

Prof. Dr. Christian Wolkersdorfer (云村)
Chair in Mine Water Remediation & Management

SALTS, DYES, AND BALLS FOR THE SOUP

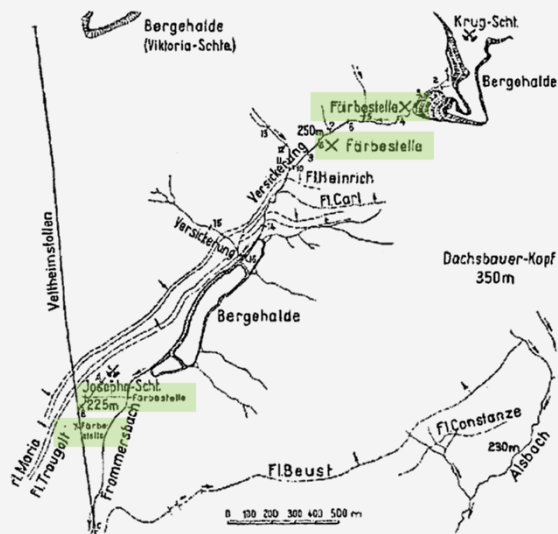
Tracer Tests in the Mining Environment

www.wolkersdorfer.info
Waterloo ON, 2011-03-31



Content

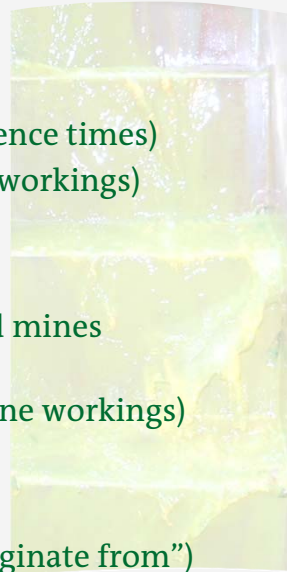
- Why?
 - Reasons for Tracer tests
- How?
 - Tracers and their Usage
- What?
 - Examples
- Outlook and Conclusions



from Semmler 1937
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Why? – Reasons

- Minimize Costs
 - Water Treatment (e.g. mean residence times)
 - Pumping (e.g. seepage into mine workings)
 - Diverting Flow
- Research
 - Stratification within underground mines or pit lakes
 - Hydrodynamics (flow through mine workings)
 - Hydrogeochemistry
- Legal Aspects
 - Flow Paths (“where does water originate from”)



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Why? – Type of Projects

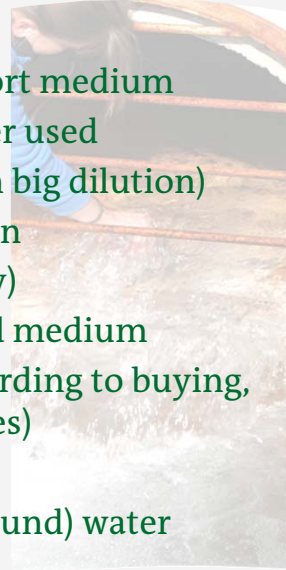
- testing the effectiveness of bulkheads dams
- investigating hydrodynamic conditions
- tracing connections between a mine and the surface
- clarifying reasons for inundations
- assessing contaminant mass flow
- estimating the decrease or increase of contaminants



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How? – General Demands on Tracer Tests

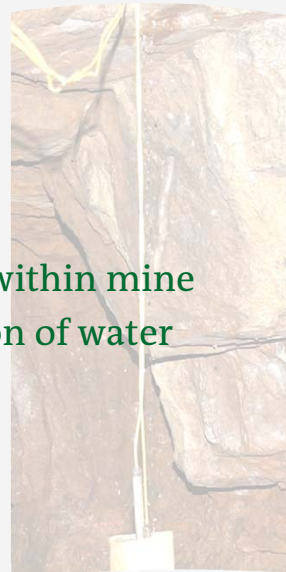
- Transport with velocity of transport medium
- No natural occurrence of the tracer used
- Good analytical detection (even in big dilution)
- Water soluble or used in dispersion
- High resistance (chemical stability)
- No interaction between tracer and medium
- Economic (reasonably priced according to buying, handling and analytical procedures)
- Physiological safe (non toxic)
- No lasting negative effects on (ground) water quality



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How? – Mining Specific

- Suitable tracer for mine water
 - Large water volumes
 - Low pH values
 - Elevated background values
- More than one injection point within mine
- Injection without contamination of water
- As deep as possible into shafts
- Tracer test must be repeatable
- Cheap and easy to handle



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How? – Tracer Types

- “Natural” Tracers
 - Environmental Isotopes
 - Environmental Chemicals
 - Organisms
 - Physical Effects
- Artificial Tracers
 - Water Soluble
 - Water Insoluble



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How? – Mining Specific | Natural

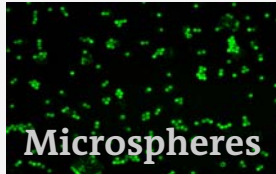
- Stable Isotopes
 - ^{18}O , ^2H , Sr
- Radioactive Isotopes
 - Tritium
- Rare Earth Elements
- Chlorofluorohydrocarbons
(*e.g.* CFC11, CFC12)
- Temperature
- Electrical Conductivity



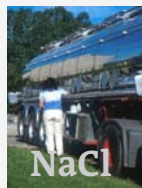
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How? – Mining Specific | Artificial
Salts – Dyes – Balls

- Balls – Solid Tracers



- Salts and Dyes – Water Soluble Tracers



- Bromide
- Lithium

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How? – Mining Specific | Test before use

- Test potential tracers with your mine water
- Duration at least as long as expected duration of your tracer test
- Tracers are pollutants! Therefore:
 - First think about potential flow paths
 - Establish conceptual model using geochemistry or natural tracers (e.g. temperature, electrical conductivity)
 - **THEN** use tracers to prove your conceptual model
 - Avoid to use tracers before you have a conceptual model



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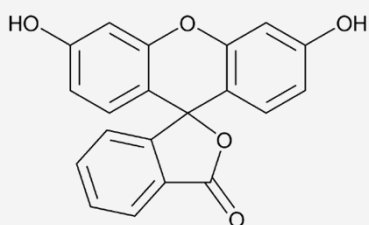
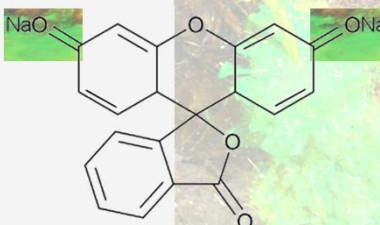
What? – Na-Fluorescein „Uranine“

- Questions I had when reading about tracer tests in the English speaking world
 - Why did “fluorescein” fail in some cases?
 - Why does the English speaking world use Rhodamin WT so often?

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What? – Na-Fluorescein

- Answer:
 - Fluorescein **IS NOT** Na-fluorescein
 - Unfortunately, in both cases C.I. is 45350
 - In German the term “Uranin” is used

Fluorescein
CAS 6417-85-2Na-Fluorescein
CAS 518-47-8CAPE BRETON
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How? – Not like that!



Stöckelgraben Speyer 2002-11-15

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How? – How much to use!

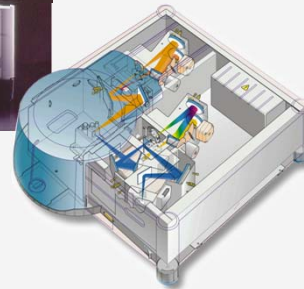
- Na-Fluorescein (uranine) is a fluorescent tracer
 - Never use it for visual detection
 - It is **not** biodegradable in a short time
- Use “Efficient Hydrologic Tracer-Test Design” (EHTD) software to calculate amount
- Visibility limit is ca. 200 µg/L
- Detection limit is ca. 2 ng/L
 - 0.000 000 002 g/L !
- Rough estimation
 - 1–5 mg per 1000 L of water



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How? – Use Fluorimetry

- Autosampler and Laboratory Fluorometer



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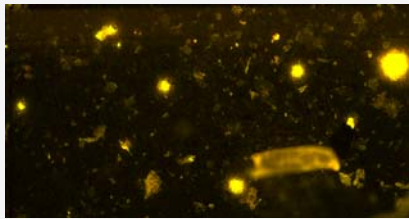
How? – Use Fluorimetry

- On-site Fluorimeters



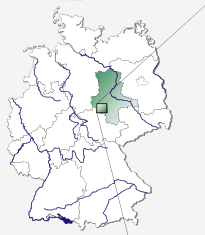
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How? – Microspheres & Lydia-Technique



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Straßberg/Harz: Location

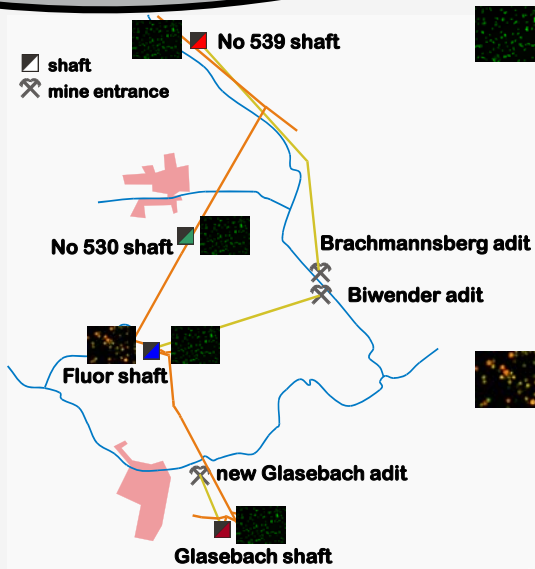


■ shaft
✂ mine entrance



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Straßberg/Harz: Tracer Injections



Microspheres

- 4 × 40 mL
- No 539 shaft
- No 530 shaft
- Fluor shaft
- Glasebach shaft

Lycopodium

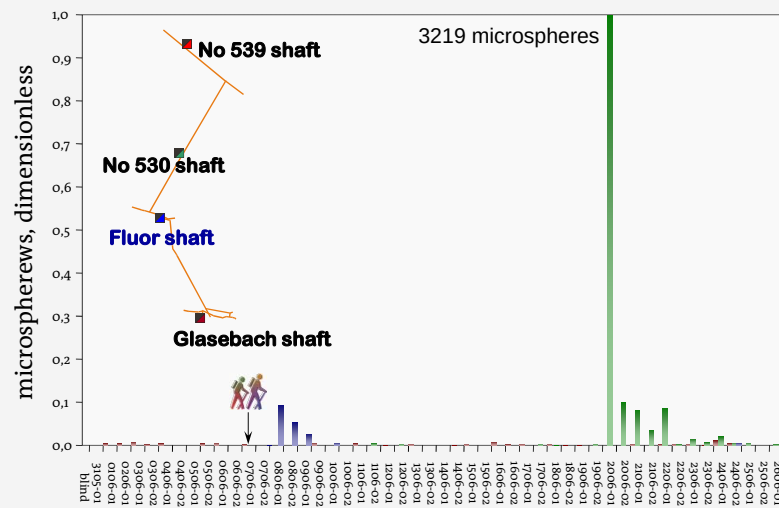
- 544 g
- Fluor shaft

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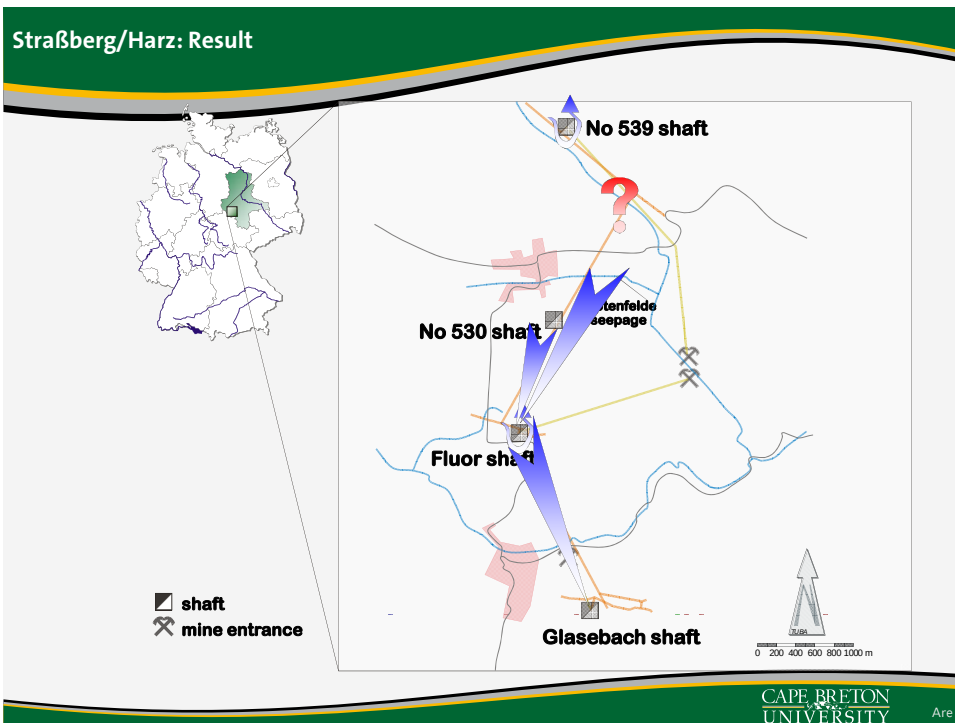
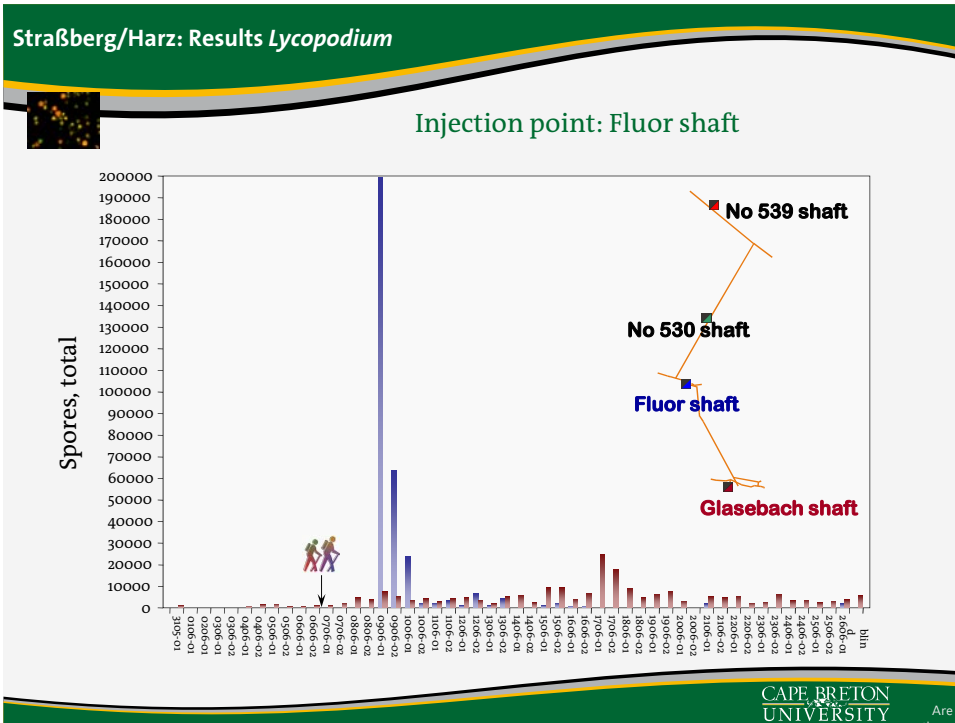
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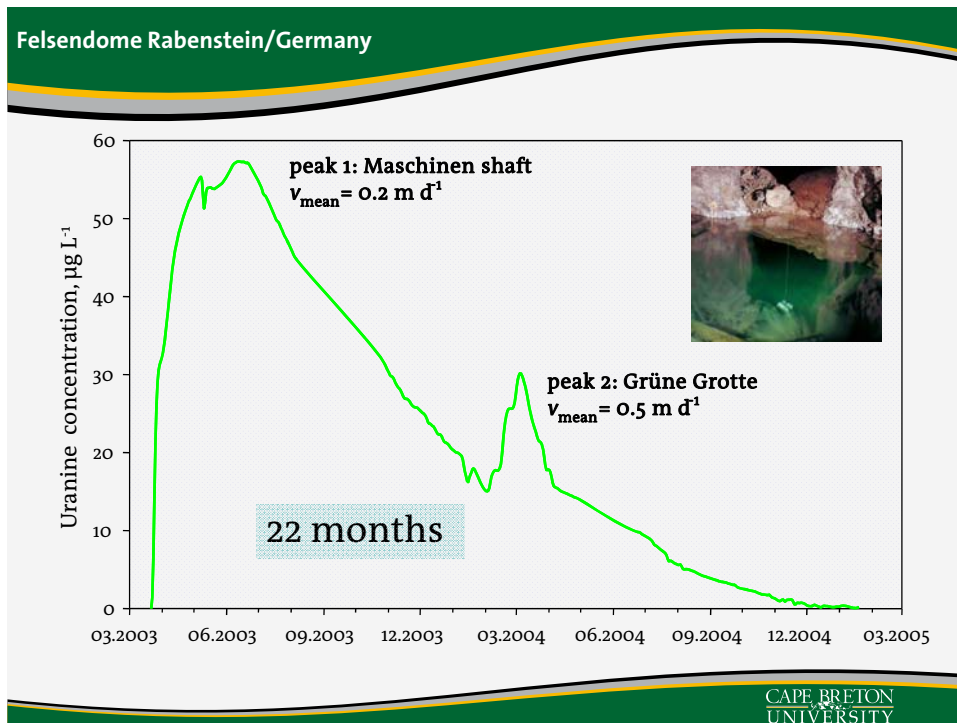
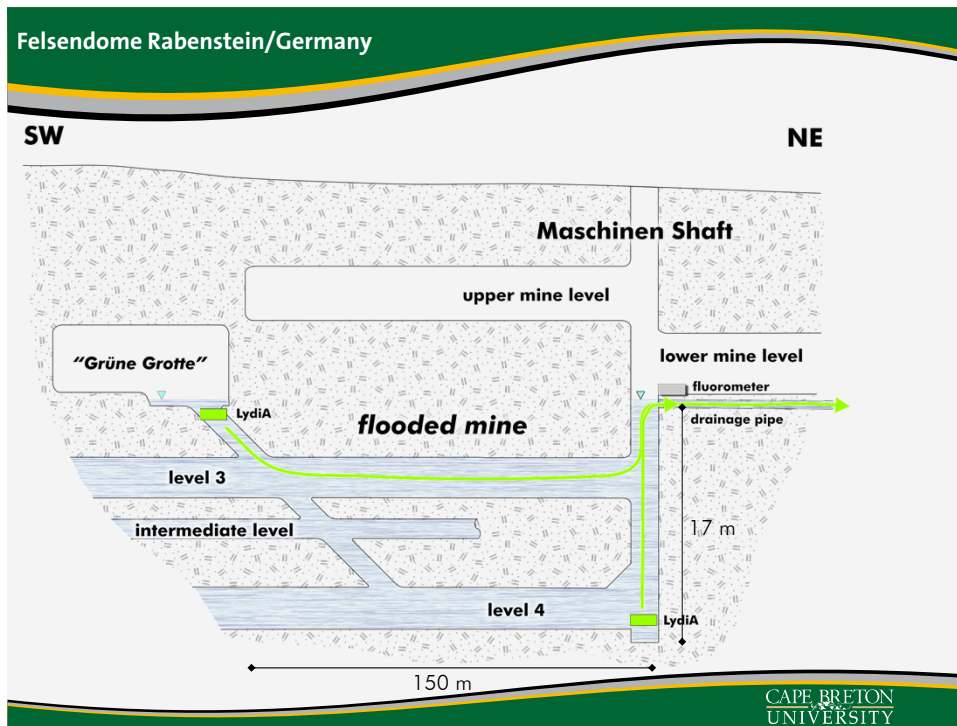
Straßberg/Harz: Results Microspheres

Sampling point: Fluor shaft

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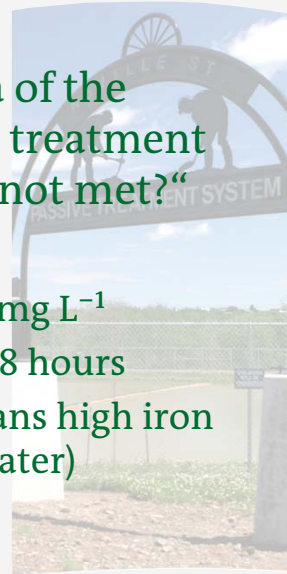
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What? – Settling Pond Passive Treatment System

- „Why are the design criteria of the settling pond in the passive treatment system of the 1B mine pool not met?“
- Design Criteria:
 - Fe_{tot} at point of discharge $< 1 \text{ mg L}^{-1}$
 - Minimal residence time: 15–18 hours
 - Low filter residue (which means high iron oxide content in discharge water)



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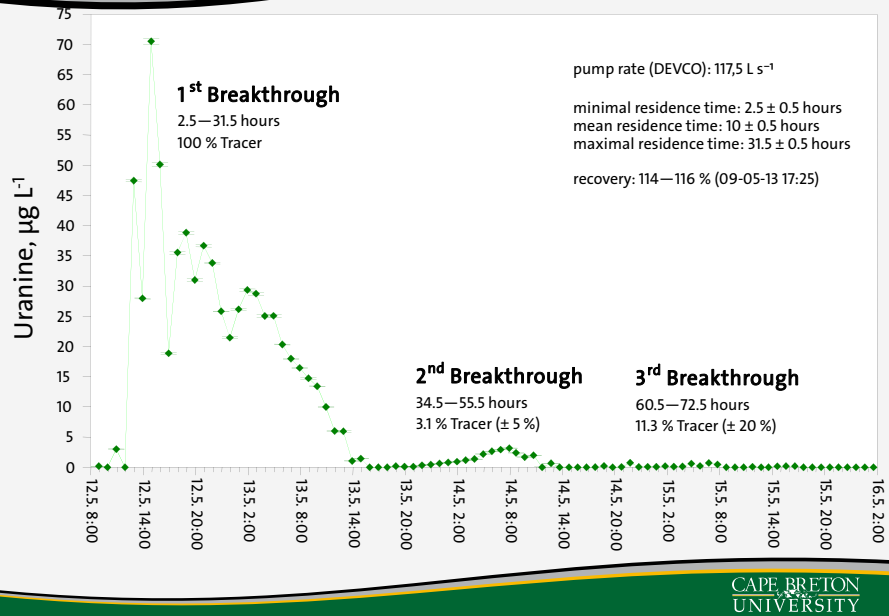
What? – Settling Pond Passive Treatment System



Settling pond 2009-05-12

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What? – Settling Pond Passive Treatment System



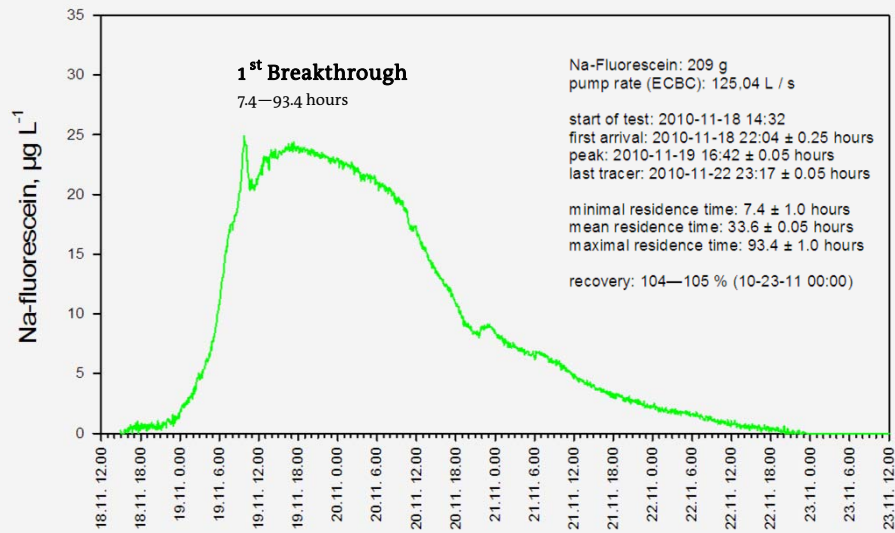
What? – Settling Pond Passive Treatment System — With baffle sheets



Settling pond 2010-06-21

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What? – Settling Pond Passive Treatment System – 2nd test



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Future developments for mine water tracer tests

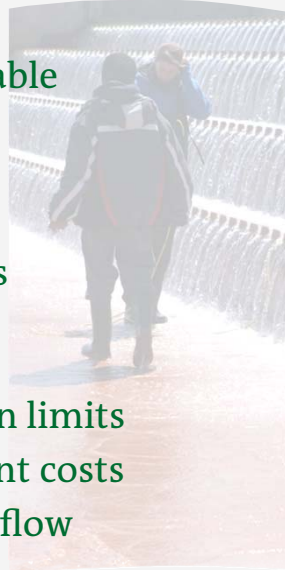
- Improved LydiA-Technique
 - Injection into wells (“TinA”)
 - Sampling optimisation
- Improved analytical techniques for Microspheres
 - Field counter for mine water environment
 - Use of solvents for microspheres
- DNA tracers



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Conclusions

- Several tracers groups are available for mine water tracing
- Tracers have to be chosen on a case to case basis
- Avoid use of extensive amounts of tracers
- Visibility limits are more than ca. 10.000 times above detection limits
- Tracer tests can reduce treatment costs
- Tracer tests help to understand flow characteristics



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The End!

Thank you
and
"Glückauf"



Walter Moers' Stollentroll

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