TXRF WEBINAR

Can TXRF be a valuable tool in biomonitoring?

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1) Bruker Nano GmbH, Berlin

2) „Micro X-ray Lab", Department of Soil, Plant and Food Sciences, University of Bari, Italy

October 2021

Welcome

Speakers

Dr. Armin Gross
Global Product Manager TXRF
Bruker Nano, Berlin, Germany

Dr. Ignazio Allegretta
Researcher
University of Bari

Dr. Hagen Stosnach
Applications Scientist TXRF
Bruker Nano, Berlin, Germany

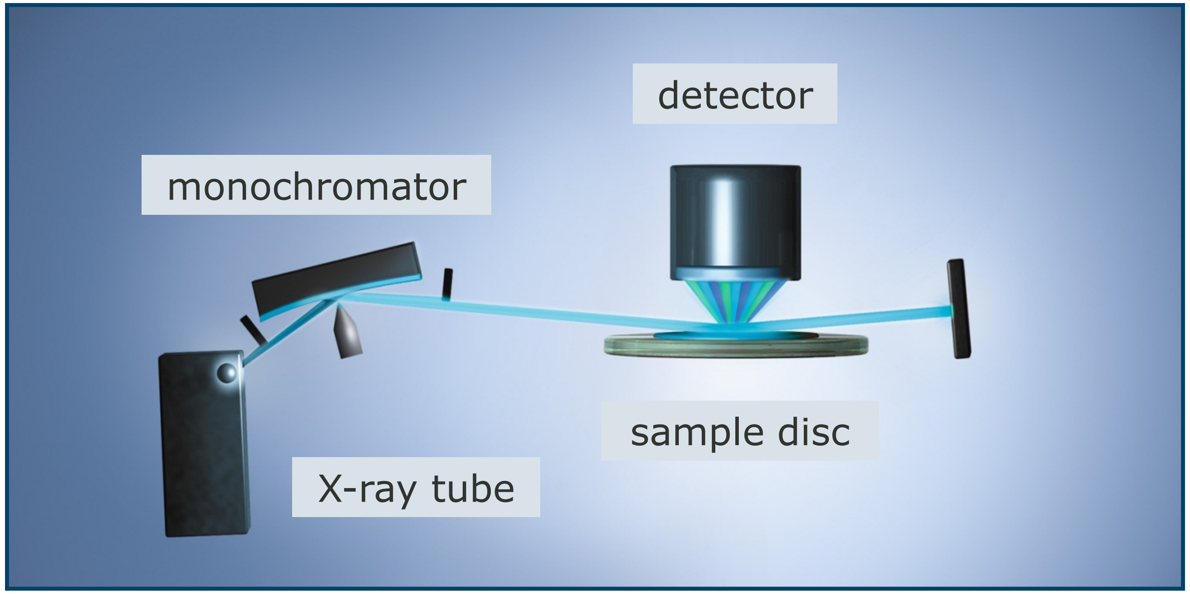
Agenda

01 Principles of TXRF

Principles of TXRF
Technical background

Total reflection X-ray fluorescence spectroscopy

- Samples must be prepared on a reflective media
- Polished quartz glass or polyacrylic glass disc
- Dried to a thin layer, or as a thin film or microparticle
- Matrix effects are negligible



Beam angle: 0°/ 90°

Principles of TXRF Quantification

$$C_i = \frac{C_{IS} \cdot N_i \cdot S_{IS}}{N_{IS} \cdot S_i}$$

C_i: Element concentration

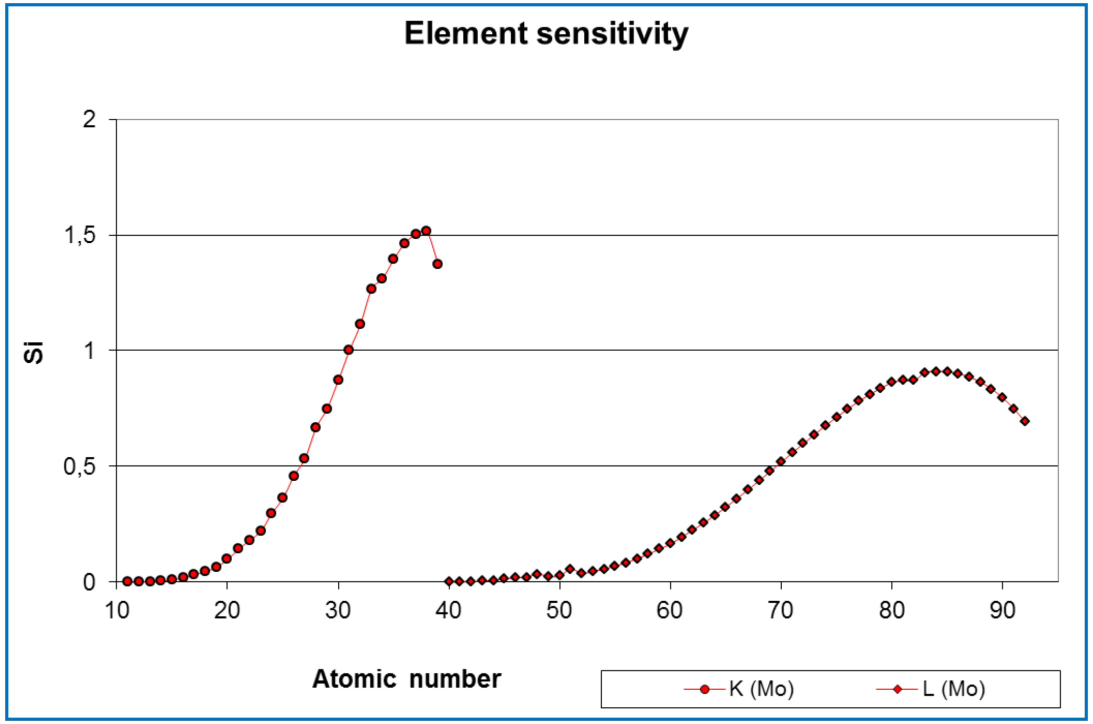
C_{IS}: Internal standard concentration

N_i: Element net countrate

N_{IS}: Internal standard net countrate

S_i: Element sensitivity factor

S_{IS}: Internal standard sensitivity factor



Principles of TXRF
Bruker Product Portfolio

S2 PICOFOX

▪ Most compact design	transportable, for on-site analysis
▪ Fixed excitation mode	easy to use, most suitable for teaching
▪ about 300 installations worldwide	well established technology

S4 T-STAR

▪ Multiple excitation modes	to detect most elements of the PSE
▪ Large area detectors	improved sensitivity for lowest limits of detection
▪ Motorized beam path	automatic beam adjustment and QC procedures
▪ Large sample capacity	up to 90 sample discs, multi-user operation

02 Overview – Environmental analysis

Overview
Environmental analysis

Air

- Airborne particulates

Soil

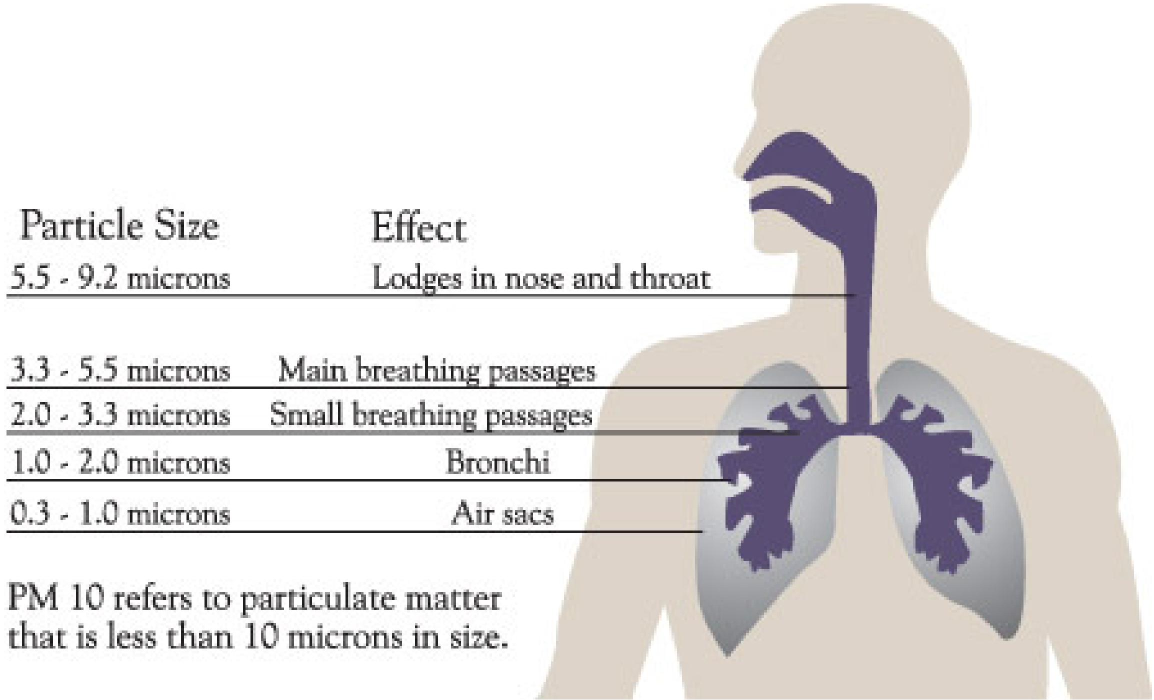
- Contaminated and uncontaminated

Water

- Surface, fresh and drinking water
- Wastewater, sewage

Overview
Environmental analysis

Air, airborne particulates

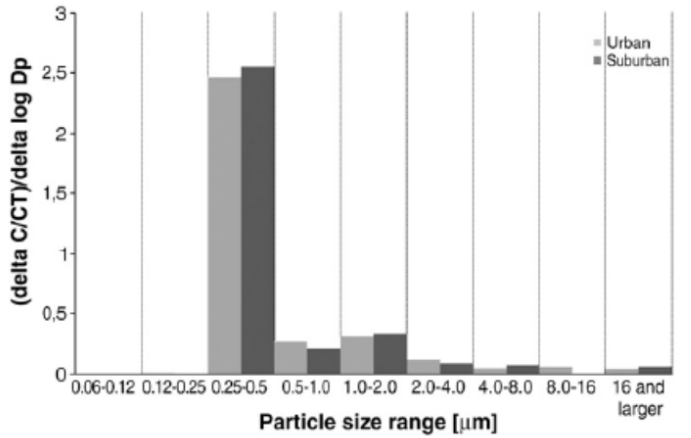


- Suspended: > 10 µm
- Respirable suspended: < 10 µm (PM10)
- Fine particles: < 2,5 µm (PM2.5)
- Ultrafine particles: < 1 µm
- Soot: < 0,3 µm

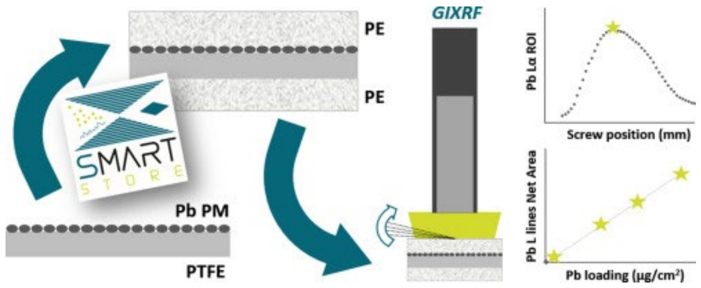
Overview
Environmental analysis

Air, airborne particulates

- Samples collected of filters can be analyzed after extraction or complete digestion
- Direct analysis is only possible qualitatively with small filter segments applying external calibrations or qualitatively
- Results can be applied for environmental monitoring or research on origin analysis of airborne particulates



Wagner & Mages (2010)

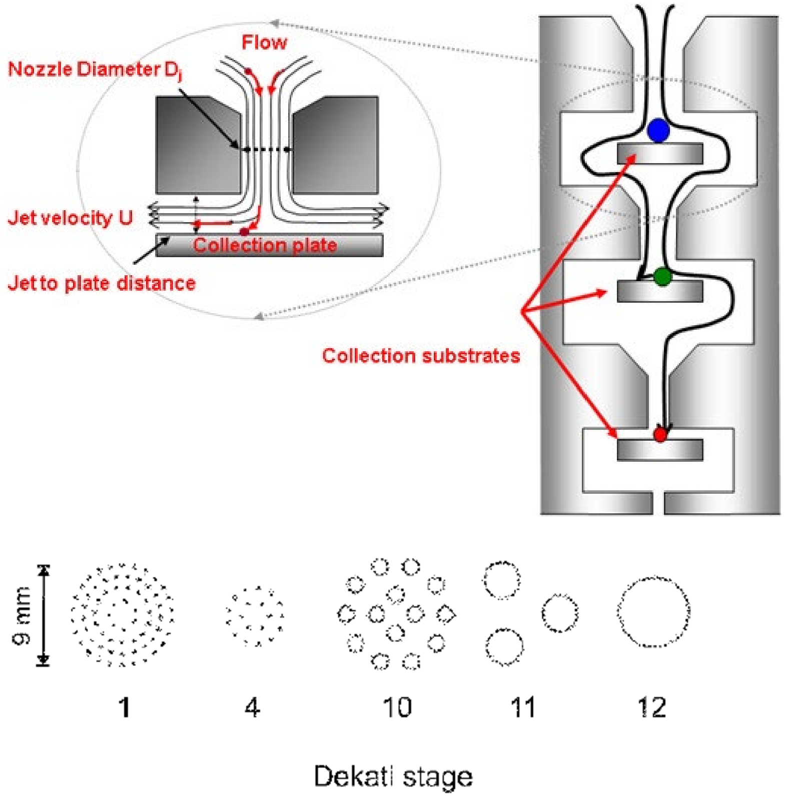


Borgese et al. (2020)

Overview
Environmental analysis

Air, airborne particulates

- Direct analysis after particle-size fractionated sampling directly in sample carriers in multiple stage impactors

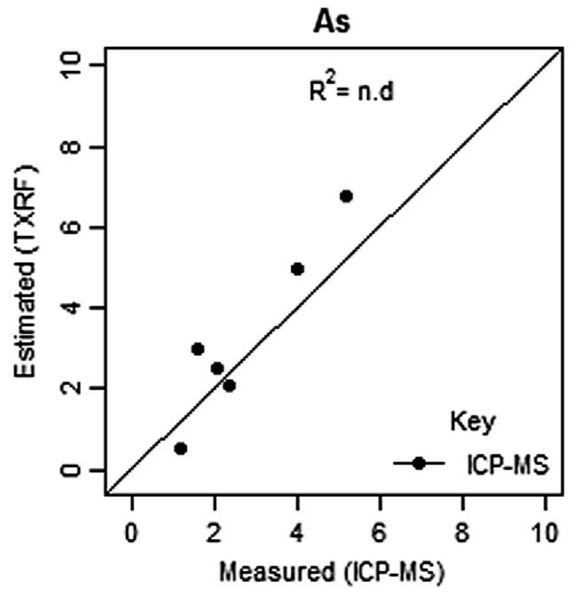


Seeger et al.(2021)

Overview
Environmental analysis

Soil

- Soil samples can be analysed directly after slurry preparation, after complete digestion or extraction
- Due to line interferences the heavy metals Cd, Sn and Sb can only be analysed with W-Brems excitation with detection limits in the higher mg/kg range



Towett et al.(2013)

Overview
Environmental analysis

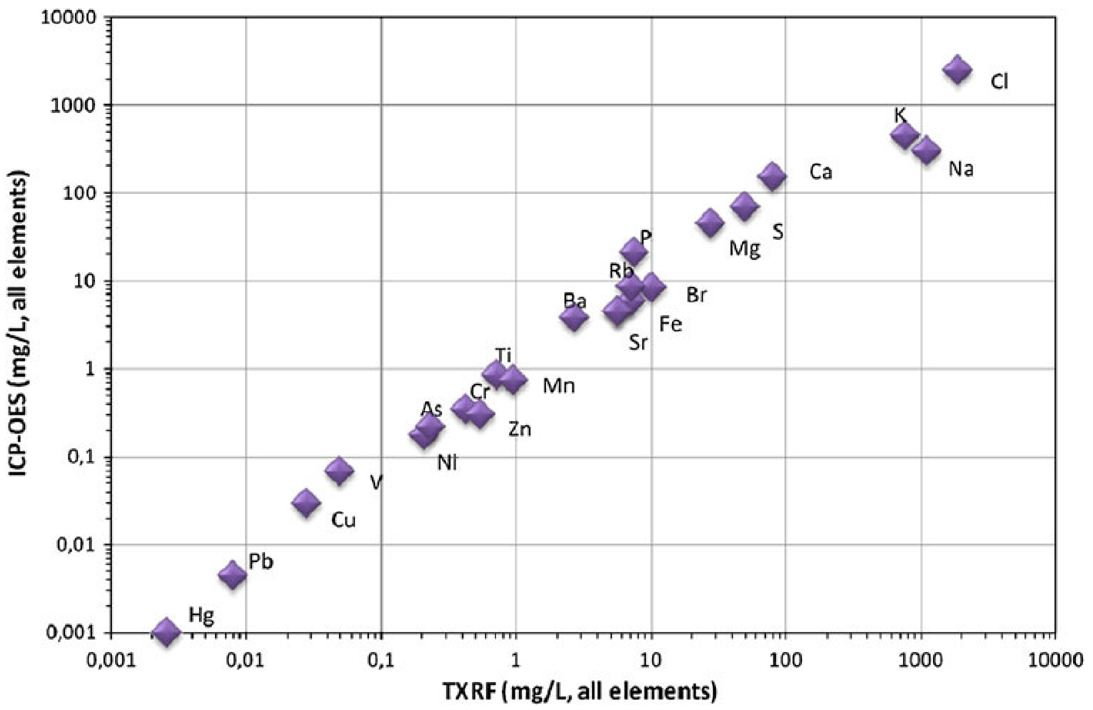
Water

- Surface-, rain-, ground-, drinking waters can be analyzed nearly directly (acidification, internal standardization, preparation on sample carrier)
- Typical detection limits are in the µg/l, sometimes pg/l range
- Mercury analysis is difficult because of its high vapor pressure
  - ➢ Complexation of Hg with thiourea at pH = 10 (Margui et al., 2002)
- Cadmium analysis is difficult because of line interferences
  - ➢ Analysis with W-Brems excitation (LLDs in the high µg/l range)
  - ➢ Liquid-liquid microextraction (Margui et al., 2012)

Overview
Environmental analysis

Water

- Water samples with high matrices (wastewater, sewages etc.) demand some additional sample preparation (adddition of detergents like polyvinyl alcohol)
- TXRF results are typically similar to those, derived by methods like ICP-OES or ICP-MS



Cataldo (2012)

Overview
Environmental analysis

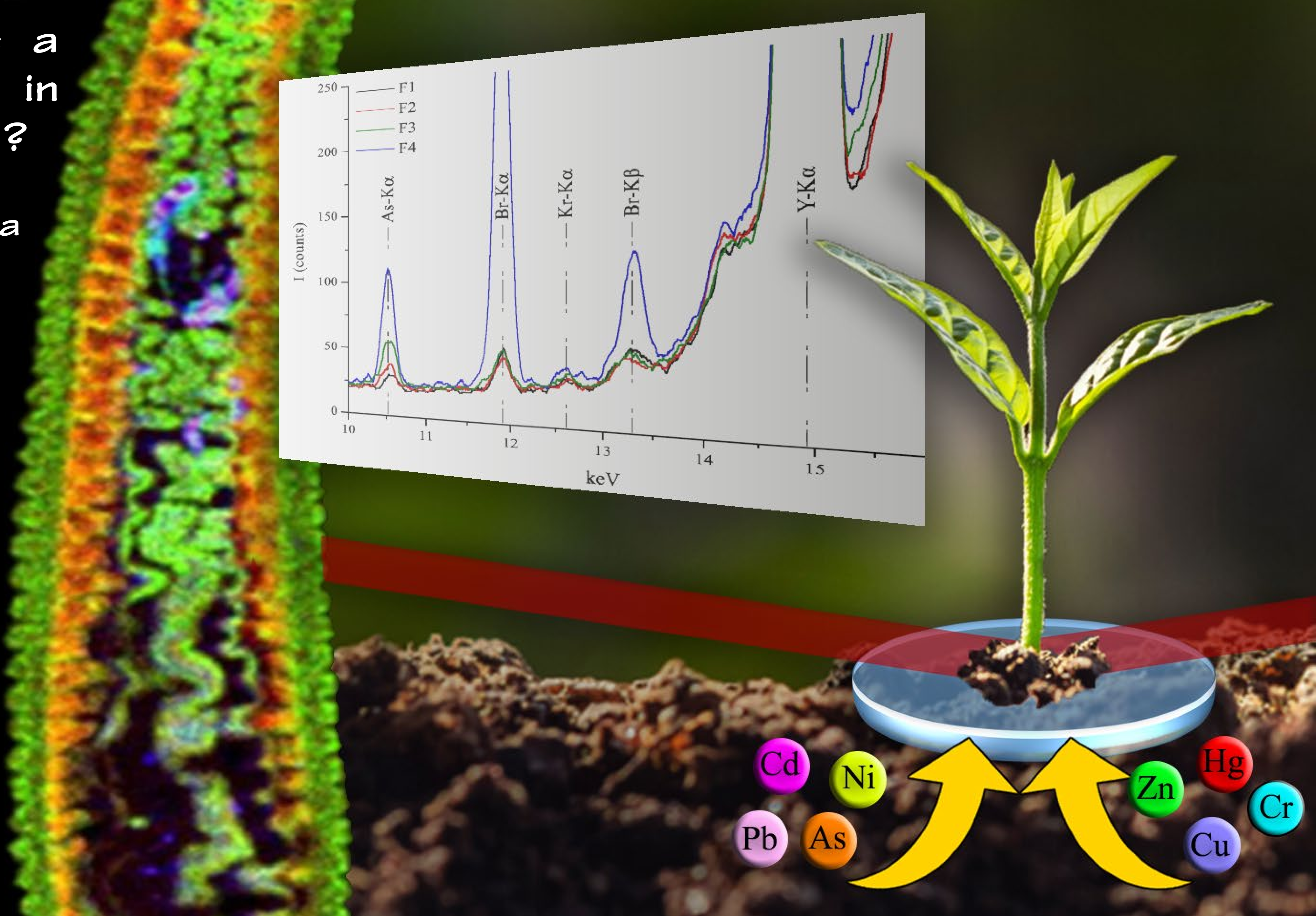
- The routine analysis of air particulates, water and soil only gives a limited actual evaluation
- For a more detailed assessment more complex investigations e.g. on biomonitors must be made

03 Biomonitoring and TXRF

Can TXRF be a Valuable Tool in Biomonitoring?

Ignazio Allegretta

Micro X-ray Lab, DiSSPA,
University of Bari, Italy




Biosphere
Hydrosphere
Atmosphere
Lithosphere

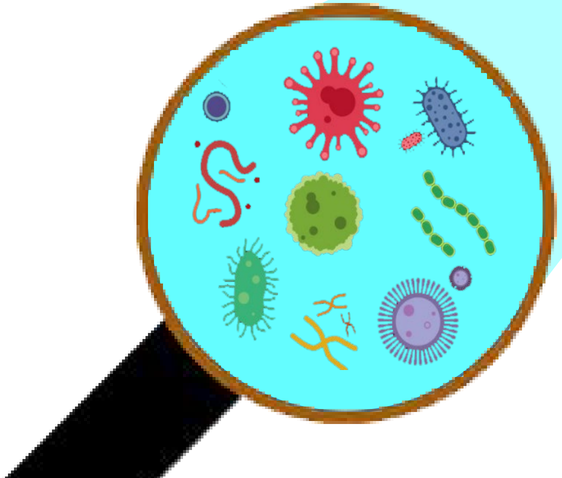

Biosphere
Hydrosphere
Atmosphere
Lithosphere

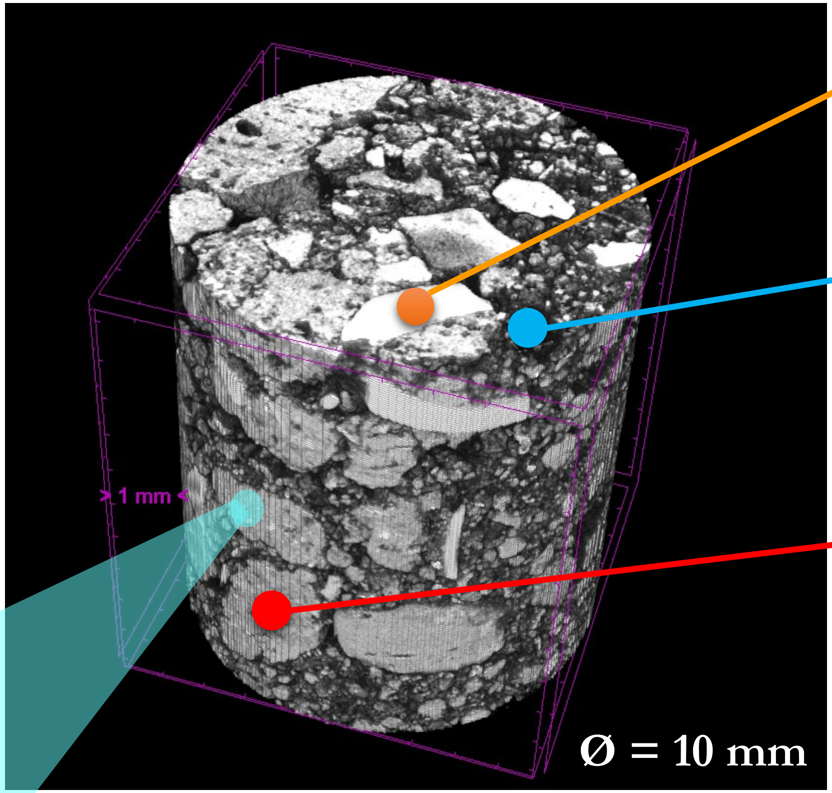

Biosphere
Hydrosphere
Atmosphere
Lithosphere

Soil system

Organisms

Microorganisms





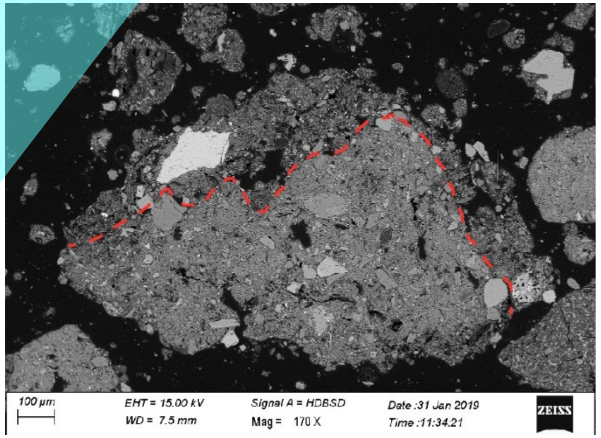
Minerals

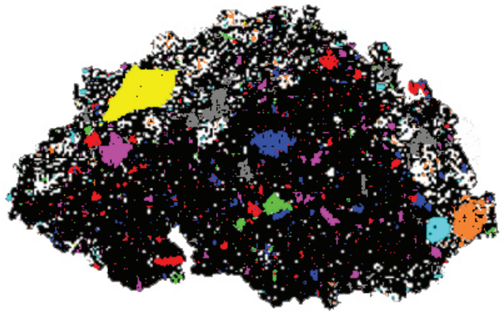
Pores

(water, solutions, air, gases)

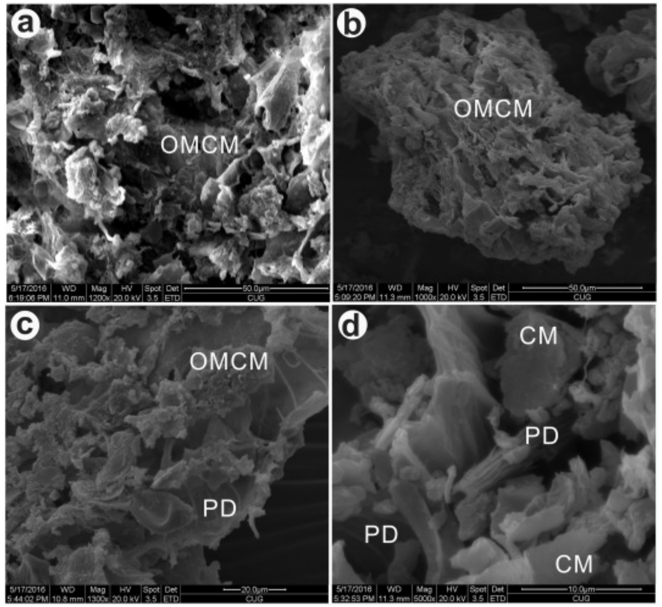
Aggregates

(OM, clays and other minerals)



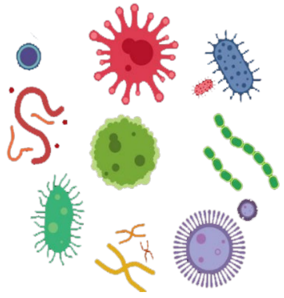


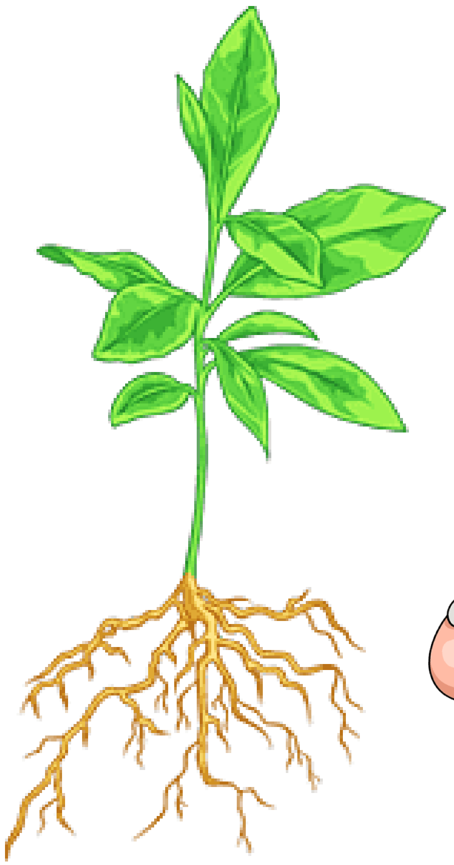
Allegretta et al. (in press) Geoderma



Hong et al. (2019) Appl. Clay Sci. 105125

Soil and Organisms





Photosynthesis vs respiration

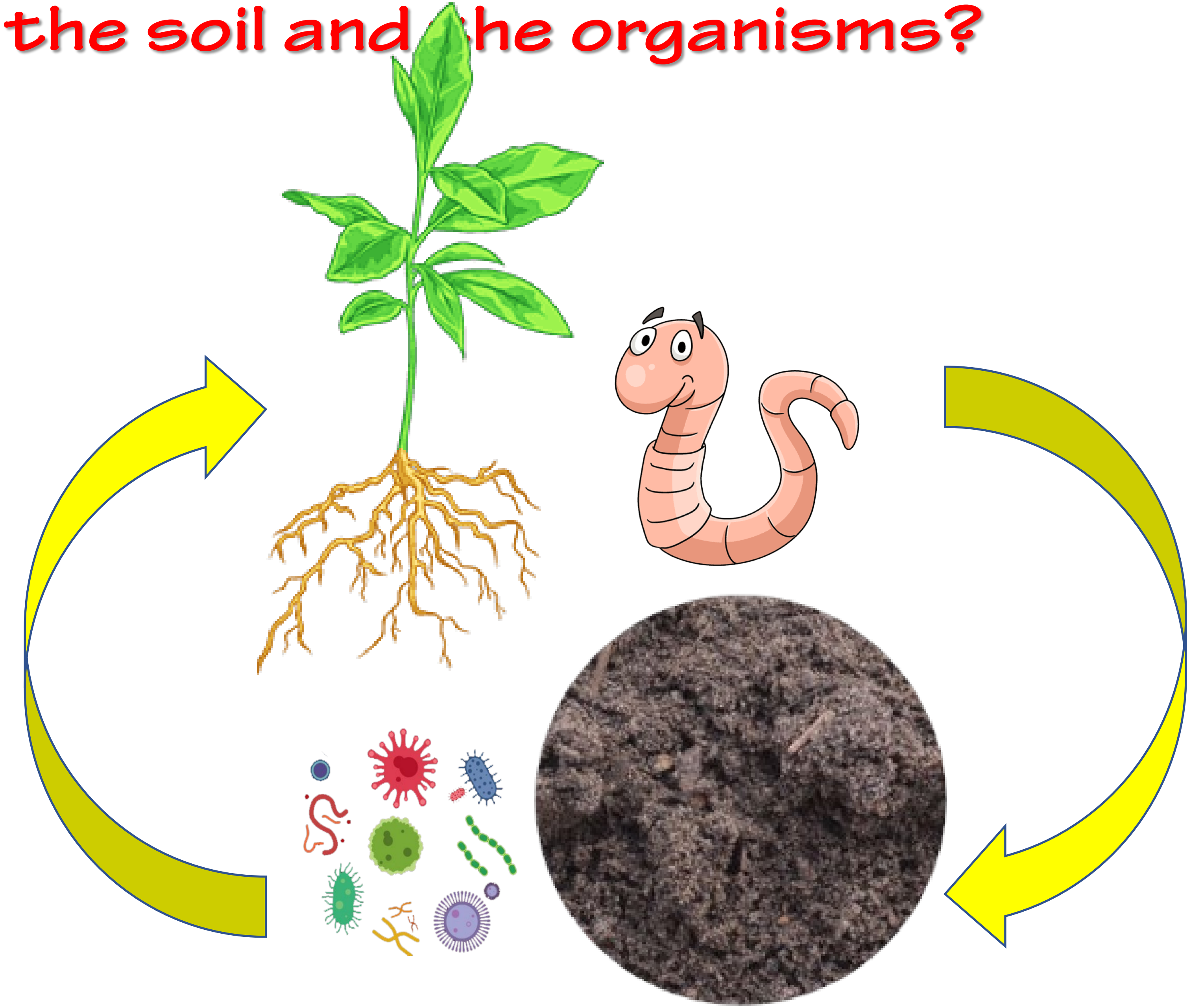
Multiple interactions

Different kind of cells, tissues and organs

Different sample matrix

(saps/fluids, parts rich in fibers, Si, +/-water)

Why do we study the interaction between the soil and the organisms?



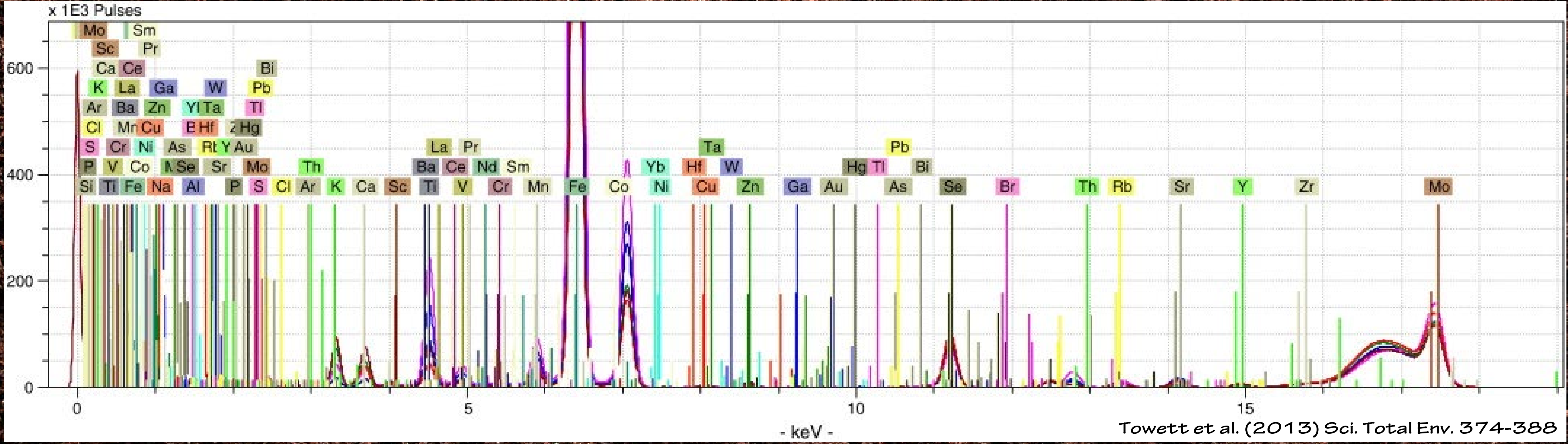
Soil

Full elemental characterization

Suspensions

Soil	50mg
Triton X-100	2.5mL
IS (Se 1000g/L)	40µL

10µL on quartz disk
1000 s



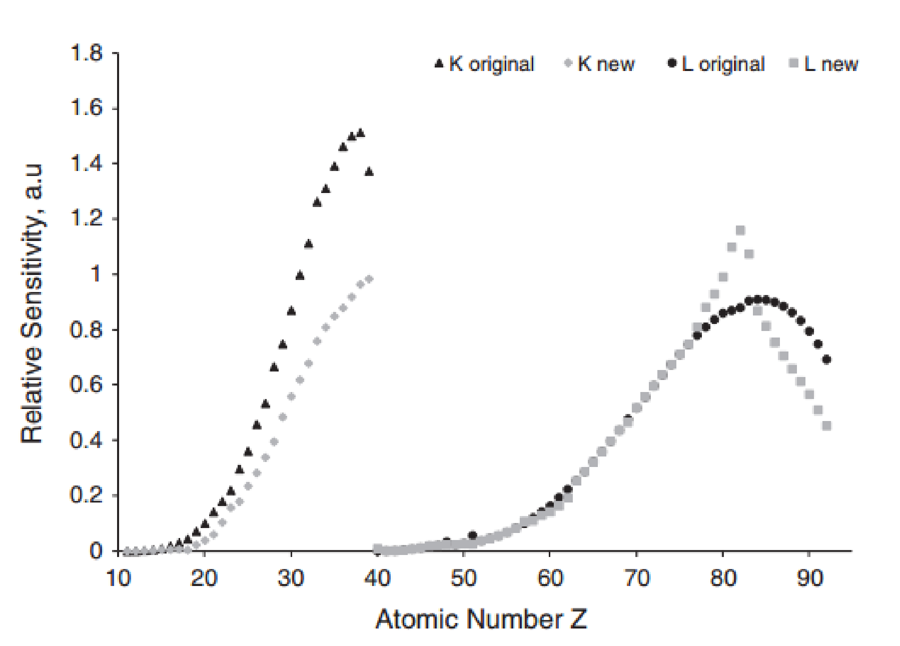
Towett et al. (2013) Sci. Total Env. 374-388

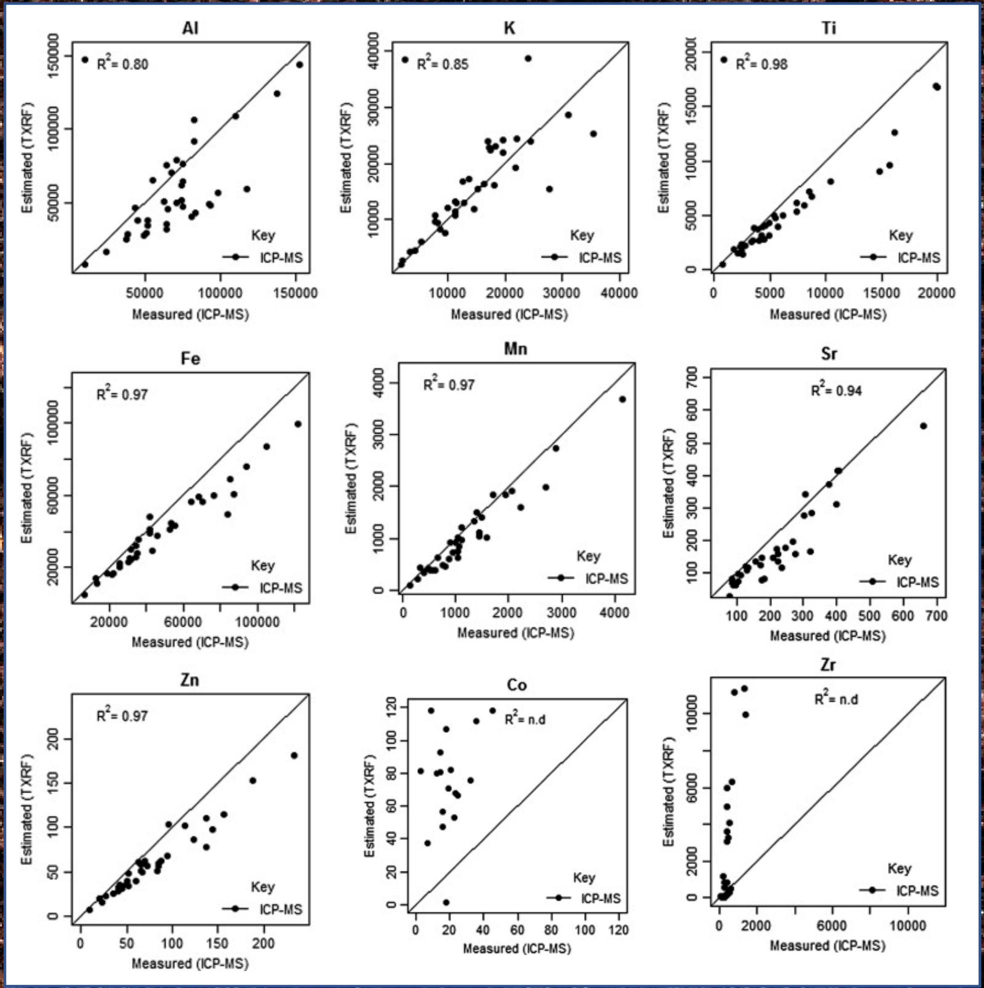
Soil

Matrix effect can't be neglected

↓

Sensitivity recalibration using ICP-MS data





Light elements (but Na and Mg)

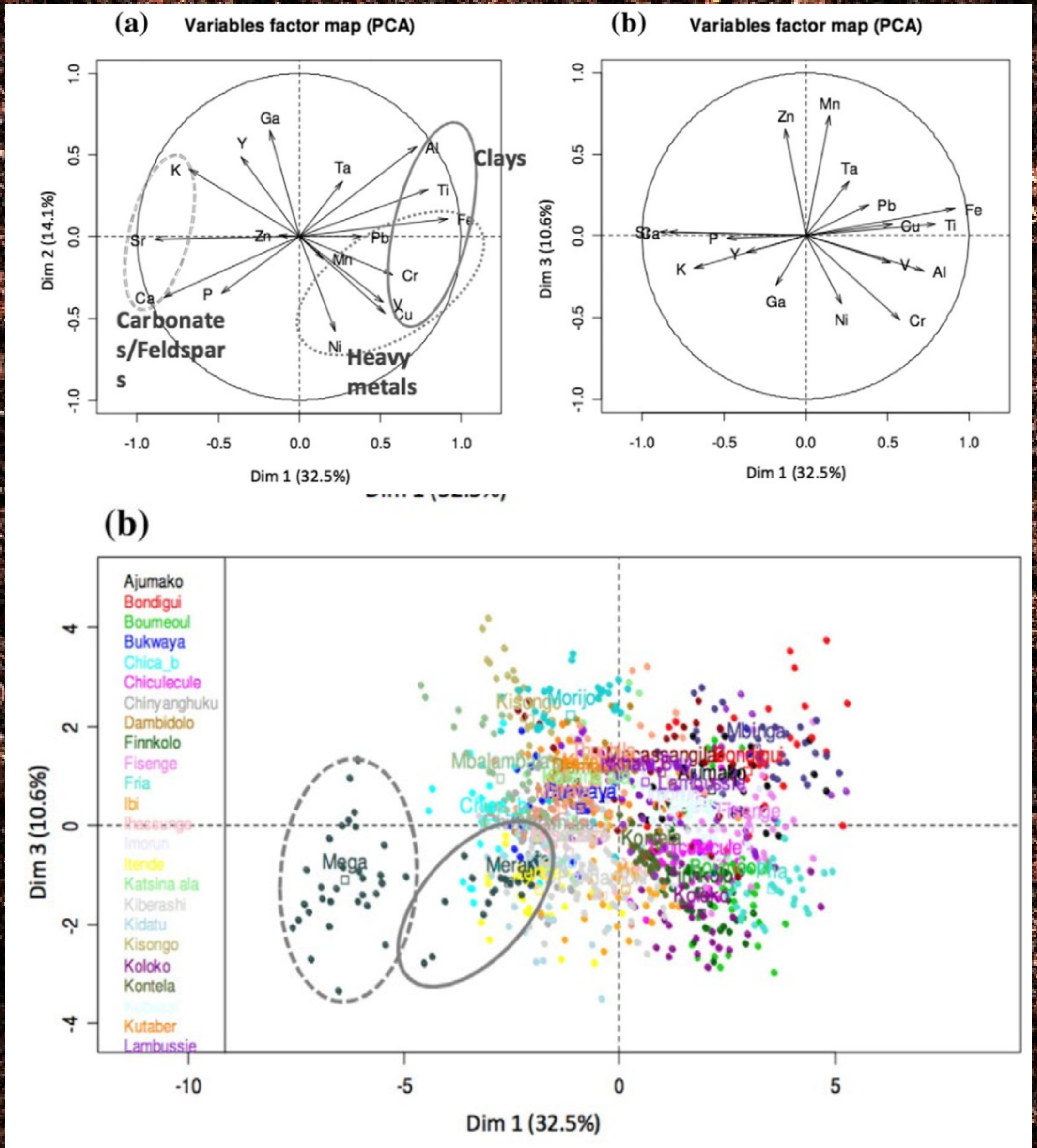
High-Z elements

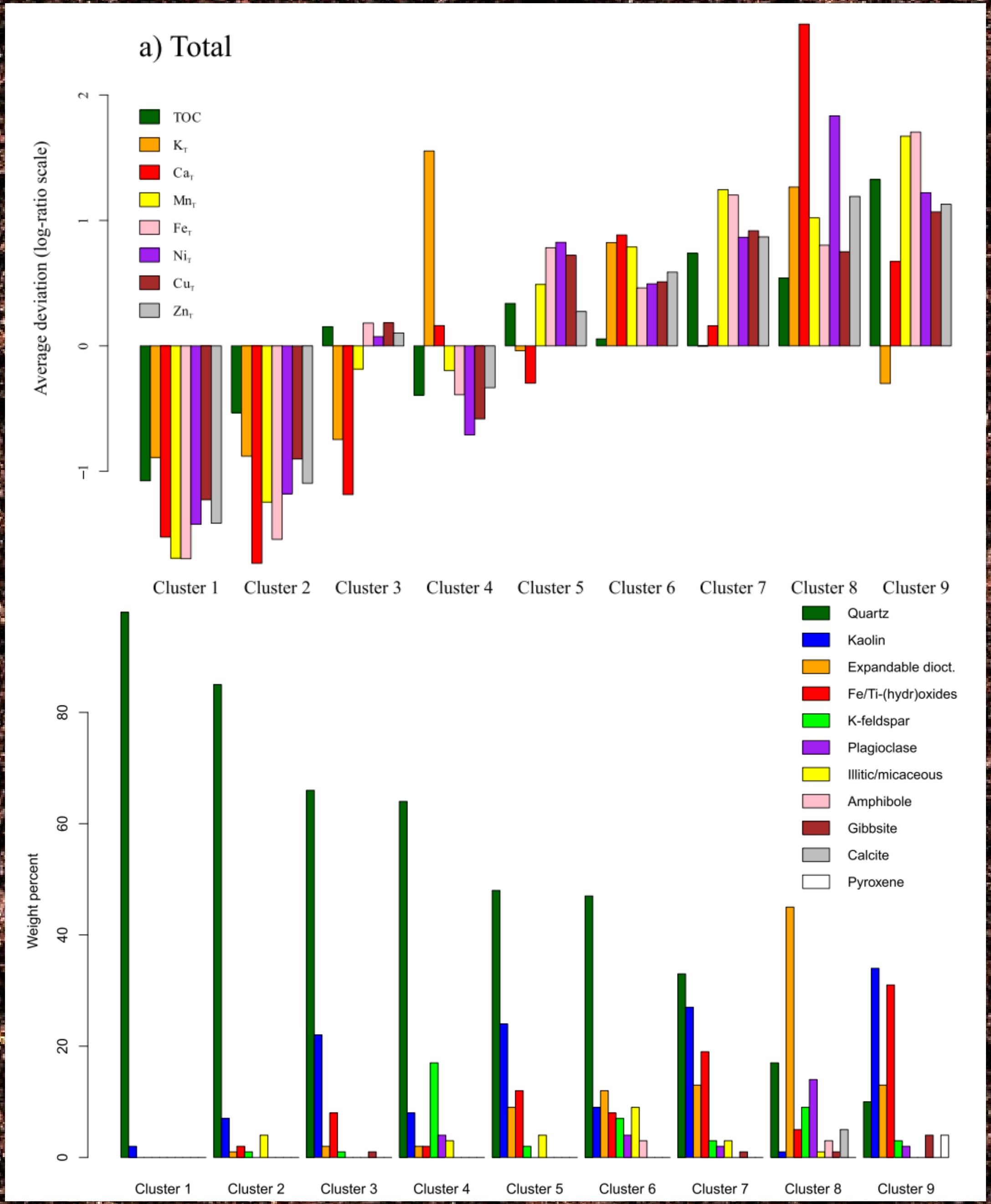
Problems in case of overlapping

confidential

Towett et al. (2013) Sci. Total Env. 374-388

Soil





Towett et al. (2015) *Geoderma Regional*, 157-168

Butler et al. (2020) *Geoderma* 114474

Soil

CEC

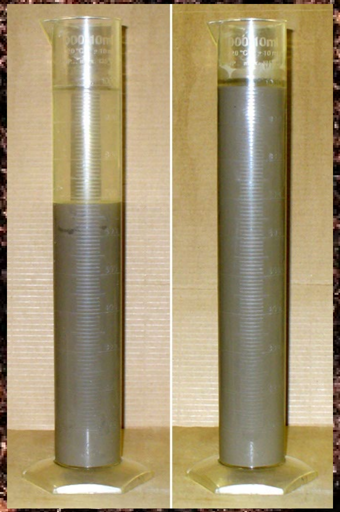
Cation Exchange Capacity

Organic Matter

Too much chemicals for the extraction → Contamination

Clay

Only water for the extraction



Soil - Clay

Which kind of sample preparation???

Full factorial experimental design

Reference materials
Optimization
Phlogopite (Mica-Mg)

Validation
Zinnwaldite (ZW-C)

Variables

Sample mass
Dispersant volume
Reflector

Comparison with

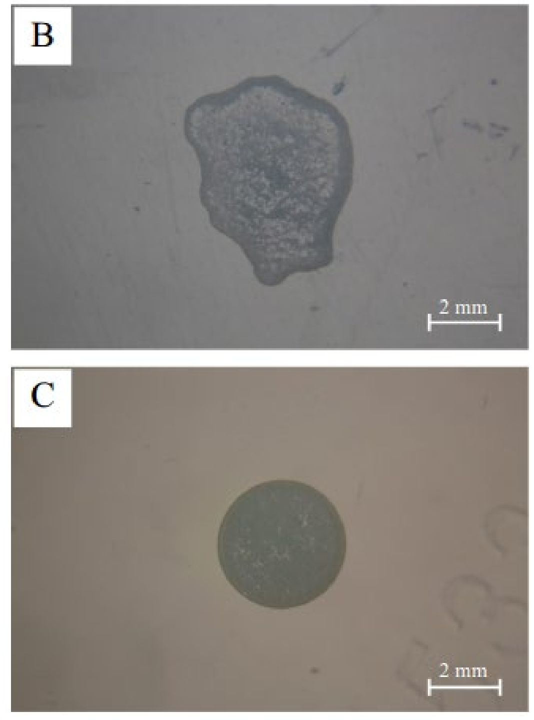
WDXRF

Soil - Clay

Variables	Levels		
	Low	Centre point	High
Sample weight (mg)	50	75	100
Dispersant volume (ml)	2.5	3.75	5
Reflector	Quartz		Plexiglas

Table 3
Recovery (%) obtained for each element after the preparation of slurries using different parameters and TXRF analysis. A recovery of 80–120% was considered acceptable for the correct element detection. The certified concentration of each element is also reported.

Sample weight (mg)	50	50	50	50	75	75	100	100	100	100	Reference Value
Triton solution volume (ml)	2.5	2.5	5	5	3.75	3.75	2.5	2.5	5	5	
Reflector	Quartz	Plexiglas	Quartz	Plexiglas	Quartz	Plexiglas	Quartz	Plexiglas	Quartz	Plexiglas	mg/kg
Mg	111	222	132	214	131	246	51	172	110	236	12.30 (%)
Al	102	185	123	192	115	204	49	137	98	194	8.04 (%)
Si	85	126	123	127	100	139	42	92	86	132	17.89 (%)
Cl	100	179	132	169	110	200	59	118	97	184	800
K	107	149	117	132	112	154	74	118	94	142	8.25 (%)
Ca	36	42	36	27	42	42	37	34	30	40	0.06 (%)
Ti	84	112	87	95	87	114	64	90	71	104	0.98 (%)
V	133	185	145	106	156	167	163	137	105	170	90
Cr	65	110	64	99	56	82	46	90	64	76	100
Mn	82	105	82	87	84	105	67	87	68	95	0.20 (%)
Fe	92	116	90	97	93	116	76	97	76	105	6.62 (%)
Ni	96	122	94	104	96	119	79	100	80	108	110
Cu	86	46	21	39	17	28	32	23	39	24	4
Zn	104	126	97	104	101	126	86	108	83	112	290
Ga	86	111	84	94	86	110	72	92	71	101	21
Rb	105	128	98	104	103	127	91	110	85	113	1300
Sr	113	126	103	106	108	119	96	112	89	107	27
Ba	75	92	71	81	72	91	54	79	63	81	4000
Pb	109	159	86	94	117	181	112	123	83	129	9
Total number of elements with a recovery in the range 80–120%	15	6	10	12	13	7	4	12	11	9	



Allegretta et al. (2019) Appl- Clay Sci 105201

Soil - Clay

Variables	Levels		
	Low	Centre point	High
Sample weight (mg)	50	75	100
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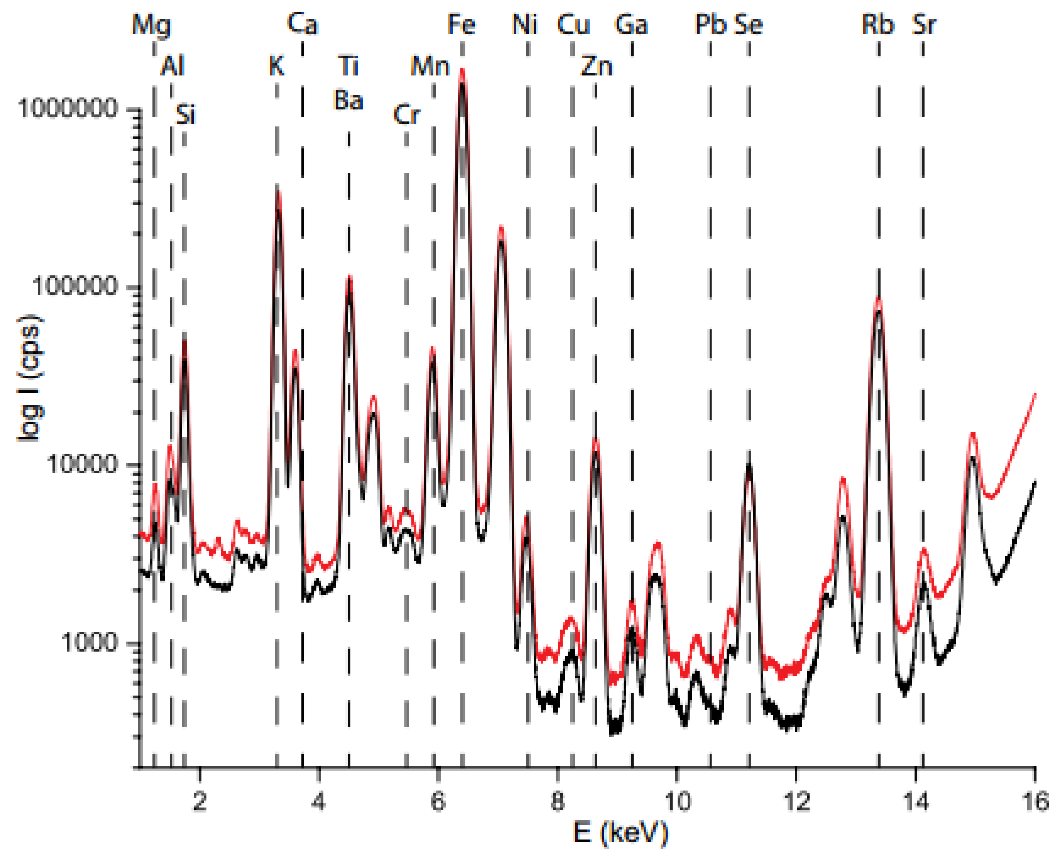
Reflector	Quartz		Plexiglas

Table 3
Recovery (%) obtained for each element after the preparation of slurries using different parameters and TXRF analysi
acceptable for the correct element detection. The certified concentration of each element is also reported.

Sample weight (mg)	50	50	50	50	75	75	100	1
Triton solution volume (ml)	2.5	2.5	5	5	3.75	3.75	2.5	2
Reflector	Quartz	Plexiglas	Quartz	Plexiglas	Quartz	Plexiglas	Quartz	P
Mg	111	222	132	214	131	246	51	1
Al	102	185	123	192	115	204	49	1
Si	85	126	123	127	100	139	42	9
Cl	100	179	132	169	110	200	59	1
K	107	149	117	132	112	154	74	1
Ca	36	42	36	27	42	42	37	3
Ti	84	112	87	95	87	114	64	9
V	133	185	145	106	156	167	163	1
Cr	65	110	64	99	56	82	46	9
Mn	82	105	82	87	84	105	67	8
Fe	92	116	90	97	93	116	76	9
Ni	96	122	94	104	96	119	79	1
Cu	86	46	21	39	17	28	32	2
Zn	104	126	97	104	101	126	86	1
Ga	86	111	84	94	86	110	72	9
Rb	105	128	98	104	103	127	91	1
Sr	113	126	103	106	108	119	96	1
Ba	75	92	71	81	72	91	54	7
Pb	109	159	86	94	117	181	112	1
Total number of elements with a recovery in the range 80–120%	15	6	10	12	13	7	4	1



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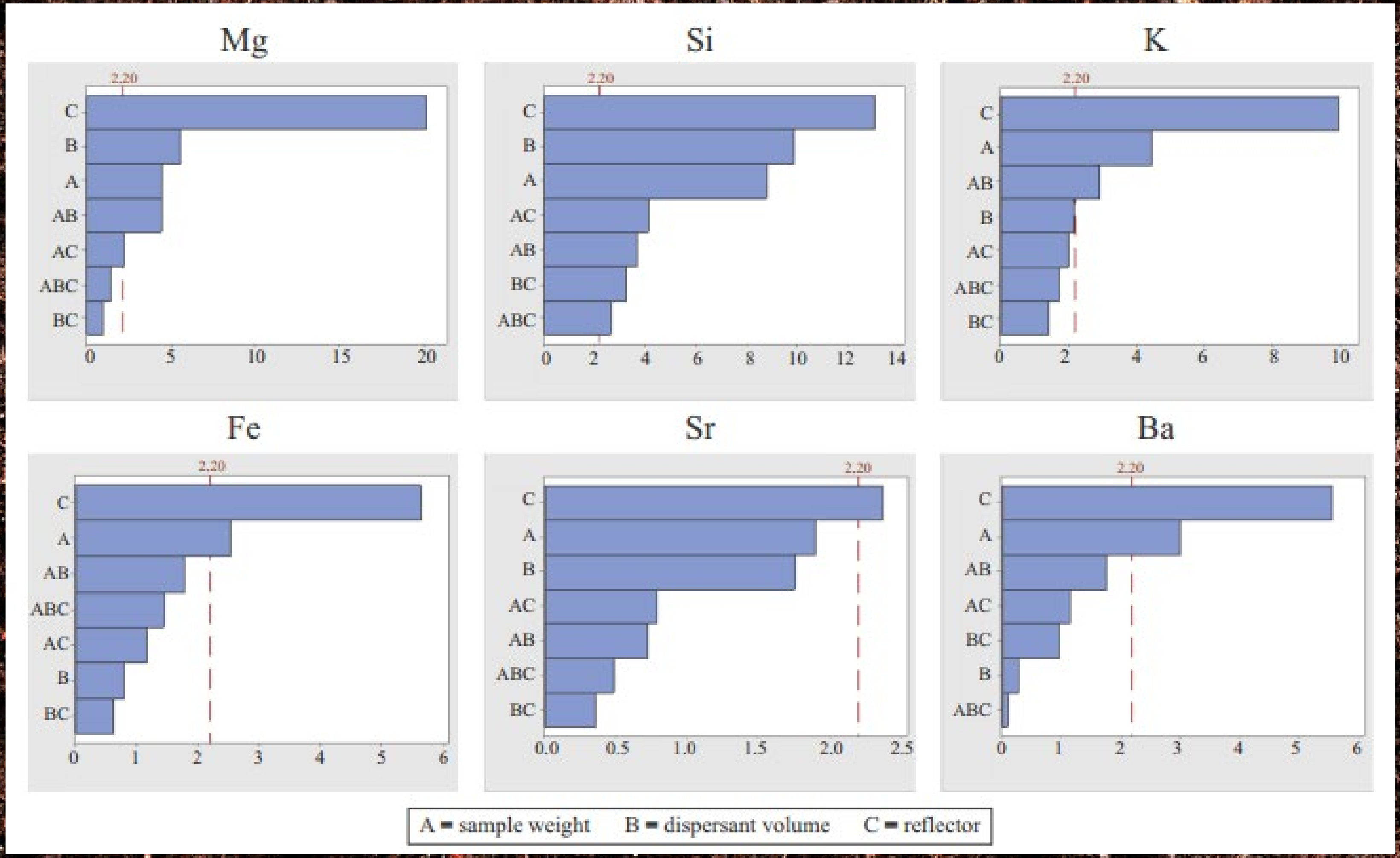
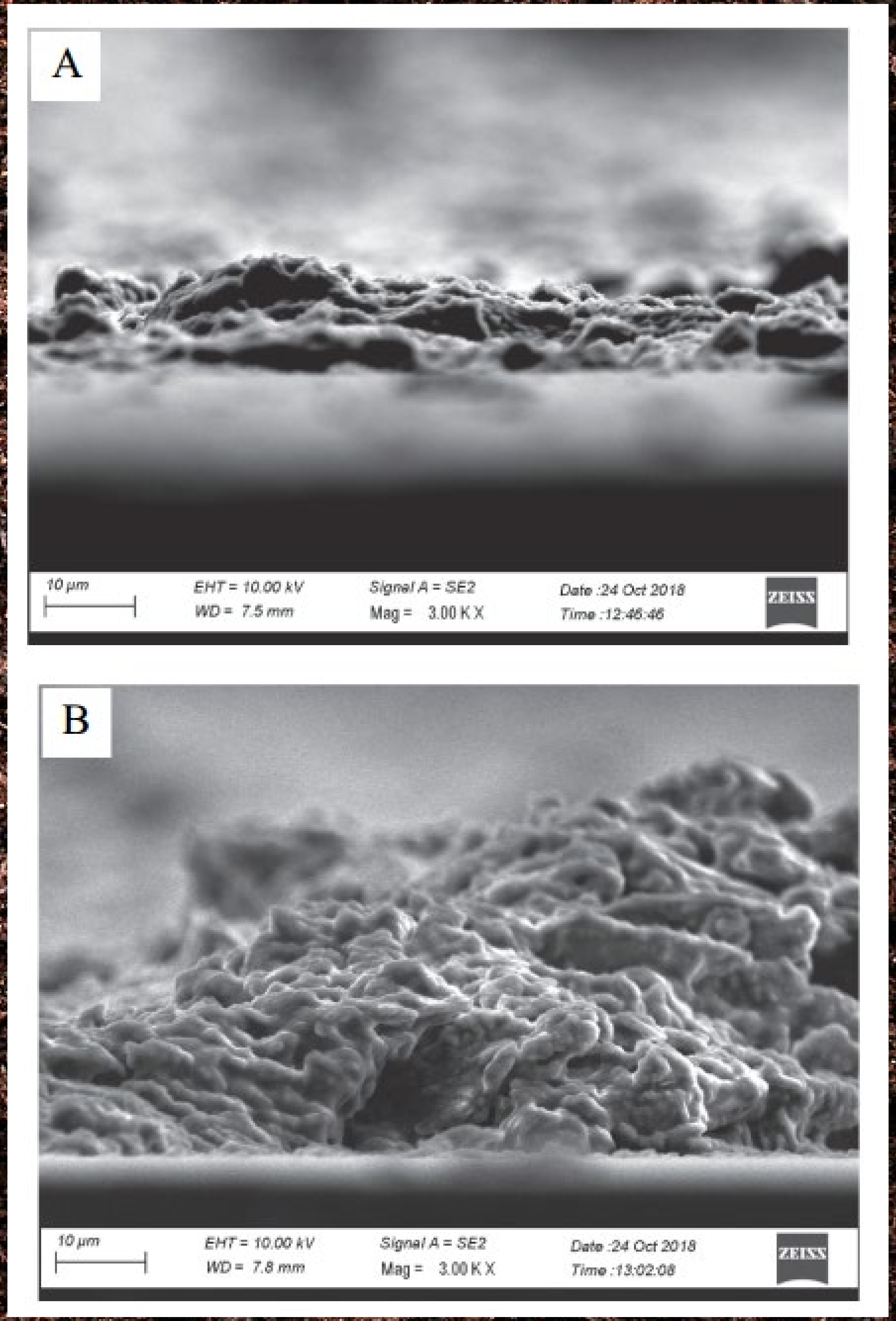
Allegretta et al. (2019) Appl- Clay Sci 105201

Soil - Clay



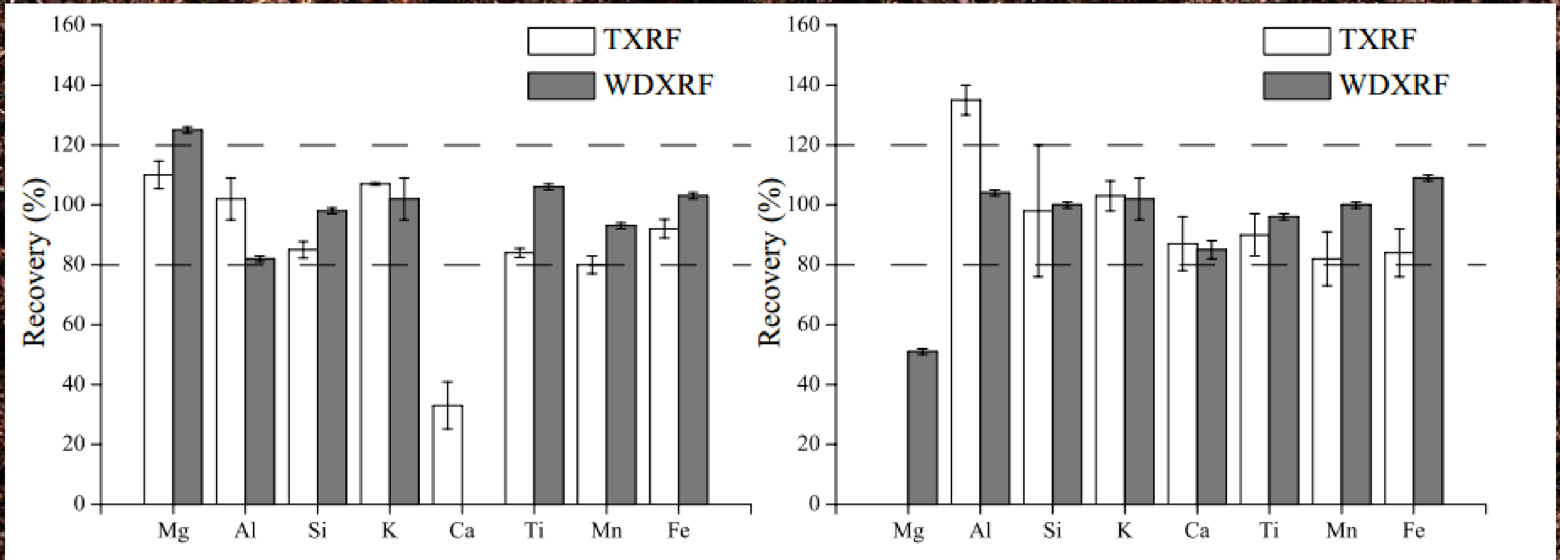


Allegretta et al. (2019) Appl- Clay Sci 105201

Soil - Clay

	Al	Si	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn	Ga	Rb	Sr	Pb
	Elements														
RV (mg/kg)	97,600	252,200	63,600	2600	300	56	7500	66,200	11	39	1050	99	8500	17	80
Mean (mg/kg)	131,938	247,412	65,803	2264	270	63	6175	55,359	14	26	1052	81	7734	18	126
Recovery (%)	135	98	103	87	90	112	82	84	127	68	100	82	91	108	158
RSD_{WLR} (%)	5	24	7	11	9	95	12	10	37	12	11	10	11	15	18
RSDr (%)	5	21	4	5	6	95	6	6	37	12	7	5	6	10	18
Day	0	21	65	79	52	0	77	66	0	2	63	68	69	58	0
Sample	19	8	9	9	28	95	13	21	1	26	21	21	20	28	0
Instrument	81	71	26	12	20	5	10	13	99	71	16	11	11	14	100
LOD (mg/kg)	1153	279	24	8	5	4	4	4	1	1	1	1	1	1	1
LOQ (mg/kg)	3845	930	81	25	17	12	14	12	3	3	3	2	3	2	2

Overlapping with Rb L-lines and K escape peak



Allegretta et al. (2019) Appl- Clay Sci 105201

Soil

Pollution
by Potentially Toxic Elements (PTE)

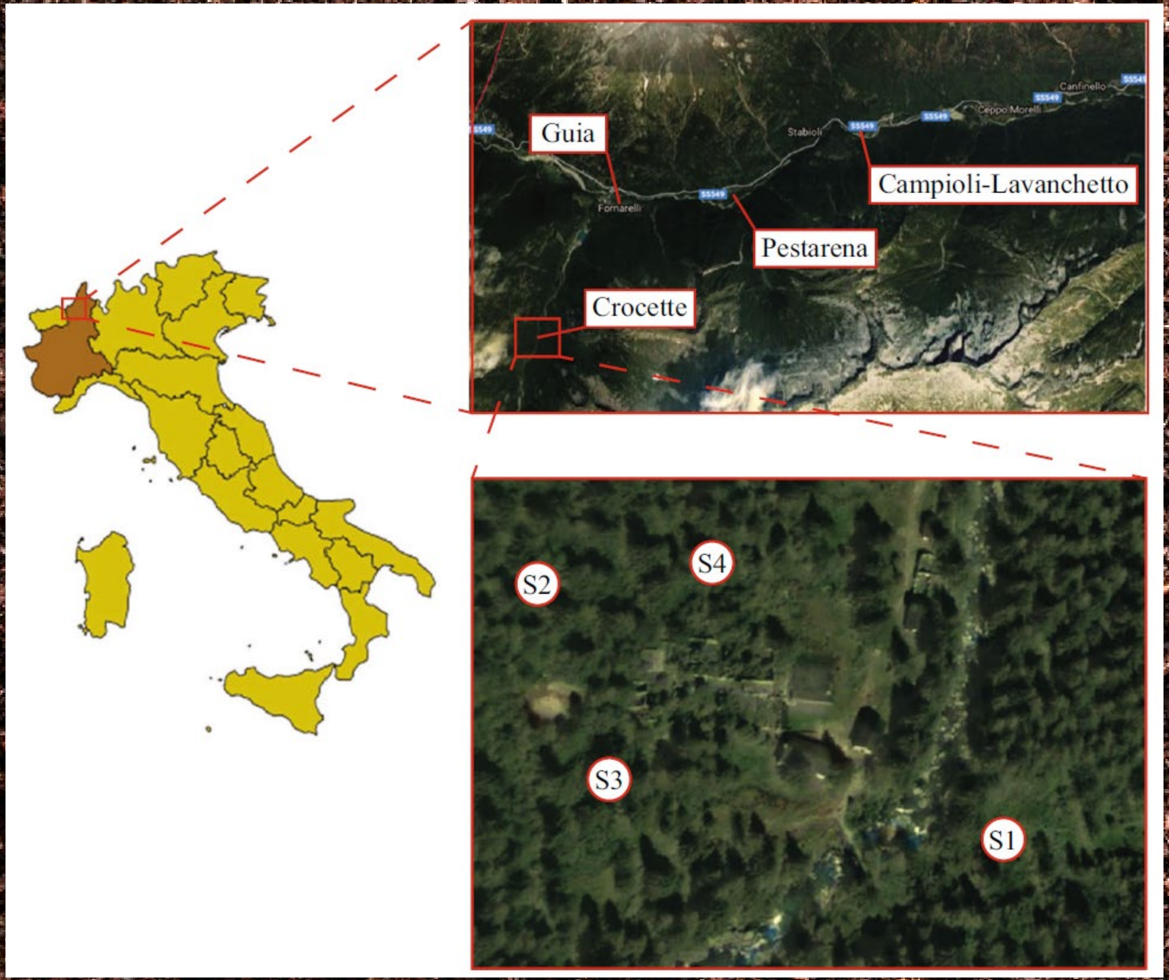
PTE concentration

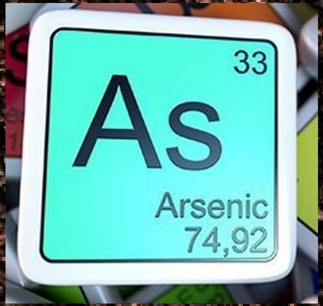
Mobility

Bioavailability

Soil - Pollution

As pollution in mining sites





As concentration

S1 = 145 ppm

S2 = 4640 ppm

S3 = 13300 ppm

S4 = 40200 ppm

Is it mobile?

Allegretta et al., 2018, Environ. Sci. Poll. Res., 25:25080-25090

Soil - Pollution

Sequential extraction

1. *Non-specifically adsorbed,* extracted with $(NH_4)_2SO_4$ 0.5 M for 4 h at 20 °C;
2. *Specifically sorbed on minerals,* extracted with $NH_4H_2PO_4$ 0.5 M for 16 h at 20 °C;
3. *Associated to amorphous and scarcely ordered Fe and Al oxides and hydroxides,* extracted with NH_4-oxalate 0.2 M for 4 h at 20 °C;
4. *Associated to well-crystallized Fe and Al oxides and hydroxides,* extracted with NH_4-oxalate 0.2 M and ascorbic acid 0.1 M for 30 min at 96 °C;
5. *Residual,* extracted using acid microwave-assisted digestion with HNO_3 and H_2O_2 (7:1, *v*/*v*).

Extraction step	Description	S1 % of total As	S2	S3	S4
1	Non-specifically sorbed	2.2 ± 0.2	0.6 ± 0.2	0.2 ± 0.1	0.3 ± 0.1
2	Specifically sorbed	10.7 ± 2.1	25.2 ± 2.7	11.9 ± 2.3	7.6 ± 3.9
3	Associated to amorphous Fe oxides/hydroxides	49.8 ± 0.8	67.2 ± 2.9	85.5 ± 1.5	87.1 ± 4.8
4	Associated to well crystalline Fe oxides/hydroxides	27.9 ± 1.1	1.6 ± 0.3	1.4 ± 0.8	4.7 ± 1.2
5	Residual	9.4 ± 1.2	5.4 ± 1.1	1.0 ± 0.6	0.3 ± 0.2

Sample prep

Centrifugation 15min 1700xg
Filtering (0.45 μm)
IS (Se 1000g/L) 40μL

1 ml o sample + 10μL of Ga (100 mg/l)
1000 s

Allegretta et al., 2018, Environ. Sci. Poll. Res., 25:25080-25090

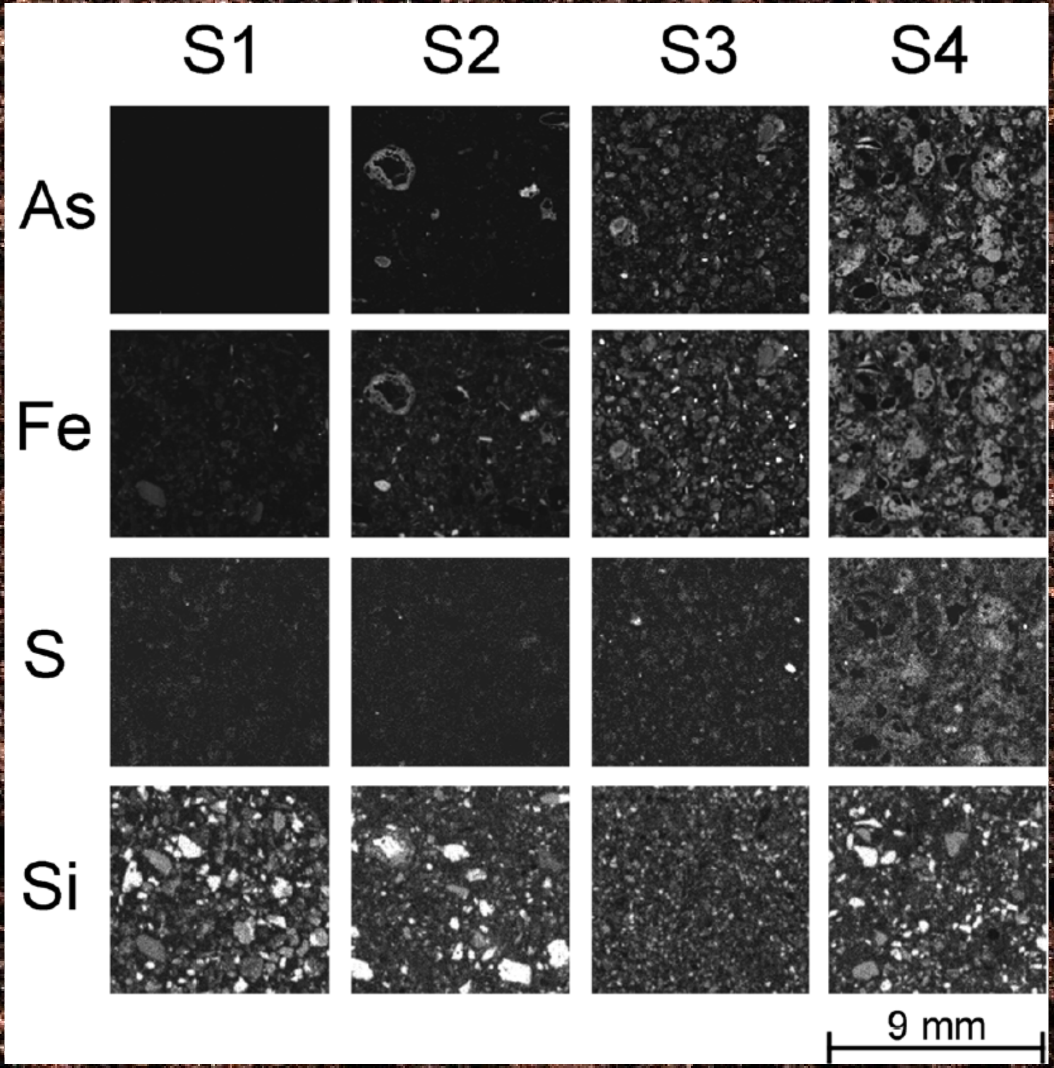
Soil - Pollution

No mobile

Mobile ≠ Bioavailable

Sentinel Organism

μXRF



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3	Associated to amorphous Fe oxides/hydroxides	49.8 ± 0.8	67.2 ± 2.9	85.5 ± 1.5	87.1 ± 4.8
4	Associated to well crystalline Fe oxides/hydroxides	27.9 ± 1.1	1.6 ± 0.3	1.4 ± 0.8	4.7 ± 1.2
5	Residual	9.4 ± 1.2	5.4 ± 1.1	1.0 ± 0.6	0.3 ± 0.2

Allegretta et al., 2018, Environ. Sci. Poll. Res., 25:25080-25090

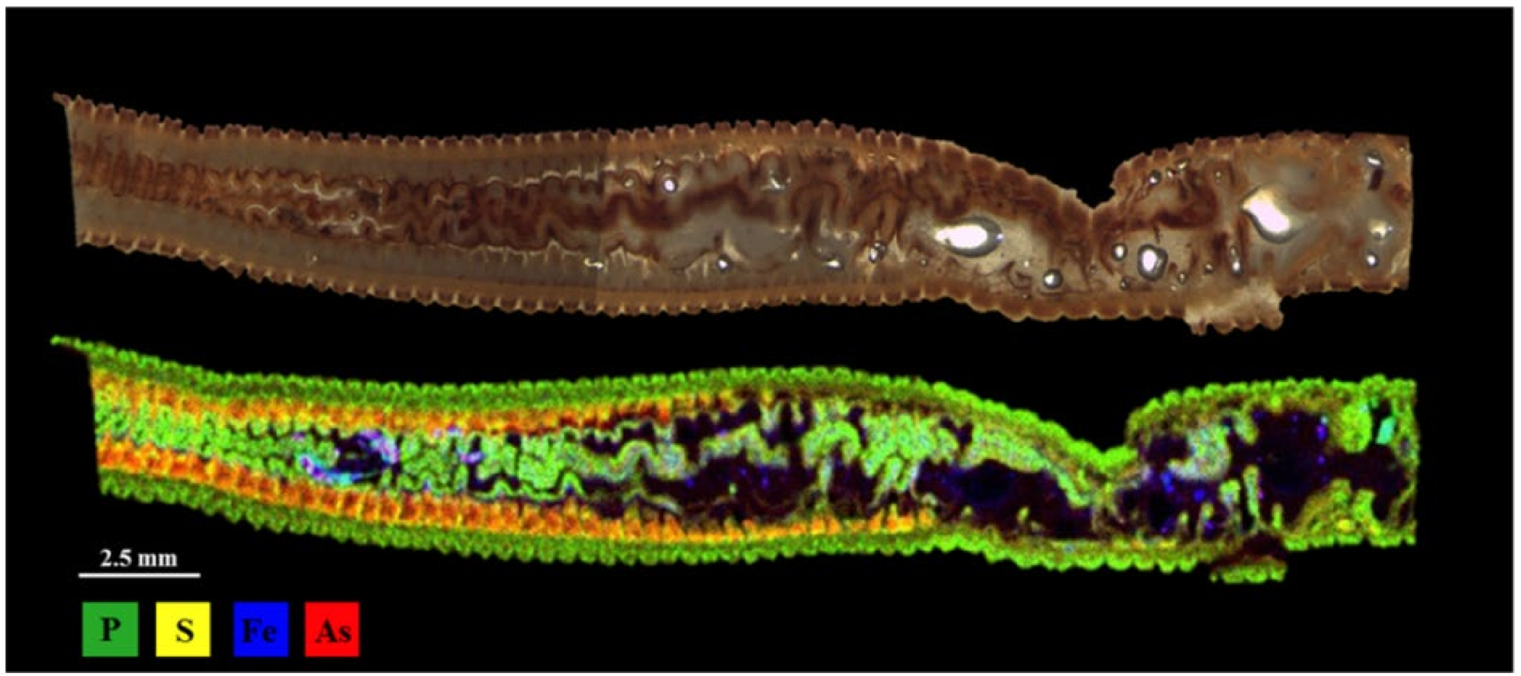
Soil - Pollution

Eisenia andrei B.

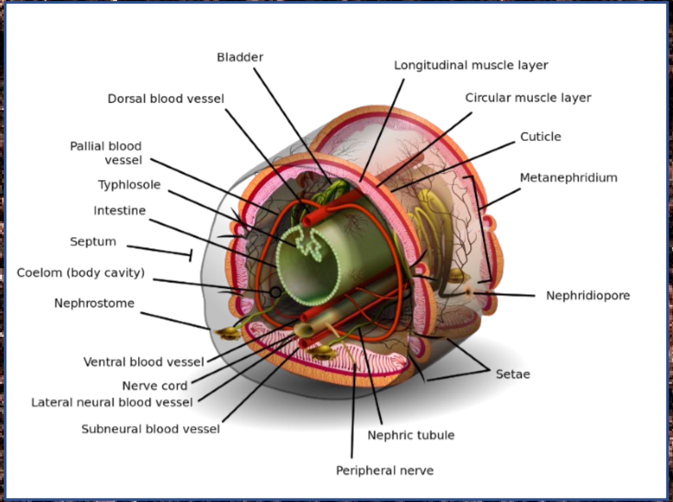
Complete digestion of the organisms

Soil - Pollution

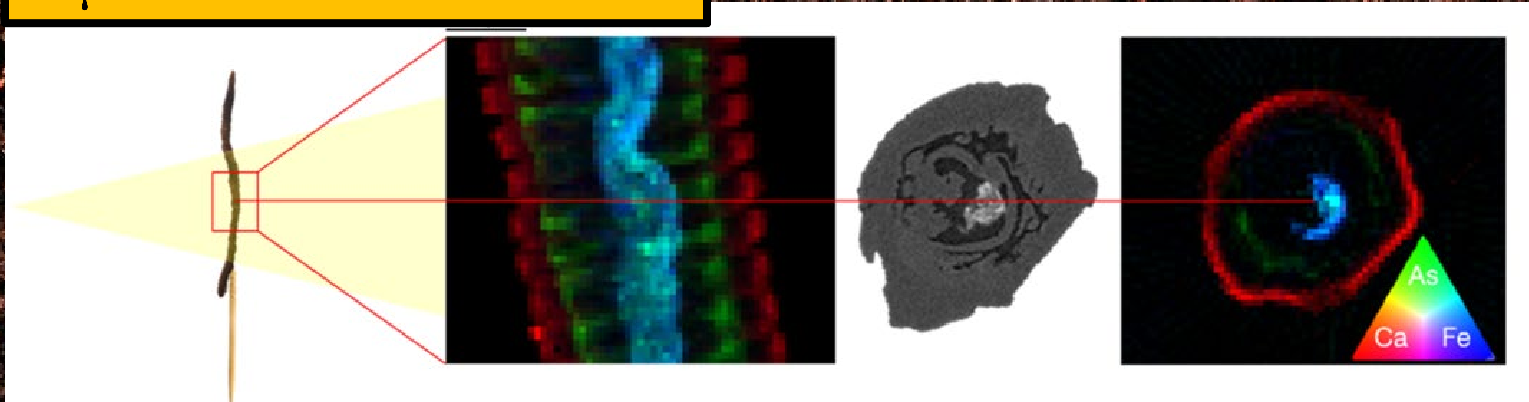
µXRF



As accumulate mainly in the coelomic cavity



µXRF TOMOGRAPHY

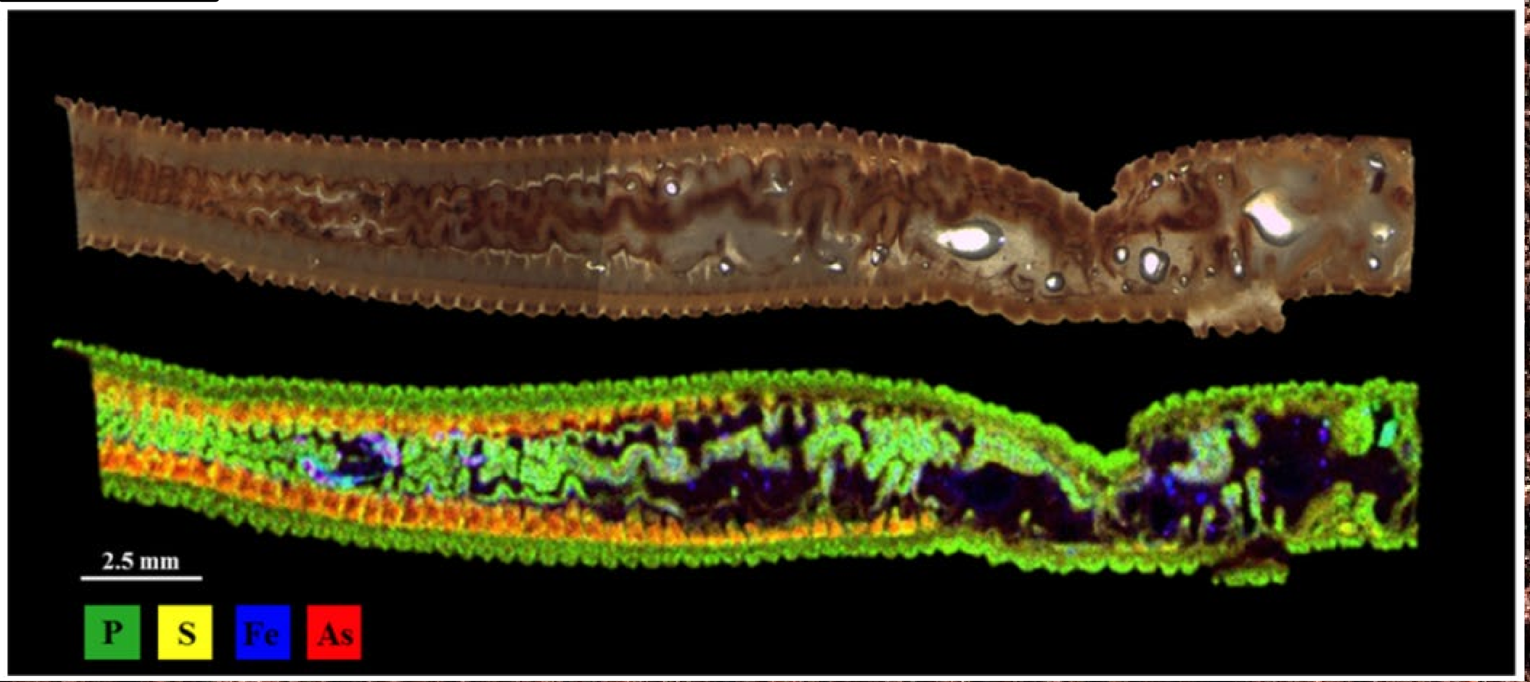


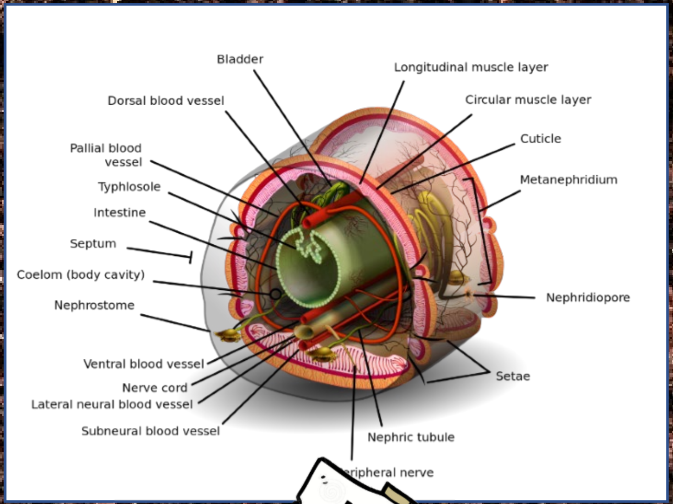
Porfido et al., 2019, Eniron. Sci. Techn. 53,10961-10968

Soil - Pollution

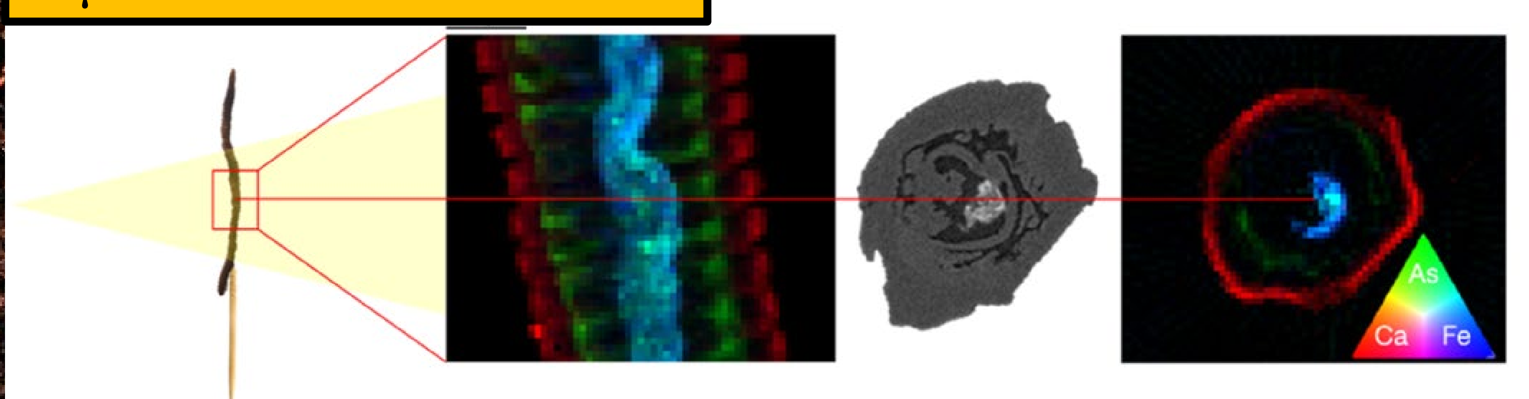
As accumulate mainly in the coelomic cavity

µXRF





µXRF TOMOGRAPHY



Porfido et al., 2019, Eniron. Sci. Techn. 53,10961-10968

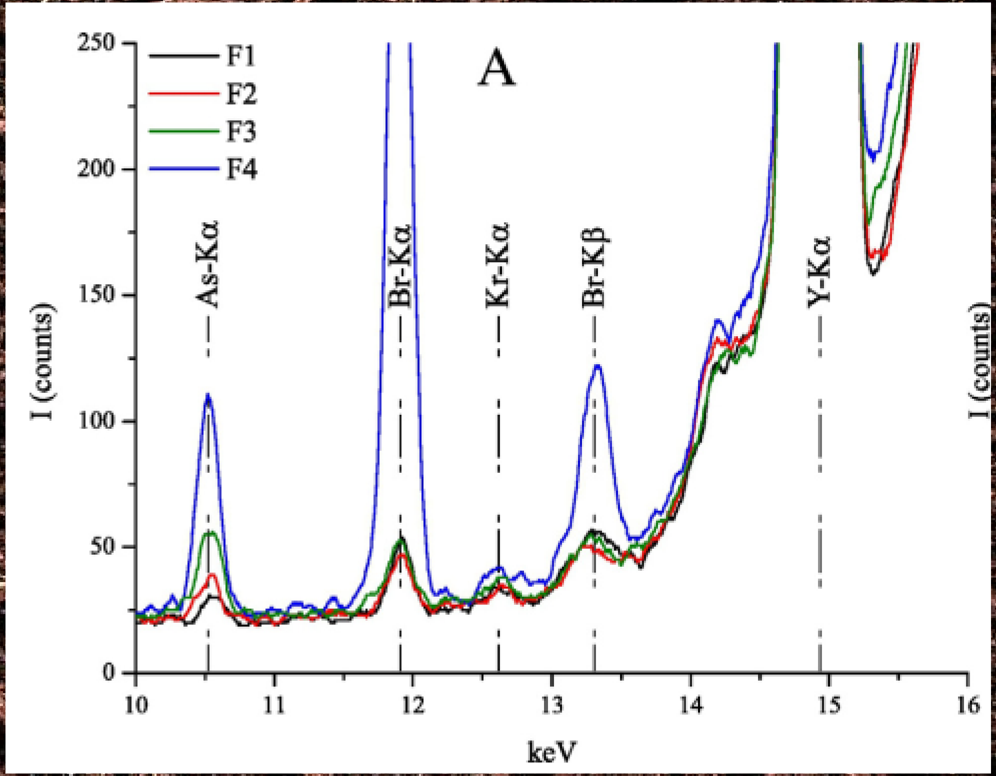
Soil - Pollution

Dilution: 1(CF):8(PVA):1(IS=Y)

Extraction (5V, 10sec)

50 - 80 µL

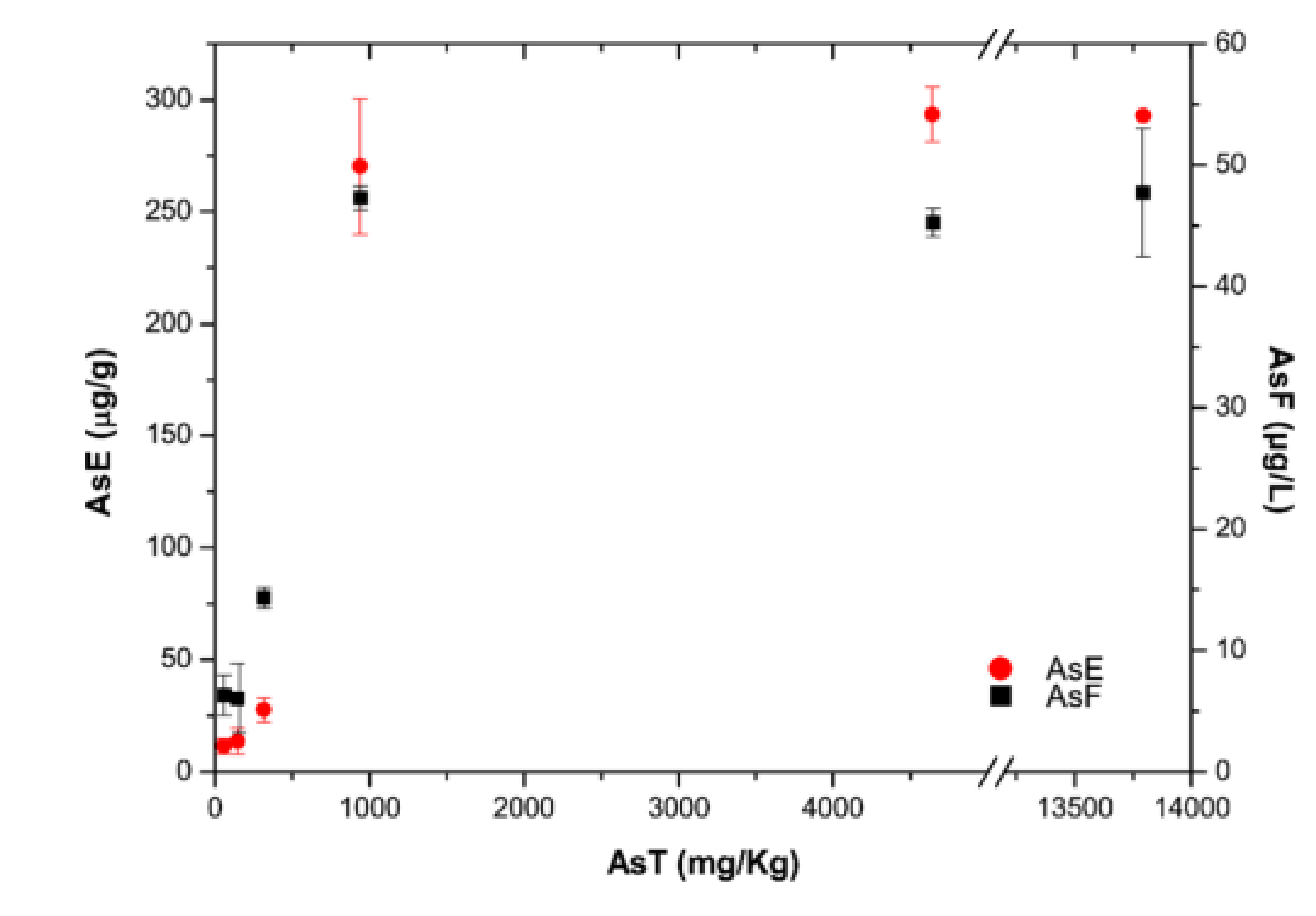
Don't worry!!!
For microsamples
you can use TXRF!!!



Sample	As concentration in the soil (mg/kg)	Analytical technique	Final		Diluted		
			Conc (µg/l)	SD (µg/l)	Conc (µg/l)	SD (µg/l)	DL (µg/l)
F1[a]	18	TXRF	5.3	1.0	0.5	0.1	0.2
		ICP-MS	3.3	0.4	0.02	0.002	0.01
F2[a]	21	TXRF	7.0	1.0	0.7	0.1	0.2
		ICP-MS	4.7	0.4	0.02	0.002	0.01
F3[a]	400	TXRF	25.3	1.6	2.5	0.2	0.2
		ICP-MS	24.8	0.2	0.1	0.001	0.01
F4[b]	600	TXRF	47.0	0.9	4.7	0.1	0.3
		ICP-MS	42.0	1.2	0.21	0.006	0.01

Allegretta et al., 2017, Spectrochim Acta B, 130, 21-25

Soil - Pollution



Porfido et al., 2019, Eniron. Sci. Techn. 53,10961-10968

Plant - Pollution

Cr concentration

C	65 mg/kg
A2	3807 mg/kg
A6	5160 mg/kg

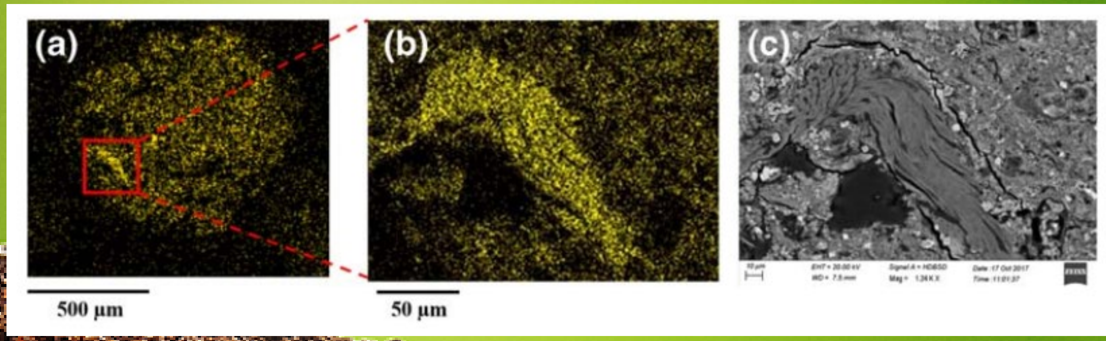
Agricultural soils

Firing

(agricultural practice)

What's app to Cr???
Is it bioavailable?

Tannery Sludge



Gattullo et al., 2020, Environ Sci Pollut Res 27, 22967-22979

Plant - Pollution

RHIZOTESTS

Phase 1

Phase 2

Phase 3

Rascio et al., submitted

https://rhizotest.cirad.fr/en/the-rhizotest
http://www.metrhizlab.com/

Plant - Pollution

Shoots ≈ 400mg

Roots ≈100mg

Small amount of sample

How much Cr is inside?

We couldn't risk
with suspensions

Rascio et al., submitted

Plant - Pollution

Digestion

100-150 mg of sample

1 ml of H_2O_2
7ml of HNO_3

TXRF analysis

Solution

Ga (IS) 10 µl 1g/l

Shoots ≈ 400mg

Roots ≈100mg

Small amount of sample

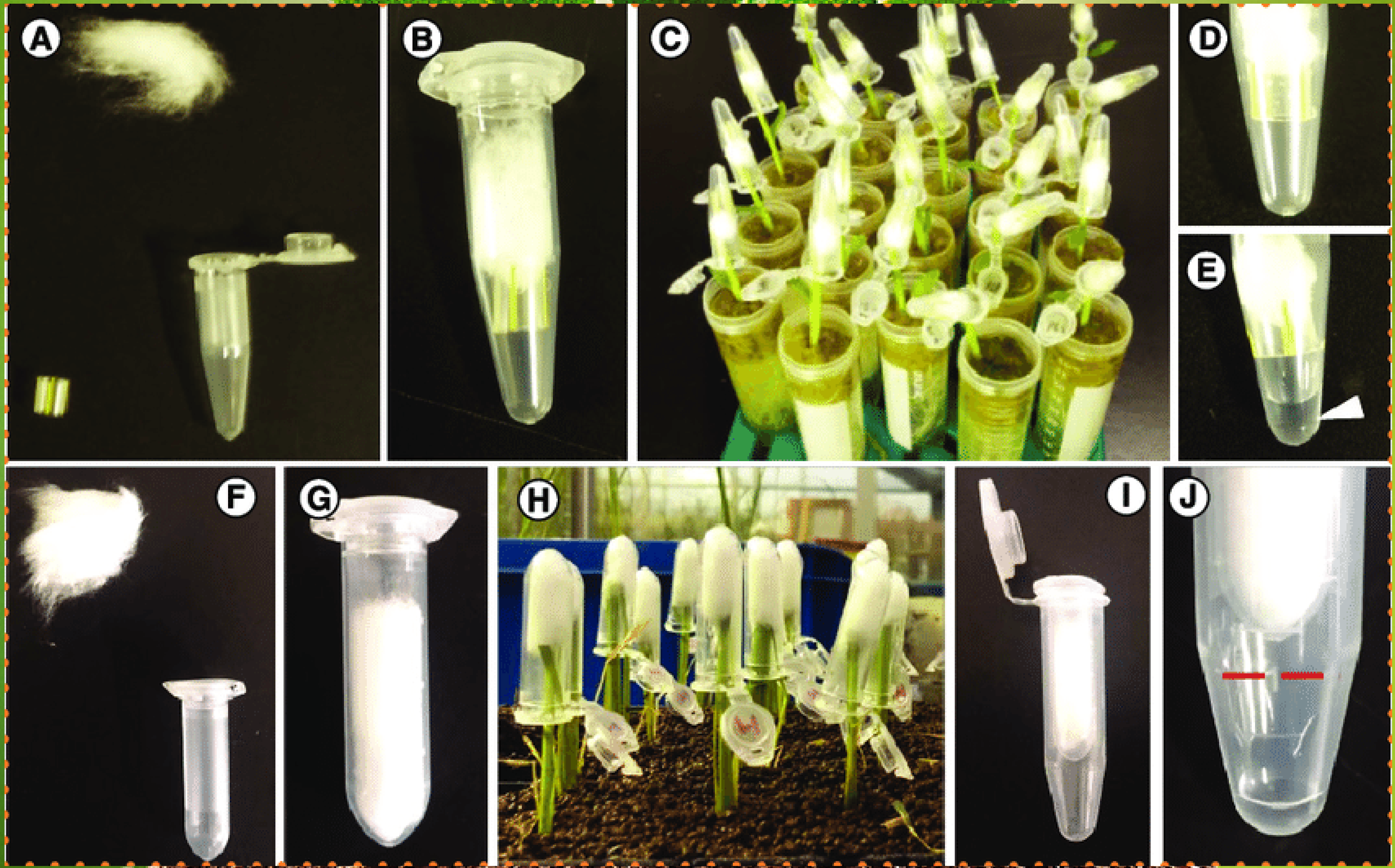
How much Cr is inside?

We couldn't risk with suspensions

Rascio et al., submitted

Plant - Pollution

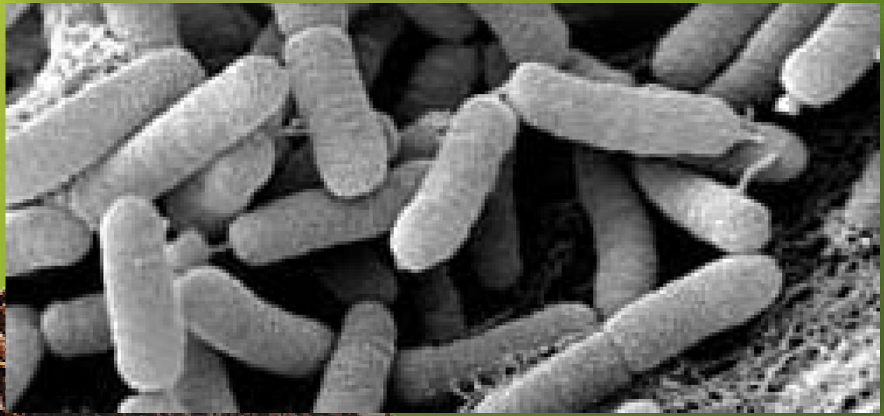
Xylem Saps



Kan et al. (2019) Biotechniques 67 (5), 1-4

Plant - Pollution

Xylella fastidiosa



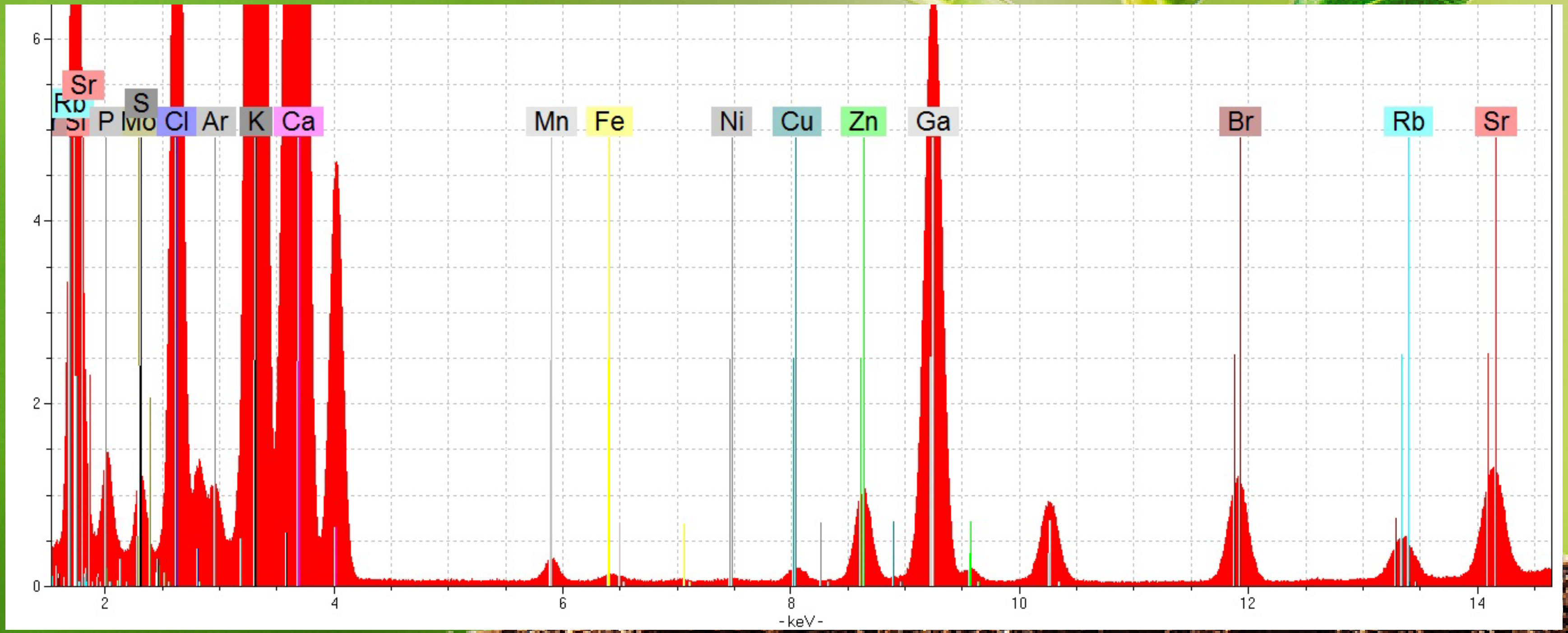
Plant - Pollution

TXRF analysis

1 ml of sap

Ga (IS) 10 µl 100 mg/l

Mn= 20-200 mg/l
Fe = 10-100 mg/l
Ni = 0.7-10 mg/L
Cu = 10-70 mg/l
Zn = 70-500 mg/l



Dr Plant
online

Hi Ignazio, I'm studying some strategies to solve the problem of Xilella fastidiosa. Could you help me?

Hi Dr Plant, it depends…what's the problem?

I should analyze the elemental composition of the olive trees' xylem saps. But I can give you just 1-2 ml.

OK no problem!!! We can use TXRF!!! 😎 😎 😎 😎 😎 😎 😎 😎 😎

Which element do you need to analyze?

S, P, K, Ca, Ti, Mn, Fe, Ni, Cu, Zn

🔝 🔝 🔝 🔝 🔝 🔝 🔝 🔝 🔝

Plant - Pollution

Xylem Saps: SE-HPLC + TXRF

Table 5
Concentrations of the metals present in the selected freeze-dried and concentrated SEC fractions of xylem sap of cucumber artificially contaminated with nickel

ΔV elution (cm^3)	2.0–2.5	2.5–3.0	3.0–3.5	3.5–4.0	4.0–4.5	4.5–5
c [μg cm^{-3} ± R.S.D. (%)]						
Ca	0.22 ± 8.7	0.13 ± 4.0	14.5 ± 10.3	18.2 ± 4.0	0.33 ± 5.4	0.52 ± 1.5
K	0.34 ± 3.2	0.69 ± 7.0	46.7 ± 11.3	80.3 ± 3.7	1.38 ± 1.2	2.83 ± 3.3
c [ng cm^{-3} ± R.S.D. (%)]						
Cu	20.0 ± 6.6	n.d.	81.1 ± 10.5	41.7 ± 2.2	12.1 ± 9.4	8.10 ± 2.6
Fe	n.d.	60.0 ± 12.2	42.4 ± 10.5	41.5 ± 22.4	10.6 ± 58.3	12.8 ± 20.6
Mn	n.d.	n.d.	45.5 ± 5.8	239.9 ± 14.0	n.d.	n.d.
Ni	15.6 ± 2.1	138.5 ± 1.2	433.9 ± 12.1	57.6 ± 9.3	20.1 ± 8.1	32.4 ± 6.5
Zn	50.2 ± 0.03	33.5 ± 8.4	38.5 ± 2.8	62.7 ± 6.3	66.5 ± 2.3	100.2 ± 2.8

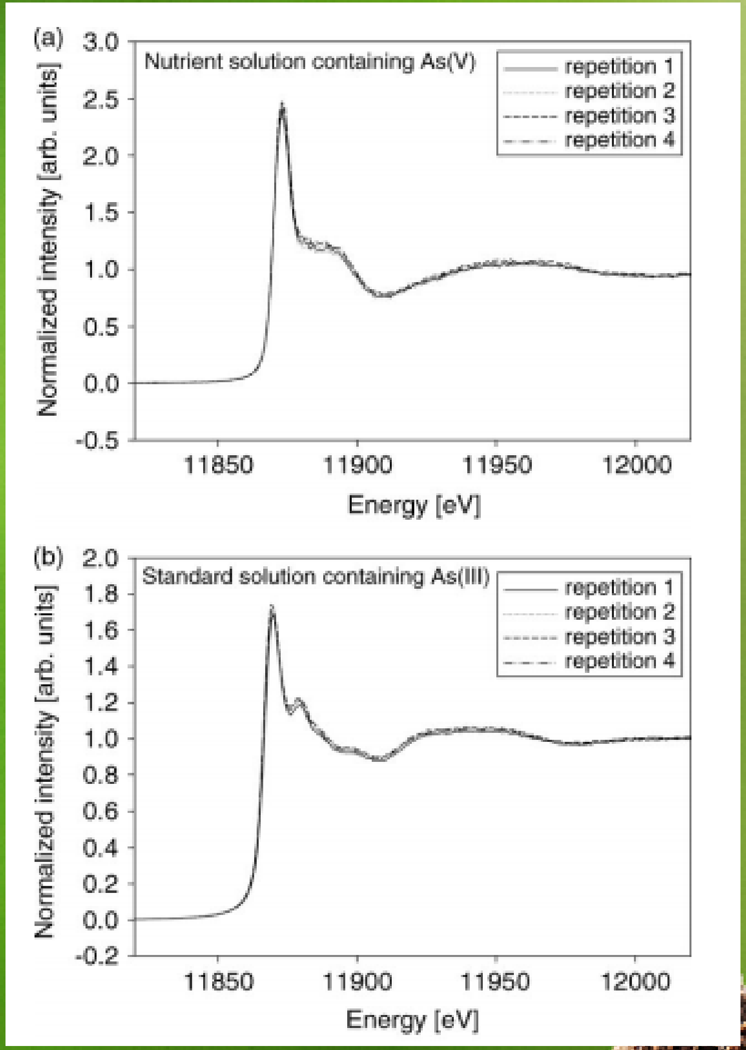
TXRF Xylem Saps
Sample 100 μl
C_{Ga} 3 μg/cm^3
25μl on Qtz disk
300 s
EXTRA IIA ATOMIKA
(Mo)

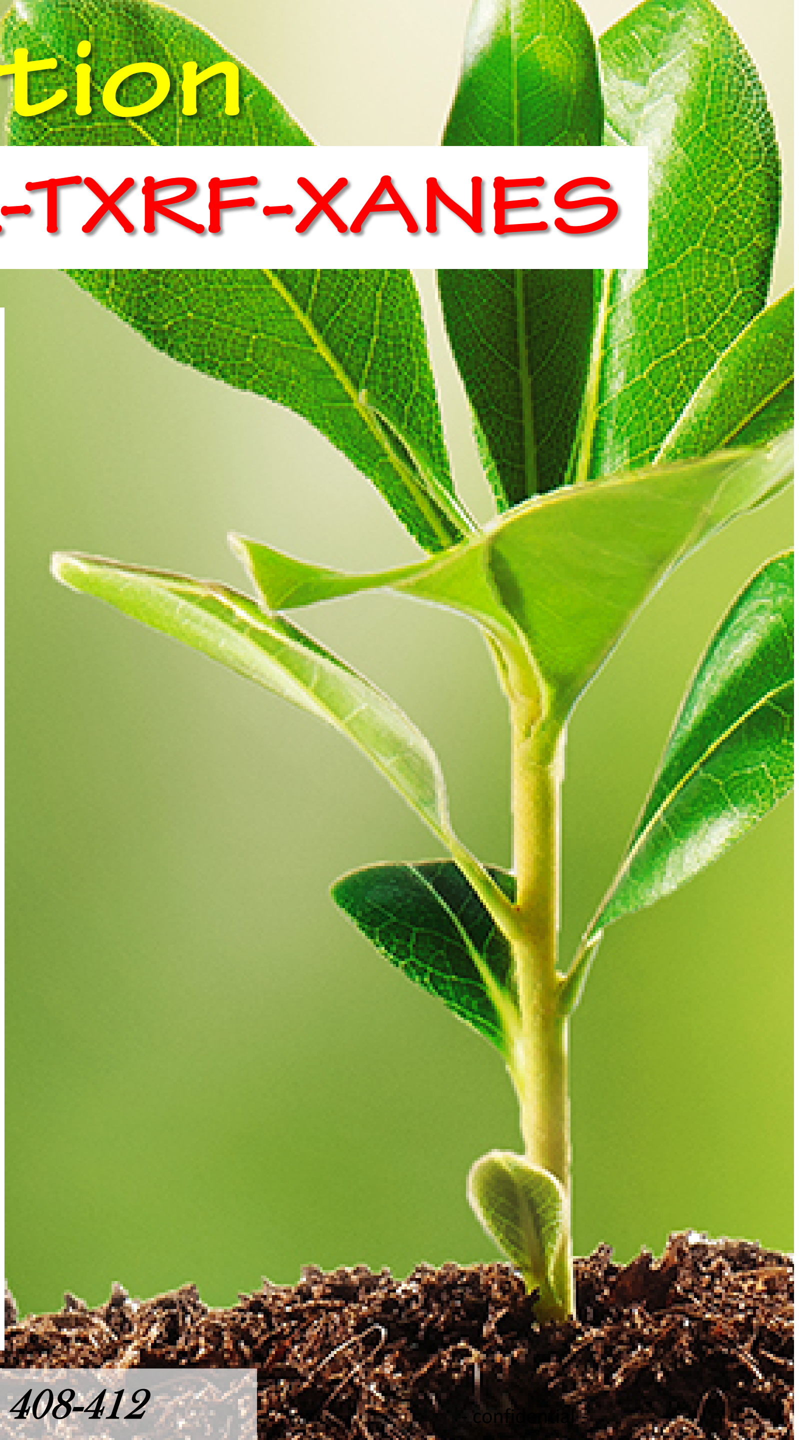
SE-HPLC
+ TXRF analysis of the fractions
500 μl
Freeze-drying
C_{Ga} 3 μg/cm^3
25μl on Qtz disk
500 s

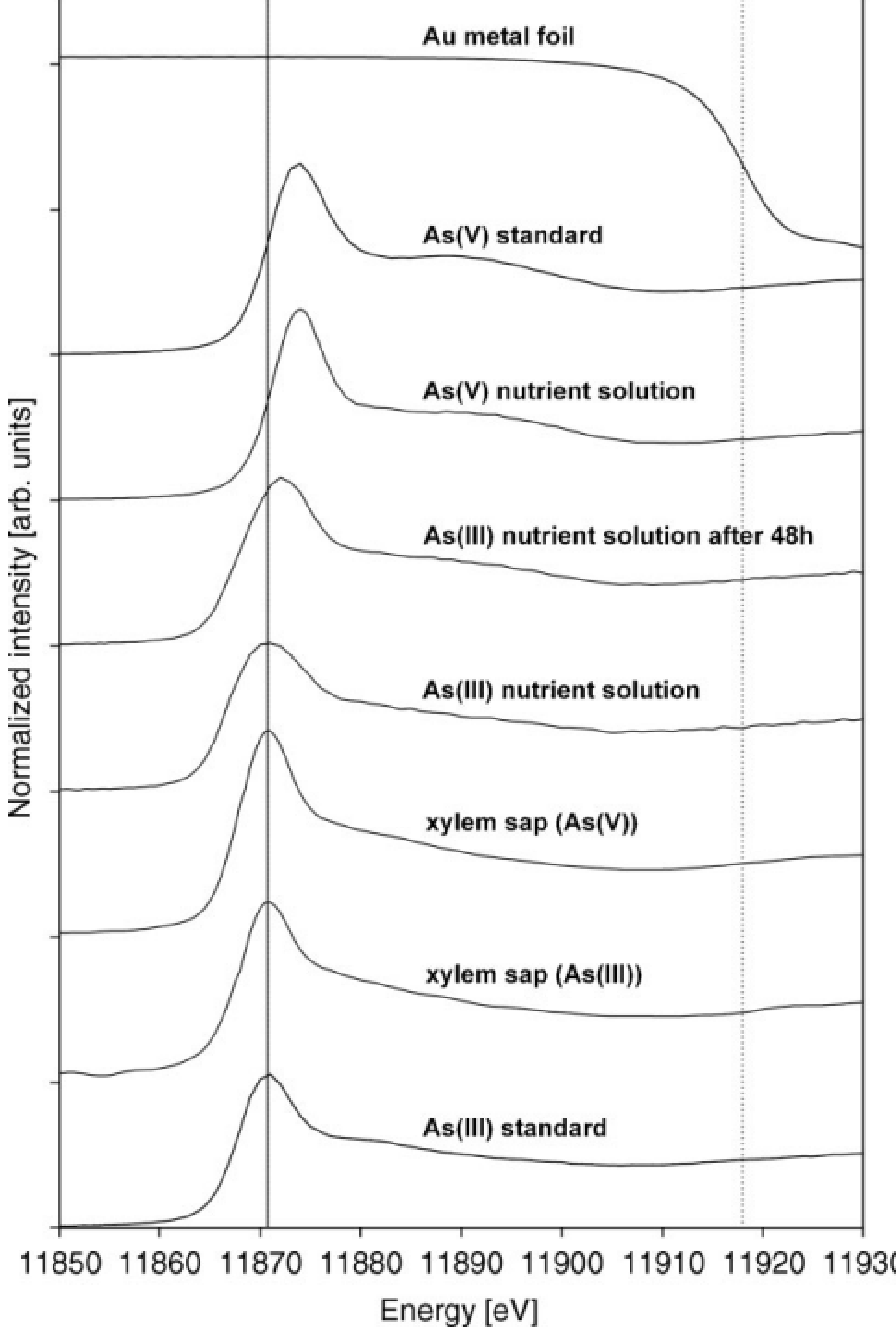
Mihucz al. (2001) Spectrochim Acta B 56 (5), 2235-2246

Plant - Pollution

Xylem Saps: SR-TXRF-XANES



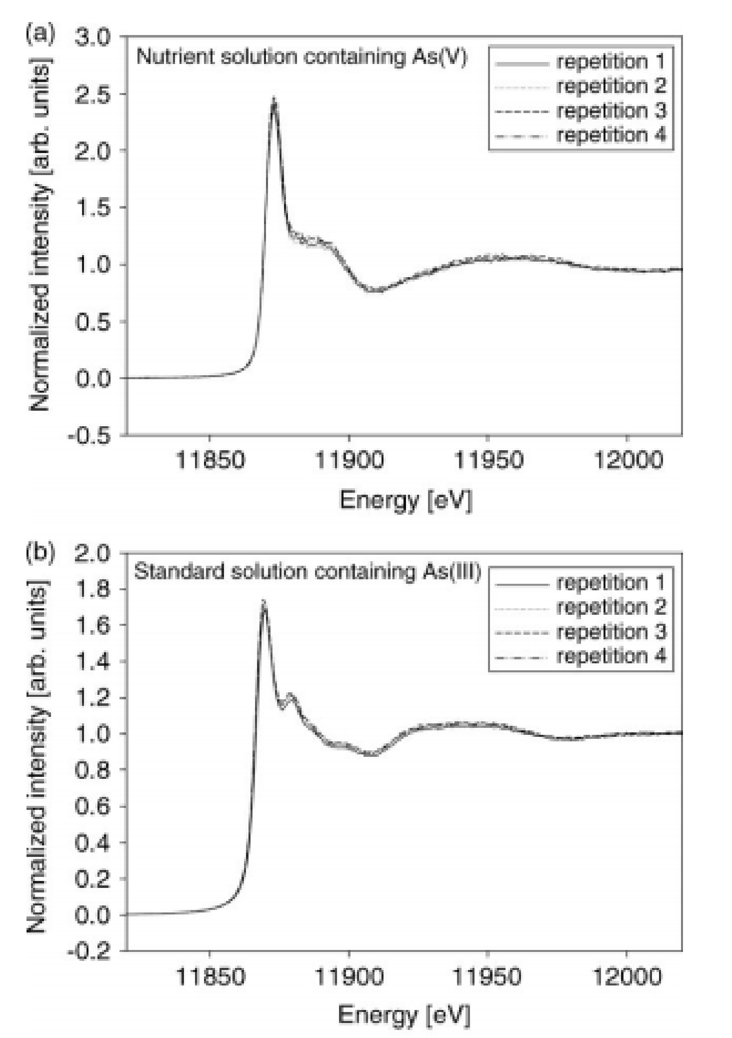




Meirer et al. (2007) X-ray Spectrometry 36, 408-412

Plant - Pollution

Xylem Saps: SR-TXRF-XANES



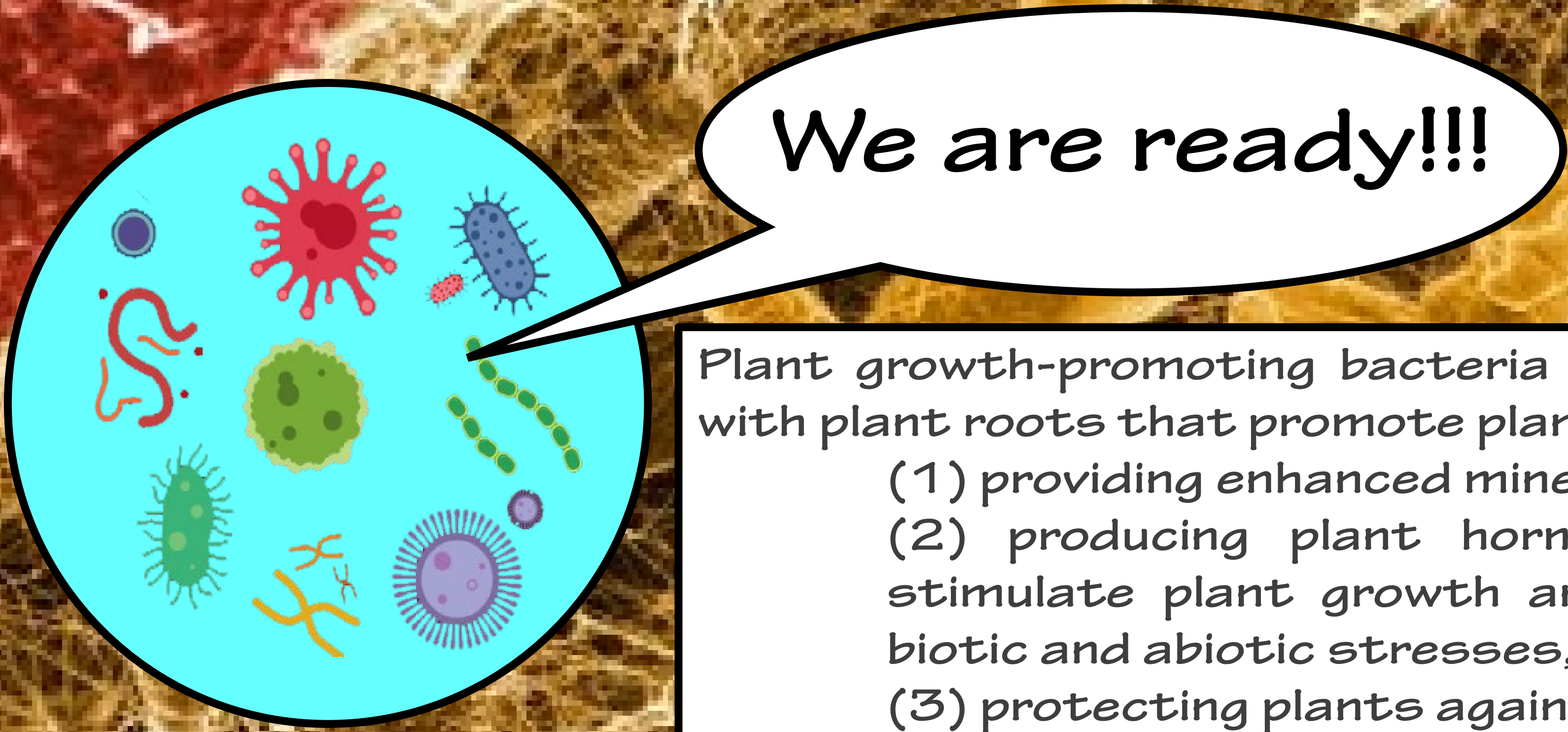
C_{As} 20-50ng
Deposition 1-20µl
Vacuum drying
Kept in Ar atm
Measurement under vacuum at HASYLAB - DESY

Sample	% As(III)[a]	% As(V)[a]	Reduced chi square	chi square
xylem sap (As(III))	88	12	0.0115	1.09
xylem sap (As(V))	83	17	0.0112	1.06
As(III) nutrient solution	100	0	0.0072	0.68
As(III) nutrient solution after 48h	71	29	0.0063	0.60
As(V) nutrient solution	2	98	0.0066	0.63

Meirer et al. (2007) X-ray Spectrometry 36, 408-412

Microorganisms

Sometimes we need to mobilize some elements



Plant growth-promoting bacteria (PGPB) are microbes associated with plant roots that promote plant growth by

(1) providing enhanced mineral nutrition,

(2) producing plant hormones or other molecules that stimulate plant growth and prime plant defenses against biotic and abiotic stresses,

(3) protecting plants against pathogens by affecting survival of pathogenic microorganisms

Lyu et al. (2019) Front. Microb. https://doi.org/10.3389/fmicb.2019.01761

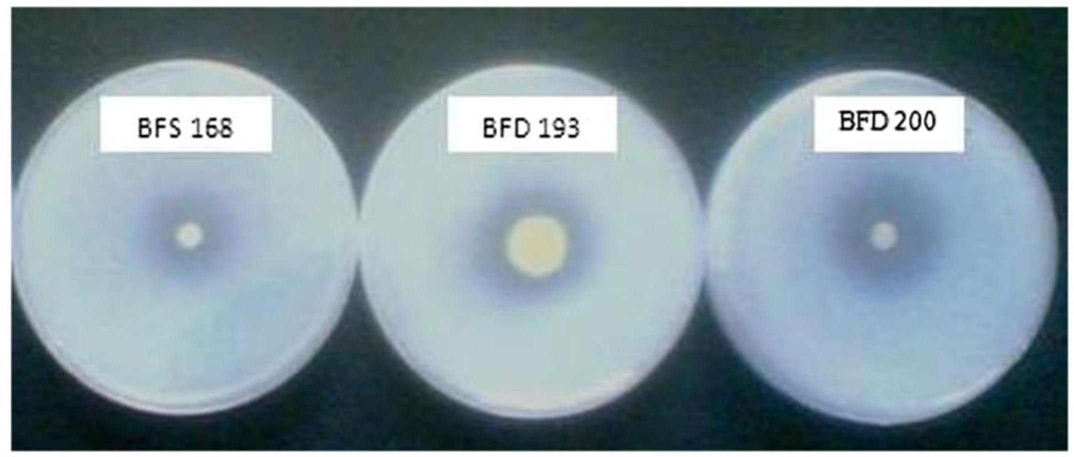
Yaghoubi Khanghahi et al., 2018, Environ Sci Pollut Res 25, 25862-25868

Microorganisms

80 PGPB
extracted from two soils

Zn-solubilizing bacteria

ZnO	$ZnCO_3$
$Zn_3(PO_4)_2$	C_{Zn}=0.1%



Tris-mineral medium
In 1000 l

D-glucose=10.0 g
$(NH_4)_2SO_4$=1.0 g
KCl=0.2 g
K_2HPO_4=0.1 g
$MgSO_4$=0.2 g

pH = 7.0

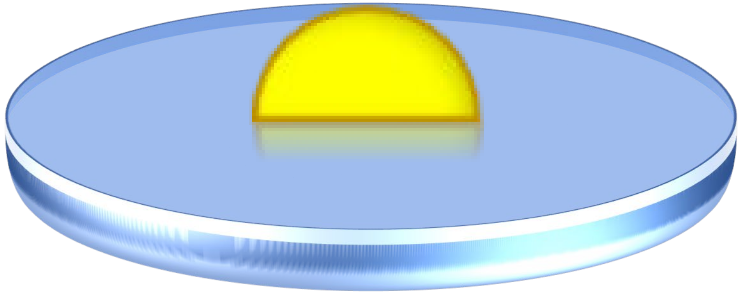
Yaghoubi Khanghahi et al., 2018, Environ Sci Pollut Res 25, 25862-25868

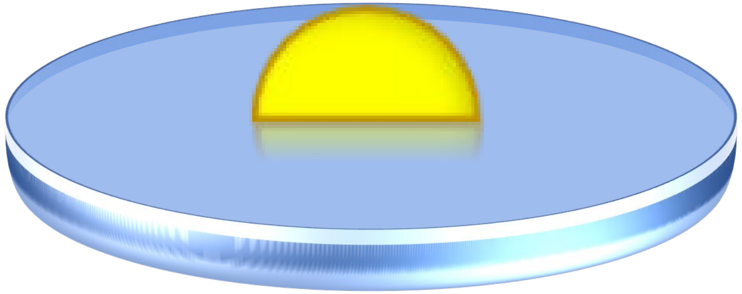
Microorganisms

10 days at 29 °C With PGPB

Direct

200 µl CM + 800 µl H20





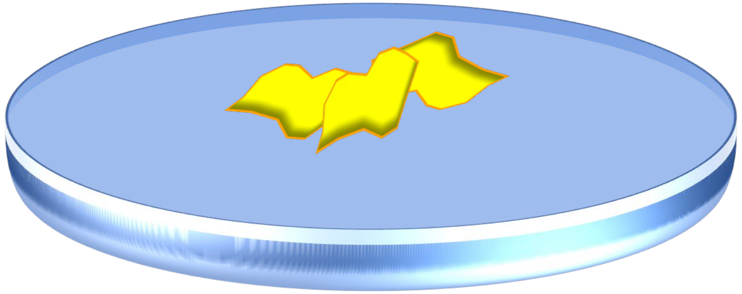
Yaghoubi Khanghahi et al., 2018, Environ Sci Pollut Res 25, 25862-25868

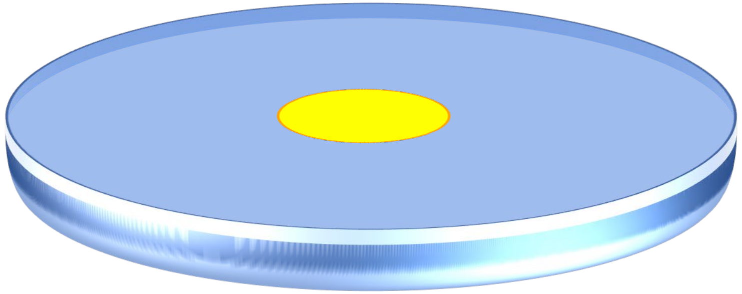
Microorganisms

10 days at 29 °C With PGPB

Direct

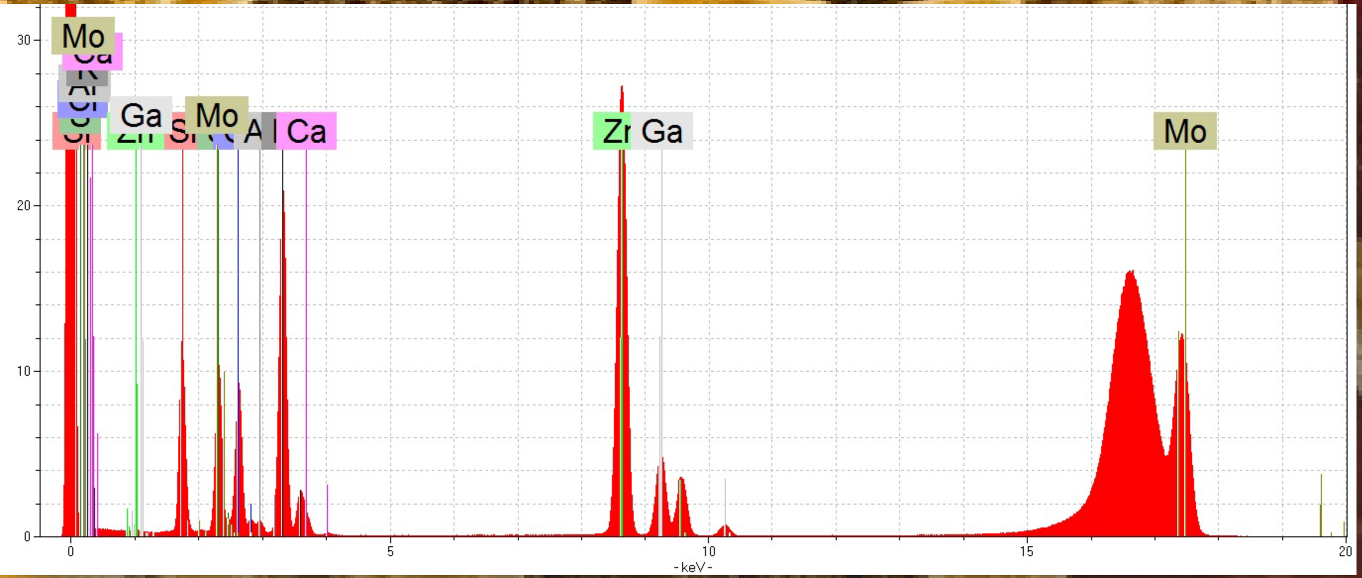
200 µl CM + 800 µl H20





Yaghoubi Khanghahi et al., 2018, Environ Sci Pollut Res 25, 25862-25868

Microorganisms



Strain	pH value	Zinc solubilization (mg/L) ± SE
Agrobacterium tumefaciens	8	1.95 ± 0.02
Agrobacterium tumefaciens	9	51.39 ± 1.73
Agrobacterium tumefaciens	10	13.03 ± 1.54
Rhizobium sp.	8	2.06 ± 0.11
Rhizobium sp.	9	72.07 ± 2.88
Rhizobium sp.	10	52.69 ± 2.31
LSD value		5.33

They can mobilize Zn in a pH range in which Zn is not mobile

Yaghoubi Khanghahi et al., 2018, Environ Sci Pollut Res 25, 25862-25868

In conclusion…

TXRF is a useful tool for the study of the interaction between soil and organisms

In particular:

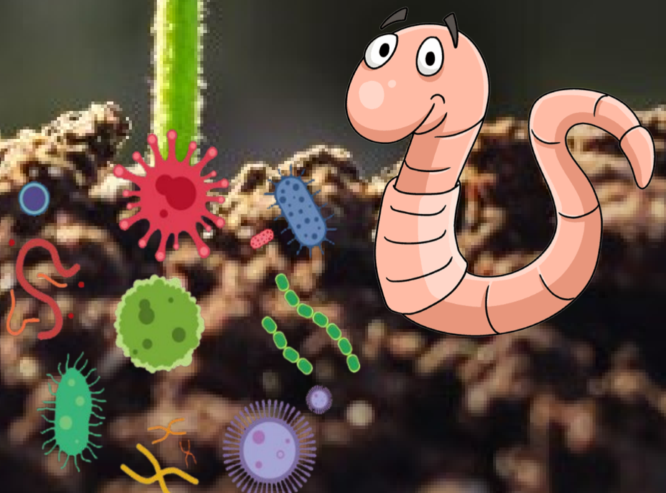
- for microsamples
- to avoid long extraction procedures
- to reduce the use of chemicals
- to speed-up sample preparation

Very useful for environmental studies:

- PTE quantification
- Bioavailability

Work with microsamples

Less cruel

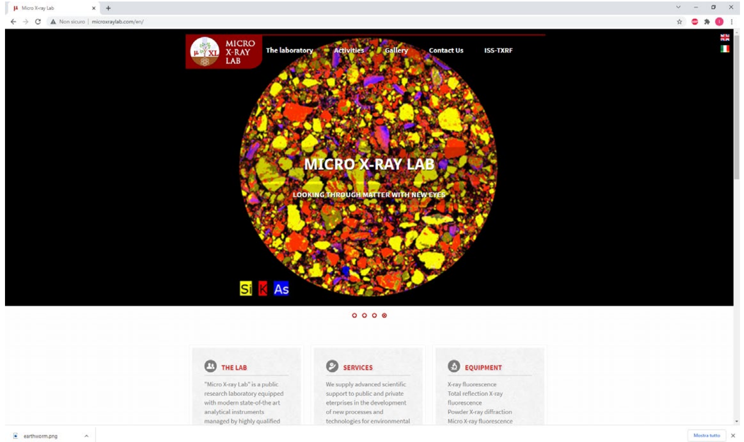


Thank to…

Bruker Nano GmbH and in particular Dr. Armin Gross and Dr. Hagen Stosnach

My colleagues from the Micro X-ray Lab

www.microxraylab.com



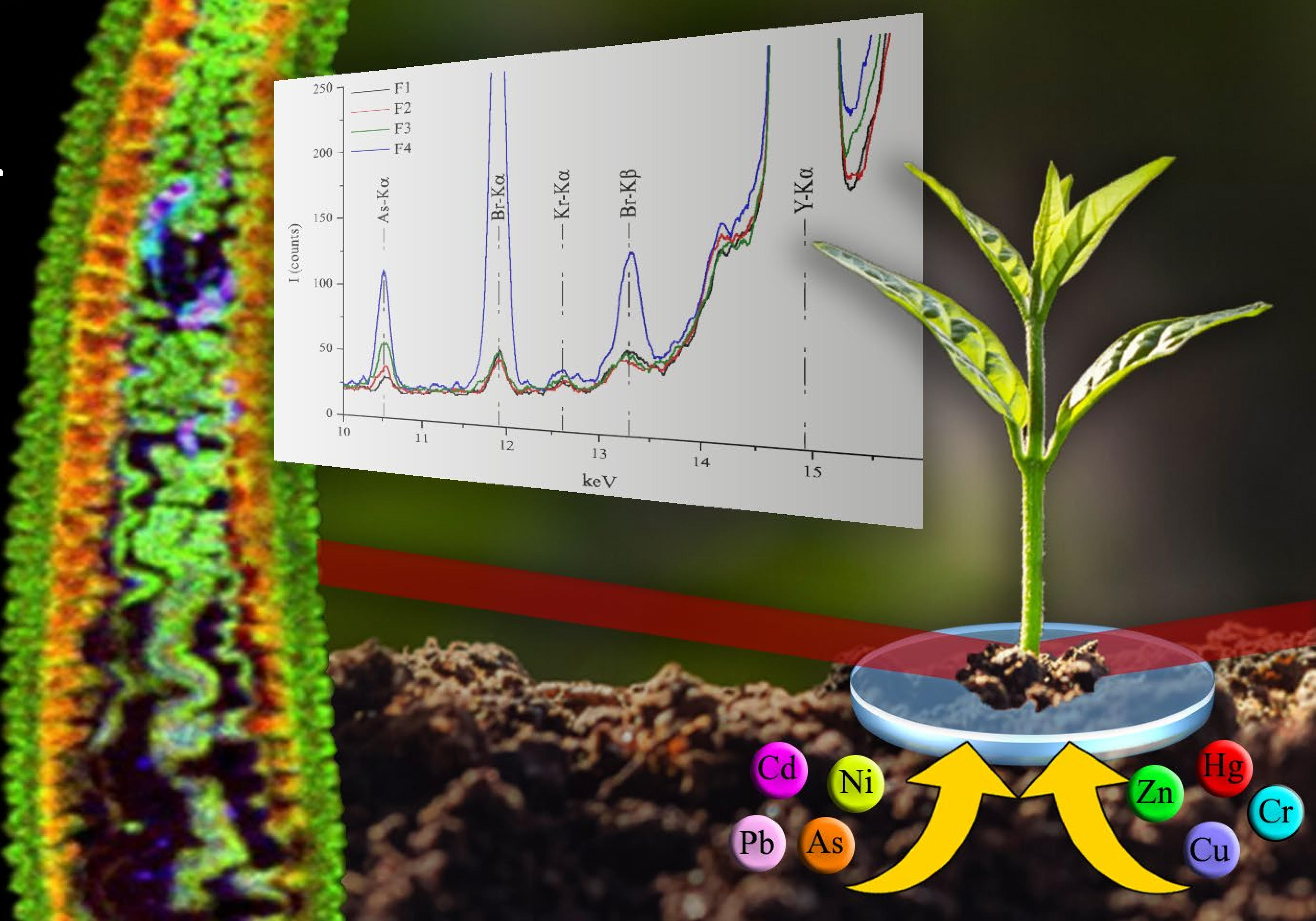
Prof. Roberto Terzano
Dr. Matteo Spagnuolo
Dr. Concetta Eliana Gattullo
Dr. Carlo Porfido
Dr. Ida Rascio

The COST Action CA18130 “ENFORCE TXRF”

enforcetxrf.eu

All the people with whom I collaborate

Thank you for your kind attention!!!



ignazio.allegretta@uniba.it
www.microxraylab.com

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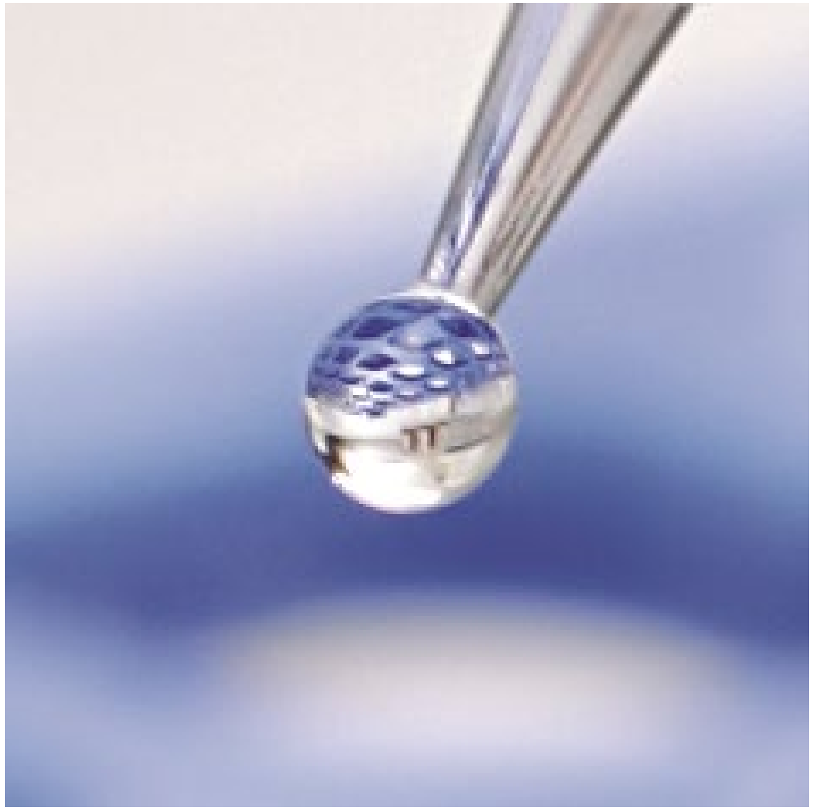
Q & A

Any Questions?

Please **type in** the questions you may have for our speakers in the **Questions Box** and click **Submit**



Thank you for your attention!

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