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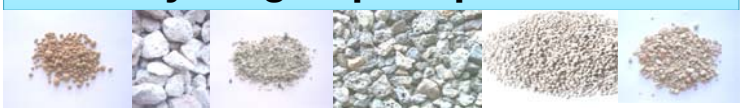
Reactive bed filter materials in wastewater treatment – removal and recycling of phosphorus



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What is reactive filter materials?

- Natural
  - Limestone
  - Opoka
  - Shell sand
  - Wollastonite
  - Zeolites
- Industrial by-products
  - Fly ash
  - Metallurgic slag (EAF, BFS, BOF)
- Industrial products
  - LECA (Light expanded clay aggregates)
  - Filtralite P® (from LECA)
  - Nordkalk Filtra P (lime, gypsum)
  - Polonite® (from opoka)

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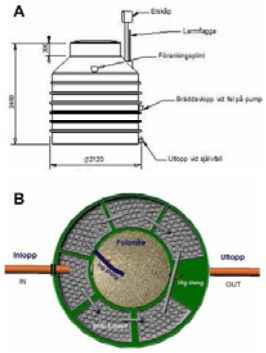
P-removal

- **Sorption**
  - (Mechanical)
  - Biological (Acinetobacter, Pseudomonas, other…)
  - Chemical (adsorption, precipitation, ion exchange)
- **Factors**
  - Particle size
  - Porosity
  - Hydraulic loading
  - pH
  - Temperature
  - Other



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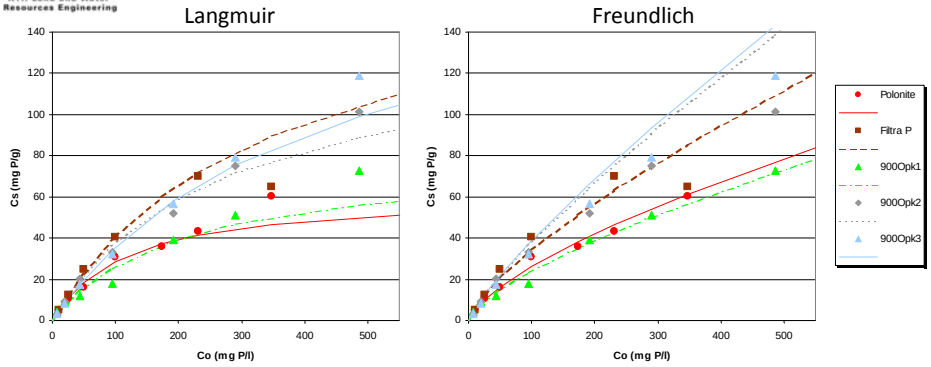
P-sorption capacity



Susbstrate	Cs^{max} (mg/g)	Langmuir maxima (mg/g)
Polonite	60	62.33
Filtra P	70	179.15
900Opk1	72	79.36
900Opk2	100	136.98
900Opk3	120	181.82

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Classification of filter materials

P sorption	P sorption capacity (g P kg^{-1})	Filter materials	
		Fine (<1 mm)	Coarse (>1 mm)
Very low	<0.1	Soils	Gravels
Low	0.1-0.5	Sand, Soils	LECA, Limestone, Opoka
Moderate	0.5-1	Bentonite, Calcareous soils, Fly ash[a], Spodosol	Bauxite, BFS[a], Zeolite[a]
High	1-10	BFS[a], Fly ash[a], Fe-coated sand and brick	BFS*, EAF, Filtra P® [b], Filtralite P®, Polonite® [b], Shell sand, UTELITE™
Very high	>10	BFS[a], Fly ash[a], Polonite® [b], Red mud	n.d.

[a] depending on chemical composition; [b] based on other studies (Brogowski and Renman, 2004; Cucarella et al., 2007; Gustafsson et al., 2008)

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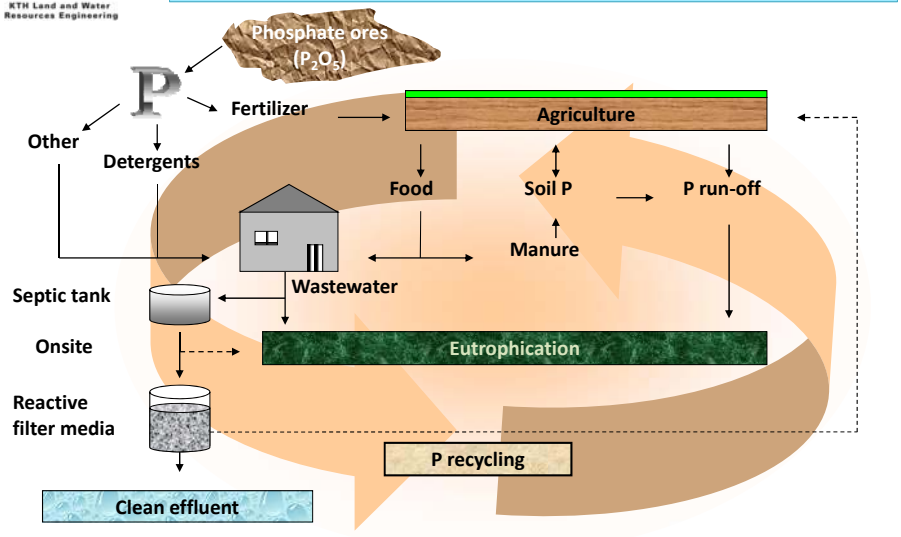
Justification for the use of reactive filter media



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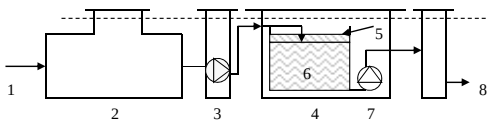
Bed filter systems – design & management

- Novel compact filter systems for on-site wastewater treatment
- Bed filters constructed for convenient replacement of exhausted media
- Recycling the spent reactive material to agriculture as a fertiliser and soil amendment



The filter system layout (not in scale): (1) Inlet of household wastewater, (2) Septic tank, (3) Dosing pump, (4) Filter well, (5) Biofilter, (6) Polonite bed filter, (7) Pump, (8) Sampling well and outlet.

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Horizontal flow bed filter system

”Absolite” = AAC = CSH (tobermorite)

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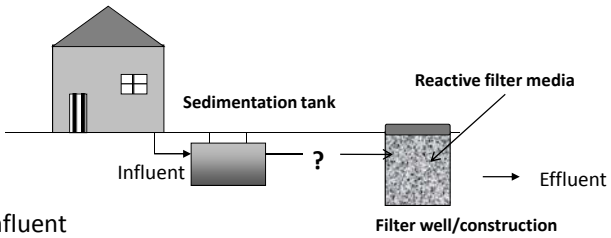
Bed filter systems – any drawbacks?



- ☐ Influent
  - ☐Pre-treatment (soil bed, CW, etc.)
  - ☐P concentration
  - ☐Organic matter
- ☐ Hydraulic loading
- ☐ Retention time
- ☐ Climatic conditions
  - ☐Temperature
- ☐ Filter media (sorbent)
- ☐ Effluent – high pH

Expensive?

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Column experiments

Loudden WWTP

Synthetic solution

On-site wastewater

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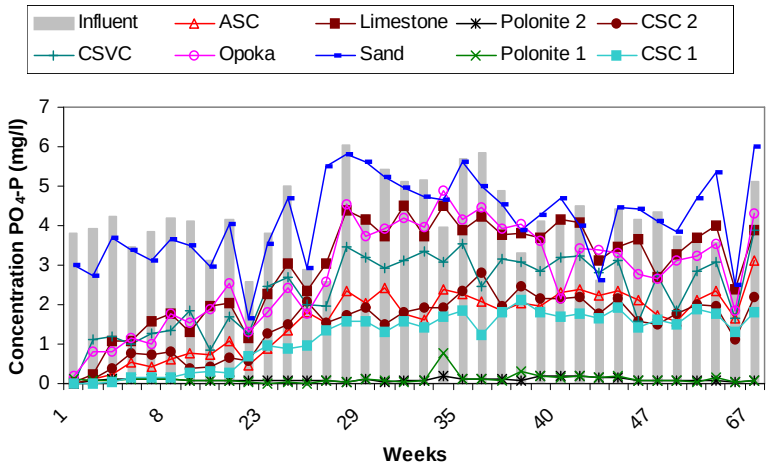
Long-term development of PO_4-P concentrations in effluents from nine columns with different filter materials fed by municipal wastewater



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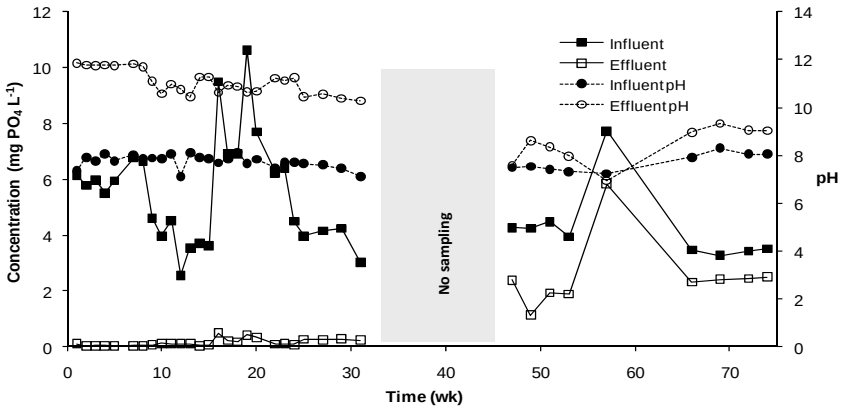
Influent and effluent concentrations of PO_4-P, pH development, in a filter well used for domestic wastewater treatment



Filter material: Polonite®, Bioptech AB

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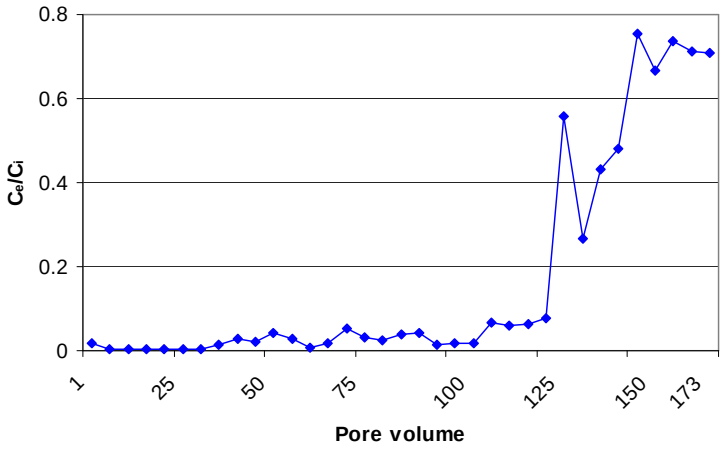
Phosphate breakthrough curve during operation of a filter well system



Filter material Polonite®, minor pre-treatment

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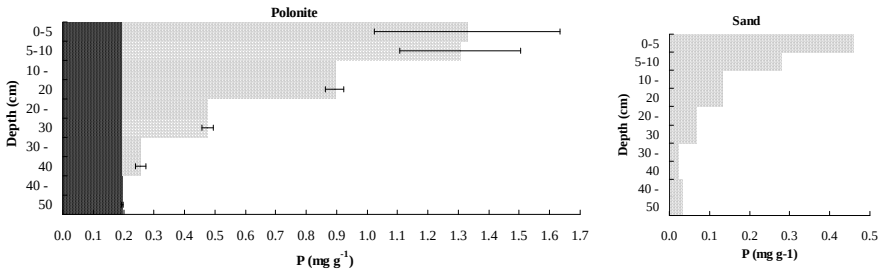
Initial P content of Polonite® (dark shaded area) and P enriched to different layers (light shaded area) after the column experiment



Note! Polonite was not P exhausted

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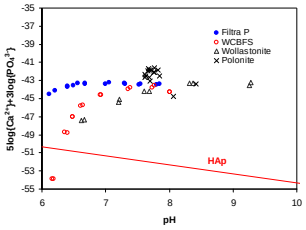
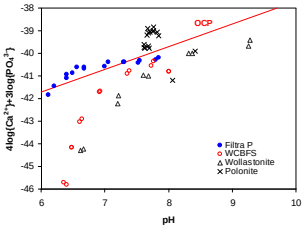
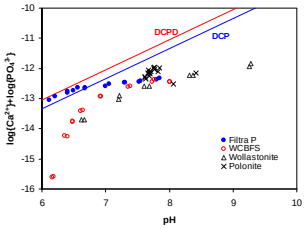
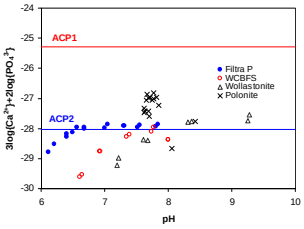
Removal mechanisms



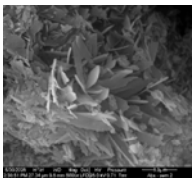






Candidates to control PO_4 solubility:

Hap, OCP, DCPD, DCP, ACP1, ACP2



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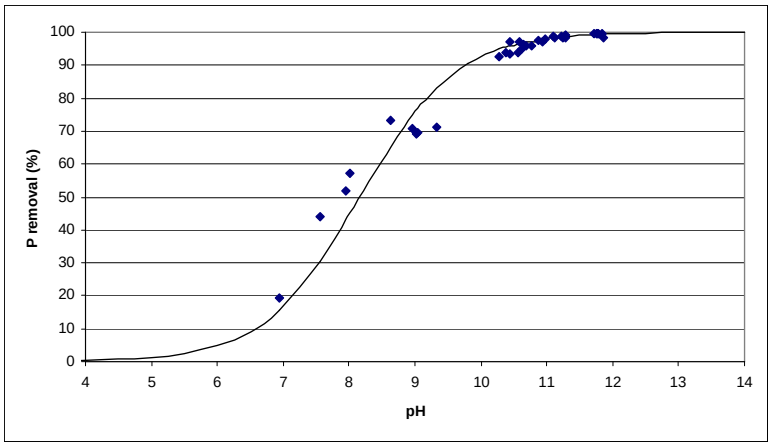
Bed filter lifetime for P removal

What is the exchange interval of filter material?



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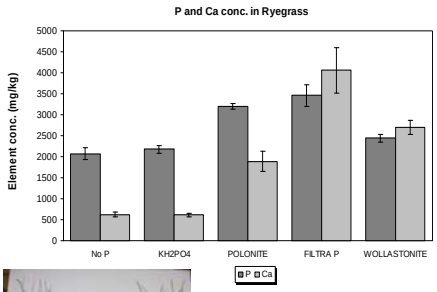
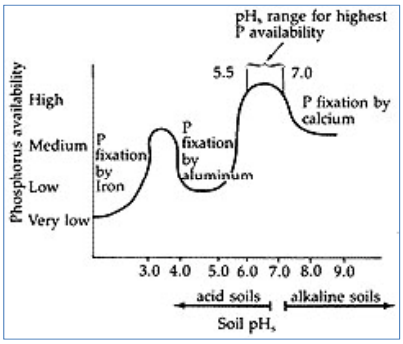
Recycling - Plant P-uptake

$$H_3PO_4 \overset{2.1}{\leftrightarrows} H_2PO_4^- + H^+ \overset{7.2}{\leftrightarrows} HPO_4^{2-} + H^+ \overset{12.3}{\leftrightarrows} PO_4^{3-} + H^+$$





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On-site systems for the future – 60% recycling of P until 2015?

What system should be recommended?

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Thank you for your attention!
Questions?