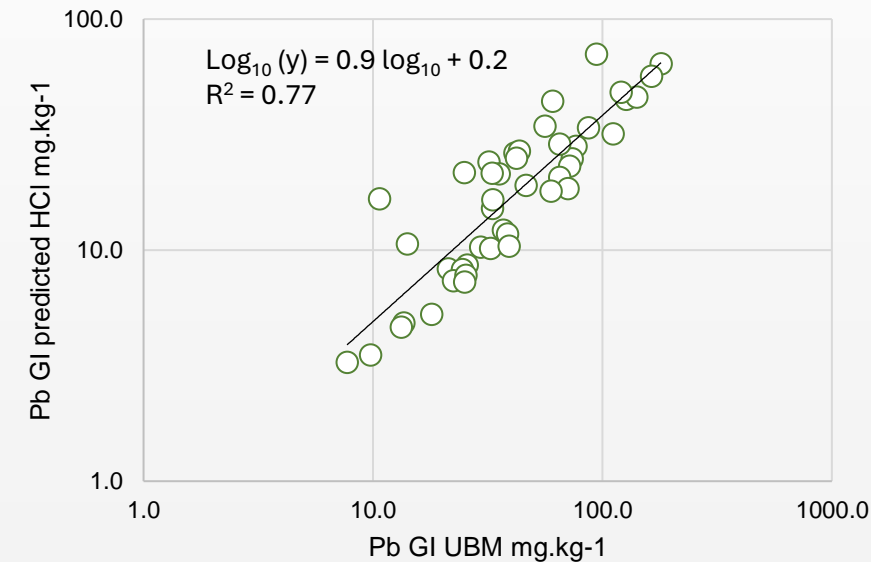
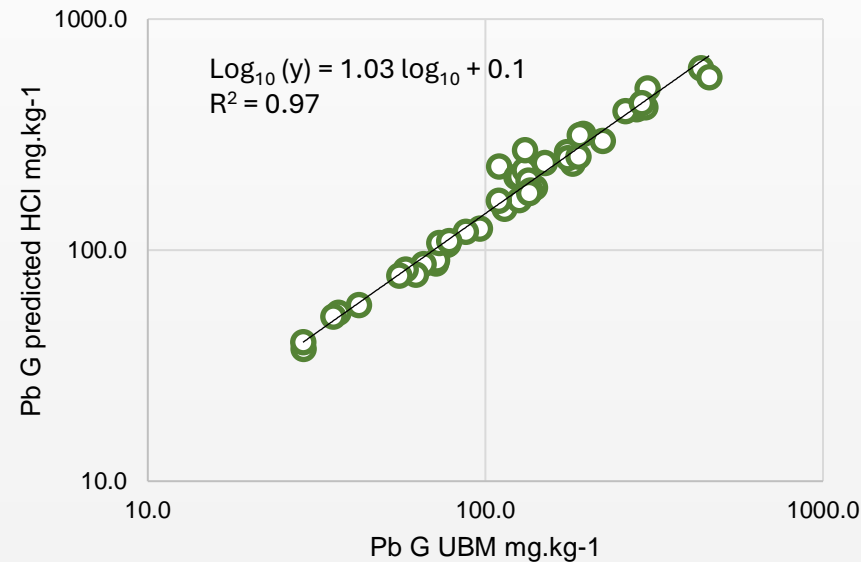
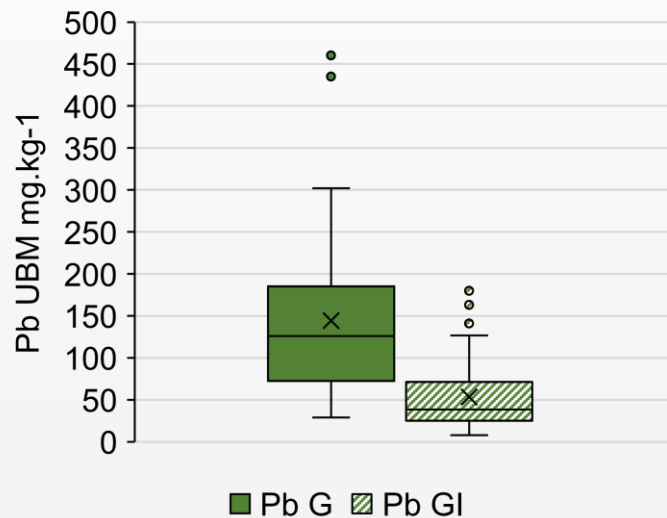
Results

Pb bioaccessibility : UBM vs HCl

Pelfrêne et al. 2020 equations (n=140)

G: $\log_{10}[\text{Pb}]_{\text{BA}_{\text{predicted}}} = 1.01 \times \log_{10}[\text{Pb}]_{\text{HCl}} - 0.06$; $r^2 = 0.99$

GI: $\log_{10}[\text{Pb}]_{\text{BA}_{\text{predicted}}} = 1.11 \times \log_{10}[\text{Pb}]_{\text{HCl}} - 1.28$; $r^2 = 0.72$



Strengthening the validity of using the HCl test to predict Pb bioaccessibility as a screening method

Results

Sieved vs. crushed fraction at 250µm Total concentrations

ANOVA, Tukey test (p < 0.05)	Number of soils	Percentage %
No difference	9	20
Crushed < sieved	34	76
Crushed > sieved	2	4

Crushing the 2mm soil fraction to 250µm underestimates the Pb pseudototal concentration of the high-risk fraction (which adheres to the hands) in ¾ of soils

Reference	Crushed	Sieved	mg.kg ⁻¹	Reference	Crushed	Sieved
410	549	839		433	146	187
411	136	160		434	180	197
412	180	289		435	220	269
413	463	780		436	198	273
414	51	106		437	171	240
415	54	57		438	186	299
416	92	106		439	204	249
417	381	548		440	201	252
418	139	161		441	432	577
419	134	164		442	104	94
420	127	159		443	88	84
421	66	74		444	111	118
422	125	138		445	308	346
423	125	135		446	331	467
424	174	232		447	168	197
425	703	396		448	101	105
426	570	324		449	48	60
427	97	126		450	92	92
428	147	199		451	51	58
429	236	274		452	147	185
430	190	227		453	313	444
431	234	309		454	70	86
432	198	211				

Results

Sieved vs. crushed fraction at 250µm Bioaccessibility %

$$\text{Bioaccessibility (\%)} = \frac{\text{Bioaccessible element mg. kg}^{-1}}{\text{Pseudototale concentration mg kg}^{-1}}$$

Pesudototal concentration :
Two preparation methods

Soil 2mm crushed
to 250µm

2mm soil sieved
to 250µm

ANOVA, Tukey test (p < 0.05)	Number of soils	Percentage %
No difference	11	24
Crushed > sieved	31	69
Crushed < sieved	3	7

Crushing the 2mm soil fraction to 250µm underestimates the Pb pseudototal concentration of the high-risk fraction (which adheres to the hands) in ¾ of soils

For Ile-de-France sites: sample crushing mostly overestimates bioaccessibility

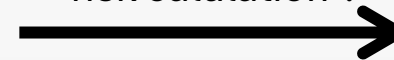
Results

Contribution of Pb bioaccessibility for health risk assessment

An example for 3 Ile-de-France soils

Pseudo total concentration (Sieved <250µm)	Bioaccessible Pb in gastric phase	Bioaccessible Pb in gastrointestinale phase
396 mg/kg	55 % 223 mg/kg	28% 111 mg/kg
289 mg/kg	60% 174 mg/kg	26% 77 mg/kg
138 mg/kg	54% 78 mg/kg	21% 30 mg/kg

Integration in health
risk calculation ?



- Current method: InVS-Ineris (2012): highest bioaccessibility and factor 2 for Pb: problem if Pb bioaccessibility > 50%
- This is why a national working group "Oral bioaccessibility of metals in soils") is currently **revising the methodology**

The consideration of the bioaccessible fraction instead of pseudototal concentration could refine and reduce the estimated risk but the methodology needs to be revised



InVS-Ineris (2012)

$$DJE_{ajustée} = DJE \cdot \frac{BA_{TERRE} \cdot fa_{TERRE}}{BA_{VTR} \cdot fa_{VTR}} = DJE \cdot \frac{BA_{TERRE} \cdot 0,8}{0,4} = DJE \cdot 2 \cdot BA_{TERRE}$$

Conclusion and perspectives

Enhance the use of the simplified test

The simplified HCl test can be used as screening to give a first idea of Pb bioaccessibility

Disparities between sample preparation method

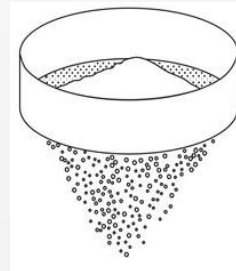
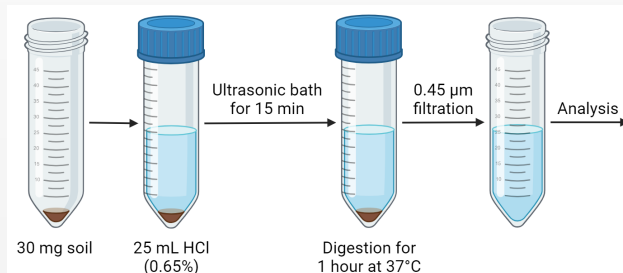
Using $<250\mu\text{m}$ crushed soil tend to overestimate the risk

→ Contradictory to the objective of refining exposure

Recommendation: use the same fraction for the total concentration and the UBM/HCl tests

Bioaccessibility integration method in exposition and risk calculation

The consideration of the bioaccessible fraction instead of pseudototal concentration could refine and reduce the estimated risk



To be investigated:

- *Choice of phase*
- *Method for integrating bioaccessibility into risk calculations*



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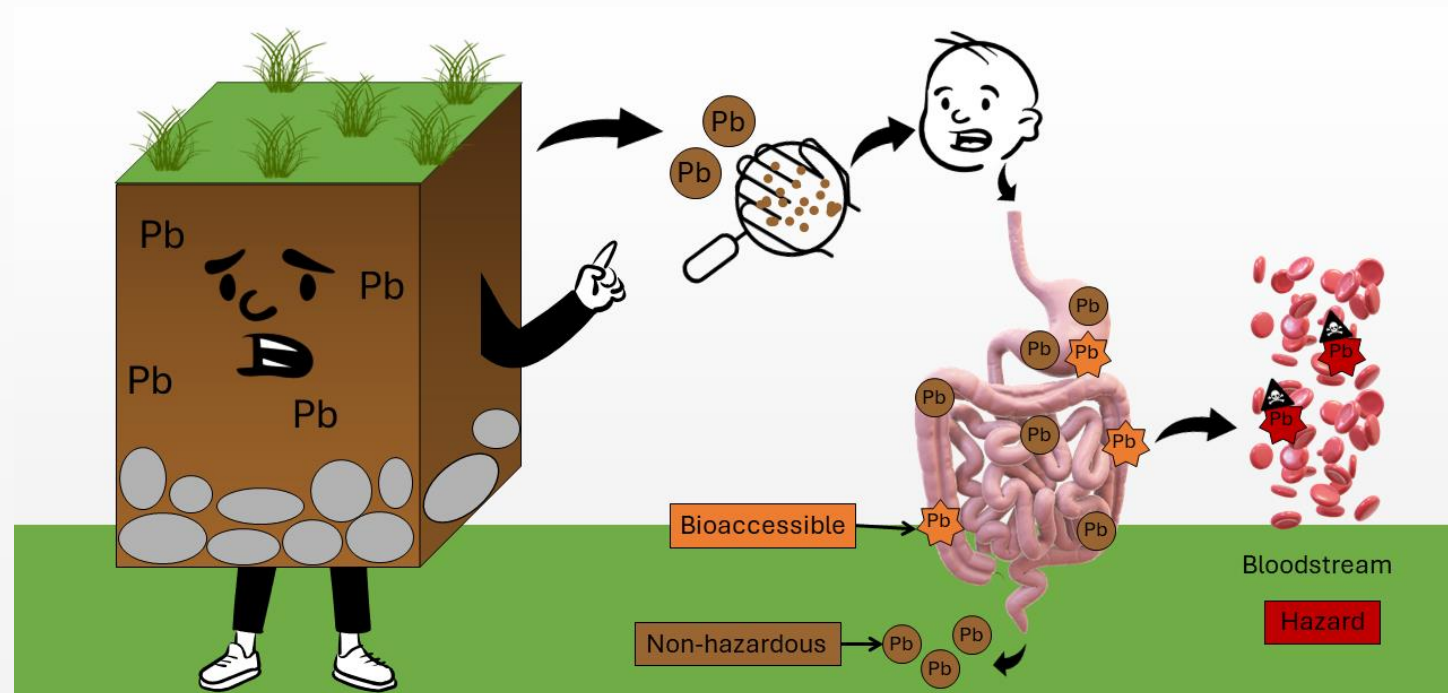
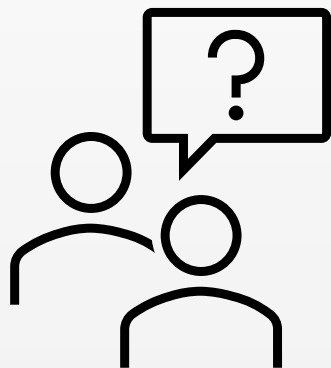
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Thank you for
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