

Screening tools for heavy metals

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Tauw

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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



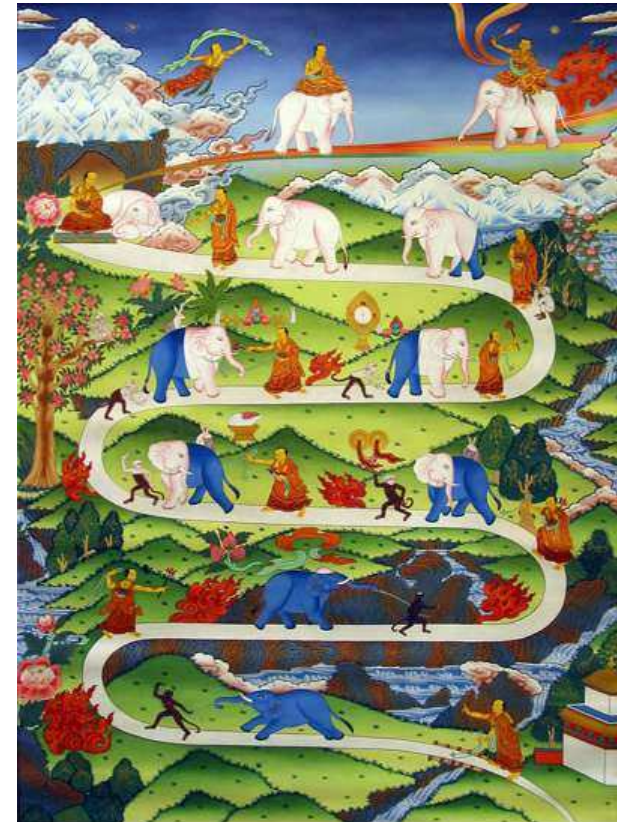
Screening tool characteristics

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

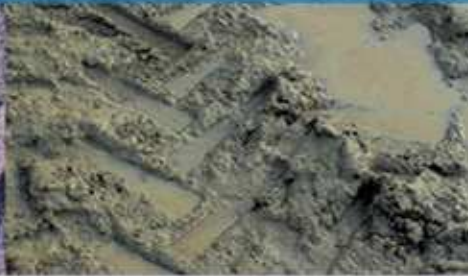


Screening tools for heavy metals

Tool	Description
Handheld XRF	Handheld detector
CPT-XRF	XRF detector mounted on CPT rod
Medusa	<ul style="list-style-type: none"> • Indirect measure for soil-bound metals • Direct measure for mine tailings
Field kit	Colorimetric assays

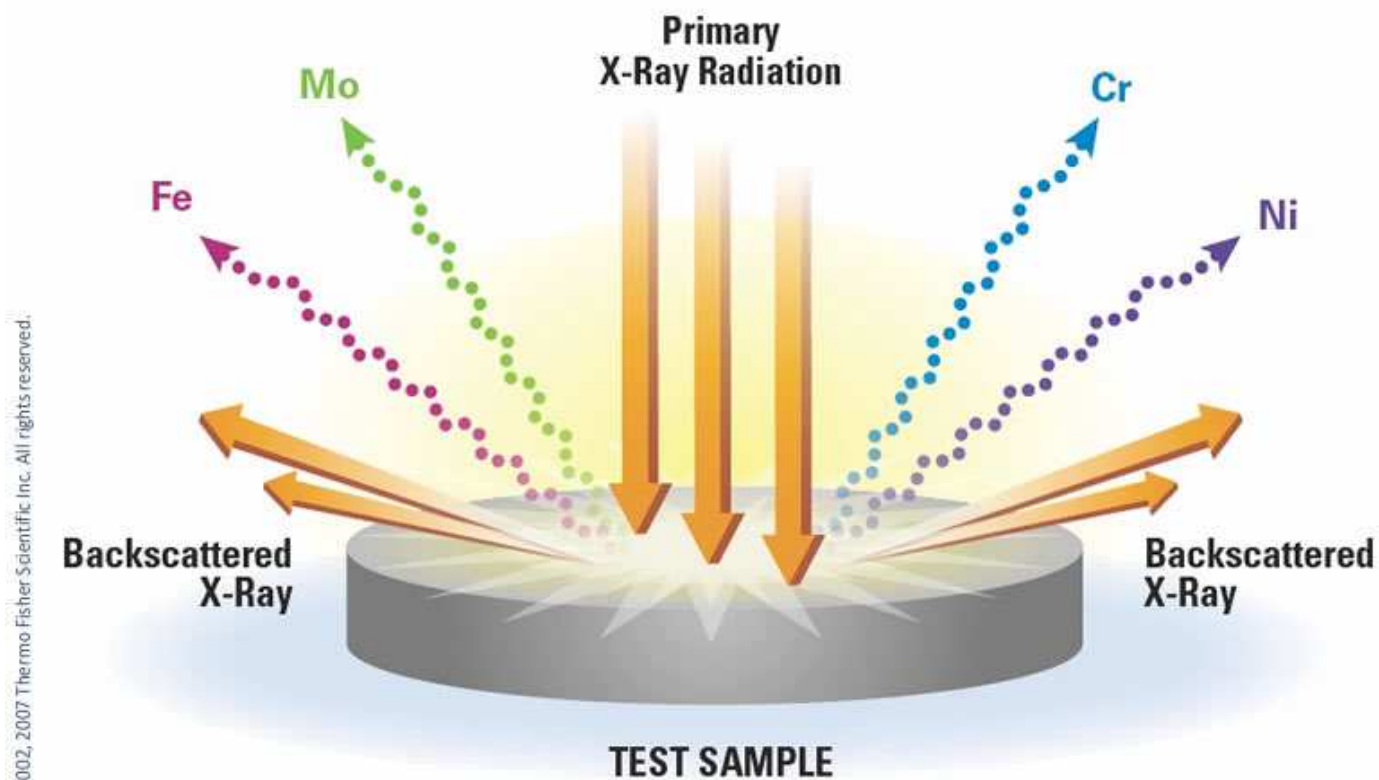


X-Ray Fluorescence (XRF)



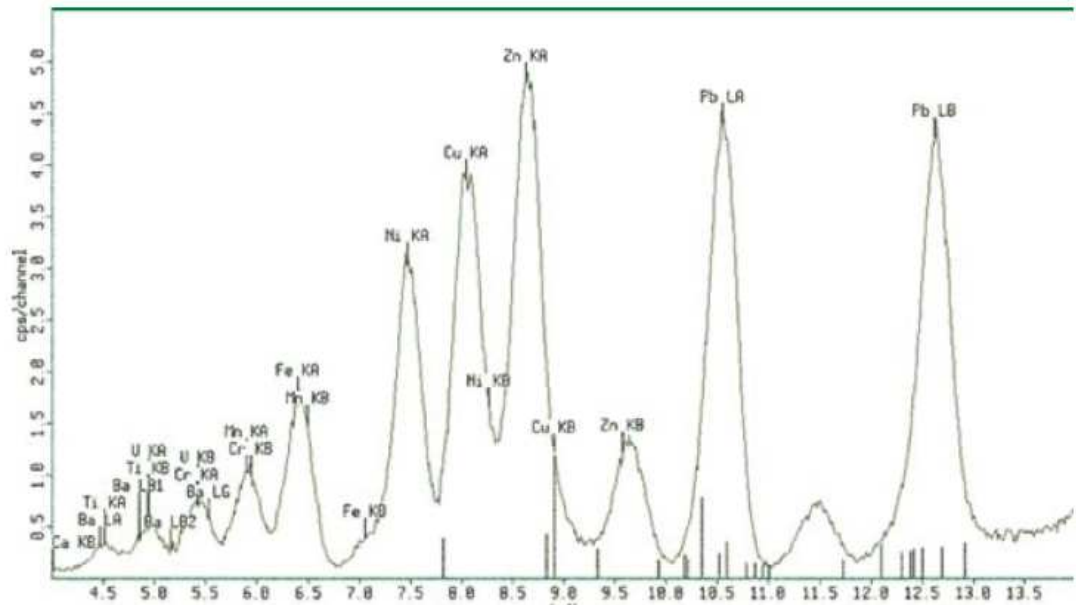
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XRF principle



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Example XRF spectrum



Lithium 3		Beryllium 4		K ₂		K ₂		Tl		Boron 5		Carbon 6		Nitrogen 7		Oxygen 8		Fluorine 9		Neon 10	
1.04	1.07	1.25	1.30	Ag								1.43		1.55	1.74	1.83	2.02	2.14	2.31	2.46	
Na Sodium 11	Mg Magnesium 12											Al Aluminum 13		Si Silicon 14	P Phosphorus 15		S Sulfur 16	Cl Chlorine 17	Ar Argon 18		
3.21	3.59	3.89	4.01	4.08	4.46	4.51	4.93	4.95	5.43	5.41	5.95	5.50	6.40	6.40	7.06	6.83	7.85	7.48	8.26	8.66	
K Potassium 19	Ca Calcium 20	Sc Scandium 21	Ti Titanium 22	V Vanadium 23	Cr Chromium 24	Mn Manganese 25	Fe Iron 26	Co Cobalt 27	Ni Nickel 28	Cu Copper 29	Zn Zinc 30	Ga Gallium 31	Ge Germanium 32	As Arsenic 33	Se Selenium 34	Br Bromine 35	Kr Krypton 36				
0.40	0.40	0.45	0.46	0.51	0.57	0.57	0.58	0.46	0.76	0.72	0.76	0.85	0.87	0.85	0.95	1.00	1.19	1.19	1.31	1.28	
Rb Rubidium 37	Sr Strontium 38	Y Yttrium 39	Zr Zirconium 40	Nb Niobium 41	Mo Molybdenum 42	Tc Technetium 43	Ru Ruthenium 44	Rh Rhodium 45	Pd Palladium 46	Ag Silver 47	Cd Cadmium 48	In Indium 49	Sn Tin 50	Sb Antimony 51	Te Tellurium 52	I Iodine 53	Xe Xenon 54				
1.69	1.75	1.81	1.87	1.92	2.00	2.04	2.12	2.17	2.26	2.29	2.40	2.42	2.54	2.56	2.80	2.76	2.88	2.94	3.15	3.13	
30.57	34.98	32.19	36.38	35.58	38.31	57.52	58.91	62.93	63.55	68.96	71.97	74.92	75.94	78.97	79.90	81.90	83.92	82.98	85.94	87.92	
Cs Cesium 55	Ba Barium 56			Hf Hafnium 72	Ta Tantalum 73	W Tungsten 74	Rh Rhodium 75	Os Osmium 76	Ir Iridium 77	Pt Platinum 78	Au Gold 79	Hg Mercury 80	Tl Thallium 81	Pb Lead 82	Bi Bismuth 83	Po Polonium 84	At Astatine 85	Rn Radon 86			
4.20	4.62	4.47	4.83	7.90	9.02	6.15	8.34	8.40	9.47	8.65	10.01	8.31	10.25	9.19	10.44	11.07	9.71	11.44	9.89	11.82	
86.11	97.47	88.47	100.1																		
Fr Francium 87	Ra Radium 88																				
12.03	14.77	12.34	15.23																		
<div><div>57-71</div><div>72-103</div></div>																					
23.44	27.80	24.71	29.26	36.02	40.76	38.93	42.37	38.65	43.85	40.12	45.88	41.53	47.03	42.90	48.72	44.47	50.98	46.89	52.17	48.53	
La Lanthanum 57	Ce Cerium 58	Pr Praseodymium 59	Nd Neodymium 60	Pm Promethium 61	Sm Samarium 62	Eu Europium 63	Gd Gadolinium 64	Tb Terbium 65	Dy Dysprosium 66	Ho Holmium 67	Er Erbium 68	Tm Thulium 69	Yb Ytterbium 70	Lu Lutetium 71							
4.05	5.04	4.94	5.26	5.03	5.49	5.22	5.72	5.43	5.86	5.84	6.21	5.85	6.46	6.06	6.71	6.29	6.96	6.35	7.25	6.72	
103.29	138.93	105.8	140.91	106.43	111.12	101.1	114.42	100.73	117.25	100.5	120.3	108.3	124	112.1	126.1	115.0	129.8	116.0	131.31	130.5	
Ac Actinium 89	Th Thorium 90	Pa Protactinium 91	U Uranium 92	Np Neptunium 93	Pu Plutonium 94	Am Americium 95	Cm Curium 96	Bk Berkelium 97	Cf Californium 98	Es Einsteinium 99	Fm Fermium 100	Md Mendelevium 101	No Nobelium 102	Lr Lawrencium 103							
12.65	15.71	12.57	16.29	13.29	16.76	13.12	17.22	13.95	17.48	14.28	18.62	18.82	18.96	19.39	15.31	19.97	19.36	20.96	18.02	21.17	
12.65	15.71	12.57	16.29	13.29	16.76	13.12	17.22	13.95	17.48	14.28	18.62	18.82	18.96	19.39	15.31	19.97	19.36	20.96	18.02	21.17	
12.65	15.71	12.57	16.29	13.29	16.76	13.12	17.22	13.95	17.48	14.28	18.62	18.82	18.96	19.39	15.31	19.97	19.36	20.96	18.02	21.17	
12.65	15.71	12.57	16.29	13.29	16.76	13.12	17.22	13.95	17.48	14.28	18.62	18.82	18.96	19.39	15.31	19.97	19.36	20.96	18.02	21.17	
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12.65	15.71	12.57	16.29	13.29	16.76	13.12	17.22	13.95	17.48	14.28											

XRF characteristics

Almost ideal screening tool for metals:

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



But:

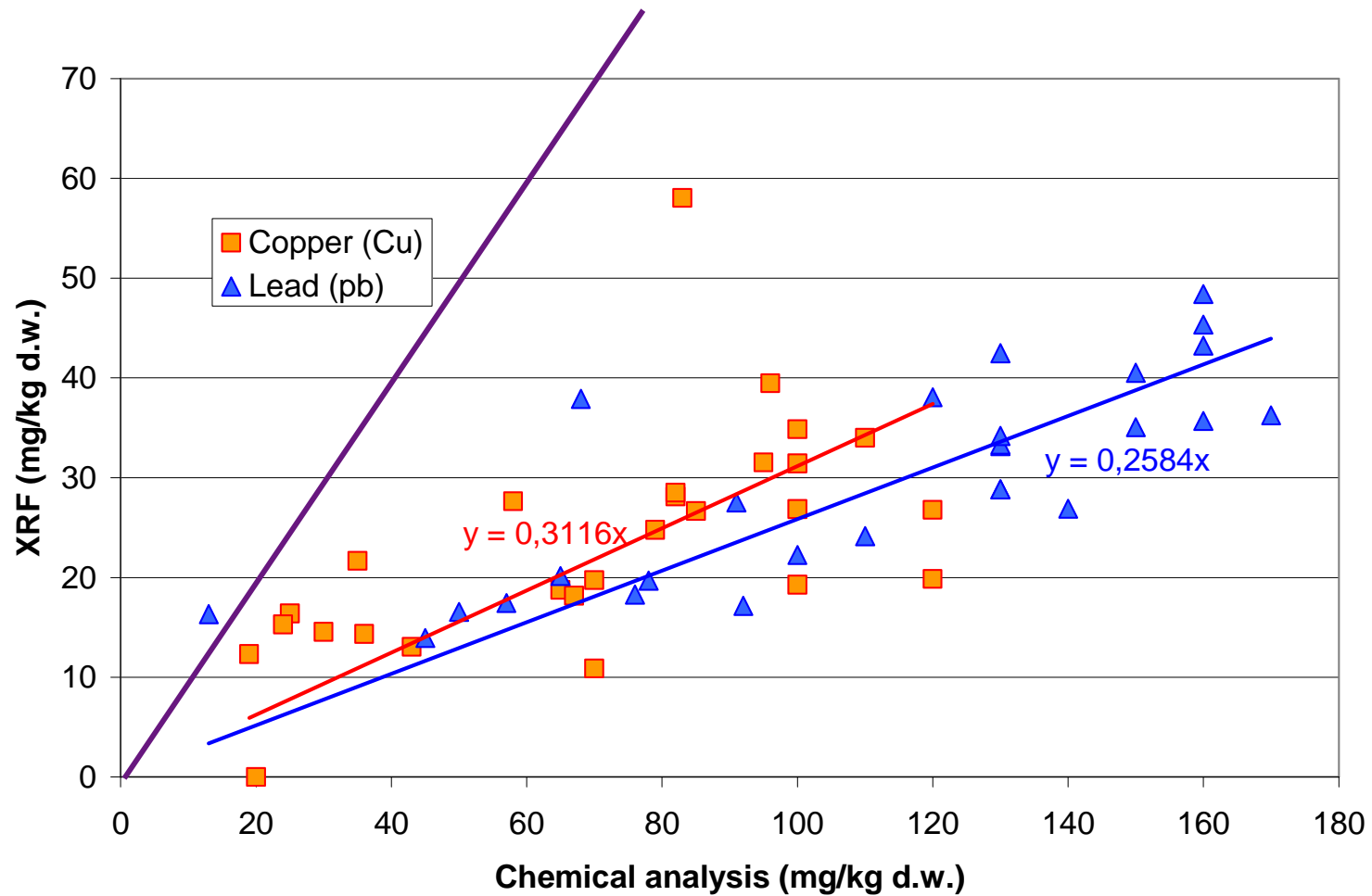
- Detection limit and accuracy varies for different metals and conditions (calibration/validation)
- X-ray safety issue

XRF performance

Metal	Detection limit (mg/kg d.w.)		Dutch standard
	standard soil	Highly contaminated	
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

Matrix effect: XRF in wet sediments



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

Application in the field



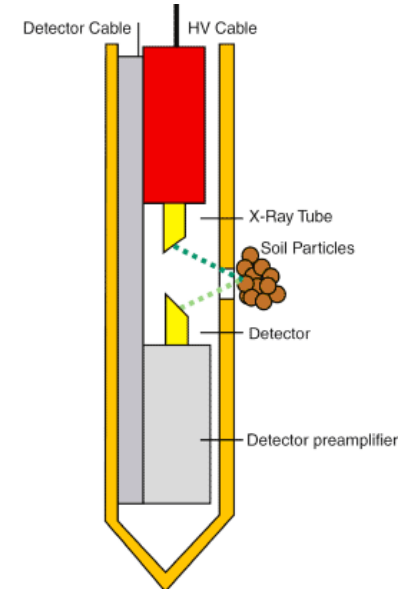
Application in lab/office



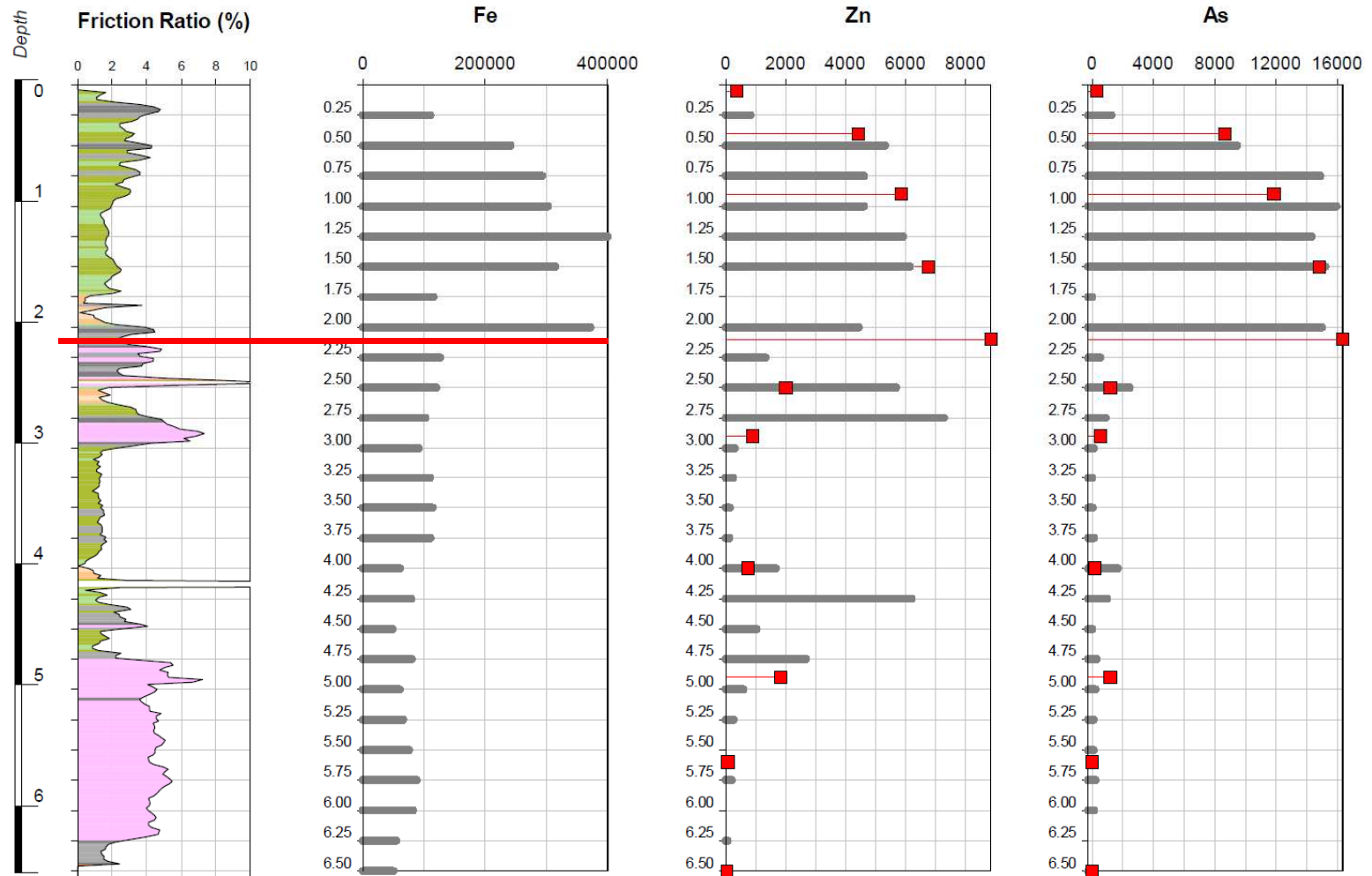
XRF sensor mounted on a CPT rod

Same basic characteristics as handheld XRF, but:

- high vertical resolution
- easier application at large depth



Example CPT-XRF (pyrite ash backfill)



■ Chemical analysis

Field application





Measuring natural radioactivity

“sensing earth”



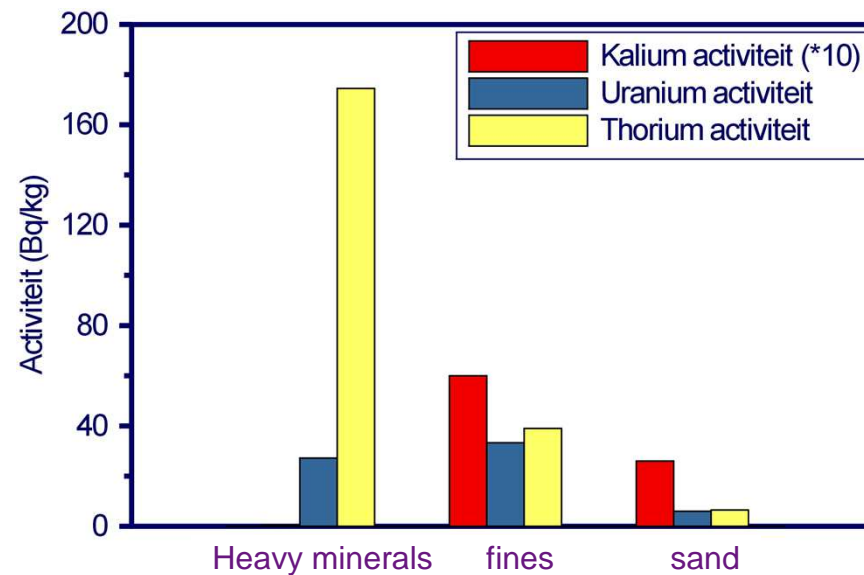
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Medusa principle

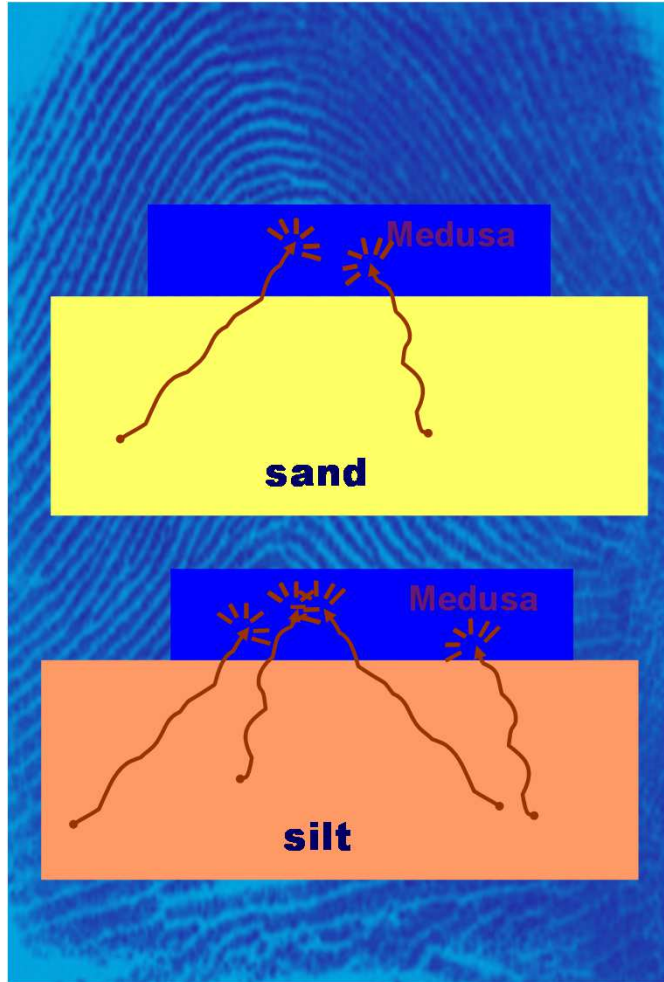
Measurement of natural radioactivity

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



“fingerprint” of minerals

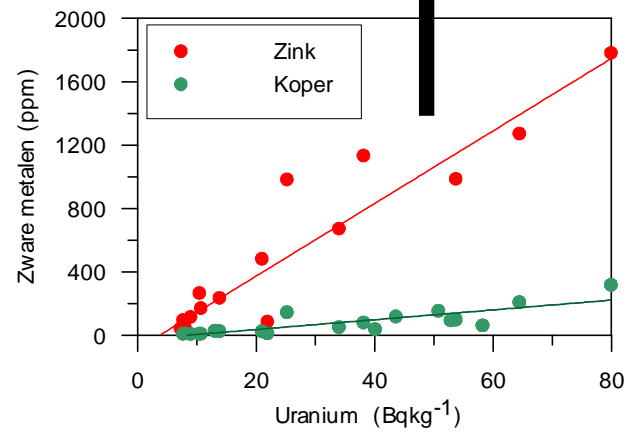
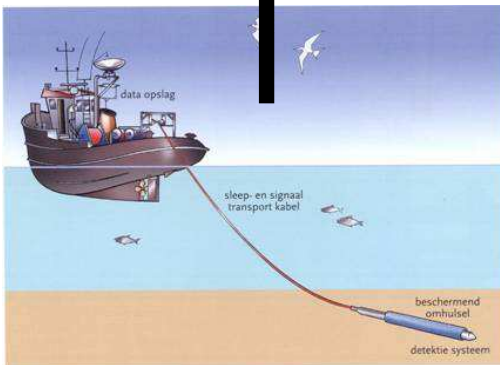
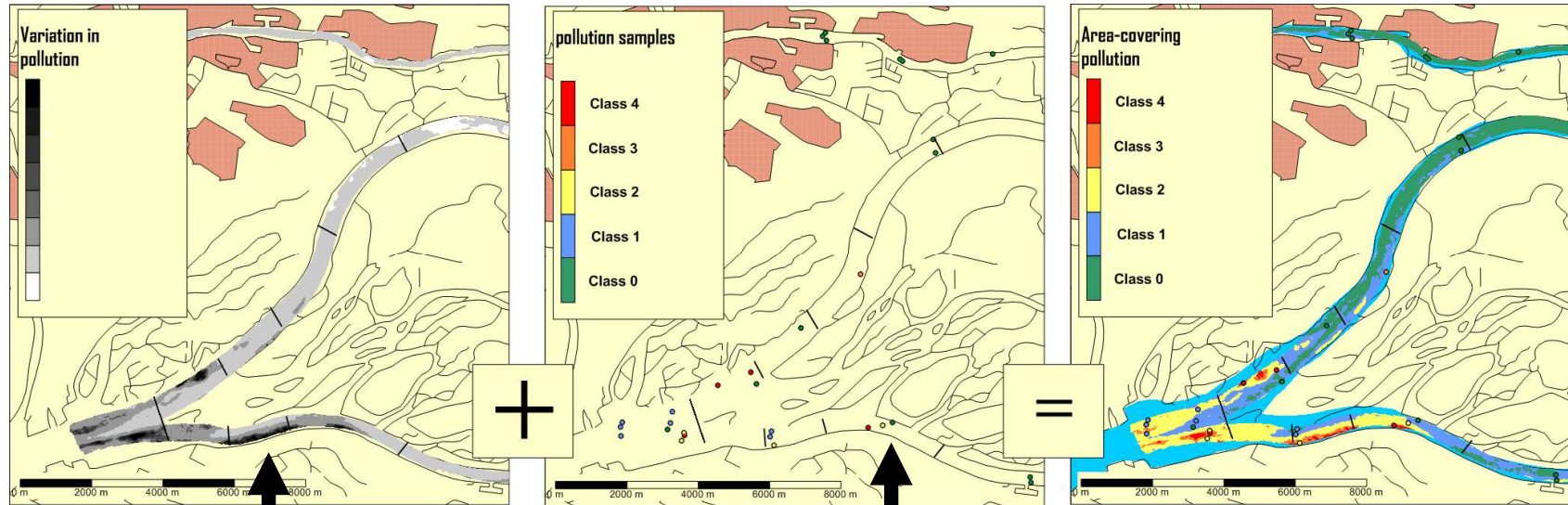


- Fingerprinting
 - Silt, clay and sand contain different concentrations of (natural occurring) radionuclides
 - The ratio of the radionuclides is a “fingerprint” of the material
- Field mapping
 - Concentrations of radionuclides can be measured in the field to a depth of 0.3 m
 - The measurement is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

Versatile application

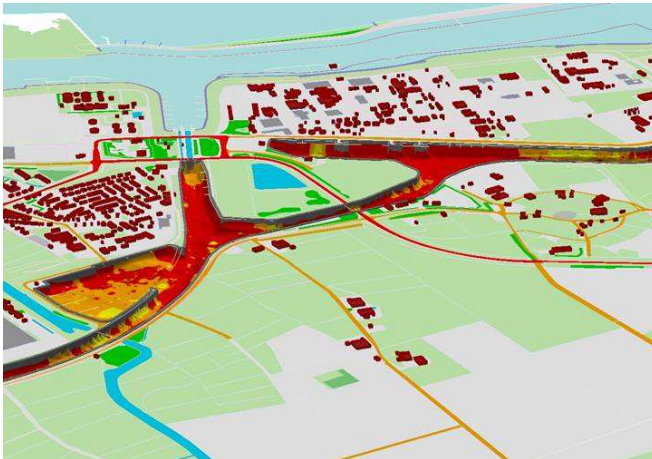


Sediment-pollution mapping



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

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