UNIVERSITEIT GENT

EXIT CONVENTIONAL ACTIVATED SLUDGE?

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The old and the new water cycle

OLD

Natural system
↓
Purification
↓
Transport
↓
USER
↓
Transport
↓
Dissipative treatment
↓
Natural system

NEW

Natural system
↓
Purification
↓
Transport
↓
USER
Local re-use
Transport & centralised re-use
↓
Natural system

Innowatech/Neptune
26-28 January 2010, Ghent

"Used water" as a resource

- Energy via AD, BES, heat pump, …
- N & P & K
- Organic fertilizer (biosolids); biochar
- "NEWater"

"Used water" as a resource

- Proteins
  - **1974 IWA prize:** Piggery manure → activated sludge → silage → protein rich feed for sheep
    (Neukermans et al., 1977; Trib. Cebedeau 407: 372-378; LabMET)

    YET, INSUFFICIENT INFO TO THE PUBLIC: TOTAL CATASTROPHY
  - **2007: Aquaculture**: Bio Floc Technology (BFT) is an accepted technique
    (Crab et al., 2007; Aquaculture 270: 1-14; LabMET)

    NOW GOOD PR AND TOTAL ACCEPTANCE

Sewage as a resource

Potential recovery	Per m³ sewage	Market prices	Total per m³ sewage
Organic fertilizer	0.10 kg	0.200 €/kg	0.020 €
Methane	0.14 m^3	0.338 €/m^3CH_4	0.047 €
Nitrogen	0.05 kg	1.0 €/kg	0.050 €
Phosphorus	0.01 kg	0.7 €/kg	0.007 €
Water	1 m^3	0.250 €/m^3	0.250 €

Take home: A potential value ≈ 0.4 €/m^3, but mainly as “water”

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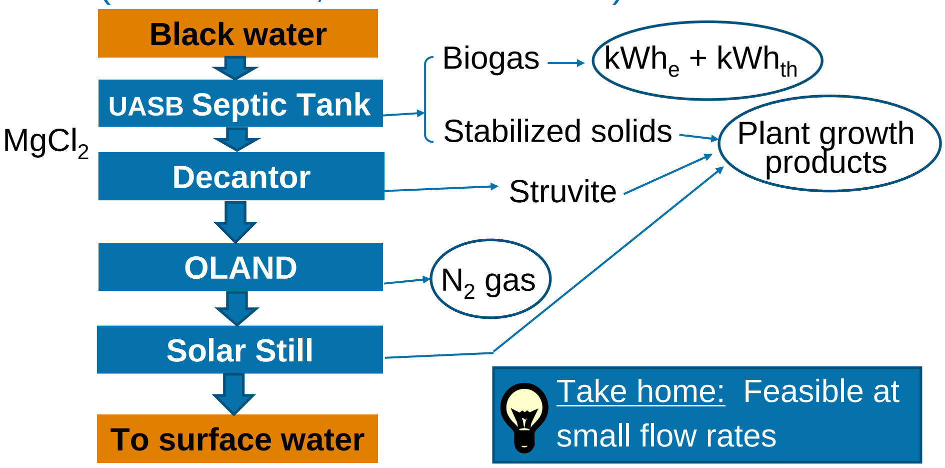
Sewage as a resource

A. Decentralised: Autonomic treatment

(Case Sneek, The Netherlands)



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(Vlaeminck et al., 2007; Appl. Microbiol. Biotechnol. 74: 1376-1384; LabMET)
(Zeeman et al., 2008; DESAR project WUR)

Sewage as a resource

B. Centralised: Conventional activated sludge (CAS) design

- Sewage
  - Capex + Opex: 0.3 – 0.6 €/m³ treated
  - Energy recovery via sludge digestion is limited
    - ◊ Theor.: 30-40 kWh/IE.yr
    - ◊ Pract.: 15-20 kWh/IE.yr
  - N, P, K → no recovery
  - All organic C via biology + sludge incineration to CO_2
  - Water → hardly re-used

    If so : +UF + RO = extra 0.4 €/m³;

    i.e. a total of ≈ 1 €/m³ treated

Sewage as a resource

"Orthodox" approaches to curb CAS

CEPT: Chemical Enhanced Primary Treatment
e.g. PE 0.5-0.8 g/m³ influent

- Efficiency of primary sedimentation

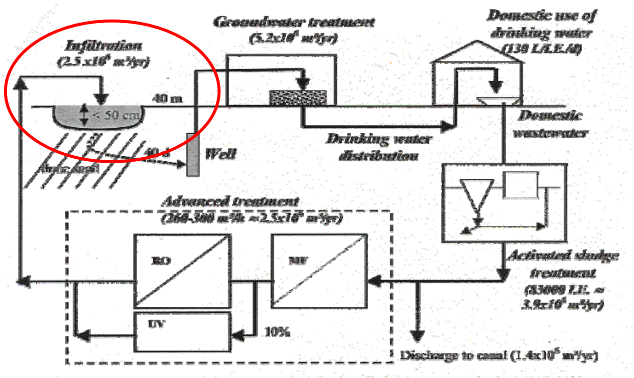
SS	from 50 to 73 % removal
COD	from 30 to 53 % removal
KjN	from 7 to 13 % removal

→ 20 % less CAS
20% more AD

(Kiestra, 2009; Energie uit water)

Sewage as a resource

HACCP & QMRA based closed water cycle in Wulpen (B)



Levels of 1 disease per 10.000 IE/yr

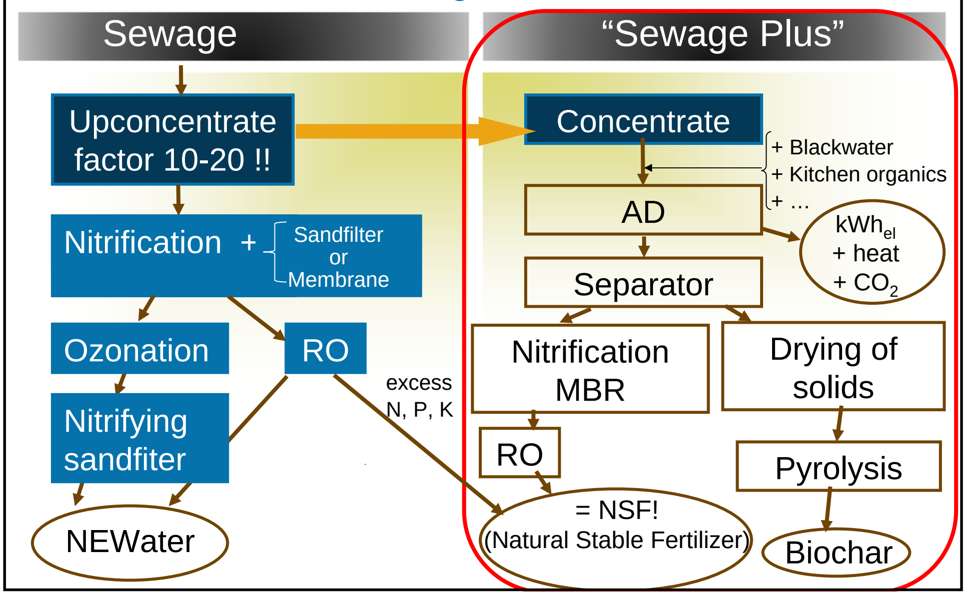
- Viruses $<10^{-8}$/L
- Protozoa $<10^{-6}$/L

Note: Microbial ecology of soil filter for integrative eco-monitoring

 (Dewettinck et al., 2001; Wat. Sci. Technol. 43: 31-38; LabMET)

Sewage as a resource

B. Centralised: C2C design *(McDonough & Braungart, 2002; North Point Press)*



Sewage as a resource

- Upconcentration of raw sewage
  - As fresh as possible/Short sewers; decentralized units
  - Technology development needed
    - VSEP®, FILMAX®, Rochem brush centrifuges, forward osmosis, flotation → at present: 4-6 €/m³ treated
    - Flotation
    - Biological upconcentration techniques: the AB process,…

- Nitrification of the “water-line”
  - Cross-metabolization of micropollutants by nitrifiers
  - Separation of suspended solids by sand filtration resp. membrane

    ↳Estimated at 0.5 €/m³ treated *(Neptune Project)*

Sewage as a resource

- **AD of the “concentrate-line”**
  - Add organics from 0.5 g COD/L to 5.0 g COD/L to 50 g COD/L
  - The burned biogas, i.e. CO_2 can be used to grow algae
- **After AD → Separator: Decantor centrifuge with(out) PE**
- **Pyrolysis to biochar**

  (Lehmann et al., 2007; Nature 447: 143-144)

  → Development needed in terms of:
  - Pyrolysis of dry solids
  - Quality & optimal use of biochar

    (1 ton C ≈ 3 ton CO_2 represents 69 € GHG-equivalent)

Sewage as a resource

Economic estimates for C2C sewage treatment

Processes	Costs (€/m³)	
Major Flow		0.53-1.15
❖ Dissolved air flotation	0.02-0.03	
❖ Dynamic sand filtration	0.05-0.06	
❖ Ultrafiltration and reverse osmosis	0.46-1.06	
Minor flow		0.08-0.10
❖ Anaerobic digestion	Break even	
❖ Mechanical separation	0.08-0.10	
❖ Pyrolysis	Break-even	
	Total costs:	0.61-1.25*

* This is the estimated cost

(Verstraete et al., 2009; Biores. Technol. 100: 5537-5545; LabMET)

Sewage as a resource

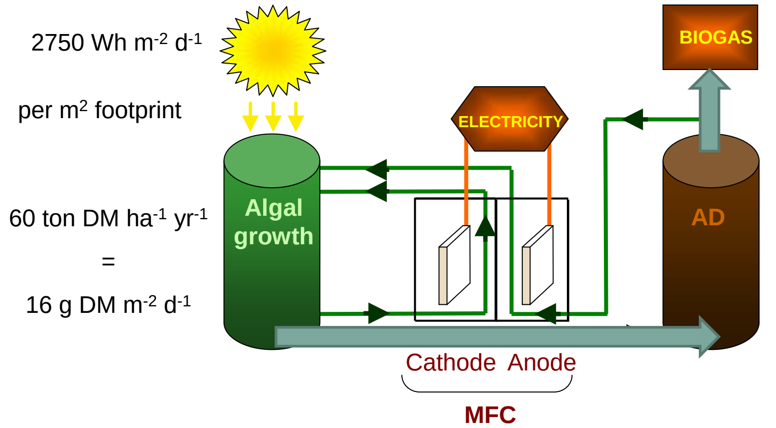
Economic balance

CAS-design	C2C design
☐ Total cost with water recovery ≈ 1.0 €/m³	☐ Total cost with up-recycling of water & nutrients ≈ 1.0 €/m³
(Van Haandel & Van der Lubbe, 2007)	☐ Perspective: ▫ CO_2 recycling via algae ▫ Recovery of struvite ▫ C-storage as biochar

Take home: The C2C design can already be achieved at equal costs of the CAS + it holds plenty of extra potentials

Advanced processes

A. CO_2 use by algal forestry



Note: Solar algal panel of 10 000 m² => 23 kW/ha power unit

(De Schamphelaire & Verstraete, 2009; Biotechn. Bioeng. 103:296-304; LabMET)

Advanced processes

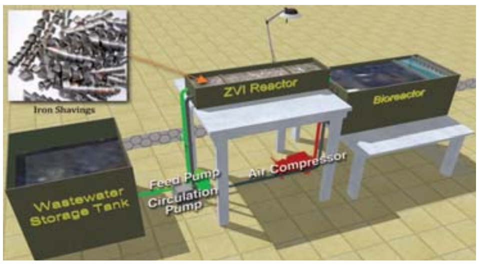
B. Polishing to remove micro-organics

- **Massive zero valent iron**

  contact reactor upfront

  (Luming et al., 2008;

  Env.Sci Technol.42: 5348-5389)

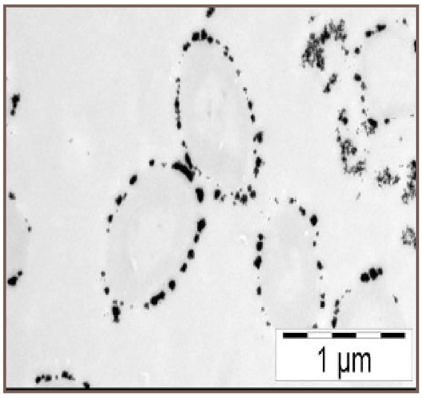


Advanced processes

B. Polishing to remove micro-organics (cont.)

- **Zero valent palladium**

"Bio-Pd": microbial precipitated Pd nanoparticles



- Microbial reduction of Pd(II) to Pd(0)
- Deposition of this biogenic Pd as nanoparticles
- On the cell wall and periplasmatic space of *Shewanella oneidensis*

17 *(De Windt et al., 2005; Environ. Biotechnol. 90: 377-389; LabMET)*

Advanced processes

B. Polishing to remove micro-organics (cont.)

- **Zero valent palladium**

Bio-Pd can be used as catalyst for dehalogenation and reduction reactions:

- PCB's, lindane, dioxines, chlorinated solvents, PBDE's and EE2
- Nitrate, perchlorate and arsenate

(De Windt et al., 2006; J. Gen. & Mol. Microbiol. 90: 377-389; LabMET)

(Mertens et al., 2007; Chemosph. 66: 99-105; LabMET)

- Pentachlorophenol

(Patel & Suresh, 2008; J. Col. & Interf. Sci. 319: 462-469)

(Hennebel et al., 2008; Trends in Biotechnol. 27: 90-98; LabMET)

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Advanced processes

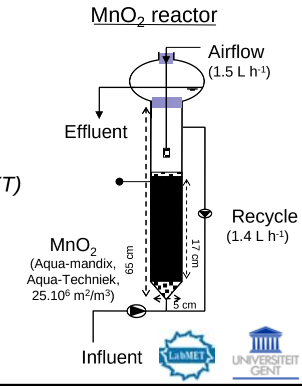
B. Polishing to remove micro-organics (cont.)

Manganese oxidising bacteria (MOB)

Application of Mn(III,IV) oxides in combination with MOB: bio-catalytic step after conventional treatment to remove micropollutants such as POPs and EDCs

Example: Upflow aerated bioreactor with MnO_2 and MOB for EE2 removal:

- 82% removal
  [infl: 15 µg EE2/L, HRT: 1h]
  (De Rudder et al., 2004; Wat. Res. 38: 184-192; LabMET)
- 84% removal
  [infl: 115 ng EE2/L, HRT: 1d]
  (Forrez et al., 2009; Wat. Res. 43: 77-86; LabMET)



Advanced processes

B. Polishing to remove micro-organics (cont.)

Nitrifier enrichment cultures (NEC)

- Recent findings:
  - EE2 removal rates in WWTP effluent up to 9 µg EE2/g VSS.h are achieved
  - A membrane bioreactor system can completely remove EE2 at µg and even ng/L level
  - Continuous removal in the MBR is possible at a minimal influent concentration of 1 mg NH_4^+-N/L and HRT of 0.4 d

Take home: Application of nitrifying enrichment cultures MBR is very promising for effluent polishing without producing byproducts

(De Gusseme et al., 2009; Wat. Res. 43, 2493-2503; LabMET)

Advanced processes

C. Chemical disinfection

Metal biocatalysis becomes efficient

- Fe^0
  - → ***Chemical reduction of virus coating***
  - *(Changha Lee et al., 2008; Env. Sci. Technol. 42: 4927-4933)*
- Visible light and Pd or TiO_2
  - → ***Oxidation***
  - *(Qi Li et al., 2008; Env. Sci. Technol. 42: 6148-6153)*
- Ag^0 produced by Lacto's
  - → ***Protein blockage***
  - *(Sintubin et al., 2008; Appl. Microbiol. Biotechnol.: 84: 741-749; LabMET)*

Take home message (1/3)

Used Water → Resources

C2C approach

Separation

Liquid → NEWater

Concentrate → N, P, Energy, Biochar

(Verstraete et al., 2009; Bioresource Technol.100:5537-5545; LabMET)

Note:
- No activated sludge with biosolids production, no denitrification, no biol. P-removal, no explicit disinfection !!!
- Full focus on recovery

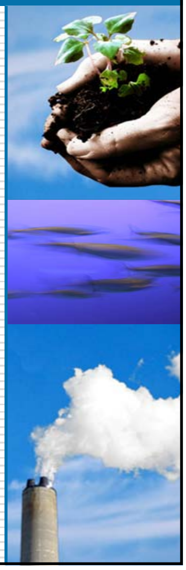
Take home message (2/3)

The N excreted per person/year

≈ 200 L fossil fuel input

(The International Nitrogen Initiative; www.initrogen.org)

We can not afford to <u>NOT</u> recover this



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Take home message (3/3)

Sustainability can only be achieved by accepting a certain risk

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<u>We</u> must help <u>our</u> politicians to accept a 'fixed' level of risk and thus to implement the C2C approach

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