Fertiliser products from the precipitation from waste water: MAP from Berliner Wasserbetriebe

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Cooperation

- Berliner Wasserbetriebe (BWB)
- HU Berlin
- Landesamt für Verbraucherschutz, Landwirtschaft und Flurneuordnung (LVLF)

Topics

- Substitution of phosphorus fertilisers by residues
- Wastewater treatment
  Induced precipitation of struvite ($NH_4MgPO_4 \bullet 6\ H_2O$)
- Assessment of struvite phosphorus
  (Nutrients, heavy metals)
- Availability and uptake of recovered phosphorus
  (Plant pot experiments)
- Declaration of struvite as a new P mineral fertiliser
- Perspectives to establish struvite as mineral fertiliser

Phosphorus resources on earth

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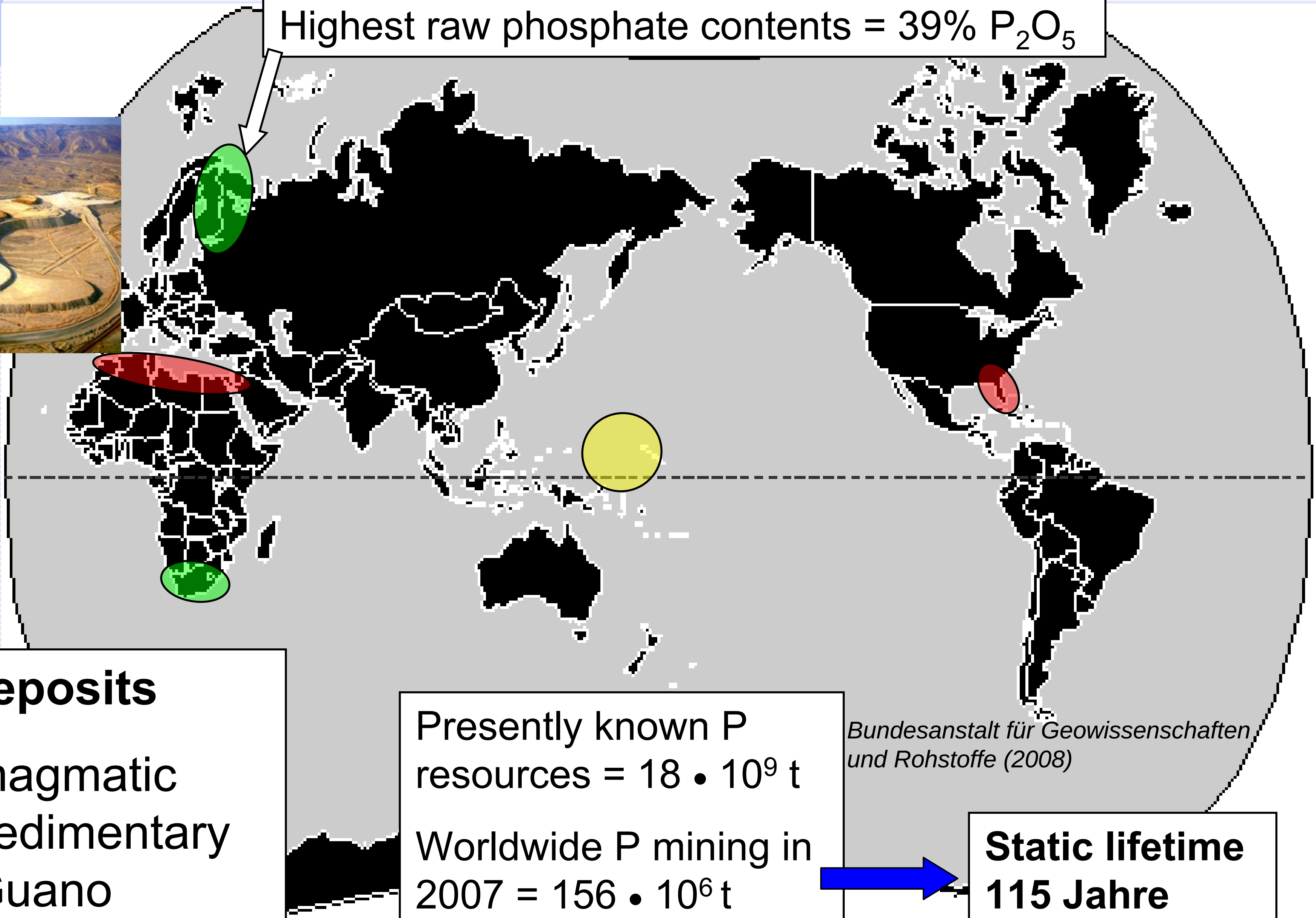

Highest raw phosphate contents = 39% P_2O_5

P deposits

- magmatic
- sedimentary
- Guano

Presently known P resources = $18 \bullet 10^9$ t

Worldwide P mining in 2007 = $156 \bullet 10^6$ t

Static lifetime 115 Jahre

Bundesanstalt für Geowissenschaften und Rohstoffe (2008)

Cadmium contents of phosporus sources

	Cd content (mg/kg P_2O_5)	Type of deposit
South Africa	0.1 - 10	**magmatic**
Russia	0.3 - 5	**magmatic**
USA	7 - 375	**sedimentary**
Jordan	12 - 28	**sedimentary**
Morocco	13 - 165	**sedimentary**
Israel	16 - 126	**sedimentary**
Tunisia	94	**sedimentary**
Senegal	161 - 336	**sedimentary**
Togo	164 - 179	**sedimentary**

Bundesanstalt für Geowissenschaften und Rohstoffe (2008)

Secondary raw material phosphorus fertilisers in Germany

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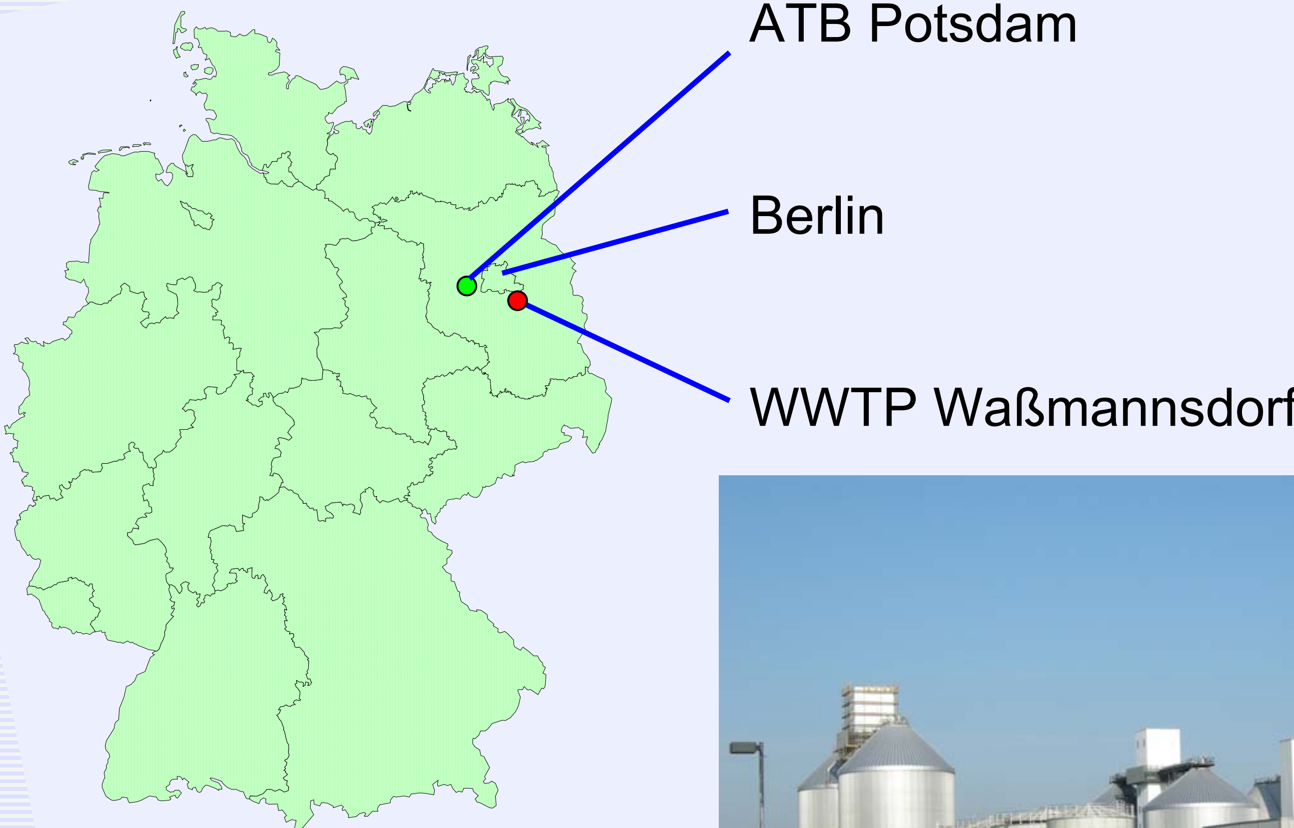
	% P_2O_5	% P	t P yr^{-1}
Sewage sludge	4.8	2.1	56,700
" ash	13.4	5.9	
" struvite	14.0	6.1	<15,000
Biowaste	1.0	0.4	15,300
Carcass meal	7.1	3.1	12,500
" ash	42.6	18.6	
Meat and bone meal	14.0	6.1	9,500

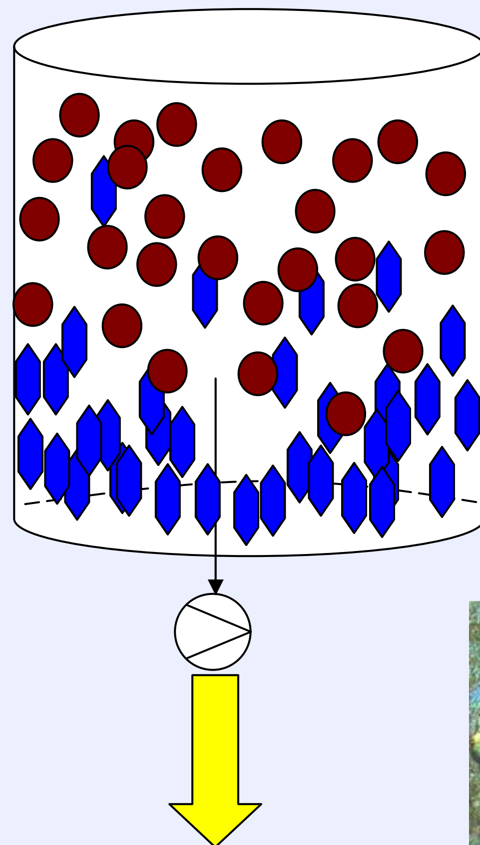
According to UBA (2003), Schirmer et al. (1999)

Contribution to phosphorus required for crop production → 15-20%

Study site in Germany

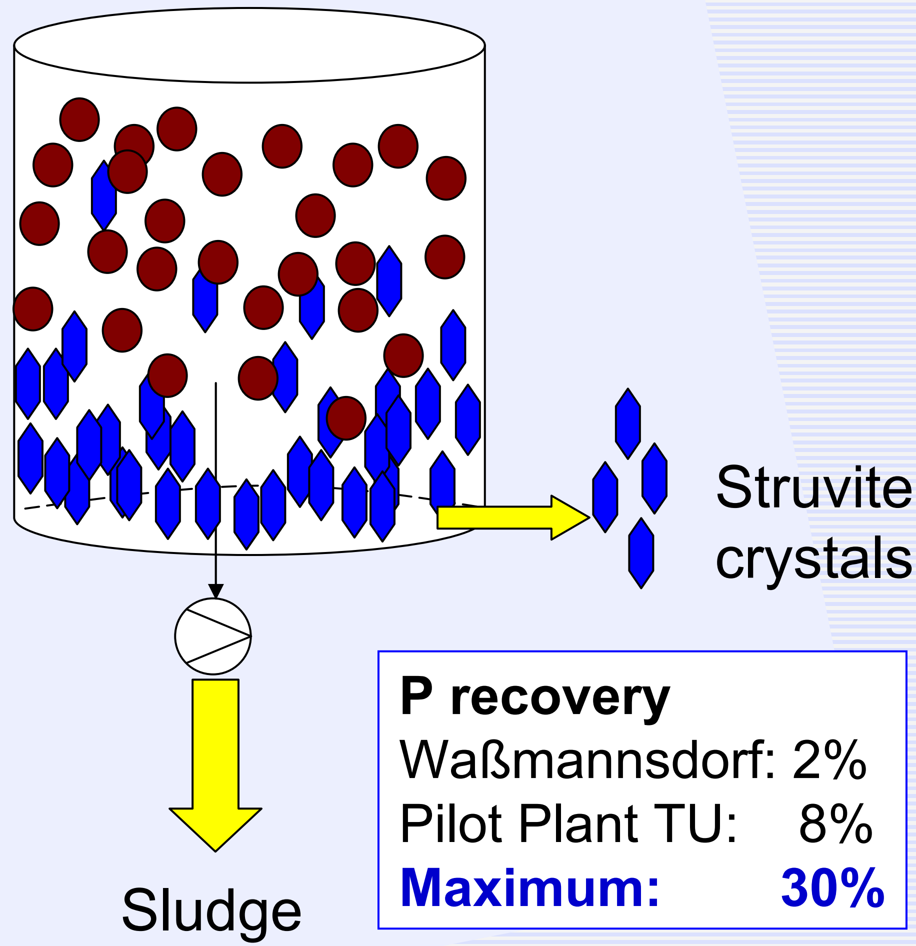


Recovery of struvite



Recovery of struvite

Digested sludge storage tank

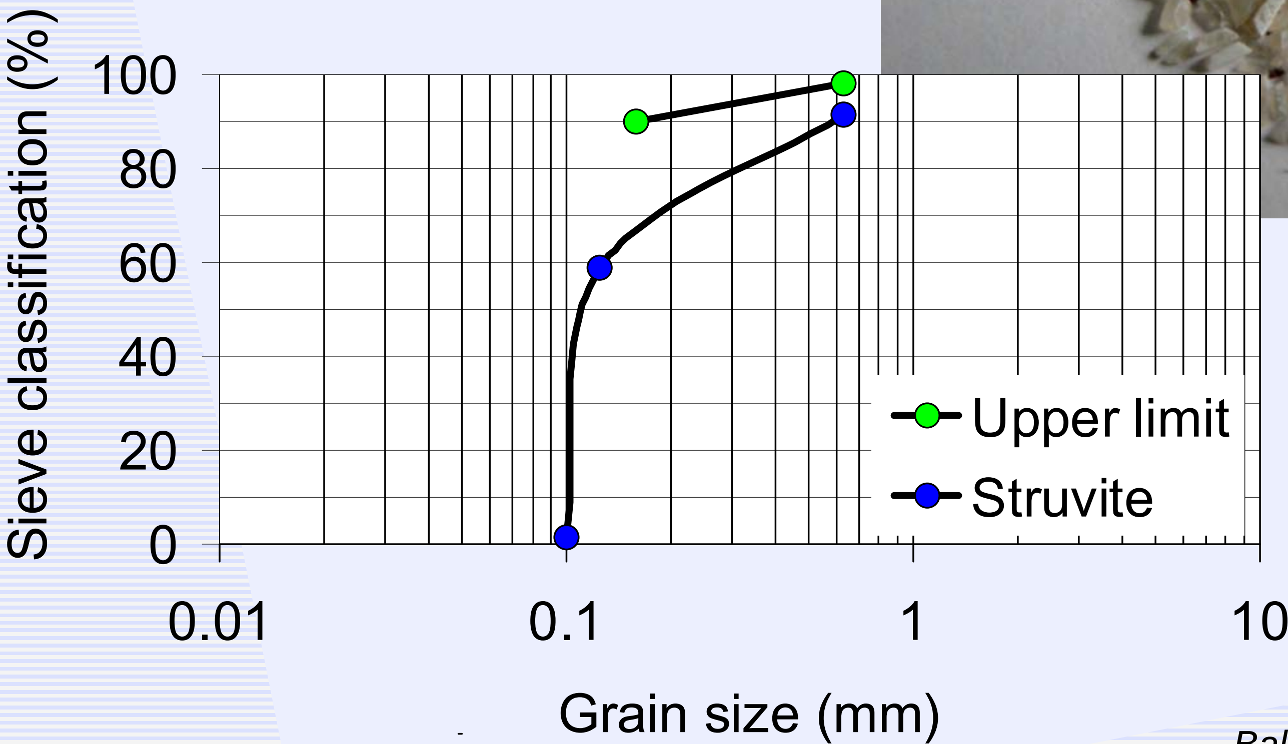


P recovery
Waßmannsdorf: 2%
Pilot Plant TU: 8%
Maximum: 30%

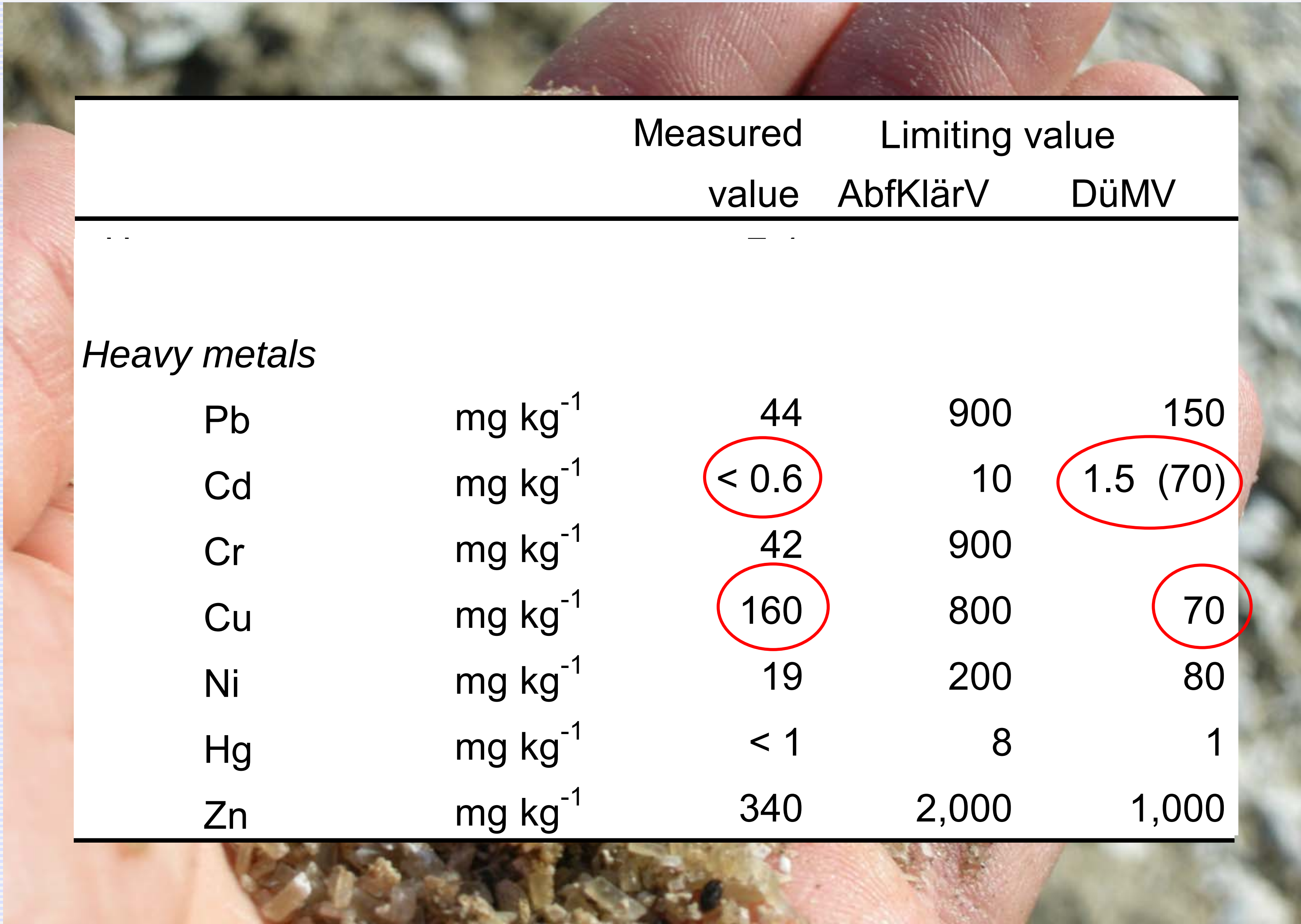
Grain size of struvite crystals

Requirements according to the German Fertiliser Ordinance:

Through fraction 98% < 0.63 mm
90% < 0.16 mm



Struvite $NH_4MgPO_4 \cdot 6\,H_2O$



		Measured value	Limiting value AbfKlärV	DüMV
Heavy metals				
Pb	mg kg^{-1}	44	900	150
Cd	mg kg^{-1}	< 0.6	10	1.5 (70)
Cr	mg kg^{-1}	42	900	
Cu	mg kg^{-1}	160	800	70
Ni	mg kg^{-1}	19	200	80
Hg	mg kg^{-1}	< 1	8	1
Zn	mg kg^{-1}	340	2,000	1,000

Assessment of recovered struvite phosphorus

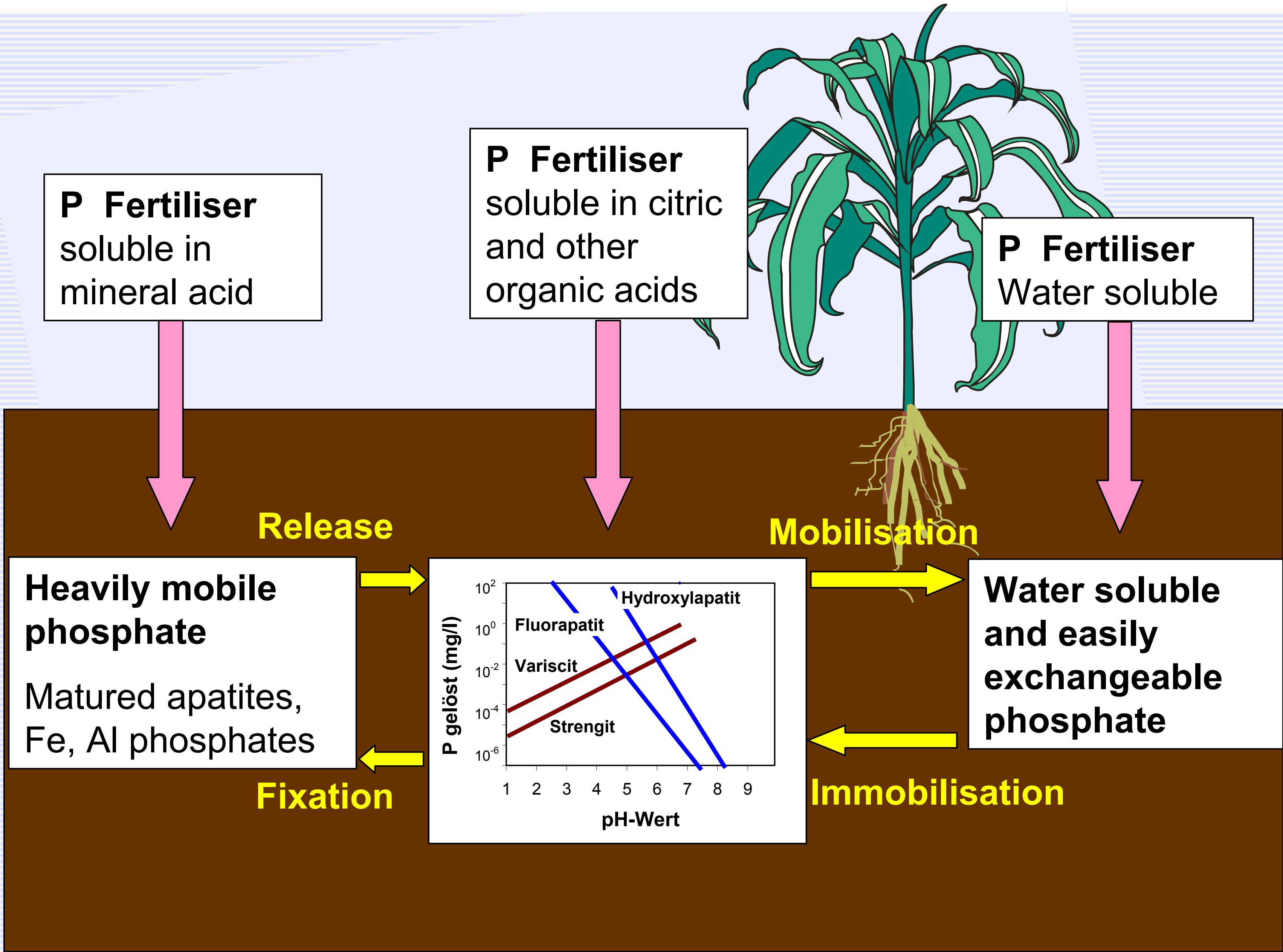
- Nutrient content
  - Phosphorus → availability ??
  - Nitrogen
  - Magnesium

- Content of toxic compounds

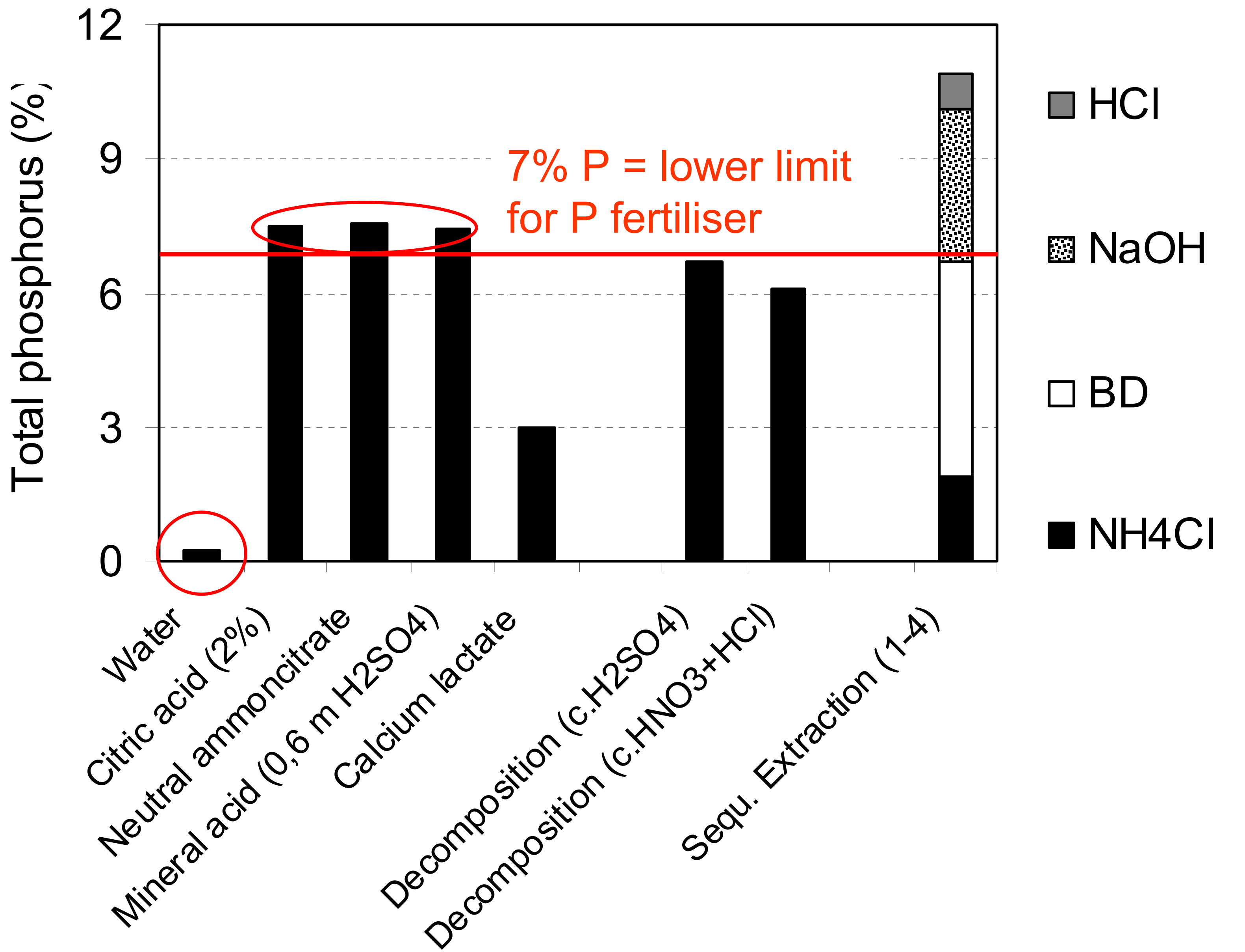
↓

Struvite produced at the WWTP at Waßmannsdorf can be characterised as partially digested raw phosphate with magnesium

Phosphorus turnover and availability in the soil



Solubility of struvite phosphorus



Assessment of struvite

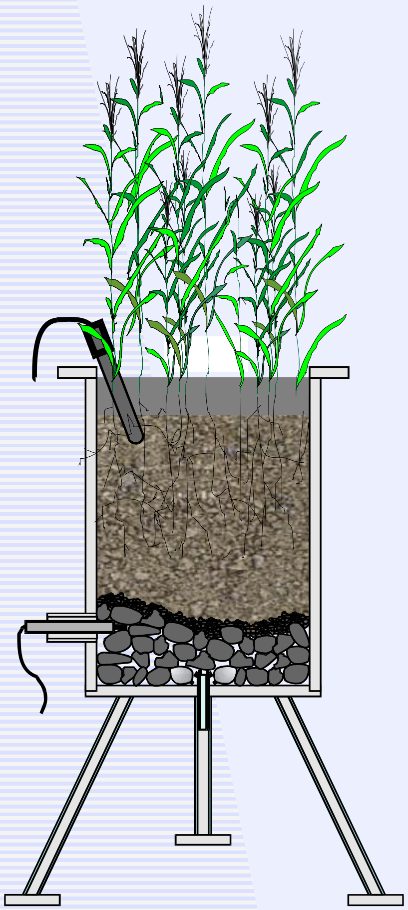
How far does struvite fulfil the requirements of the German Fertiliser Ordinance?

• Nutrient content	
Phosphorus	**+**
Nitrogen	**+**
Magnesium	**+**
• Solubility	**(-)**
• Content of toxic compounds	**(+) Cu, Zn**
• Grain size	**-**

Phosphorus availability and uptake by plants

How efficient is the plant uptake of recycled phosphorus from struvite and other residues?

Cooperation with the Humboldt University at Berlin



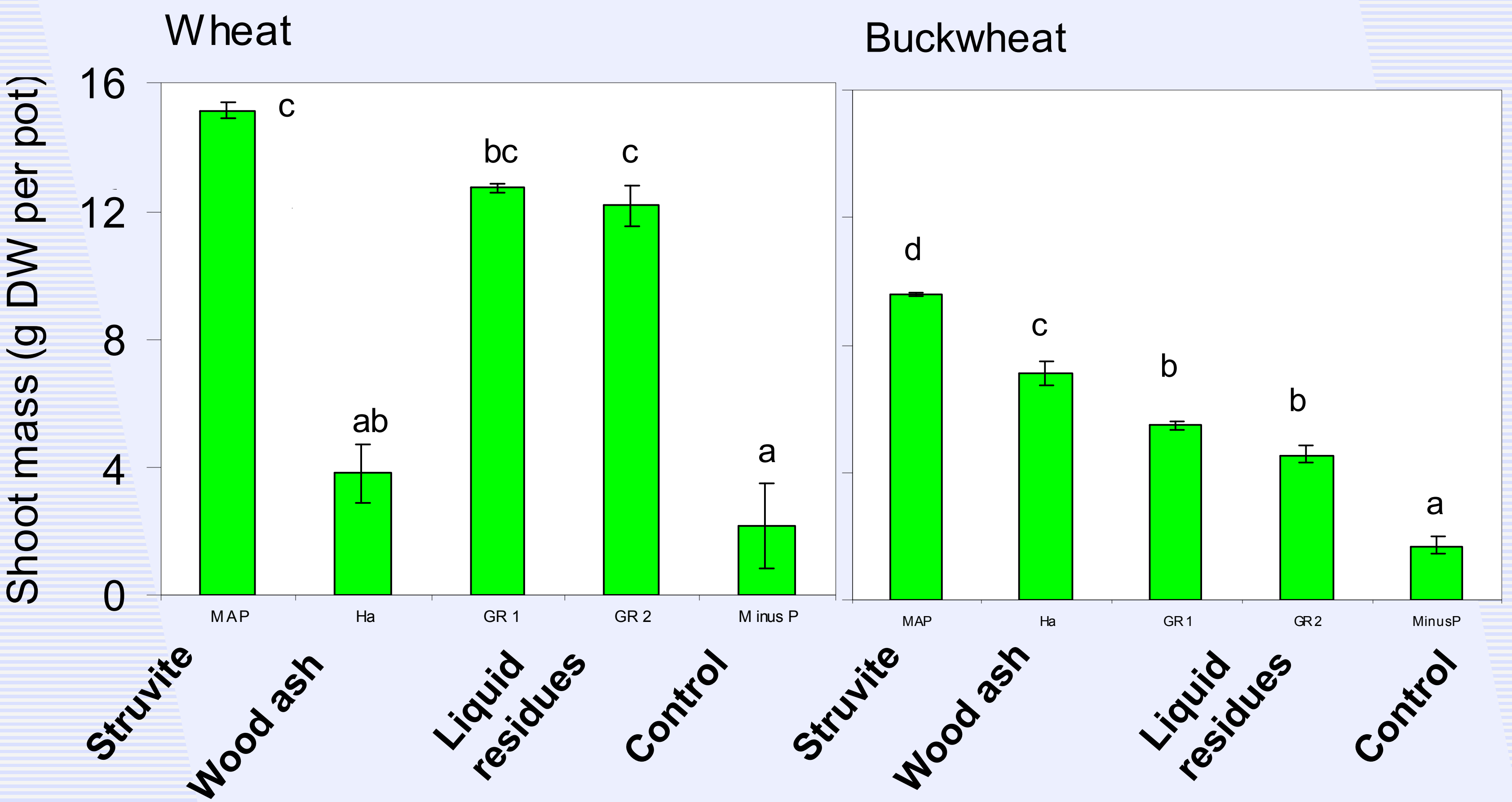
- 2.5 L pot experiments with 15 plants per pot of wheat (*Triticum* sp.), buckwheat (*Fagopyrum esculentum)* and maize (*Zea mays*)
- mixture of siliceous sand and perlite (5:1 vol.)
- uniform supply with macronutrients except P
- each pot was adjusted to 50 mg P by substrate amendment
- growth period in a greenhouse from 22.3.07-14.5.2007
- harvest 53 days after sowing
- shoots and roots were dried at 65 °C and ashed at 500 °C
- ash dissolved in 25% HCl
- P measurement at 366 nm as phosphomolybdate

Fertilisation effects on rate of germination

	Buckwheat	Wheat
KH_2PO_4	94%	99%
Struvite	94%	96%
Wood ash	92%	95%
Liquid residue	80%	78%
Control	92%	96%

Markus (2008)

Biomass production after fertilisation



Markus (2008)

Utilisation of struvite phosphorus by crops

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Agronomic efficiency of a fertiliser depends on the amount of P uptake

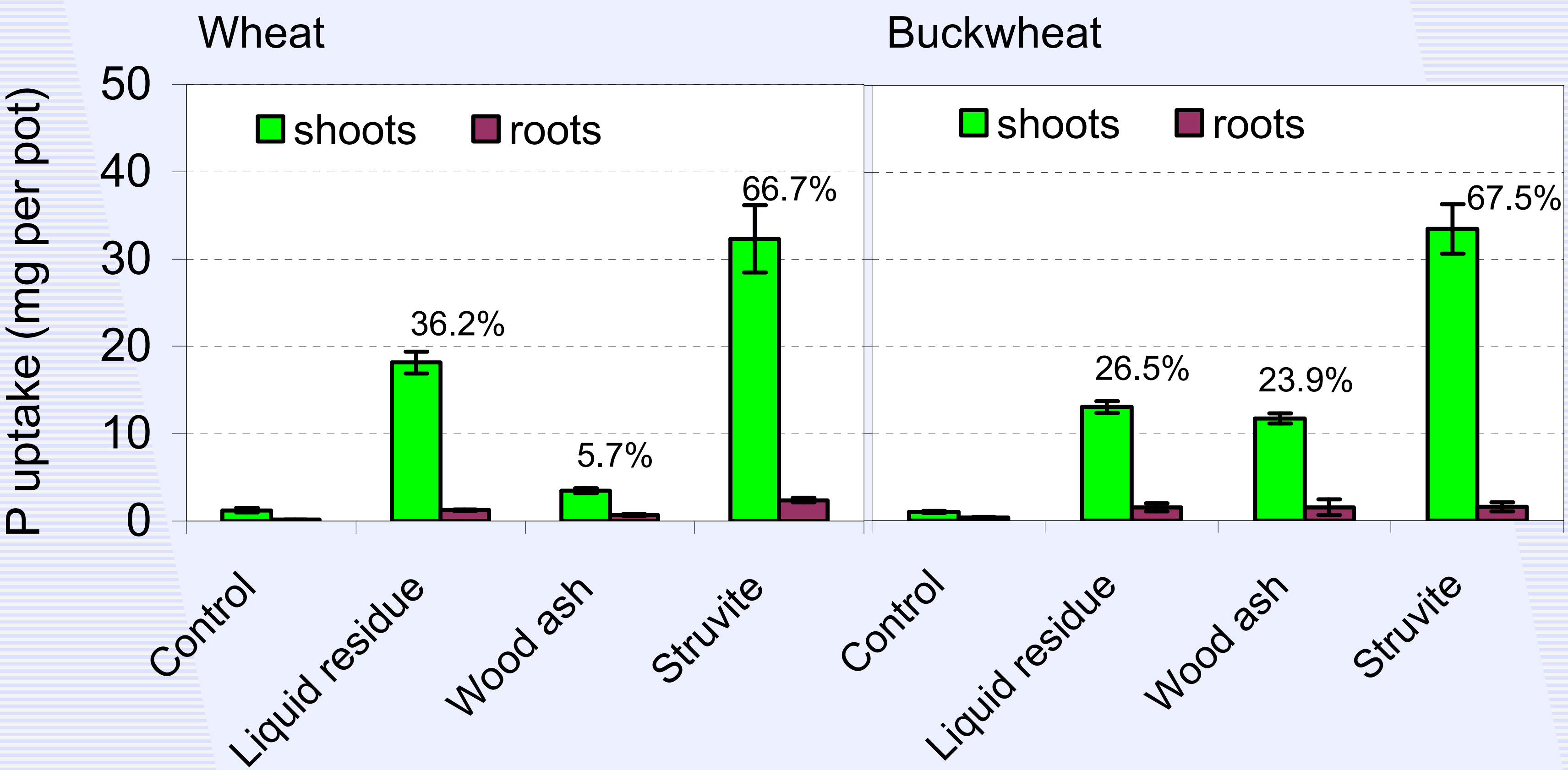
⇓

Utilisation rate = Nutrient uptake from fertiliser by plants
% of nutrient supply related to the growing period

calculated according to

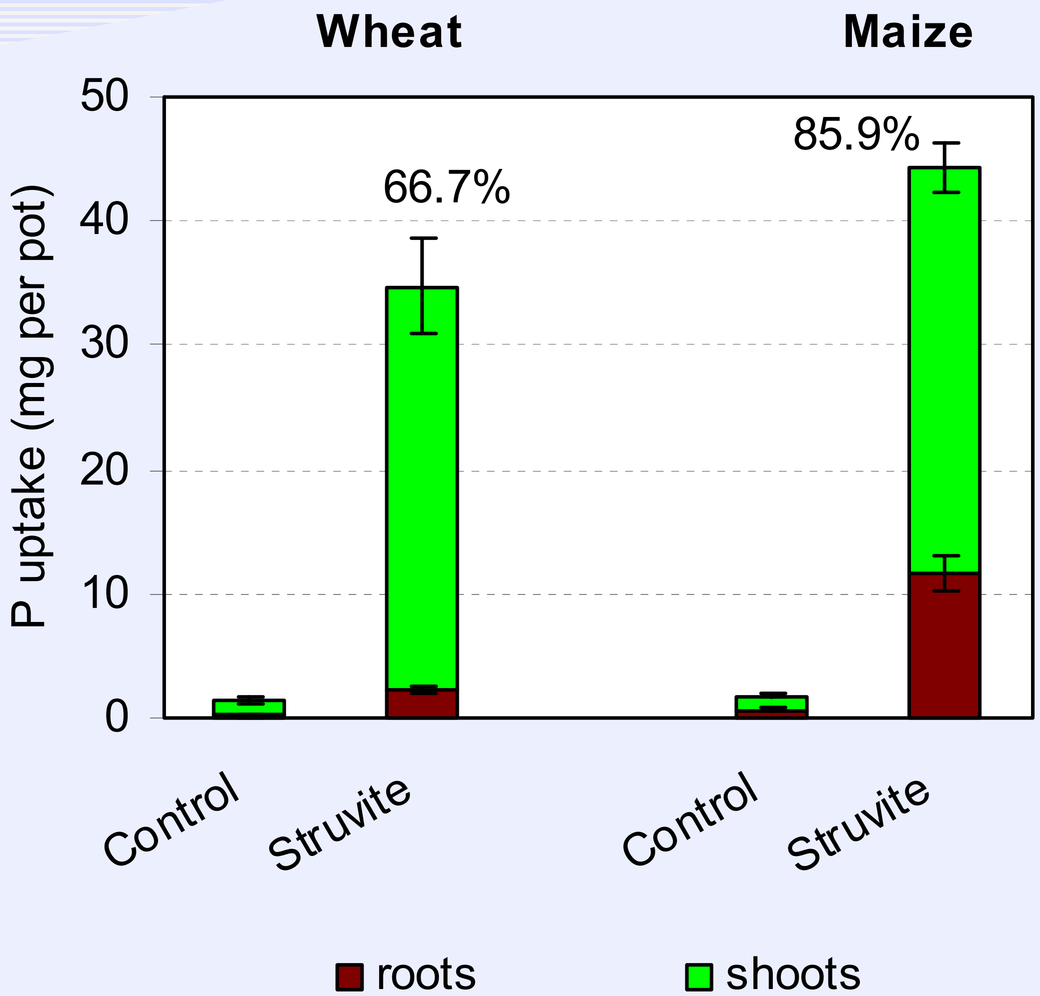
$$\frac{(\text{Total P uptake} - \text{P uptake from the soil pool} - \text{P content of seeds}) \bullet 100}{\text{Phosphorus derived from fertiliser}}$$

Phosphorus utilisation by crops



Markus (2008)

Phosphorus utilisation from struvite



Kaufmann (2007), Markus (2008)

Declaration of struvite from BWB (MAP) as a new phosphorus mineral fertiliser

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Struvite produced at the WWTP at Waßmannsdorf can be characterised as partially digested raw phosphate with magnesium

However: Water solubility of 40% as required for type of phosphorus fertiliser is not given

→ Solubility of phosphorus in the soil does not reflect sufficiently the plant availabilty

↓ 2 years discussion and optimisation of precipitated struvite together with local authorities in order to get the certification by the Federal Ministry of Food, Agricultlure and Consumer Production

In May 2008 struvite from the WWTP at Waßmannsdorf was considered as mineral P fertiliser according to the German Fertiliser Ordinance

Pollution assessment

$$\text{Pollution Index (PI)} = \frac{\text{Pollution content (P)}}{\text{Pollution limit value (PLV)}}$$

Compound		AbfKlärV	Struvite		Sewage sludges		Triplesuper-PO_4	
		PLV	P	PI	P	PI	P	PI
Pb	mg/kg DW	900	44	0.05	46	0.05	13	0.01
Cd	"	5	0.6	0.12	1.3	0.26	27	5.40
Cr	"	900	42	0.05	34	0.04	287	0.32
Cu	"	800	160	0.20	264	0.33	27	0.03
Ni	"	200	19	0.10	23	0.12	33	0.17
Hg	"	8	1	0.13	1.1	0.14	0.07	0.01
Zn	"	2,000	340	0.17	862	0.43	333	0.17
Σ PI				**0.81**		**1.36**		**6.11**
AOX	"	500	55	0.11	211	0.42		
PCB	"	0.2	0.05	0.25				
PAH	"	20	7.2	0.36				

Fertiliser requirements

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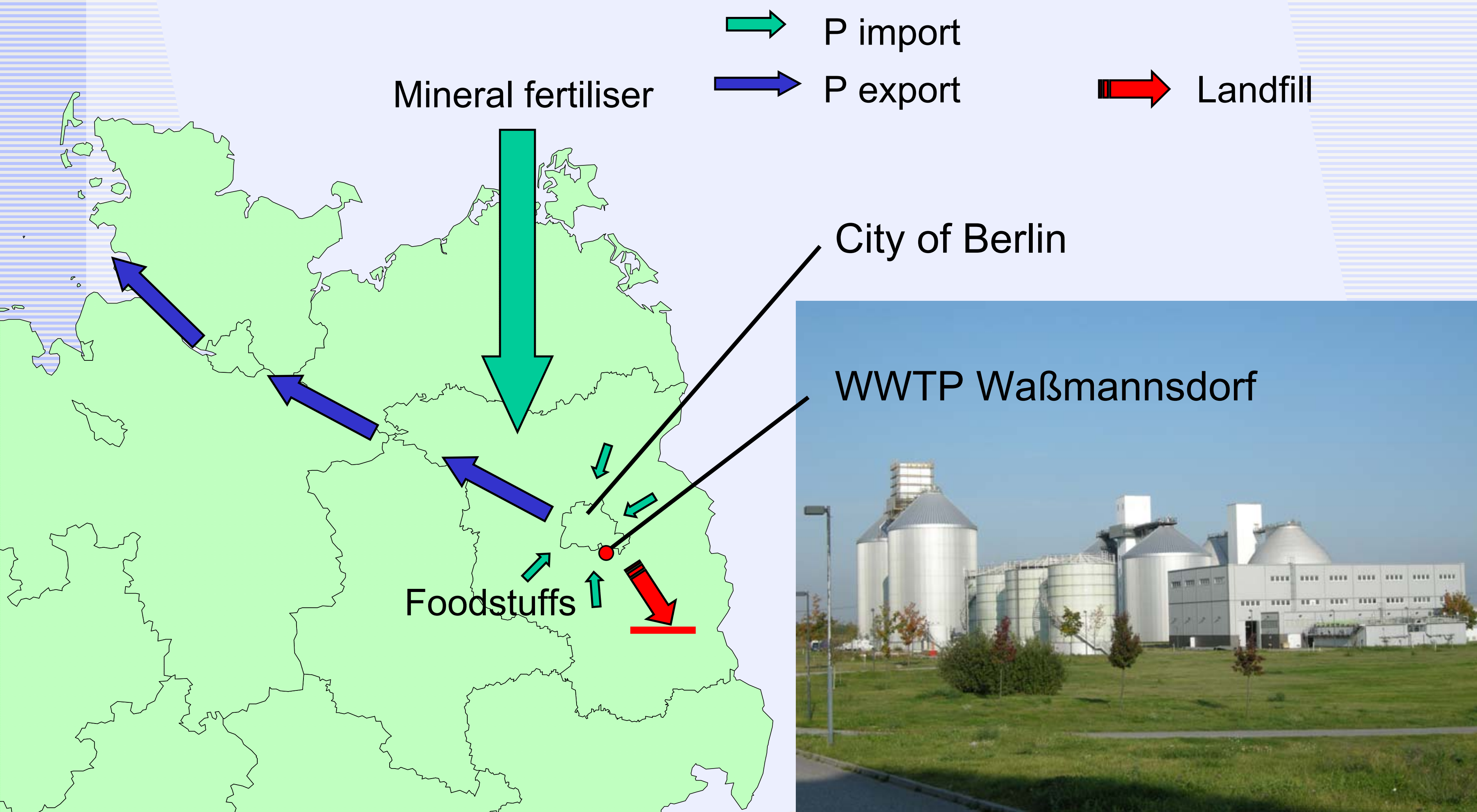
- Medium-term warranted supply **+**
- Sufficient content of total and soluble P considering the turnover in the soil **+**
- Low contents of undesirable minor components **(+)**
- No negative image **+**
- Standardisation of product properties **(+)**
- Economic efficiency **?**

Phosphorus recycling between Berlin and agricultural sites of state Brandenburg

Integrated project in preparation

Objective | Sustainable use of phosphorus resources



Phosphorus recycling between Berlin and agricultural sites of state Brandenburg

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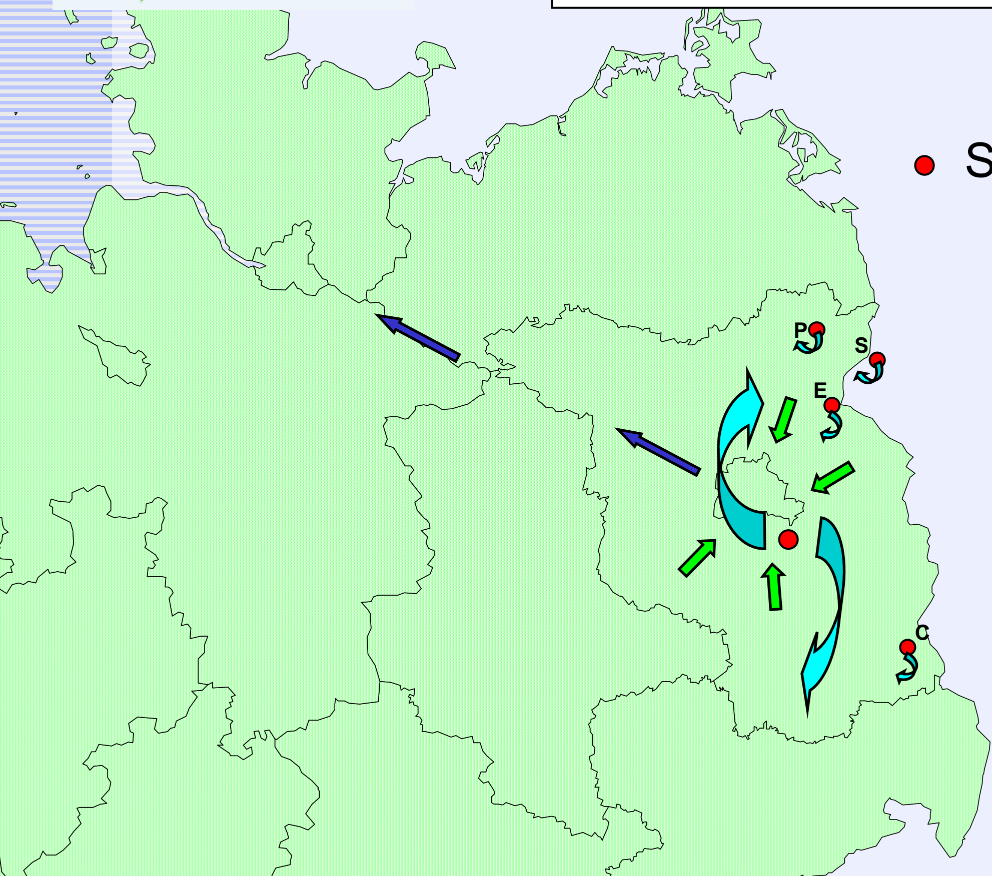
Goals

P.C.S.
Pollution Control Service GmbH
water – and sludge treatment
Hamburg, Germany
www.pcs-consult.de

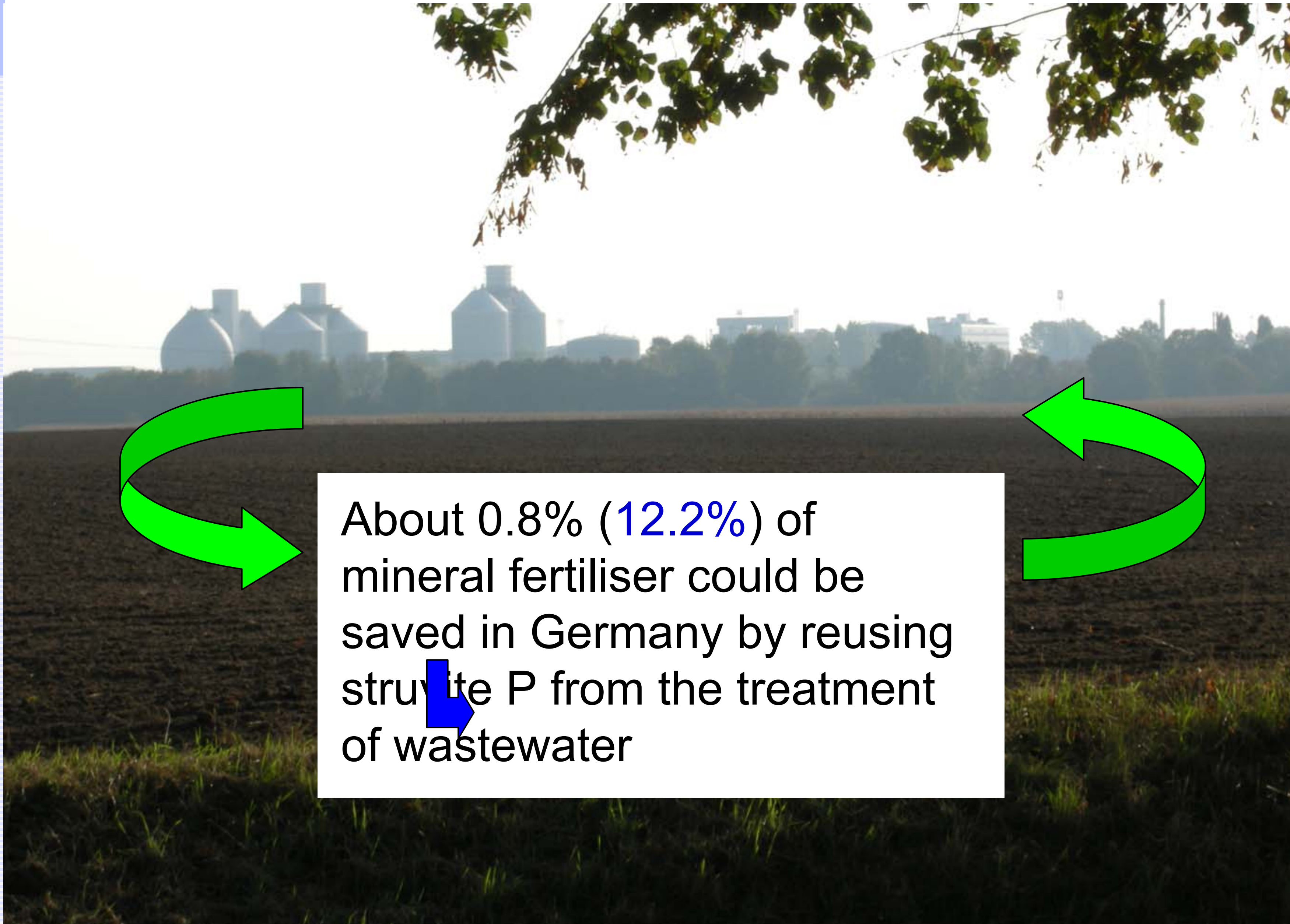
Berliner Wasserbetriebe

- Recycling of P from wastewater by use of struvite as a new fertiliser on basis of a life cycle assessment (coop. BWB)
- Introduction of struvite precipitation in wwtp (coop. P.C.S.)
- Reduction of cadmium fluxes by mineral fertiliser
- Reduction of phosphorus inputs to surface water



● Selected wastewater treatment plants

Potential to substitute phosphorus mineral fertiliser by recovered struvite in Germany



About 0.8% (12.2%) of mineral fertiliser could be saved in Germany by reusing struvite P from the treatment of wastewater

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Thank you for your attention

Loading rates of heavy metals during fertilisation

		Triplesuper-phosphate	Struvite		German Soil Protection Act
				adapted to 30 kg P/ha	
Field application	kg/ha	150	150	492	
Heavy metals					
Pb	g/ha	2	6.6	**21.6**	400
Cd	"	4	< 0.1	< 0.3	6
Cr	"	43	6.3	20.7	300
Cu	"	4	24.0	**78.7**	360
Ni	"	5	2.9	**9.3**	100
Hg	"	0.01	< 0.3	**< 1.0**	1.5
Zn	"	50	51.0	**167.3**	1,200