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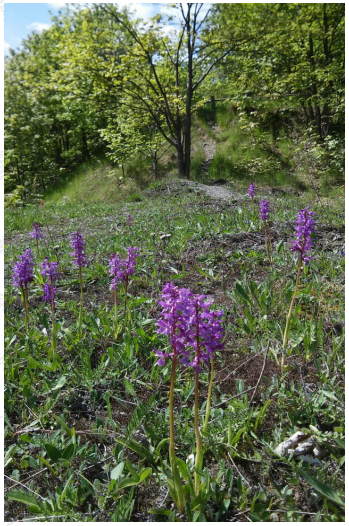

Accumulation of arsenic by various grass species growing in strongly contaminated sites affected by historical As mining and processing

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Study site
Złoty Stok, SW Poland
(formerly: Reichenstein)

- Złoty Stok, a town at the foothill of Złote Mts., was the main Silesian producer of gold (13-17th century).
- Beginning from 1709, arsenic extracted from the ores became the most important product of local mines.
- Old type ore enrichment facilities were modernized in 1930-1937 to apply an efficient flotation technology.
- Over the entire period of mining activity in Złoty Stok, ca. 1 mln. tons of ore has been excavated.
- Total amounts of procuded gold and arsenic were: 16 tons and 120 thousand tons, respectively.
- Mining and ore processing was ceased in 1962.

What has remained there?

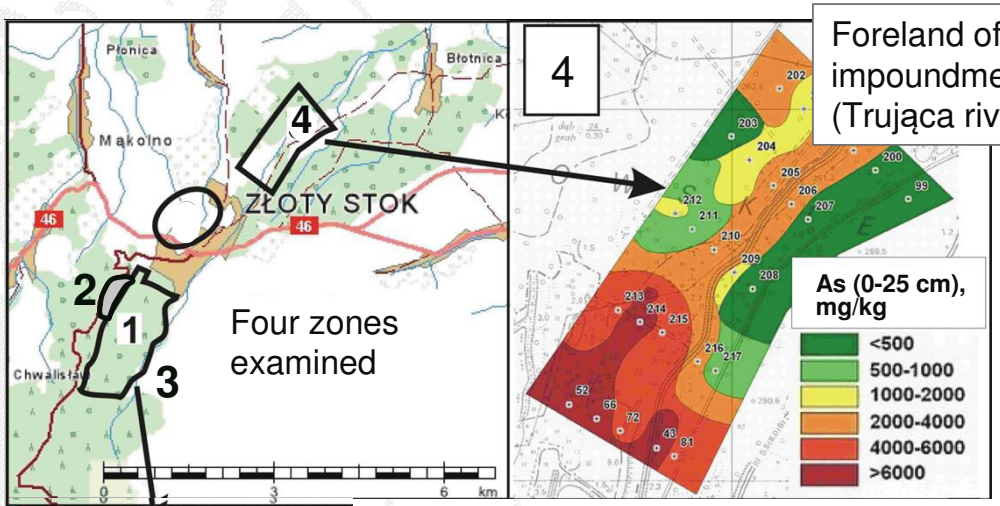
- The Gold Mine made available for turists

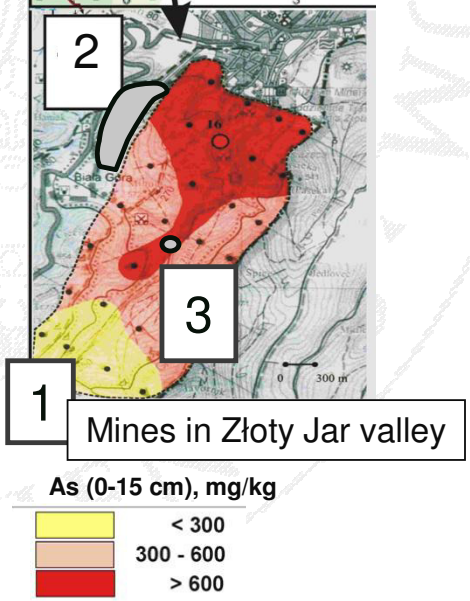
- Mine dumps

- Tailings impoundments

- Valley frequently flooded with tailings in the past, strongly enriched in As within a distance of ca. 2 km down the stream.

Soil enrichment in As in Złoty Stok





1 – Mining region (Złoty Jar valley)
soils developed of natural rocks: 194-**5450** mg/kg
soils developed on mine dumps: up to **28 300** mg/kg

2 - „Orchid" Dump (mine wastes dump) 750-**55 000** mg/kg

3 - Slag dumps : 3 100-**15 900** mg/kg

4 – Trująca valley:
foreland of tailings impoundment: 7 800-**13 300** mg/kg
floodplain soils (flooded by tailings):
(680) 4 700-**7 800** mg/kg

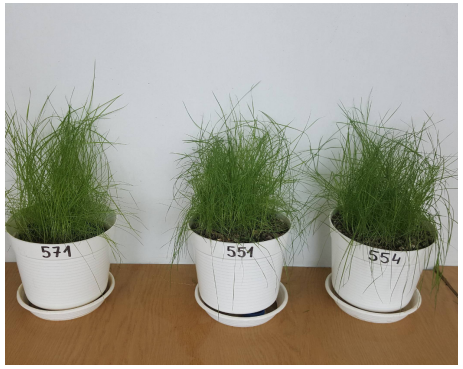
Grasses
- good candidates for phytostabilization

- Relatively large biomass
- Quick growth
- Thick root systems
- Efficient coverage of the surface → prevention against water and wind erosion
- Resistance to toxic elements present in soils
- Some species develop particular tolerance to toxic compounds
- Low root to shoot translocation factor

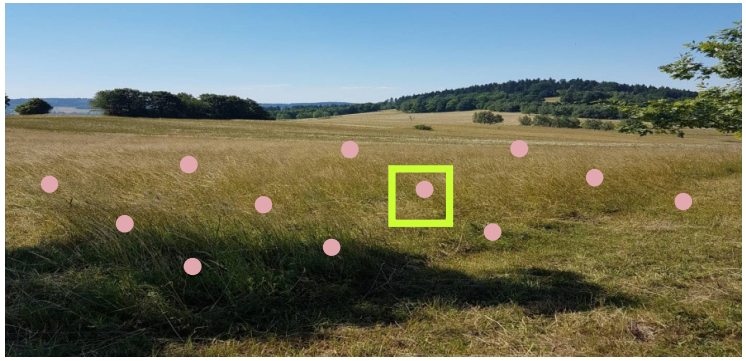
- Three species commonly ocurring in As-enriched areas of Złoty Stok:
  - Red fescue (*Festuca rubra*)
  - Yorkshire fog (*Holcus lanatus*)
  - Common bent (*Agrostis capillaris*)

The aims of this study

- Determination of As extractability in soils
- Determination of As uptake by 3 grass species commonly growing in the soils enriched in As
  - Data from the field
  - Comparison of As concentrations in shoots with a value set as safe in forage (4 mg/kg)
- Examining the effects of inorganic and organic fertilization and forest litter on the growth of grasses and As uptake
  - Data from controlled conditions (pot experiment)
- Examining the relationships between As extractability in soils and its uptake by grasses



Methods



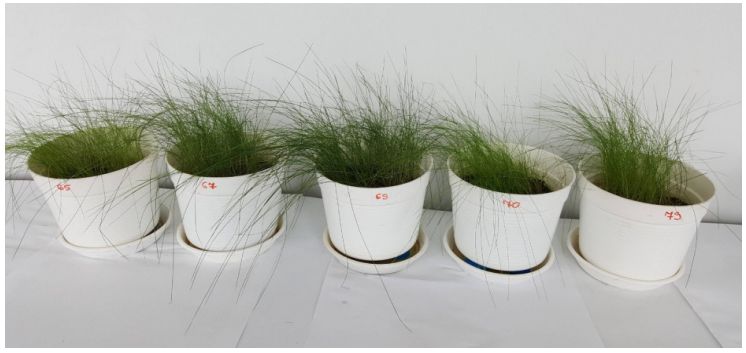
1. Field: screening

- 5 sites in Złoty Stok
- In each site → soil and plant sampling in 12 points
- Determination and separation of plant species growing in each point
- Selection of samples that represent 3 grass species chosen to this study
- In the laboratory: examination of soil and plant material
  - Soil analysis: basic soil properties, total As, 1M NH_4NO_3-extractable As (ISO 19730: 2008)
  - Plant (roots and) shoots: total As

Selection of points representative for each site → collection of soil for the pot experiment

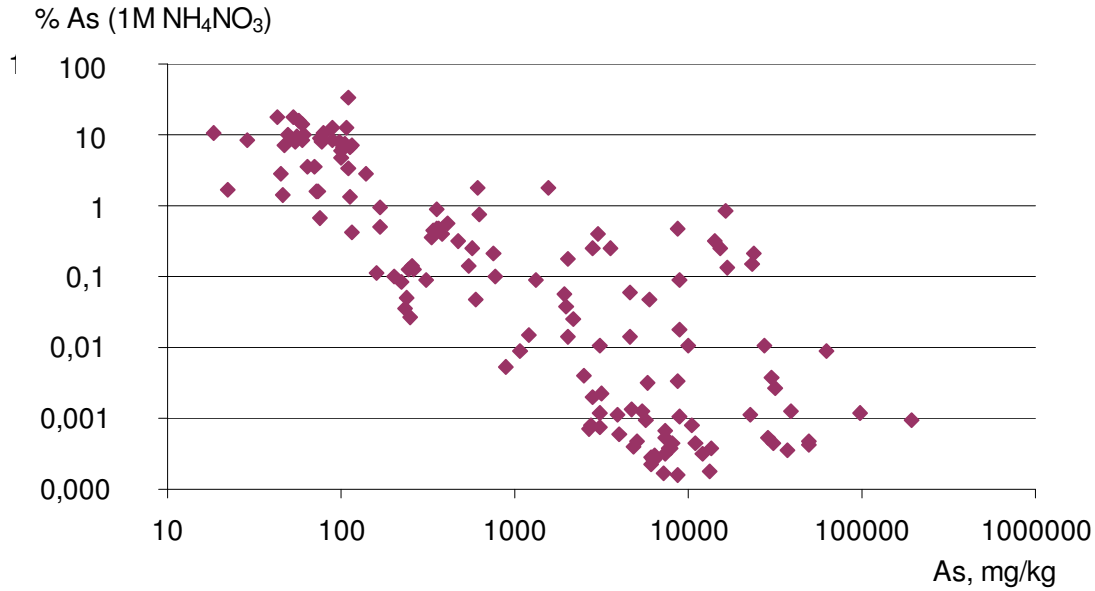
2. Pot experiment:

- Treatments:
  - control (unpolluted soil),
  - non-amended soil,
  - soil fertilized with inorganic fertilizers,
  - soil amended with organic matter (manure / forest litter)
- Growing 3 grass species; 10 weeks, 3 replicates
- Measurement of As extractability, plant biomass and As uptake (by roots and shoots)



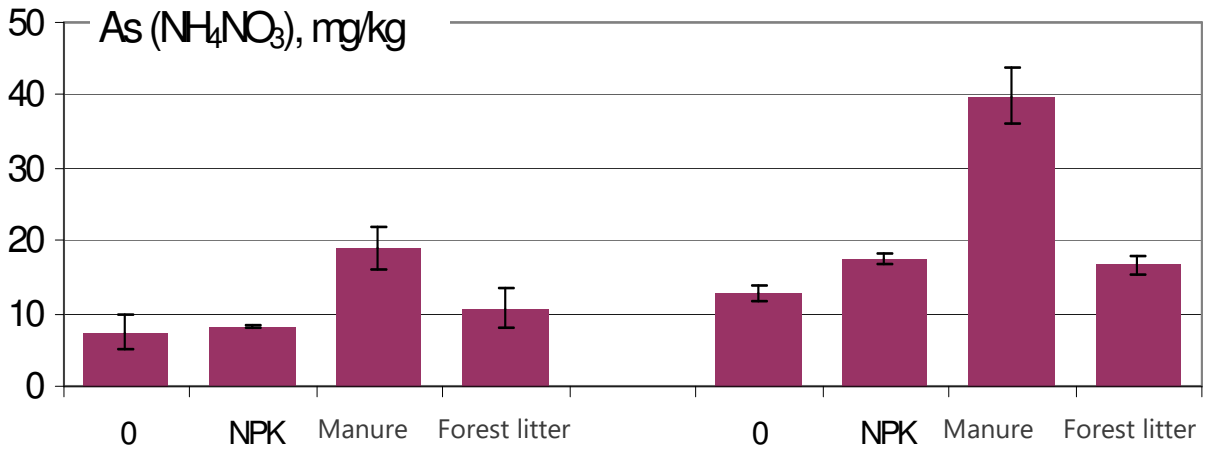
As extractability with 1M NH_4NO_3

Soil groups	As (1M NH_4NO_3), mg/kg		
	Min	Max	Median
Mine dumps (>5000 mg/kg)	0.2	**58**	3.2
Forest litter on the dumps	1.7	**135**	7.2
Tailings foreland	3.7	**37**	7.6
Other soils	<0.01	**9.4**	0.3



The effects of soil treatment with inorganic fertilizers (NPK) and organic matter (cattle manure, forest litter)

Pot experiment

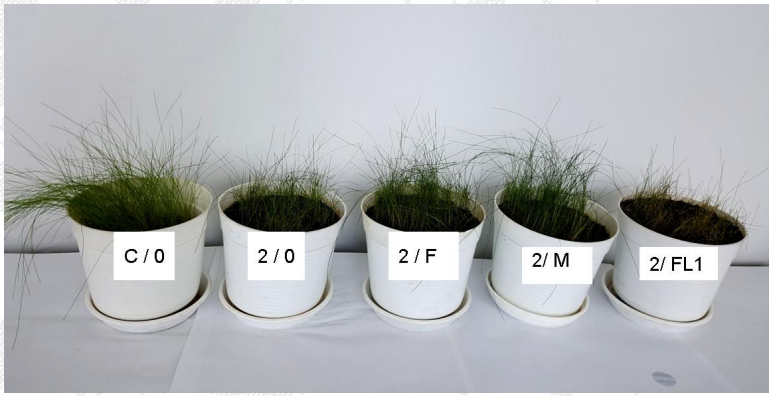


Soil No 2: Trująca valley
As: 5 250 mg/kg

Soil No 3: Foreland of tailings impoundment
As: 8 000 mg/kg

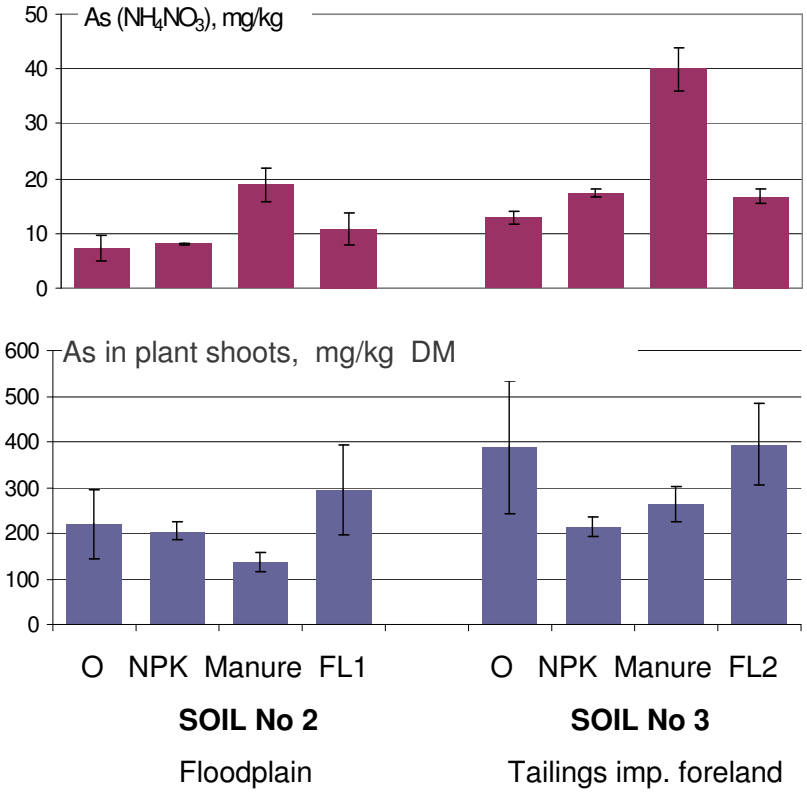
As phytotoxicity and phytoavailability in the pot experiment

Red fescue (*Festuca rubra* L.)



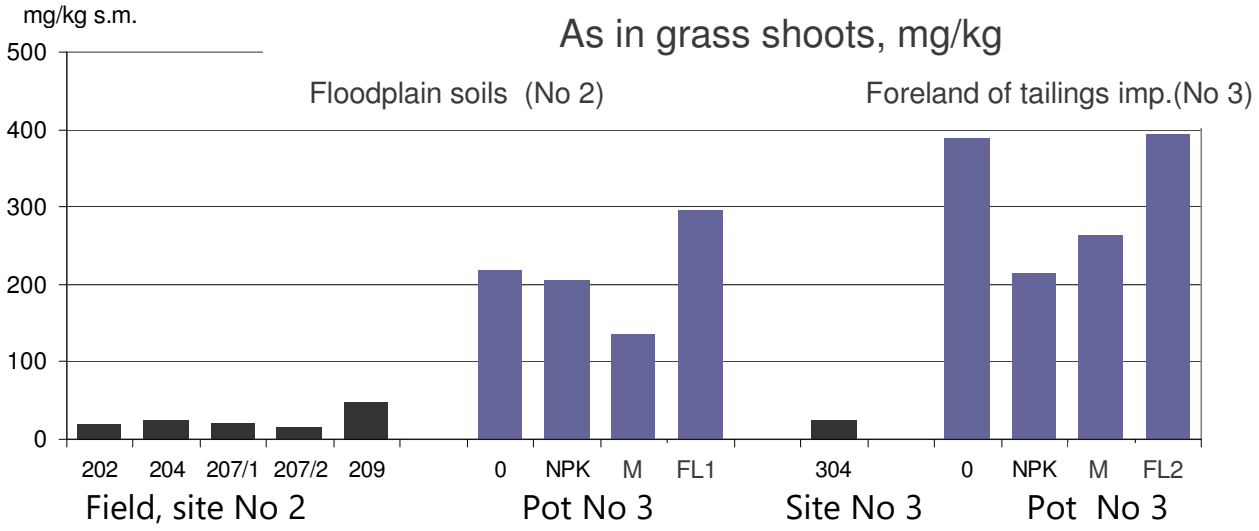
Control
(unpolluted soil)

SOIL No 2
Floodplain



As uptake by grass in the field and in the pot experiment

Red fescue (*Festuca rubra* L.)

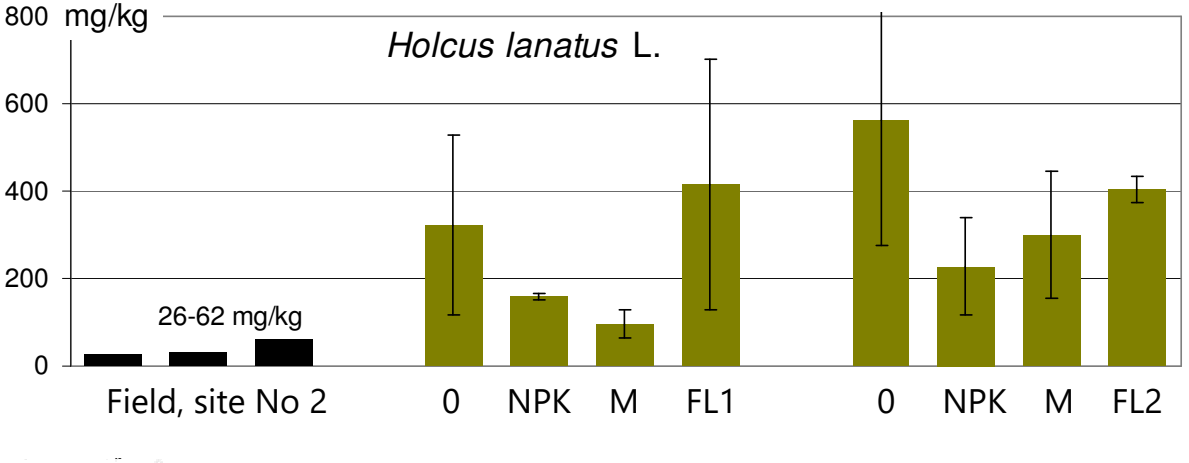


Possible explanations for those differences:

- Specific conditions in pot experiment
- Plant fenology
- Differences between cultivars
- Adaptation of plants in the field, As-induced tolerance
- ... ?

As uptake by grass in the field and in the pot experiment

2. *Yorkshire fog (Holcus lanatus* L.)



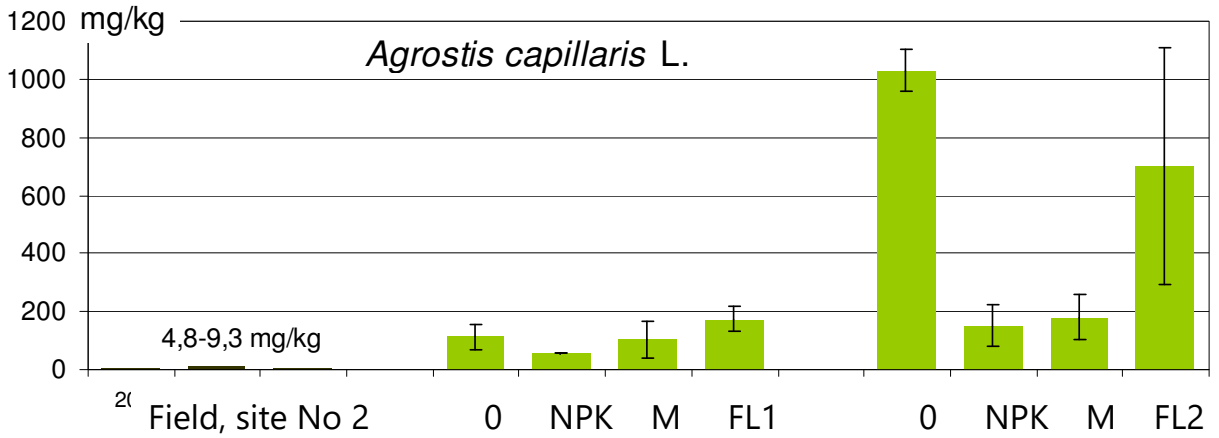
Pot experiments

Soil No 2
Floodplain
As: 5 250 mg/kg

Soil No 3
Tailings foreland
As: 8 000 mg/kg

As uptake by grass in the field and in the pot experiment

3. *Common bent (Agrostis capillaris* L.)



Pot experiments

Soil No 2
Floodplain
As: 5 250 mg/kg

Soil No 3
Tailings foreland
As: 8 000 mg/kg

The main observations:

- Soil treatment with manure increased strongly As extractability in soils but did not increase As uptake by grasses.
- Root to shoot translocation factor remained in all cases far below 1.
- The concentrations of As in plant shoots were in the pot experiment by manifold higher than those in the field.
- The maximum concentrations of As reported from the field for *F. rubra*, *A. capillaris* and *H. lanatus* were: 51, 9.3 and 62 mg/kg, while the corresponding maximum concentrations from the pot experiments were: 390, 1020 and 570 mg/kg, respectively.
- Large differences between the field and pot data indicate that the populations growing in highly contaminated sites have probably developed a specific tolerance to soil As.

Conclusions:

- Large differences between the field and pot data indicate that the populations growing in highly contaminated sites have probably developed a specific tolerance to soil As.
- Therefore, further pot experiments should be carried out with the seed material collected from enriched sites rather than with commercial cultivars.
- As concentrations in grass shoots poorly correlated with extractable As in soils. Soluble P in soils was apparently the factor that influenced As uptake by grass.
- The data from the field indicate that all the species of grass examined are As excluders and relatively good candidates for phytostabilization of As-rich soils.
- However, the concentrations of As in the shoots of grasses growing in most strongly enriched sites exceeded 4 mg/kg, the value set as a safe As content in fodder, posing therefore a risk to potential animal consumers.

Thank you for your attention !

Acknowledgements

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