Workshop on
the Role of Geochemical Data in Ecological and Human Health Risk Assessment

Metal Bioaccessibility In Tri-National Survey Soil Samples

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What is Bioavailability?

Bioavailability

- Bioavailability generally refers to how much of a contaminant is “available” to have an effect on humans or other organisms
- Contaminant can be ingested, inhaled and/or dermally applied

Oral Bioavailability

- The fraction of an ingested dose that crosses the gastrointestinal epithelium and becomes available for distribution to internal target organs (USEPA, 2007)

Why Study Oral Bioavailability?

Oral bioavailability data can be used to:

- Provide more realistic information on the potential health effects of contaminant ingestion
- Modify generic guidelines using site specific data
- Help prioritize sites based on contaminants exposure scenario

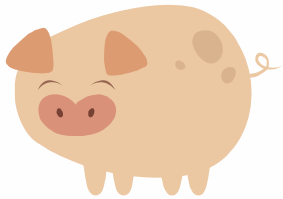
Bioavailability can be determined by

Mineralogical assay

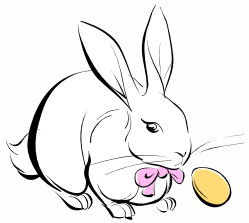
- Scanning electron microscopy, x-ray diffraction, and sequential extractions

In vivo assays

- Rodents, rabbits, primates and swine



In vitro assays



- Biological fluids
- Acids e.g., EU Toy Safety Protocol
- Simulated gastric and intestinal fluids - Physiologically Based Extraction Test (PBET)

Physiologically Based Extraction Test (PBET)

- PBET validated against in vivo models for some metals
- Incubate soil in solution that mimics stomach conditions
  - Low pH (1.5 – 2.5), residence time (1 – 2 hr), organic acids
- Increased to near neutral to mimic small intestine
  - Residence time 2 – 4 hr, enzymes and organic acids added
- Determine fraction of metal that goes into solution (bioaccessible)

Physiologically Based Extraction Test (PBET)

- PBET validated against in vivo models for some metals
- Incubate soil in solution that mimics stomach conditions
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Bioaccessibility

- Measure of the physiological solubility of the metal at the portal of entry into the body (NRC, 2003)
- Fraction of the contaminant that is released from the soil into solution during digestion making it available for absorption

$$\text{Bioaccessibility} = \frac{\text{Amount released into solution}}{\text{Total concentration in the soil}} \times 100\%$$

- Surrogate for bioavailability
- Less expensive and less time consuming compared to in vivo tests

Bioaccessibility at Royal Roads

Three models

- European Standard Toy Safety Protocol (EN-71, 1995)

- Simplified PBET

- Gastrointestinal (GI) Model

Simplified PBET

- Dried an <40^{O}C
- Sieved to <250 µm
- 1.0 g soil:100ml glycine/HCl
- pH 1.5, 37^{O}C
- Filter through 0.45µm
- Analyze soil & extract by ICP-MS

Tri-National Survey Samples Analyzed

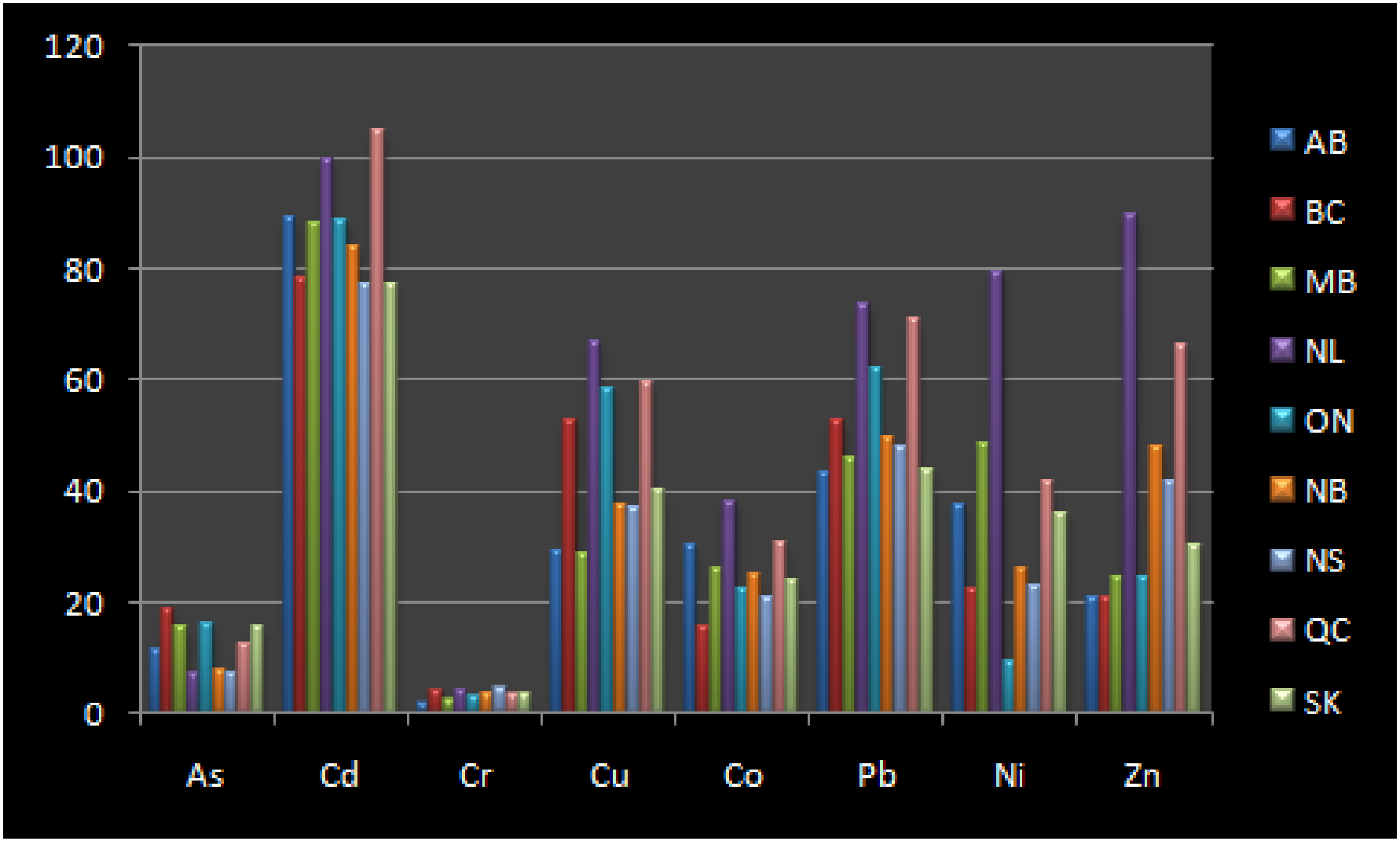
Province	PH	B	C		URBAN	PH
AB	10		10		Halifax	10
BC	10		10		Windsor	4
MB	10		10		Chatham	4
NB	24	22	59		London	4
NS	17	17	27		Woodstock	4
NL	9		9		Guelph	4
NT	1	1	3		Ottawa	8
ON	12	1	13		Regina	8
PE	1	1	5		**Total**	**46**
QC	10		10			
SK	10		10			
YT	0	1	4			
Total	**114**	**43**	**170**			

Metal Bioaccessibility Statistical Summary

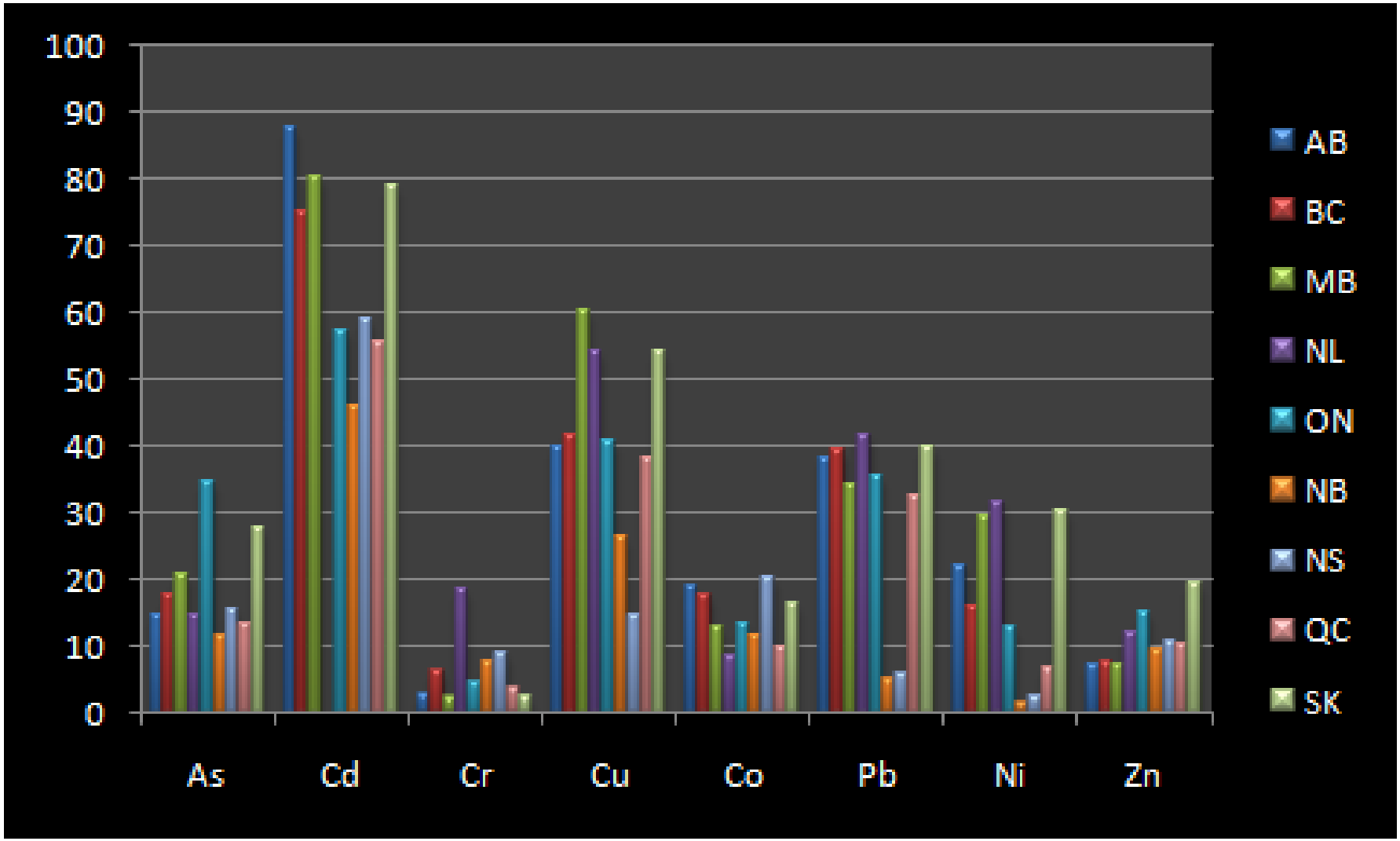
	As	Cd	Cr	Cu	Co	Pb	Ni	Zn
Count	334	256	251	306	276	279	333	337
Mean	**14**	**72**	**6**	**39**	**18**	**39**	**18**	**22**
Std Dev	14	25	6	21	14	21	20	24
Min	0.3	7.4	0.6	0.2	0.7	0.2	0.2	0.7
Max	94	116	40	112	79	93	111	115
95%	40	107	18	79	43	74	62	79

*Excluding urban samples

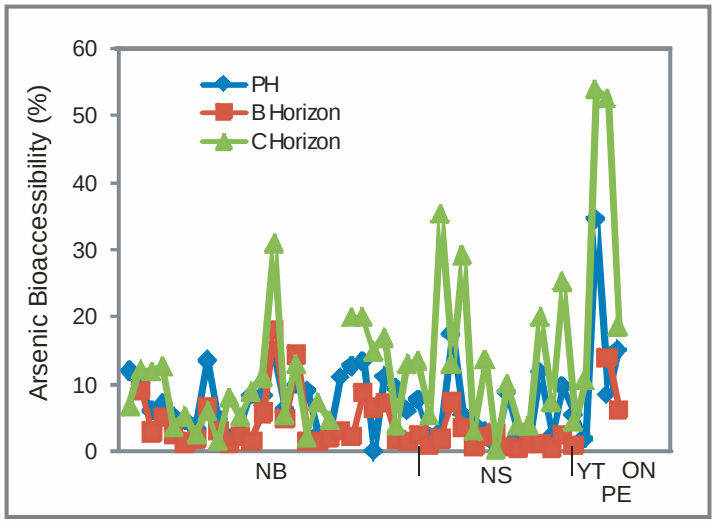
PH Layer Mean Metal Bioaccessibility (%)

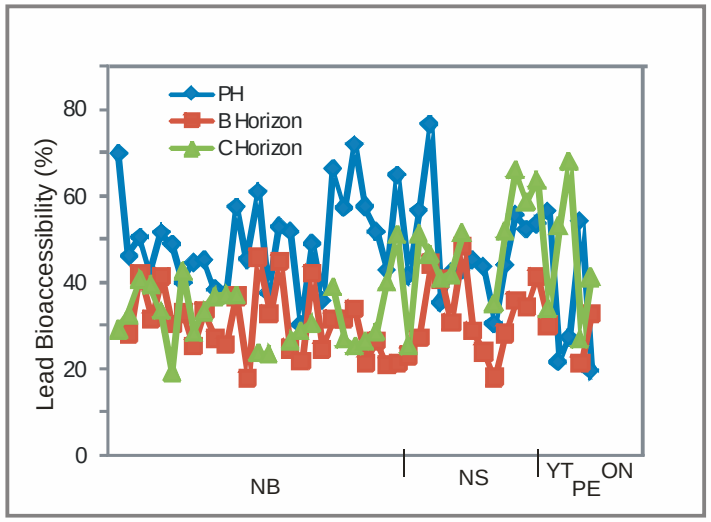


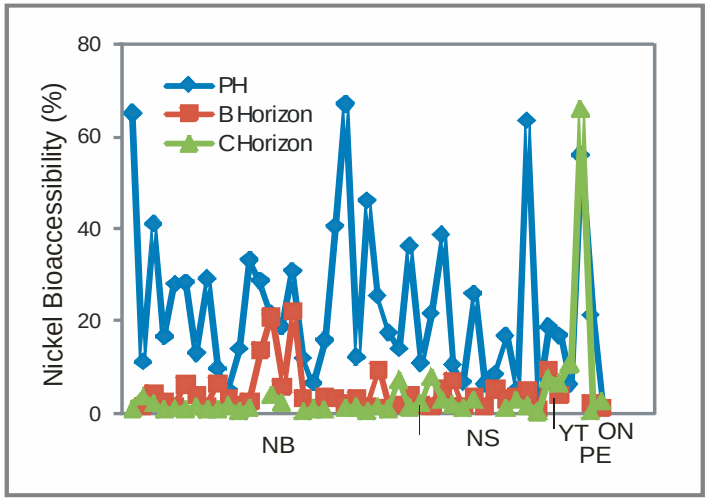
C Horizon Mean Metal Bioaccessibility (%)

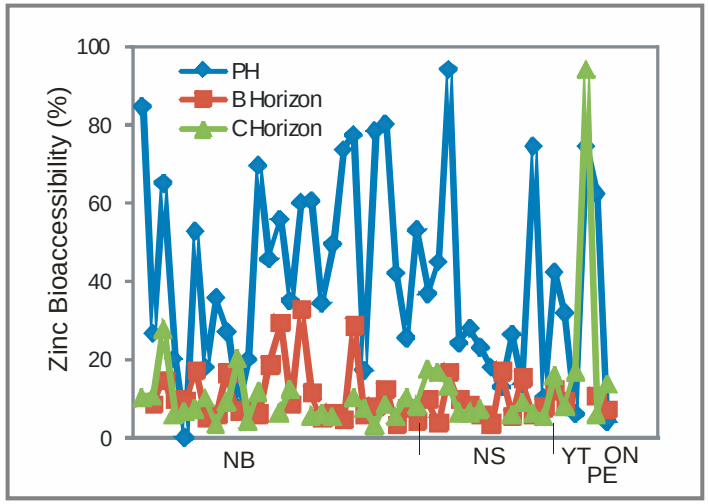


Arsenic, Lead, Nickel and Zinc Bioaccessibility

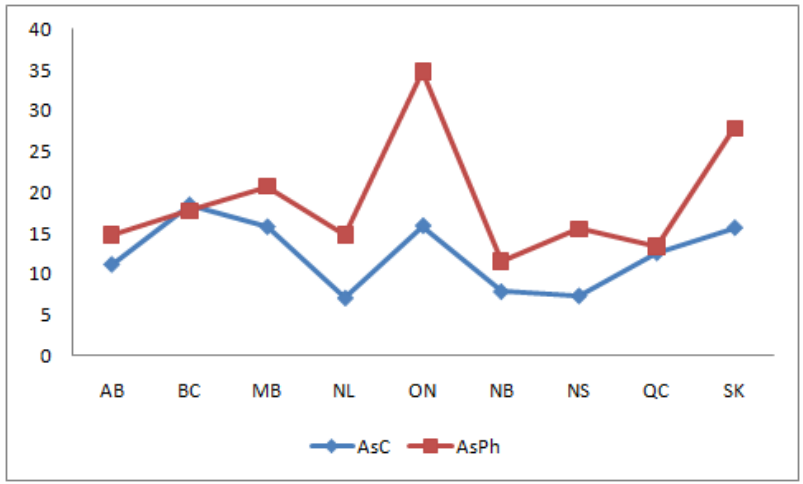


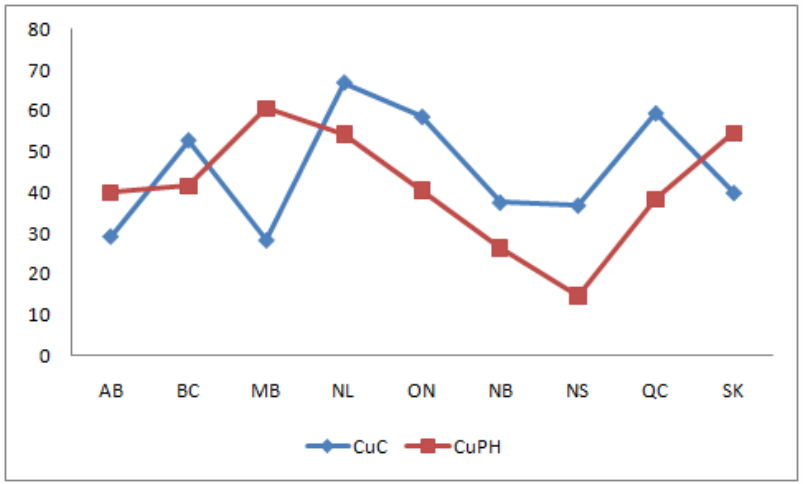


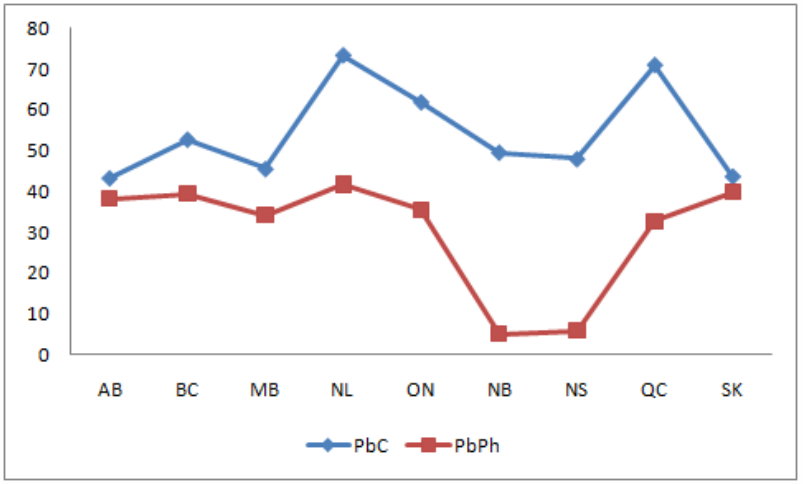


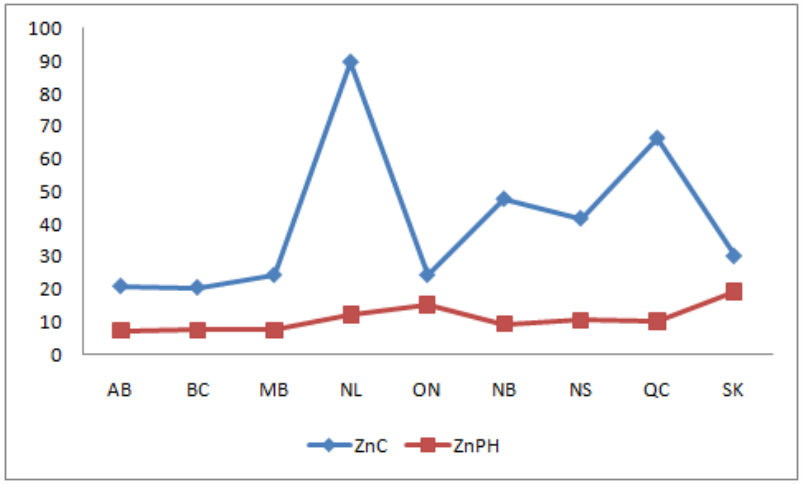


Comparison of PH and C Bioaccessibility (%)





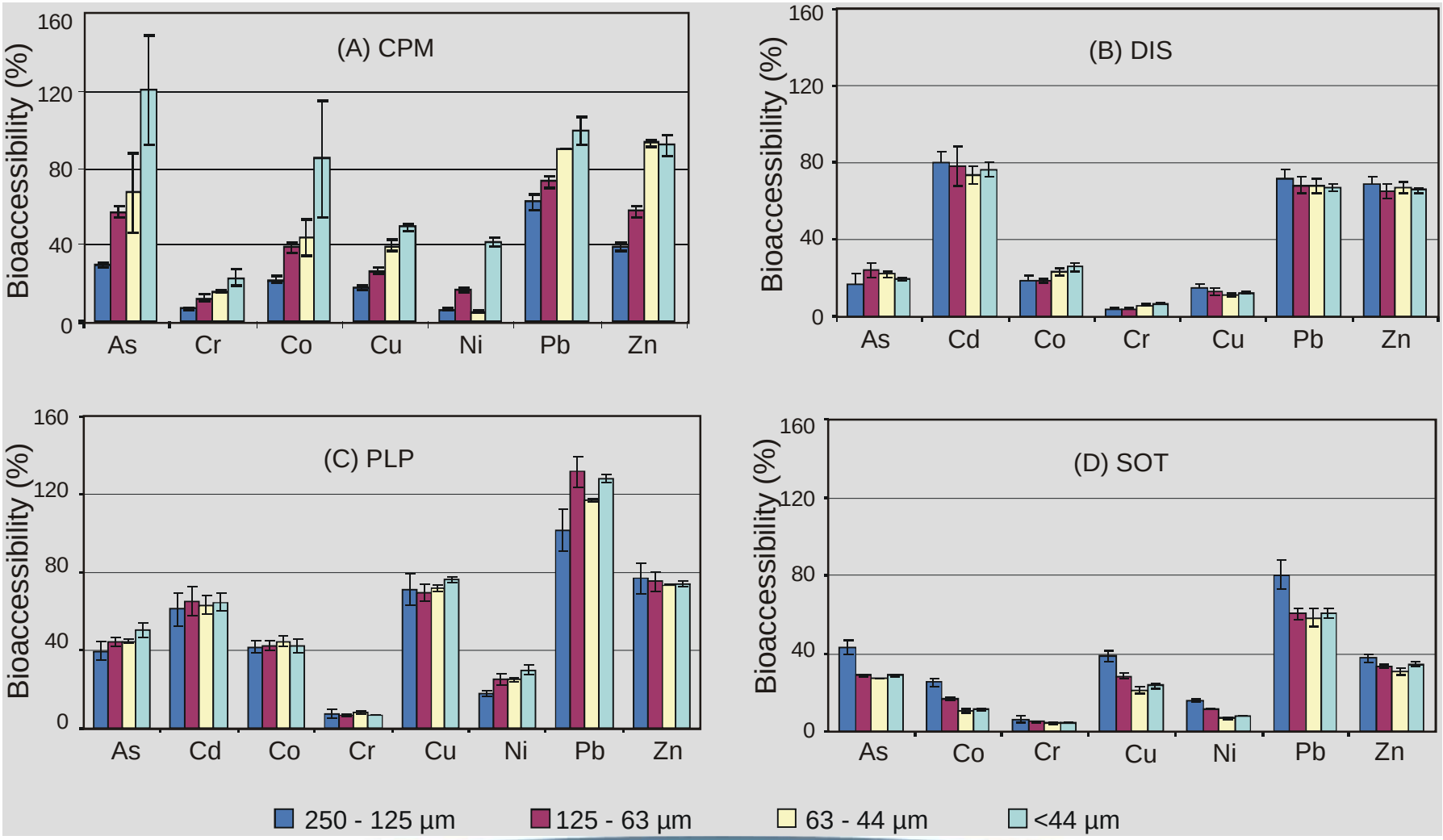




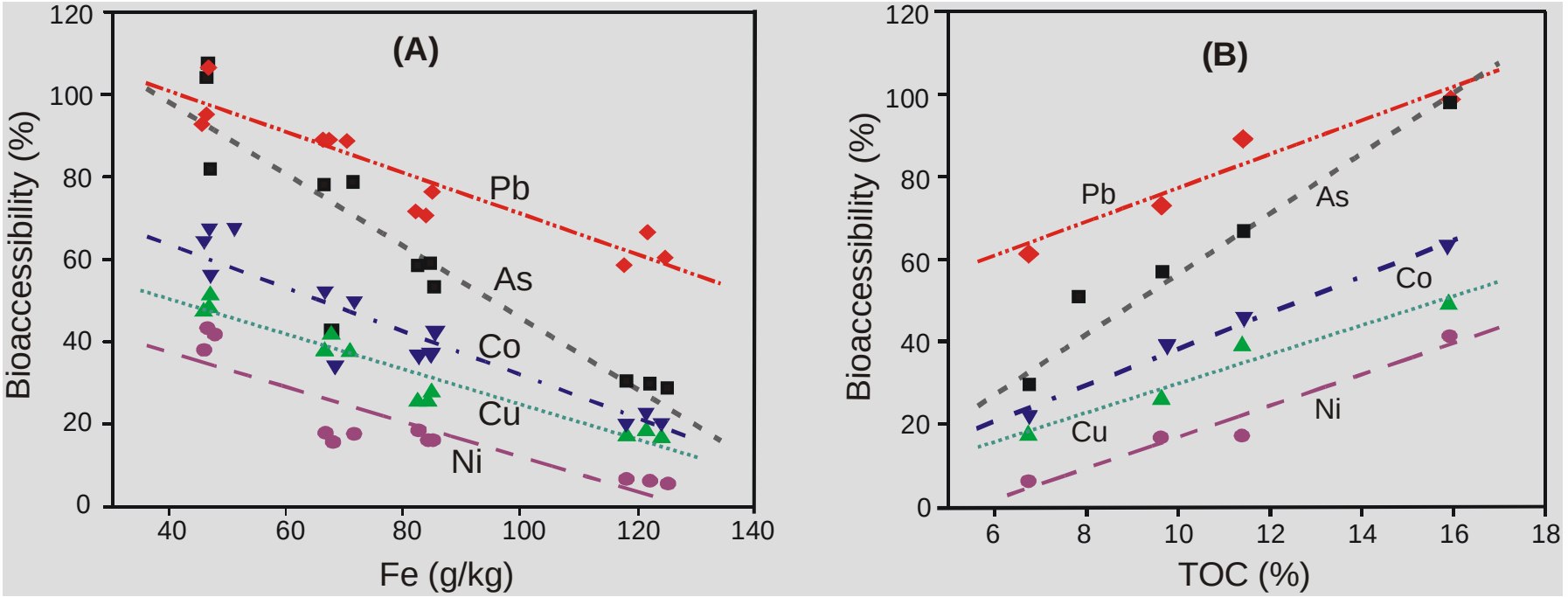
Some Key Issues for Bioaccessibility Study

- What is the relationship between metal bioaccessibility and geochemical data
  - Total metals, soil pH, TOC, IC, LOI, etc
  - Particle Size**
  - Soil:extraction solution ratio**
- How can the data be potentially used in HHRA e.g., in RAF?
- How comparable are the results to previous studies?
- How applicable are the results to other regions?

Variation of Bioaccessibility with Soil Particle Size



Bioaccessibility as a Function of (A) Total Fe and (B) TOC (Cape Mudge)



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  - Erin Park
  - Devon Yacura

Key to Abbreviations

- TOC - Total Organic Carbon
- IC - Inorganic carbon
- LOI – Loss-on-ignition
- HHRA – Human Health Risk Assessment
- RAF – relative absorption factor
- PH – “Public Health” sampling layer (0-5cm)
- B,C – soil horizons
- AB – Alberta
- BC – British Columbia
- MB – Manitoba
- NL – Newfoundland and Labrador
- ON – Ontario
- NB – New Brunswick
- NS – Nova Scotia
- PE – Prince Edward Island
- QC – Quebec
- SK - Saskatchewan
- YT – Yukon Territory