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european centre of excellence for sustainable water technology

Simultaneous calcium phosphate granules and methane recovery from black water

MSc Jorge Ricardo Cunha

Promoters: prof. dr. ir. Grietje Zeeman
prof. dr. ir. Cees J.N. Buisman

Supervisors: dr. Renata D. van der Weijden
dr. ir. Lucía Hernández Leal

combining scientific excellence with commercial relevance

Resources Recovery - Oriented Sanitation

		Black water (Feces + Urine)	Kitchen waste	Grey water	Conventional sewer
Volume	$L\ cap^{-1}\ d^{-1}$	6	0.6	79	300
COD_{Total}	$g\ L^{-1}$	8	98	0.7	0.6
P_{Total}	$mg\ L^{-1}$	190	330	5	12
NH_4^+- N	$g\ L^{-1}$	0.8	-	0.02	0.07

Tervahauta et al. (2013) Water

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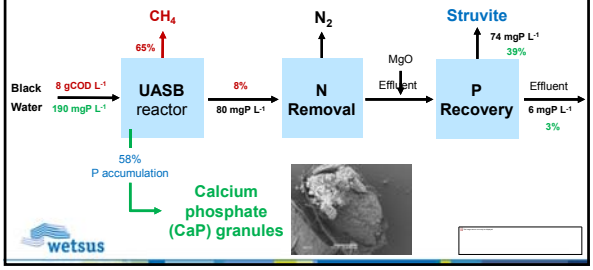
Current concept for black water treatment

Rapport 48 STOWA (2014)



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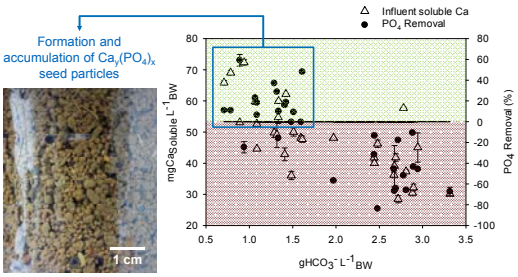
Why does P accumulate in the UASB reactor?



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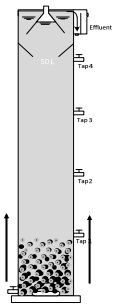
Biomass granulation in UASB reactors



Upflow velocities between **100 cm h^{-1}** to **3 m h^{-1}** are generally applied

Constant selection pressure for retention of biomass agglomerates over disperse biomass, triggering formation of granules

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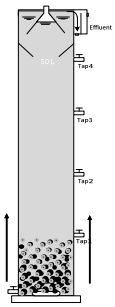
Black water treatment in UASB reactor



$$[COD] = 8\ gCOD\ L^{-1}$$

$$\frac{COD_{Suspended}}{COD_{Total}} = 0.6$$

Long hydraulic retention time (**HRT**), resulting in an upflow velocity of **less than 1 cm h^{-1}**

No selection pressure, allowing retention of fine solids, such as inorganic seed particles

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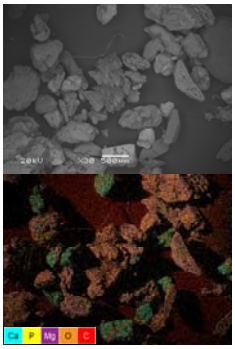
Formation of CaP granules from seeds

$$SI = \frac{1}{5}\frac{(Ca^{2+})^3(PO_4^{3-})^2}{K_{sp,ACP}}$$

Increase of Ca in BW



Backscattered SEM image

SEM-EDX analysis

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Formation of CaP granules from seeds

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Increase of Ca in BW

↓

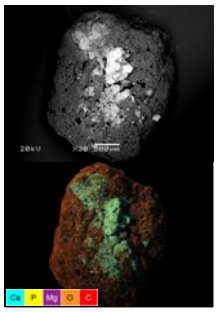
Microbial colonization

↓

Formation of an outer biofilm

$CH_{3-}COO^- + H_2O \rightarrow CH_4 + HCO_3^-$

$HCO_3^- + H^+ + 4H_2 \rightarrow CH_4 + 3H_2O$



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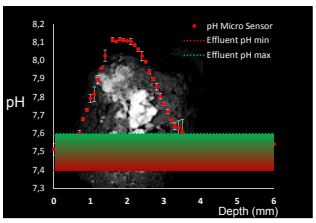

Increase of internal pH (7.4 to 8)

$H_3PO_4 \leftrightarrow H_2PO_4^- + H^+ \leftrightarrow HPO_4^{2-} + 2H^+ \leftrightarrow PO_4^{3-} + 3H^+$

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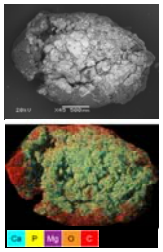

Preferable accumulation of CaP in the granules

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Enhances the crystallization of **Hydroxyapatite**

$5Ca^{2+} + 4OH^- + 3HPO_4^- \rightarrow Ca_5(PO_4)_3(OH) + 3H_2O$

Increase of internal pH (7.4 to 8)

$H_3PO_4 \leftrightarrow H_2PO_4^- + H^+ \leftrightarrow HPO_4^{2-} + 2H^+ \leftrightarrow PO_4^{3-} + 3H^+$

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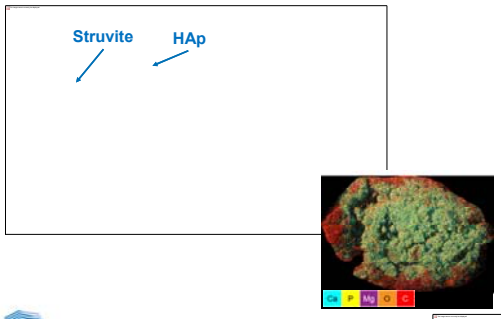
Hydroxyapatite in the granules (XRD)



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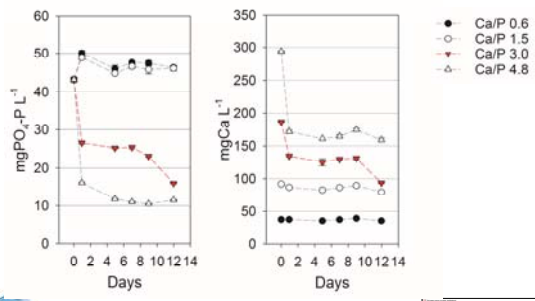
Higher P accumuation by adding Ca^{2+}



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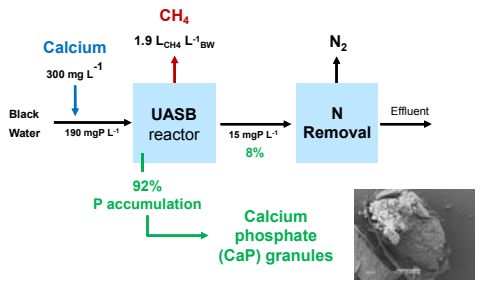
Impact on treatment concept



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