Towards optimal $DESAR_3$

Developments in the Netherland.

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Research on domestic wastewater treatment at Wageningen University.

AnWT-pre-treatment sewage:

- at temperatures > 18 ^{o}C (starting 1976).
- at temperatures from below 10 ^{o}C (starting 1981).

NBMS-post-treatment systems (from 1985), emphasis on Ae_{micro}WT

Alternatives for domestic wastewater treatment.

AnWT-pre-treatment of sewage:

- Very well feasible in simple one-step UASB-systems at temp > 18 ^{o}C , it is proven technology.
- Well feasible at temperatures down to 10 ^{o}C, it still needs demonstration at big scale.

A **high rate Ae$_{\mathbf{micro}}$WTstep** for post-treatment is a very attractive option, it is proven technology at full scale for various types of industrial wastewaters and has been demonstrated for anaerobically pre-treated sewage.

The 64 m^3 demonstration UASB-plant in Cali Colombia (1983-1989)

But in order to achieve a really sustainable environmental protection in the Public Sanitation Sector our societies (wherever) should become delivered from the present

‘flushing away technologies’ ,

consequently from the need to treat enormous amounts of highly diluted sewage.

It is far too expensive, hardly any recovery of resources, creating severe environmental pollution problems, etc. etc.

We need the optimal DESAR$_3$-(EcoSan) concept, it is the road towards a sustainable EP a healthy life environment for everybody!

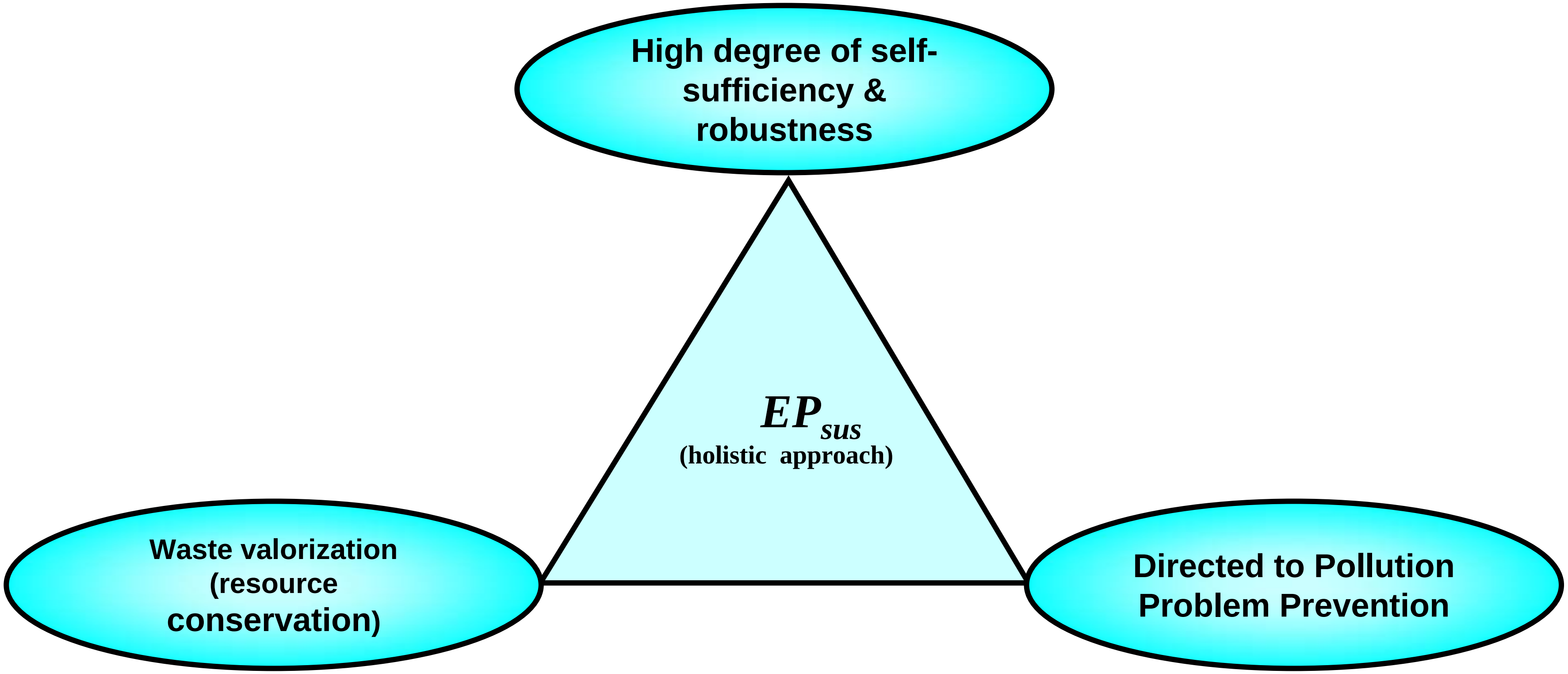
- Optimal source separation of waste and wastewaters and little if any dilution of all domestic waste(water)s!!
- Merely waste(water) transport at the site,
- Application of NBMS-based on-site waste & wastewater treatment completed with physical-chemical treatment,
- Minimization consumption of water & energy,
- Recovery and (on-site) of Resources & Reuse (on the site, stimulation urban agrculture).

DESAR$_3$

Focus on self-sufficiency!
at the scale of community, municipality, buildings (hotel, schools, hospitals), industry, etc.

Focus resource recovery and reuse
(stimulation of urban agriculture)

Focus on prevention man-made (pollution, social) problems!
But which authorities take the decisions?? e.g. about what is acceptable risks, e.g. public health risks, about the sanitation concept/system to be implemented?



High degree of self-sufficiency & robustness
EPsus
(holistic approach)
Waste valorization (resource conservation)
Directed to Pollution Problem Prevention

Faeces plus Urine plus kitchen waste

- A human being produces *ca.* 1.5 litres faeces plus urine plus kitchen waste;
  - 91% of the nitrogen;
  - 70% of the COD;
  - 69% of the phosphate;
  - main part of the **pathogens;**
  - **medicine rest and hormones**

faeces plus urine: the most risky for public health!!!

Wastewater collection in DESAR$_3$

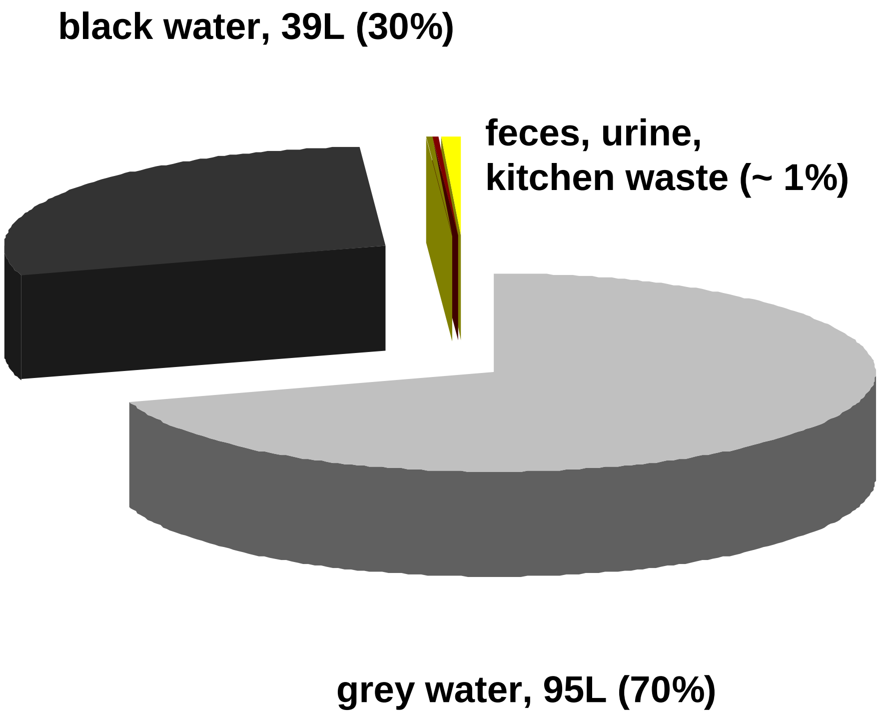
Use of water saving toilets:

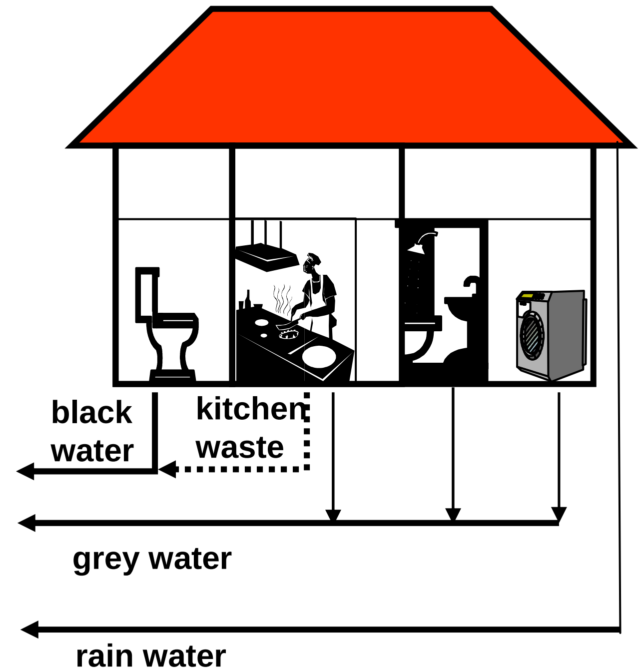
- **basket type collection** (zero water consumption),

- vacuum toilets (mixed collection feces & urine),

- vacuum toilets (separate collection feces & urine),

Separation at source in the household.





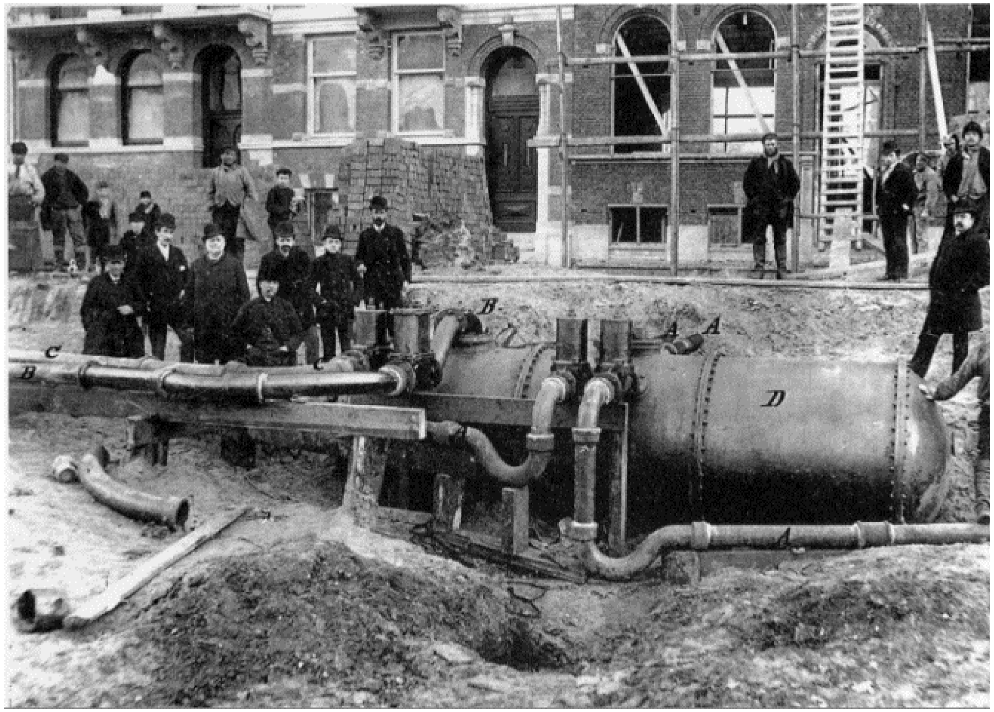
Demonstration toilets in Water museum, Arnhem

Waste(water) Transport

mainly/merely on-site transport and with very limited use of water as transport medium!!

(already big progress in industry)

1870's: Vacuum sewerage for collection of blackwater

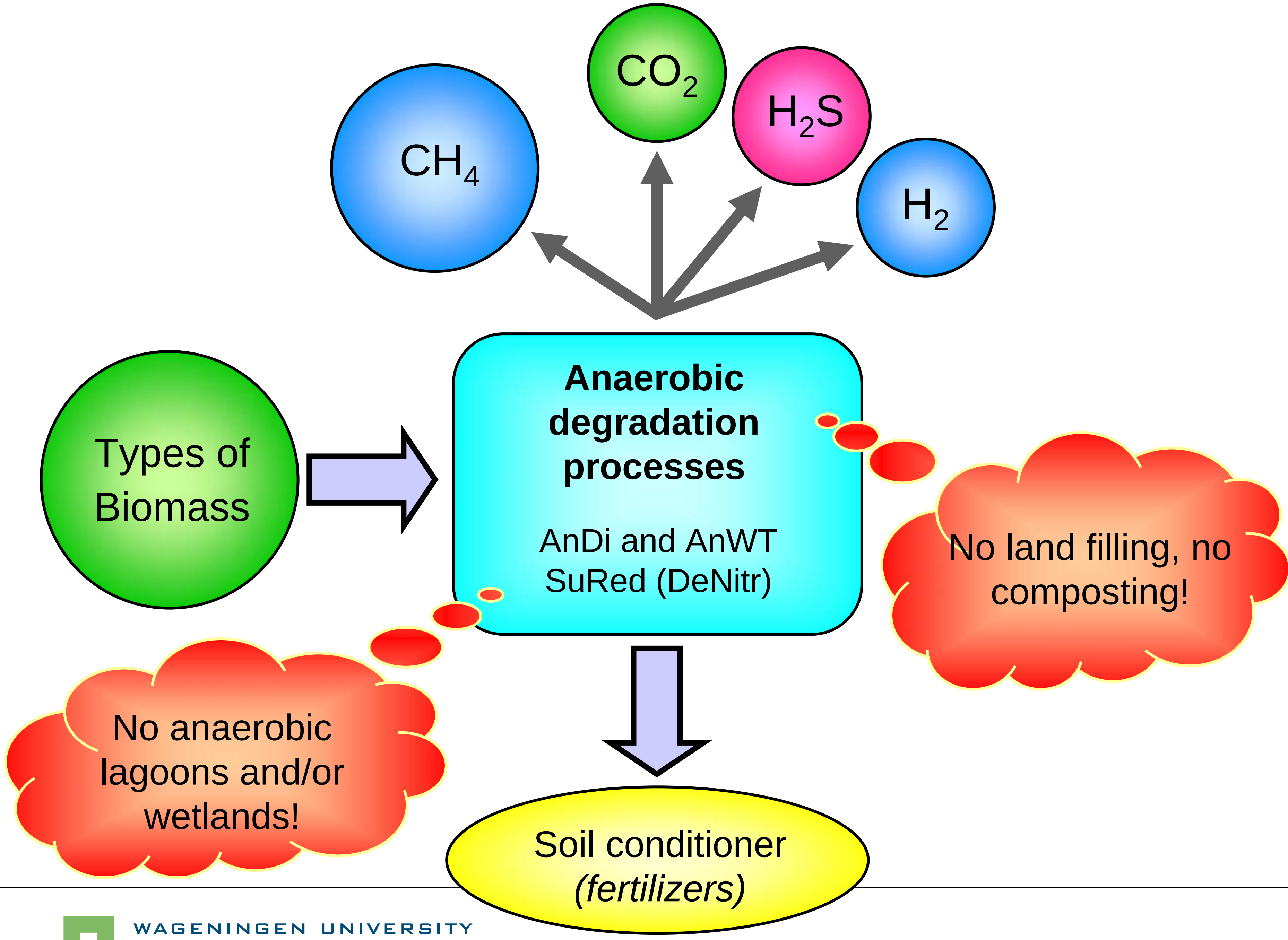


1. **Developed by Charles Liernur in 1867 as alternative to waterborne sewerage**
2. **Basic idea: reuse of concentrated black water in agriculture**
3. **Collection via subsurface iron pipes by application of vacuum suction through 'locomobile'**
4. **Human manure was directly used, dried or used for production of ammonium sulphate (Amsterdam)**
5. **Exploitation was in most cases cost effective (gains = costs)**

Leiden (1200 pe, 1870-1915), Dordrecht (800 pe, 1872-1887), Amsterdam (1700 pe, 1872-1912), Prague (15.000 pe), St. Petersburg (20.000 pe), Luxembourg

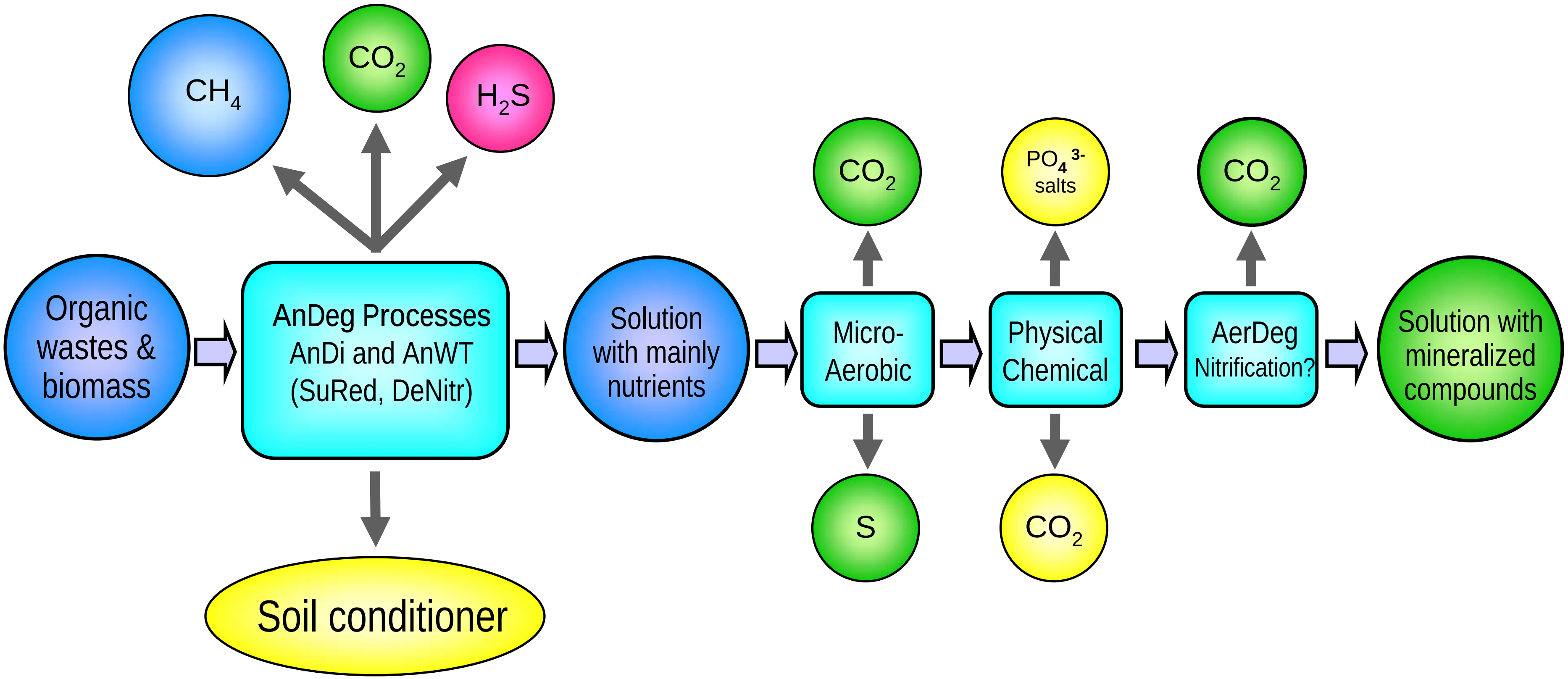
Sustainable waste(water) treatment:

Application of the Natural Biological Mineralization Sequence (NBMS) treatment concept

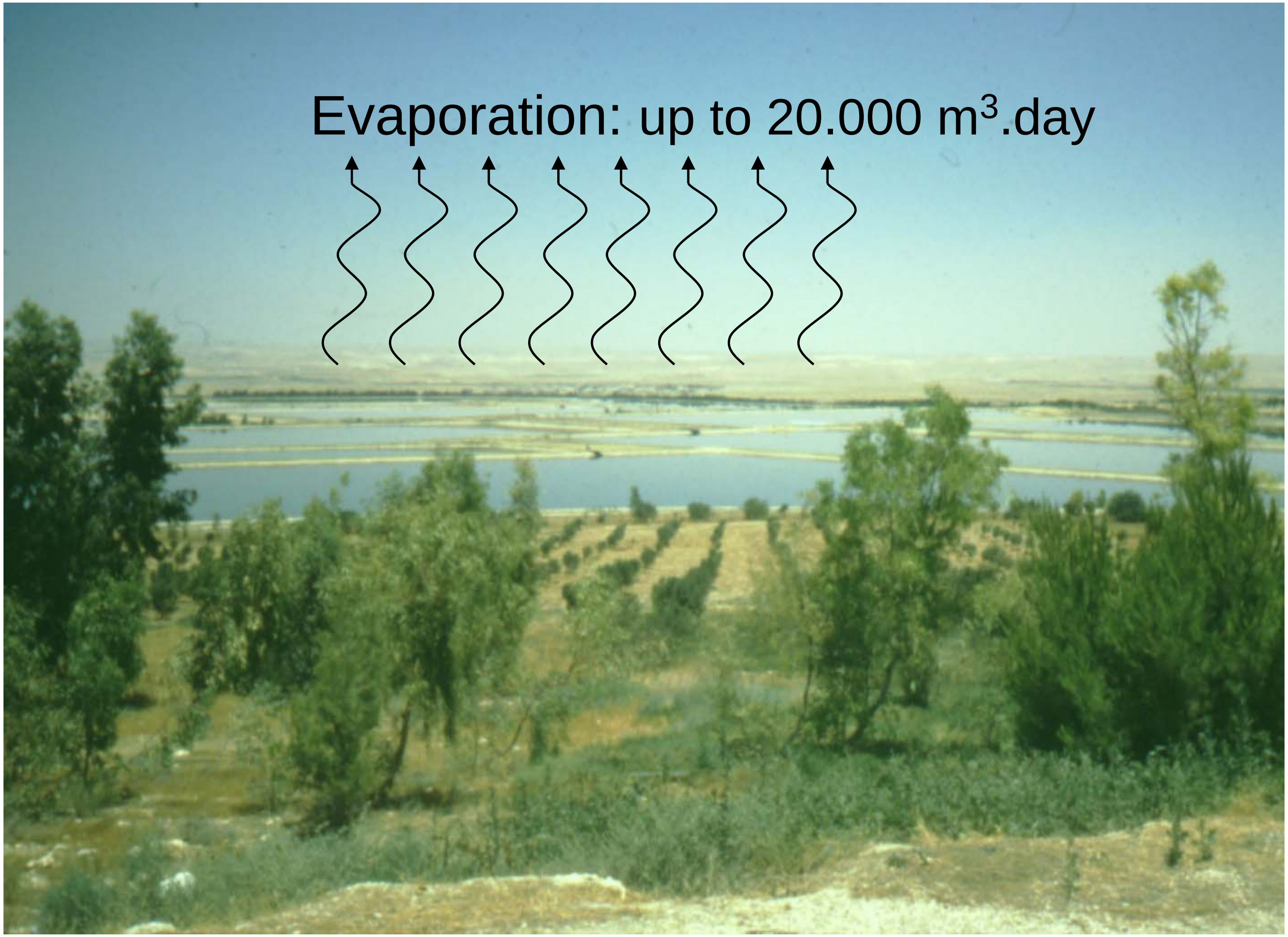


CH_4
CO_2
H_2S
H_2
Types of Biomass
Anaerobic degradation processes
AnDi and AnWT
SuRed (DeNitr)
No land filling, no composting!
No anaerobic lagoons and/or wetlands!
Soil conditioner *(fertilizers)*

Natural Biological Mineralization Sequence (NBMS)



Overview 200 ha Pond System at “Khirbet As Samra”



AnDegr-processes:
the first NBMS-biological treatment step, viz. high rate AnWT and AnDi-systems.

- For stabilizing biodegradable organic matter,
- For generating useful energy carriers, i.e. **CH_4**, possibly H_2, or even direct generation of electricity.
- For making available of nutrients (fertilizers), and elementary biological sulphur
- For Producing valuable organic soil conditioners

Anaerobic treatment can be ideally applied 'on the site'

***(in separate buildings, houses and neighbourhoods, consequently building <u>on-site</u> and <u>community</u> on-site up to > >1000 houses, depending on the location)* for:**

- **black water (with or without kitchen waste)**
- **combined black + gray water**
- **solid organic wastes as well.**

Ae$_{micro}$WT –systems:

role as **first** NBMS-**post-treatment** step

1. Conversion of reduced S-compounds into elementary biological sulfur. (use of the oxidative part of the **S$_{biol}$-cycle**)
2. Degradation of remaining, easily biodegradable organic pollutants,
3. Oxidation of reduced inorganic compounds (e.g. Fe^{II}),
4. Removal of colloidal matter (+ dispersed pathogenic organisms).

Anaerobic pre-treatment of black, combined black + grey water, and black water + solid organic wastes

- septic tanks, Imhoff tank
- improved septic and Imhoff tanks,
- pit latrines,
- accumulation type digesters (mixed and non-mixed).

(for house on-site and community on-site)

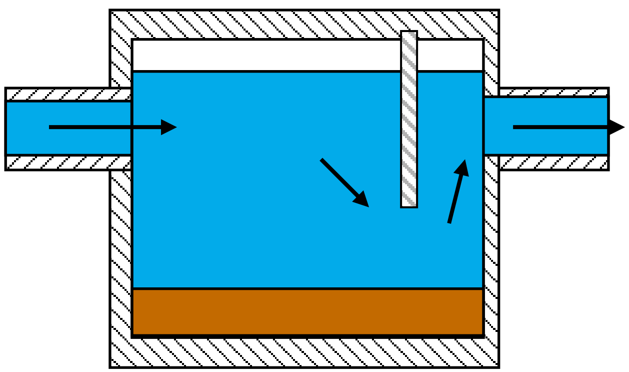
UASB septic tank system

- differs from the conventional septic tank by its up-flow mode of operation in order to improve:
  - Contact between sludge bed and wastewater;
  - Physical removal of suspended solids and biological conversion of dissolved components.

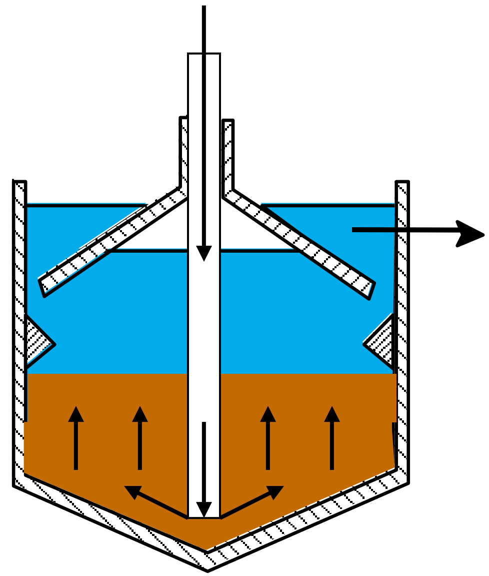
- differs from the UASB system by its extra volume for the accumulation and stabilisation of the entrapped sludge.
  - Sludge only (partially) discharged, once every 4-8 years (depending on the size of neighbourhood)

On-site anaerobic treatment

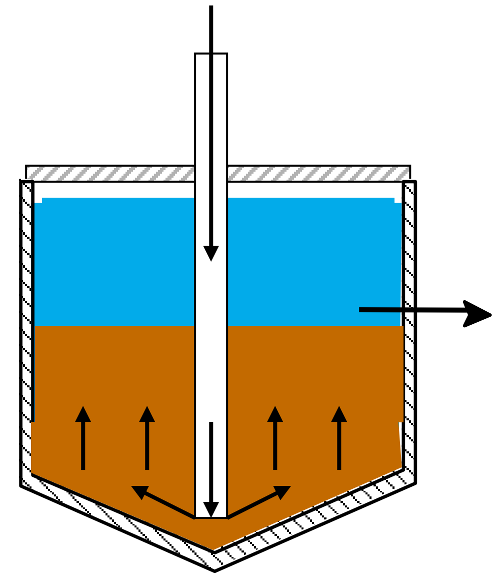
In many areas extensive sewerage is economically not feasible
Anaerobic treatment may play an important role as house-on-site treatment technology:



Conventional septic tank



Upflow septic tank
With gas withdrawal

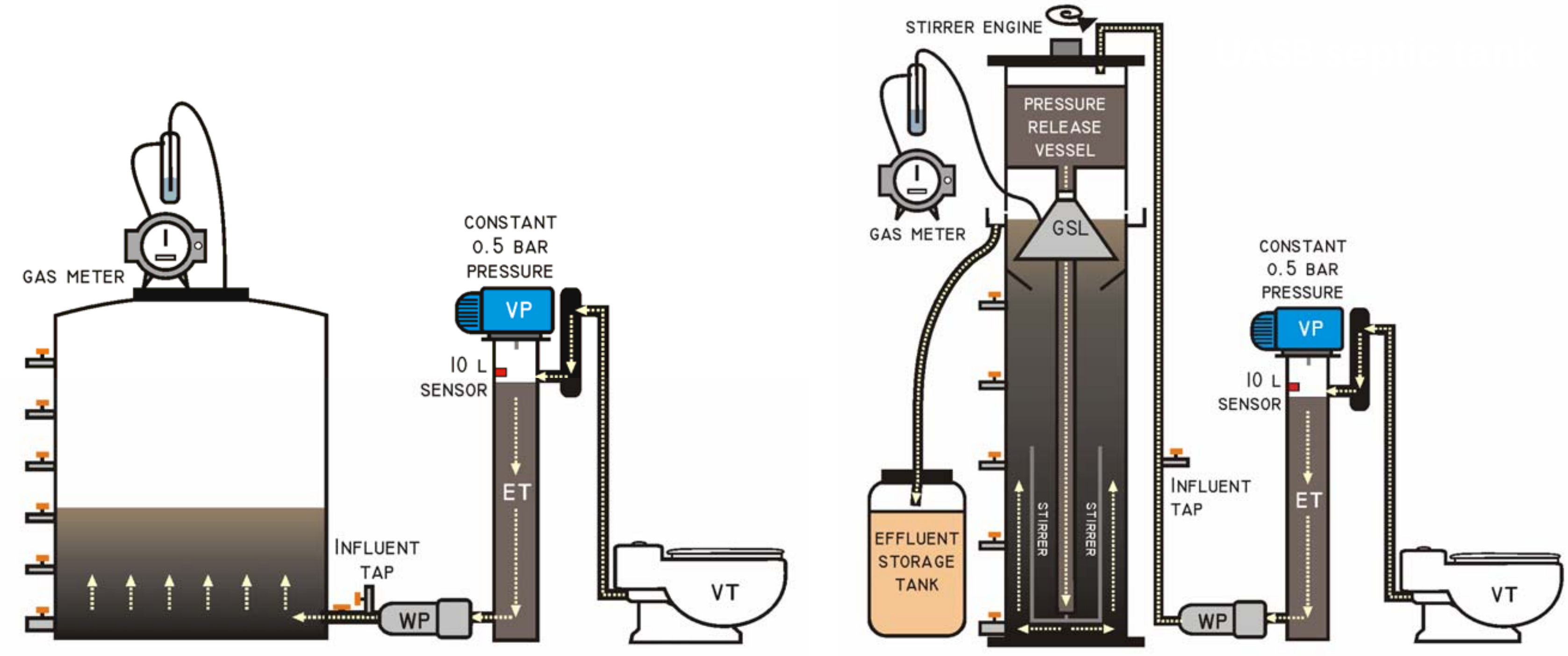


Upflow septic tank

Pilot-Plant Set Up

Accumulation tank reactor

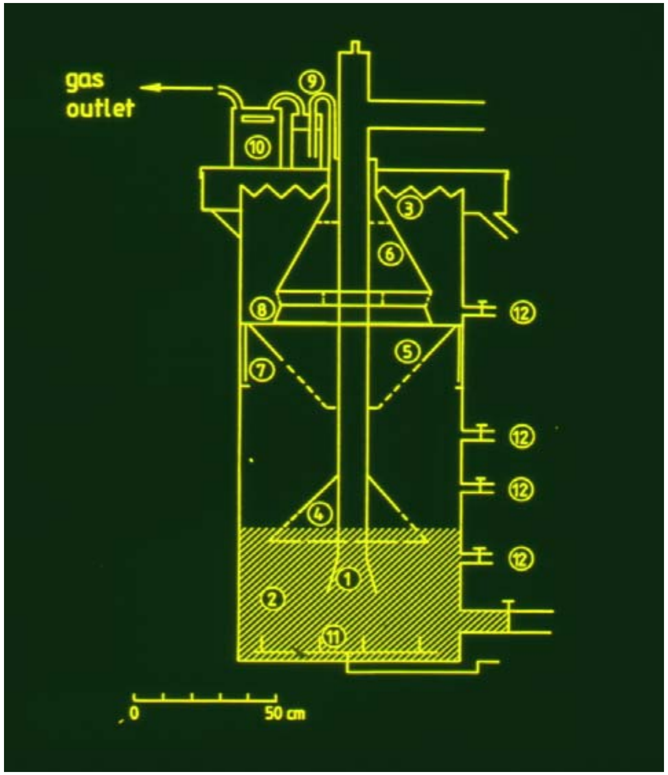
Upflow septic tank system



V_{CH4} = 11 m^3/person/year (black water + kitchen waste)

70 % methanisation (Zeeman et al., 2007)

Pilot family-scale UASB-Septic tank: Bandung, Indonesia



	COD_{in} g/l	HRT days	COD (%)	BOD (%)	TSS (%)	Path.	CH_4-prod. l/cap./day
Black Water	5.5	15	90-93	92-95	93-97	insuff.	20 - 30
Total sewage	1.35	1.4	67-77	75-82	74-81	insuff.	12 - 15

Experiments at WUR dealing with digestion of concentrated black water and kitchen wastes at small pilot plant scale (*Sub-department of Environmental Technology*)

- **temperatures: 15, 20, 25 °C**
- **influent $COD_{blackwater}$: 9-13 g/l**
- **influent $COD_{blackwater + kitchen}$: 13-23 g/l**

Treatment of Black water treatment

Comparison :

UASB–ST$_{pilot}$

7

l/p.d^{-1}

7

l/p.d^{-1}

UASB-pilot

Conditions at the treatment of BW in UASB (-ST) reactors

	UASB-ST (pilot-2 toilets)	UASB-ST (32 houses)	UASB; (lab)
Duration experiment (months)	36	12	12
Reactor volume, L	200 (2*)	7m3 (2*)	50
HRT (d)	29	35	8.7
OLR, kg COD/m^3/d	0.33-0.42	0.4	1.1
Temp. (^{o}C)	15 & 25	20 & 35	25

Black water concentration

Parameter	Unit	BW UASB-ST pilot	BW; UASBST Sneek
Volume	L/p/d	7.0	5
COD_{tot}	gCOD/L	9.5-12.3	17
TN	gN/L	1.0-1.4	2.0
Ammonia N	mgN/L	0.71-1.0	1.2
P total	gP/L	0.11-0.14	0.26
P Soluble	gP/L	0.03-0.045	0.1

Effluent composition of UASB (ST); BW

	UASB-ST; pilot	UASB-ST 32 houses	UASB; BW;25
COD_{tot} (COD/L)	2.7-3.7	1.3-1.7	2.6
CH_4 (L/d)	5-6	520-780	13
Ammonia (gN/L)	0.8-1.1	1.2-1.4	1.0
P soluble mgP/L	52-59	116-120	97

Sneek, the Netherlands
Demonstration project at housing estate: 32 houses
Future: black and grey water treatment in 200 houses!

Treatment of Black water treatment

Comparison :

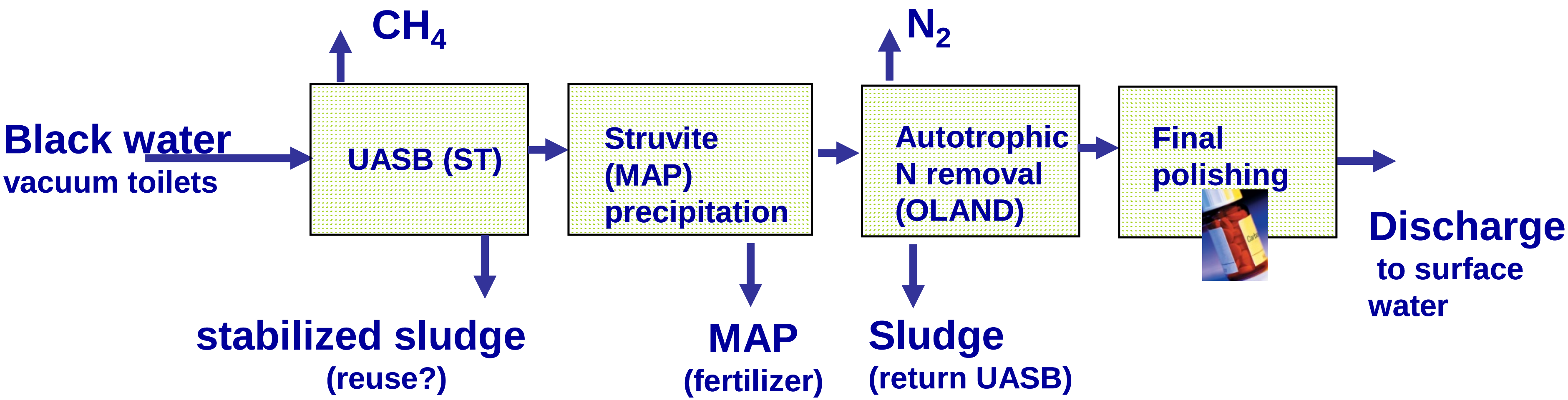
UASB–ST$_{pilot}$

UASB–ST$_{demo}$

7 L/p.d^{-1}

7 L/p.d^{-1}

Black water treatment (Sneek)



UASB (ST)	HRT_{min}=7d; T_{max} = 30°C
Struvite	$t_{contact}$=30min
OLAND	HRT_{min}=3.5d

Black water treatment; struvite precipitation demo scale

- nitrogen and phosphorus ratio: 11 mgN/mgP;
- molar base : 24 mol N/mol P;
- applying struvite precipitation with sufficient Mg added, will theoretically result in recovery of almost: 100% of phosphate;
- but only recovery of 1.6 % nitrogen;

- phosphate recovery: 0.28 kgP/p/y.

DeSaR in Sneek

- **two 7 m³ UASB-septic tanks;**
  - **20°C**
  - **30°C;**
- **COD-removal: 90%**
- **Gasproduction:**
  - *ca.* 1.6-3.1 m^3 biogas/$m3_{influent}$
  - resp. *ca.* 0.6 en 1.25 m^3 biogas/day

  - **Post-treatment effluent UASB's**

  Biorotor for COD and N-removal.

  - Struvite precipitation for P en N removal**.**

A more optimal 'black water' treatment tackle

Step 1: Proper collection (toilet); reduction flushing volume (<6 l/p/d);

Step 2: AnWT/AnDi mineralization step; UASB(-septic);

Step 3: SS-settling + liquid effluent storage tank; depends on step 1;

Step 4:

- use of a mobile treatment unit for removing and ecovering nutrients and completing treatment;
- direct reuse in agriculture (transport to arable land)
- periodical transport from the site to a central treatment unit?

Considerations handling the Grey water

- Grey water (2/3 of total wastewater can be treated locally quite well !!

- The treated grey water can be used for (depending on the treatment system applied):
  - Ground water recharge,
  - Domestic purposes, (attractive urban environment)
  - Irrigation.

Grey water composition

Parameter	Unit	Groningen	Sneek	Dormitory, Jordan*
Volume	L/p/d	90	60-70	66±13 (20)
COD_{tot}	mgCOD/L	425	626	548
COD_{ss}	mgCOD/L	115	163	157
COD_{col}	mgCOD/L	193	194	92
Ammonia N		7.3	4.2	6.4
Soluble P		2.3	1.6	13.9

Treatment of Grey water

- Several treatment options: e.g.
  - **AnWT (UASB)+ (micro-) aerobic bio-rotors (+ PC-polishing or sand filtration),**
  - High rate aerobic systems,
  - Low rate aerobic systems (constructed wetlands),
  - Membrane bioreactors, etc.

- In the Netherlands the application of constructed wetlands in urban residential areas is legally accepted, but ….. the application of various other needs further demonstration.

Research for some grey water treatment options

Anaerobic pre-treatment in a UASB

V= 5 L; HRT= 20 h; 20-30°C

Aerobic treatment sequencing batch

V = 3.6 L; HRT 5 -72 h

Temperature = 20-30°C

Constructed wetlands - examples

Rural environment (Sweden)

Urban environment (Oslo)

Landscape architects on constructed wetlands:

"Constructed wetlands are very interesting for urban design"
"By integrating constructed wetlands in urban design there are de facto hardly any extra costs"

Grey water removal efficiencies in a combined UASB-activated sludge process (%)

	Anaerobic	Aerobic	Total
Total COD	50.6	84	87
Suspended	48.6	68	89
Colloidal	49.3	93	98
Dissolved	44.6	76	75

The Micro-aerobic post-treatment step

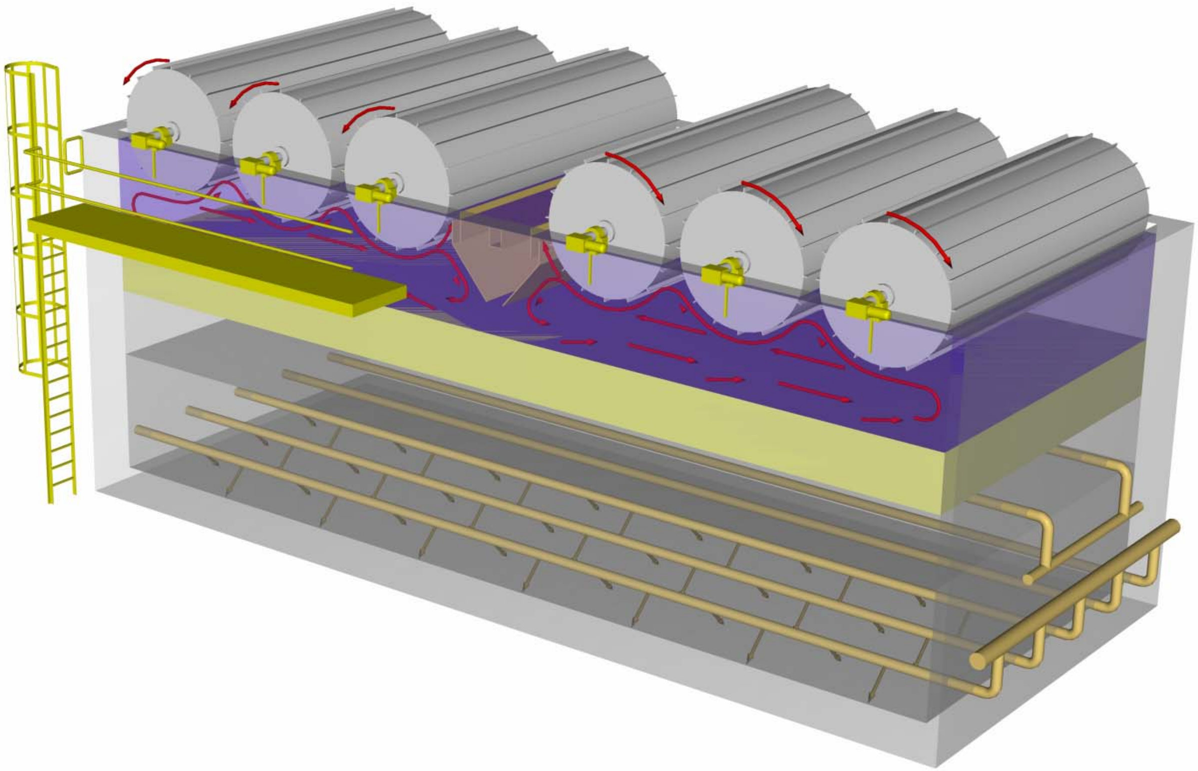
An **one and/or two step micro-aerophilic RBC-reactor** highly efficient in removing:

- Mal-odorous compounds and reduced inorganic compounds (at HRT < 15 min.),
- $COD_{biodeg,sol}$ at HRT:30-150 min. (depending of the quality of the effluent),
- Colloidal matter/pathogens at HRT in the range 30-150 min. (depending on the effluent quality).

Big potentials for a UASB + Ae_{micro}WT for grey water treatment at temperatures > 18°C, and likely lower!

(UASB-A_{plus} –reactor system)

An impression of a UASB-A_{plus} – reactor, here equipped with a biorotor system

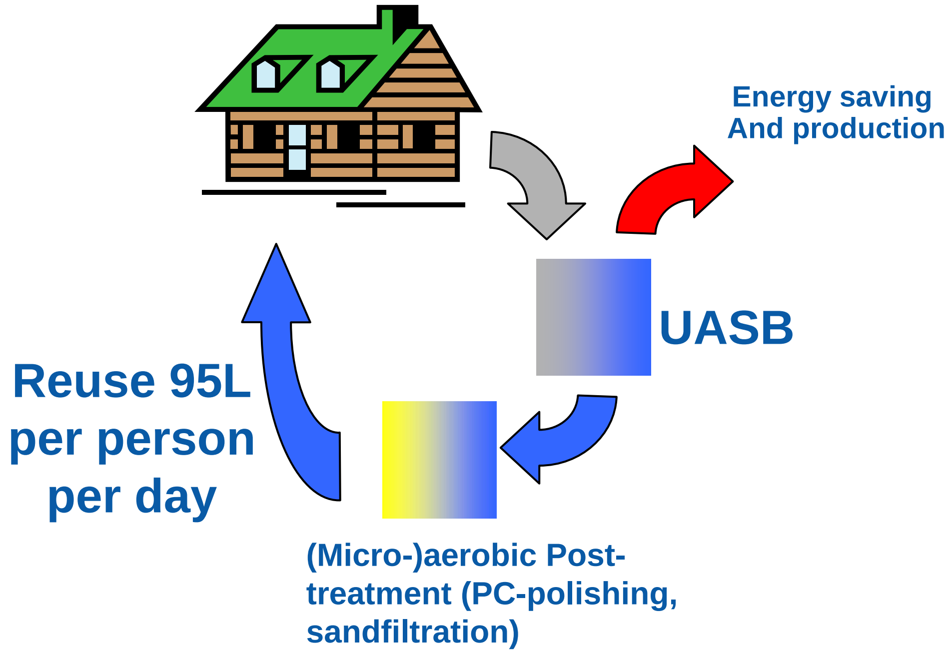


The UASB-A$_{plus}$-reactor system system for grey water treatment

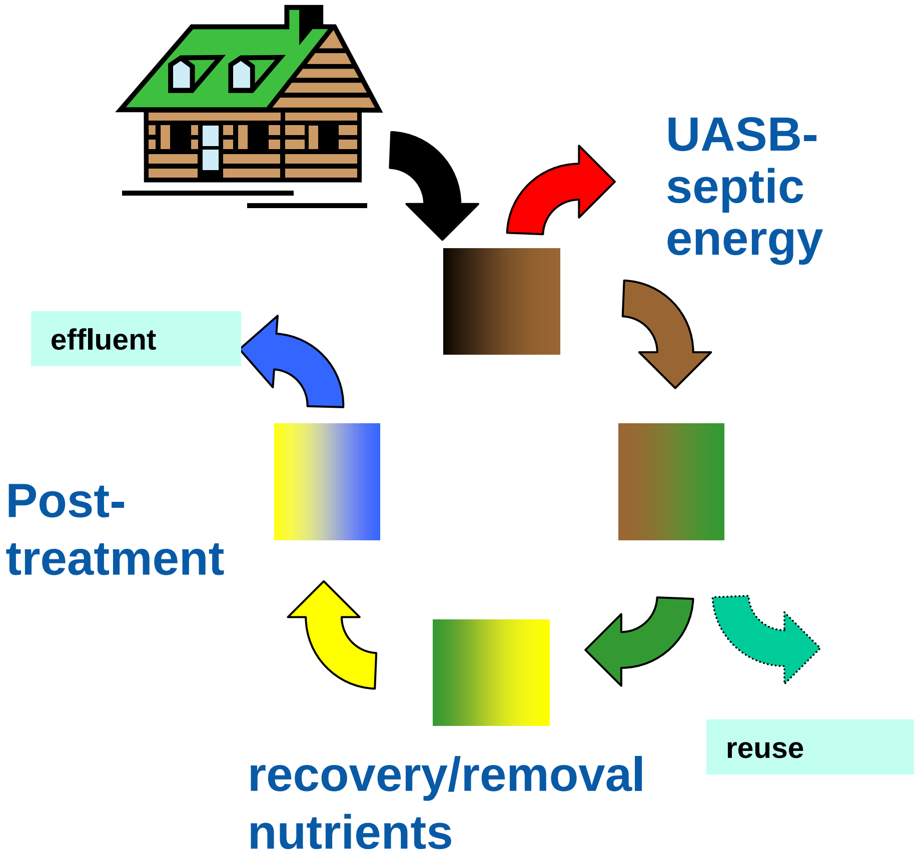
(at temperatures > 18^{o}C and likely lower)

is very compact and opens possibilities for down-town implementation!

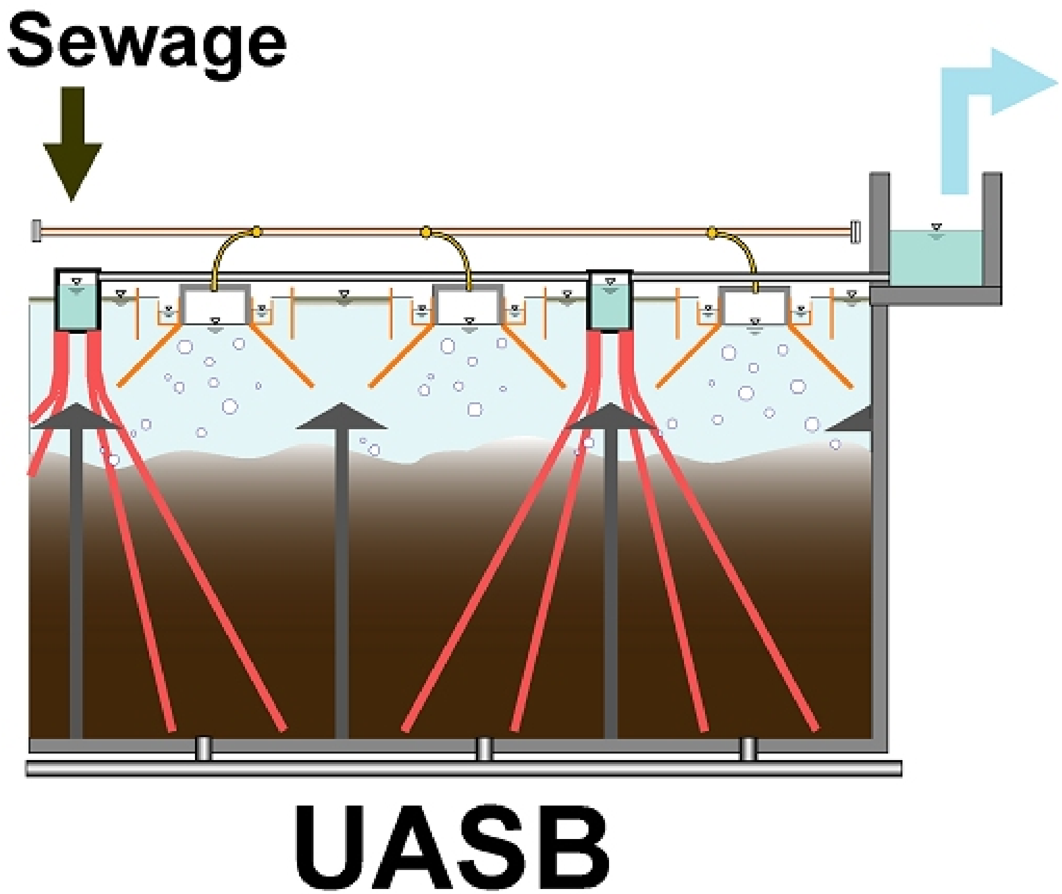
Grey water



Black water



How to reach effluent re-use standards ??



Post-treatment:

- Activated sludge ?
- Lagoons (aerated) ?
- Membrane systems ?
- Rotating Bio-Contactors ?
- Constructed wetlands ?
- Sand filtration ?
- Trickling filters ?
- Flocculation
- Flotation
- Physico-chemical ?
- Forced oxidation ?
- others ????

Energy balance

Biogas production (BW, KW, GW)		10,5 $m^3CH4/p.y^{-1}$	374 $MJ/p.y^{-1}$	131 $MJ_{electric}/p.y^{-}$
Energy consumption	Vacuum transport	-[1]25 (kWh/p/y)		-90 (MJ/p/y)
	Kitchen waste grinders	-5 kWh/p/y		-18,0 MJ/p/y
	Post-treatment			-43 MJ/p/y
Energy saving	STP	24 kWh/p/y		86 MJ/p/y
	Conventional sewer	30 (kWh/p/y)		108 MJ/p/y
	[5]Drinking water	0.5 $kWh*m^3_{produced}$		26 MJ/p/y
Total				200 MJ/p/year

The immense problems of the implementation.

- How to convince the established CENSA-directed sanitation world, including policy makers?

- How to involve the citizens, communities?

Likely the easiest way is via the bigger private polluters, e.g. hospitals, hotels, camping sites, etc.

Also for winter time conditions in sub-tropical and moderate climate zones there exist big potentials for NBMS-systems, viz.

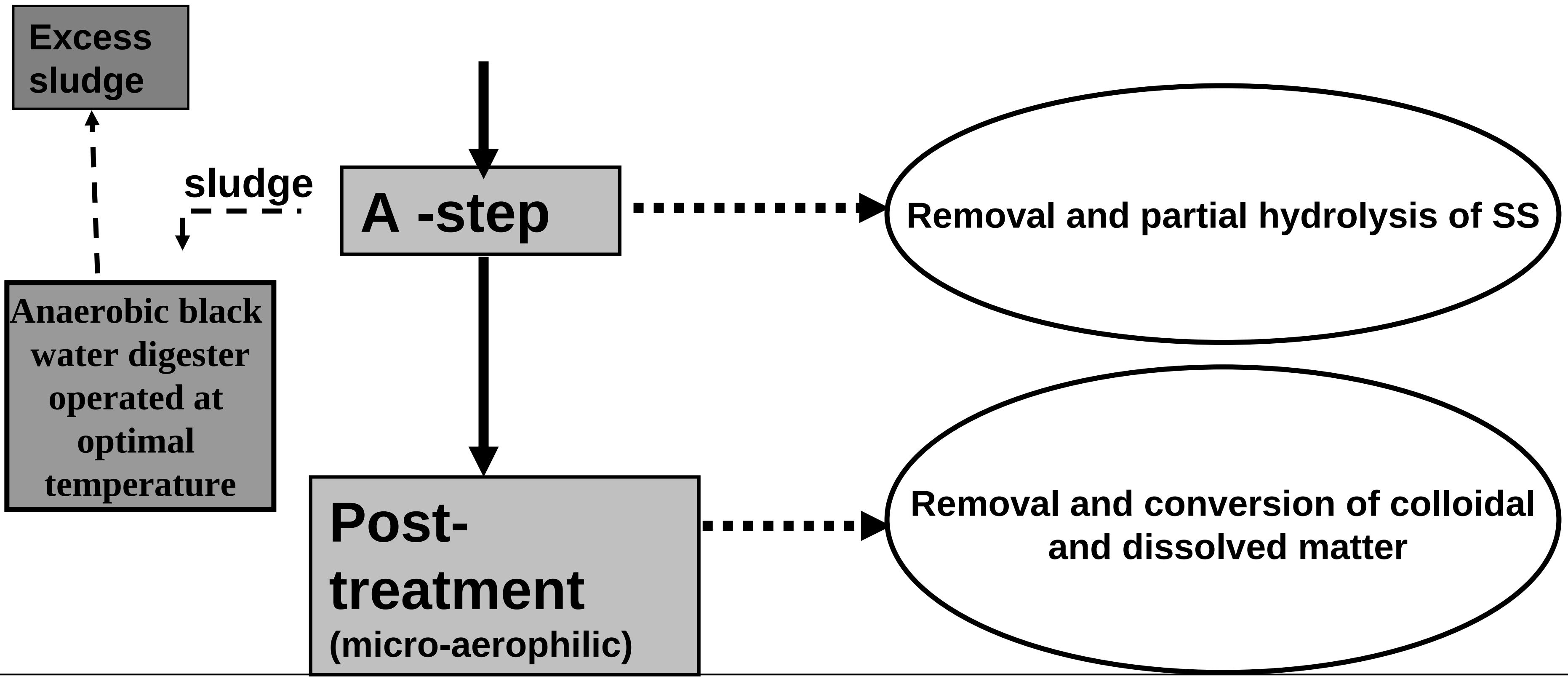
The **UASB/AD- A $_{plus}$ reactor** system which can use the Ae_{micro}WT-unit :

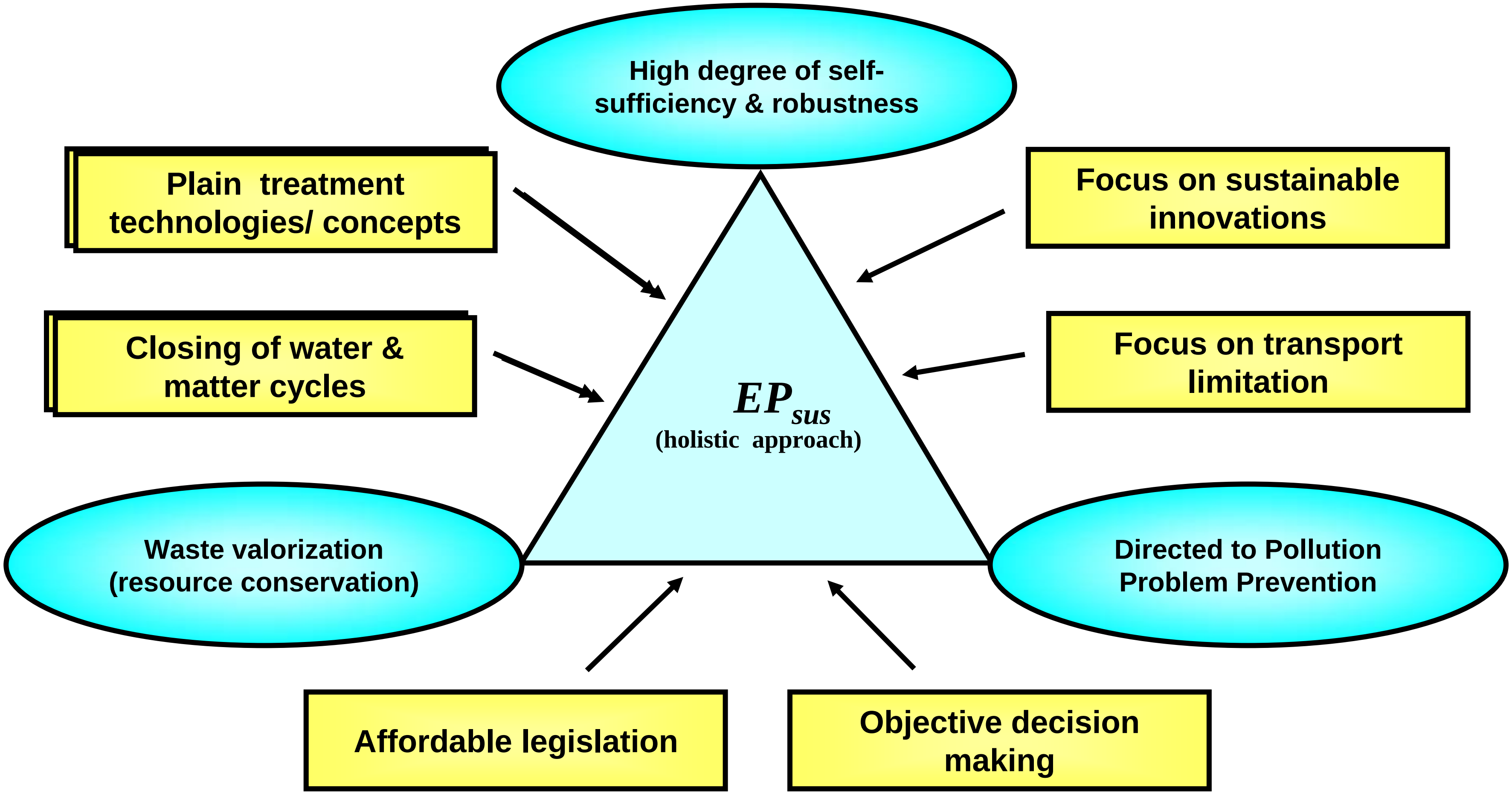
- **in front of the UASB**
  (as high rate A-step conform *Böhnke, 1978),*

and/or

- **the Ae_{micro}WT-unit as first post treatment step**

Two stage system is more appropriate for the anaerobic treatment of domestic sewage at low temperature than one stage (Mahmoud, et al 2004).




High degree of self-sufficiency & robustness
Plain treatment technologies/ concepts
Focus on sustainable innovations
Closing of water & matter cycles
Focus on transport limitation
EP_{sus}
(holistic approach)
Waste valorization (resource conservation)
Directed to Pollution Problem Prevention
Affordable legislation
Objective decision making

Conclusions

- Optimal $DESAR_3$ solutions already exist as sustainable alternative for the modern costly, vulnerable and non-sustainable CENSA-systems,

- The $DESAR_3$- concept will enable ‘us’ (but who make the decisions??) to attain the MDG!!

- The interest in $DESAR_3$ systems is rapidly, even in the established PuSan-sector.