High Performance Constructed Wetlands for Cold Climates

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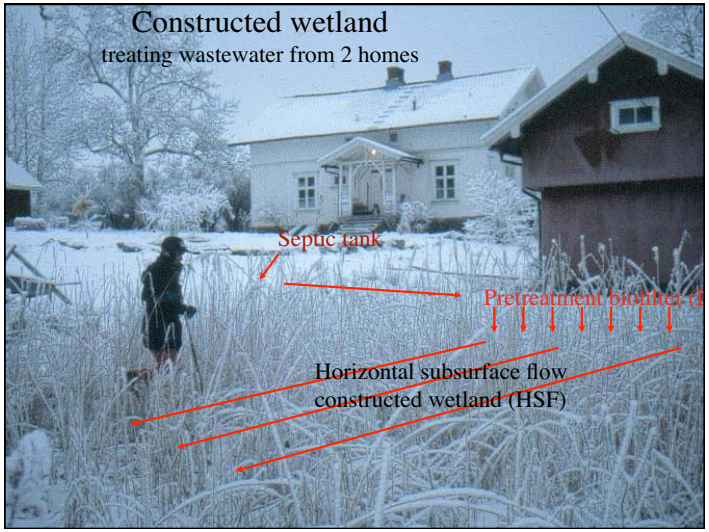
Presentation overview

- About Norway and climate
- Development of design for cold climate – insulation needs and pretreatment
- Removal results and mechanisms
- Reuse of wetland substrate saturated with phosphorus

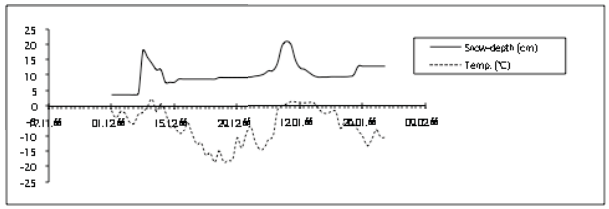


Thermal properties of various materials and insulation equivalent to the insulation provided by 10 cm of Styrofoam.

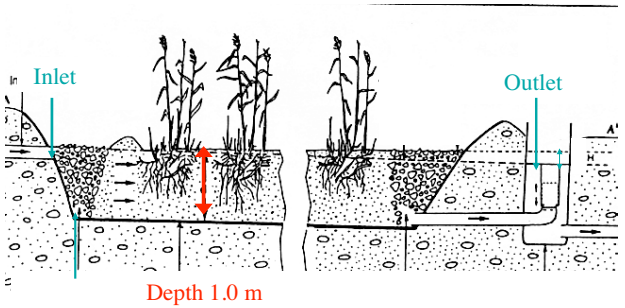
Material	Therm. cond (W/mK)	Specific heat (J/m^3 °C)	Density (kg/m^3)	Eq. thickness to 10 cm Styrofoam (cm)
Styrofoam	0,030		@??	10
Air	0,025	0,003		8,3
Water	0,57	1,0	1000	190
Ice	2,2	0,45	920	733
Snow	0,049 - 0.190		100-700@	16
Peat dry	0,06 1)	0,35	100-300	20
Peat fc [b)]	0,29 1)	0,5	@??	97
Peat sat [c)]	0,5-1,25 ?	0,7	900-1200	166
Straw dry	0,09		@??	30
Sand Haugstein	1,77#		1710#	590
@Sand Haugstein fc [b)]	1,78#		1710#	590
Leca (0- 4 mm) sat [c)]	0,56#		340#	186
Leca (0- 4 mm) unsaturated	0,07#		340#	23

Note: [a]Data from Hillel 1980, Incropera and DeWitt 1981, Norsk Standard 1987, Sundberg 1988. [b]At field capacity. [c]At saturation. # own measurements

Temperature and snow depth
Tveter wetland Ås – winter 1994

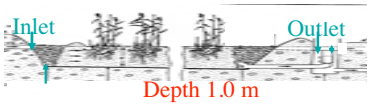


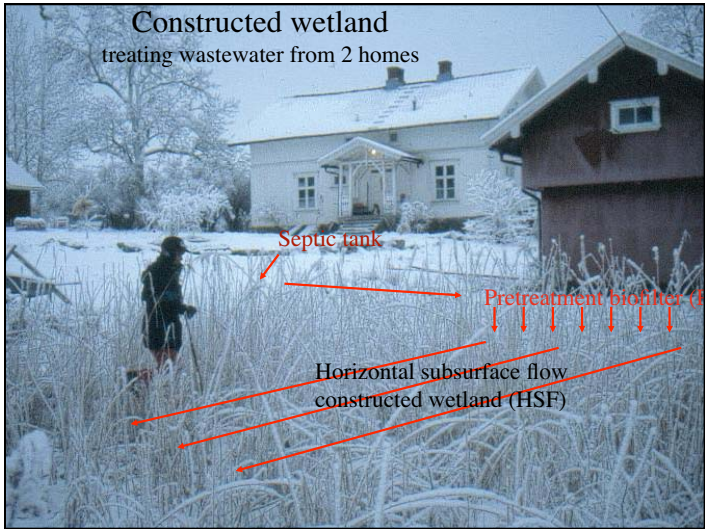
Mitigating frost

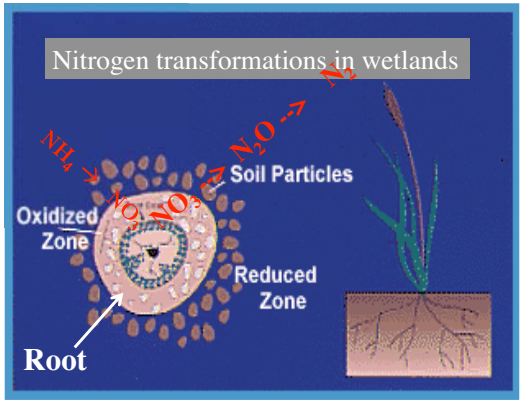


Frost mitigation

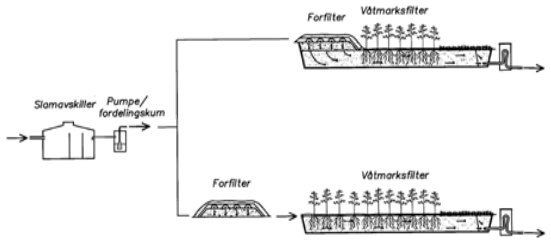
- Increase the depth
- Keep the water level at least 10 cm below the surface of the wetlandInsulate with straw (new systems)
- Freeze an ice cap



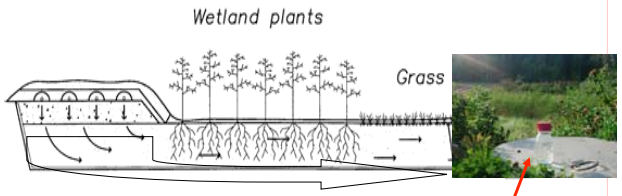


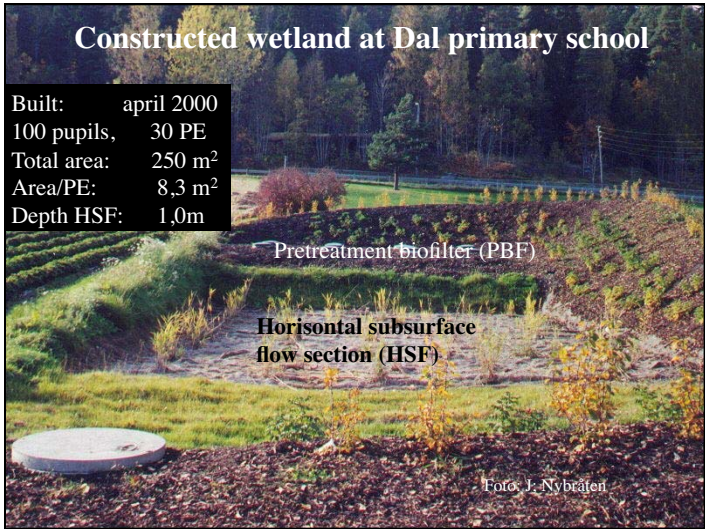


Constructed wetland with a pretreatment biofilter

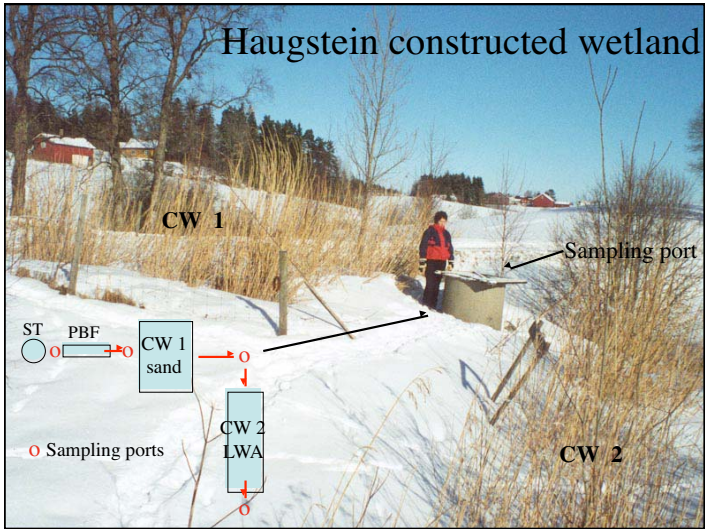


Constructed wetland





Constructed wetland at Dal primary school



Haugstein constructed wetland

Average influent (STE) and effluent concentrations (mg/l)

Parameter	Influent	Effluent
Total - P	10,0	0,3
Total - N	111	40
COD	240	52
SS		< 5
T. coli. /100ml		< 100

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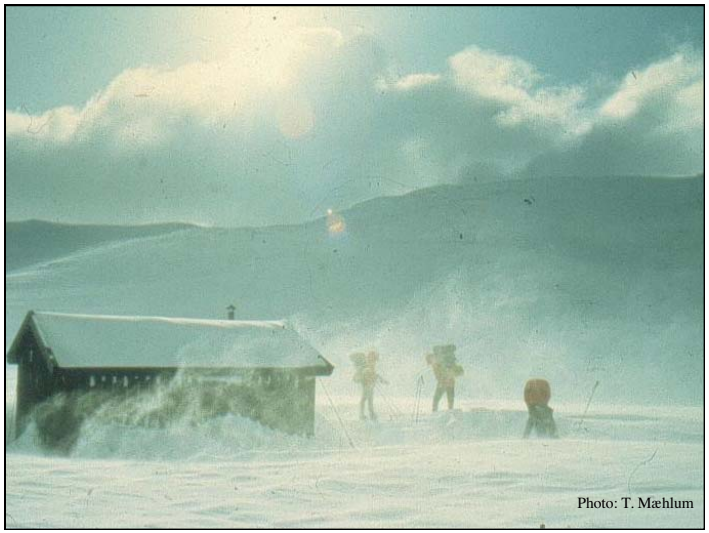
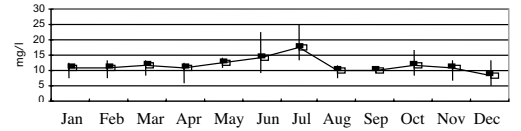
Typical treatment efficiency (%)

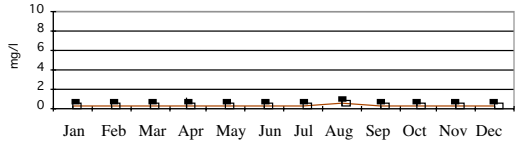
• Total - P	> 90
• Total - N	40 - 60
• COD	60 - 80
• BOD	70 - 90
• SS (mg/l)	<10
• Termotolerant coli/100ml	< 100



Total-P monthly average and variation
1991 - 2001
Haugstein multistage consructed wetland

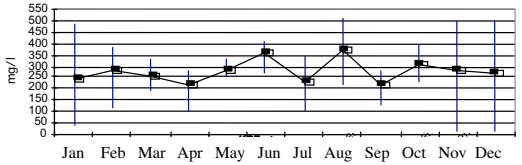


Influent (STE)

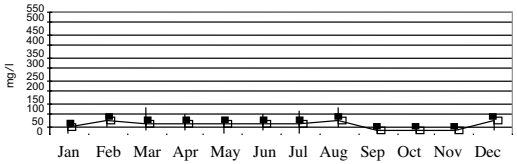


Effluent

COD monthly average and variation
1991 - 2001
Haugstein multistage consructed wetland

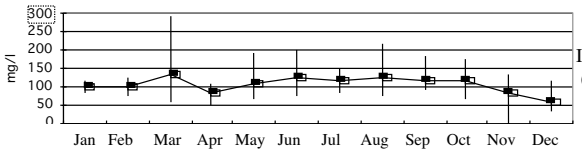


Influent (STE)

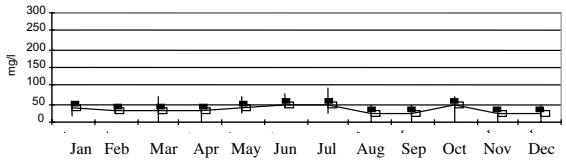


Effluent

Total-N monthly average and variation
1991 - 2001
Haugstein multistage consructed wetland

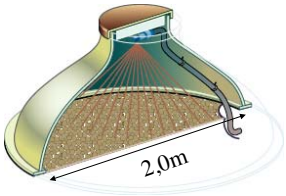


Influent (STE)

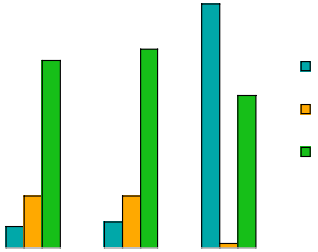


Effluent

The pretreatment biofilter
3. generations of distribution systems

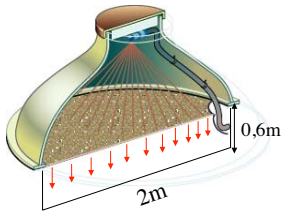


BOD-removal vs. distribution system
in full scale biofilters

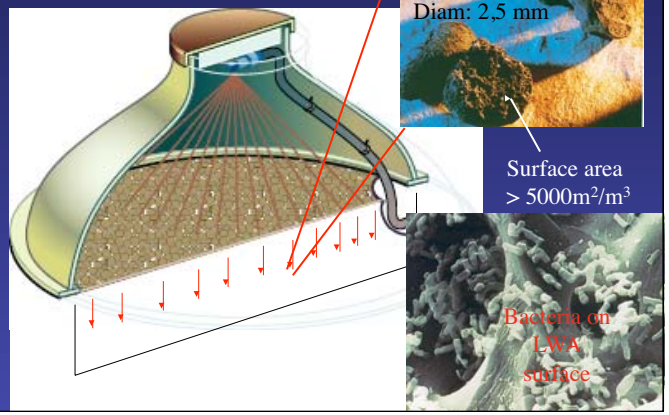


The pretreatment biofilter

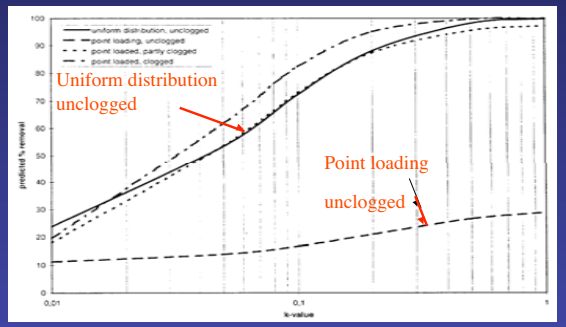
The pretreatment biofilter
Effective wetted area (EWA)



Pretreatment biofilter
Porous media

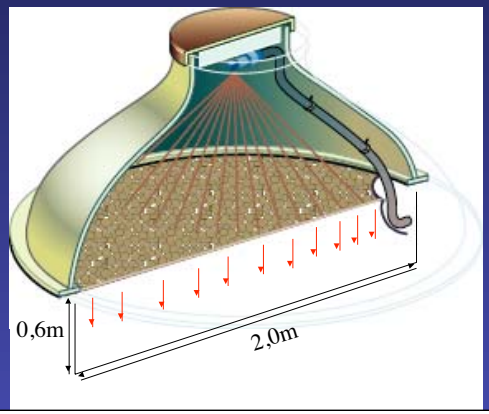


BOD-removal in coarse sand as a function of wastewater distribution



Ausland (1998)

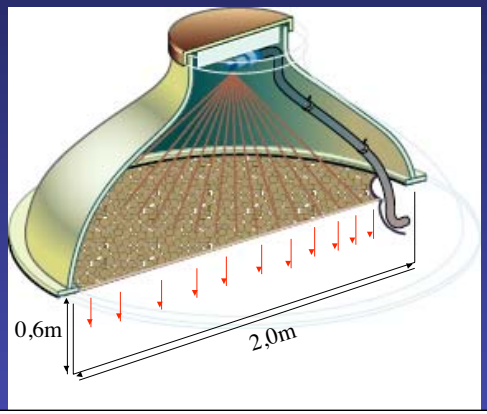
Pretreatment biofilter
Porous media



Grain size:
- 2-4 (10) mm

Material:
- LWA
- Gravel
- Crushed rock
- Chrushed brick
- Other

Pretreatment biofilter
Loading rate - commercial systems



Dom. wastew.
- 10 - 20 cm/d

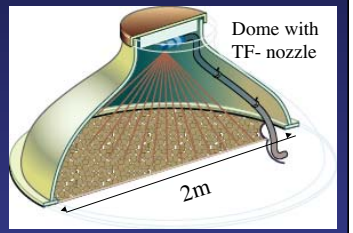
Greywater
- 20 - 30 cm/d

Dosing
- 24 - 48/d
- minimum 8/d

Area/person
- 0,3 - 2,0 m²

3rd. generation pretreatment biofilter

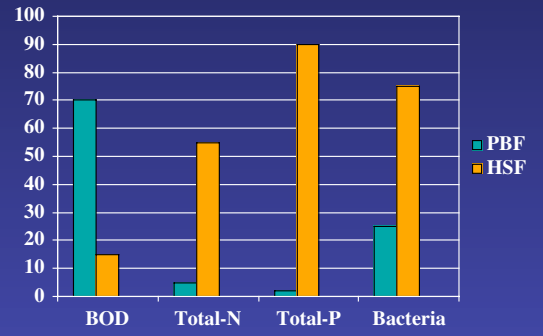
BOD removal: 70 - 80%
Complete nitrification
Total-N removal 5-40%
SS 60 - 70%
Bacteria reduction: up to 5 logs

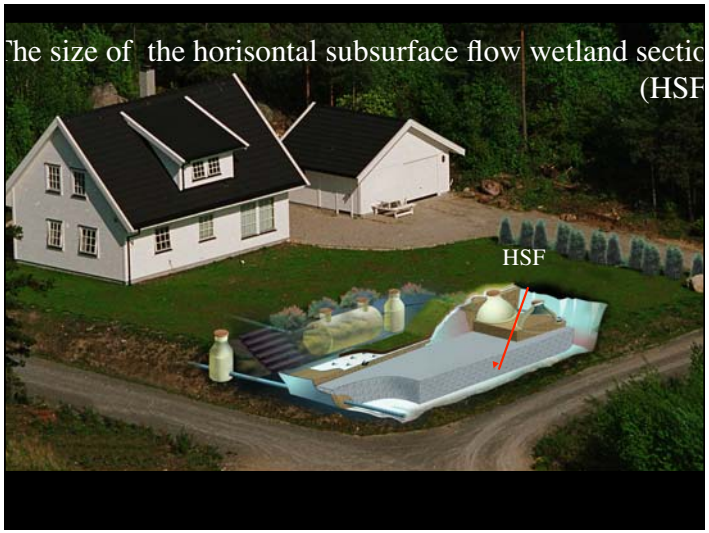


Grain size: 2 - 10 mm
Depth: 50 - 60 cm
Area: 0,3 - 2,0m^2/person

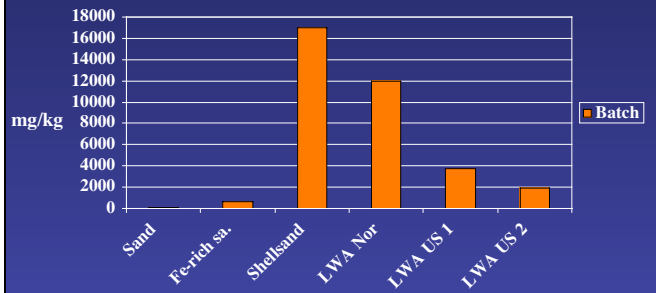
Removal efficiency

Pretreatment biofilter (PBF)
Horizontal subsurface flow constructed wetland (HSF)

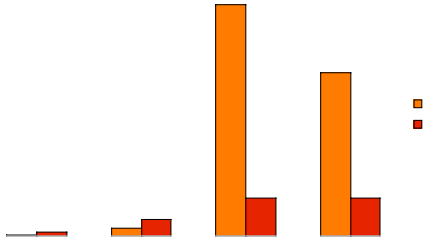




P-sorption in batch experiments for some natural porous media and LWA

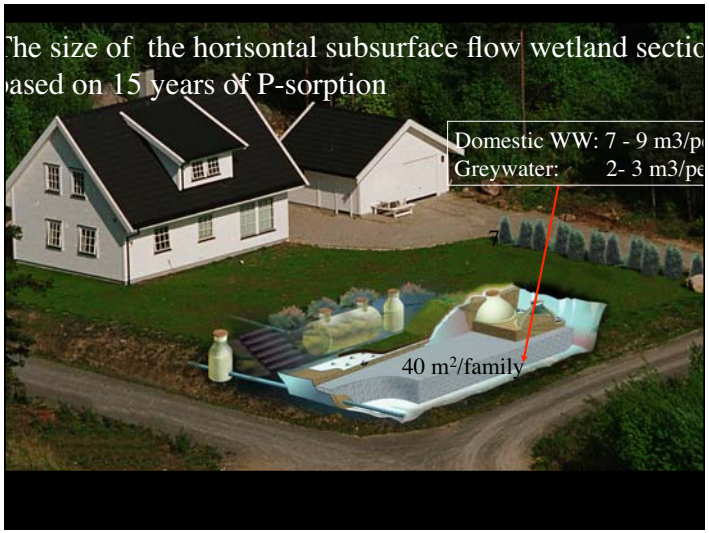


P-sorption in batch tests and fullscale natural systems for wastewater treatment

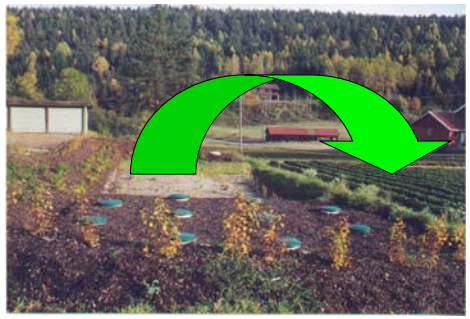


Volume needed to sorb P emitted from one person over 15 years

700	700	1,4
17 000	2 500	0,7
12 000	2 500	0,7



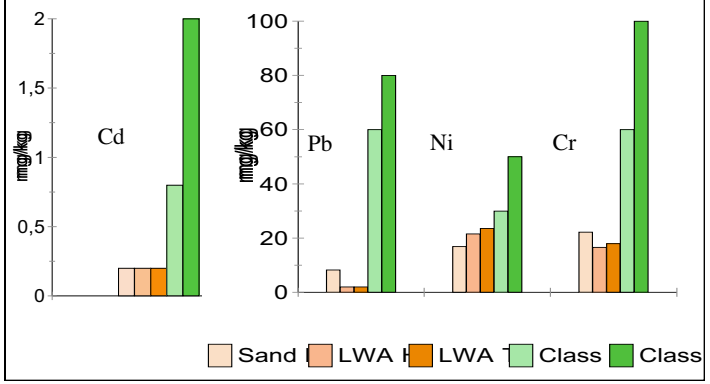
Reuse of P-saturated filter material



Heavy metal content (mg/kg) LWA filter material

	LWA used 8 years		LWA before use
	Inlet zone	Outlet zone	Background
Cd	<0.4	<0.4	<0.4
Pb	<4	<4	<4
Cu	18.0	20.3	23.4
Zn	22.9	26.8	19.1
Ni	28.0	19.1	17.6
Cr	17.8	18.2	15.3
Co	4.7	4.6	4.1
V	17.1	16.9	15.0

Heavy metal accumulation in light weight aggregate (LWA) and sand used in constructed wetlands vs. Norwegian limits for use on cultivated areas (class 1 and class).



High Performance Constructed Wetlands for Cold Climates

Conclusions

- Constructed wetlands with pretreatment biofilters remove > 90% of P 40-60% of N. P, and bacteria to meet European standards for swimming water quality
- Constructed wetlands with pretreatment biofilters produce an effluent quality not affected by season
- Pretreatment biofilters that nitrify and reduce BOD are a necessary component of cold climate CW´s

High Performance Constructed Wetlands for Cold Climates

Conclusions

- Better prediction of the long tm P-sorption and further optimizing of the PBF will yield more cost effective sytems
- Greywater treatment needs less area and open for decentralized treatment of greywater in urban areas

High Performance Constructed Wetlands for Cold Climates

Conclusions

- Low heavy metal accumulation - facilitates reuse of P-saturated filter material as fertilizer
- The fertilizer effect of P-saturated LWA is comparable to mineral fertilizer