Recovering metals from sewage sludge, waste incineration residues and similar substances with hyperaccumulative plants

alchemia nova
institute for innovative phytochemistry & closed loop processes

IWWATV

Industrial Waste & Wastewater Treatment & Valorisation

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bio ore

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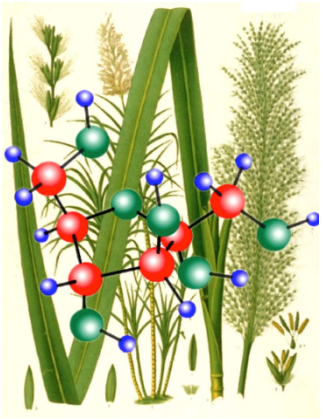
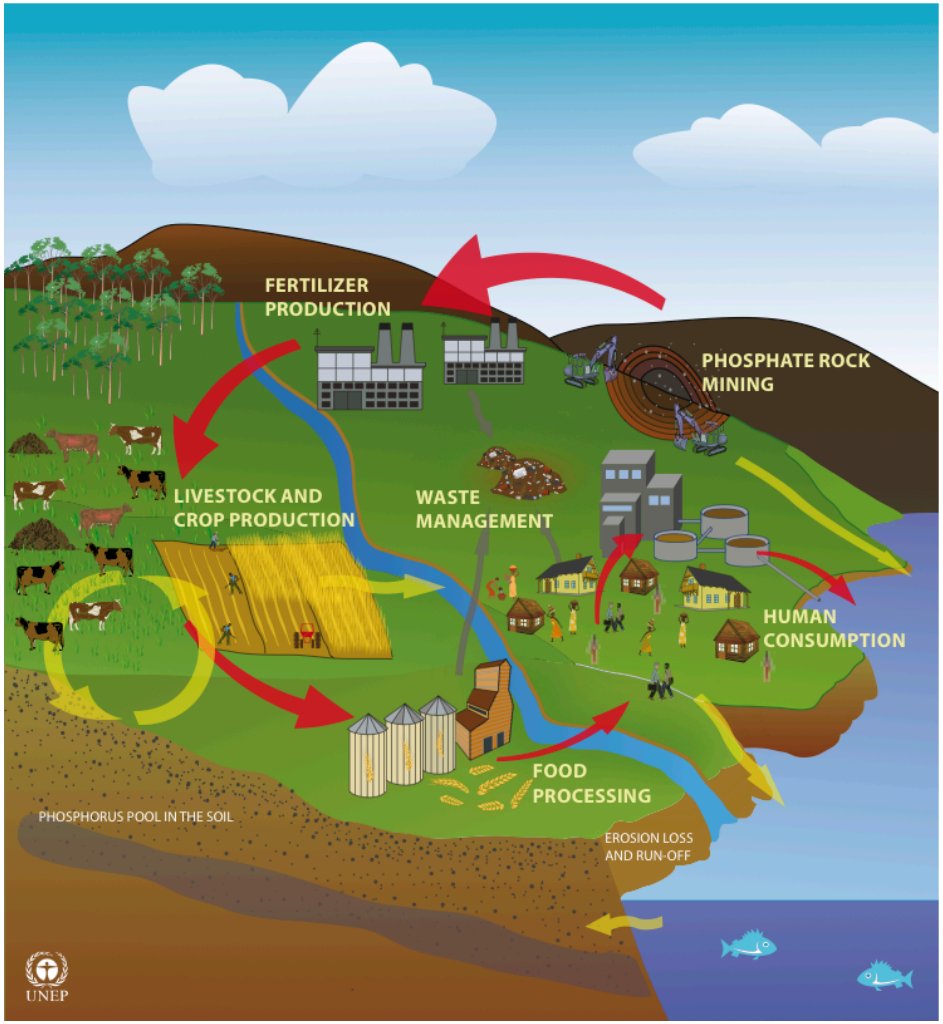
Background

- Natural resources
- Circular flow economy
- Cascading utilization strategies
- Phytotechnologies



- Consulting on waste disposal and utilization
- Evaluation of all kinds of contamination
- Environmental quality aspects
- Sampling and analysing

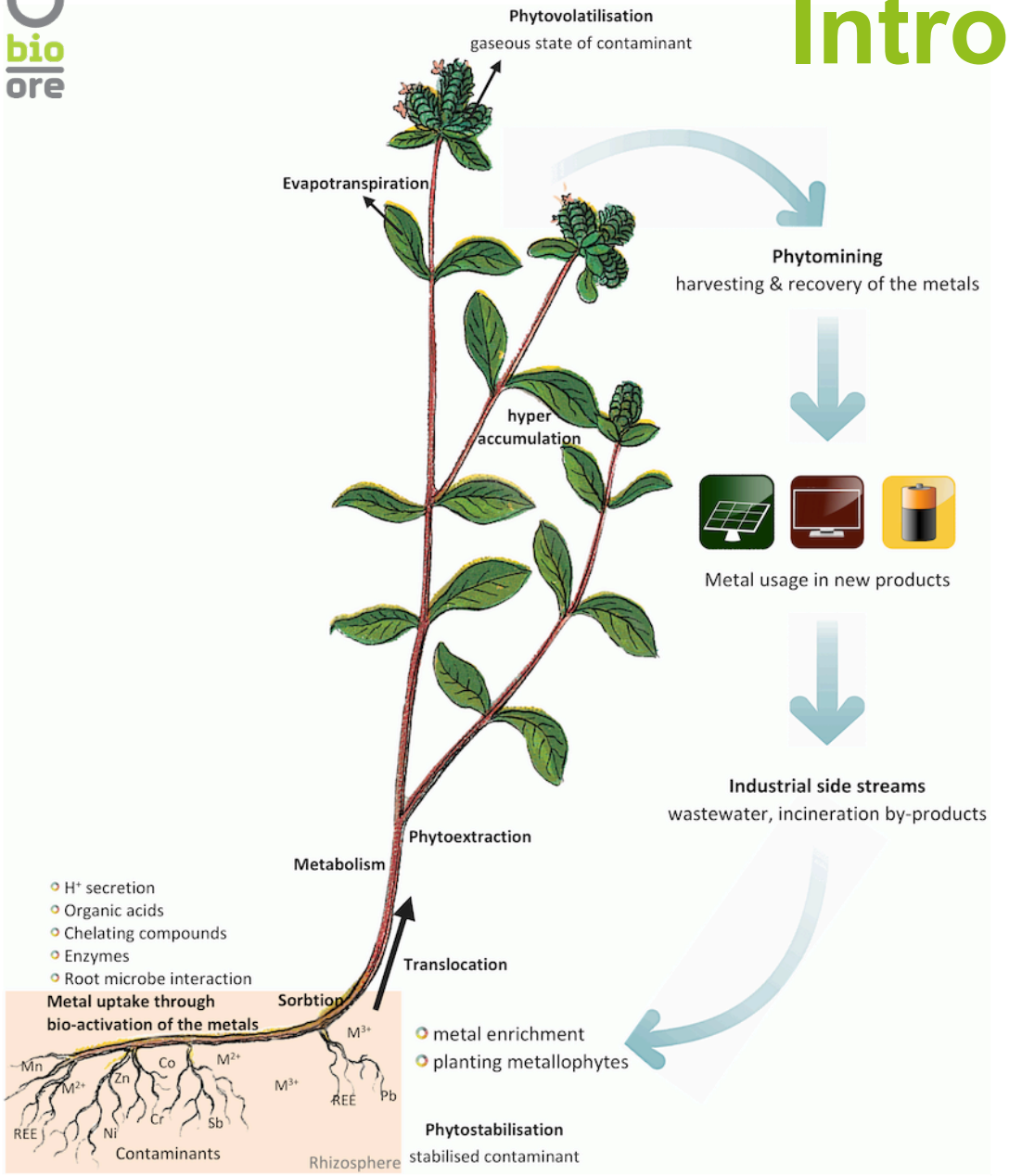
Motivation



- More than 90% material import
- Resource scarcity → price ↑
- Technologies to recover rare metals are almost non-existent
- Sewage sludge is burnt (or disposed) due to contamination with heavy metals

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

Introduction



- Hyperaccumulating metalophytes
- Phytoextraction of metals from substrate
- Removing heavy metals from sewage sludge
- Harvesting plants to gain “BIO-ORE”
- “BIO-ORE” can be utilised for metal recovery (Phytomining)

Methods

Substrate optimization

- Selected plants are member of *Brassicaceae, Asteraceae, Pontedericaceae, Pteridaceae* and *Gleicheniaceae* families
- Pre-germination of plants in normal substrate
- Mixture of 50% sewage sludge, 5% incineration ashes, sand, compost, straw clippings
- Heavy metal concentrations set limits
- Citric acid used for pH and mobilisation support

Methods

Light and water

- LED optimized for photoactive light spectrum
- All plants receive about 4200 Lux
- Deionized water to avoid further adding of metals (Ca, Mg)
- Automatic irrigation system with soil resistance sensor

Results - observations

- Sewage sludge forms hard substrate
- Soil additives are necessary
- Salts have to be washed out
- Live explodes on rich substrate
- High activity of microorganisms and insects
- High biomass producing plants are in favour

Results - 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**

Amounts for Vienna:

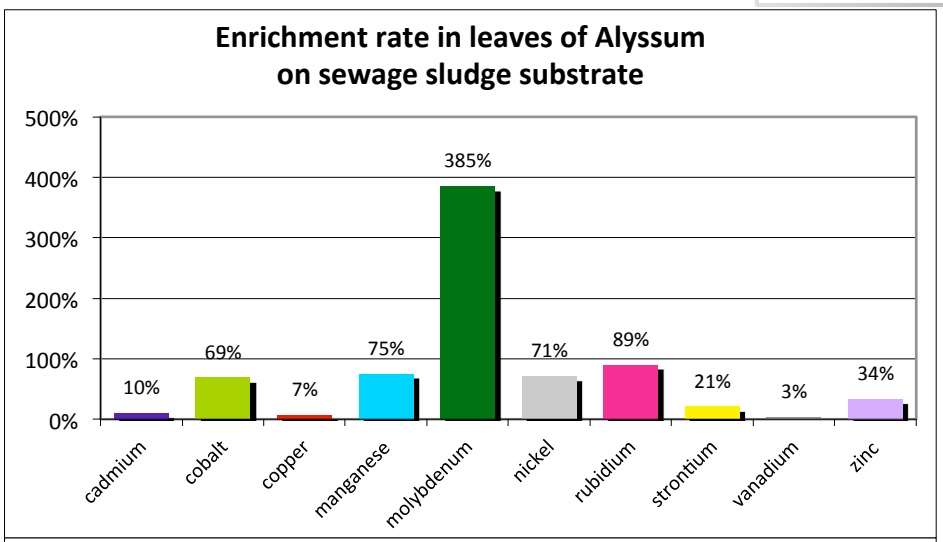
Ash: 15.000 t/a (fluidized bed furnace 1-3)

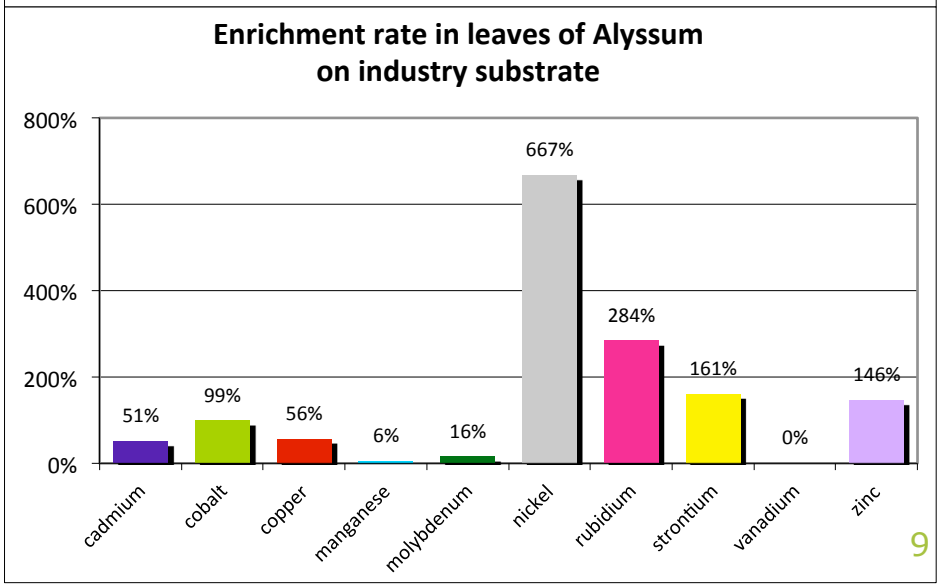
Sludge: 67.500 t/a from EBS Vienna

Slags: 150.000 t/a

Results- *Alyssum murale*

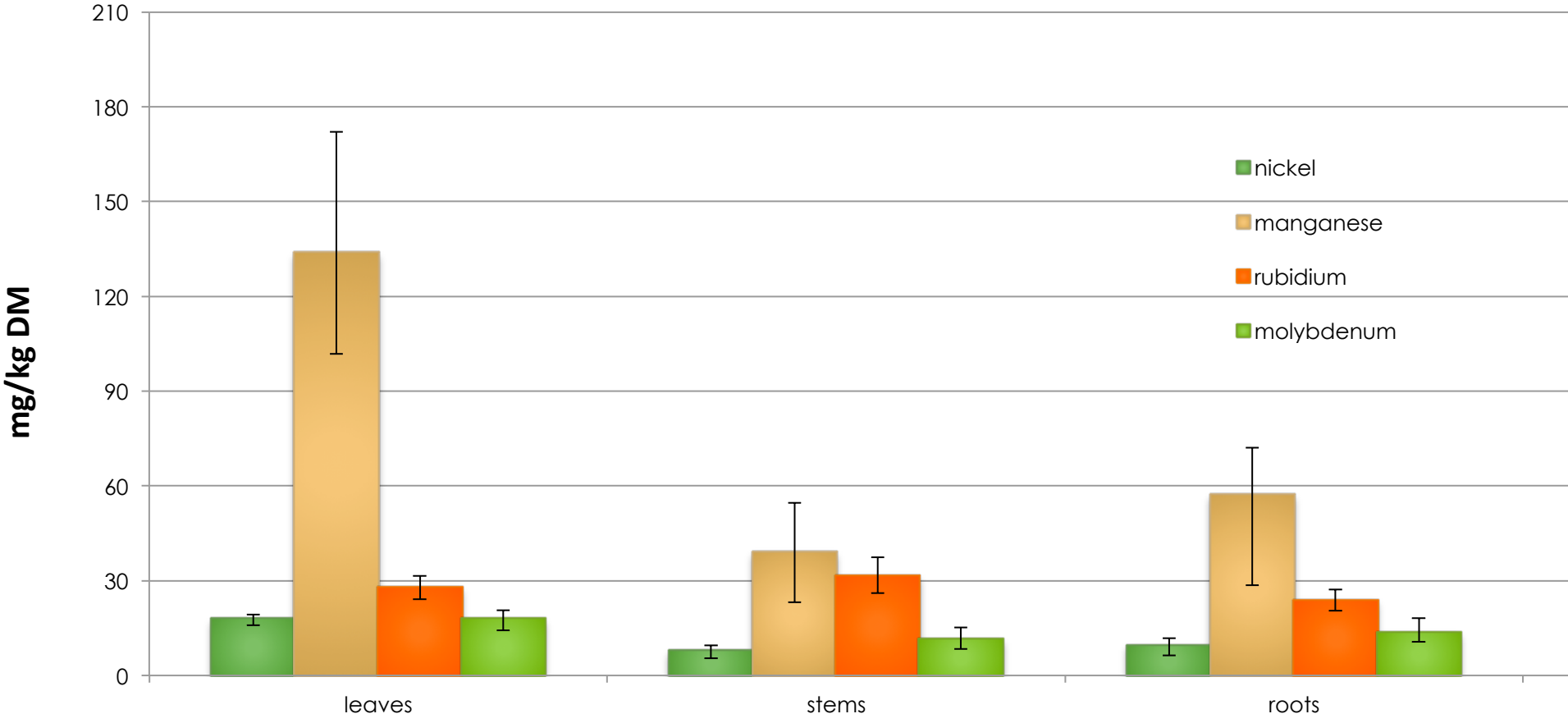
relative accumulation



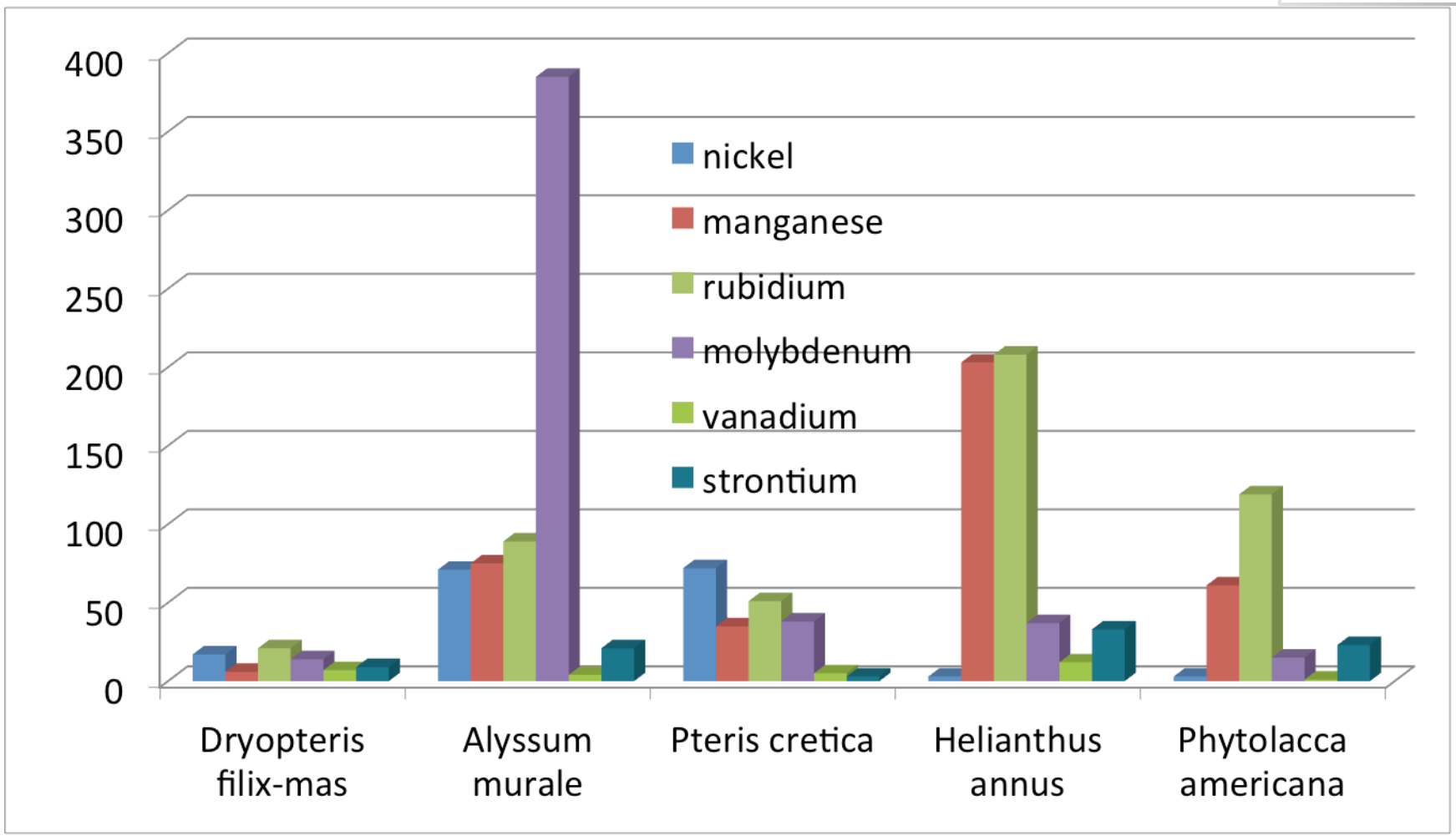


Results - *Alyssum murale*

accumulation in organs (sewage sludge)



Relative accumulation of leaves on sewage sludge



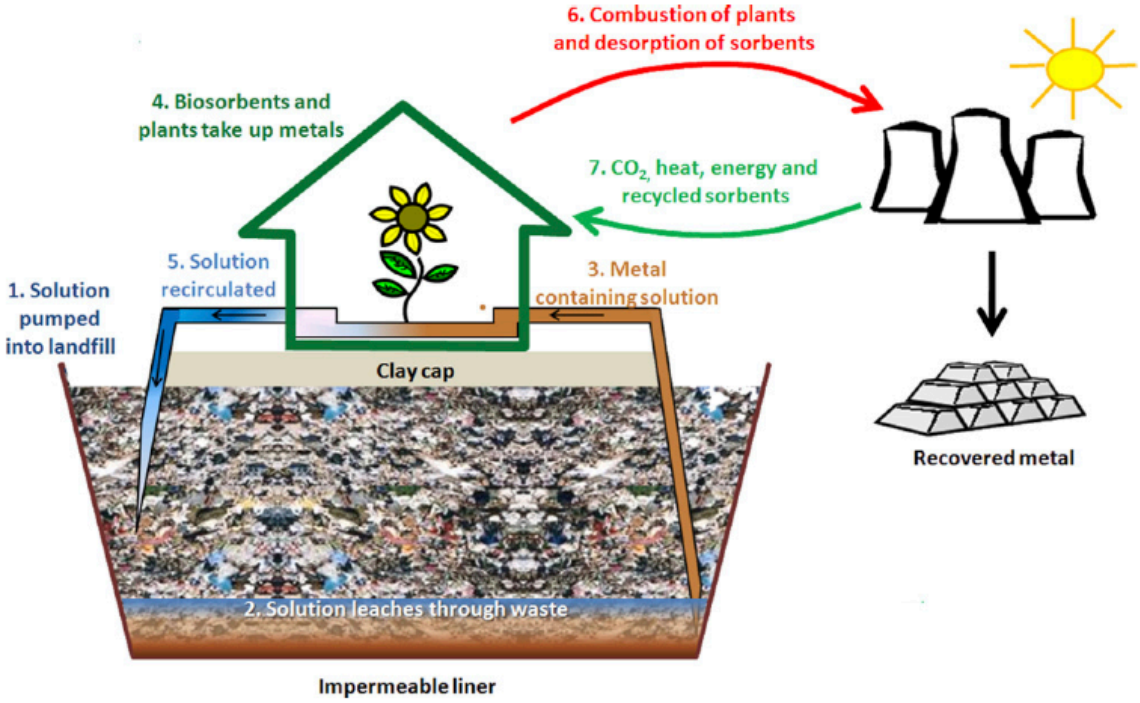
Overview

	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)

Outlook

- Screening of possible hyperaccumulators for elements of interest
- Gaining biomass and recovering metals with 5 different methods (biological, physical, chemical) → Phytomining
- Possible strategies to utilise rest of the biomass
- Evaluation of different methods



Source: J.R. Dodson et al., Chemical Engineering and Processing 51 (2012) 69–78

Thank you for your attention!

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