REMEDIATE

Oral Bioaccessibility of Potentially Toxic Elements (PTEs) in urban area of Belfast

Presenter: Tatiana Cocerva

Joint SoBRA/RSC Conference

5th December 2017

QUESTOR CENTRE

REMEDIATE

Funded by the European Union

QUEEN'S UNIVERSITY BELFAST

Outline of Presentation

Remediate project

I. Introduction

II. Materials and Methods

III. Results

IV. Work in progress

V. Dissemination and engagement activities

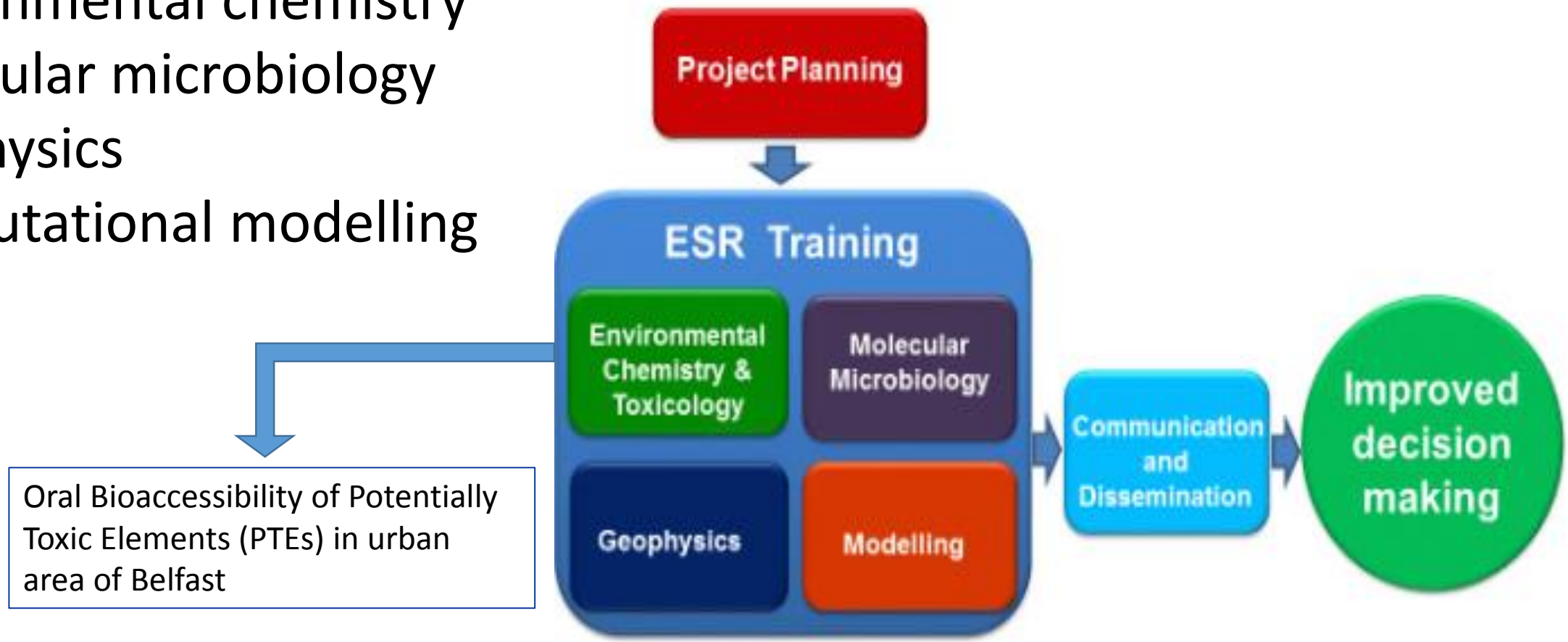
Remediate: Improved decision-making in contaminated land site investigation and risk assessment

- Marie Skłodowska-Curie Initial Training Network funded by European Union's Horizon 2020 programme
- 13 researchers hosted in UK, Ireland, Germany, Denmark, and Italy
- Researchers from Portugal, Greece, Italy, India, Canada, Moldova, Iran, Serbia, and China
- Coordinated by the QUESTOR Centre at Queen's University Belfast

Remediate: Improved decision-making in contaminated land site investigation and risk assessment

Research in:

- Environmental chemistry
- Molecular microbiology
- Geophysics
- Computational modelling



I.1 Importance of bioaccessibility testing in HHRA

Bioaccessibility testing is used in Detailed Quantitative Risk Assessment (DQRA):

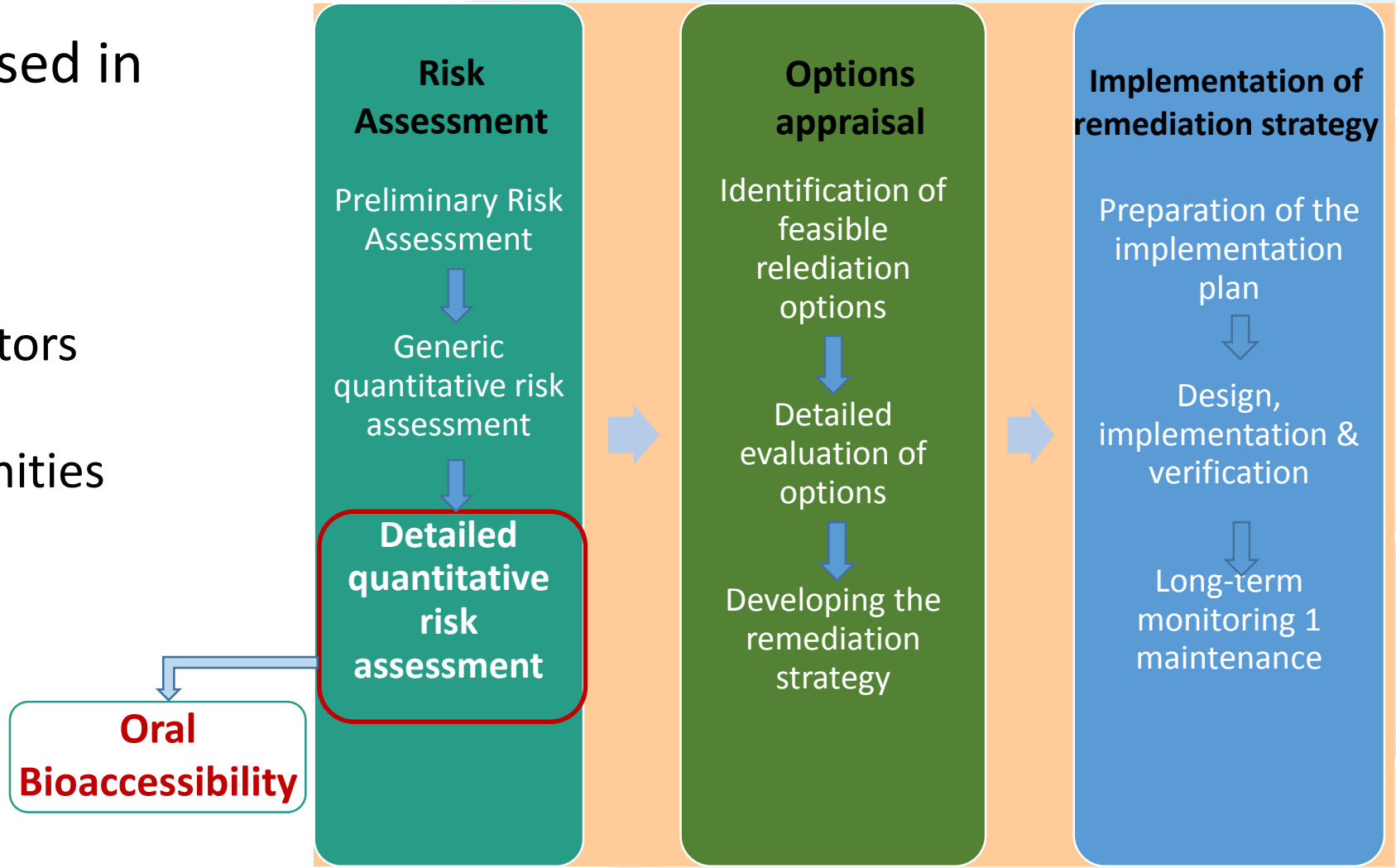
- refine the risks posed to receptors

- better accounting for uncertainities

- less conservative

- site specific risk assessment

The process of managing land contamination



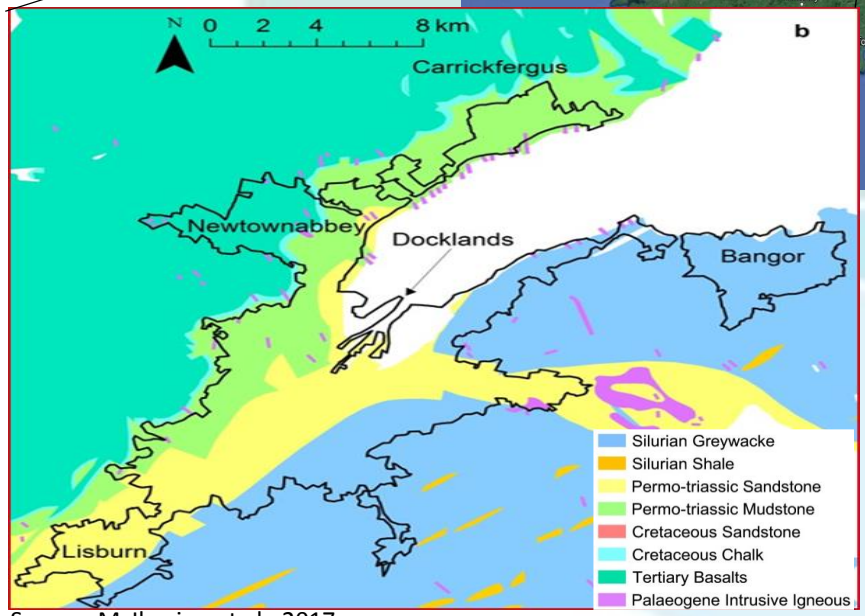
CLR11 – developped by EA and Defra, 2004

I.2 Study Area: Urban area of Belfast

- Industrial history in linen production (from early 18th Century) and shipbuilding (late 18th Century)

- Varied bedrock geology known to control PTE concentrations:

  - Basalts to the north
  - Sherwood sandstone
  - Greywacke to the south



Source: McIlwaine et al., 2017

II. Materials and Methods

II.1 Tellus Geochemical Data

Geochemistry Soil Samples

Belfast

Inorganics

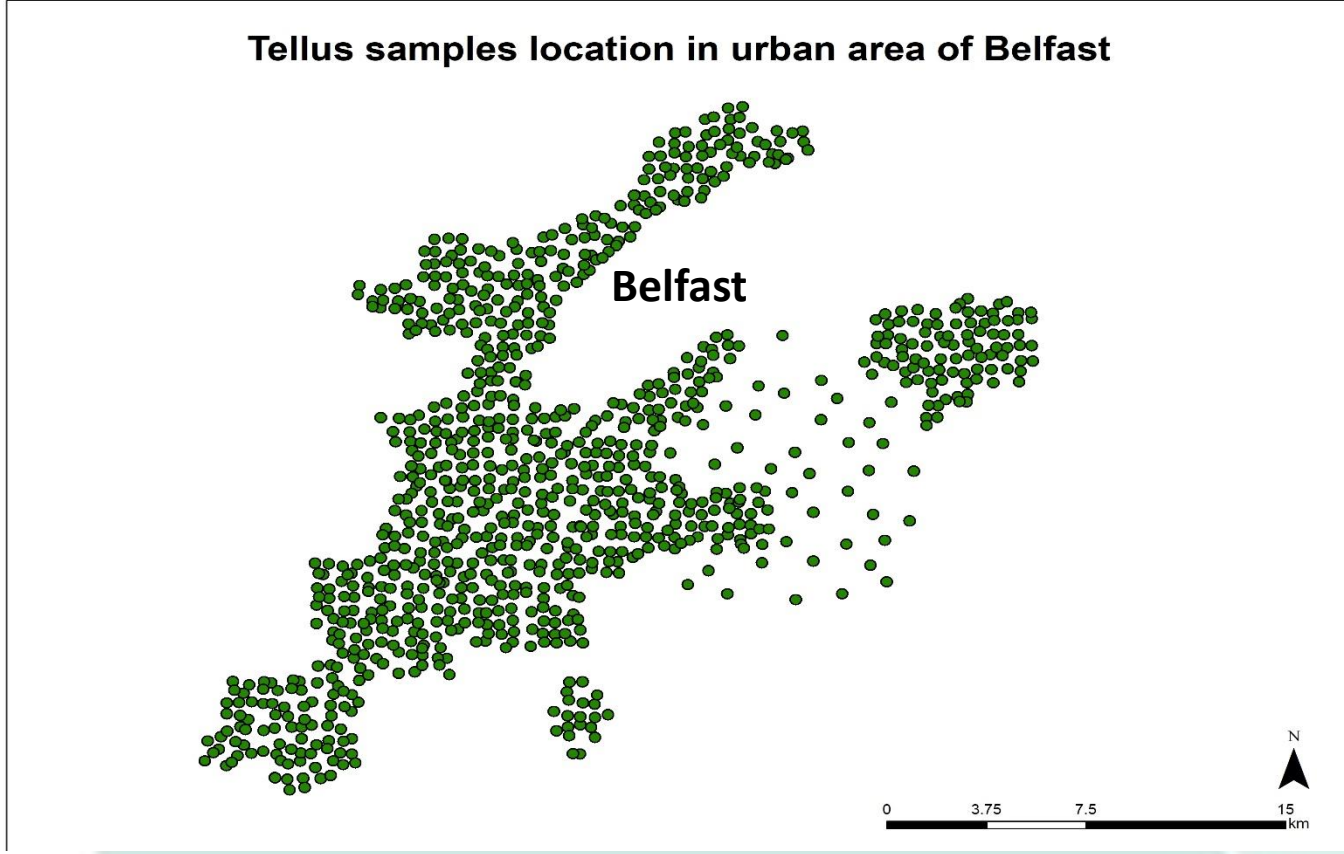
4 samples per km^2

781 samples

Shallow sample at 5 - 20cm depth — XRF → **Bioaccessibility testing**

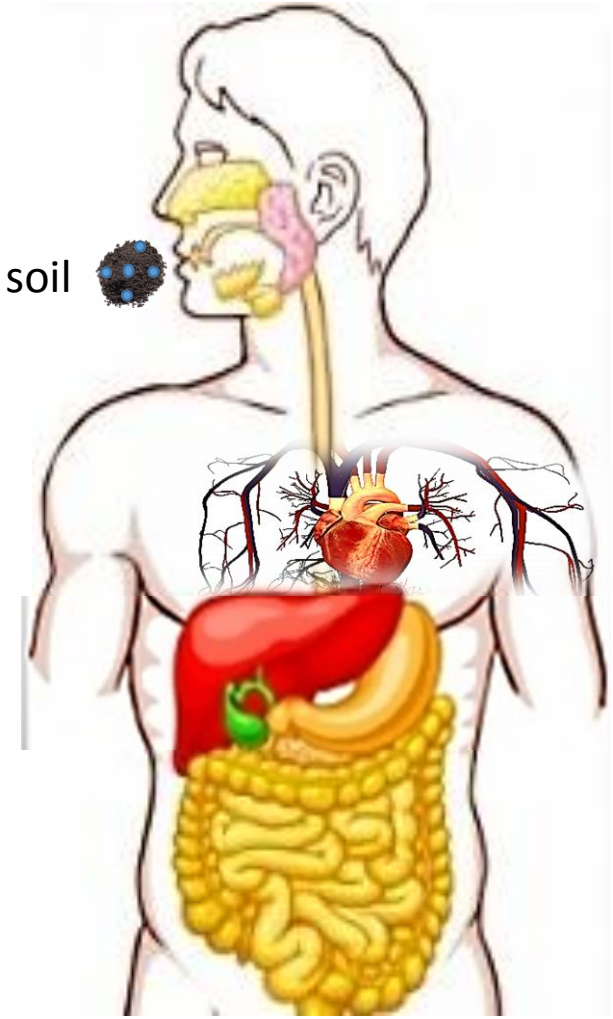
Shallow sample at 5 - 20cm depth — ICP following aqua regia digest

Deep sample at 35 – 50cm depth — ICP following aqua regia digest



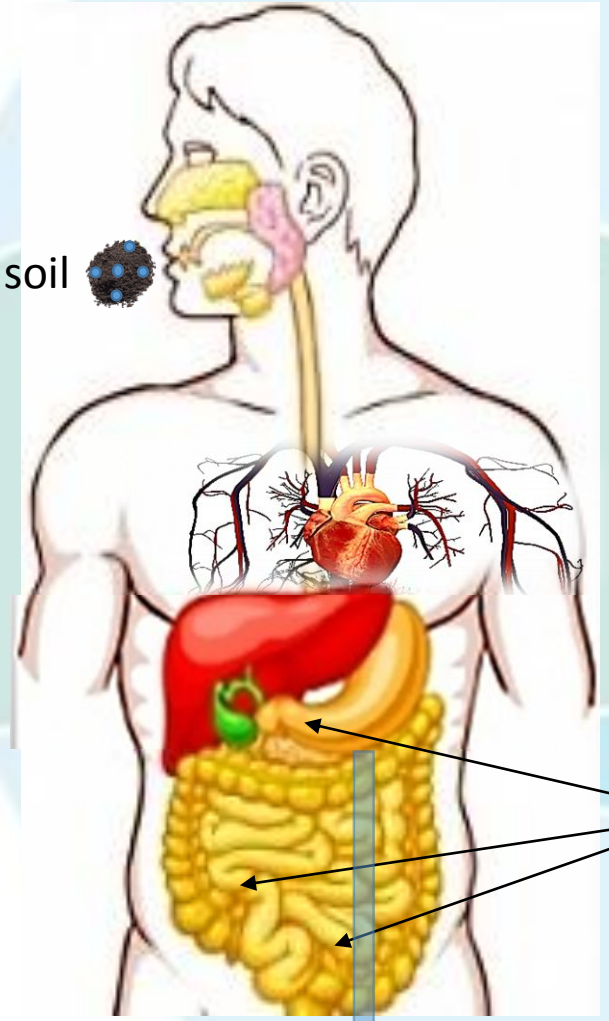
II. Materials and Methods

Bioavailability



- Soil ingestion scenario

Bioaccessibility



Bioaccessible contaminants measured using the **Unified BARGE Method**

Non-bioaccessible metals are excreted with undigested soil.

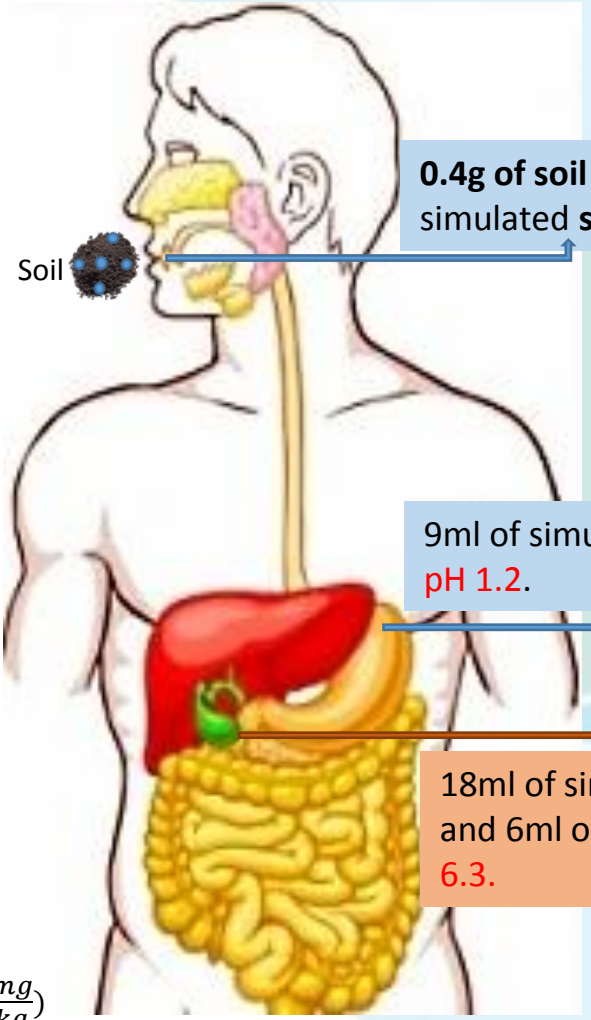
II. Materials and Methods

II.2 The Unified BARGE Method (UBM)

- **BARGE** – **B**io**A**ccessibility **R**esearch **G**roup of **E**urope

- **UBM** is an *in vitro* method which simulates the human gastrointestinal environment using 4 synthetic digestive fluids:

- Saliva
- Gastric fluid
- Duodenal fluid
- Bile



0.4g of soil mixed with 6ml of simulated **saliva**, pH 6.5 for 10s.

9ml of simulated **gastric solution**, pH 1.2.

18ml of simulated **duodenal fluid** and 6ml of simulated **bile fluid**, pH 6.3.

Stomach Phase
End-over-end for **1h**, 37°C.

Stomach + Intestinal Phase
End-over-end **4h**, 37°C

$$\%\text{Bioaccessible fraction}(\mathbf{BAF}) = \frac{Concentration\ of\ bioaccessible\ metal\ (\frac{mg}{kg})}{Concentraion\ of\ total\ metal\ in\ sample\ (\frac{mg}{kg})} \text{ x } 100$$

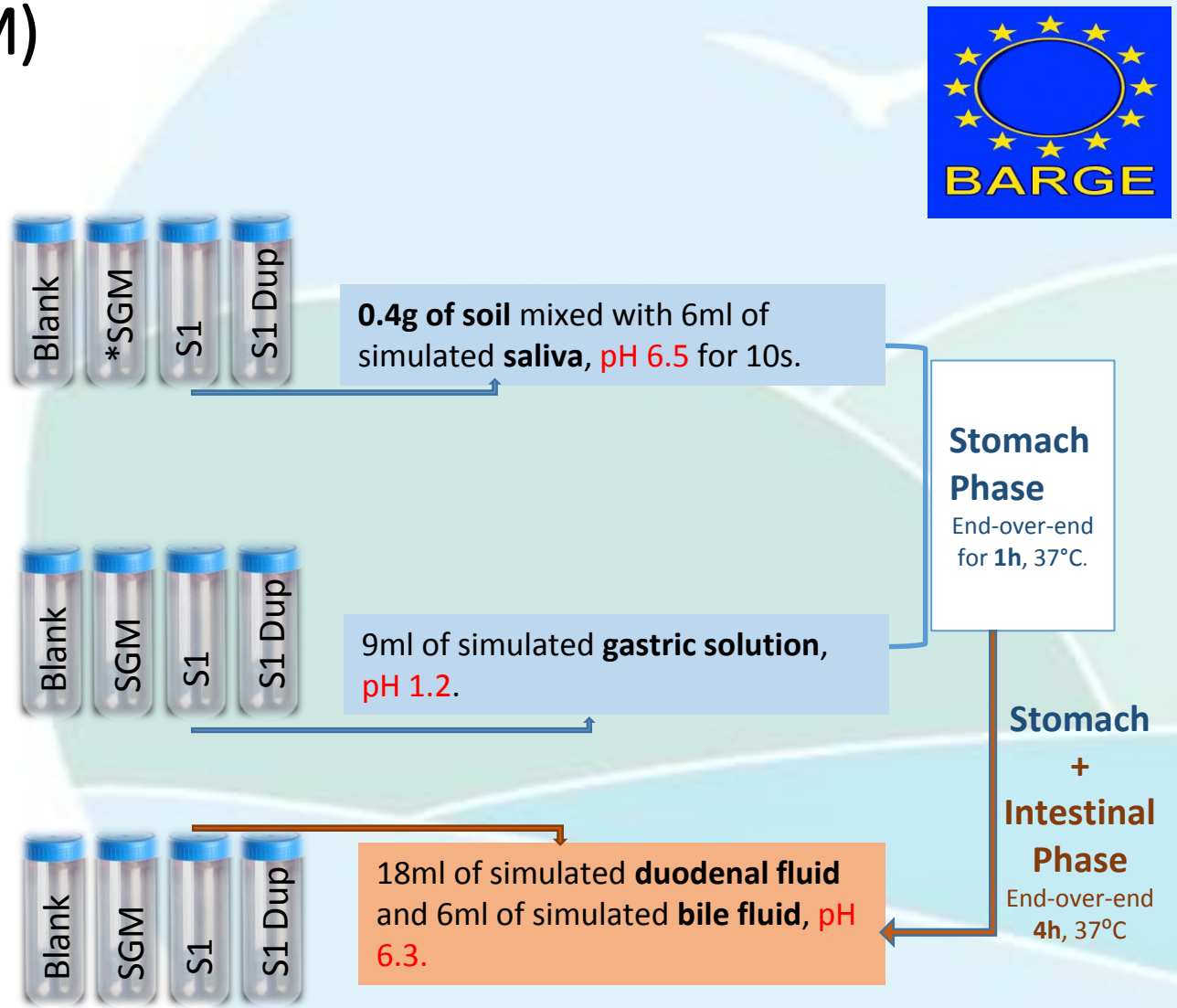
II. Materials and Methods

II.2 The Unified BARGE Method (UBM)

- **BARGE** – **B**io**A**ccessibility **R**esearch **G**roup of **E**urope

- **UBM** is an ***in vitro*** method which simulates the human gastrointestinal environment using 4 synthetic digestive fluids:

- Saliva
- Gastric fluid
- Duodenal fluid
- Bile



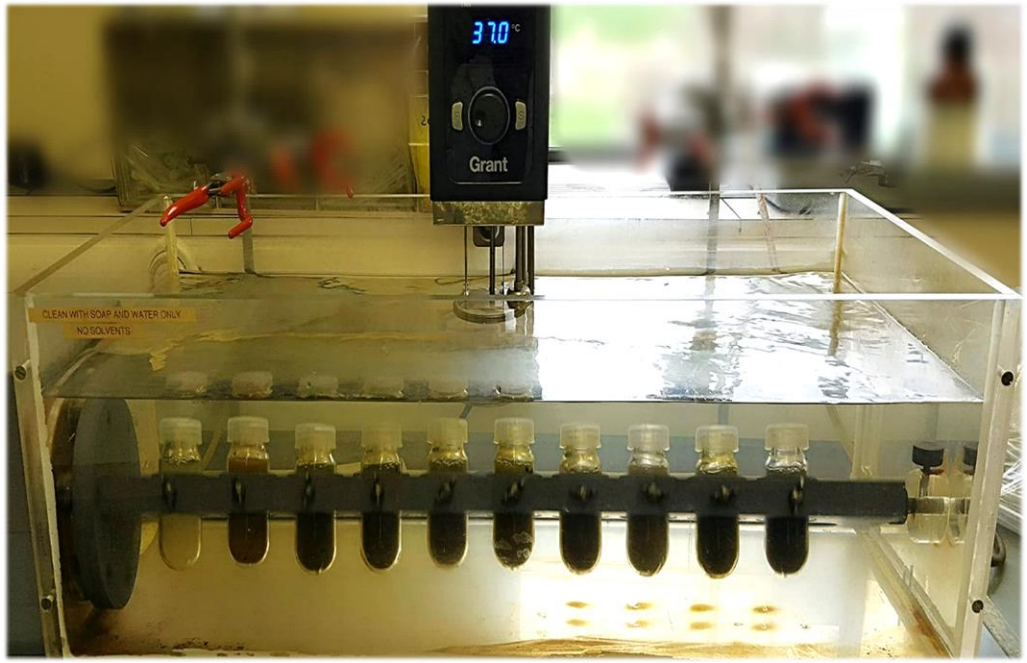
$$\%\text{Bioaccessible fraction}(\mathbf{BAF}) = \frac{Concentration\ of\ bioaccessible\ metal\ (\frac{mg}{kg})}{Concentraion\ of\ total\ metal\ in\ sample\ (\frac{mg}{kg})} \text{ x } 100$$

*SGM – Soil Guidance Material BGS102; Hamilton et al., 2015

II. Materials and Methods

II.2 The Unified BARGE Method (UBM)

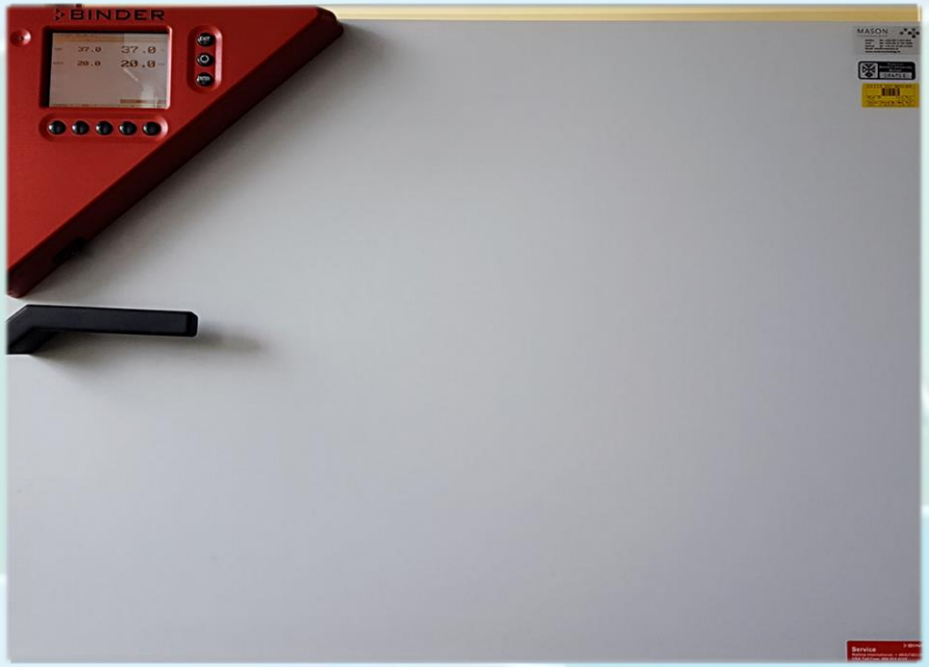
Water Bath



UBM - British Geological Survey (BGS)

Manufacturing cost*: $6000.00 USD

Oven



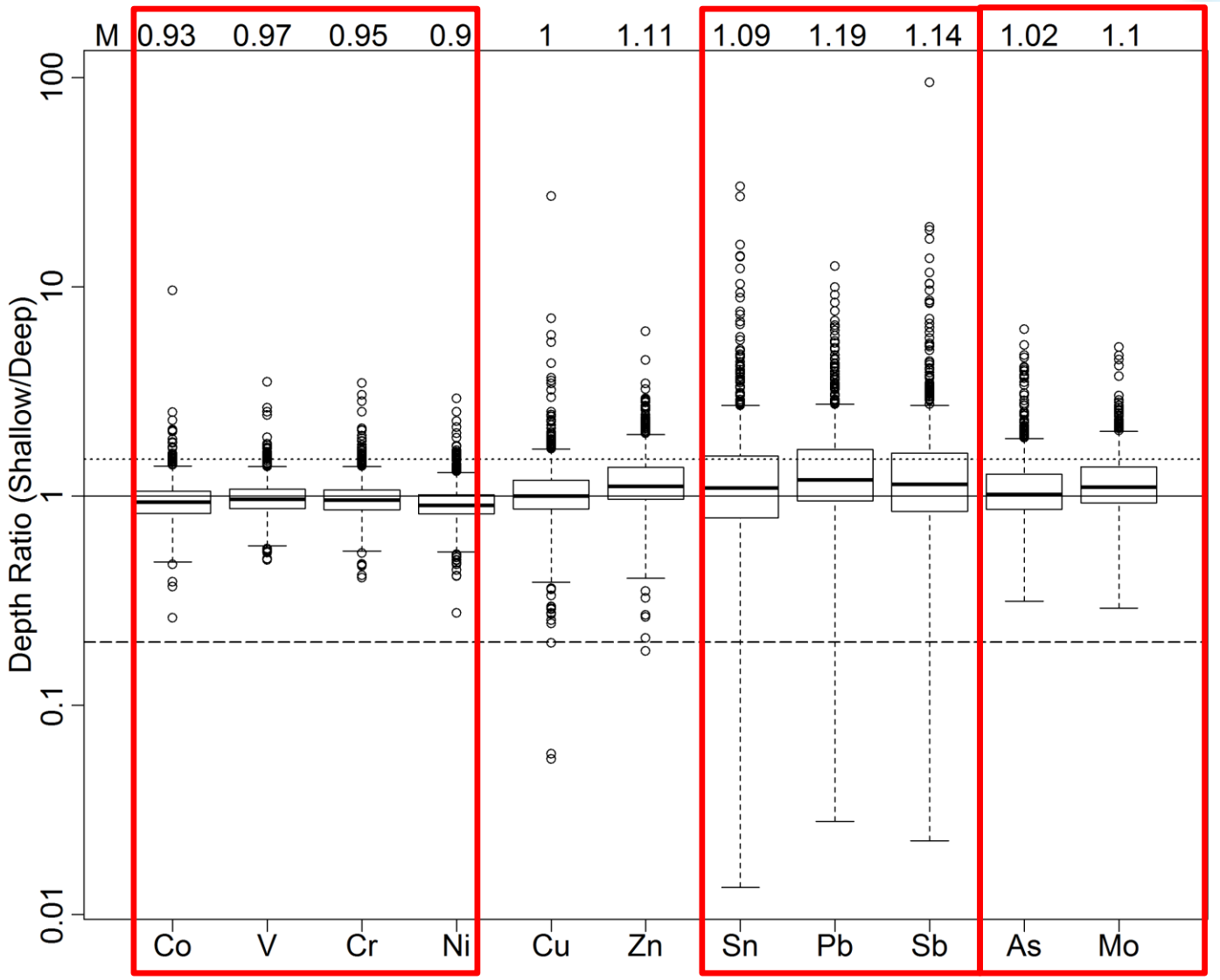
UBM - Queen's University Belfast (QUB)

Equipment available at QUB laboratory

* Astro Endyne Company, USA

III. Results

III.1 Geochemical Data analysis



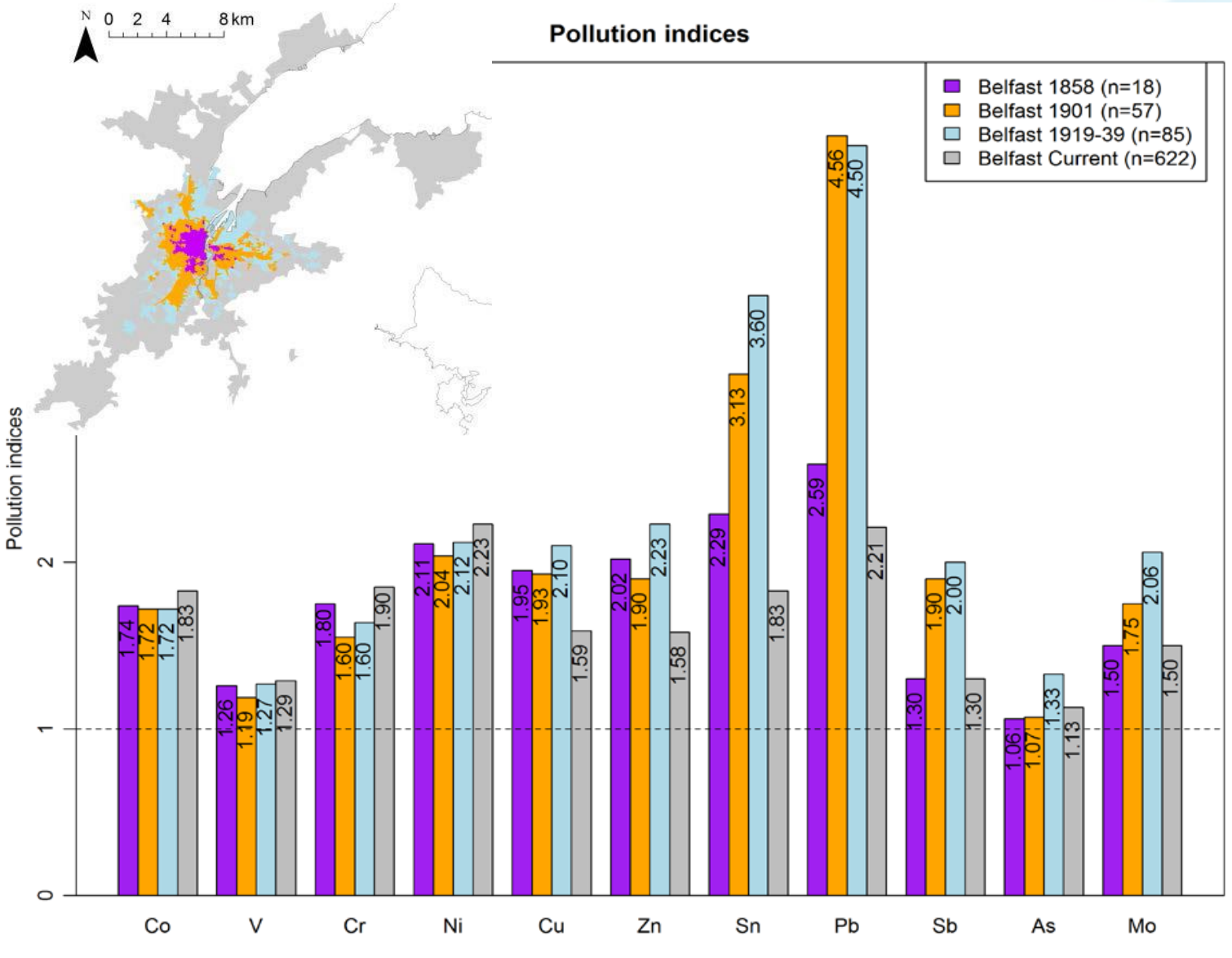
- Anthropogenic
  - more likely to be elevated at surface (Ratio >1)
  - less likely to have lower outliers
  - wider distribution
- Geogenic
  - more likely to be elevated at depth (ratio <1)
  - more likely to have lower outliers

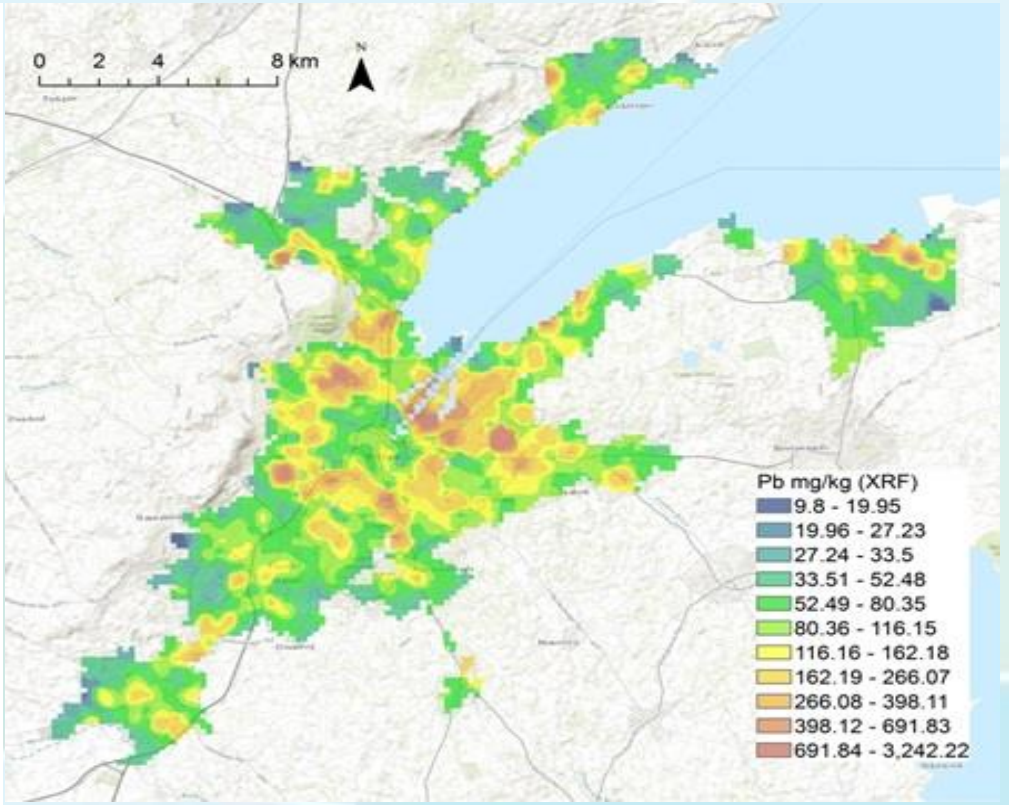
Source: McIlwaine et al., 2017

III. Results

III.1 Geochemical Data analysis

Belfast: Pollution Indices





- Pb and Sn show considerably higher enrichment

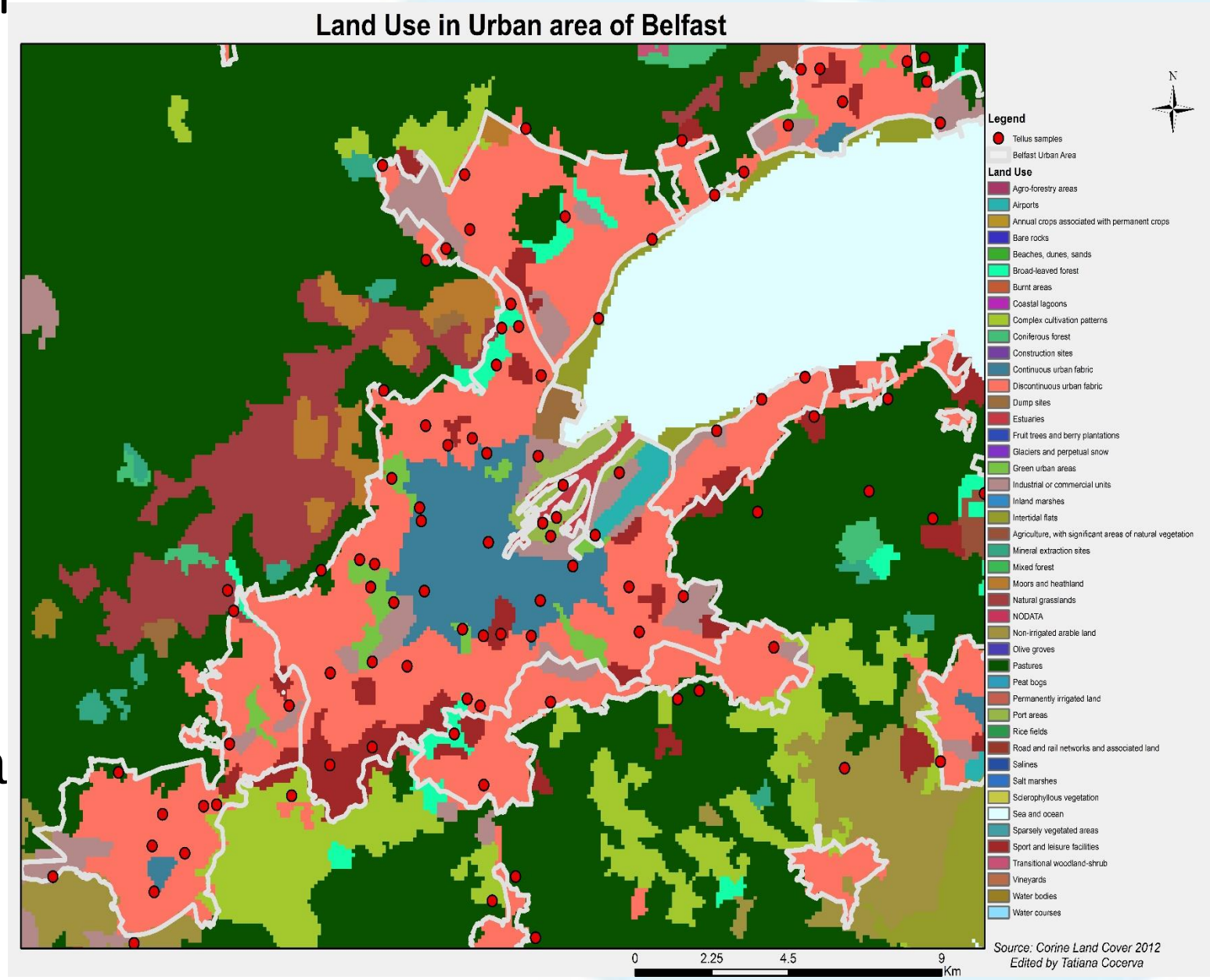
Source: McIlwaine et al., 2017

III. Results

III.1 Tellus Sample selection

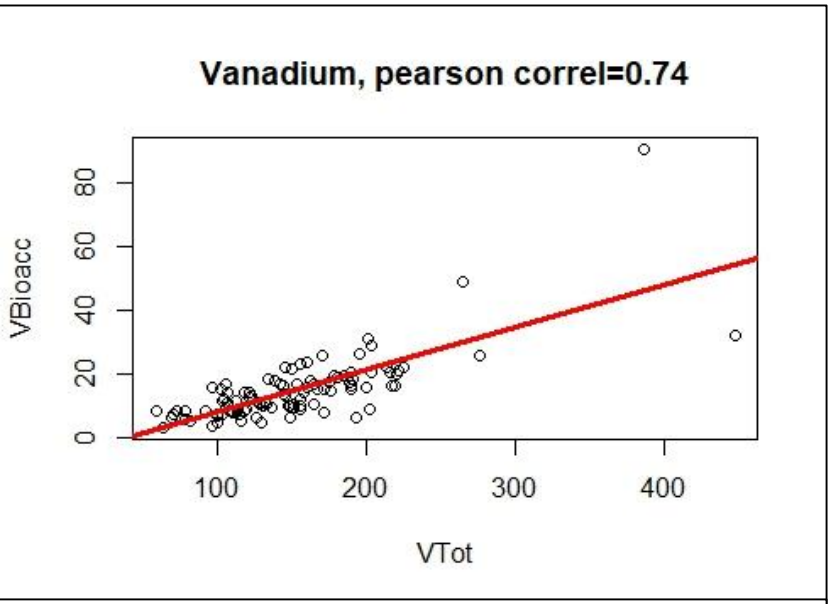
- Selected 103 TELLUS samples for UBM testing

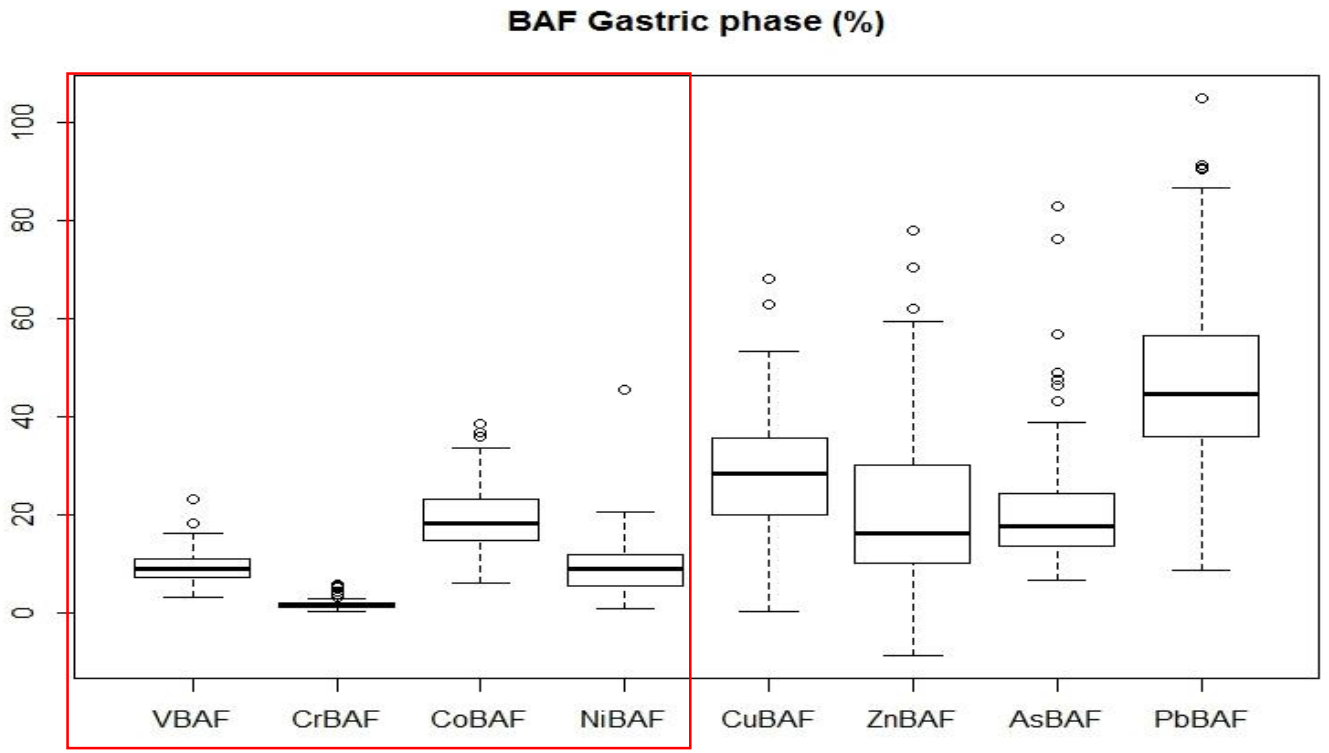
- Includes different
  - -land uses
  - -geology
  - -soil assessment criteria values (S4ULs)

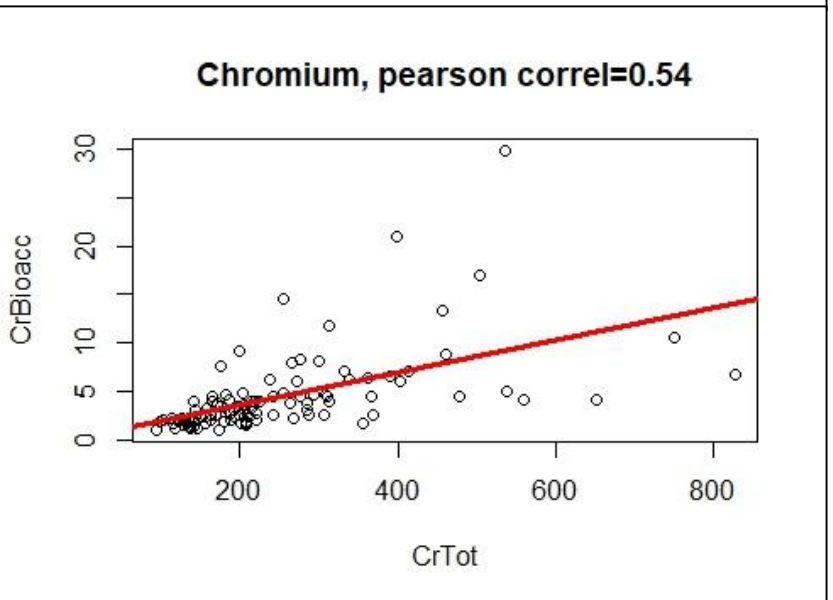


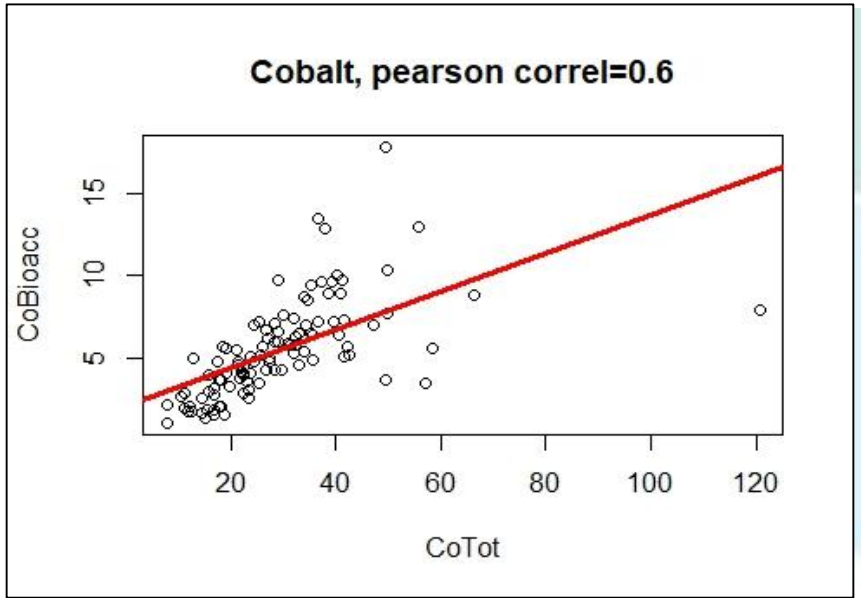
III. Results

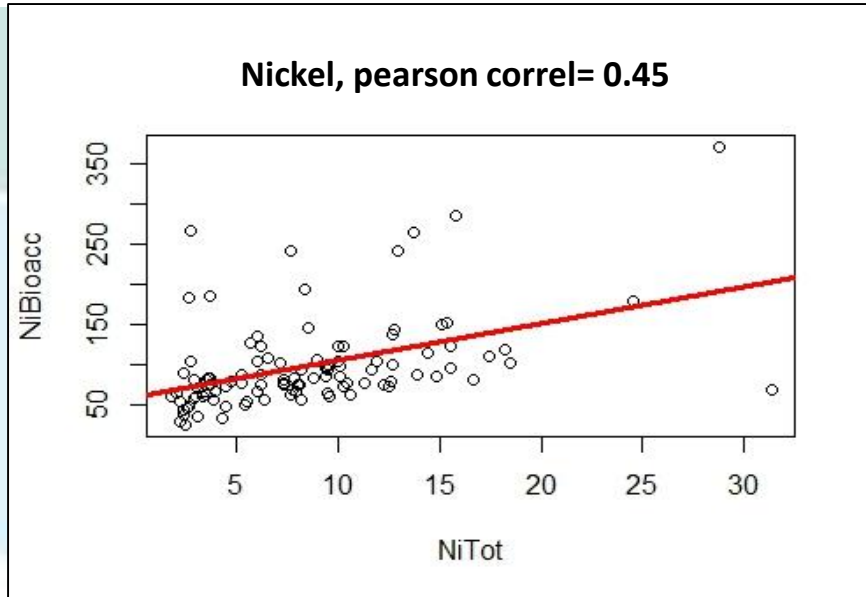
III.2 Bioaccessibility extraction for the Gastric phase





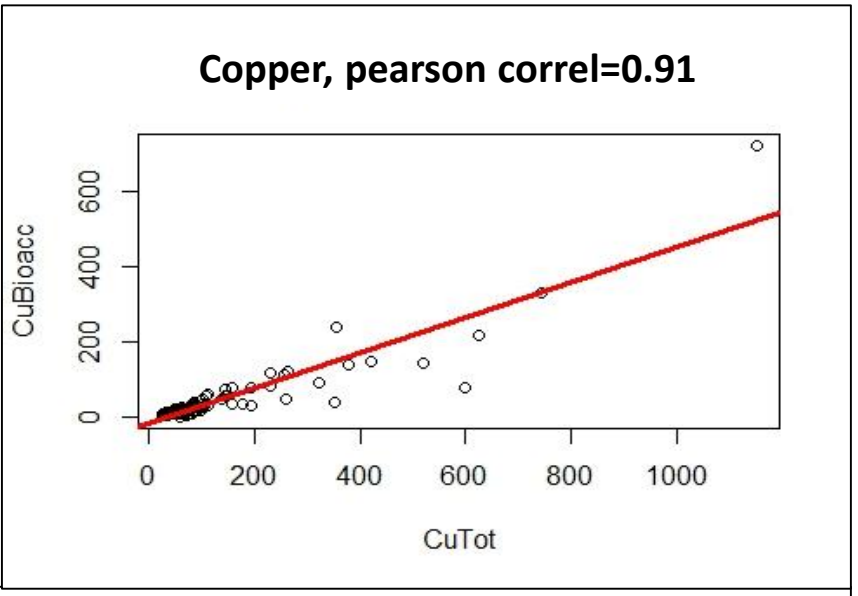


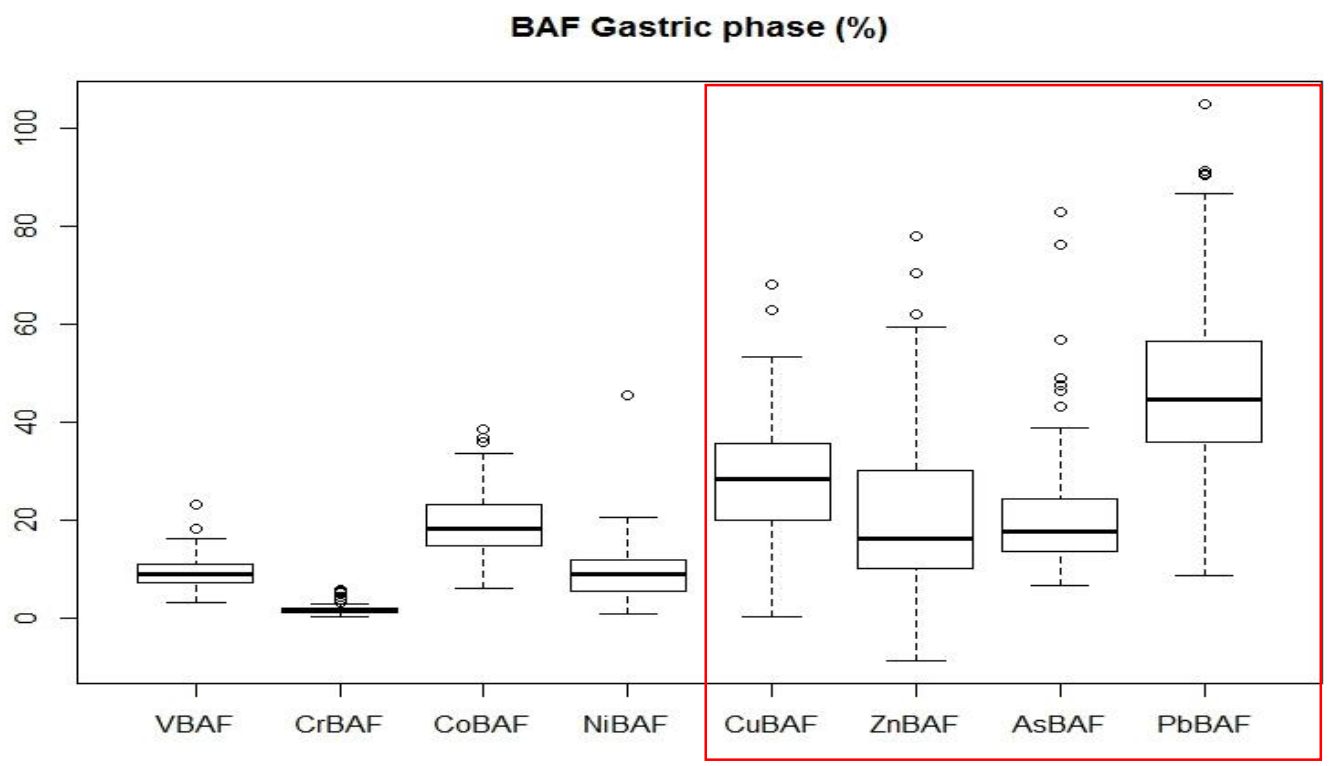


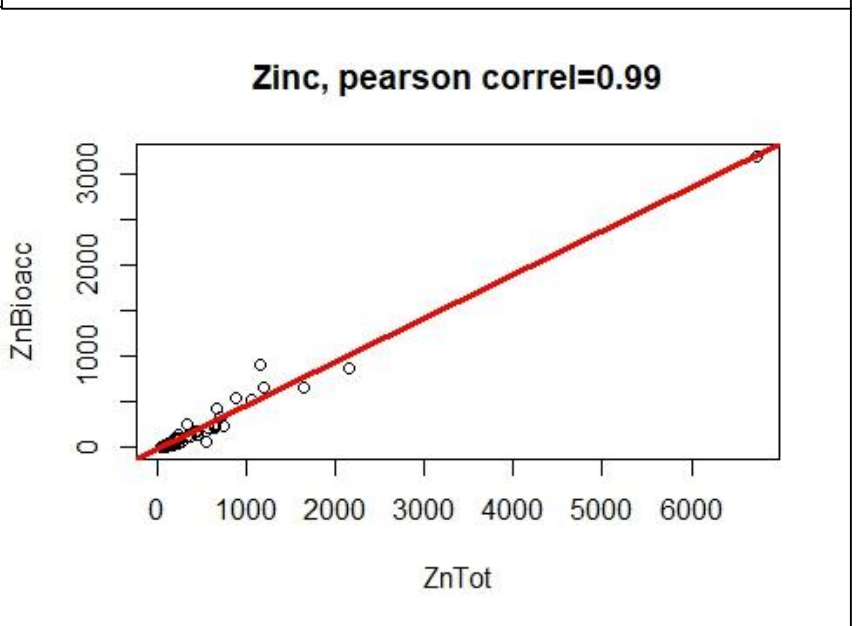


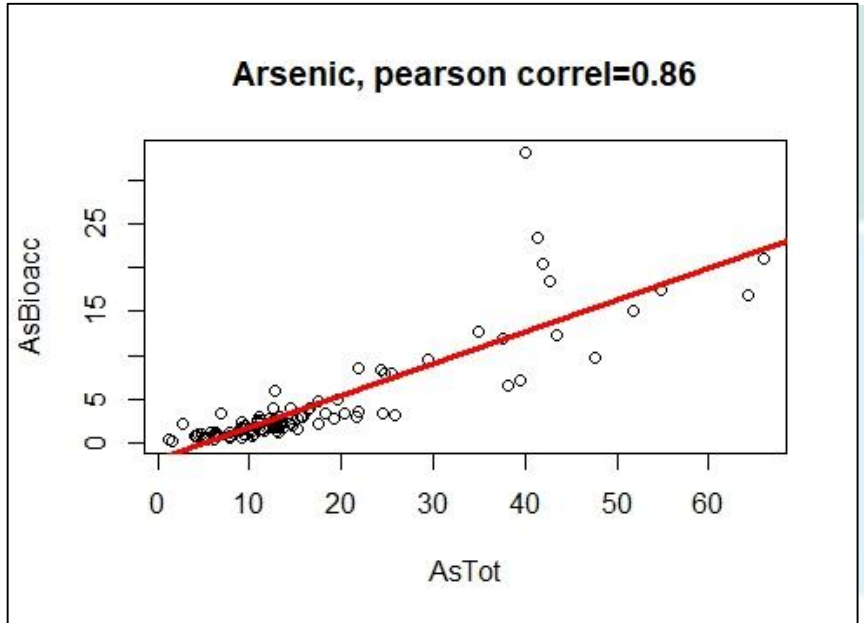
III. Results

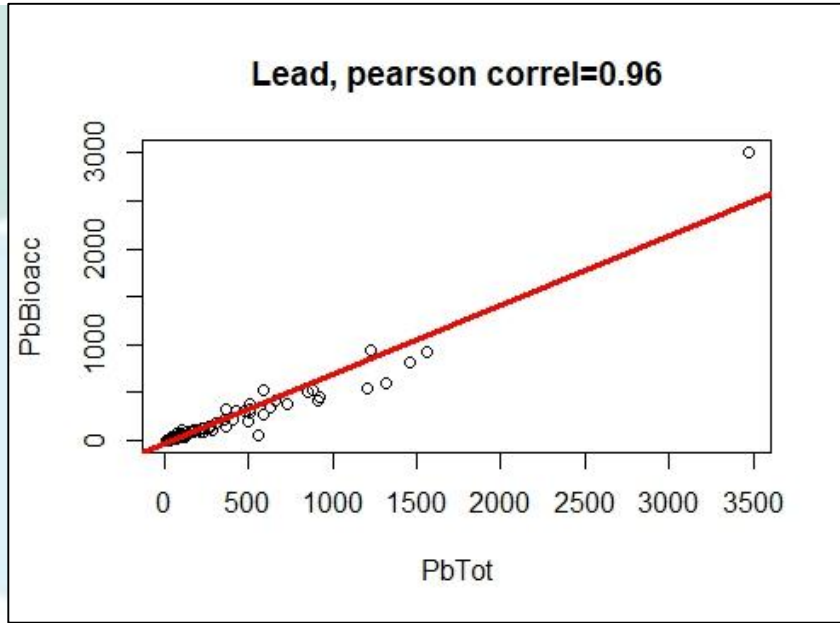
III.2 Bioaccessibility extraction for the Gastric phase







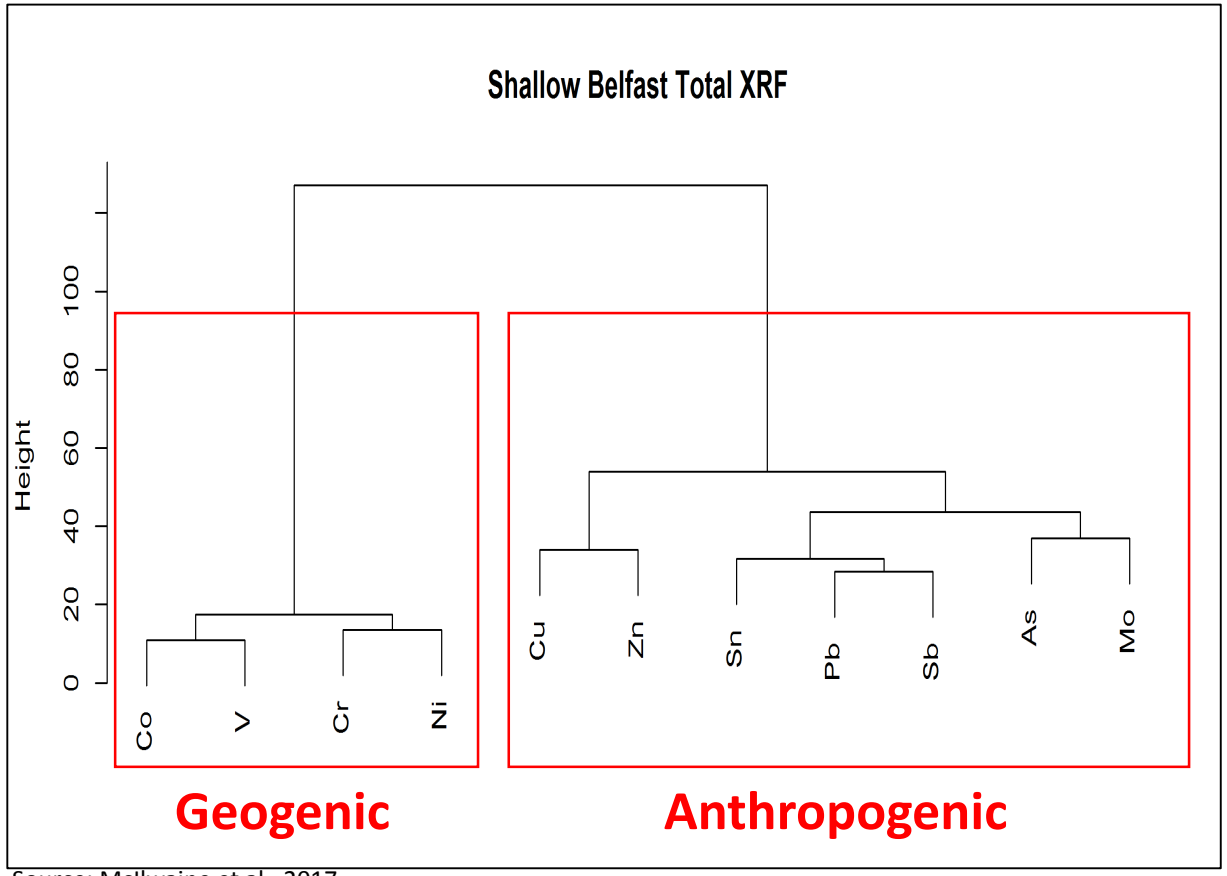




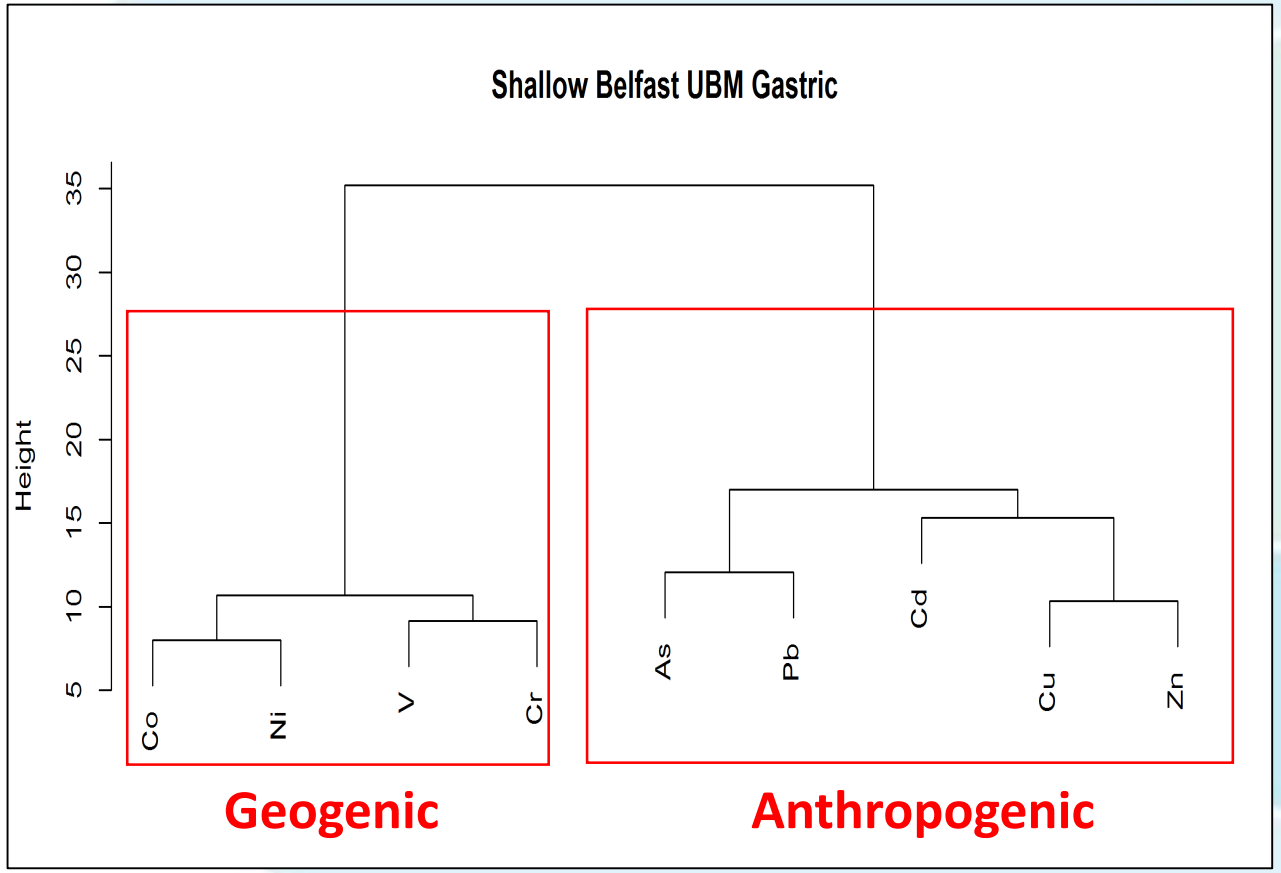
III. Results

Cluster Analysis

Total concentrations

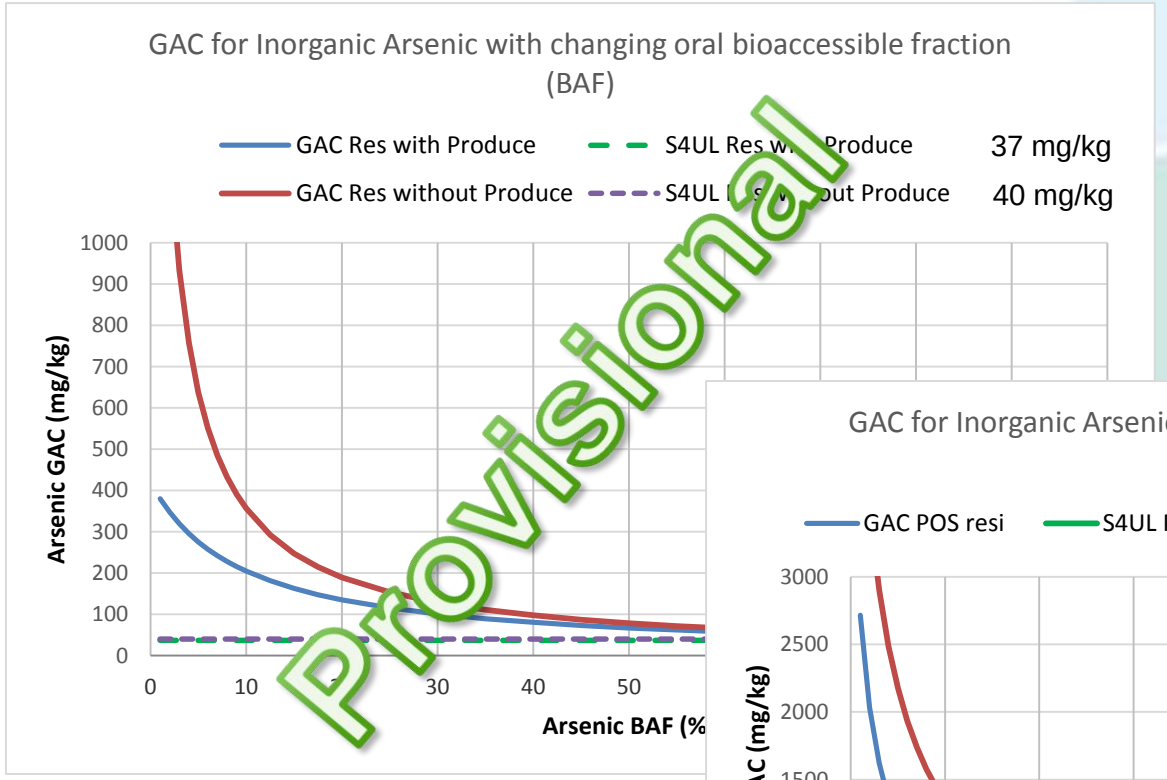


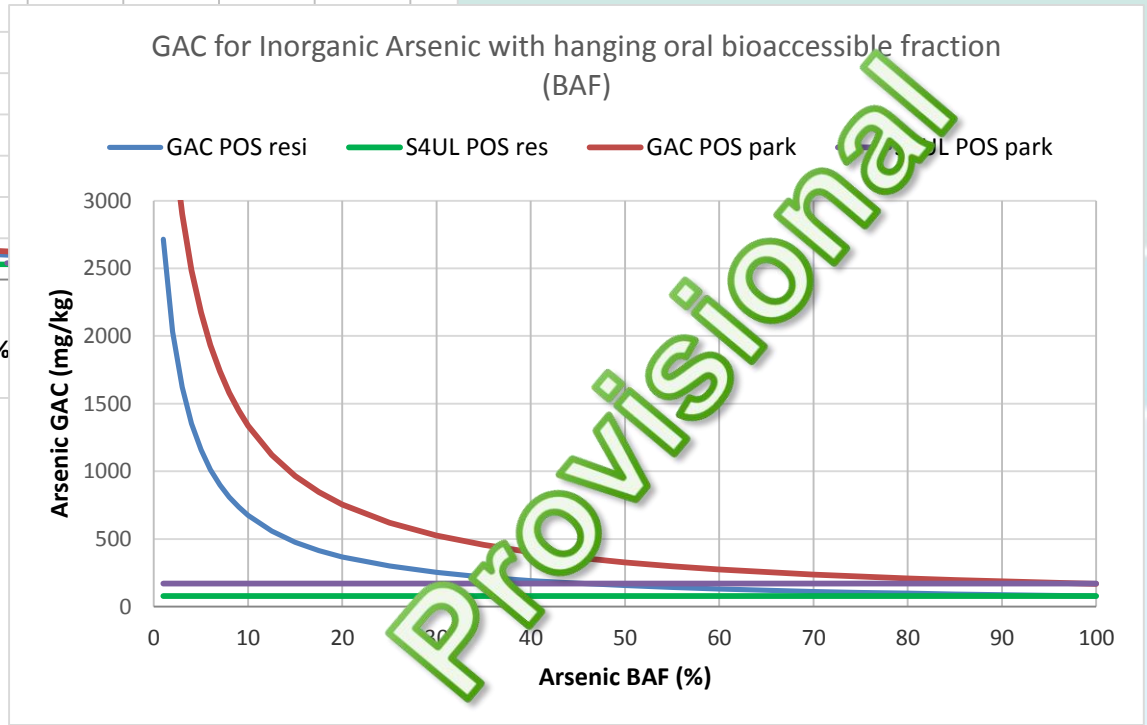
Bioaccessibility concentrations



Source: McIlwaine et al., 2017

How do we use bioaccessibility testing in Risk Assessment?

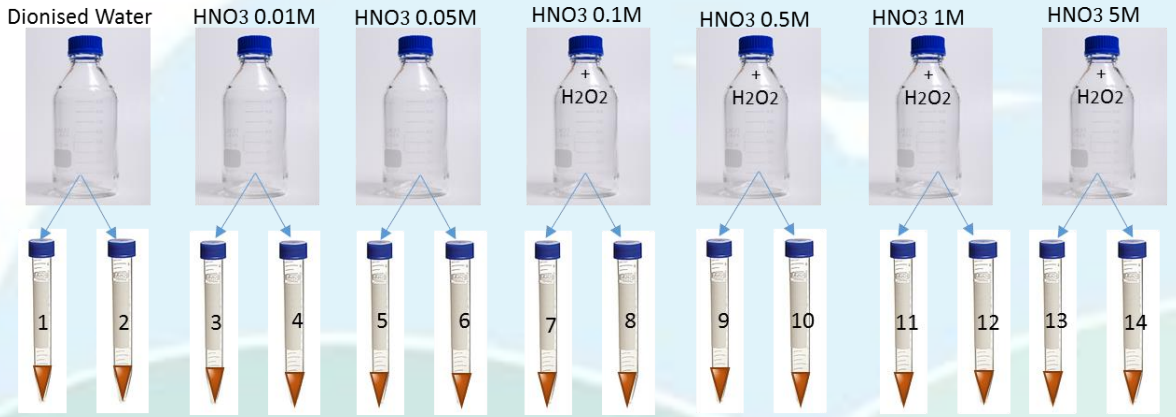




- QUB deriving graphs of GACs for varying BAF for a variety of contaminants & land uses based on S4ULs
  - Methodology adapted from Scott and Nathanail, 2011

Work to be completed in collaboration with **RSK**

IV. Work in progress

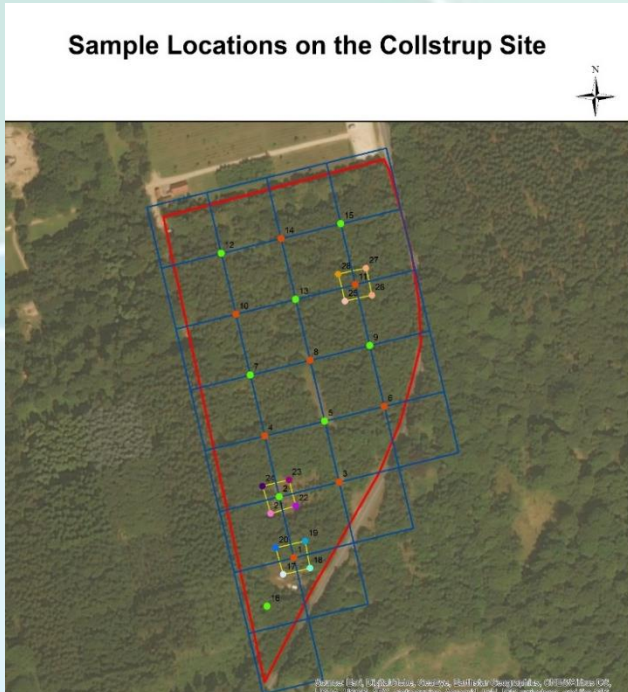


1. CISED sequential extraction for 15 Tellus samples.

(Work completed in collaboration with *Cranfield University*)

2. Develop a sampling technique for bioaccessibility testing using a contaminated site in Denmark.

(Work completed in collaboration with **University of Copenhagen**)



V. Secondments, Conferences, dissemination and engagement activities

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Secondments:

- **British Geological Survey** – Unified BARGE Method
- **Cranfield University** – CISED extraction
- **University of Copenhagen** – Sampling on a contaminated site
- **RSK** - Risk Assessment

Conferences:

- **ISEH International Symposium on Environment and Health, 14-18 Aug 2016, Galway, Ireland**
- **AquaconSoil 26-30 Jun. 2017 Lyon, France**
- **MedGeo'17 28 Aug. – 1 Sept. 2017 Moscow, Russia**

Dissemination and engagement activities

- **Science Uncovered Event, Ulster Museum, Belfast: 29 Sept. 2017**
- **LIFE AS A POSTGRAD, THE PHD MOVIE AND STUDENT TALKS, QUB 18 Sept. 2017**
- **Hosted** visitor Dr. Oderson Antonio de Souza from Brazilian Geological Survey, 08 Nov. 2017, QUB

Acknowledgements

British Geological Survey

- Especially Dr. Mark Cave, Dr. Joanna Wragg

Geological Survey of Northern Ireland

- Especially Dr. Robert James Raine, Mr. Alexander Donald, Dr. Marie Cowan

The Institute for Global Food Security, QUB

- Especially Mr. Manus Carey, Prof. Andrew Meharg

QUESTOR CENTER

- Especially Dr. Julie-Anne, Mr. David Parker

Cranfield University, University of Copenhagen

This work was completed as part of the **REMEDIATE** (Improved decision-making in contaminated land site investigation and risk assessment) **Marie-Curie Innovation Training Network**. The network has received funding from the European Union's Horizon 2020 Programme for research, technological development and demonstration under grant agreement n. 643087. REMEDIATE is coordinated by the QUESTOR Centre at Queen's University Belfast http://questor.qub.ac.uk/REMEDIATE/

REMEDIATE

Thanks For Listening

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 643087

Project coordinated by the QUESTOR Centre at Queen's University Belfast
www.qub.ac.uk/questor

References:

- Denys, S. et al., 2012. In vivo validation of the unified BARGE method to assess the bioaccessibility of arsenic, antimony, cadmium, and lead in soils. *Environmental Science and Technology*, 46(11), pp.6252–6260.
- Hamilton, E.M. et al., 2015. Bioaccessibility performance data for fifty-seven elements in guidance material BGS 102. *Microchemical Journal*, 123, pp.131–138. Available at: http://www.sciencedirect.com/science/article/pii/S0026265X1500123X.
- McIlwaine, R., Doherty, R., Cox, S.F., Cave M. R. (2017) The relationship between historical development and potentially toxic element concentrations in urban soils. Environmental Pollution, 220(B): 1036-1049 http://dx.doi.org/10.1016/j.envpol.2016.11.040
- Nathanail, C.P. et al. 2015. The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham.
- Nelson, C.M. et al., 2013. Evaluation of a low-cost commercially available extraction device for assessing lead bioaccessibility in contaminated soils. *Environ Sci Process Impacts*, 15, pp.573–578. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23738355.
- Palmer, S., Cox, S.F., McKinley, J.M., Ofterdinger, U., 2014. Soil-geochemical factors controlling the distribution and oral bioaccessibility of nickel, vanadium and chromium in soil. Appl. Geochemistry 51, 255–267. doi:10.1016/j.apgeochem.2014.10.010
- Wragg, J. et al., 2011. An inter-laboratory trial of the unified BARGE bioaccessibility method for arsenic, cadmium and lead in soil. *Science of the Total Environment*, 409(19), pp.4016–4030. Available at: http://dx.doi.org/10.1016/j.scitotenv.2011.05.019