



On-Site and communal Greywater treatment for Reuse

Univ-Prof. Dr.-Ing. Ralf Otterpohl

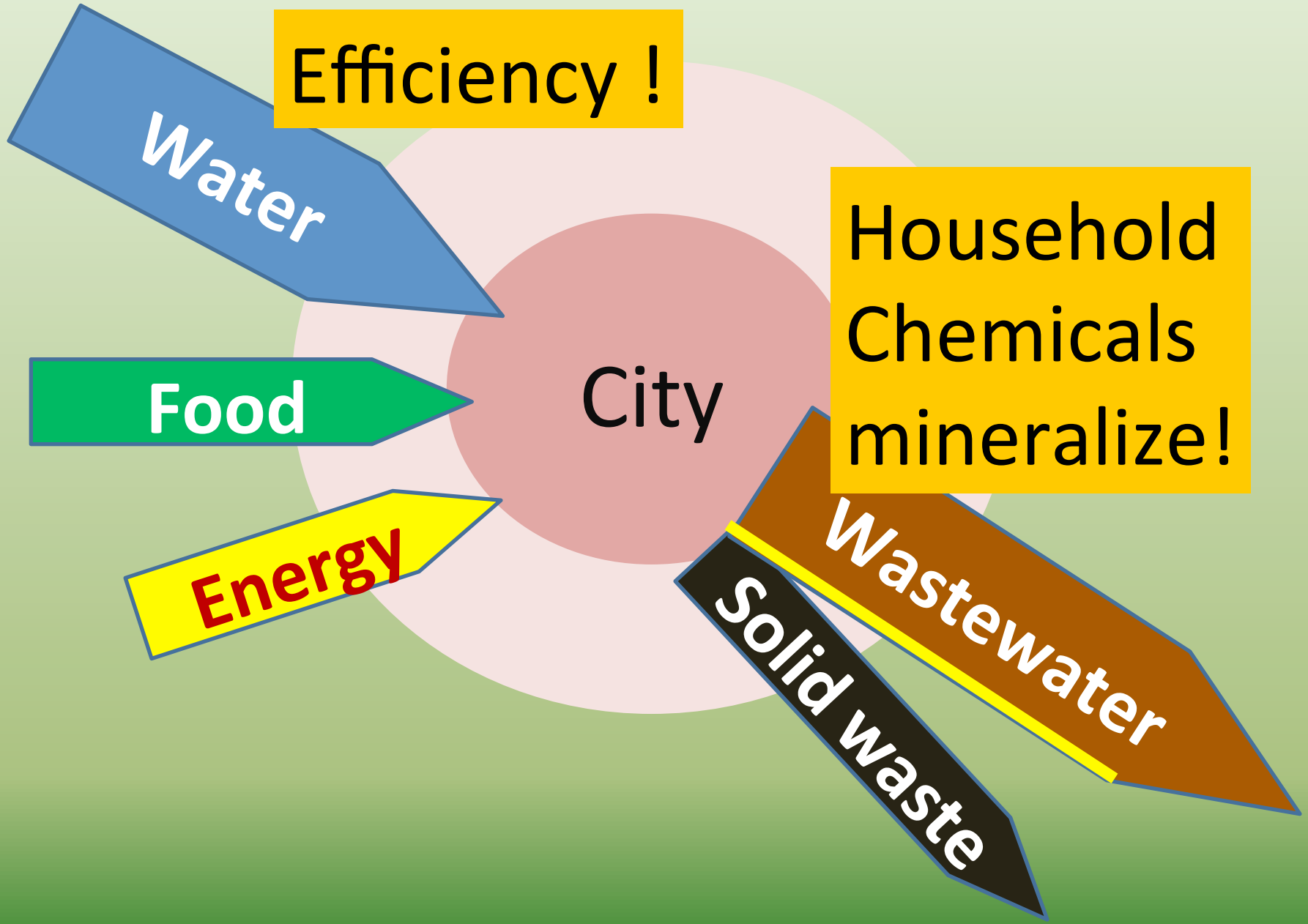
Director

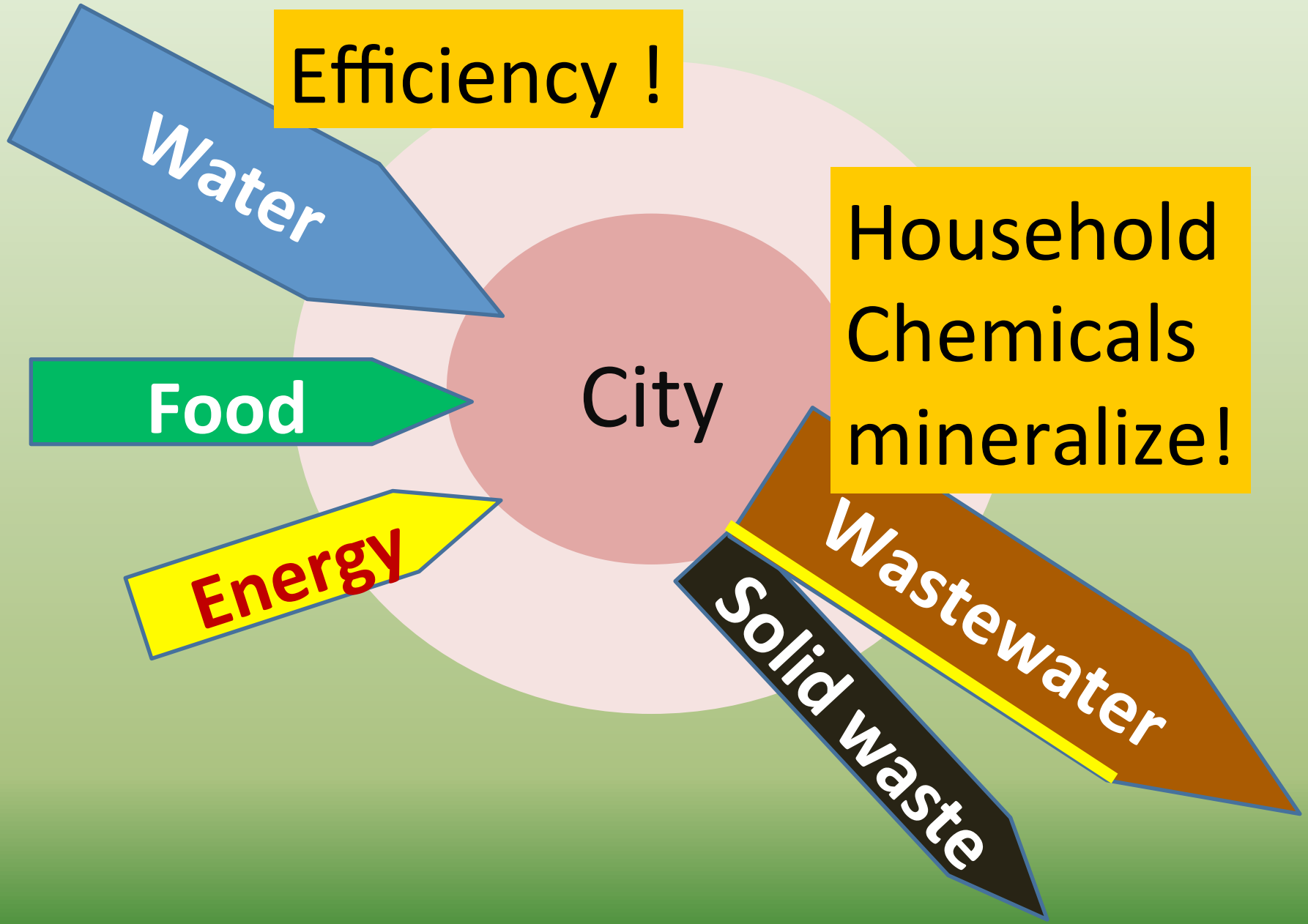
Institute of Wastewater Management and Water Protection

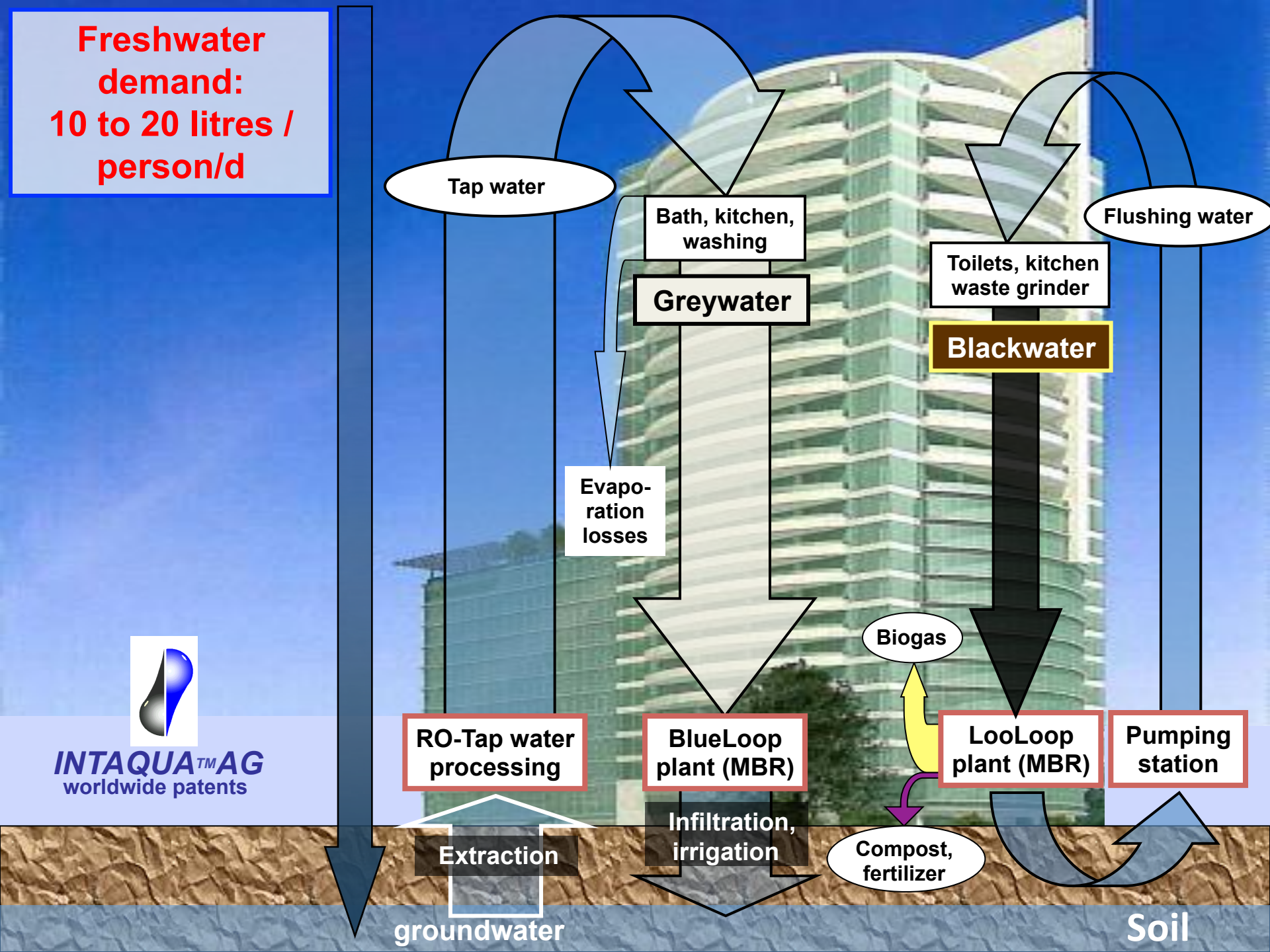
Hamburg University of Technology, Germany

TUHH

Hamburg University of Technology


Efficiency !
Water
Food
Energy
City
Household Chemicals mineralize!
Wastewater
Solid waste


Efficiency !
Water
Food
Energy
City
Household Chemicals mineralize!
Wastewater
Solid waste

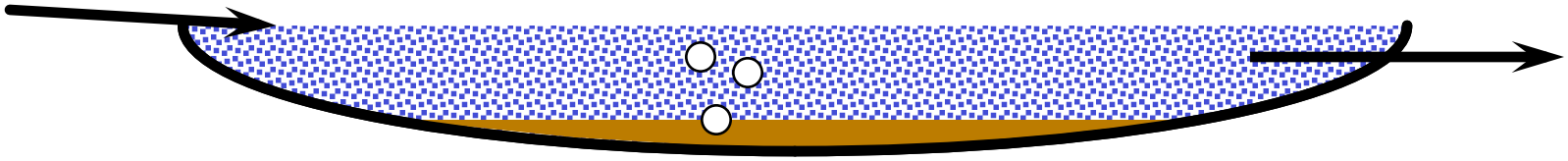

Freshwater demand: 10 to 20 litres / person/d
Tap water
Bath, kitchen, washing
Greywater
Flushing water
Toilets, kitchen waste grinder
Blackwater
Evapo-ration losses
Biogas
RO-Tap water processing
BlueLoop plant (MBR)
LooLoop plant (MBR)
Pumping station
Infiltration, irrigation
Compost, fertilizer
Extraction
groundwater
Soil
INTAQUA™AG
worldwide patents

greywater treatment options

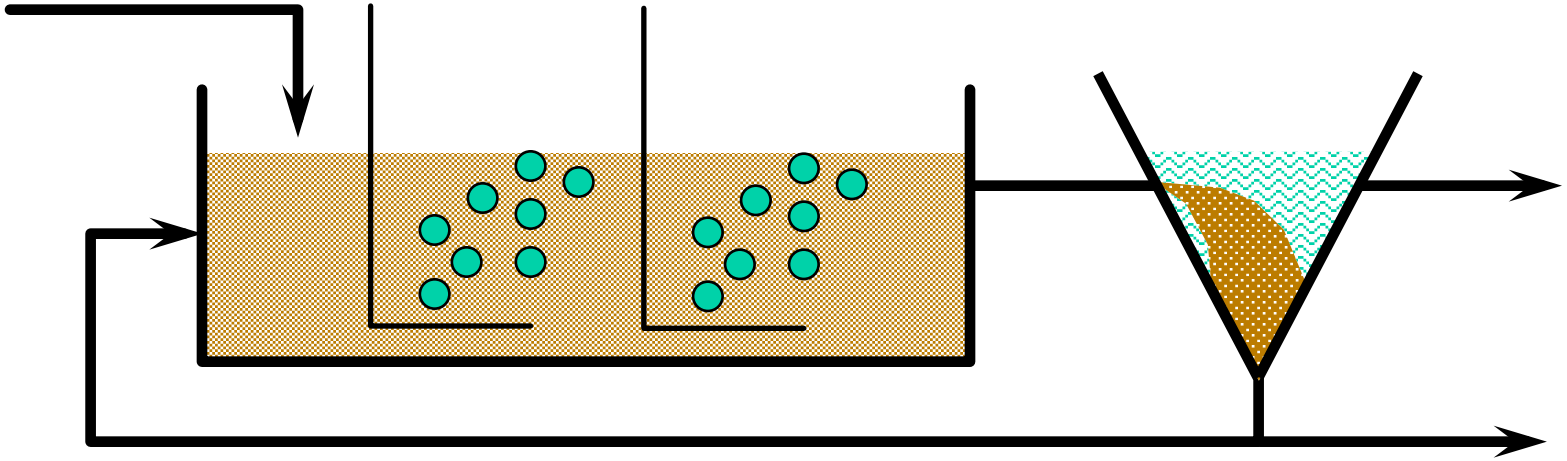
- **Constructed Wetlands or WW-forests**
- **Filtration (Sand, Membrane)**
- **Anaerobic baffled bioreactor**
- **Upflow Anaerobic Sludge Blanket (UASB)**
- **Membrane Bioreactor**
- **Rotating Biological Contactor (RBC)**
- **Coagulation and flocculation**

Simple and cheap with Moringa Seeds

Suspended biomass in a pond or river



Activated sludge process

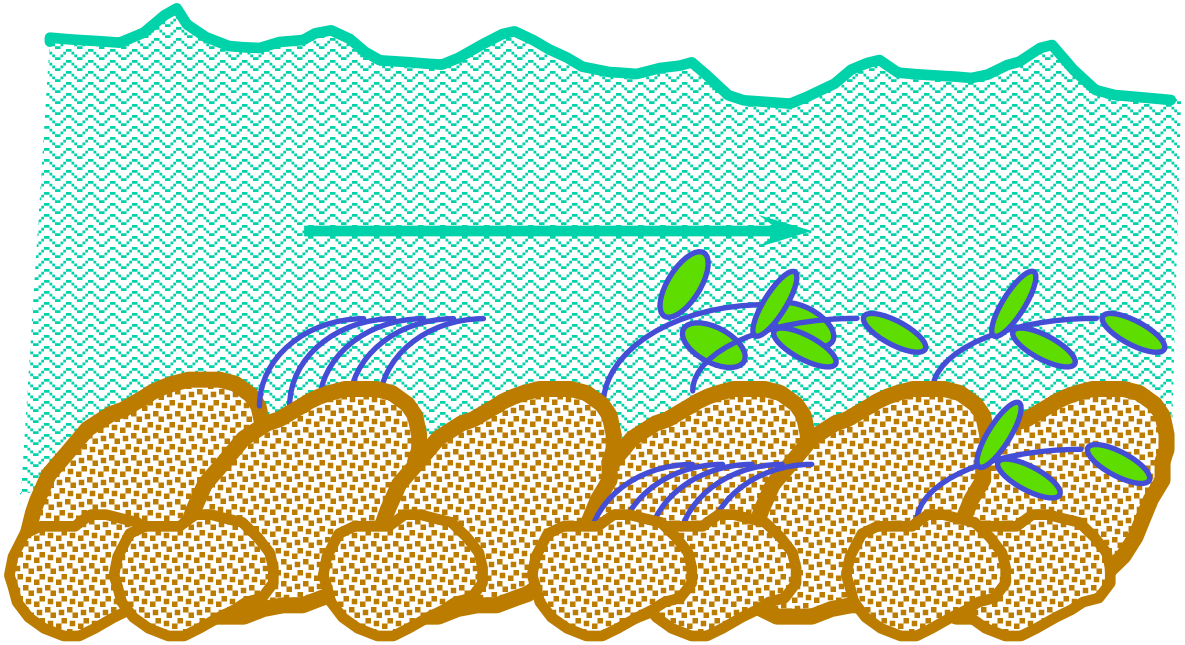


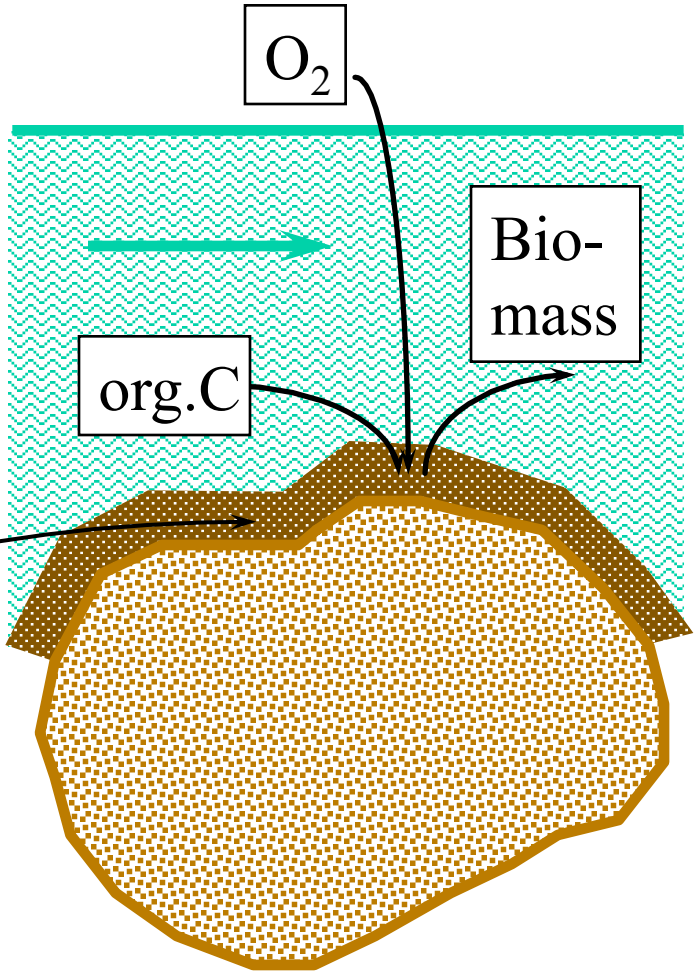
Oxidation Ditch

flexible operation for nitrogen removal

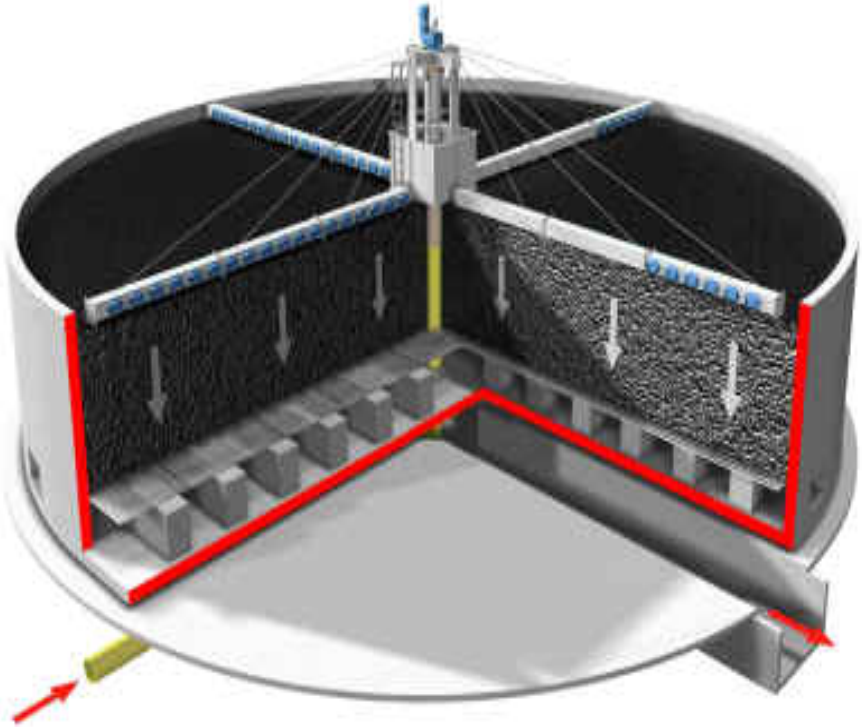
TUHH
Technische Universität Hamburg-Harburg

Biochemical degradation in rivers





Biofilm or
attached Biomass



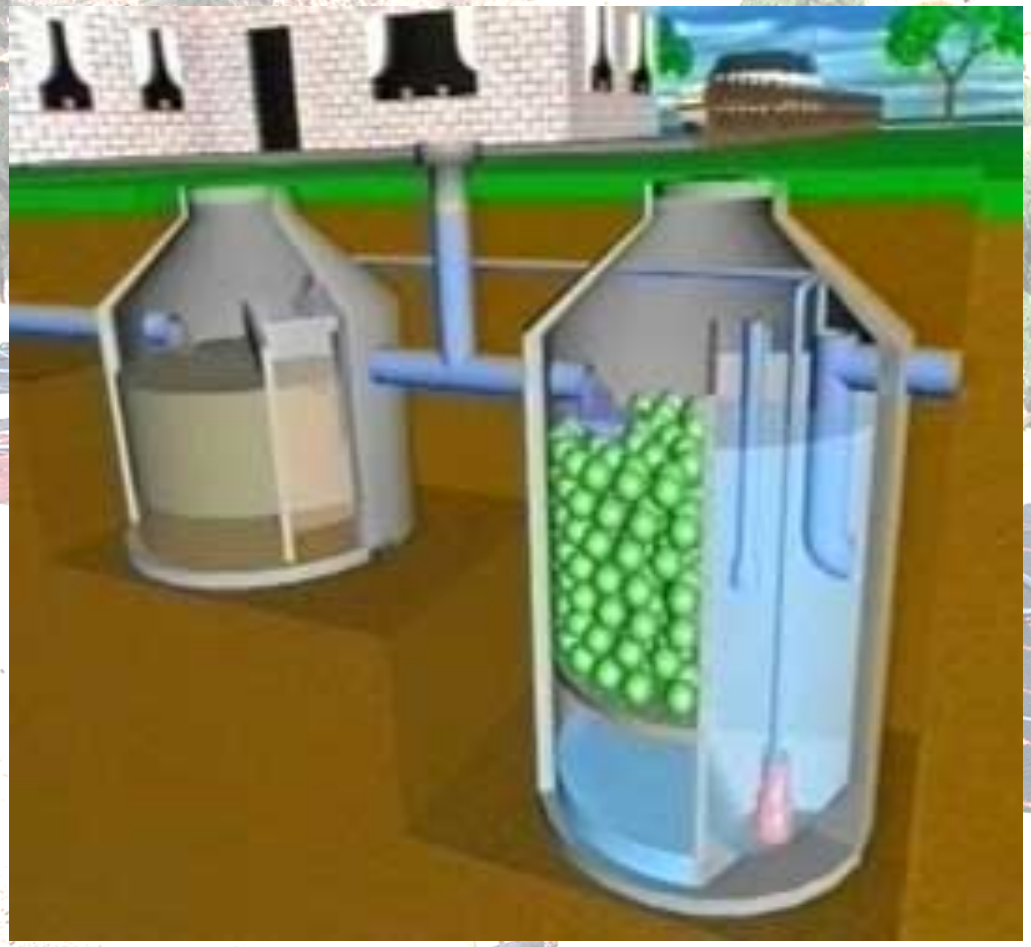
Factors affecting the performance of a trickling filter

- Concentration of substrate / oxygen
- Bed material
- Hydraulic loading / recirculation
- Bed height
- Temperature
- pH
- Nutrients
- Toxics
- Particles

from www.stud.sb.luth.se

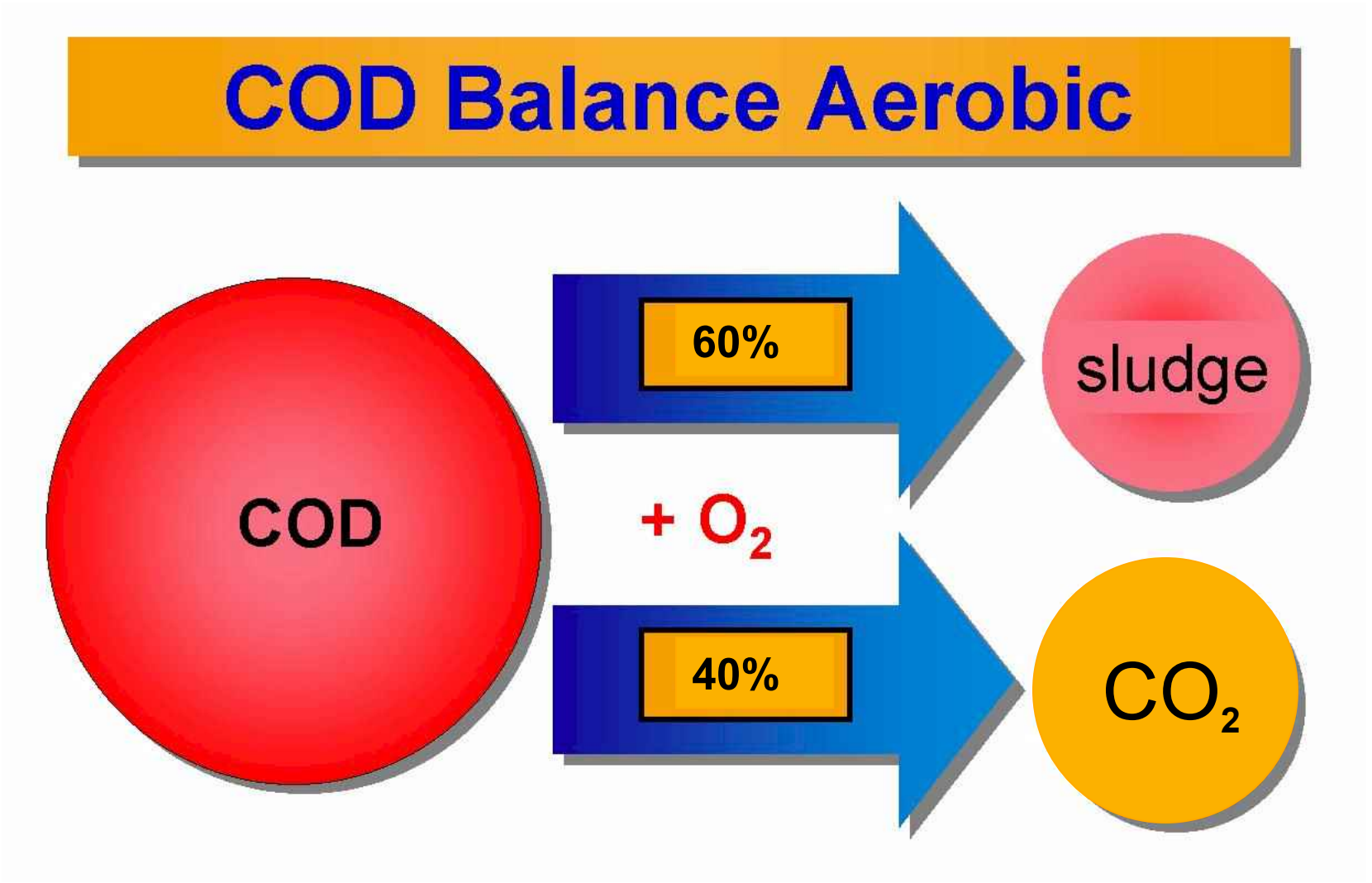
Trickling Filters

Also on-site, small scale systems, small footprint, cost efficient, but deep…

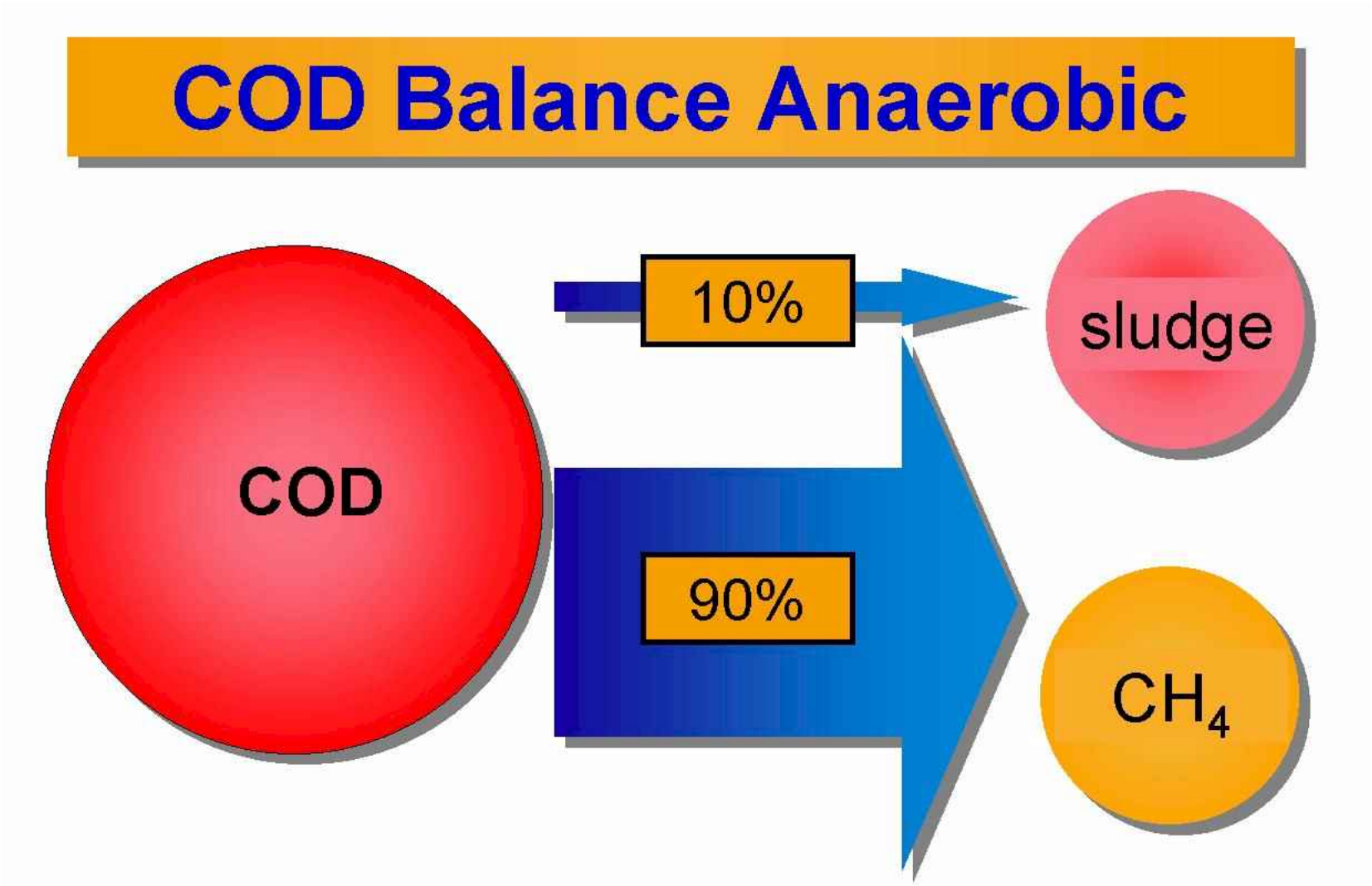


Constructed wetland – vertical flow

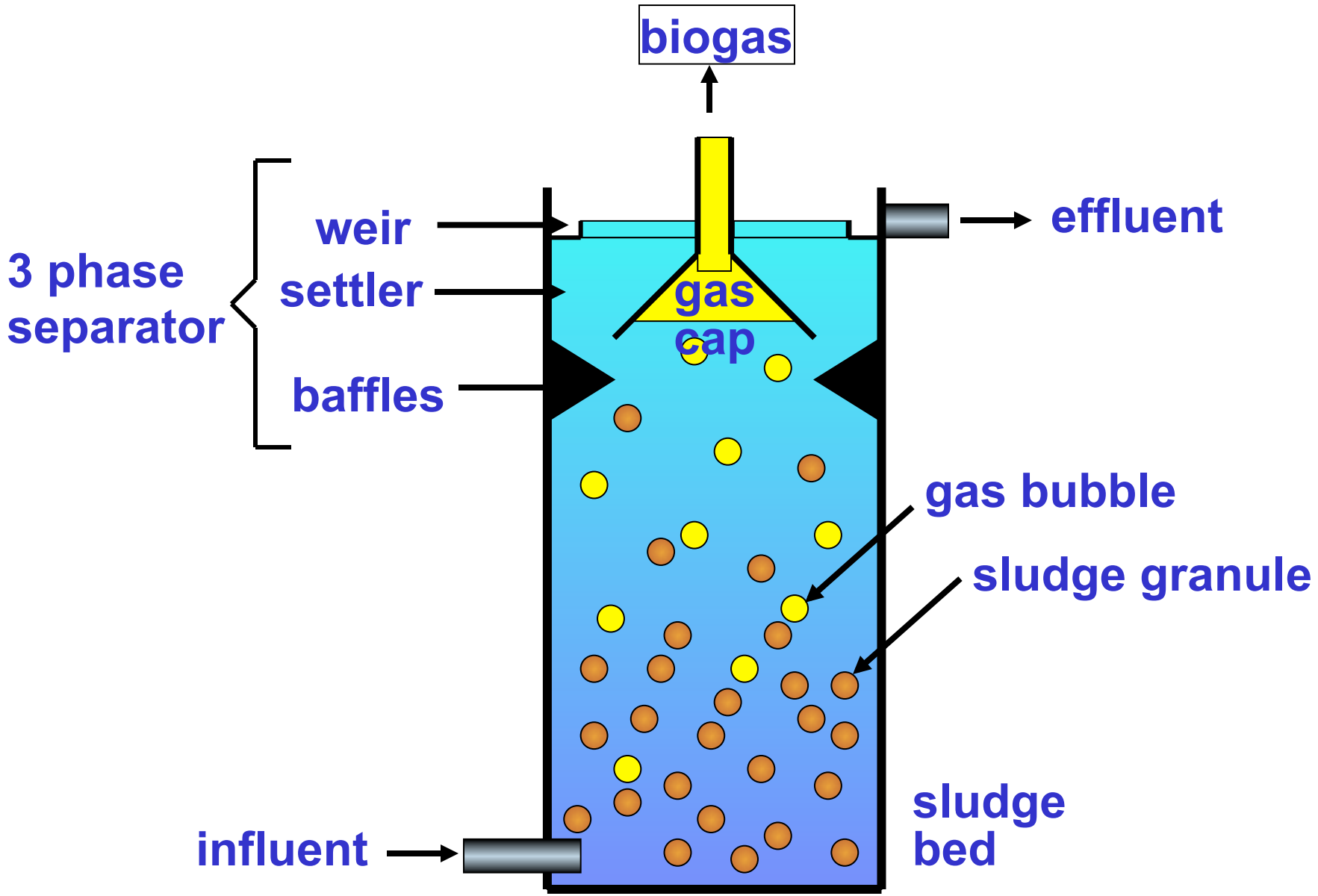
COD Balance Aerobic Biodegradation

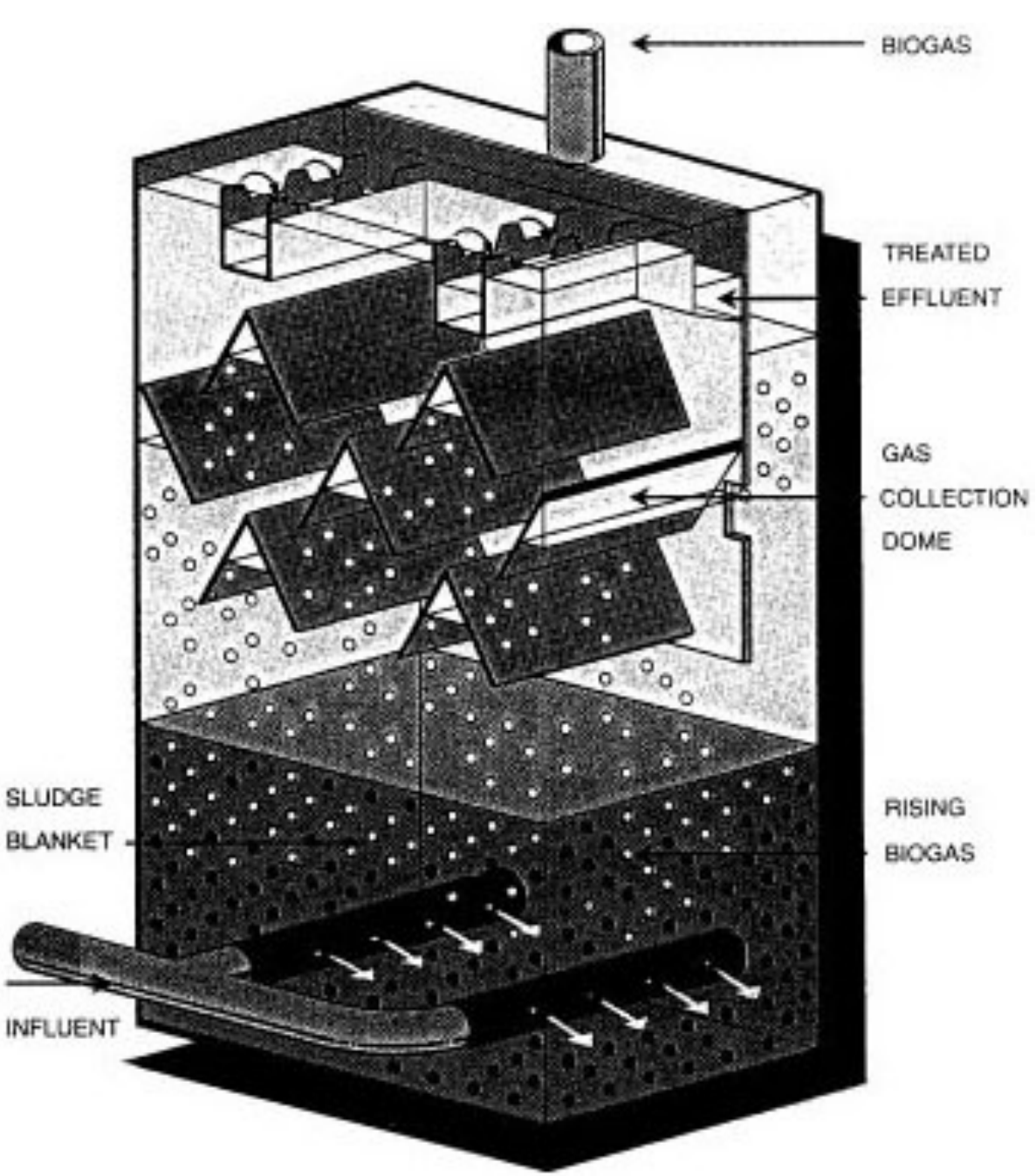


COD Balance Anaerobic Biodegradation

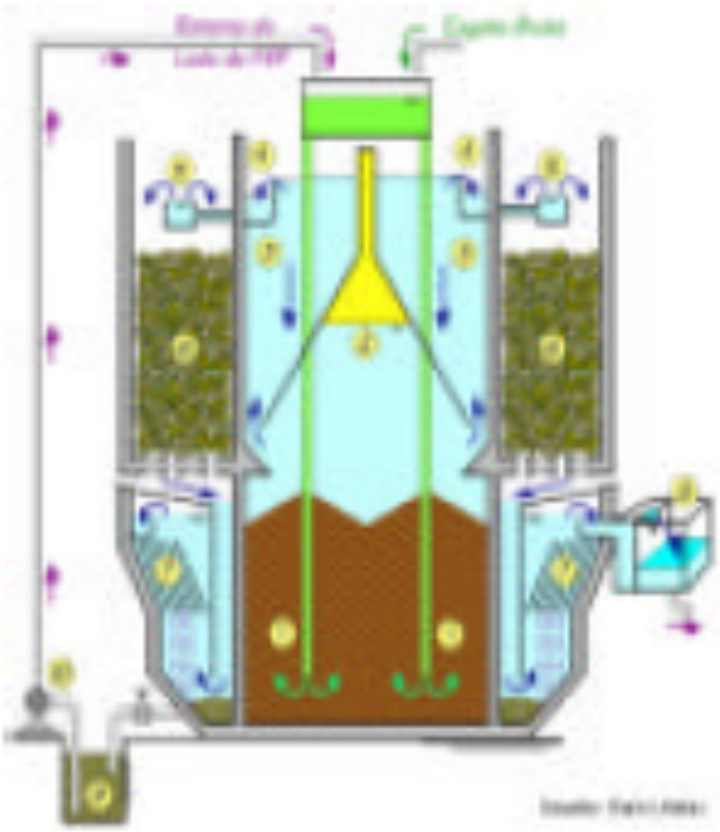


UASB reactor




BIOGAS
TREATED
EFFLUENT
GAS
COLLECTION
DOME
SLUDGE
BLANKET
RISING
BIOGAS
INFLUENT

UASB + Trickling filter



From Tarek Elmitwalli, TUHH, 1-02

Decentral Wastewater Treatment

Treatment of wastewater close to its source, resp. the location of its reuse

Main distinction:
On-Site or Off-Site
(communal plant/semi-central)
if communal: Simplified Sewerage!

Reuse is ideal in decentralized systems, preferably with separate collection and treatment of Toilet and Greywater (wastewater without toilet ww)

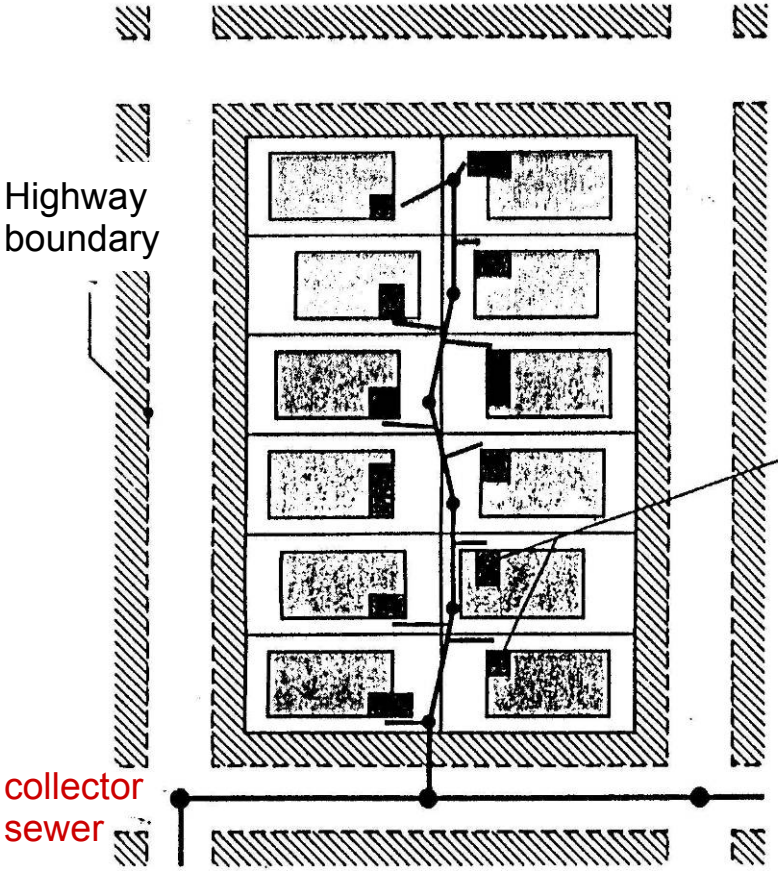
SIMPLIFIED SEWERAGE

- conveys unsettled wastewater
- essentially conventional sewerage stripped down to its hydraulic basics (ie, without any of the conservative design features/rules-of-thumb that have accrued over last ~100 years)
- backyard version: condominial sewerage
- formerly called shallow sewerage

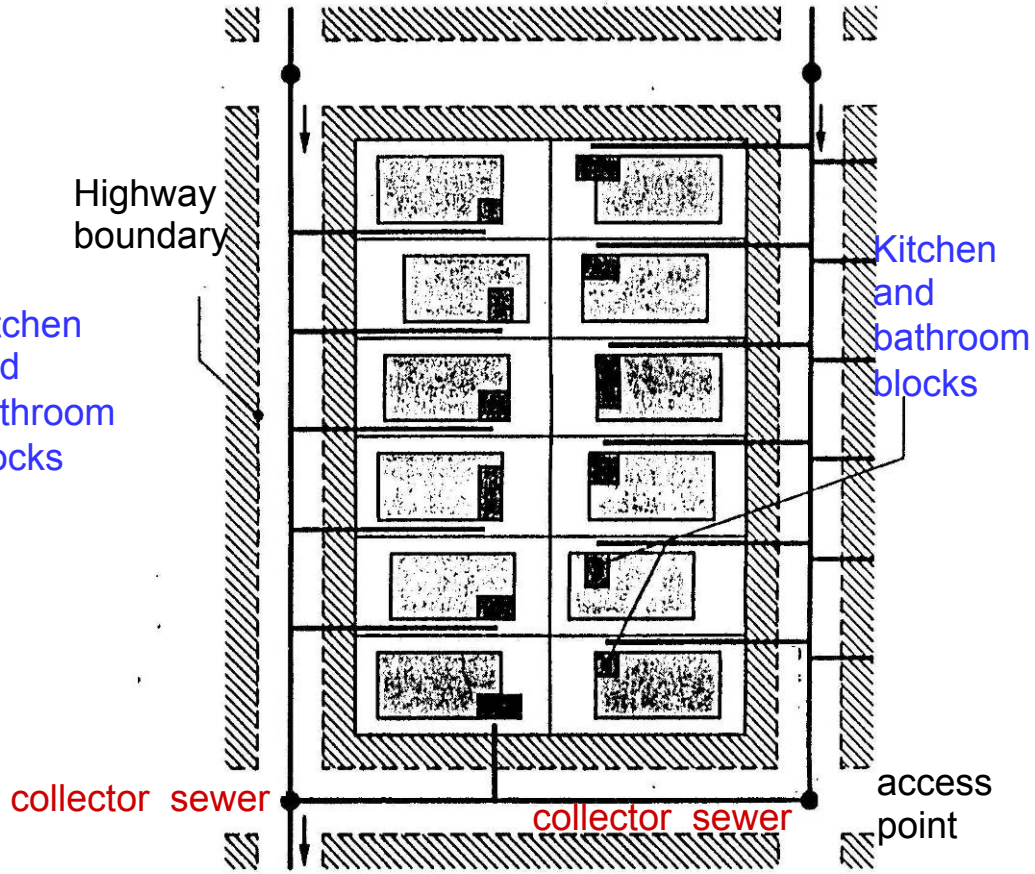
from Duncan Mara, Univ. of Leeds, UK

Sewerage systems require 80 to 90% of the total ww investment, avoid them or make them cheaper

CONDOMINIAL SEWERAGE



CONVENTIONAL SEWERAGE



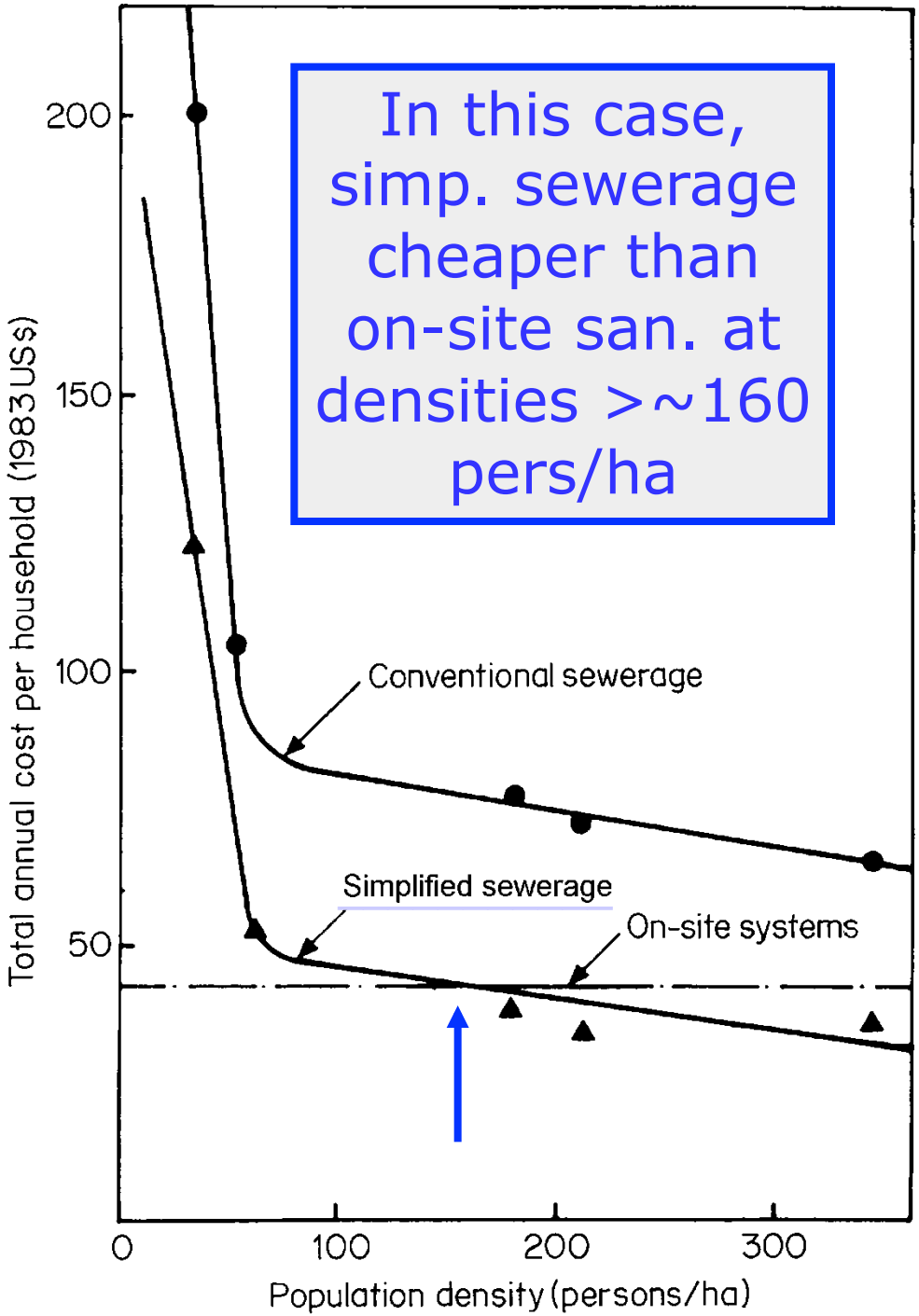
Drawings from Prof. Dr. Duncan Mara, Univ. of Leeds

Simplified sewerage installation, Sri Lanka

Prof. Dr. Duncan Mara
Univ. of Leeds

“Slum Networking” in India

Prof. Dr. Duncan Mara
Univ. of Leeds



Natal, Northeast Brazil, 1983

Condominial Sewerage

Prof. Dr. Duncan Mara
Univ. of Leeds

why greywater reuse?

- Less nutrients, pathogens and pharmaceuticals, easier treatment than mixed waste water
- Volume around 70% of mixed wastewater → pollution prevention
- Reduce demand of freshwater
- To be combined with low diluting toilet systems
- Integral part of housing areas without expensive sewerage

Experimental Investigation of Greywater Treatment by *Moringa Oleifera* Seed Powder

Asri Indiyani, Mayrina Firdayati, Ralf Otterpohl

Moringa is a win-win-win-win… Tree
Can be irrigated with greywater?
Produces Food, Fodder and Wood

TUHH
Hamburg University of Technology

why *moringa seed as coagulant*?

- Aluminum salts resulting in residual aluminium
- Aluminium salts change pH, >> volume of sludge & costly
- *M.Oleifera* grow easily on tropical and sub-tropical semi-arid climates, able to grow on clay or sandy soils and also on the area where droughts or short term flooding occur
- Moringa has many other benefits
- *M.Oleifera is organic* non toxic to human and animals
- *M.Oleifera* seeds quite efficient in reducing turbidity and microorganisms from raw waters

M.Oleifera Seed

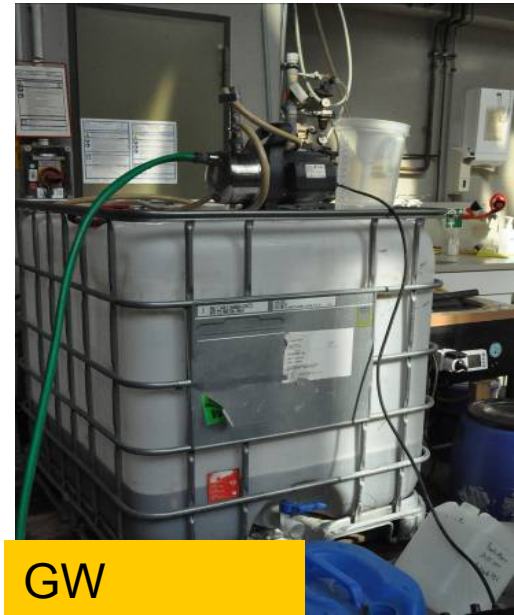
Deshelled M.Oleifera Seed

Raw greywater

Eco Settlement, Luebeck

Greywater Source

Pump



GW

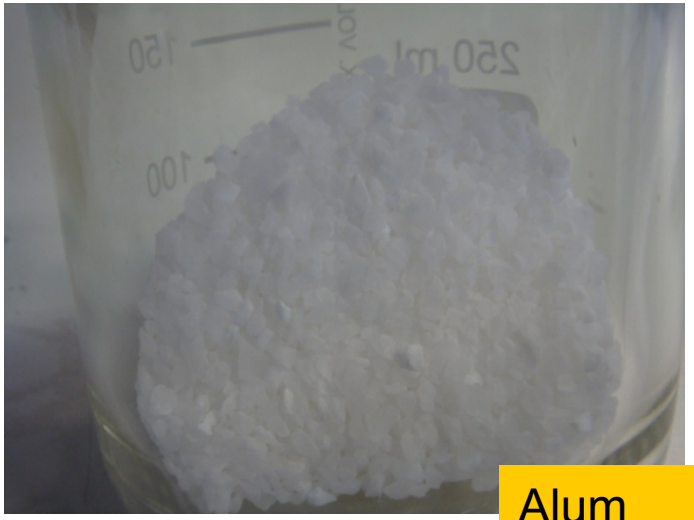
COAGULANTs

Grinding

Sieving

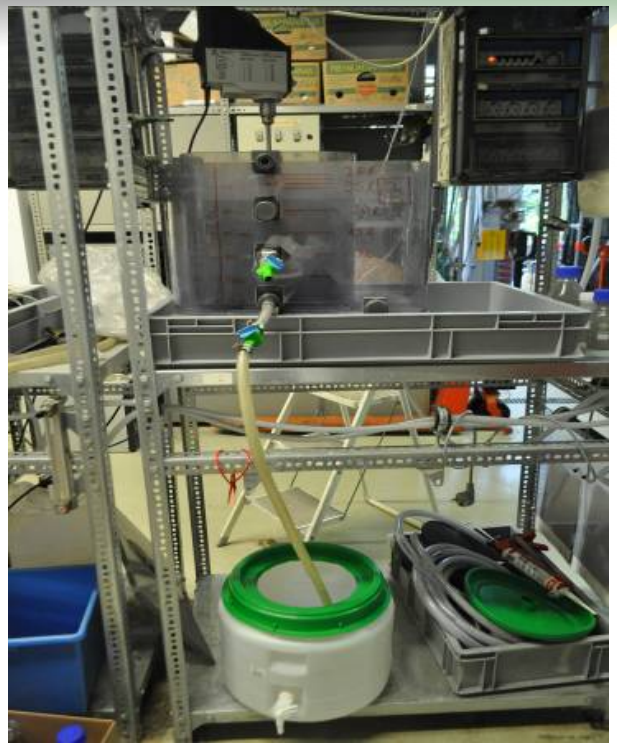
Stiring

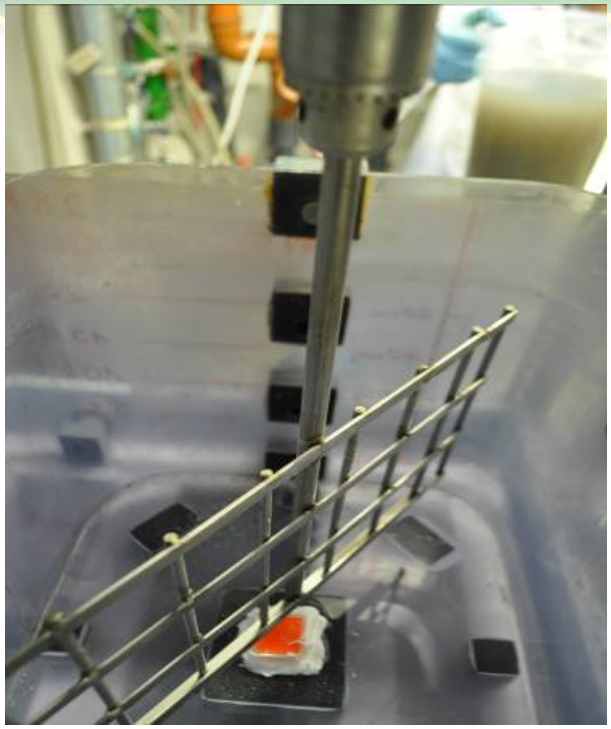
Filtering

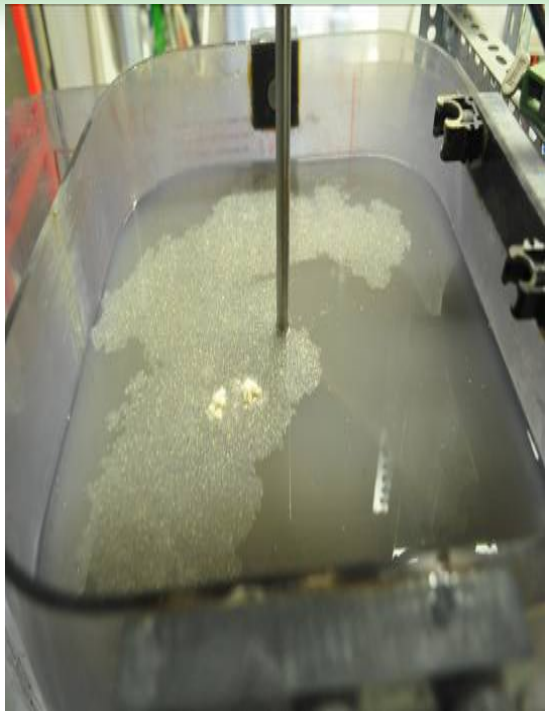


Alum

Lab scale test







Volume: 25 liter
Dosage: 100 mg/l M.Oleifera Powder
Mixing time: 3 min, 200 rpm + 5 min 20 rpm.
Sedimentation Time: 1 hour
Test using Alum & without coagulant also done

Series of Jar Test Experiment

1st SERIES			
No.	**Rapid Mixing**	**Slow Mixing**	**Dosage Used (mg/L)**
1-1	3min 200 rpm	5min 20 rpm	• 0 • 50 • 100 • 250 • 500 • 750
1-2			
1-3			
1-4	Best of 1-3 on 200 rpm	25min, 20 rpm	
1-5		40min, 20 rpm	

65 mg/litre

2nd SERIES (Using best combination of Rapid and Slow Mixing)		
No	**Coagulant Type**	**Dosage Used (mg/L)**
2-1	*MO* powder	0, 50, 100, 150, 200, 250
2-2	*MO* solution	
2-3	Aluminum Sulfate	

3th SERIES (Using best combination of Rapid and Slow			
No	**Coagulant Type**	**Dosage Used (mg/L)**	
3-1	*MO* powder	0, 10, 20, 50, 100	Re
3-2	*MO* solution		for

Note: all experiment set up repeated 3 times.

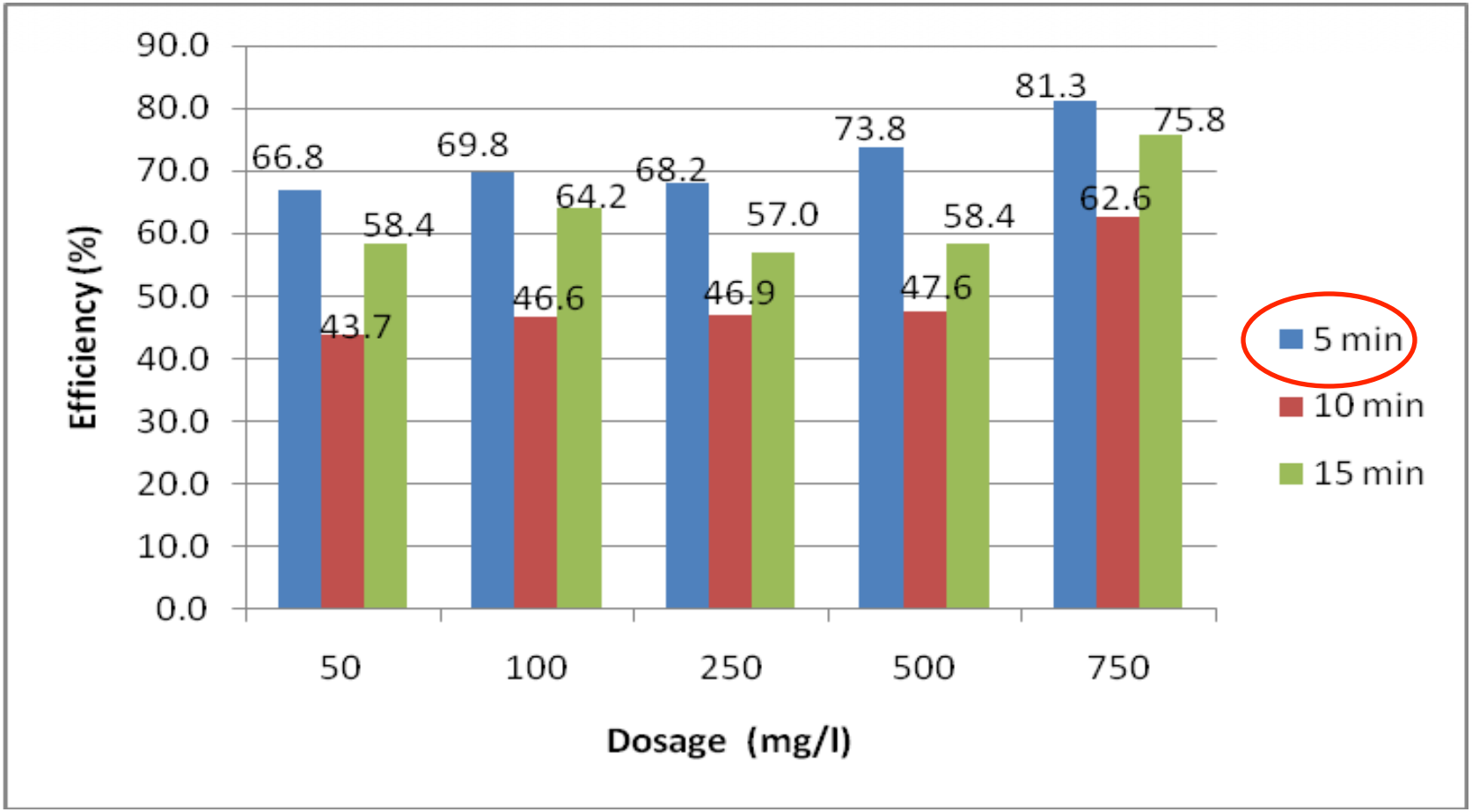
Average Results

No	Parameter	Unit	Raw Grey water	Treated w/ *Moringa powder*	Efficien-cy (%)	Treated w/ *Alum*	Efficiency (%)	Requirement for irrigations
1	**Turbidity**	NTU	480.00	198.00	58.75	130.00	72.92	
2	**TSS**	mg/L	189.00	80.00	57.67	58.00	69.31	-
3	**pH**	-	7.06	7.10		6.80		6-9*
4	**Temperature**	Deg Celcius	20.10	20.10		20.10		-
5	**Conductivity**	mS/cm	1.10	1.12		1.18		<1,3**
BOD removal not relevant as the powder adds natural BOD (before and after around 200)								
7	**Zinc**	mg/L	0.80	0.28	65.00	< 0.15	> 81.25	<2**
8	**Total Coliform**	/100 ml	2×10^6	10^4		2×10^6		< 200
9	**Average Oil & Grease**	g/L	0.65	0.22	65.84	0.30	53.84	
10	**Detergent (MBAS)**	mg/L	11,55	9,81	15,06	8,97	22,34	-

*Indonesian Water Classification, Class D, Water for Irrigation
**Mara, 2003

Determination of Slow mixing time

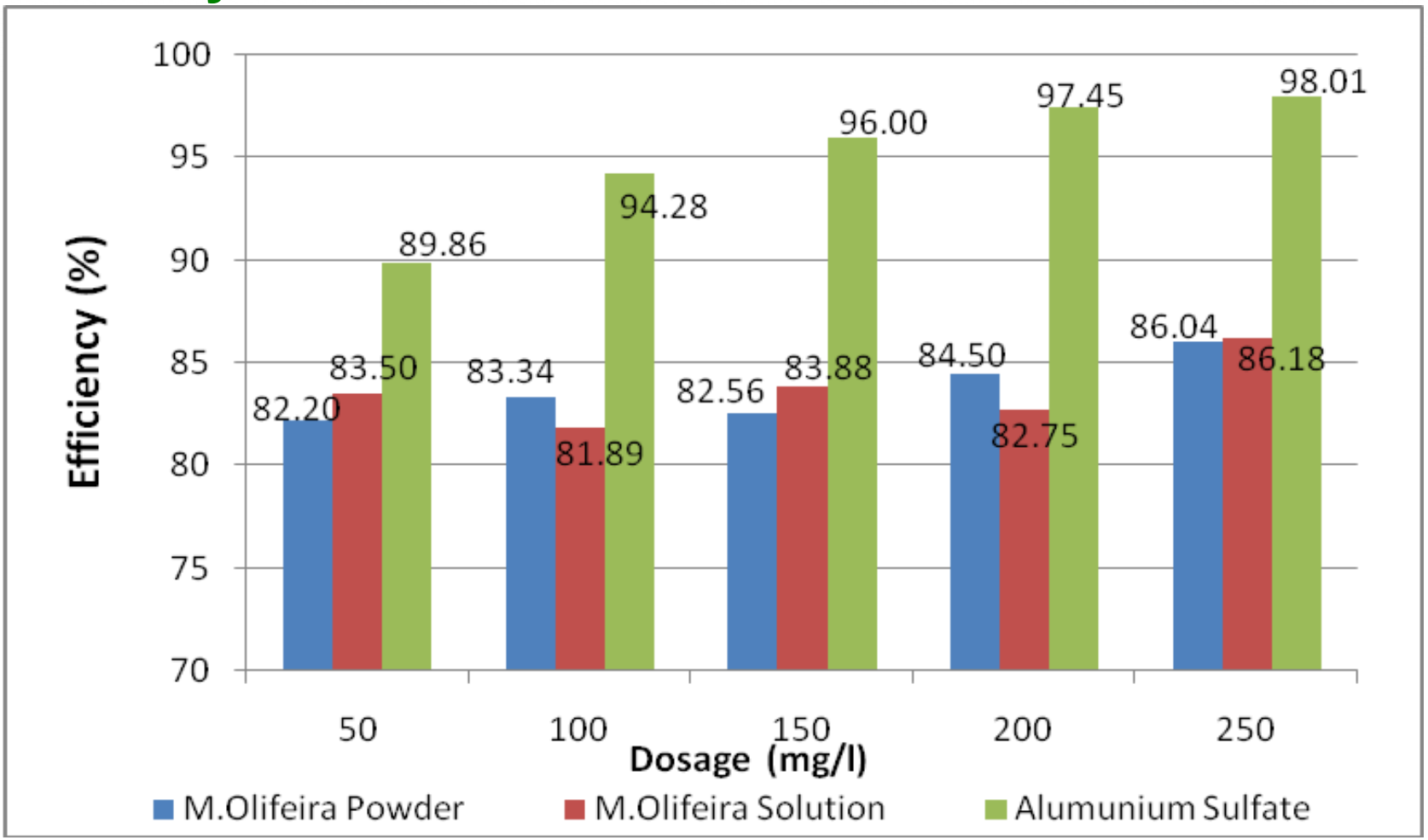
Turbidity Removal

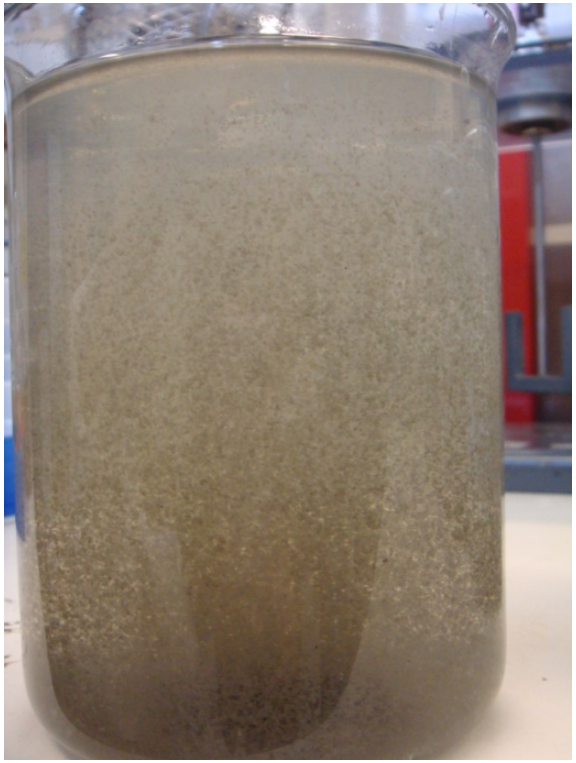


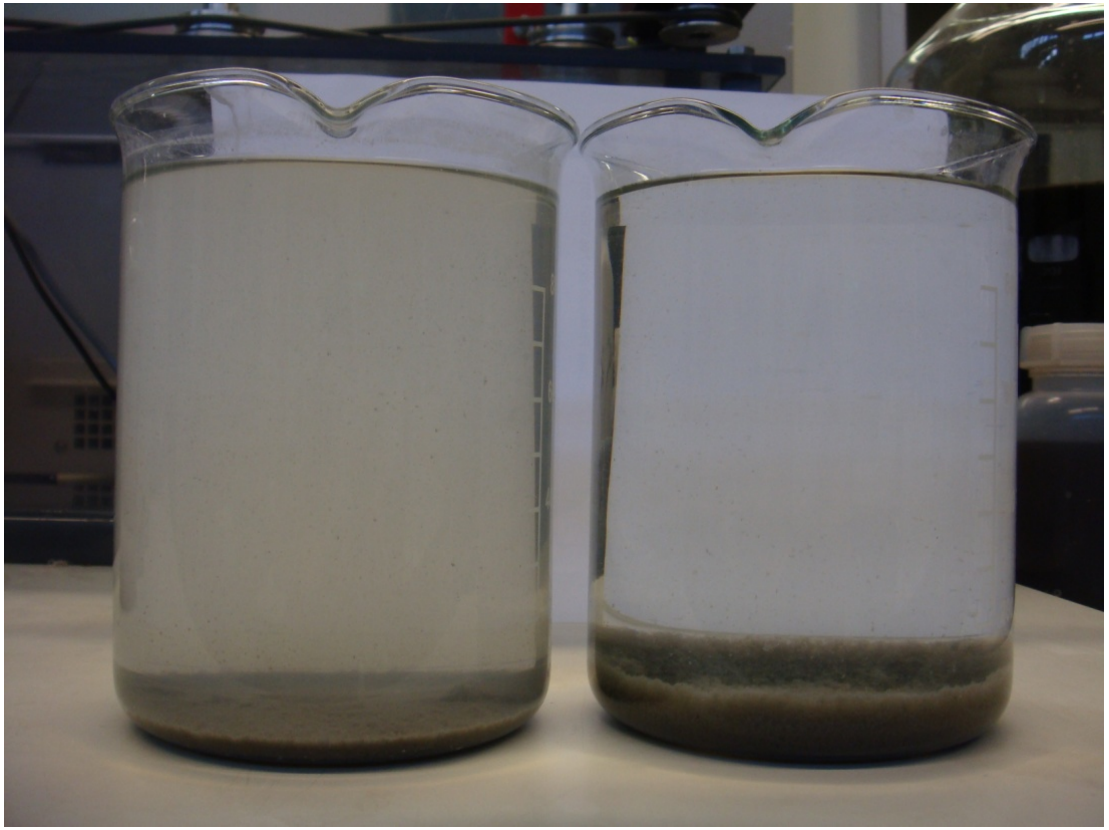
5 minutes of 20 rpm mixing time

cOmparison between coagulants

Turbidity Removal



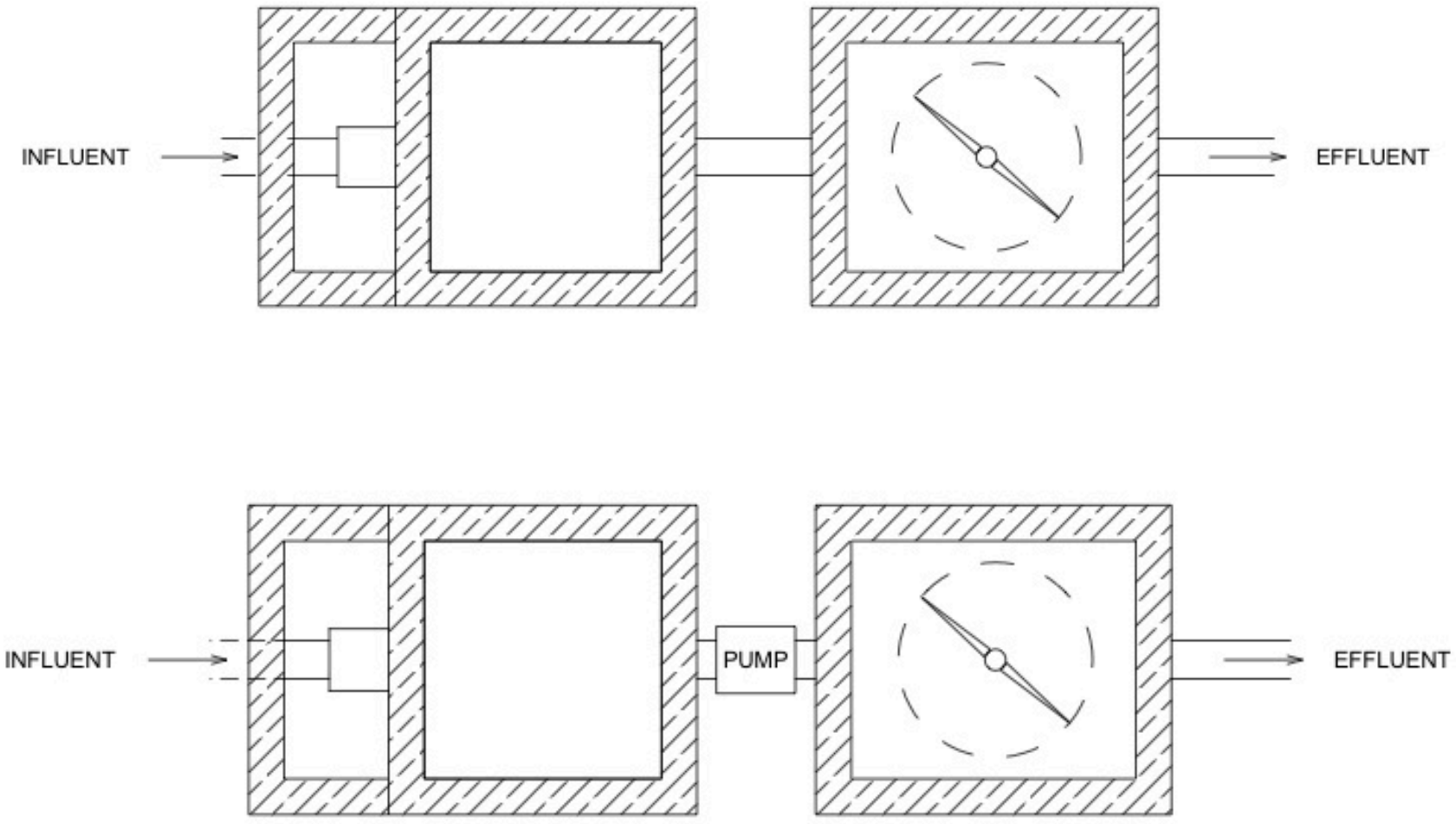




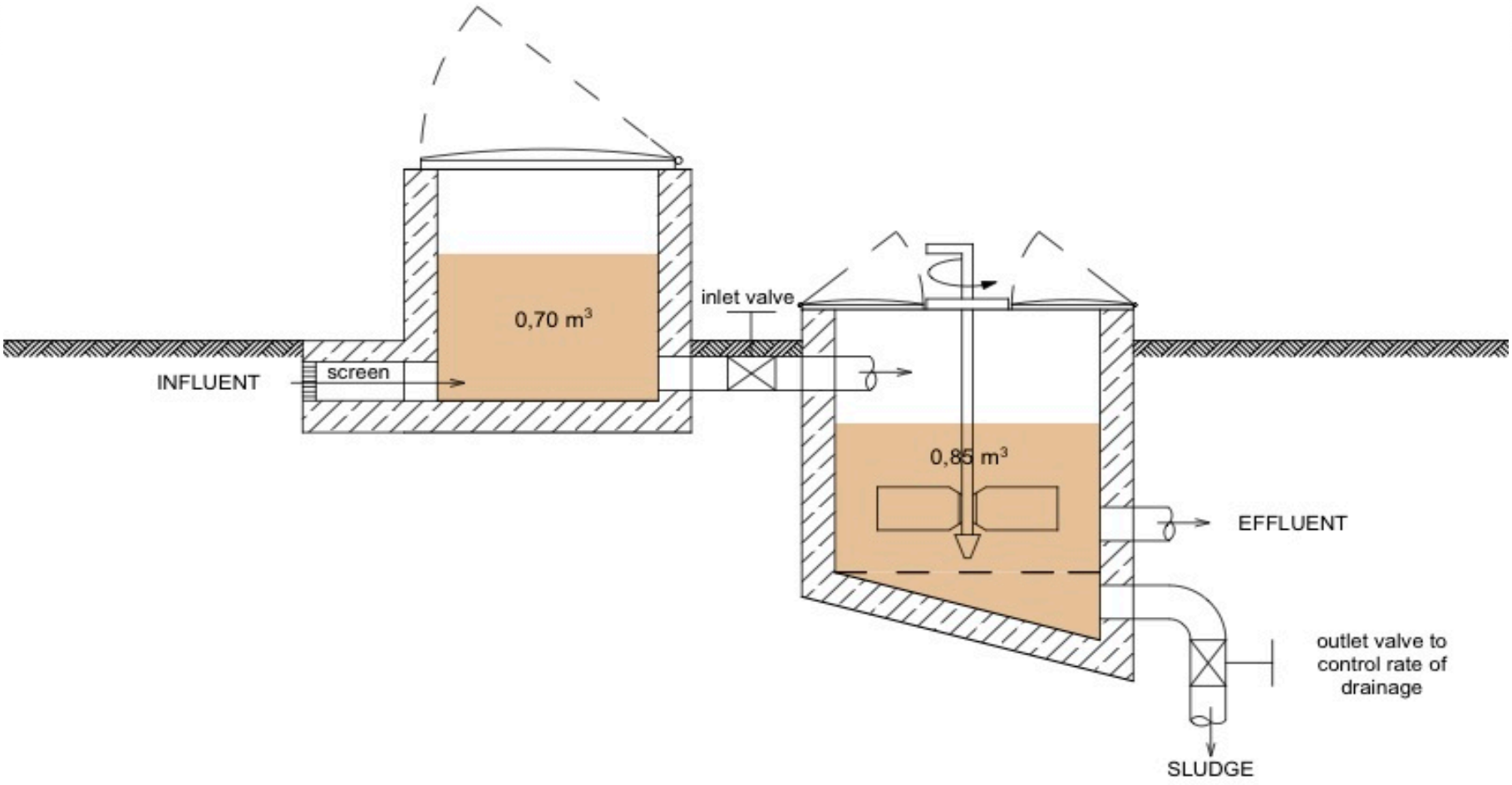
M. Oleifera

Alum Sulfate

Design example

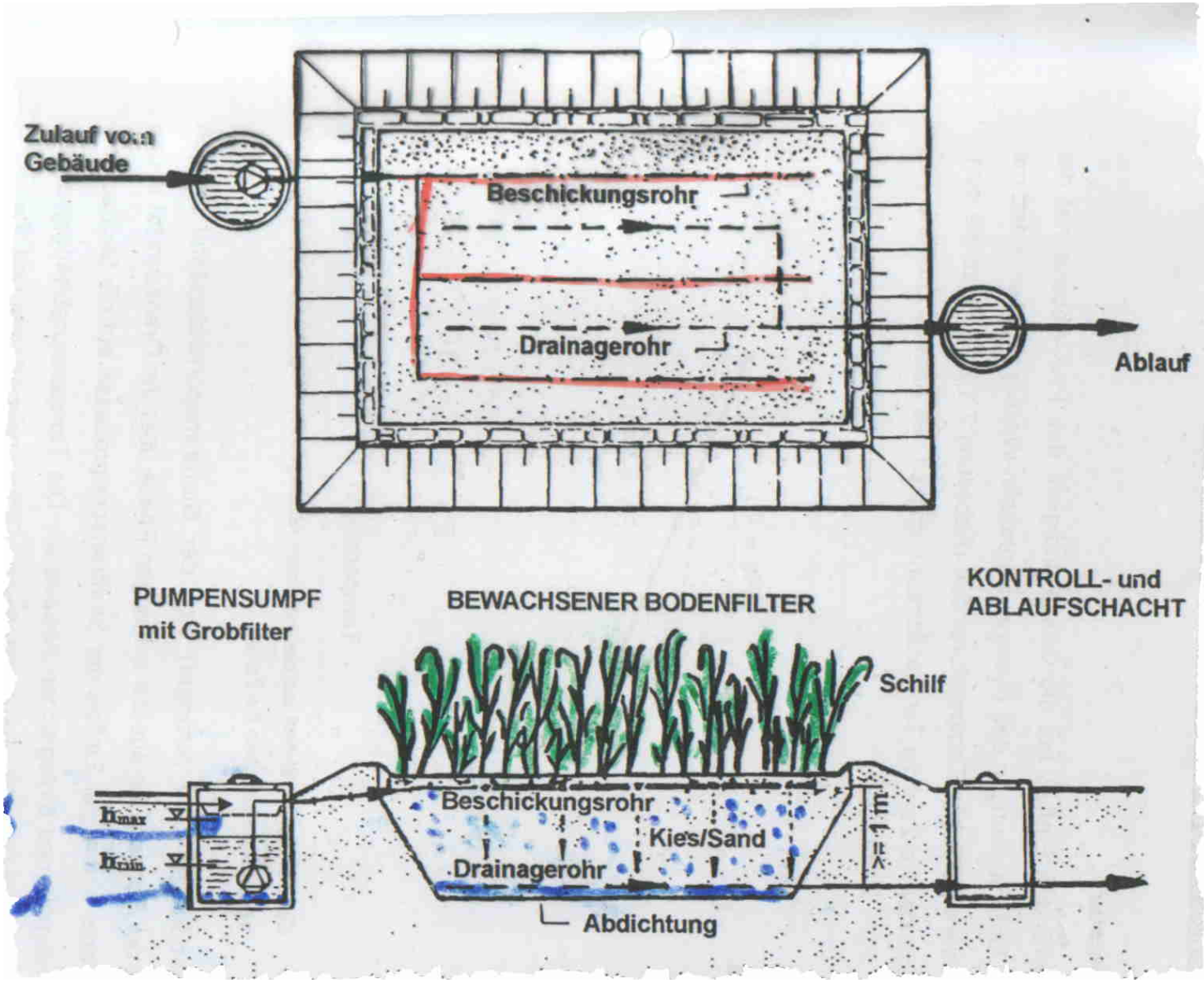


Design example



Constructed Wetland / Bio-Sandfilter vertical flow:

1. vertical flow 2. water level at bottom 3. intermittant feeding



Settlement Lübeck-Flintenbreite
Water consumption 65 l/capita/day

Double-Houses

Terraced Houses

OtterWasser GmbH

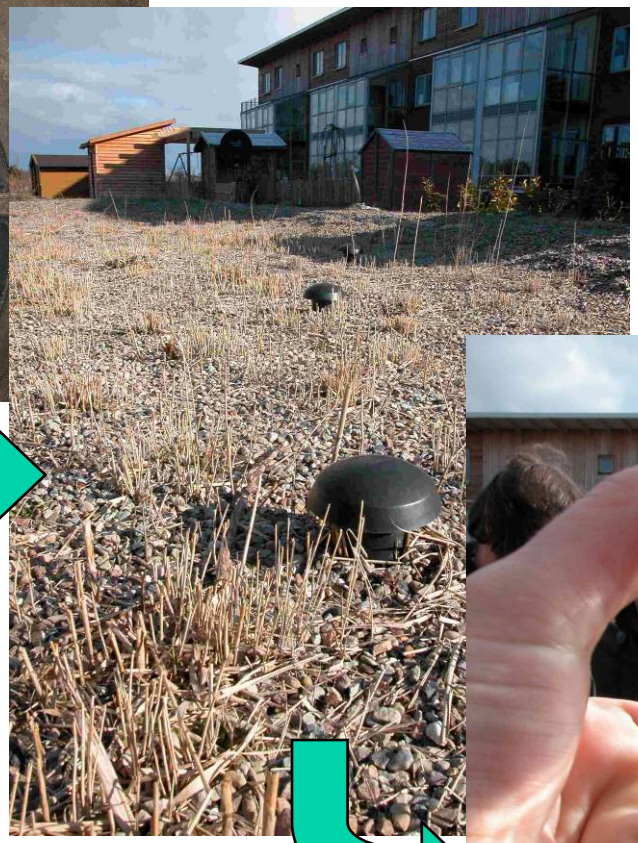
Greywater Treatment with a constructed wetland / reedbed filter for 200 PE Lübeck-Flintenbreite, Germany (2 m²/ person)

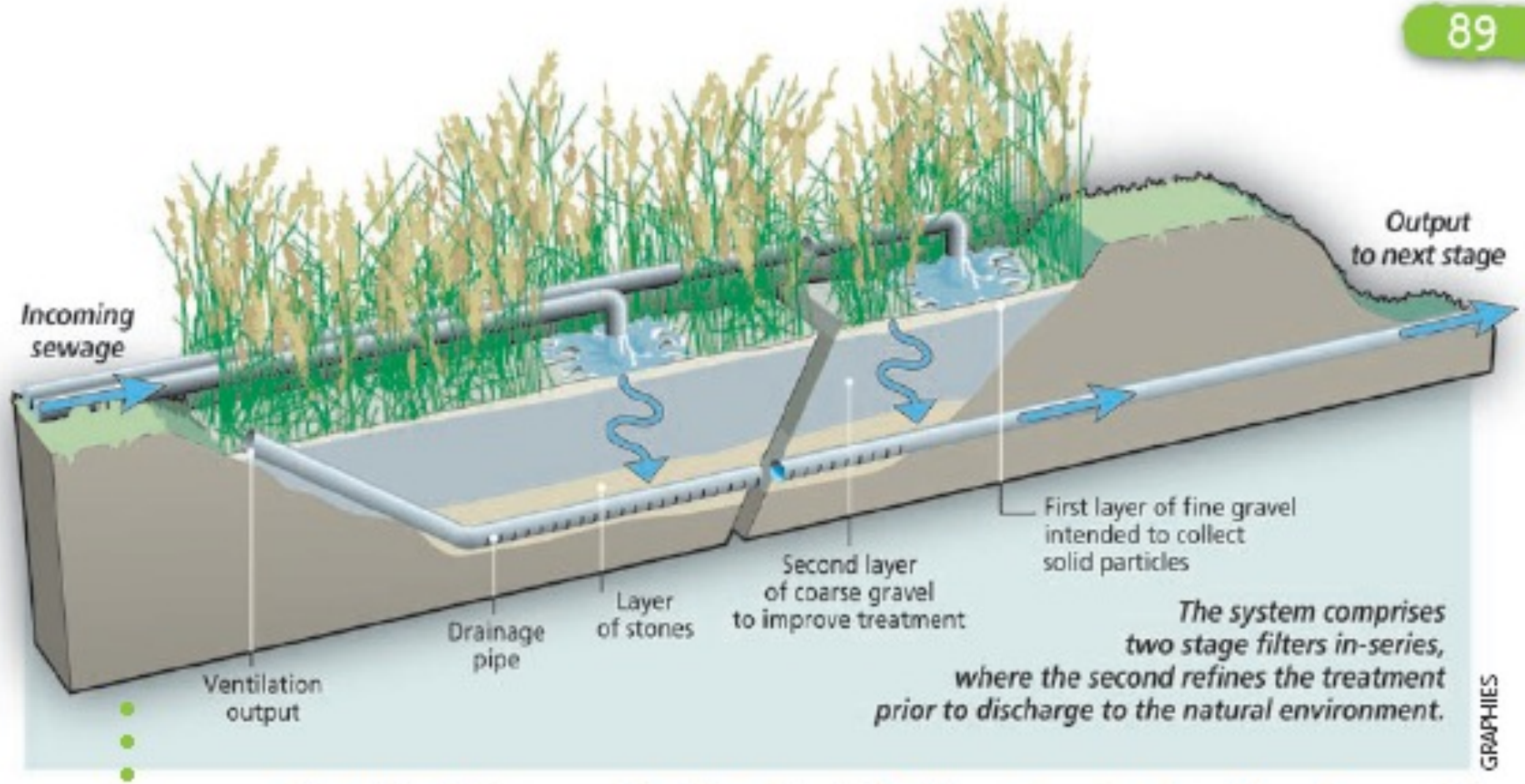
OtterWasser GmbH

Constructed wetland – vertical flow

OtterWasser GmbH

www.otterwasser.de





Simplified diagram of a filter planted with reeds, developed by Cemagref.

SINT
Société d'Ingénierie
NATURE & TECHNIQUE

CEMAGREF, France

Queige (73) – 500 p.e. – Phragmifilter® wastewater treatment plant

CEMAGREF, France

Greywater biofilter in Mali, West Africa

Boata

Biological Aquatic System Warrah School, Dural


E L'ENVIRONNEMENT
PHYTOREM
Accueil
La Société


E L'ENVIRONNEMENT
PHYTOREM
Accueil
La Société


TUHH
Hamburg University of Technology


TUHH
Hamburg University of Technology

Terra Preta Sanitation

Cleansing of bowl with spray bottle or spray hose, also suitable for anal cleansing
Low dilution is needed
The toilet gets lactic acid bacteria with some sugar sourse to make it smell free
Collection once per week and transport to composting site where the compost can be used

The winner of the TUHH-WTO ,
TPS Toilet Design Award
Triften Design, Sabine Schober, Hamburg, 2012

Terra-Preta-Sanitation.net **www.tuhh.de/aww**

λT 2.1 Développement du foyer
λquelque étapes






Woodgas Stoves: Clean and very Efficient
by Jörg Fingas Climatefarming, Germany

Options for Terra Preta Sanitation 1

Cleansing with Spray Bottle or Spray Shower

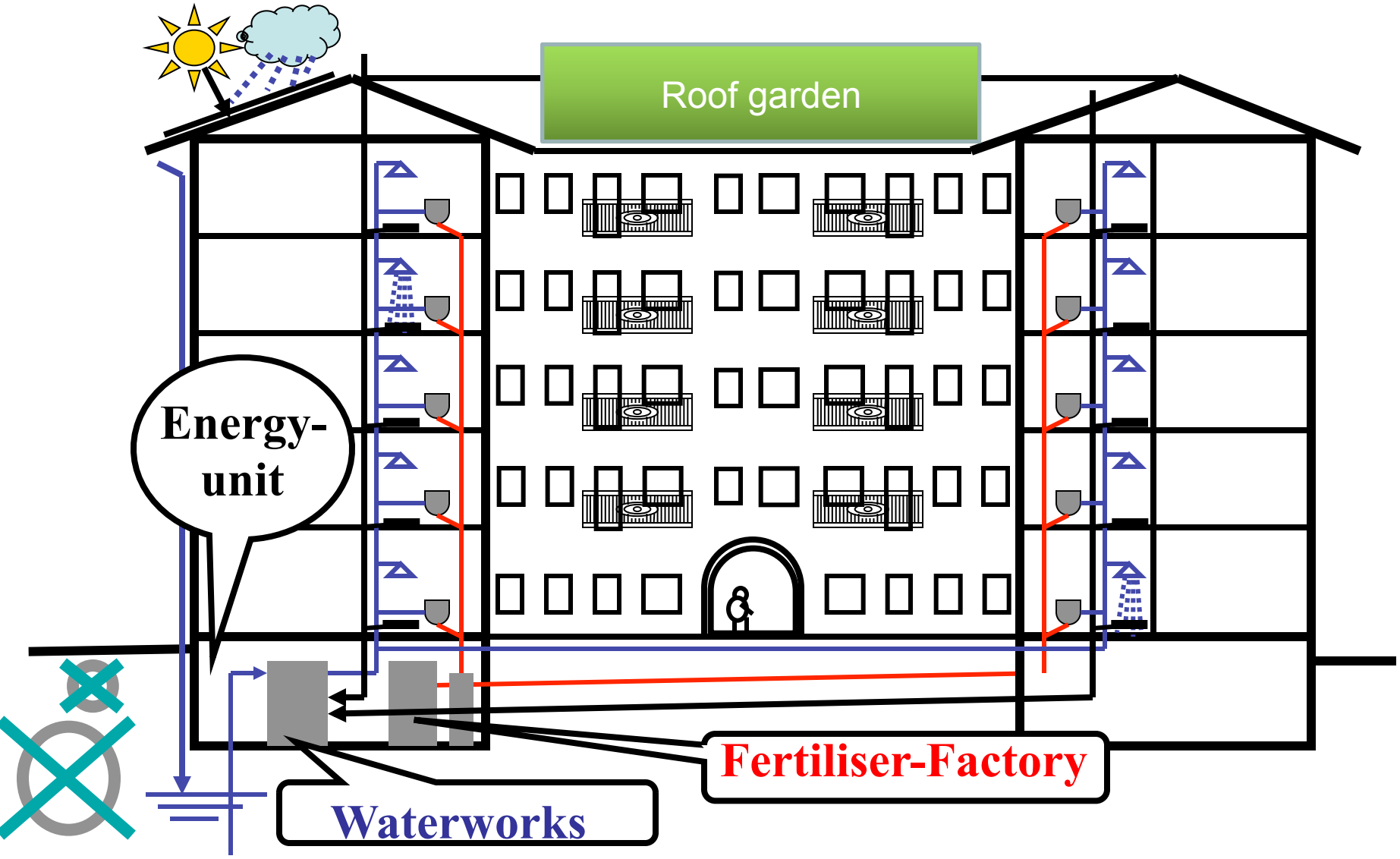
LAB can be added (Food Quality)

Lactic Acid Bacteria

add 500ml concentrated LAB
plus plenty of waste Sugar
(2-3g/Person/year)

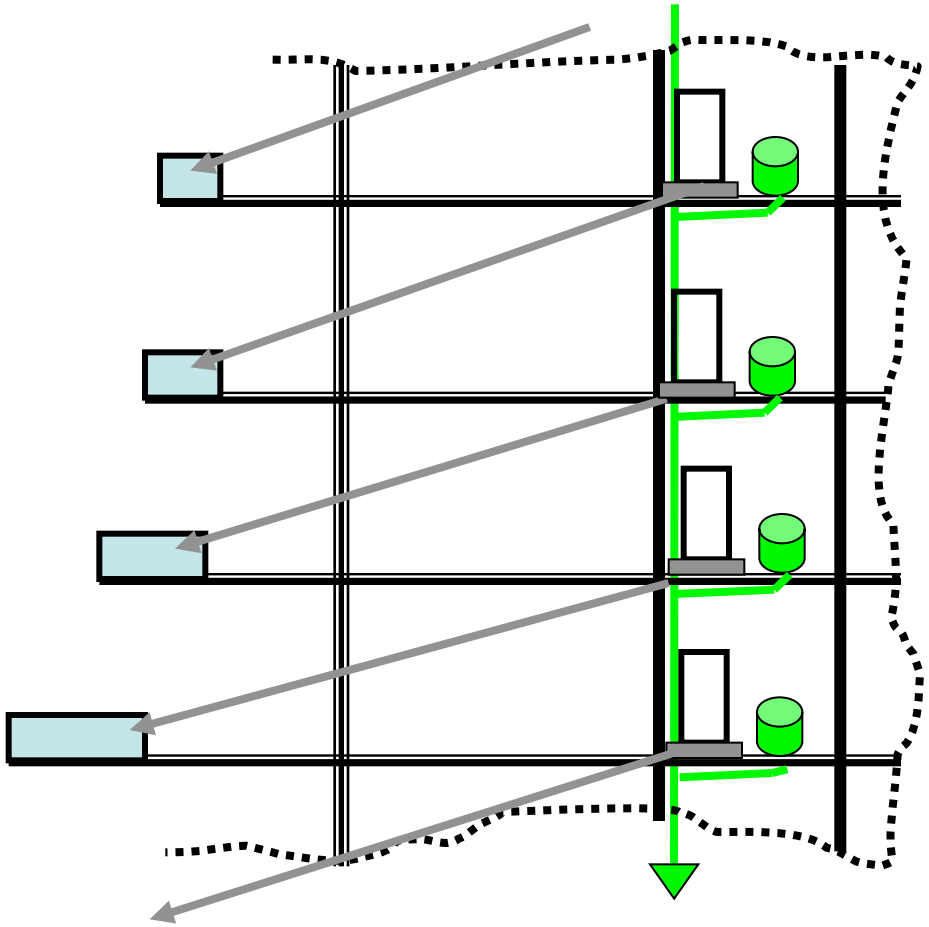
Tanc Transport or or Suction Truck or Mazerator Pump

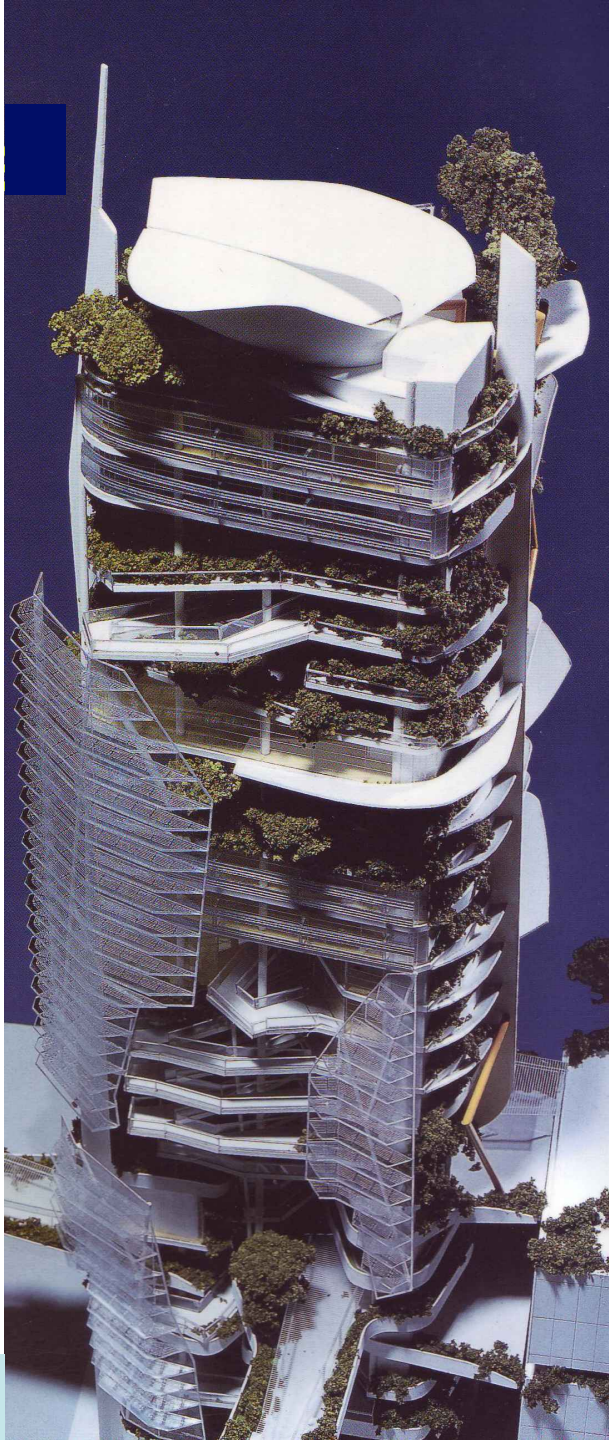
Composting Unit where compost can be utilized!!



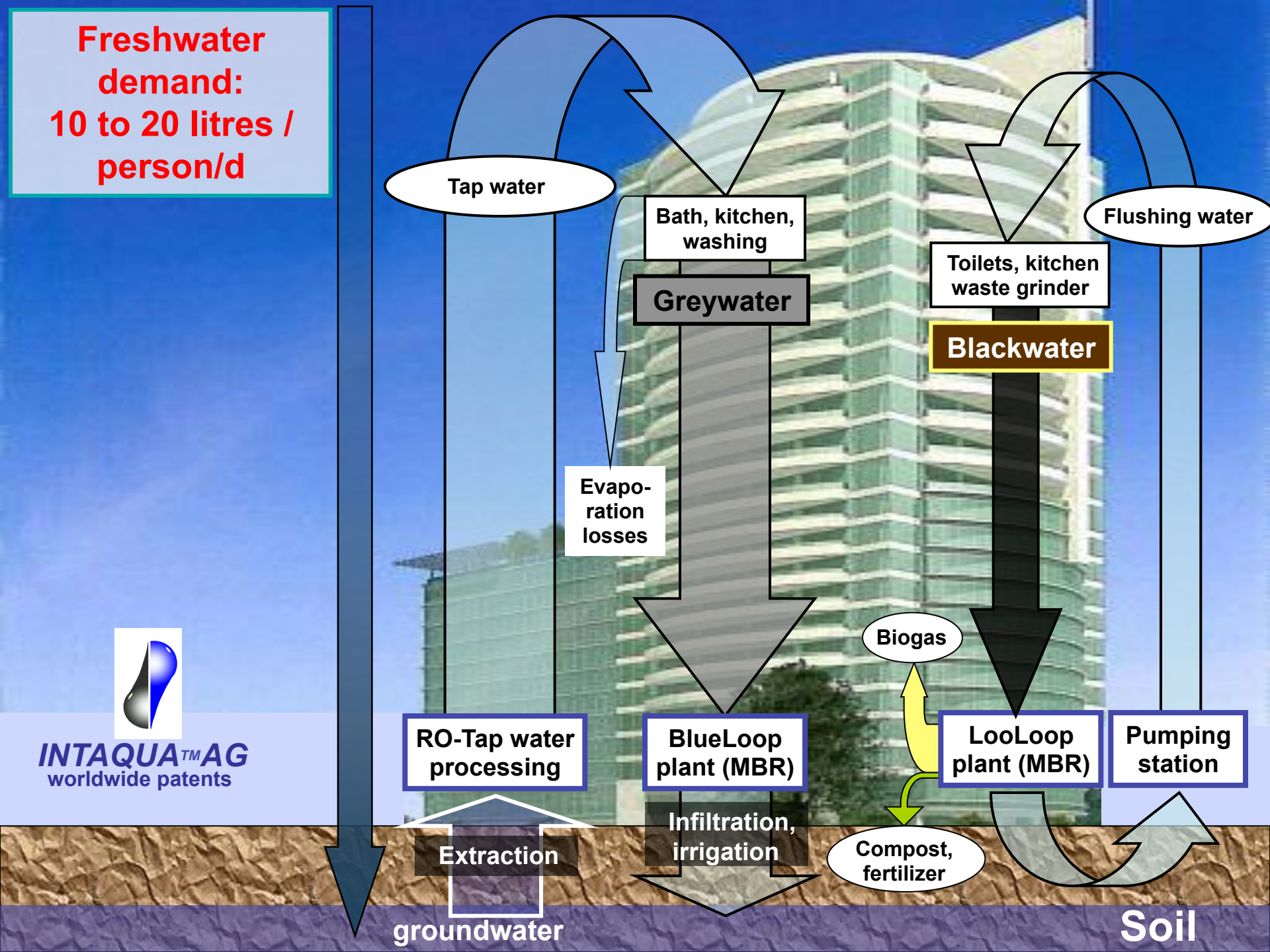
Integrated-Systems with production of dry fertiliser
Modules for 500 to 10.000 persons

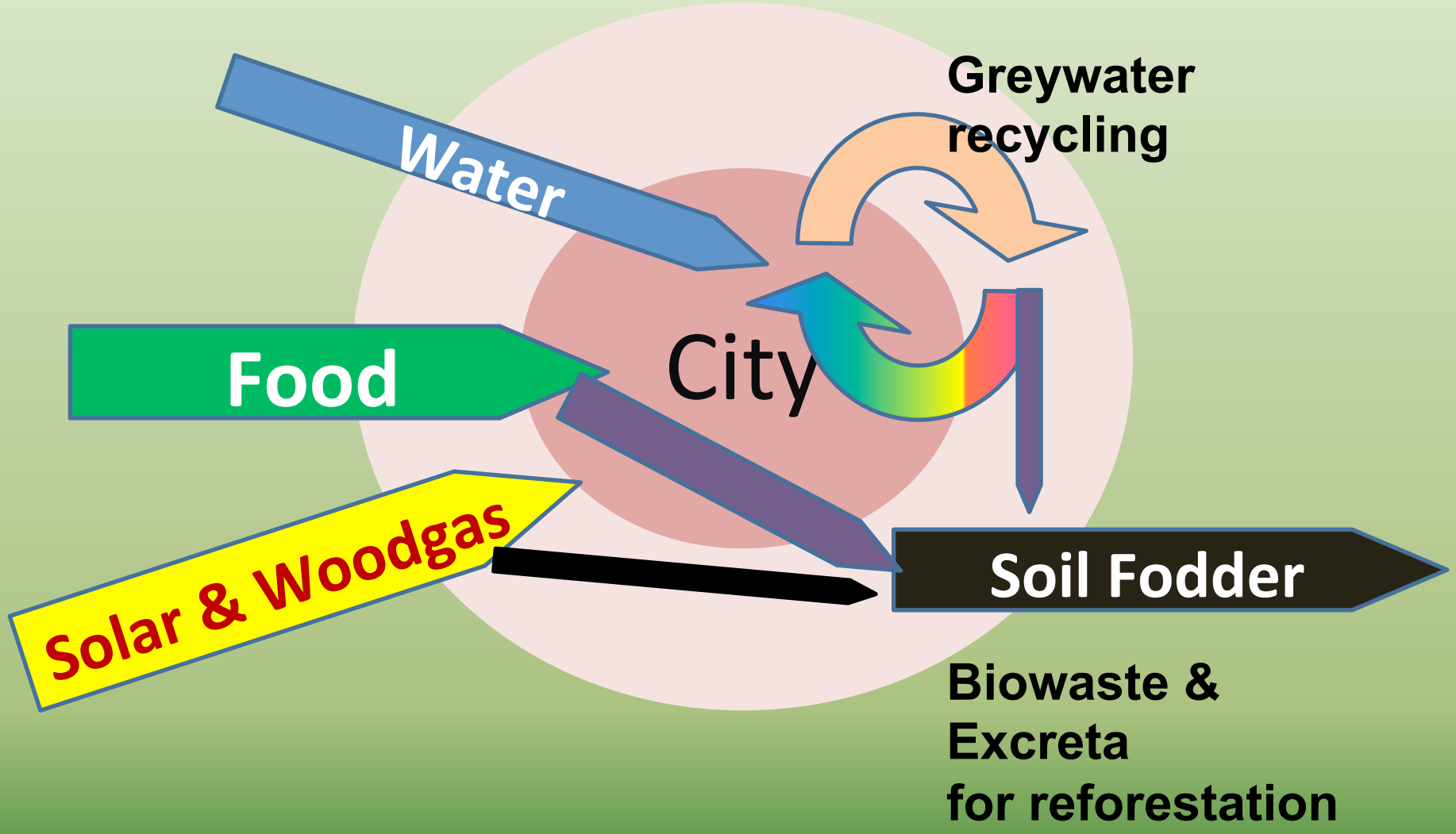
Integrierte Ver- und Entsorgung bei hoher Verdichtung





Pic from: Ken Yeang, The green Skyscraper


Freshwater demand: 10 to 20 litres / person/d
Tap water
Bath, kitchen, washing
Greywater
Flushing water
Toilets, kitchen waste grinder
Blackwater
Evapo-ration losses
Biogas
RO-Tap water processing
BlueLoop plant (MBR)
LooLoop plant (MBR)
Pumping station
Infiltration, irrigation
Compost, fertilizer
Extraction
groundwater
Soil
INTAQUA™AG
worldwide patents


Water
Greywater
recycling
Food
City
Solar & Woodgas
Soil Fodder
Biowaste &
Excreta
for reforestation