Alternative biohydrometallurgical recovery of metals from sewage sludge, waste incineration residues and similar substances with hyperaccumulating plants

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Tinos 2015
3RD INTERNATIONAL CONFERENCE
on Sustainable Solid Waste Management

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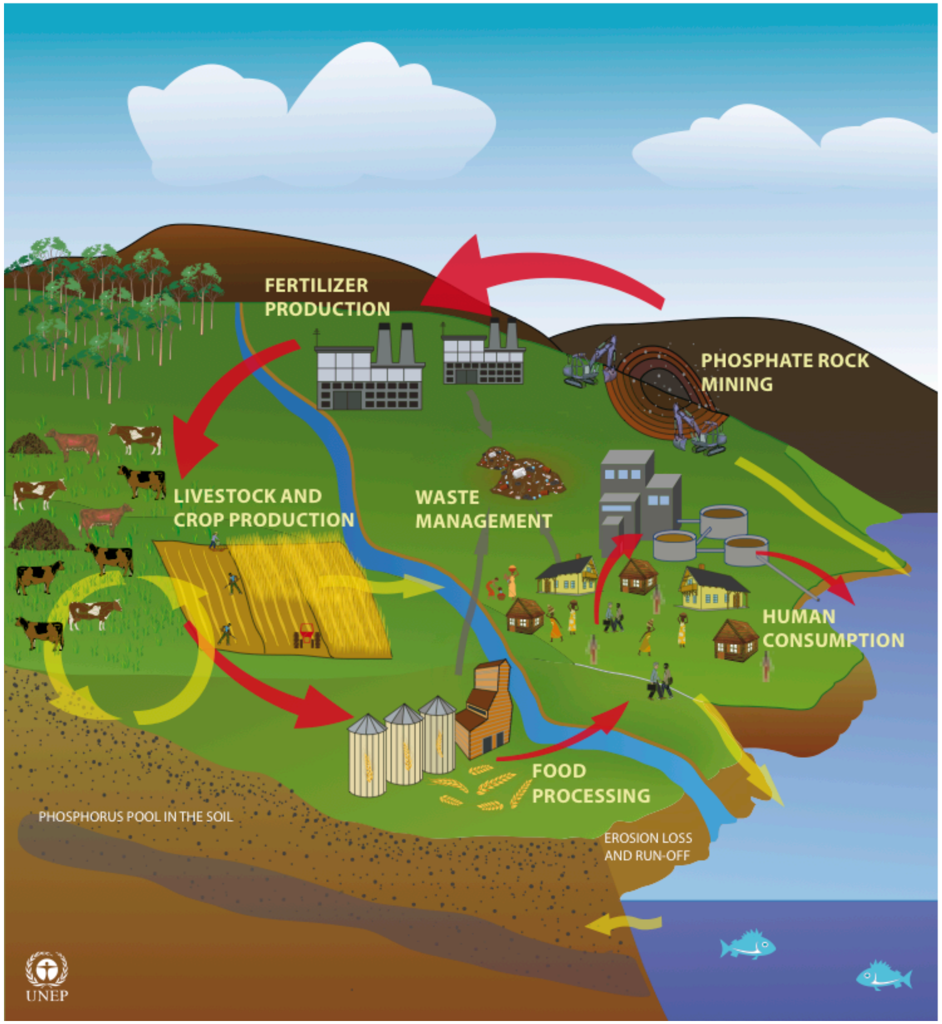
bio ore

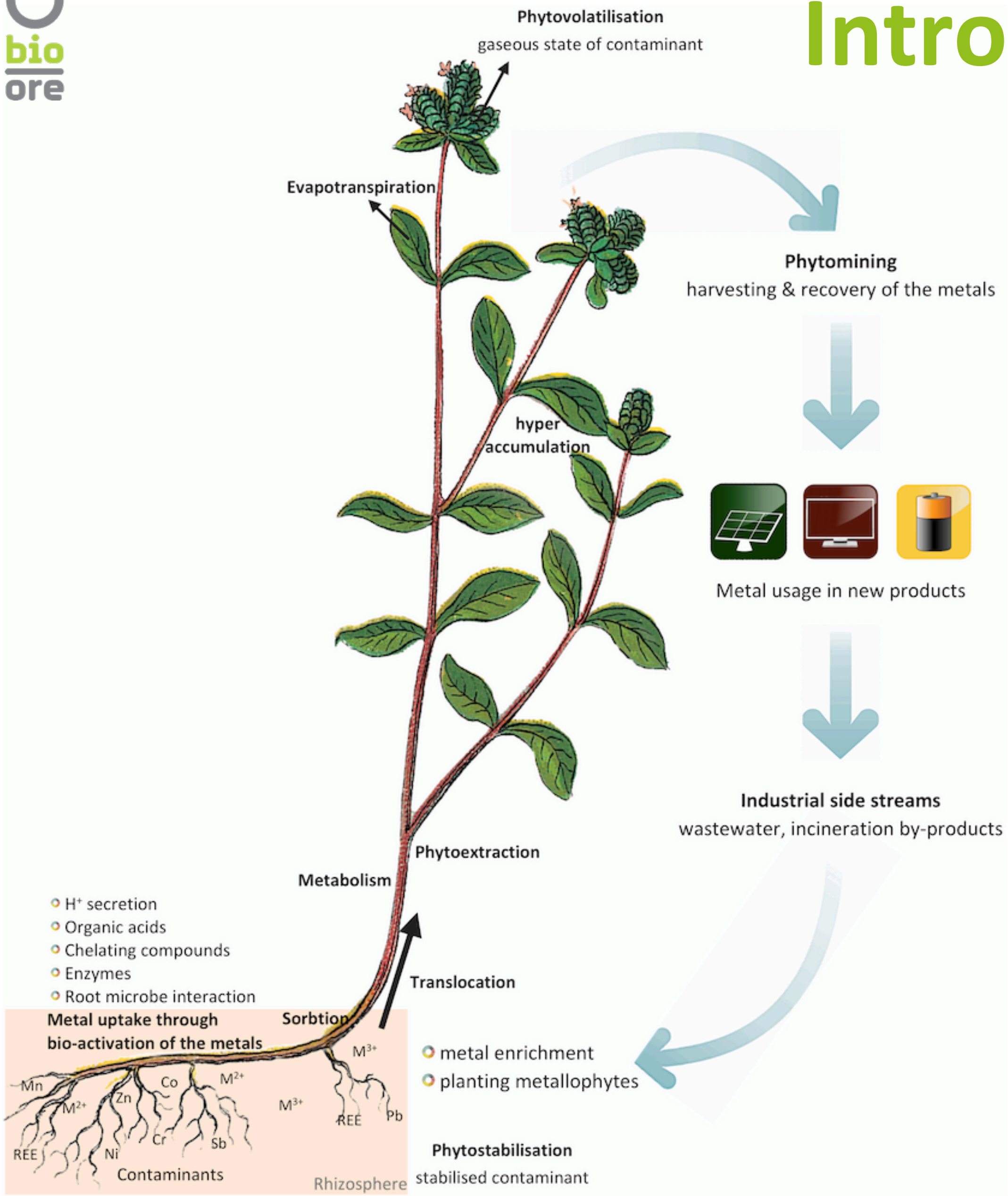
FFG
Production of the Future

Motivation



Source: UNEP Year Book 2011, Emerging issues in our global environment

- More than 90% material import
- Resource scarcity ➔ price 🡅
- Technologies to recover critical raw materials are rare and expensive
- Linear solutions are not sufficient



Introduction

- Hyperaccumulating metalophytes
- Phytomining developed from phytoremediation
- Phytoextraction of metals from substrate
- Harvesting & treating plants to gain “bio-ore”

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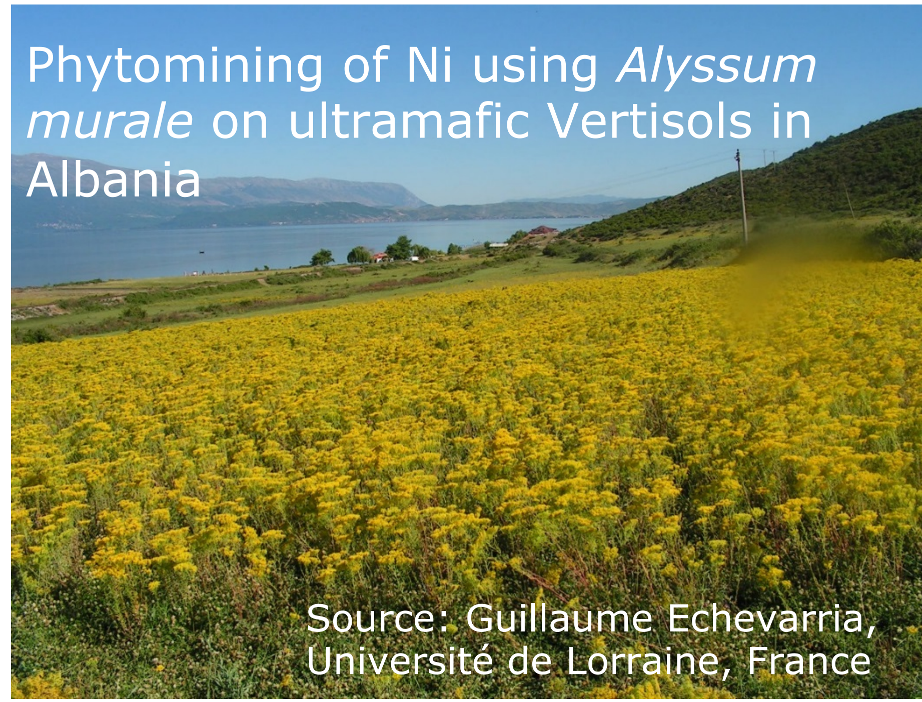
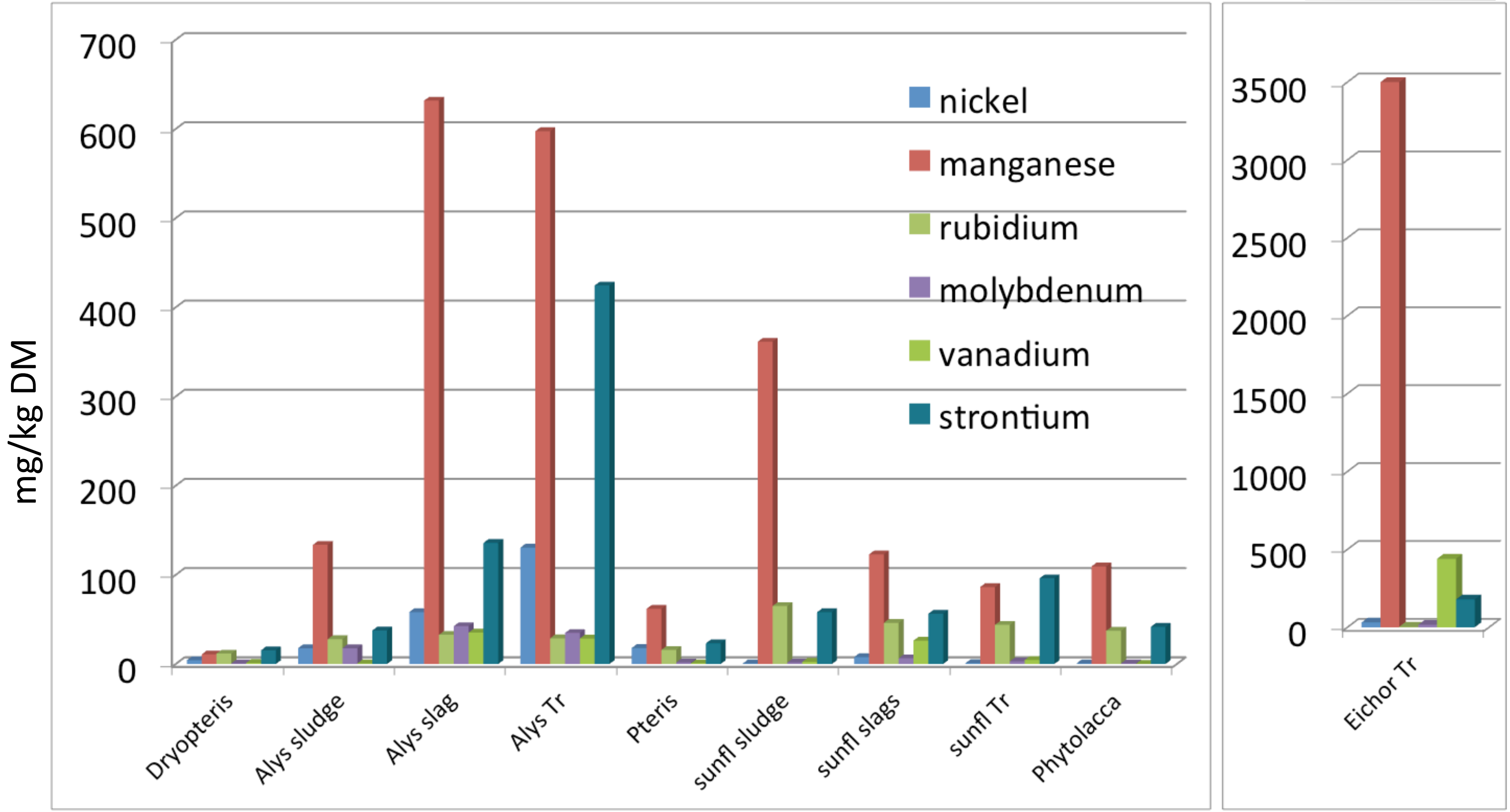
Phytomining

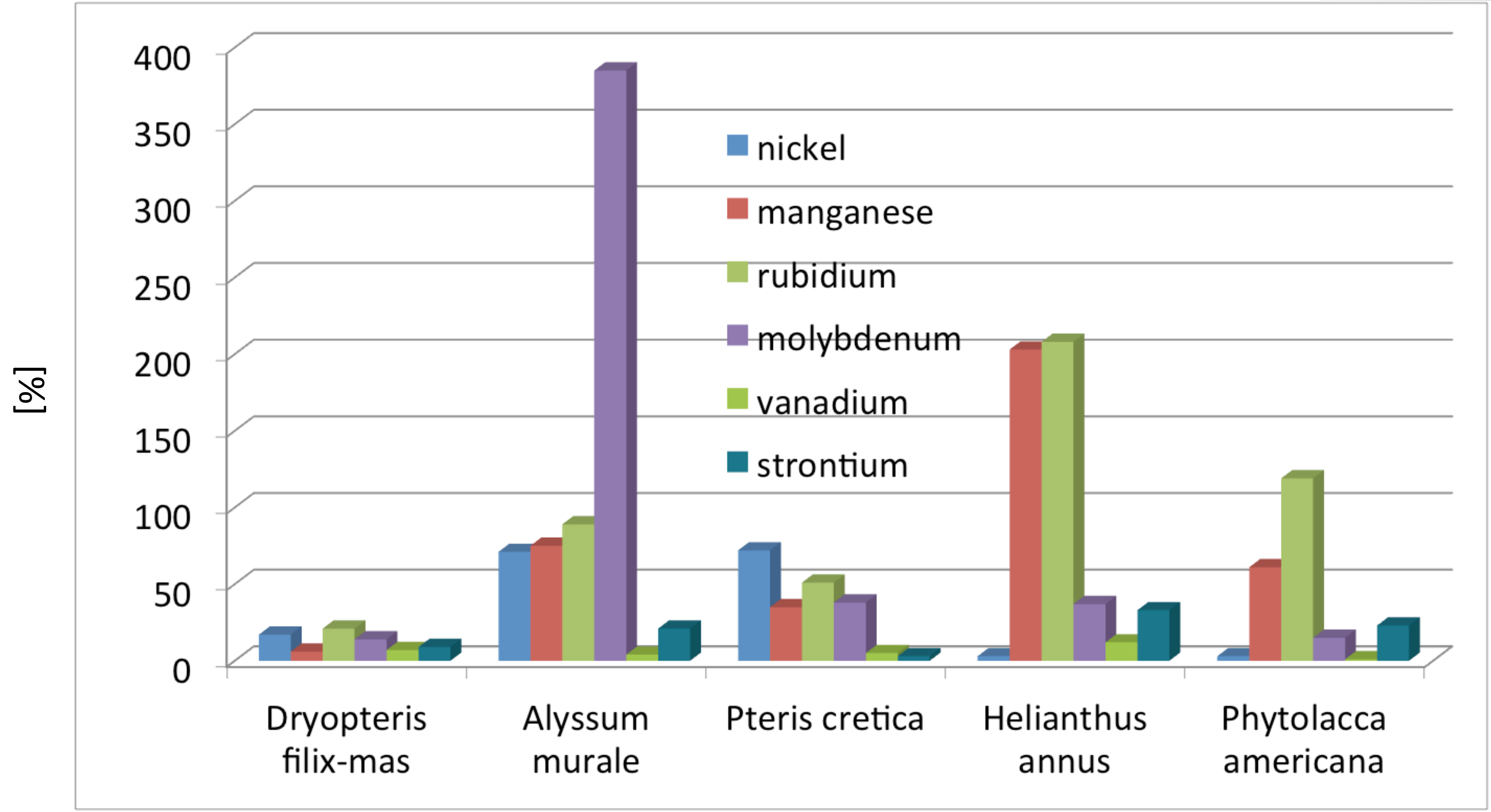
- First suggested by Baker & Brooks in 1989
- Ni extraction & biomass combustion resulted in bio-ore containing 15% Ni
- Fertiliser amendments to increase extraction
- Improving phytoextraction with
  - Increasing metal bioavailability (microorganisms, pH-decrease, chelating agents)
  - Crops themselves (species selection, biotechnology, seed coating)
  - Environmental factors - shortening growth cycle (CO_2, shade)



Absolute accumulation on different substrates from pre-trials



Relative accumulation on sewage sludge from pre-trial



Overview for sewage sludge

	Alyssum murale	*Helianthus annus*	*Pteris cretica*	*Dryopteris filix-mas*	*Eichhornia crassipes*
nickel	✓✓				✓
molybdenum	✓		✓	✓✓	
rubidium	✓✓	✓✓			✓
strontium	✓				
zinc	✓				
cobalt	✓				
manganese		✓			
vanadium				✓	
cadmium					✓
zinc	✓				✓

✓✓ high relative accumulation (5x-20x)
✓ moderate relative accumulation (1x-5x)

Value potential

sewage sludge – ashes – incinerator slags

element	amount [mg/kg]=[ppm]			price for elements or oxides [€/kg]		value potential [€/t resource]			value potential [€/a]		
	sludge	ash	slags			sludge	ash	slags	sludge	ash	slags
Rb	12,89	30,46	15,77	€ 792,00	bulk	€ 10,21	€ 24,12	€ 12,49	€ 689.099	€ 361.864	€ 1.873.476
Co	3,38	16,7	39,55	€ 20,33	oxide	€ 0,07	€ 0,34	€ 0,80	€ 4.639	€ 5.093	€ 120.624
Cr	44,6	169,7	570,5	€ 4,40	bulk	€ 0,20	€ 0,75	€ 2,51	€ 13.246	€ 11.200	€ 376.530
Mn	176	736	1653,5	€ 1,04	oxide	€ 0,18	€ 0,76	€ 1,72	€ 12.343	€ 11.471	€ 257.698
Mo	3,695	24,05	57,3	€ 15,20	bulk	€ 0,06	€ 0,37	€ 0,87	€ 3.791	€ 5.483	€ 130.644
Ni	33,1	140	200,5	€ 13,57	oxide	€ 0,45	€ 1,90	€ 2,72	€ 30.329	€ 28.507	€ 408.260
Sb	0,4	43,8	30,3	€ 7,10	bulk	€ 0,00	€ 0,31	€ 0,22	€ 192	€ 4.665	€ 32.270
V	20,2	72,5	54,65	€ 9,10	bulk	€ 0,18	€ 0,66	€ 0,50	€ 12.408	€ 9.896	€ 74.597
Zn	1000	4175	3118	€ 1,40	oxide	€ 1,40	€ 5,85	€ 4,37	€ 94.500	€ 87.675	€ 654.780
Ce	7,15	18,9	45,25	€ 5,14	oxide	€ 0,04	€ 0,10	€ 0,23	€ 2.480	€ 1.457	€ 34.875
Er	0,206	0,514	4,2315	€ 494,80	bulk	€ 0,10	€ 0,25	€ 2,09	€ 6.880	€ 3.815	€ 314.062
Eu	0,155	0,531	0,9155	€ 627,99	oxide	€ 0,10	€ 0,33	€ 0,57	€ 6.570	€ 5.002	€ 86.239
Gd	0,506	1,298	2,175	€ 35,40	oxide	€ 0,02	€ 0,05	€ 0,08	€ 1.209	€ 689	€ 11.548
Ho	0,065	0,162	0,3095	€ 144,15	oxide	€ 0,01	€ 0,02	€ 0,04	€ 632	€ 350	€ 6.692
La	4,23	12,2	28,75	€ 12,18	oxide	€ 0,05	€ 0,15	€ 0,35	€ 3.477	€ 2.229	€ 52.523
Lu	0,0213	0,0587	0,149	€ 1.887,79	oxide	€ 0,04	€ 0,11	€ 0,28	€ 2.714	€ 1.662	€ 42.192
Nd	2,76	6,73	13,94	€ 73,96	oxide	€ 0,20	€ 0,50	€ 1,03	€ 13.779	€ 7.467	€ 154.657
Pr	0,754	1,94	4,6	€ 59,75	oxide	€ 0,05	€ 0,12	€ 0,27	€ 3.041	€ 1.739	€ 41.230
Sc	1,35	2,84	2,73	€ 5.480,64	oxide	€ 7,40	€ 15,57	€ 14,96	€ 499.423	€ 233.475	€ 2.244.322
Sm	0,534	1,269	2,1955	€ 6,85	oxide	€ 0,00	€ 0,01	€ 0,02	€ 247	€ 130	€ 2.256
Tb	0,075	0,167	0,3955	€ 536,65	oxide	€ 0,04	€ 0,09	€ 0,21	€ 2.717	€ 1.344	€ 31.837
Y	1,96	7,02	15,18	€ 18,27	oxide	€ 0,04	€ 0,13	€ 0,28	€ 2.417	€ 1.924	€ 41.598
					sum	**€ 20,83**	**€ 52,47**	**€ 46,62**	**€ 1.406.135**	**€ 787.137**	**€ 6.992.909**

- **Metal content of waste incinerator bottom ash (slags)**
- **Only critical elements**
- **Slags have biggest potential**

Amount for Vienna:

Ash: 15.000 t/a (fluidized bed furnace 1-3)

Sludge: 67.500 t/a from EBS Vienna

Slags: 150.000 t/a

Bottom ash is a challenging substrate for plant growth

High pH value (up to 12.5)

High electrical conductivity (2-8 mS/cm)

Low total nitrogen content (< 1 g/kg)

Toxic levels of some heavy metals (total content
Cu= 1730-2390 mg/kg , Cr= 140-470 mg/kg
plant available fraction Cu > 2500 µg/kg Cr= 60-580 µg/kg)

Work done by Theresa Rosenkranz from BOKU

Substrate conditioning

First greenhouse trials (Theresa Rosenkranz, BOKU)

- At first treatment with diluted nitric acid to lower pH &increase N
- Leaching with deionized water to decrease salinity
- Amendments: compost (also from MBT), biochar

Field trials on landfill Vienna & further greenhouse trials

- Mixing with compost & 2 months ageing with high surface (reaction with CO_2 from air) →pH decrease

Strategies

- Known hyperaccumulators
- High biomass producing plants in favour
- Annual & perennial plants
- Landfill-endemic plants (decided after field collection & analysis)

- Intercropping strategies for rhizosphere interaction
- Aided phytoextraction with EDTA
- Interactions with microorganisms (extraction, selection, inoculation)

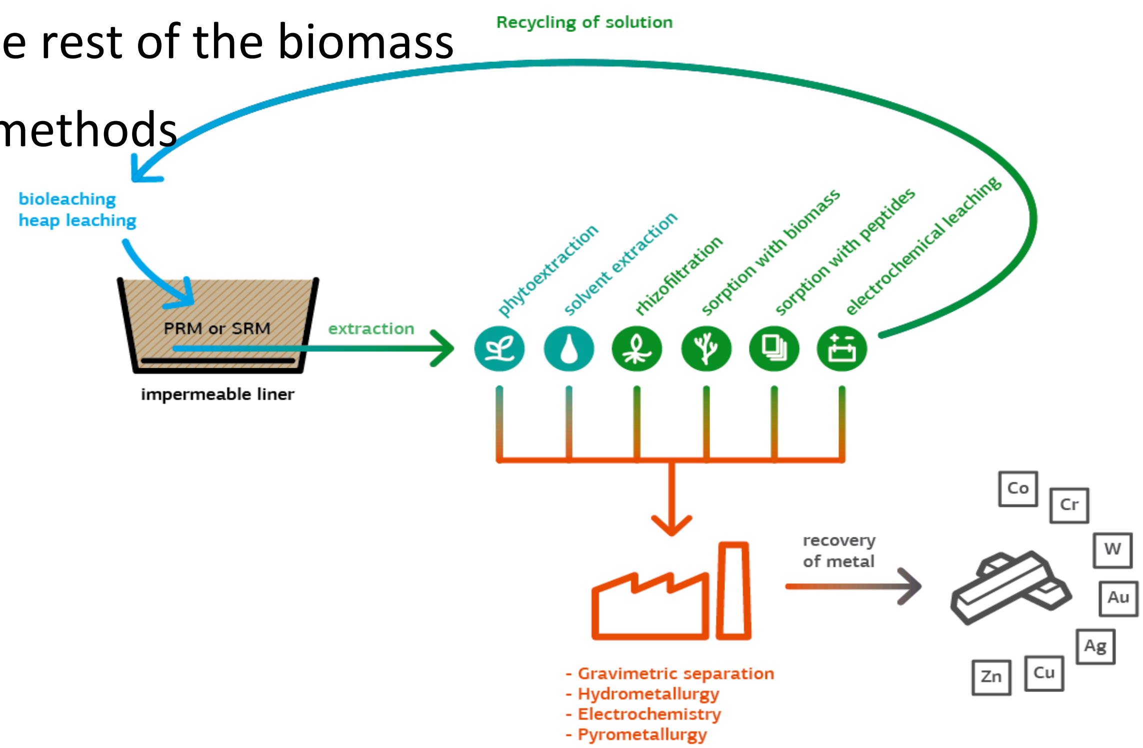
Conclusion

- Plants grow also successfully on less amended bottom ash
- Hyperaccumulators did not show expected results so far
- Package of strategies could improve uptake (ageing, EDTA, microorganisms, intercropping)
- Accumulation of some greenhouse trials with aided phytoextraction not yet evaluated
- Field trials just started, results expected this autumn
  (if goats won't eat our sprouts)

Source: MA48, municipality of Vienna

Outlook

- Screening of possible (hyper)accumulators for elements of interest also with aided phytoextraction
- Gaining biomass and recovering metals with 5 different methods (biological, physical, chemical) → Phytomining
- Possible strategies to utilise rest of the biomass
- Evaluation of all different methods
- Follow-up projects!



Thank you for your attention!

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