The fate of diffuse Pb pollution in urban soil; a case study from Sheffield, UK.

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Introduction

Lead (Pb): probable human carcinogen; damages nervous system, brain and kidneys

It is widely dispersed across urban soils in industrialised nations

Sheffield: diffuse Pb pollution* in topsoil estimated around 100 mg kg^{-1} (Rawlins et al., 2005).

We do not know: i) where this diffuse Pb resides in the soil or, ii) how mobile it is?

We have investigated this using in and around Sheffield

* from an anthropogenic, not a geogenic or pedogeochemical, source

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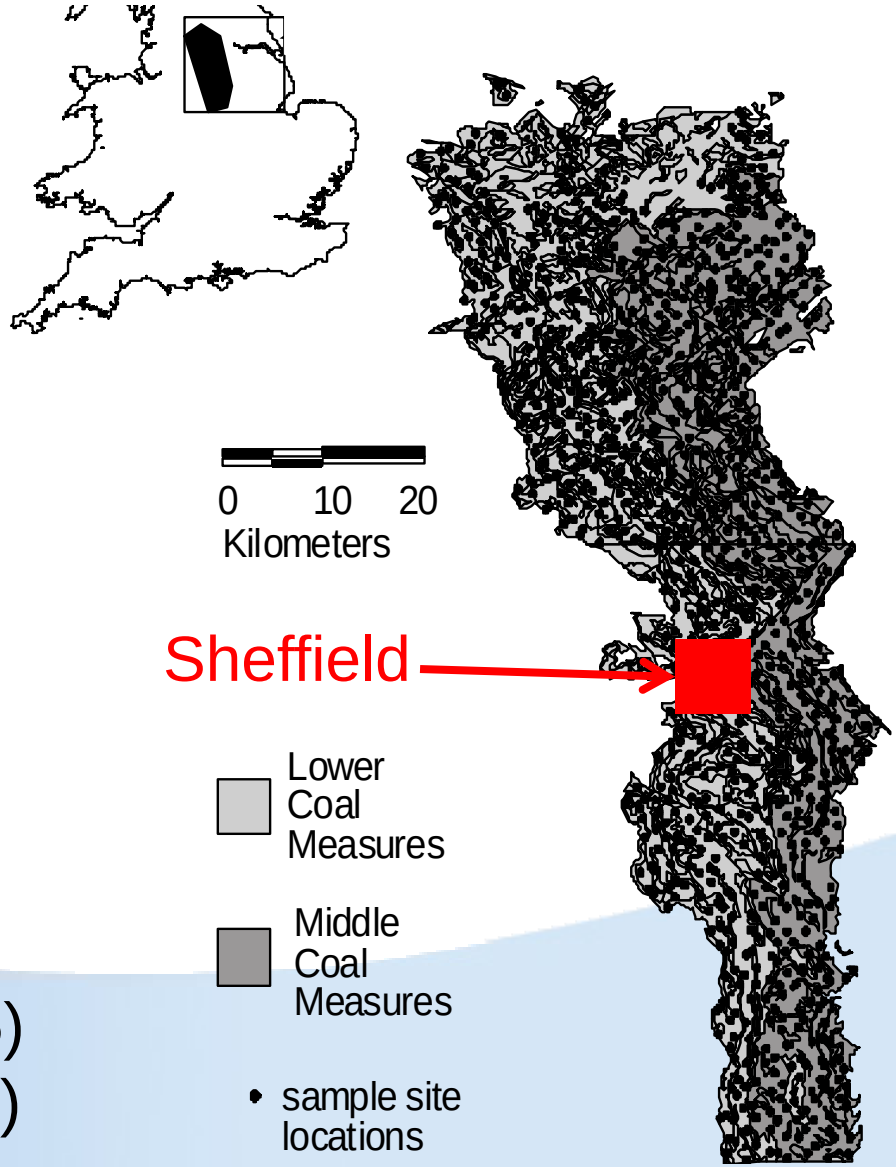
Background

Rural topsoil survey (Rawlins et al., 2002)

Locations of topsoil samples (depth 0-15 cm; <2mm)

Two parent material types which occur in Sheffield:

Lower Coal Measures (n=415)
Middle Coal Measures (n=413)



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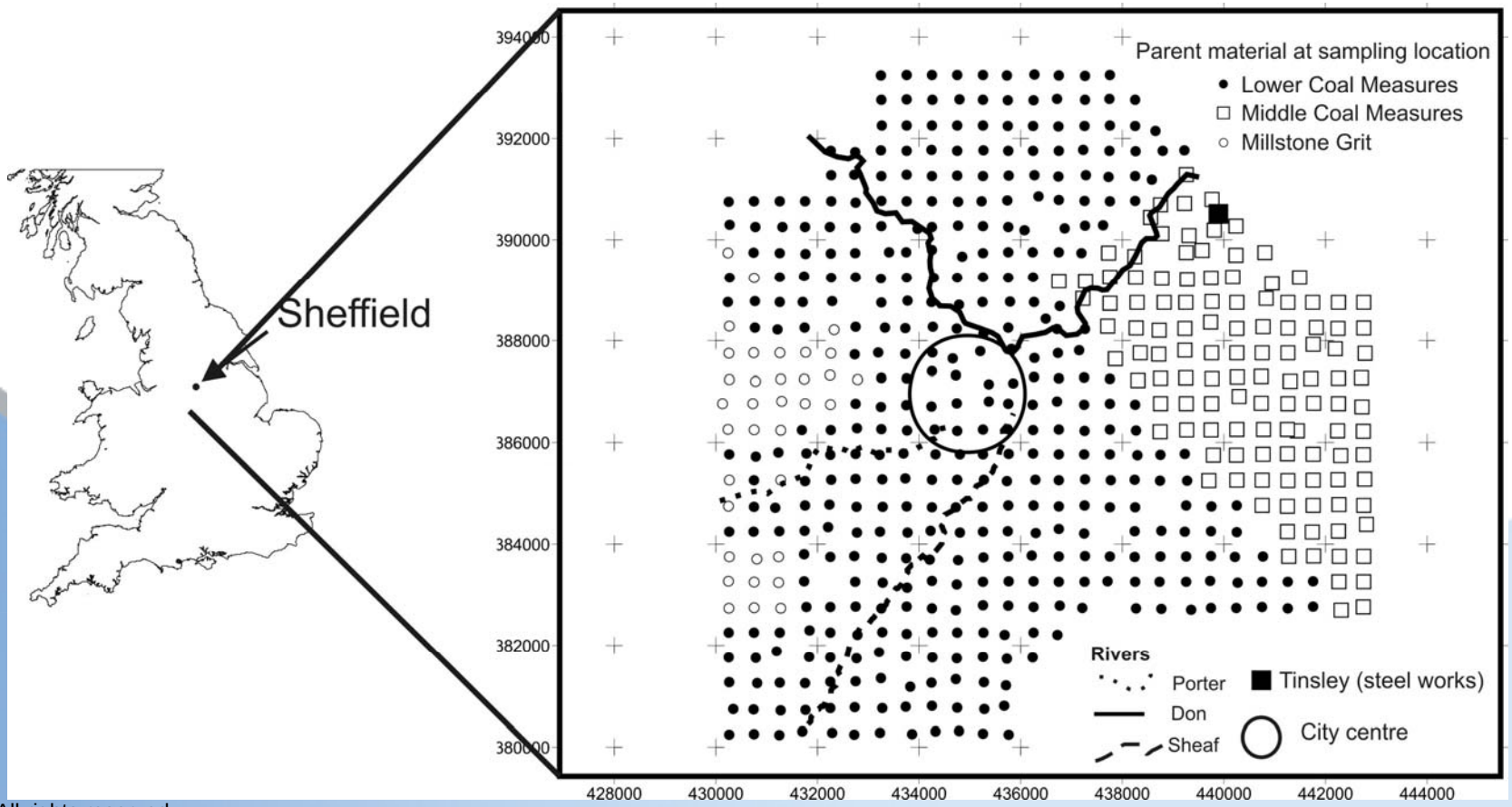
Urban topsoil survey: Sheffield (n=569; 0-15cm depth, <2mm)
Same parent material: urban survey has larger proportion of sites over Lower Coal Measures



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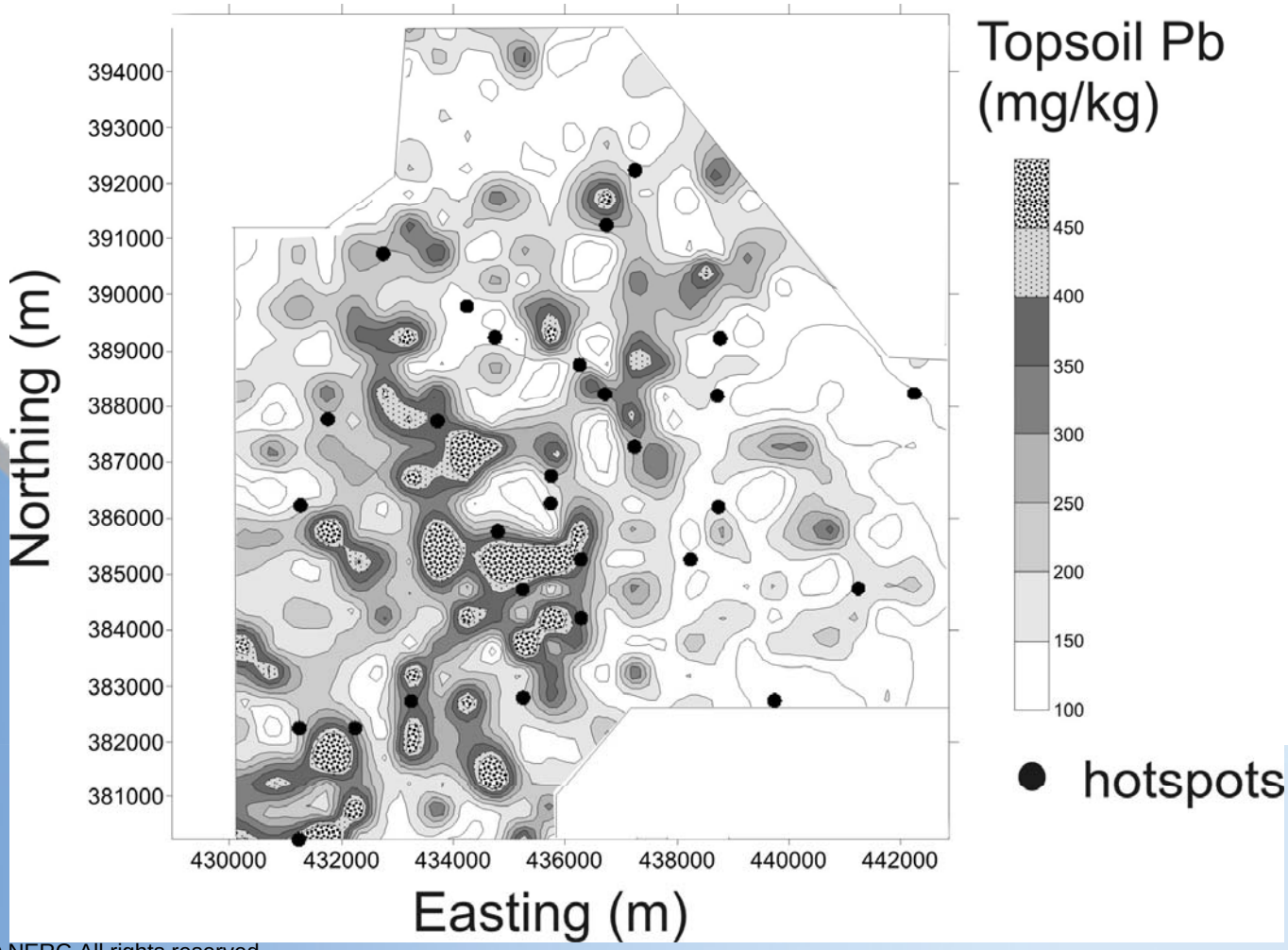
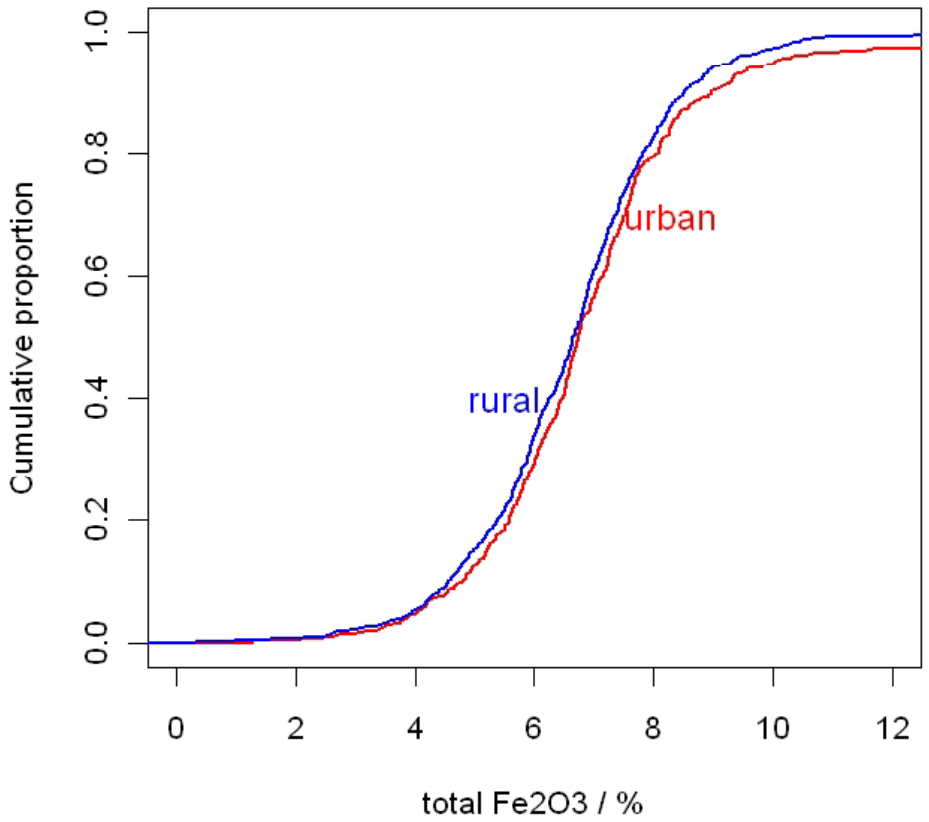
Contour maps of Pb concentrations (mg kg^{-1}) based on punctually kriged estimates with spatial outliers (hotspots) removed from the original data (Rawlins et al., 2005).

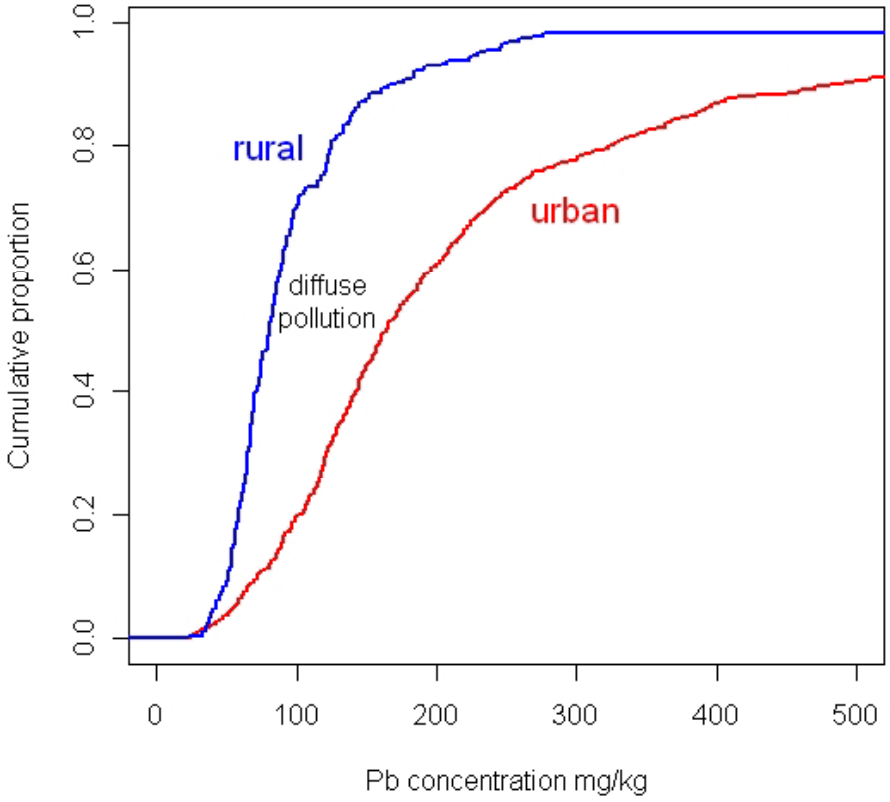


Complex spatial variation

We can identify hotspots

Cumulative distributions of topsoil iron (Fe2O3) and Pb: urban (n=569) and rural (n=818)
Similar native Fe; larger urban Pb





Objectives:

By selecting 10 samples from rural and urban sites and applying a sequential extraction procedure we can investigate:

1. Whether extra components of urban soil are present?

2. What soil components is the Pb associated with?

3. Whether the associated Pb is mobile and therefore potentially available to human receptors?

Sample selection

Urban: aim large range diffuse Pb

1. Lower Coal Measures only
2. Remove samples at hotspots
3. Remove samples below mean: lowest diffuse pollution
4. Order remaining samples by total Pb
5. Select one randomly from each decile of the Pb distribution

10 urban samples
total Pb range: 205 – 534 mg kg^{-1}

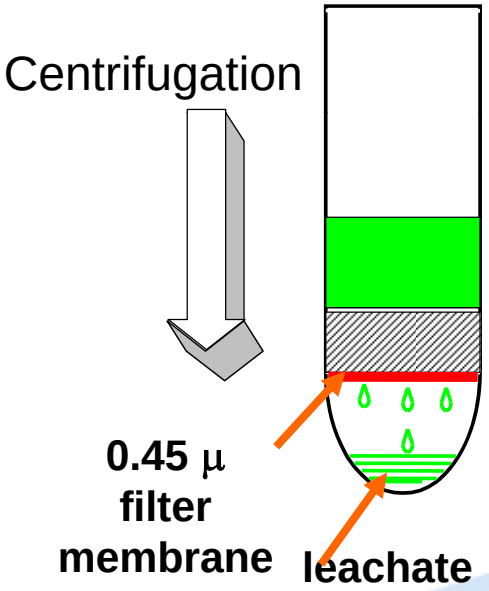
Rural: aim small range diffuse Pb

1. Lower Coal Measures only
2. Remove samples in areas of higher population (>diffuse poll)
3. Remove samples above mean (greatest diffuse pollution)
4. Order remaining samples by total Pb
5. Select one randomly from each decile of the Pb distribution

10 rural samples
total Pb range: 21 – 90 mg kg^{-1}

Analytical Methodologies

- <2mm fraction, dried and homogenised
- Pressed powder pellet XRF analysis
  - Total Elements
- Chemometric Identification of Substrates and Element Distributions
  - Solid Phase Distribution
  - 6 Rural, 6 Urban
  - Aqua Regia = non-specific extractant
  - DI – 5.0M
  - ICP-AES determination – 23 major and trace elements



N.B: All 10 of each type were further assessed for human bioaccessibility – not presented here

Data modelling

- Each CISED from each rural and urban locations produces a data matrix of 23 elements by 14 extracts
- The data matrices were grouped for the urban and rural locations
  - Based on same parent material

- Number of soil components and element distributions for each location type were modelled using SMMR based on the method of Cave 2008*

- Components from the two location types were compared wrt to composition to identify differences in source, natural or anthropogenic, if any.

* SMMR = self modelling mixture resolution, M. R. Cave (2008) The use of self modelling mixture resolution methods for the interpretation of geochemical data sets, MSc Thesis, Sheffield Hallam University

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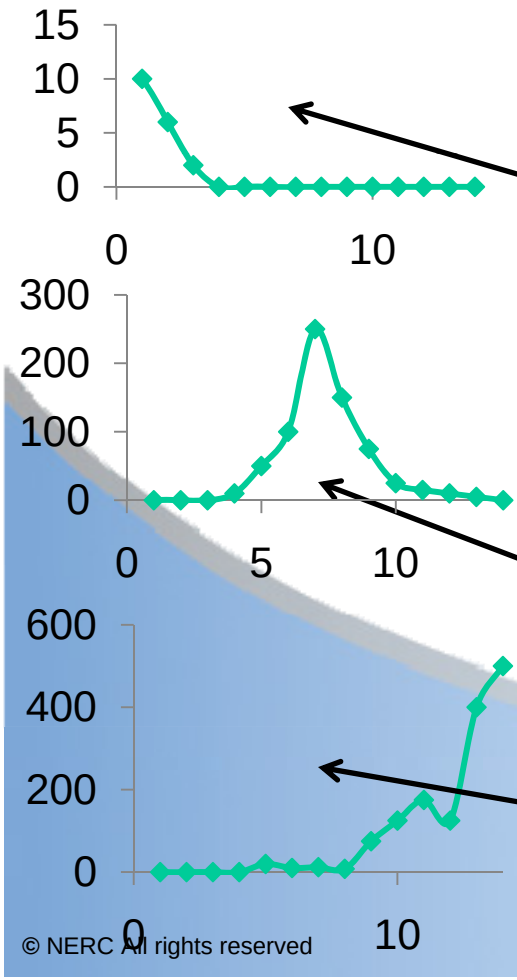
What components were identified?



Component Extractability	Rural Soils	Urban Soils
High	Residual PW	Residual PW
High	Organic	Organic
High	Exchangeable	Exchangeable
High	Carbonate	Carbonate
Medium	Al/Mn oxide	Al/Mn oxide
Medium		Al oxide
Low	Fe oxide	Fe oxide

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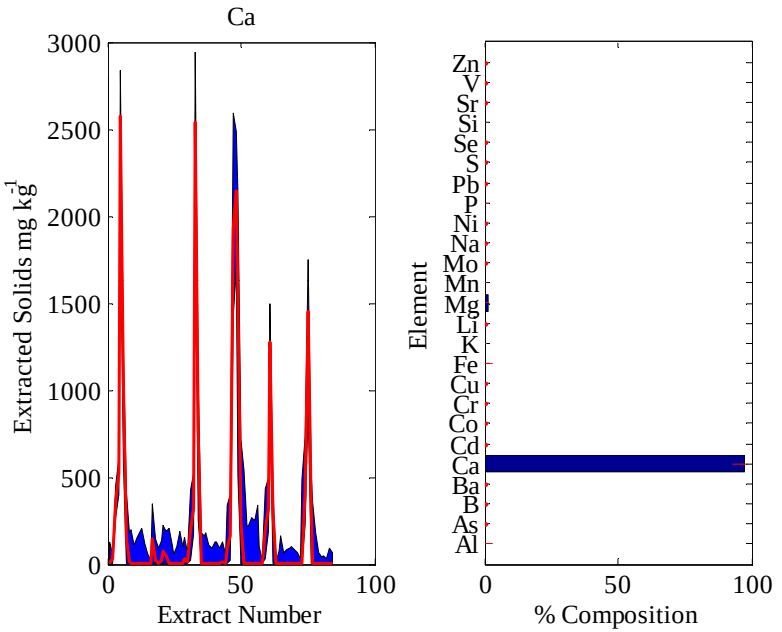
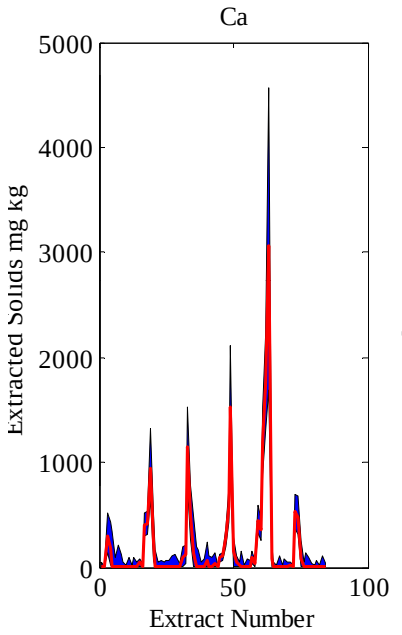
Urban



Rural



- Example of similar components, with similar composition in both land use types
- Ca dominated component probably Carbonate
  - All soils contain the component, but at different concentrations
  - Likely to be a function of different activities at the individual sites e.g. soil liming etc.,

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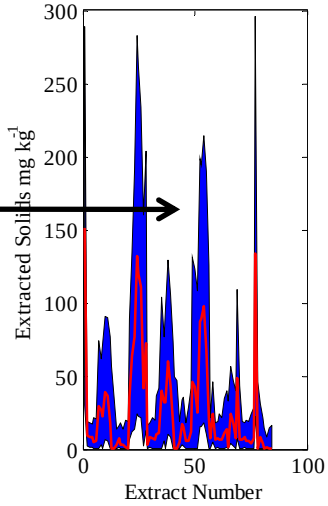
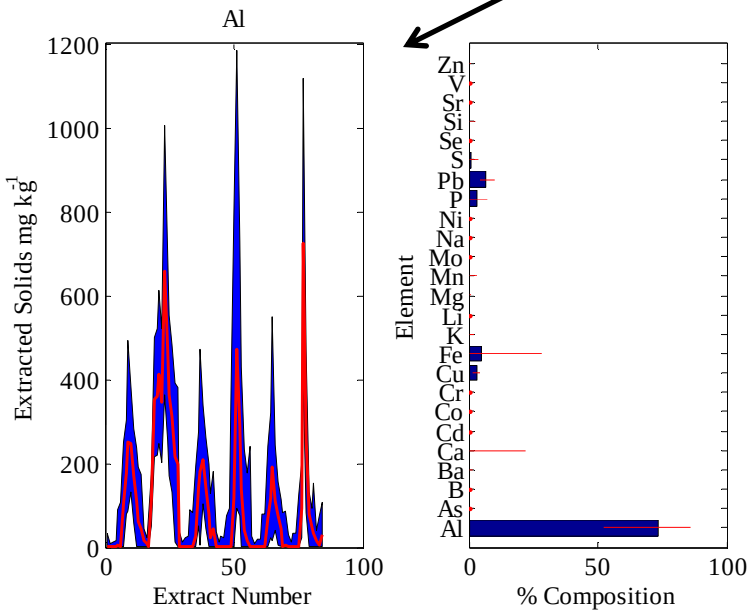
Differences in observed components

Rural Soils	Urban Soils
Residual PW	Residual PW
No component	Al oxide



- 2 x PW components observed
- 1 x only in the urban soils
  - Had a higher Na content and thought to be as a result of road salt application



- Not identified in the rural soils
- Observed in all urban samples – at differing concentrations
- Relatively mobile – extracted at medium acid strengths – 0.10-01.0M
- Has a significant Pb and Cu association

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Pb distribution and mobility

Increasing mobility

Component Type	Urban	Rural
	Pb association across the soil type mg kg^{-1}	
Residual PW	0	0
Organic	0	0
Exchangeable	0	0
Carbonate	<50	<50
Al/Mn oxide	c. 250	c. 200
Al oxide	600	n/a
Fe oxide	c. 800	<50

Similar distribution for the easily extractable components

Fe oxide component - overlapping extraction gives rise to larger uncertainty

Al oxide - significant Pb distribution - the sum of all 6 soils
Relatively mobile therefore the Pb is potentially available for human uptake

Interpretation

Two explanatory hypotheses:

1. There is an extra mineral component in urban soil (introduced through development/human activity) with which the extra Pb is associated

   ? ettringite from widely dispersed cements

2. Soil formation or weathering processes are different in the urban soils – accounting for the different Al-oxide component

Future investigations

- Interrogation of the solid phase distribution data
  - Determine the Pb distribution at the individual locations within each component and each location type
  - Further investigate the source of the unidentified Pb bearing component in the urban soils
    - On a sample by sample basis, including previous land use data
- Complete the measurement of human availability of Pb on each sample
  - By in vitro bioaccessibility test using a gastro-intestinal simulation
- Identify relationships (if any) between the solid phase distribution and bioaccessibility of Pb