

**WISMUT**

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### Investigations of arsenic emissions from flooded ore mines of the Westerzgebirge region, Saxony, Germany

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### Location of former German Uranium mines

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### The problem

- Decommissioned uranium mines at Schlema and Pöhl are being flooded since 1991/92
- Mine waters treated with regard to U, Ra-226, As, Mn, Fe
- Slow decrease of dissolved arsenic concentrations, or even constant emissions
- Mines at Schneeberg, Johann'stadt exhibit high arsenic emissions decades after flooding
- No systematic investigations of As inventory of the uranium mines
- Lack of knowledge regarding As mobilization from typical arsenic minerals

Mine	Vol Mm <sup>3</sup>	Q Mm <sup>3</sup> /a	HRT a	V <sub>flushed</sub>
S	36.5	6.0	6.1	1.6
P	1.0	0.14	7.1	2.2

HRT ... Hydraulic retention time

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### Schlema and Pöhl uranium mines: U and As Measured vs. calculated dilution curves

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### Important Arsenic minerals at Schlema

**Polymetallic hydrothermal mineralisation**

- Native As, Bi, Ag / Oxides: Fe, Mn, U
- Arsenides: Fe, Ni, Co; Sulfides: Fe, Cu
- Gangue: Quartz; Carbonates

Primary Mineral	Formula	As [%]	Relative Abundance
Native Arsenic	As	... 100	~10 %
<b>Mixed Co-Ni-Arsenides</b>			
Skutterudite-Chloanthite	(Co,Ni)As <sub>3</sub>	63 - 79	~70 %
Rammelsbergite/Safflorite	NiAs <sub>2</sub> / CoAs <sub>2</sub>	~ 72	
Nicolite	NiAs	~ 56	~10 %
Loellingite	FeAs <sub>2</sub>	72	
Arsenopyrite	FeAsS	46	~5 %

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**Work done**

- | Collection of 50+ ore samples rich in As from waste dumps
- | Mineralogical and geochemical characterization of primary minerals and their weathering products
  - Reflected light microscopy, XRD, SEM, Electron microprobe
  - Bulk analysis (ICP-MS, AAS)
- | Selection of "type samples" for leach tests
- | Corrosion tests on polished sections of ore samples with periodical microscopic control (SEM/interference microscopy)
  - Surface water, Mine water
- | Batch experiments
  - Distilled water
  - Seepage water
  - Mine water, Mine water with reductive

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**Mineralogical composition of „Native arsenic“**

Mineralogical composition of 4 samples, XRD



Mineral	Sample			
	As 1	As 2	As 1_B	As 2_B
Native Arsenic	73	61	41	66
Arsenolithe As <sub>2</sub> O <sub>3</sub>	27	37	57	33
Quarz	< 1	2	2	1

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**Corrosive mass loss on polished sections**

Duration: 7 weeks  
Nomarski interference microscopy

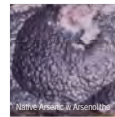
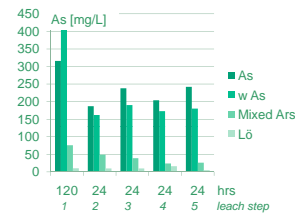


Mineral	Calculated mass loss [kg As/m <sup>2</sup> a]	
	Seepage water	Mine water
Native Arsenic (Sb depleted)	3.6	3.0
Native Arsenic (Sb rich)	2.8	3.0
Nicolite	1.4	1.3
Rammelsbergite	0.2	0.2
Safflorite	None detected	None detected
Loellingite	None detected	None detected

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**Batch experiments: As mobilization from arsenic ores with A. dest.**

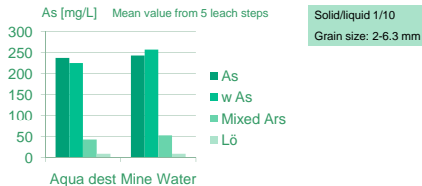


Sample	As	As w	Mixed Ars	L6
Composition	Native Arsenic, Arsenolithe	Native Arsenic, Arsenolithe	Nicolite-Rammelsbergite, minor Lo	Loellingite, w Musc, Qu, Do
As <sub>total</sub> (%)	69.6	70.8	58.1	56.4
As <sub>2</sub> O <sub>3</sub> (%)	32	33	n.d.	n.d.

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**Batch experiments: As mobilization with A. dest. vs. Mine Water**

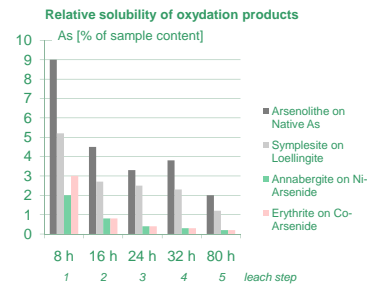


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**Solubility of oxydation products**



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### Conclusions # 1

- | Native Arsenic respectively its oxydations products main source for the arsenic loads in mine waters of Saxon ore mines
- | Substantial arsenolithe content associated with native Arsenic
- | Liability to weathering:
  - Native As > Mixed Tri-Arsenides > pure Co/Ni Arsenides > Loellingite > Arsenopyrite
- | Solubility also determined by microstructure and type of accompanying minerals
- | Arsenates less soluble
- | Arsenic mobilization seems to be independent of redox milieu of mine water

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### Conclusions # 2

- | Assessing the Arsenic potential of the Schlema mine
  - U/As ore: ~ 1/1
  - Total U resources: 100,000 t
  - Mobile Arsenic: ~ 1,000...10,000 t
  - As removed from mine (1991-2010): ~ 100 t
  - Actual As removal: 6 t/a @ 1 mg/L
- | Long term As-mobilization leading to concentrations above the authorized water quality standards will cause a long-term need for treatment

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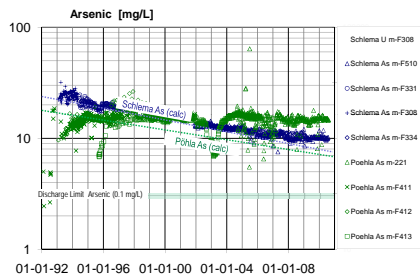


### As – a challenge

Retention time of flooded mines

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