Screening tools for heavy metals

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Why use screening tools?

- **Cost-effective: typically cheaper than chemical analysis**
- **Higher information density:**
  - More samples/sampling points
  - High resolution (horizontal/vertical)
  - → Better decision making
- **Essential for dynamic work plan: real-time information is input for investigation strategy**

Figure 1: The Triad Approach

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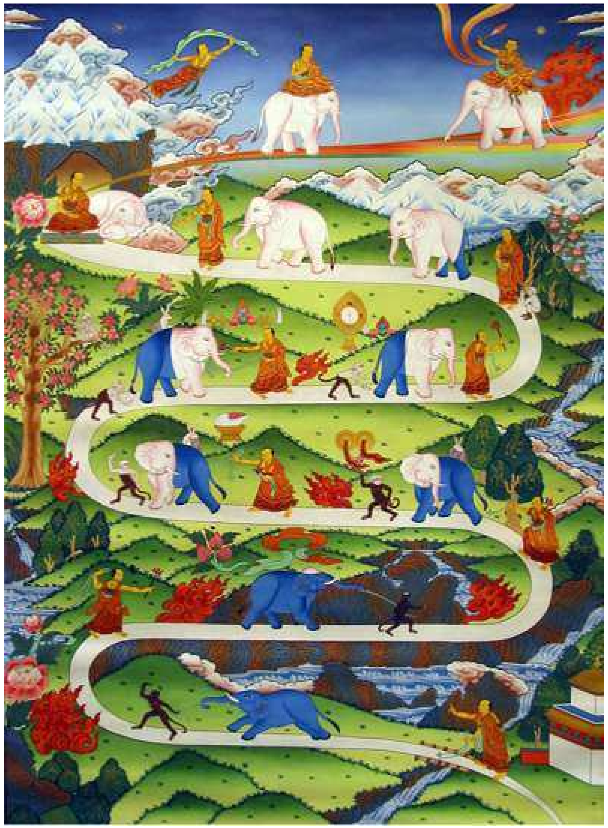
Screening tool characteristics

Ideal screening tool:

- quantitative
- specific,
- accurate, low detection limit
- inexpensive
- easy to use
- Accepted by authorities



Real-world screening tools:

- Qualitative / semi-quantitative
- Often a-specific or semi-specific
- Higher scatter and detection limits
- some are inexpensive
- some are easy to use
- Authorities are sceptic / regulation prevent application

Screening tools for heavy metals

Tool	Description
Handheld XRF	Handheld detector
CPT-XRF	XRF detector mounted on CPT rod
Medusa	• Indirect measure for soil-bound metals • Direct measure for mine tailings
Field kit	Colorimetric assays

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X-Ray Fluorescence (XRF)

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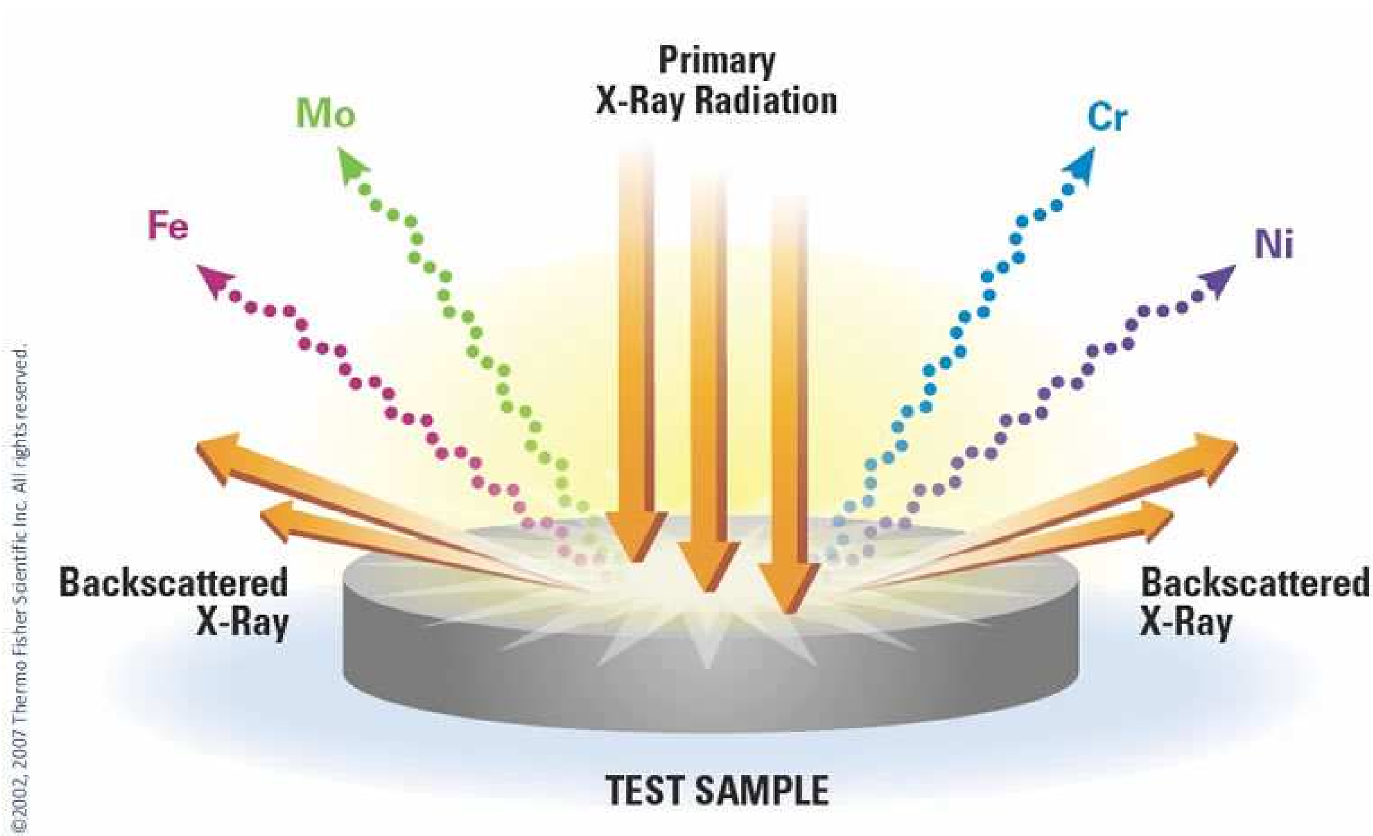
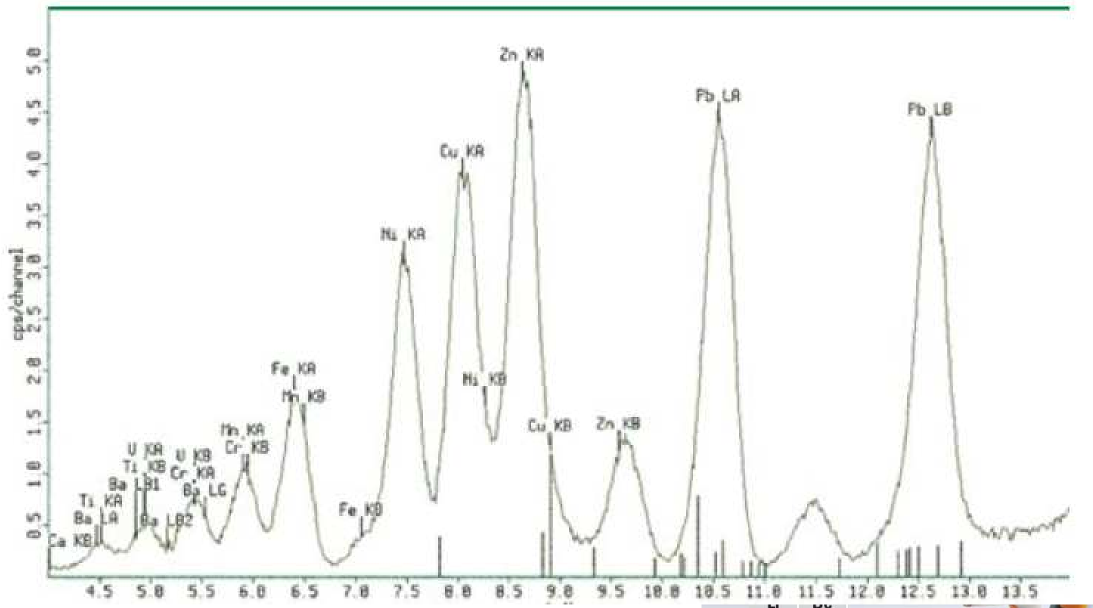
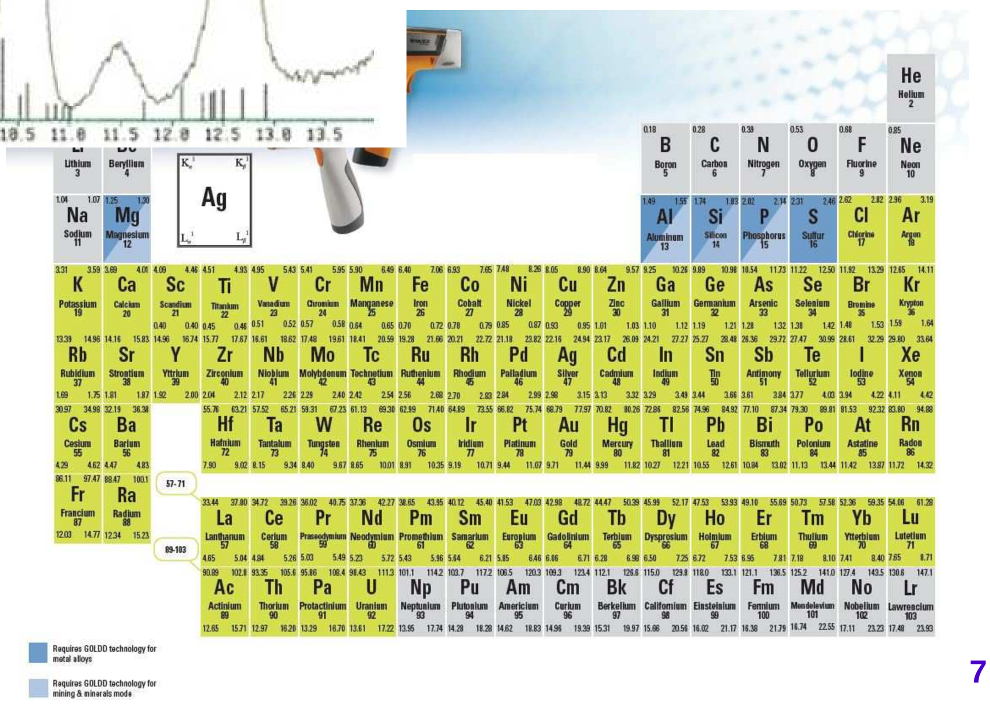
XRF principle



Example XRF spectrum





XRF characteristics

Almost ideal screening tool for metals:

- Handheld
- Easy to use
- Specific
- Quantitative
- Applicable to all metals

But:

- Detection limit and accuracy varies for different metals and conditions (calibration/validation)
- X-ray safety issue

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XRF performance

Metal	Detection limit (mg/kg d.w.) standard soil	Detection limit (mg/kg d.w.) Highly contaminated	Dutch standard
As	6	*	43
Cd	34	598	7.5
Cr	89	*	97 (total)
Cu	21	661	92
Hg	10	481	26
Mo	11		191
Ni	42	451	35
Pb	12	*	336

*: sample highly contaminated with As, Cr, Pb

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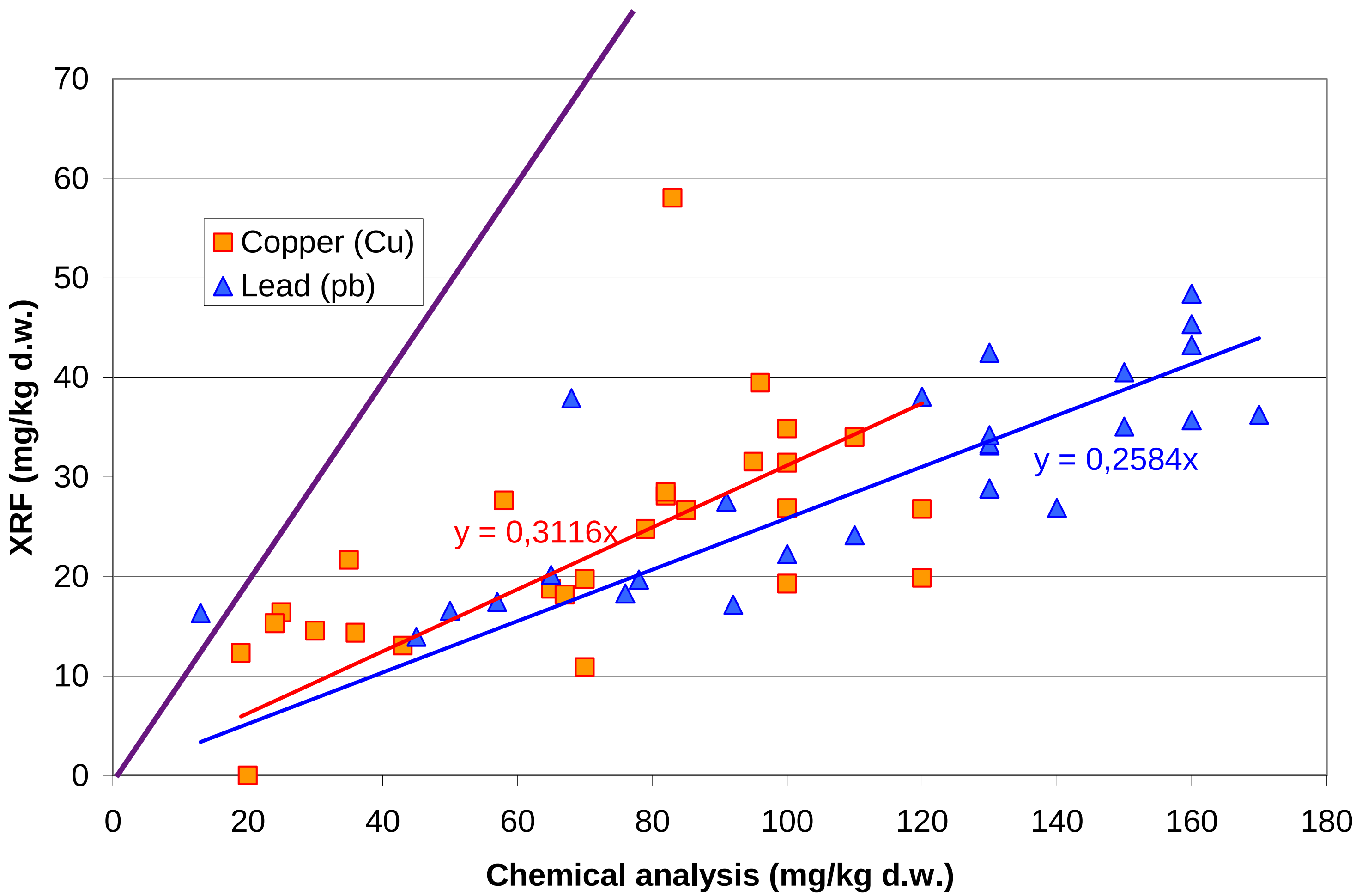
Matrix effect: XRF in wet sediments



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XRF application: general

Operation relatively easy:

- Normal soil sampling
- Homogenizing in bucket
- Calibrations:
  - Energy calibration (startup)
  - Clean sample (startup)
  - Standard reference material for metals (regularly)
- Longer analysis time (2-3 min) for better results
- 40 - 80 samples/day in the field
- 90 - 110 samples/day in lab/office

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Application in the field

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Application in lab/office

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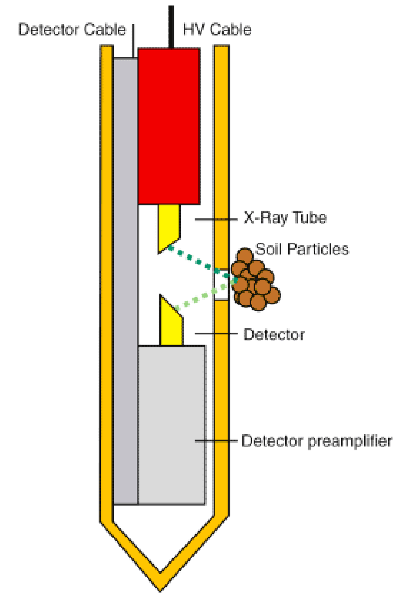
XRF-CPT

XRF sensor mounted on a CPT rod

Same basic characteristics as handheld XRF, but:

- high vertical resolution
- easier application at large depth



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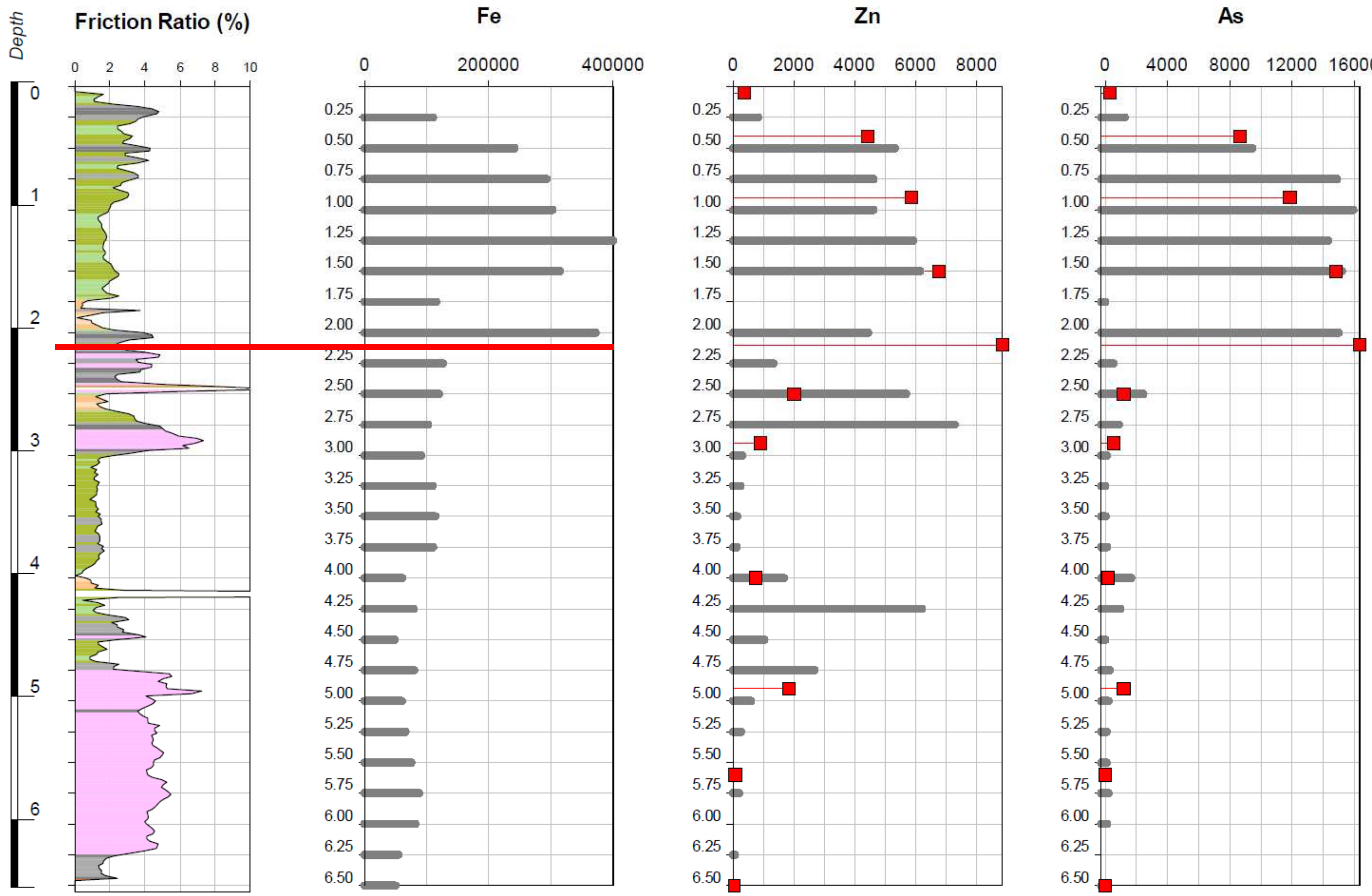
Example CPT-XRF (pyrite ash backfill)



Chemical analysis

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Field application

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Measuring natural radioactivity

“sensing earth”

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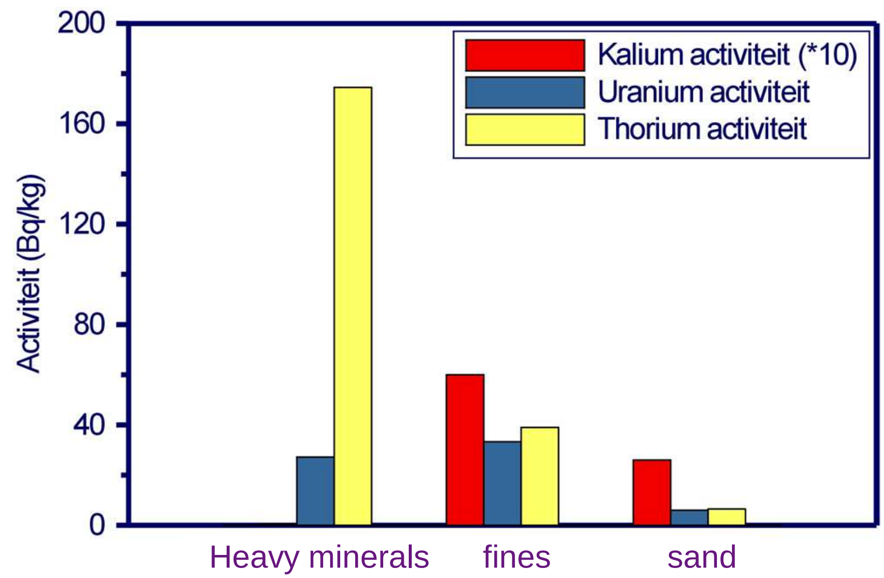
Medusa principle

Measurement of natural radioactivity

Measurement of radioactive K, U, and Th can be used as proxy for heavy metals:

- Concentrations of K, U and Th are often related to concentrations of other heavy metals (Zn, Cd, Cu)
- Concentrations of K, U and Th are related to soil composition



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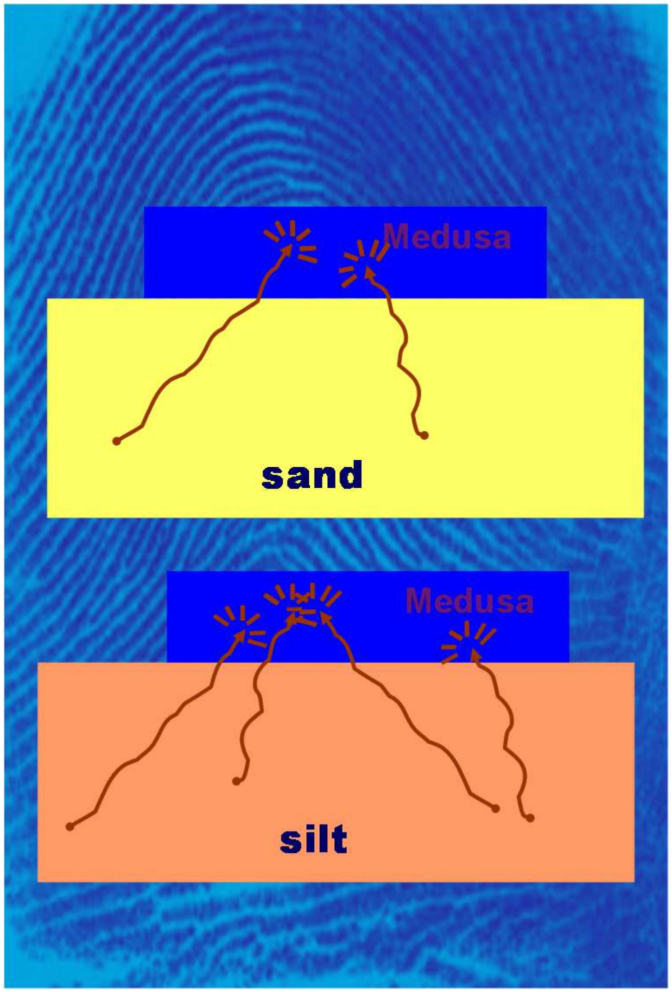
“fingerprint” of minerals



- Fingerprinting
  - Silt, clay and sand contain different concentrations of (natural occurring) radionuclides
  - The ratio of the radionuclides is a “fingerprint” of the material
- Field mapping
  - Concentrations of radionuclides can be measured in the field to a depth of 0.3 m
  - The measurement is passive, a radioactive source is not required
  - Measuring radionuclides is non-destructive
- Maps of:
  - Soil texture (clay/sand)
  - Mineral composition

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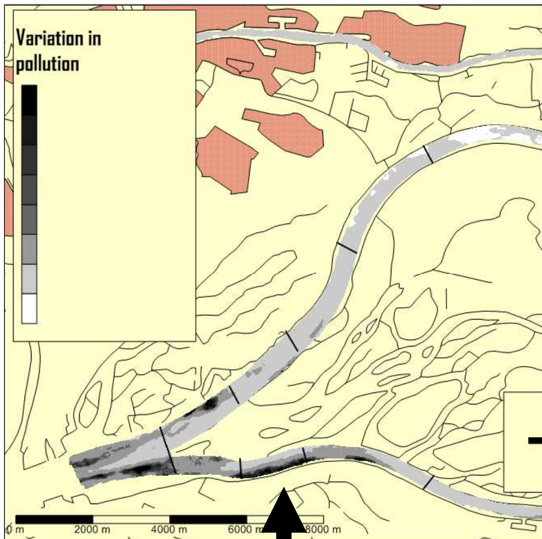
Versatile application

Sediment-pollution mapping



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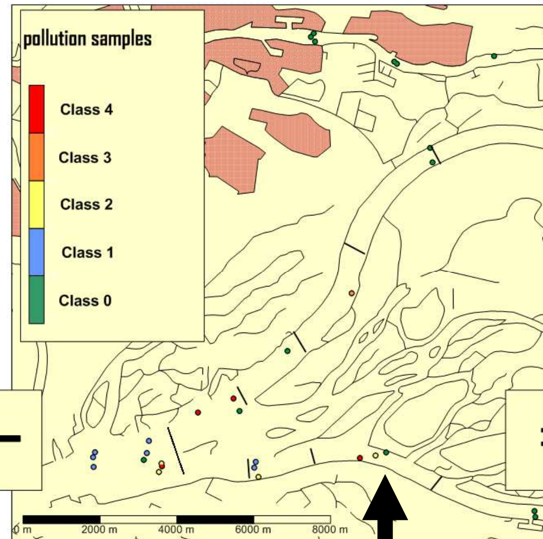

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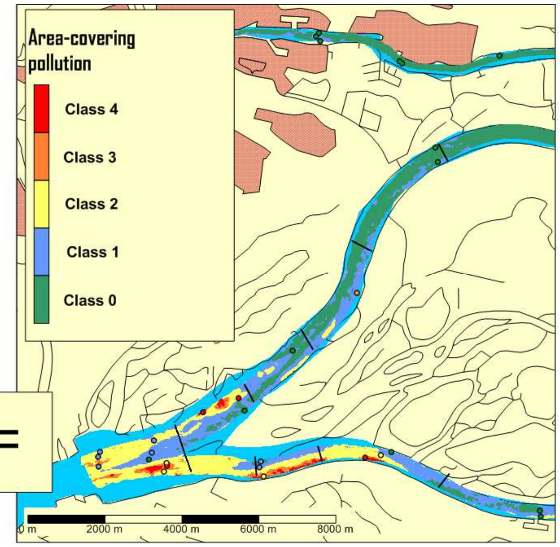
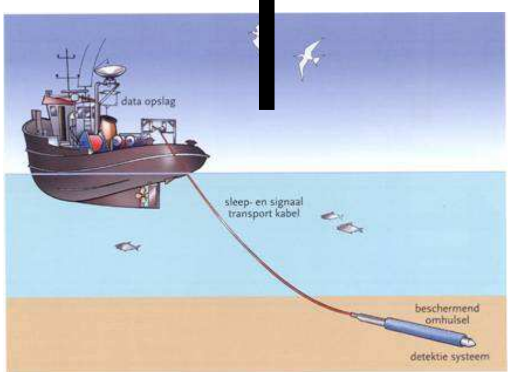
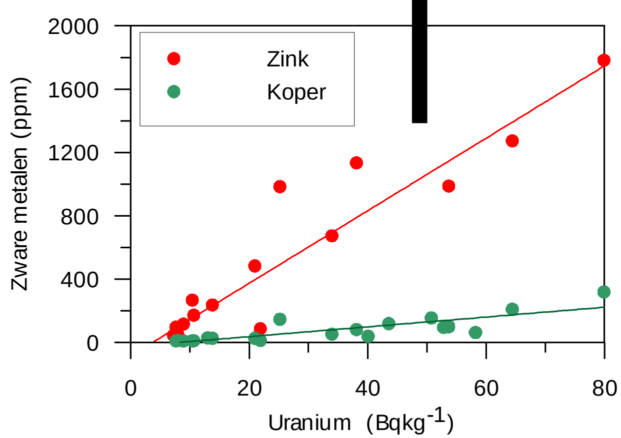
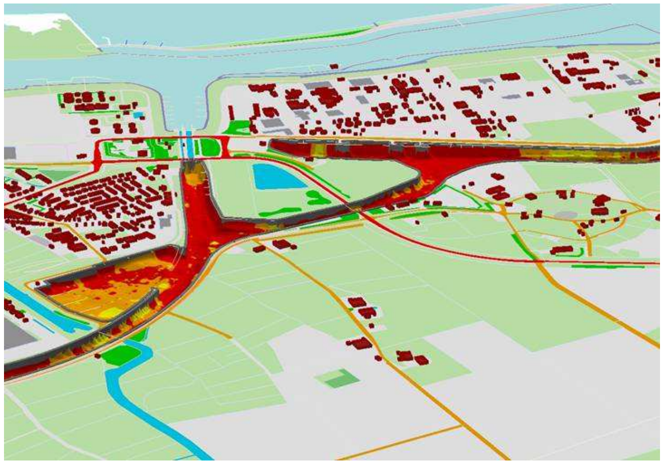






Mercury pollution mapping

Canal polluted with mercury by a chemical factory



- Mercury distribution unknown
- Site investigation:
  - Sediment mapping by a boat using the Medusa system
  - Samples were taken
  - Samples used for calibration of Medusa signal
  - Detailed map of pollution levels
- Movie (next slide)
  - Spatial variation of sediment pollution
  - Red colors: high levels of pollution

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Concluding

XRF nearly ideal screening method for individual samples:

- Specific, quantitative, fast, direct results, cost-effective
- Easy application (hand-held)
- XRF-CPT for vertical profiling

Medusa strong tool for indicative screening of soils and sediment:

- Can cover large areas in a short time
- Provides basis for more detailed investigations
- Suited for identifying mine tailings
- Limited depth

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