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Make Mining Sustainable: Understanding metals in the environment

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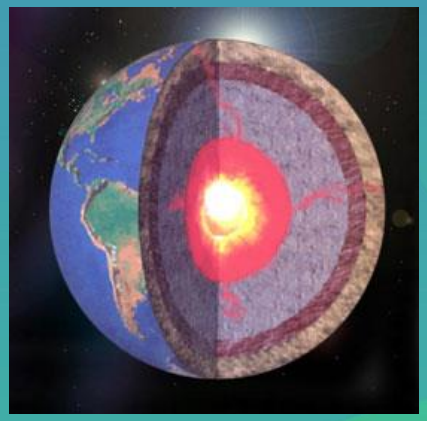
Dec 12 2018, Mongolia



Make Mining Sustainable:
Understanding metals in the environment

Purpose: To support sustainable mining through rigorous environmental assessments.

Method: Enhance understanding of biogeochemical cycles for assessing environmental risk and mitigation.

Terms: Ore, mineral, element, anomaly, background, variation, weathering, crustal abundance, toxic, analytical chemistry, soil horizon, robust

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Responsibility for Ensuring Environmental Sustainability.

Role for on the ground inspections.

Field inspections. On-going

Identification of environmental issues

Environmental Impact Assessment Approval. Once- prior to opening

Critical assessment of validity and comprehensive content of mining company's assessment as supported by auditor's report.

Environmental Management Plan Approval. On a yearly basis

Critical assessment of validity and comprehensive content of mining company's plan as supported by auditor's report.

Useful input to these processes requires a scientific appreciation of the environment and rigorous data.

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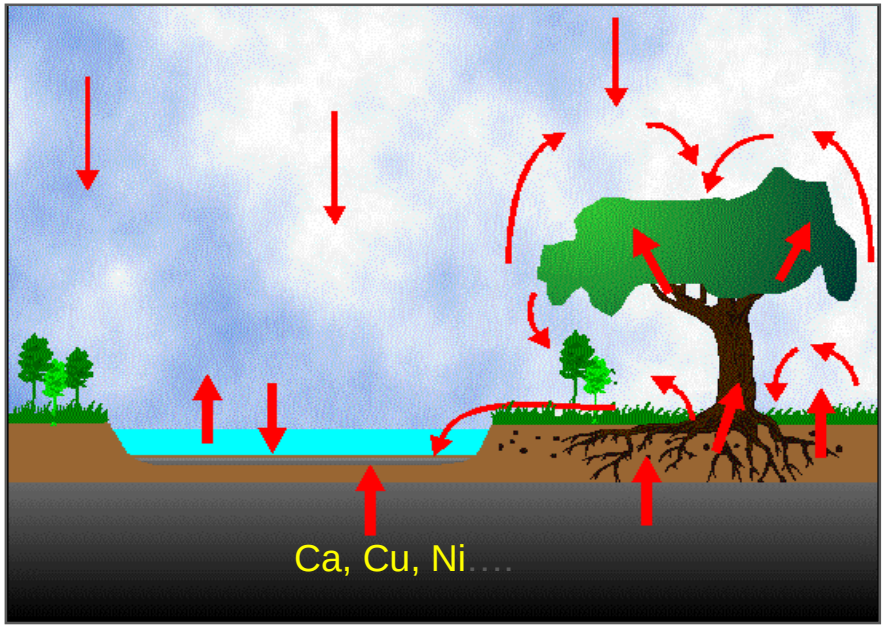
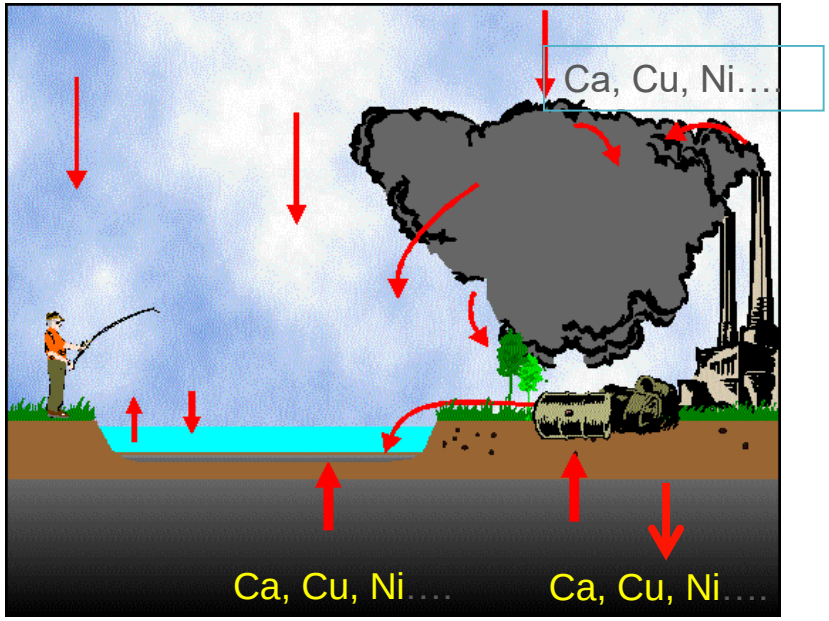
Sources of chemical variation in the environment

Biogeochemical Cycles



Natural Cycle



Anthropogenic Cycle

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Need to understand the natural to quantify the impact of anthropogenic inputs into the environment

Click to edit Master title style

Biogeochemical Cycles

Why is it important?

- Elements are essential to the well being (health) of the environment and they need to be at levels.
  - Concentrations that are too high or too low may be .

- The various components of the system are linked.
  - High concentration in one part will typically mean a high level in all parts

- An understanding of the biogeochemical attributes of a system will support

- Meaningful impact assessments depend on analysis of elements in the environment.

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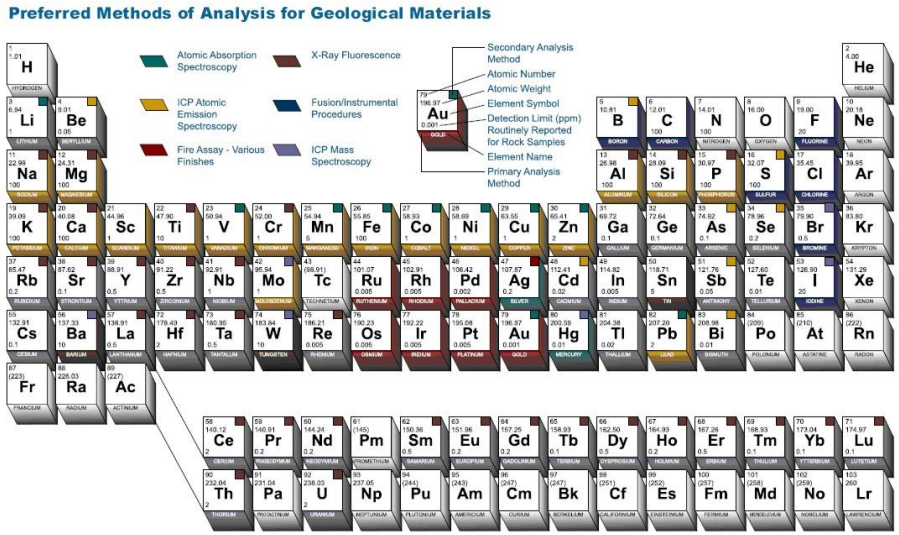
Biogeochemical cycles Master title style

Elements

are the building blocks of all

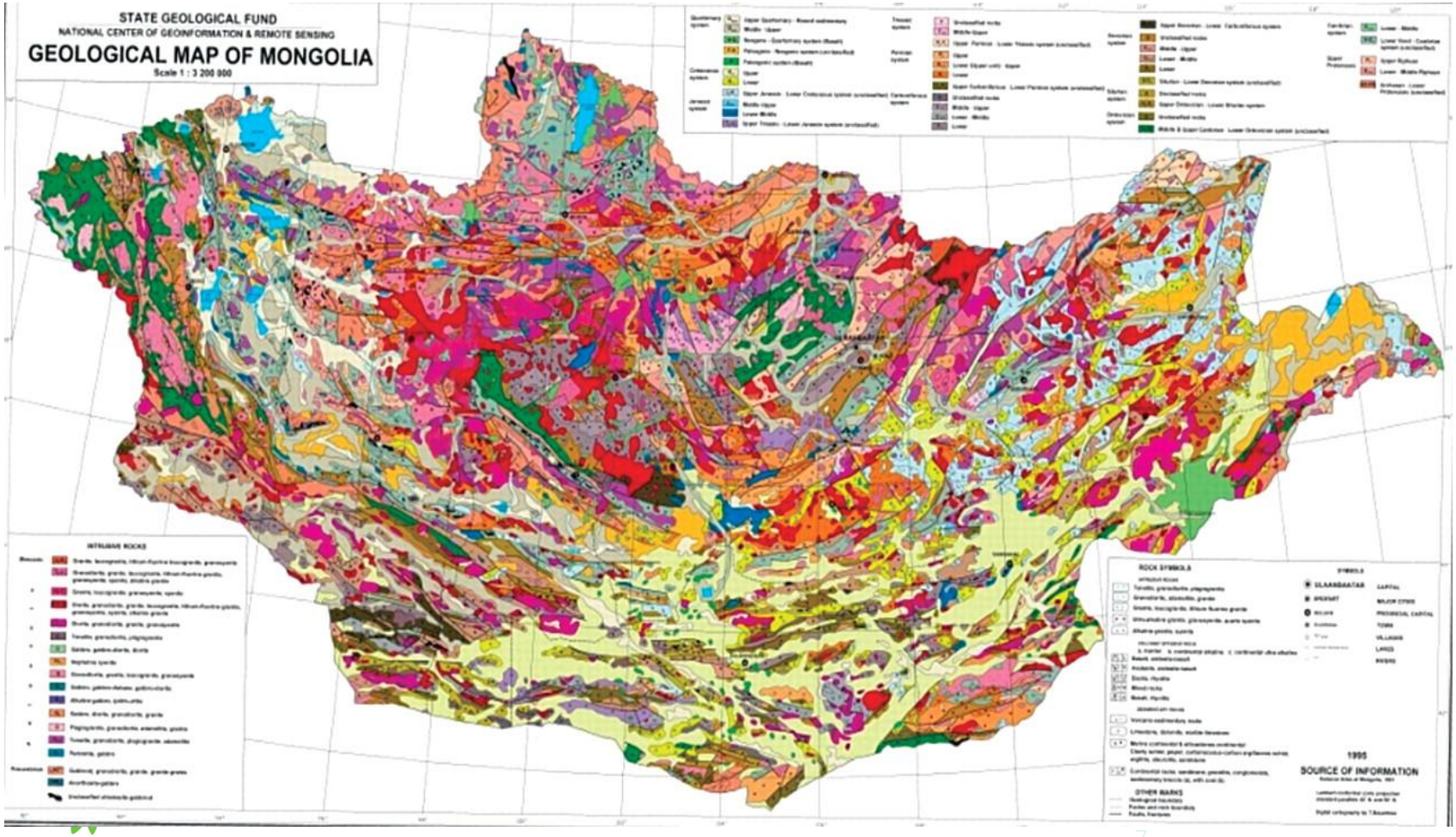
- 118 elements and 93 occur naturally in the environment.
- each element has unique chemical which determine its benefits and risks.



Periodic table of elements

Natural Source of Variation

Lithology- Rocks



Chemical variation is related to differences in rock types

Natural Source of Variation

Minerals

- **naturally occurring chemical compound, in crystalline form**
- **specific chemical composition and form building blocks for rocks**
- **over *5000* minerals**

Predominant minerals around ShinShin.

Galena

Lead sulfide: May contain impurities, such as silver, arsenic, antimony, and copper

Sphalerite

Zinc sulfide: May contain impurities such as lead.

Arsenopyrite

Iron arsenic sulfide: Will break down to release As

Minerals

Pyrite cubes: Sulphide mineral. FeS_2

May contain other elements such as gold as in mine at Tinkhun Mine

Minerals

Source of elements

Basis for

- Mining activity – what type of mine
- Mineral processing- what benefication process
  - Extraction process and chemicals
  - Contamination type
- Chemistry of the environment
  - Background in the area

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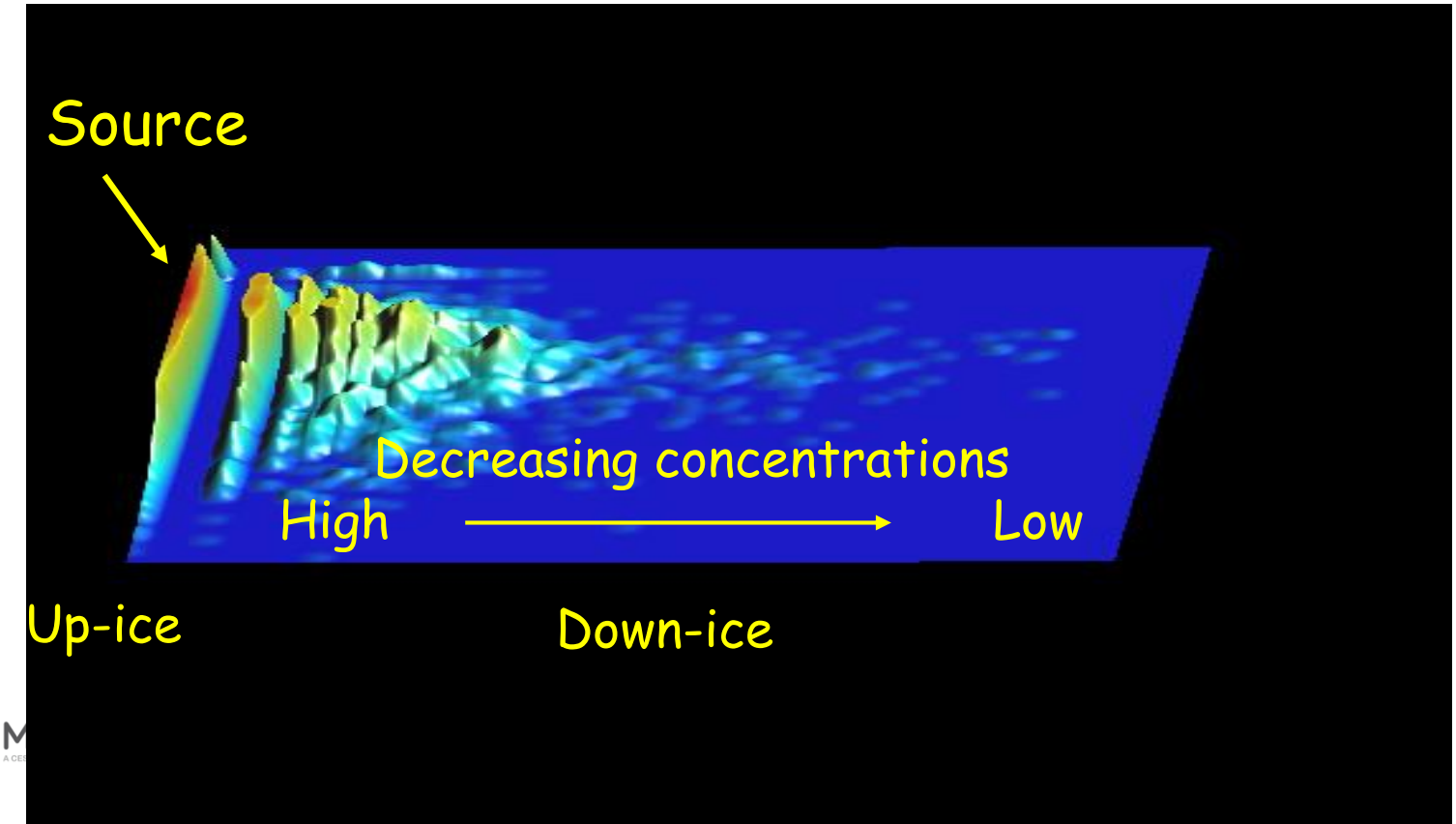
Natural Processes affecting variation

Do not translate the figure.

Glaciation

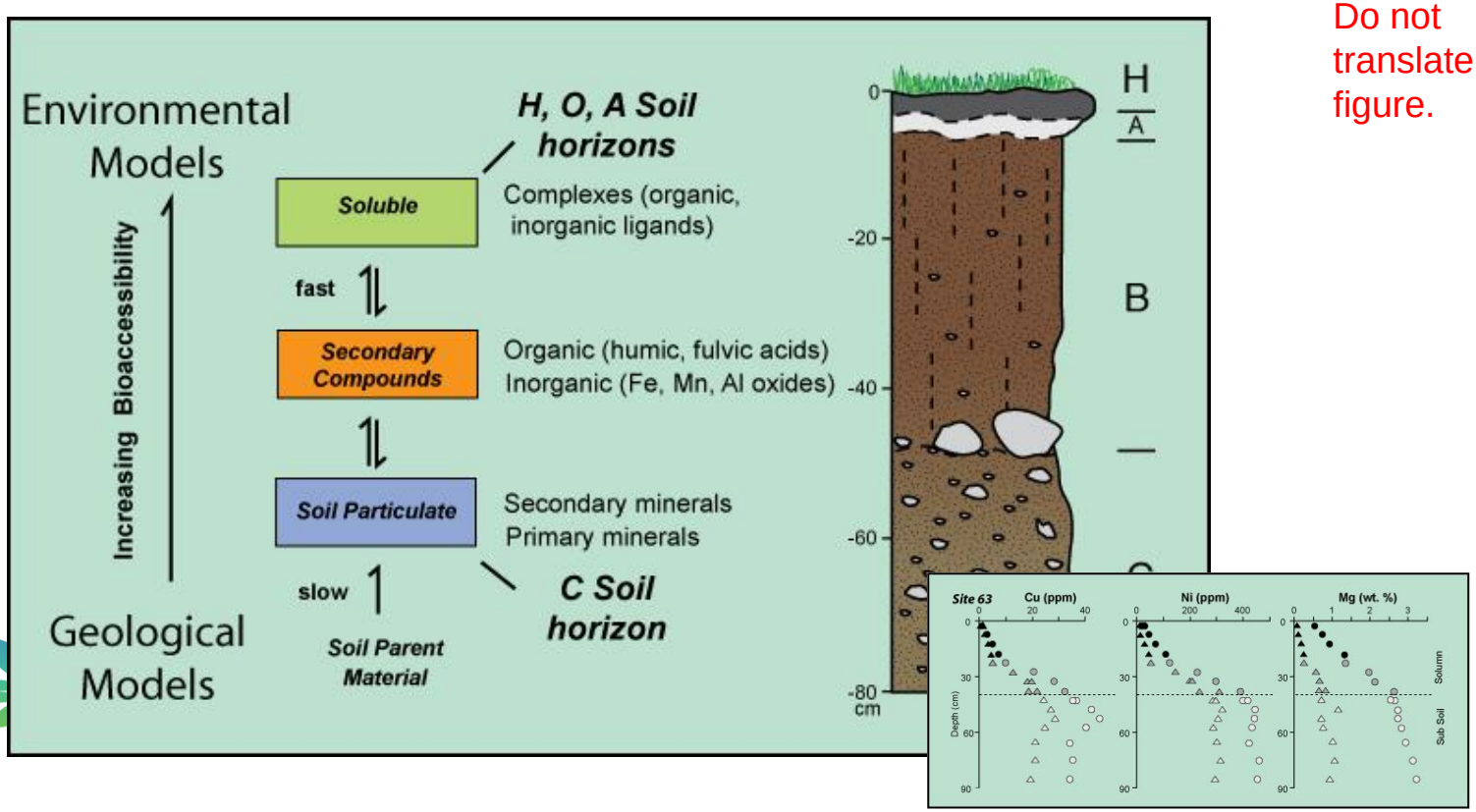
Glaciers disperse minerals from the source in a fan shaped pattern with decreasing concentrations in the down-ice direction.



Natural processes affecting chemical variation

Weathering: Soil

- soils develop from bedrock through weathering processes that breakdown the minerals and alter the characteristics of the soil.
- concentrations of elements in the soil horizons will vary in predictable ways down the soil column



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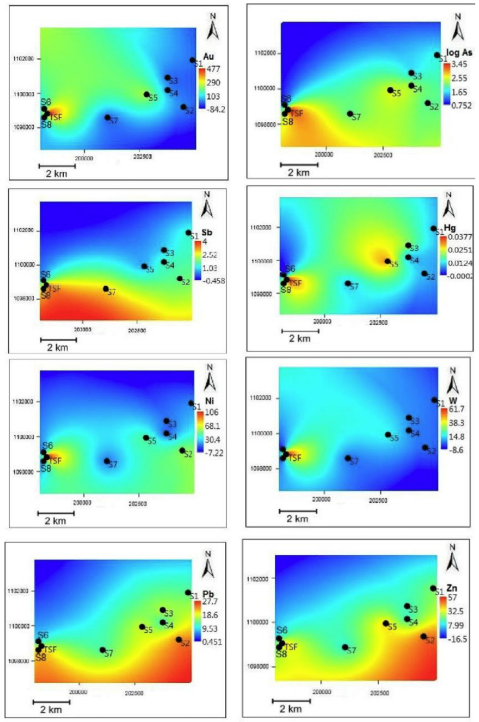
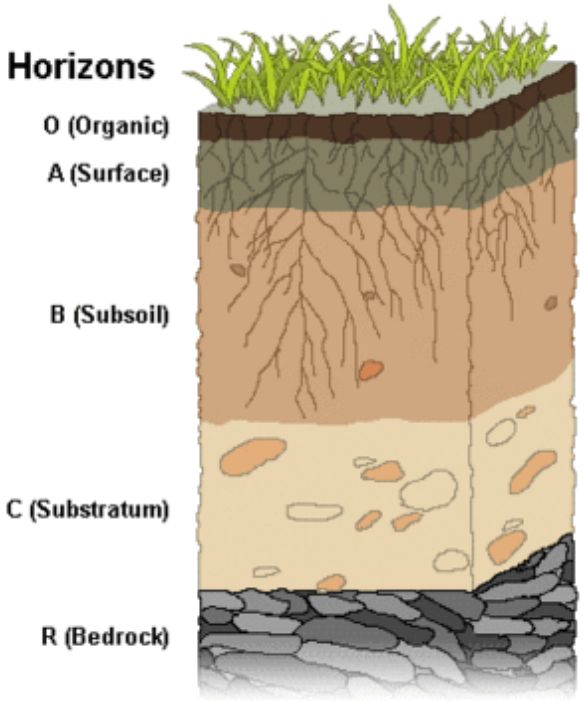
Natural processes affecting chemical variation

Spatial Variation





Au	Zn
ppb	ppm
10	100
13	500
19	1000
6	
20000	

horizontally and vertically

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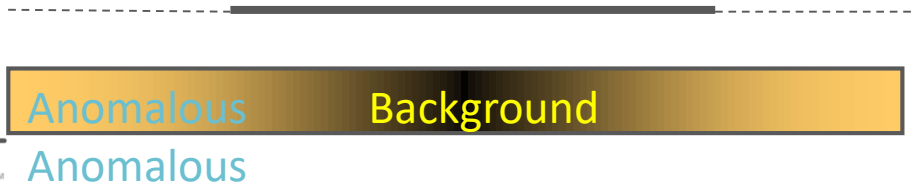
Separating anthropogenic and natural variation

Geochemical background

The usual abundance of a chemical element in unmineralized earth materials (e.g., rocks, soils, sediments, water, vegetation, air) is often referred to as ***background***.

Element abundances that occur outside background are said to be ***anomalous***.



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Geochemical Background e.g.

Arsenic in India

•Levels of As in well waters up to **100 times** permissible levels have been reported in West Bengal, India.

- As toxicity in ground waters of West Bengal, India affects **5 to 50 million** people are reportedly affected. Arsenic has been associated with numerous diseases: skin effects, including skin cancer, cancer in the lungs, ….

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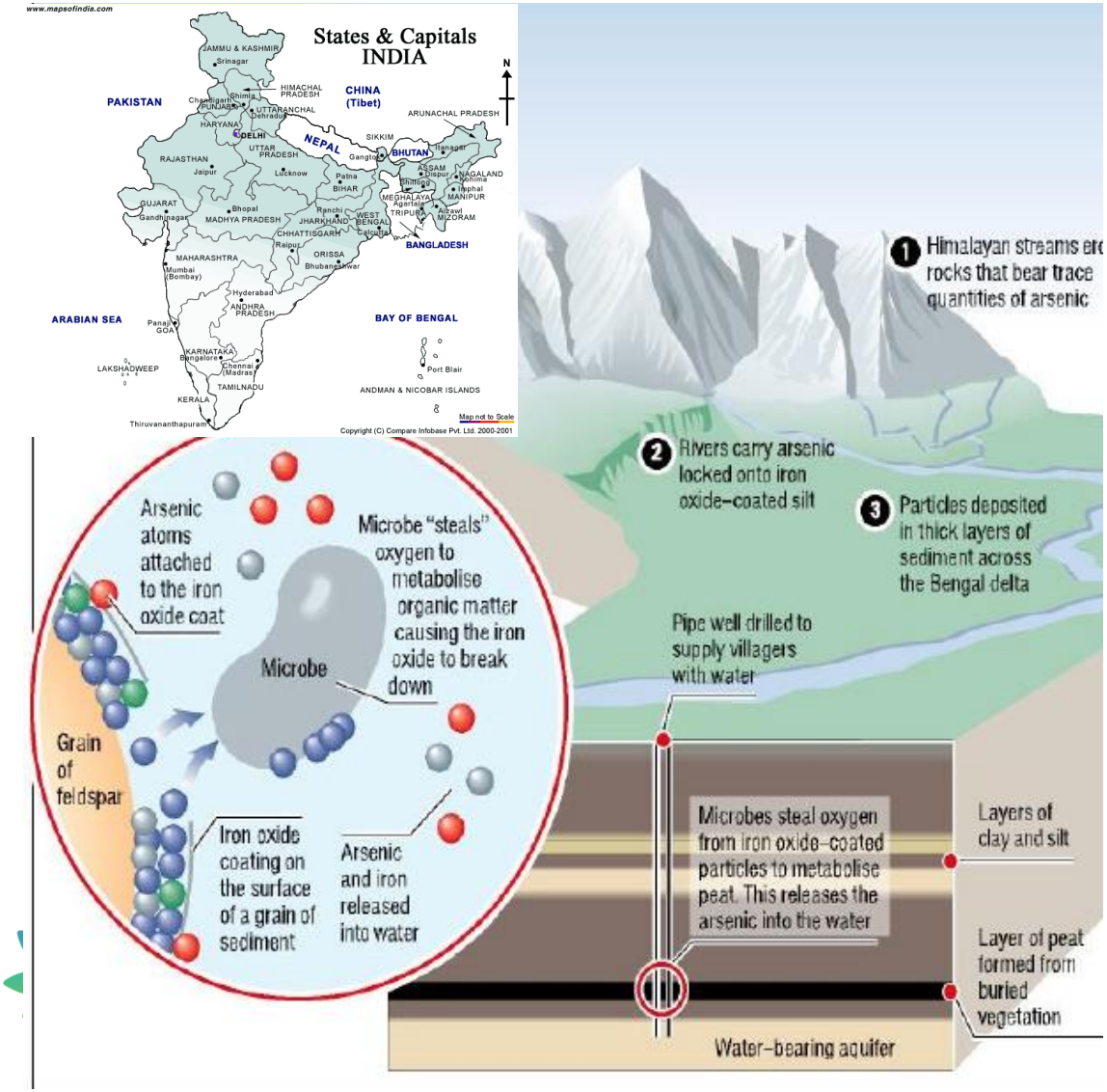
Geochemical Background e.g.

Arsenic in India



Arsenic bearing minerals in Himalayas

Weathering process and river transport of minerals across India

High As in groundwater gets in wells used for drinking

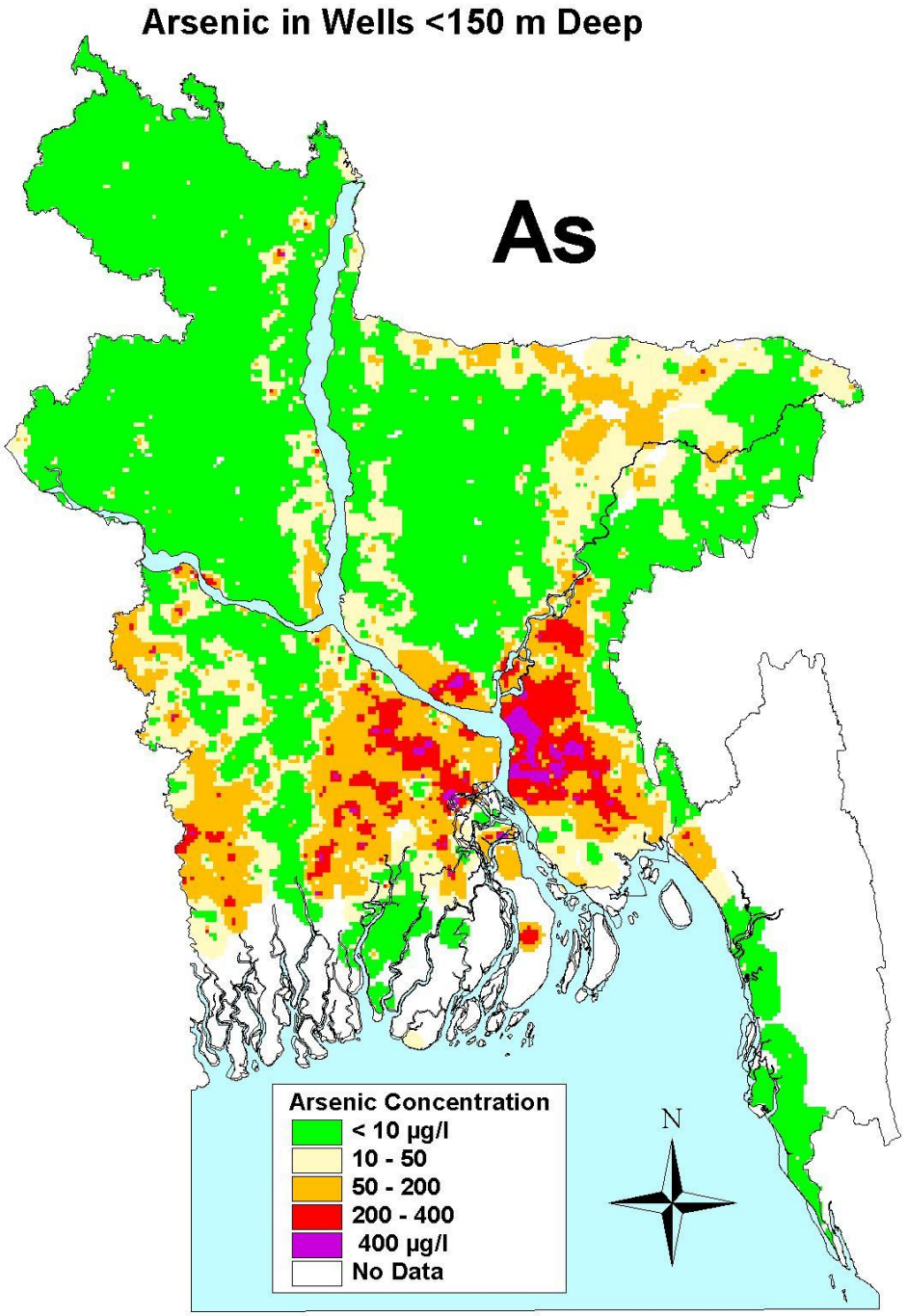
Geochemical Background e.g.

Arsenic in India

The map shows the average arsenic concentration in the upper 150 m of the alluvial aquifer system.

Note that there are many areas above the accepted level of 10µg per gram.

The high levels are considered to be of natural consequences.



Anthropogenic Processes affecting variation

Smelters

Coal Fired Emission Plants- Hg Mitigation:

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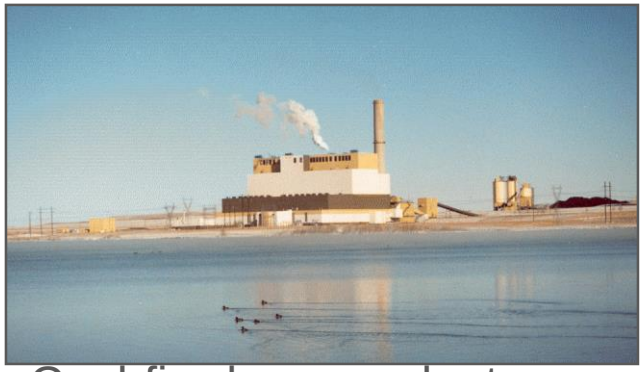
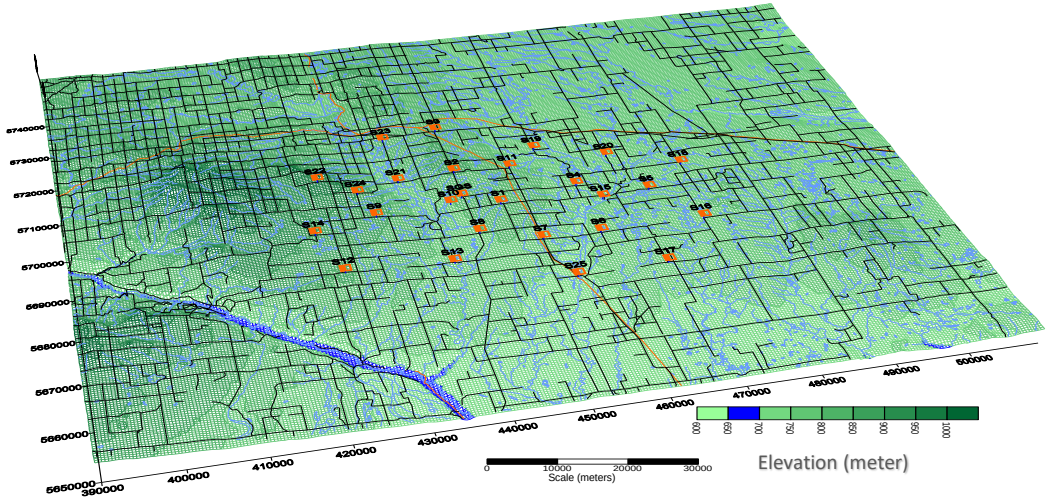


Coal-fired power plant

Monitoring stations around plant



Dispersal of Hg around plant

Anthropogenic sources affecting variation

Chemicals

Chemicals stored at Shin Shin.

№	Бодисын нэр, томьёо	Уялдуулсан системийн код	Хаана хадгалдаг
1	2	3	4
1	Цайрын сульфат $ZnSO_4$	7446-20-0	Химийн бодисын тусгай агуулах
2	Зэсийн сульфат $CuSO_4$	7758-98-7	
3	Натрийн бутилксантат $C_4H_9OCSSNa$	141-33-3	
4	Кониферолын тос $C_{10}H_{17}OH$	9-3-8002	
5	Дикрезил-дитиофосфорын хүчил $(C_7H_7O)_2PSSH$	27157-94-4	
6	Кальцийн оксид CaO	1305-78-8	Шохойн агуулах
7	Натрийн диэтилдитиокарбамат $(C_2H_5)_2NCSSNa{\cdot}3H_2O$	20624-25-3	Химийн бодисын тусгай агуулах
8	Натрийн этилксантат $C_2H_5OCSSNa$	140-90-9	
9	Натрийн сульфит Na_2SO_3	7757-83-7	
10	Давсны хүчил HCl	7647-01-0	
11	Азотын хүчил HNO_3	7697-37-2	

Chemicals must be considered from a storage/contamination/ hazardous material perspective as well as their concentration in waste material created during processing stage.

Anthropogenic sources affecting variation

Chemicals

Tinkhun LLC

836	Sodium cyanide	50.3 tn
703	Acetic Acid	9 kg
703	Calcium hypochlorite	30 tn
703	Nitric acid	2889 kg
703	Oxalic acid	100 kg
703	Sodium carbonate	375 kg
703	Sodium hydroxide	2400 kg
703	Hydrochloric acid	899 kg
703	Sodium sulfite	3975 kg
703	Sulfuric acid	396 kg
703	Calcium oxide	35 tn
703	Ammonium fluorocrystalline	9kg
703	EDTA salt	2kg
703	Silver (I) nitrate	0.7kg
703	Hydrogen peroxide	22.8 kg
703	Acetone	3.2 kg
703	Chloroform	2 kg
703	Calcium carbonate	0.5kg
703	Potassium iodide	22 kg
703	Sodium chloride	9.9 kg
703	Phosphoric acid	10.5 kg
703	Polyacrylamide	500 kg
703	Starter	9.5 kg
703	Sodium thiosulfate	20 kg
703	Tiomochyevin	0 kg
703	Sodium hydrofoam	4.5kg
703	Potassium dihydroflox	4 kg
703	Chloramine B	4.5 kg
703	Nicotine Acid	2.5 kg
703	Potassium nitrate	2.5 kg
703	Pyrazolone	9 kg
703	Ethyl acctate	10 kg
703	Dimethylphormamide	20 kg
703	Tartaric acid	10 kg

Chemical Results Variation

Do not translate the instrument column.

Chemical Analysis: Rocks/Soils

Analytical processing steps:

Grind →	Sieve →	Digestion →	Instrument
	1: Texture	2: Partial	3: ICP MS
		Near-Total	AAS
		Total	AES
			INAA
			…….

Digestion is the step in which the minerals are broken down and elements are brought into solution. Typically acids are used.

Chemical Results Variation

Texture (measure of soil grain size)

size fractions- clay (.< 002 mm) …… silt (.005 mm)……..> sand (.02 mm)

typically metal concentrations increase with smaller size fractions as there is increased Cation Exchange Capacity and therefore more binding sites

silt fraction- less than 63 microns (.063 mm) is a *"standard"* size fraction in exploration geochemistry

To be rigorous a comparison of soil geochemical results must all be of the same size class.

Chemical Results Variation

Analytical Digestion Methods

Chemical reagents (acids) only release a portion of the elements from the soil/matrix matrix- elements must be in solution for analysis to be analyzed:

Extractions:

Partial: *Aqua regia* (mixture of HCL & HNO3) is common but does not release all metals from its matrix. There are numerous AR variants

Near Total: Includes stronger acids such as HF or HClO3 to "attack" the mineral. Some minerals still resistant: chromite, zircons

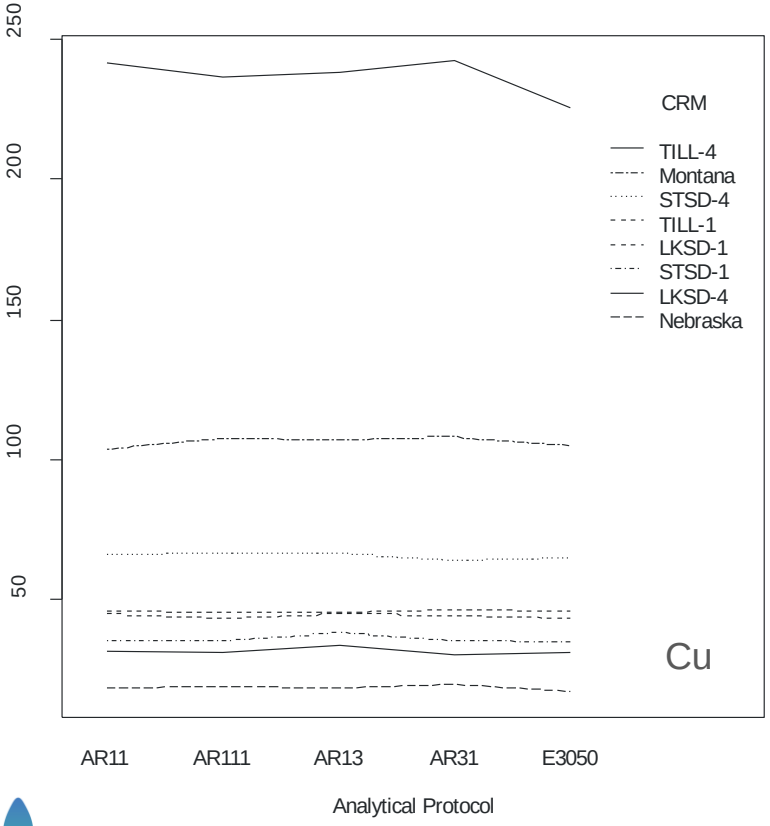
Total: Some chemical methods like fusion techniques but total typically uses instrumentation: eg XRF and INAA are most common

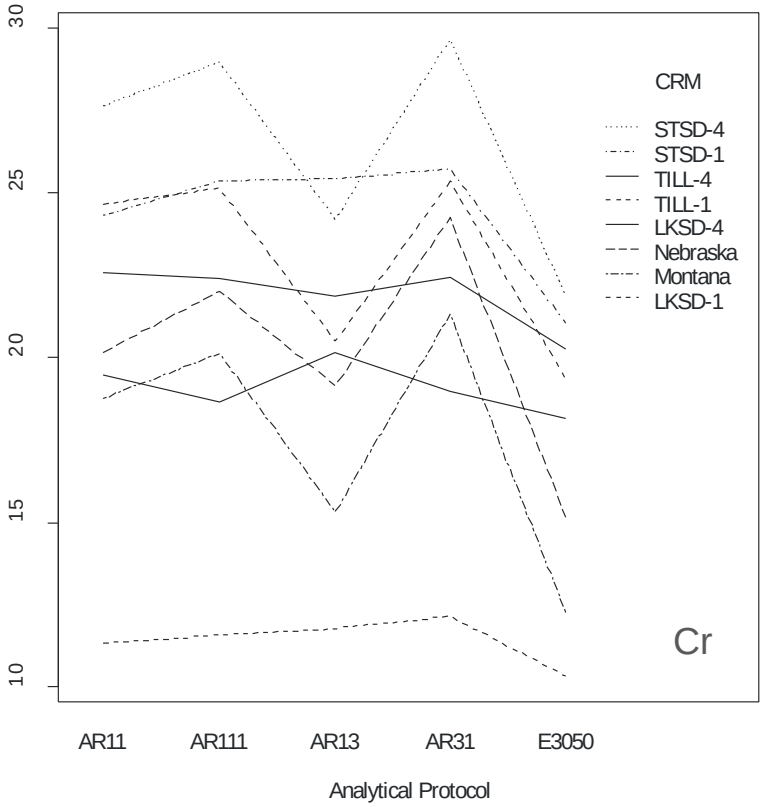
To be rigorous a comparison of chemical results must all be analyzed using same method.

Do not translate after the word METHODS

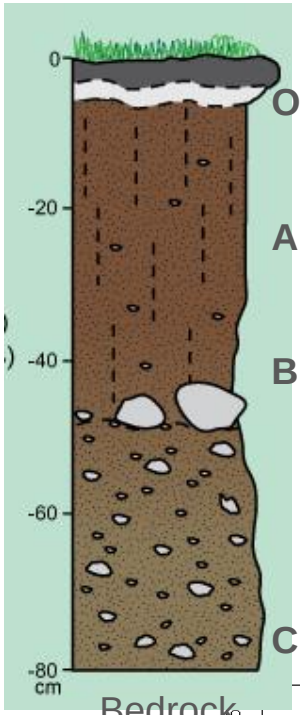
Soils Analytical Variation

Methods





- An experiment comparing aqua regia and 4 variant digestions
- Graphs for Cu and Cr are different. Why?



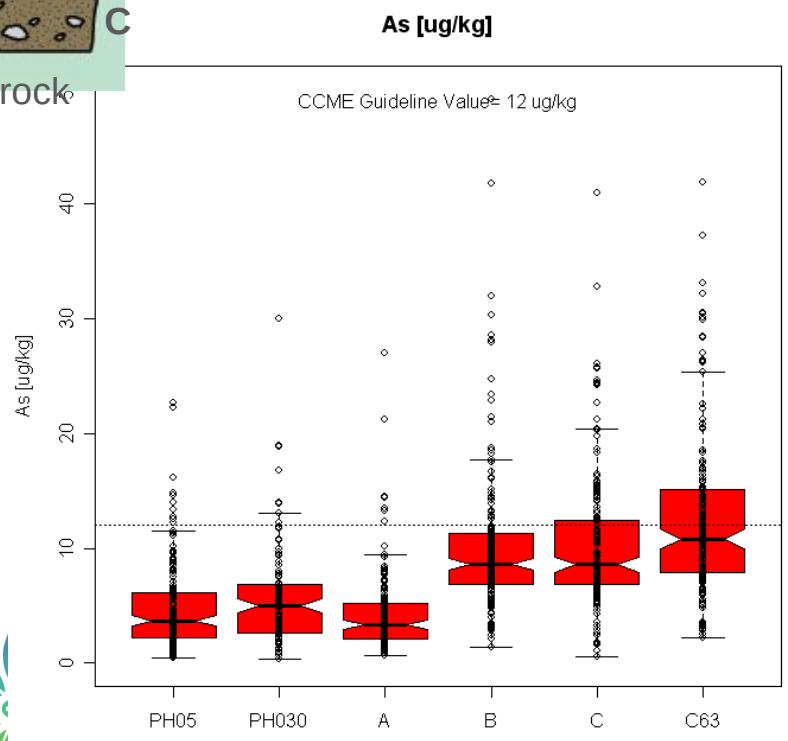
Questions

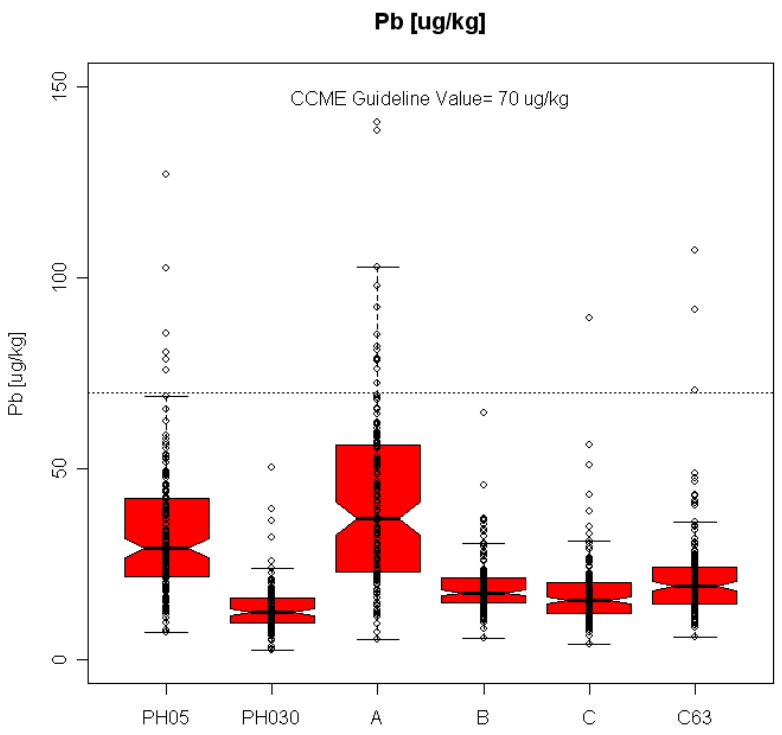
1: Why are concentrations for both elements greater in the C63 (<.063 mm) analysis than the C(>2 mm) analysis?

2: In As the concentrations are higher at the bottom of the soil column whereas in Pb the results are opposite. Why? Could it tell anything about the source of the Pb.

3: For As the concentrations are lower in the O (organic rich) horizon than in the other horizons. Why?

4: Which element is more mobile in the environment- it cycles faster .





Analytical Variation

To compare results

Soils:

- Sample location
  - lat., long., depth (soil Horizon)
- Sample preparation:
  - texture
- Analytical technique
  - Extraction process
  - instrumentation

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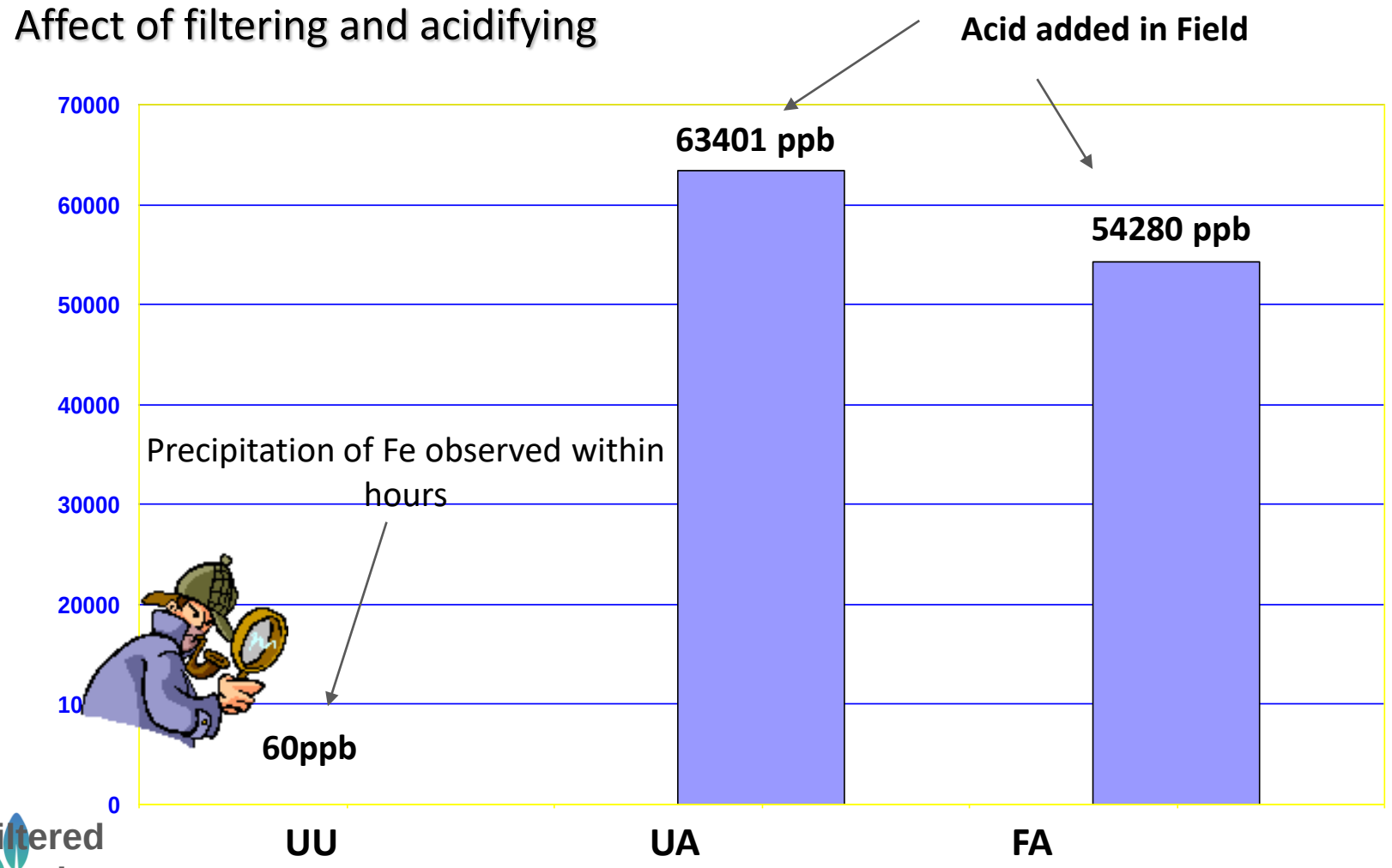
Analytical Variation: Waters

Do not translate the graph but do translate the small box in the lower left (unfiltered, filtered, acidified and unacidified)



U-- unfiltered
F-- filtered
A-- acidified
U-- unacidified

Analytical Variation

Assess Validity (is it right)

Reference Materials are 'controls' or standards used to validate analytical measurement methods.

1: Reference Material
Material, sufficiently homogeneous and stable with respect to one or more specified properties.

2: Certified Reference Material (CRM's)
A **certified reference material** is a particular form of measurement standard.
Reference material characterized by a valid procedure (ISO) for one or more specified properties, accompanied by a certificate that provides the value of the specified property, its associated uncertainty.

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Analytical Variation

Put in the table as is

Standardizing Results

Certified Reference Material

Steps in producing **Certified Reference Material**

Certified Reference Material

Sample: Stream **Homogenize** **Analyze**

Metal	Con
As	100 pp
Cu	1000 ppb
Ni	500 ppb
Pb	20 ppb
….	

Certified Reference Material: Insert a portion of the CRM as a sample just like any other sample. Analytical company should not know it is a CRM

CRM's are available from Central Geologic Laboratory of Mongolia

Analytical Variation

Ensuring Validity of Results

Three types of non-field samples to include in your submission of samples to verify validity of the results:

1. Add CRM or make up your own standard reference material with a known concentration of a metal or metals.
2. Include an analytical blank (distilled water) as a sample.
3. Include a field blank: a sample of purified water that you take to the field and process it like any other sample that you are taking in the field. - Indicates whether or not your sampling procedure is affecting the results.

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Biogeochemistry and Health Toxic

"A substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that:

A. have or may have an immediate or long-term harmful effect on the environment or its biological diversity;

B. constitute or may constitute a danger to the environment on which life depends; or,

C. constitute or may constitute a danger to human life or health."

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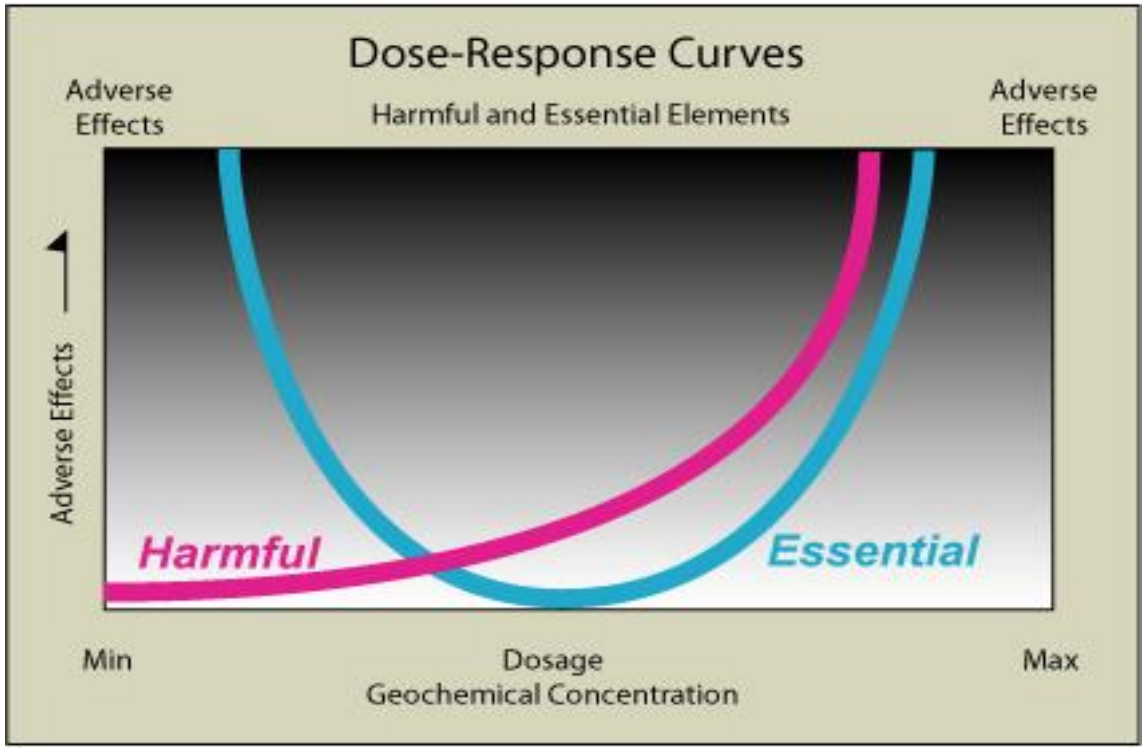
Biogeochemistry and Health

Toxic

Dose-Response curves indicate health effects



Basis for definition of acceptable or critical levels of all substances in the environment including metals.

Biogeochemistry and Health

Quality Guideline Levels -

	Freshwater[1]	Sediment[2]	Soil[3]
Element	µg/L (ppb)	µg/kg (ppb)	mg/kg (ppm)
As	5	17000	12
Cr^{+6}	1	90000[4]	.4
Cr^{+3}	8.9	X	64[5]
Hg	.026	486	6.6
Se	1	X	1
Zn	7.0	315000	250

Most countries have their own quality guidelines.

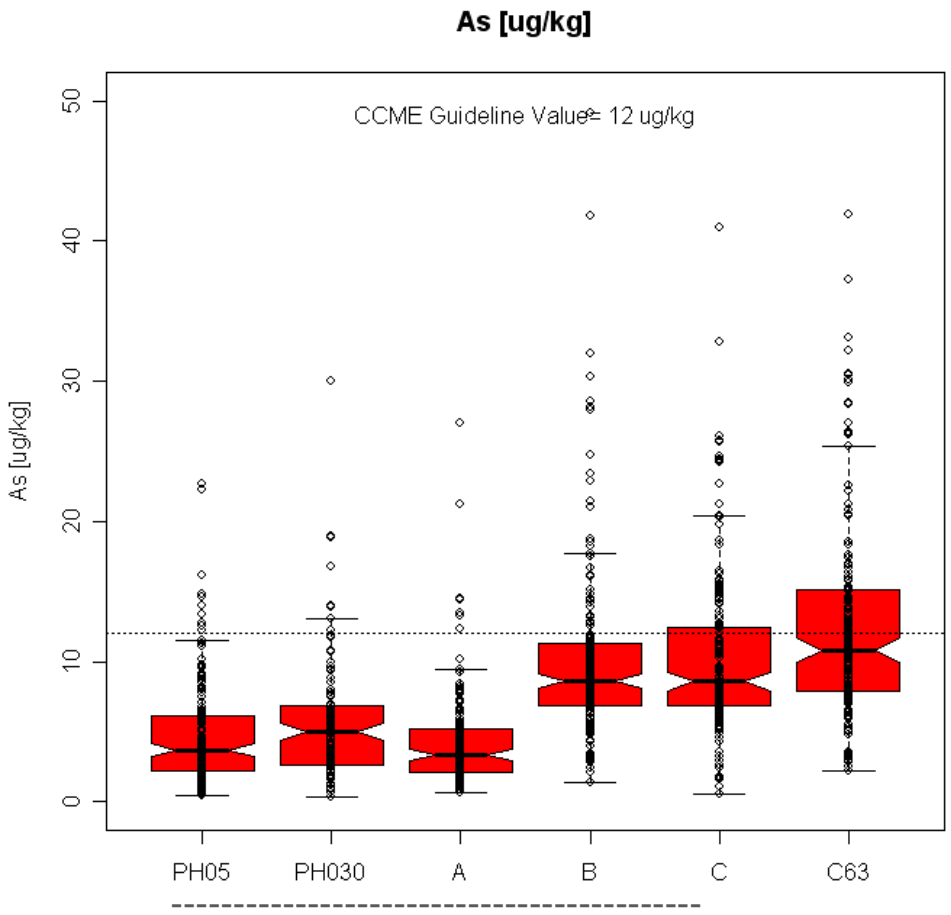
1: Risk to aquatic life.
2: Risk to aquatic life.
3: Risk to human health
4: Total Cr.
5: Total Cr.

http://st-ts.ccme.ca/en/index.html
Canadian Council of Metals In Environment

https://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/

Biogeochemistry and Health

Quality Guideline Levels



5 different soil horizons

2 different soil textures

Do not translate or include the question in the translated slide presentation

Question:

What is the importance of the differences in the concentrations between the various media with specific reference to the quality guideline limit of 12 ug/kg?

Geochemical Data Management

Геохимийн мэдээллийн менежмент

All information needs to be put into a data base.

Бүх мэдээллийг мэдээллийн санд оруулах хэрэгтэй.

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Metal concentrations in soil.

#	As	Cd	Pb	Zn	Mn	Cu
1	59.4	0	0	0	0	0
2	25.2	0	0	0	0	0
3	43.4	0	135.8	0	0	0
4	29.3	0	66.6	0	0	0
5	23.9	0	0	0	5	0
6	34.7	0	29.9	0	0	0
7	21.1	0	0	0	0	0
8	52.3	0	6.0	0	0	0
9	16.3	0	0	0	0	0
10	24.3	0	0	0	0	0
15	520	40	0	650	8000	65
30	104.3	0	164.0	228.0	0	0
31	39.3	0	89.0	0	1286.0	0
32	103.8	0	12.0	215.0	574.0	0
33	67.3	0	337.2	192.5	1077.0	0
34	19.5	0	0	0	950.0	0
35	26.3	0	0	0	728.0	0
36	33.3	0	0	0	1270.0	0
37	37.3	0	0	0	1092.0	0
38	222.3	0	525.0	620.0	1809.0	0
39	394.2	0	5086.2	6964.0	1721.0	0
40	32.3	0	31.0	1942.0	870.0	0
41	248.5	0	3065.0	763.0	1180.0	0
LIMIT	**12**	**1.4**	**70**	**250**	**XX**	**63**

Questions?

1: What observations can you make from this data set about the environment?

2: What critical information is missing from this data set that you need to interpret it?

3: Given the association of certain elements with other elements can you suggest what is a probable reason for the variation?

4: Do you accept results for sample 15? If not what would you do?

5: Do you accept the results for sample 39? If not what would you do?

6: Would these results concern you about possible negative affects in the environment?

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Geochemical Data Management

Geochemical data requires other information.

Ancillary			Geochemical			
?	?	?	As	Cu	Pb	
			10	15	8	
			2	4	6	
			7	9	10	
			4	8	3	
			.	.	.	
			.	.	.	

Required to: Compare results from other organizations
Compare time trends

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Geochemical Data Management

Ancillary Data:

Where	When	What	How Field	How Lab				
?	?	?	?	?	As	Cu	Pb	
					10	15	8	
					2	4	6	
					7	9	10	
					4	8	3	
					.	.	.	
					.	.	.	

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Conclusion:

Make Mining Sustainable:
Understanding metals in the environment

Message:
Useful environmental impact assessments and evaluation of EIA's depends on *rigorous understanding and* analysis of elements in the environment.

Thank you

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Mongolia: Enhancing Resource Management through Institutional Transformation

Хаяг: Нэйшнл таймс ньюс тауэр, 3-р давхар
Худалдааны гудамж, Хороо 1
Чингэлтэй дүүрэг, Улаанбаатар-15160

Утас: 7610-5000