Session 3

Session 3 – Rainwater, Domestic Wastewater, Energy and Nutrient Aspects

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Session 3 – Rainwater, Domestic Wastewater, Energy and Nutrient Aspects

3.1 Rainwater Harvesting and Grey Water Management – Case Study for Istanbul

Dr. Elif Atasoy Aytis, Tubitak Marmara Research Center

TÜBİTAK

Zero Emission Buildings
Integrating Sustainable Technologies and Infrastructure Systems

Rainwater Harvesting and Grey Water Management
Case Study for Istanbul

Elif Atasoy AYTIŞ-Dr. Ahmet BABAN
TUBITAK Marmara Research Center

Sungkyunkwan University
Seoul Campus, Republic of Korea

15th January 2013

Outline

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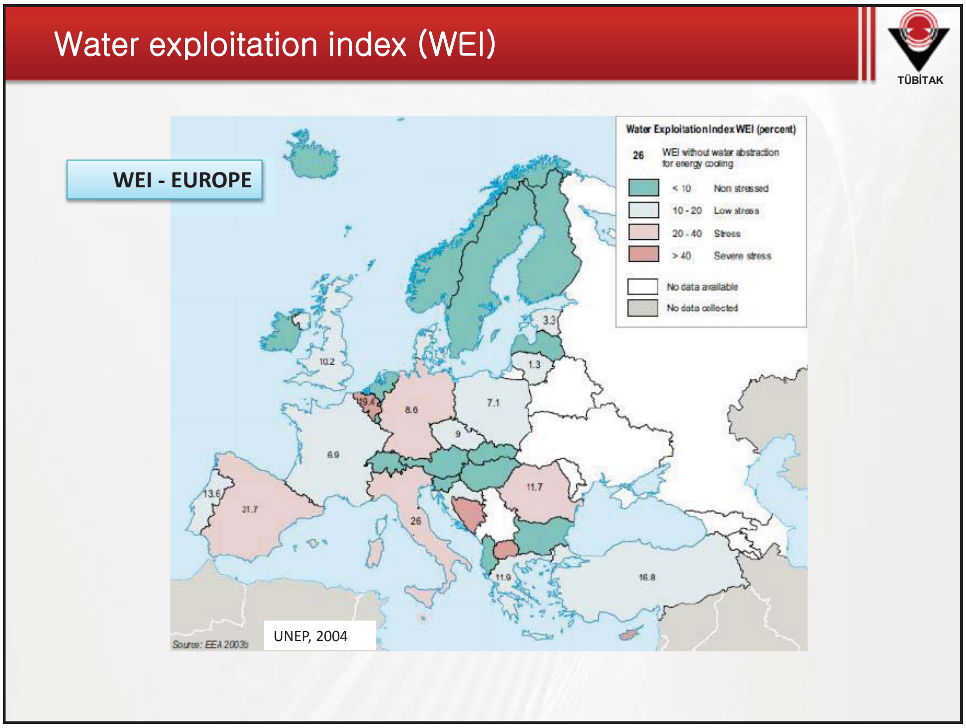
- Basic info on Istanbul and water issues,
- Climate change impacts,
- RW, GW potential for Istanbul,
- Pilot study model for GW and RW, case study area,
- Concluding remarks

Relevant projects – TUBITAK MRC Environment Institute

Prepared enabling change

www.zer0-m.org

www.prepared-fp7.eu

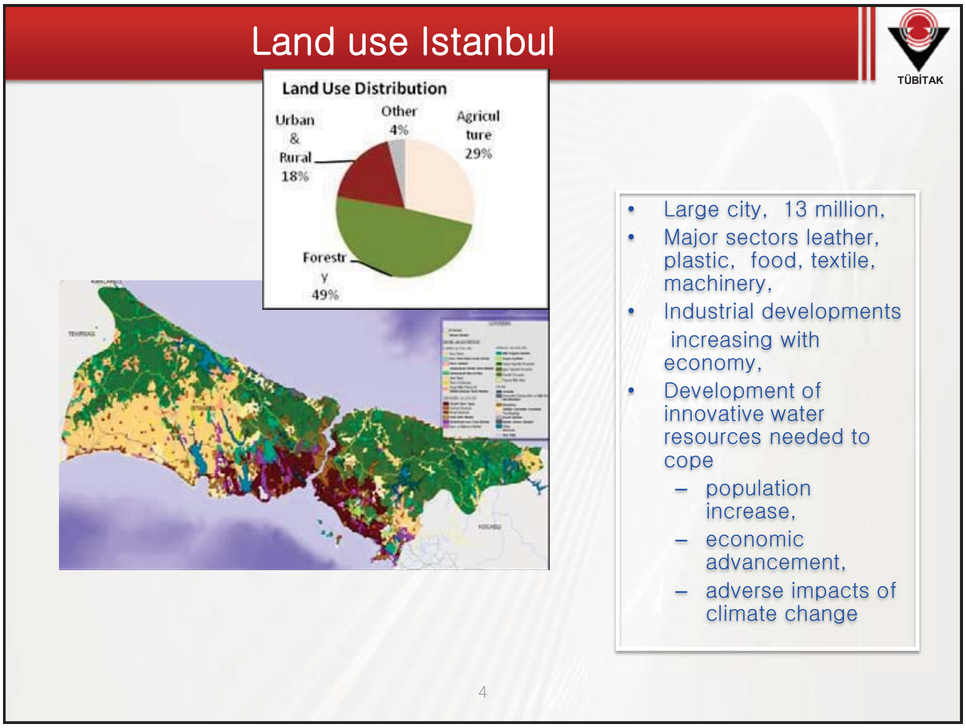


Water exploitation index (WEI)

WEI - EUROPE

Source: EEA 2003b

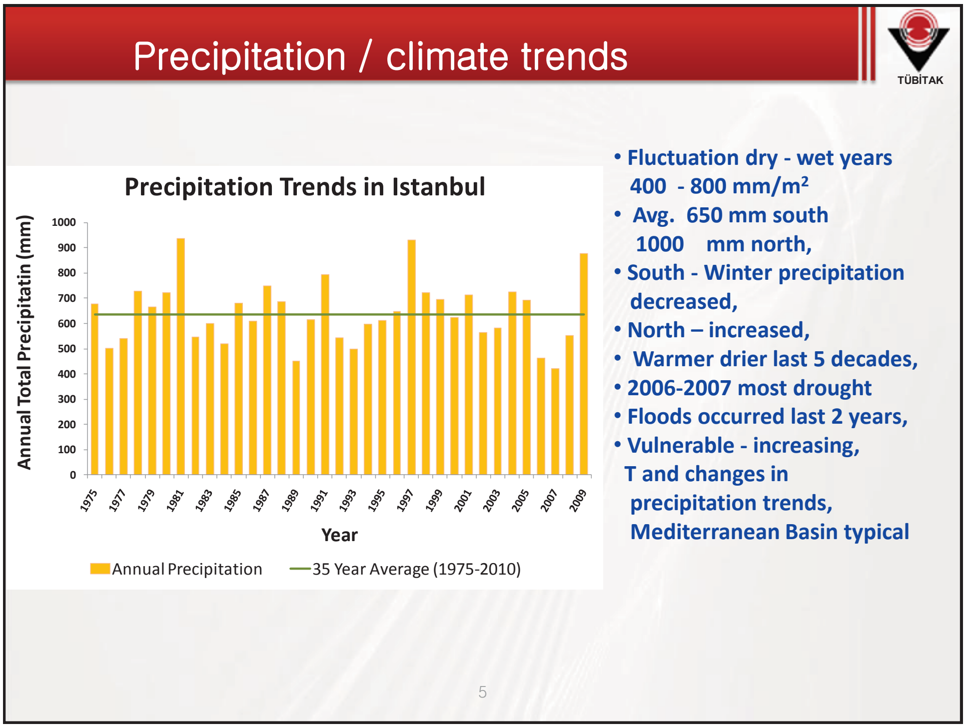
UNEP, 2004



Land use Istanbul

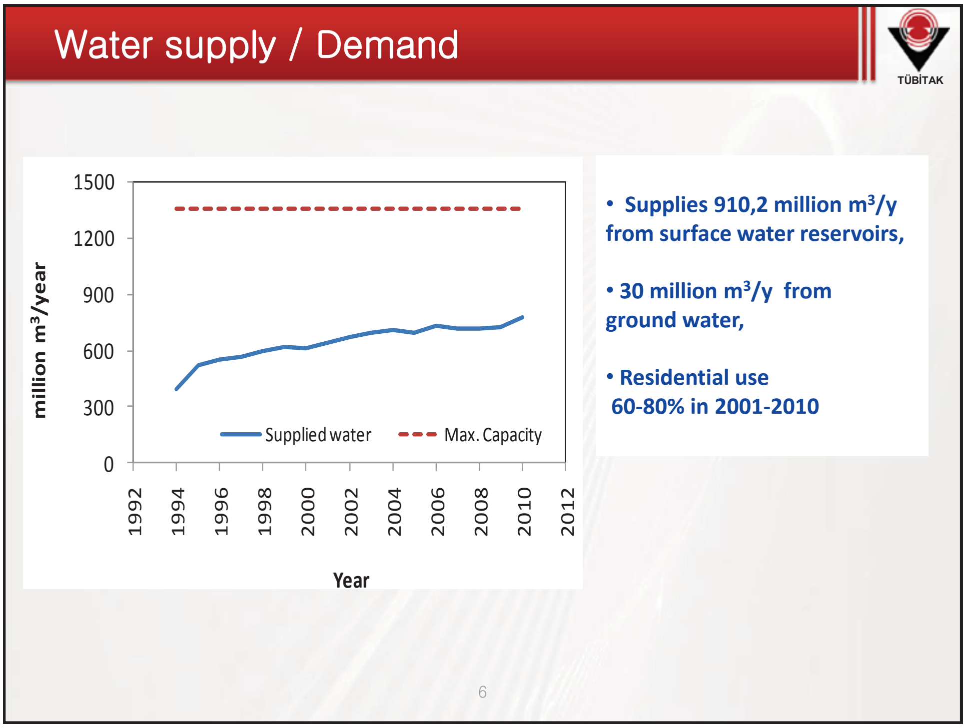
Land Use Distribution

- Large city, 13 million,
- Major sectors leather, plastic, food, textile, machinery,
- Industrial developments increasing with economy,
- Development of innovative water resources needed to cope
  - population increase,
  - economic advancement,
  - adverse impacts of climate change



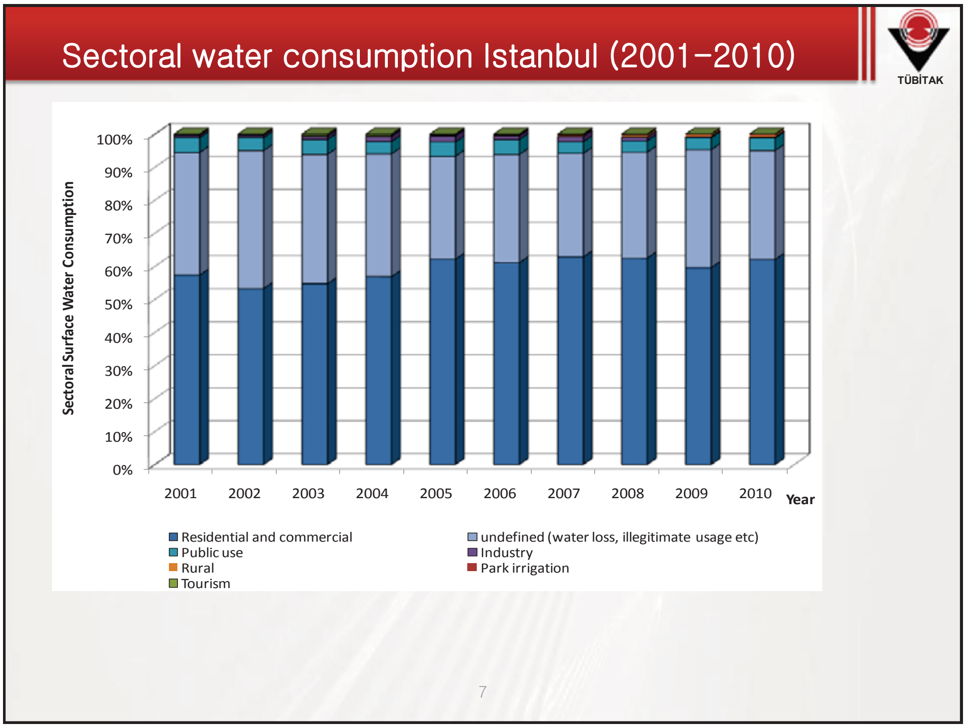
Precipitation / climate trends

- Fluctuation dry - wet years 400 - 800 mm/m^2
- Avg. 650 mm south 1000 mm north,
- South - Winter precipitation decreased,
- North – increased,
- Warmer drier last 5 decades,
- 2006-2007 most drought
- Floods occurred last 2 years,
- Vulnerable - increasing, T and changes in precipitation trends, Mediterranean Basin typical



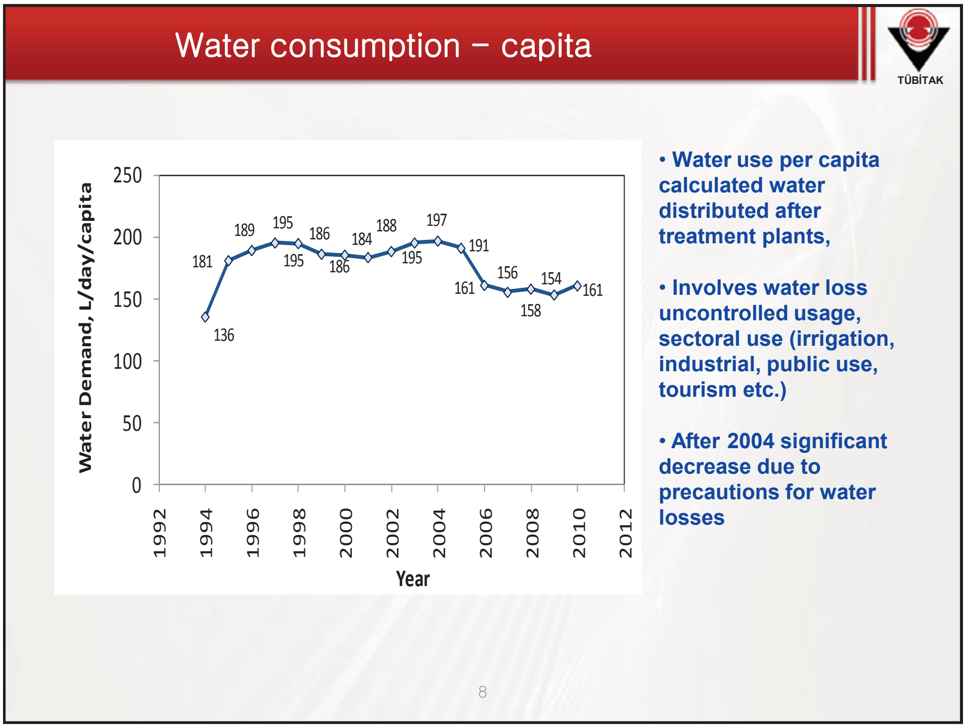
Water supply / Demand

- Supplies 910,2 million m^3/y from surface water reservoirs,
- 30 million m^3/y from ground water,
- Residential use 60-80% in 2001-2010



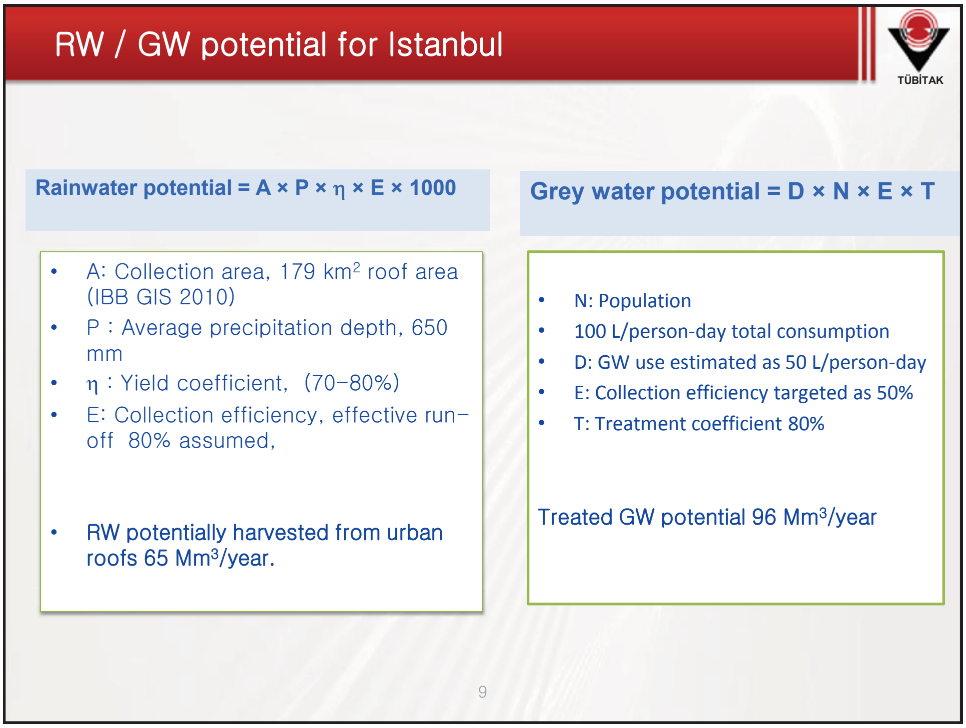
Sectoral water consumption Istanbul (2001–2010)

🟦 Residential and commercial
🟦 Public use
🟧 Rural
🟩 Tourism
🟦 undefined (water loss, illegitimate usage etc)
🟪 Industry
🟥 Park irrigation



Water consumption – capita

- Water use per capita calculated water distributed after treatment plants,
- Involves water loss uncontrolled usage, sectoral use (irrigation, industrial, public use, tourism etc.)
- After 2004 significant decrease due to precautions for water losses



RW / GW potential for Istanbul

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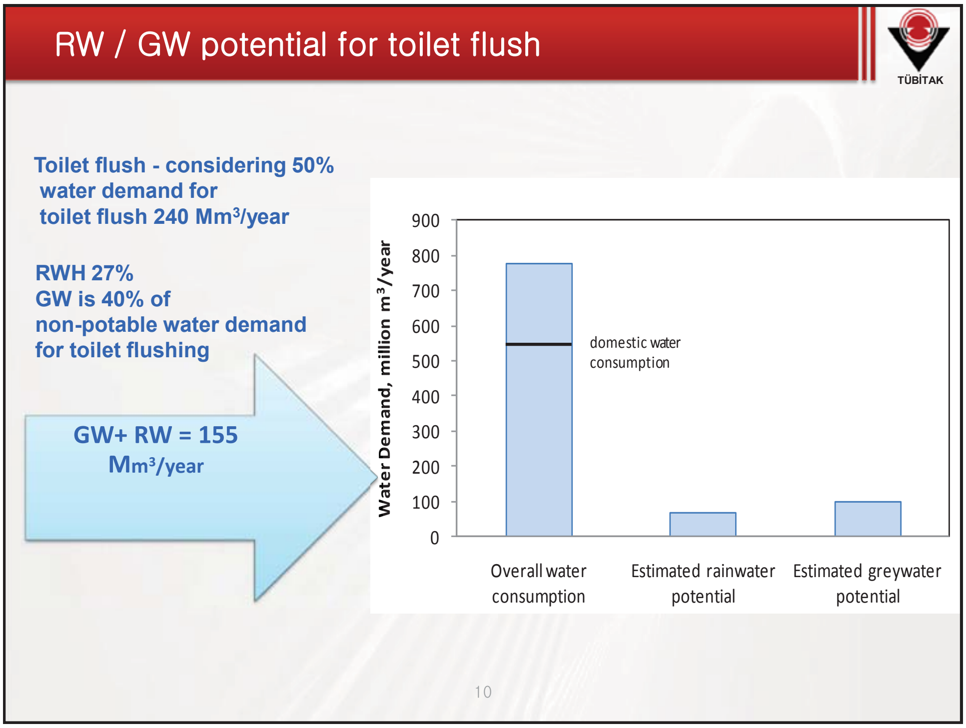
Rainwater potential = A × P × η × E × 1000

- A: Collection area, 179 km^2 roof area (IBB GIS 2010)
- P : Average precipitation depth, 650 mm
- η : Yield coefficient, (70–80%)
- E: Collection efficiency, effective run-off 80% assumed,
- RW potentially harvested from urban roofs 65 Mm^3/year.

Grey water potential = D × N × E × T

- N: Population
- 100 L/person-day total consumption
- D: GW use estimated as 50 L/person-day
- E: Collection efficiency targeted as 50%
- T: Treatment coefficient 80%

Treated GW potential 96 Mm^3/year



RW / GW potential for toilet flush

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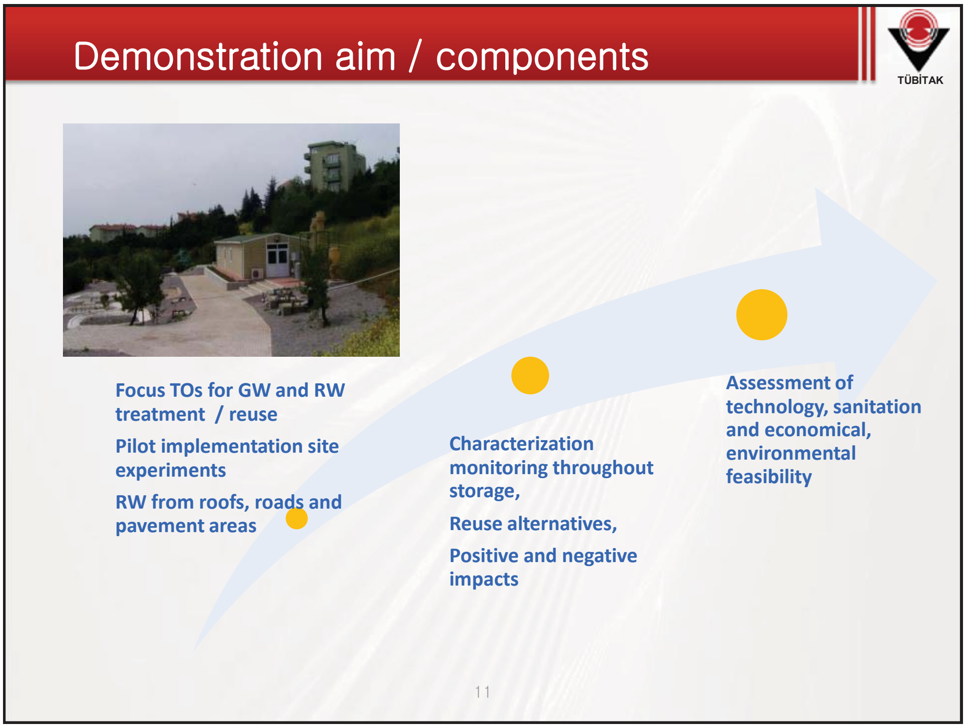
Toilet flush - considering 50% water demand for toilet flush 240 Mm^3/year

RWH 27%
GW is 40% of non-potable water demand for toilet flushing

GW+ RW = 155 Mm^3/year

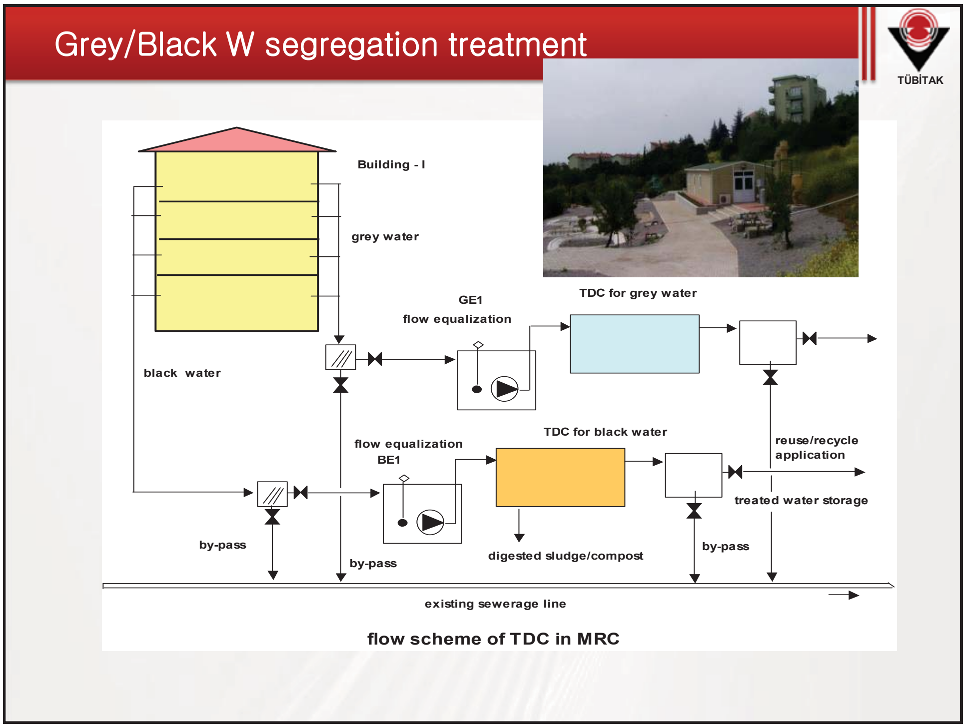


Demonstration aim / components

- Focus TOs for GW and RW treatment / reuse
- Pilot implementation site experiments
- RW from roofs, roads and pavement areas

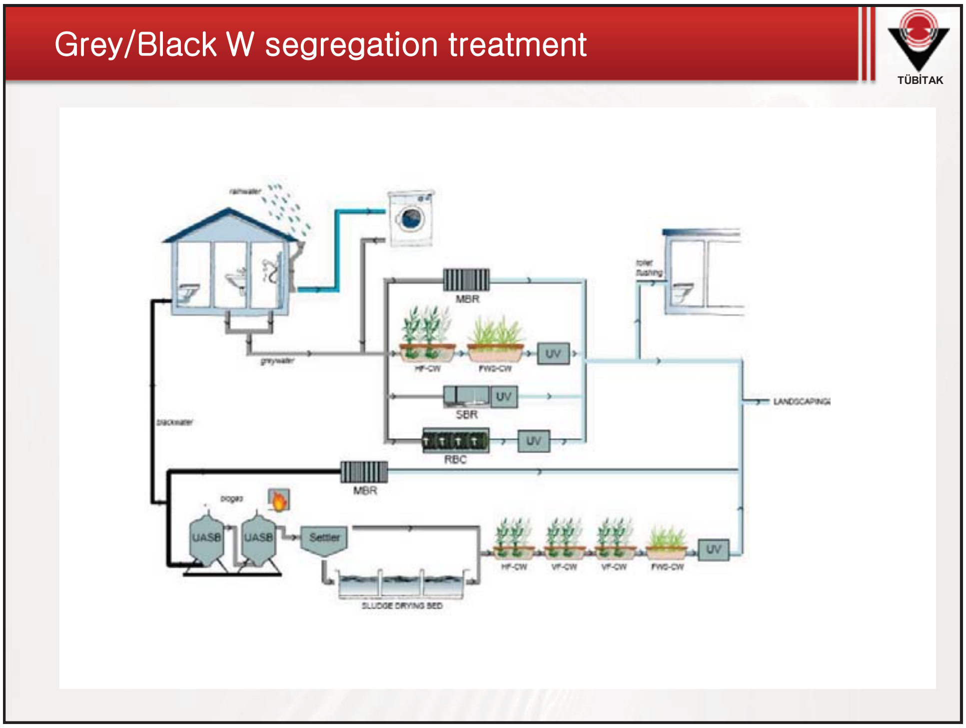
- Characterization monitoring throughout storage,
- Reuse alternatives,
- Positive and negative impacts

- Assessment of technology, sanitation and economical, environmental feasibility



Grey/Black W segregation treatment

flow scheme of TDC in MRC



Grey/Black W segregation treatment

GW BW treatment systems – pilot

GW inlet characteristics

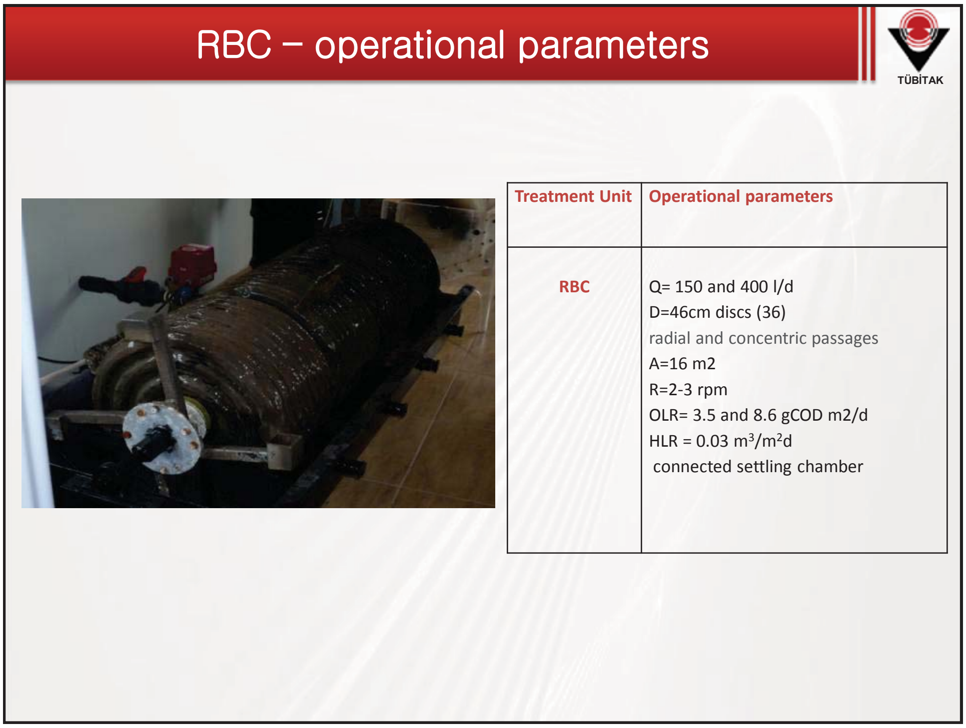
- 2 buildings (28 apartmens)
- 18-26 people (21 avg)
- 18 month period results
- Flow

Q= 197 l/c-d (60%BW 40% GW)

parameter	Influent avg. (std. dev.)
pH	7.2 (0.3)
COD_T, mgL^{-1}	295 (79)
COD_{sol}, mgL^{-1}	191(54)
BOD_5, mgL^{-1}	110 (55)
T Coliform /100mL,	$>10^6$
Turbidity, NTU	90 (50)
TSS, mgL^{-1}	63 (30)
TKN, mgL^{-1}	7.4 (3.7)
NH_4^+-N, mgL^{-1}	1.6 (1.4)
TP, mgL^{-1}	7.3 (3.1)
Alkalinity, $CaCO_3$, mgL^{-1}	192 (29)

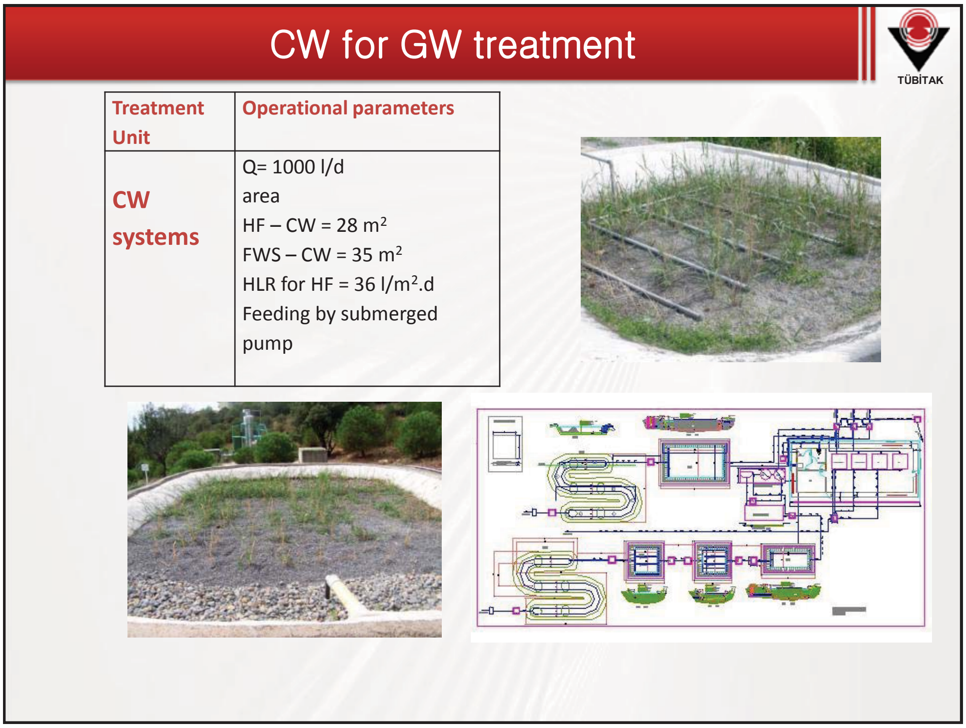
MBR – operational parameters

Treatment Unit	Operational parameters
MBR	Q= 800 l/d V= 600 L working vol. BUSSE GmbH Company a micro-filtration plate and frame module (KUBOTA) T. filtration area = 5 m^2 HRT=18h OL=0.3 $kgCOD/m^3$-d Feeding by submerged pump



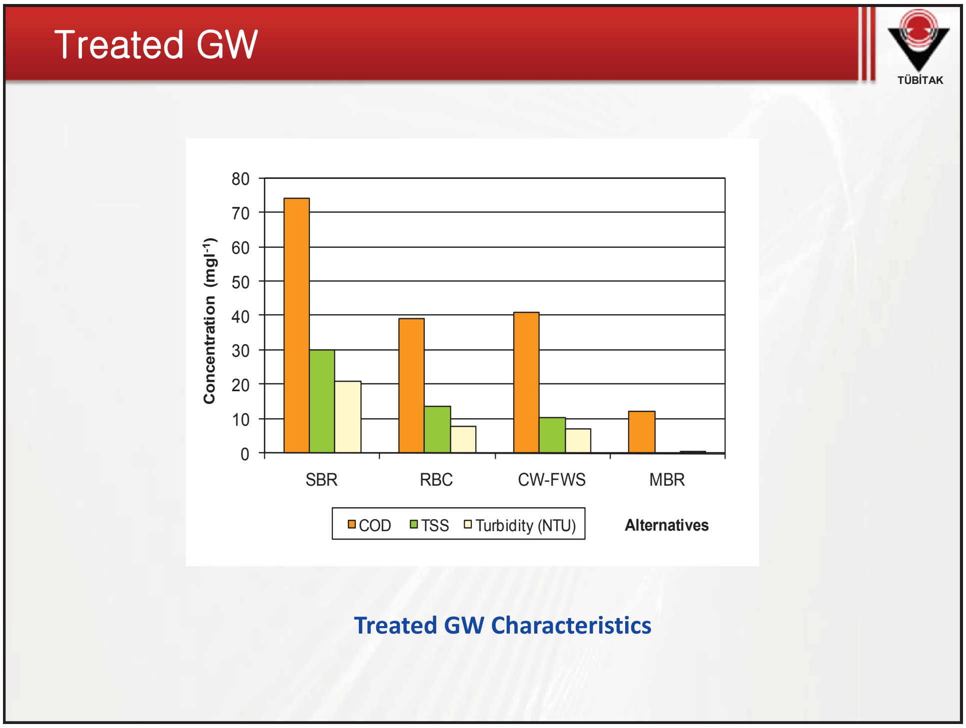
RBC – operational parameters

Treatment Unit	Operational parameters
RBC	Q= 150 and 400 l/d D=46cm discs (36) radial and concentric passages A=16 m2 R=2-3 rpm OLR= 3.5 and 8.6 gCOD m2/d HLR = 0.03 m^3/m^{2}d connected settling chamber



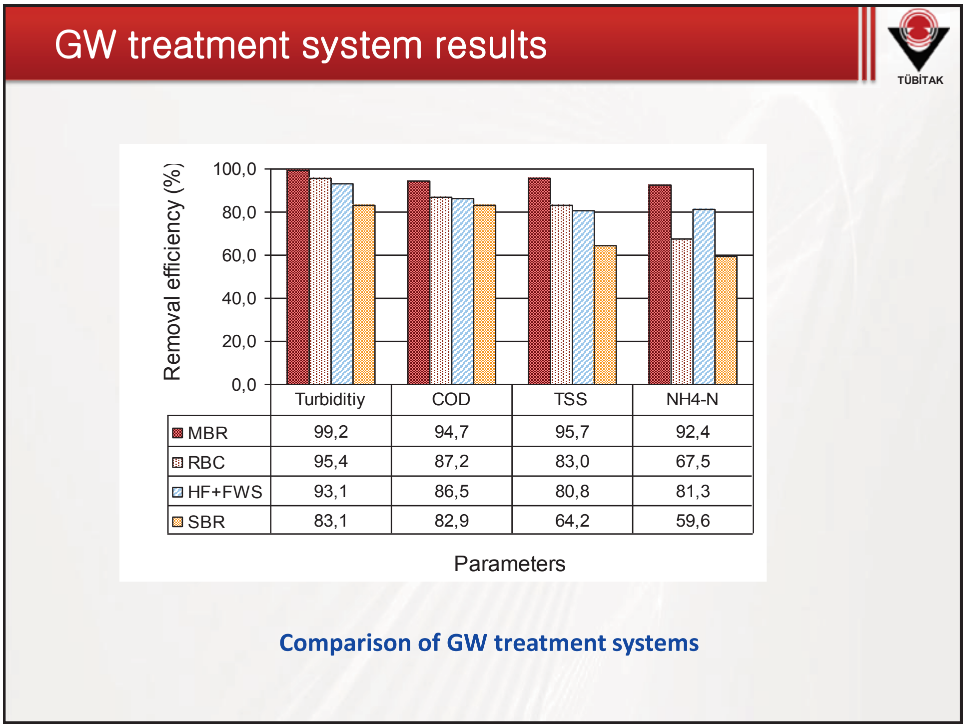
CW for GW treatment

Treatment Unit	Operational parameters
CW systems	Q= 1000 l/d area HF – CW = 28 m^2 FWS – CW = 35 m^2 HLR for HF = 36 l/m^2.d Feeding by submerged pump



Treated GW

Treated GW Characteristics



GW treatment system results

	Turbiditiy	COD	TSS	NH4-N
▩ MBR	99,2	94,7	95,7	92,4
▦ RBC	95,4	87,2	83,0	67,5
▨ HF+FWS	93,1	86,5	80,8	81,3
▧ SBR	83,1	82,9	64,2	59,6

Parameters

Comparison of GW treatment systems

GW treatment – reuse pilot experiments

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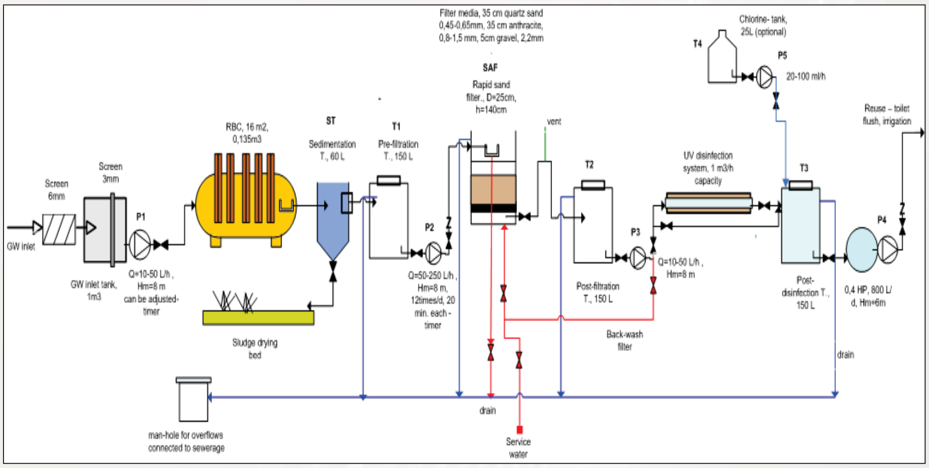

RW pilot experiments process flow sheet

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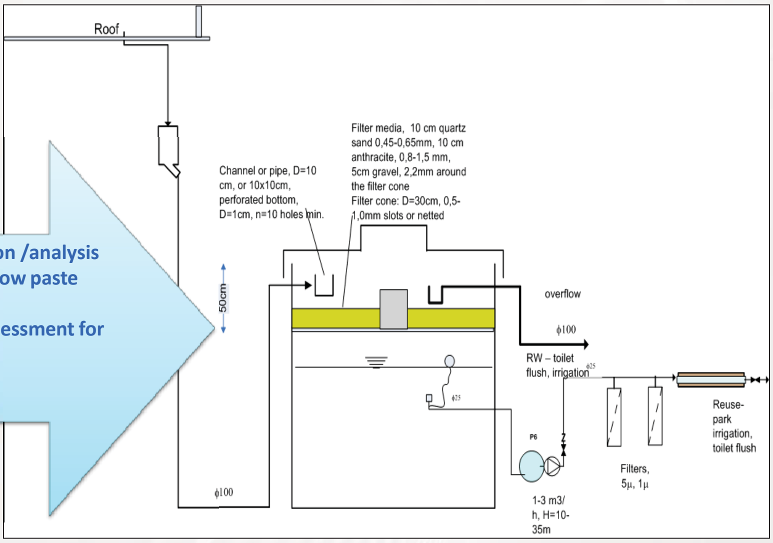
RW collection /analysis time time-flow paste
Effluent analysis/assessment for reuse



RW pilot system

sand-anthracite filter – storage tank

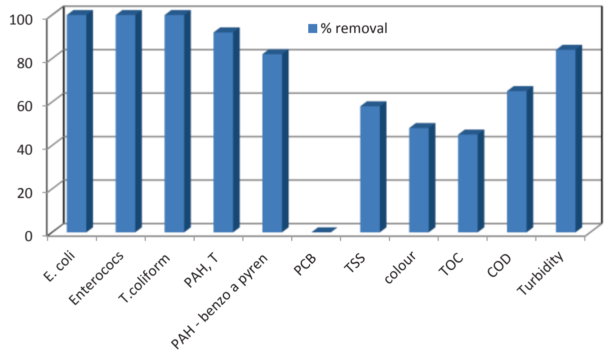
pump – cartrige filters, UV

RW collection – treatment results

Parameters	inlet (avg.)	outlet (avg.)	tank(avg.)
E.coli (n/100 mL)	10349	0	276
Enterococs (n/100 mL)	28268	0	374
T.coliform (n/100mL)	34672	0	2241
PAH, T *(µg/L)	0,060	0,005	0,005
PAH - benzo a pyren (µg/L)	0,006	0,0012	0,0028
PCB** (mg/L)	0,01	0,01	0,01
Suspended Solids (mg/L)	9	3,75	3,5
Colour (Pt-Co)	10,8	5,6	5
conductivity (µs/cm)	153,8	210,3	247,8
TOC (mg/L)	4,0	2,2	2,2
COD (mg/L)	14,4	5	7,5
Turbidity (NTU)	8,7	1,43	2,23
pH	7,44	7,36	7,42

**Total of Benzo(b)fluoranthene, Benzo(k) fluoranthene, Benzo(g,h,i) perylene, Indeno(1,2,3-c,d) pyrene, ** PCB results are less than detection limit*

RW pilot system – removal efficiencies



Removal efficiencies obtained for RW collection treatment (filtration) system

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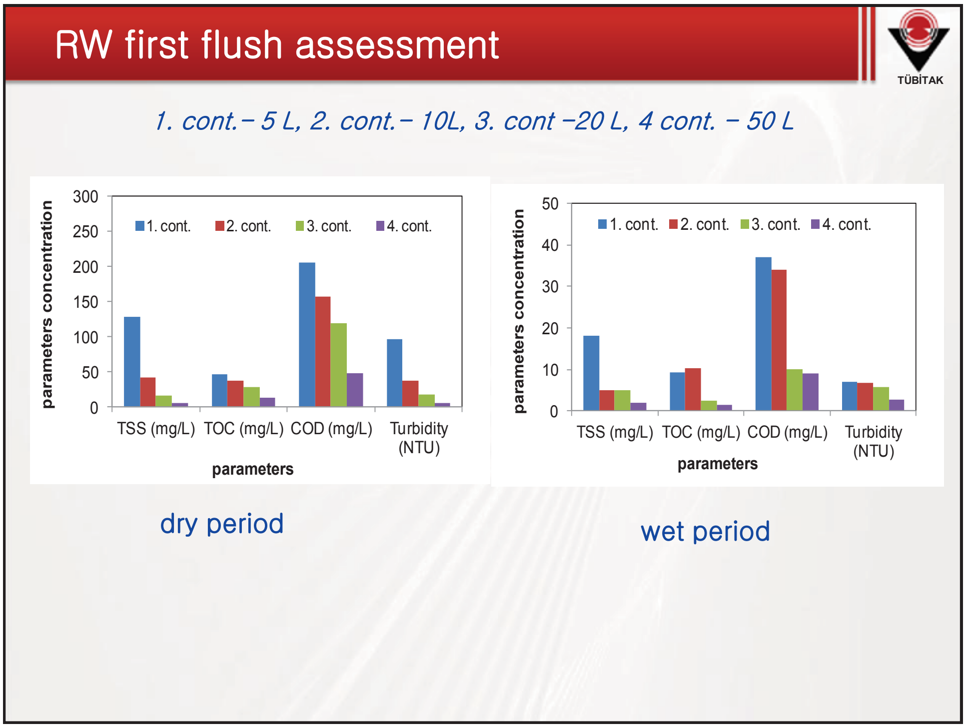
RW first flush sampling

RW sampling system from roof

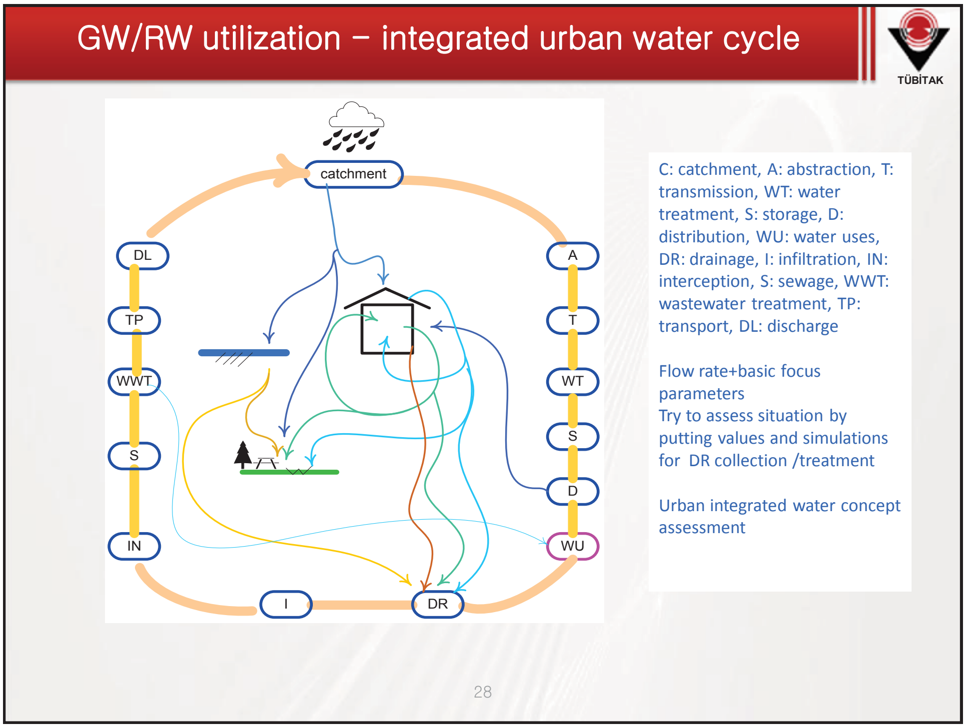


RW first flush assessment

1. cont.– 5 L, 2. cont.– 10L, 3. cont –20 L, 4 cont. – 50 L

dry period

wet period



GW/RW utilization – integrated urban water cycle

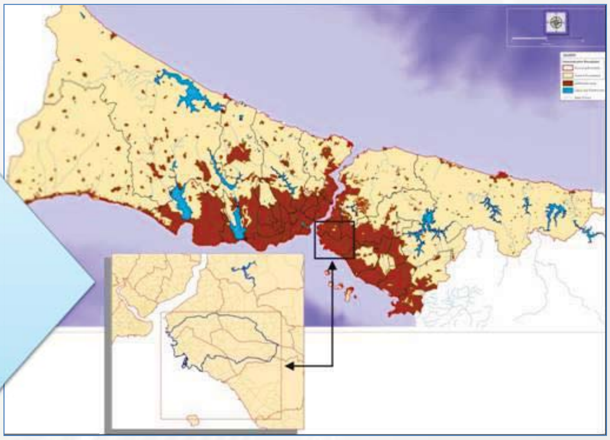
C: catchment, A: abstraction, T: transmission, WT: water treatment, S: storage, D: distribution, WU: water uses, DR: drainage, I: infiltration, IN: interception, S: sewage, WWT: wastewater treatment, TP: transport, DL: discharge

Flow rate+basic focus parameters
Try to assess situation by putting values and simulations for DR collection /treatment

Urban integrated water concept assessment

Case study area – Istanbul (kurbagalidere location)

- Conceptual test results of pilot studies
- Storm water samples from roads and paved areas analyzed for parameters including PAH and PCB periodically



Results

GW treatment-reuse

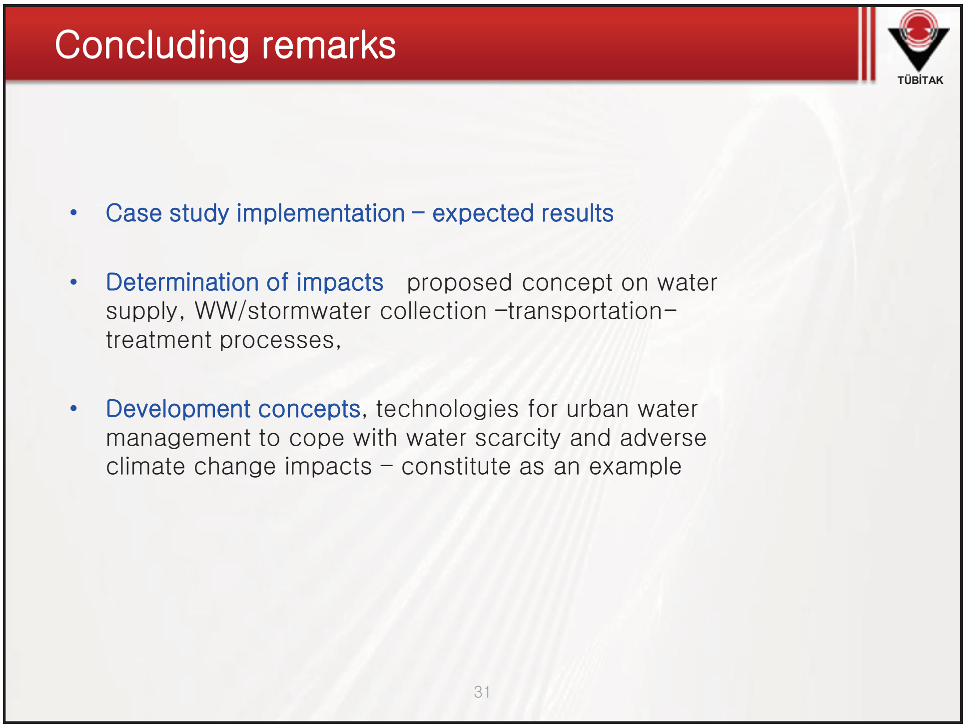
- All cases - high removal,
- Best removal performance MBR,
- Effluent satisfied EPA suggested guidelines urban reuse criteria incl. toilet flush
- Criteria violated sometimes for TSS, turbidity due to detached particles RBC and some detoriations in effluent for SBR → filtration (gravity or pressure recommended)
- For RBC UV disinfection advisable
- CWs systems are proved to be favorable especially for large areas,

RW treatment - reuse

- Efficiency obtained by sand/anthracite filtration satisfactory,
- risk of malfunctioning system

breakthrough may occur for anthracite filtration layer
flow rate so high, filtration rate high, treatment efficiency reduced, UV not efficient due to high turbidity

Foreseen advantages
Reduced water consumption,
Reduced hydraulic load to sewers and WWTPs,
increase operational ease and flexibility,
Reduced risk of floods,
Reduced adverse impacts on receiving waters ecosystems, by poor quality RW



Concluding remarks

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- Case study implementation – expected results
- Determination of impacts proposed concept on water supply, WW/stormwater collection –transportation–treatment processes,
- Development concepts, technologies for urban water management to cope with water scarcity and adverse climate change impacts – constitute as an example

TÜBİTAK

THANKS

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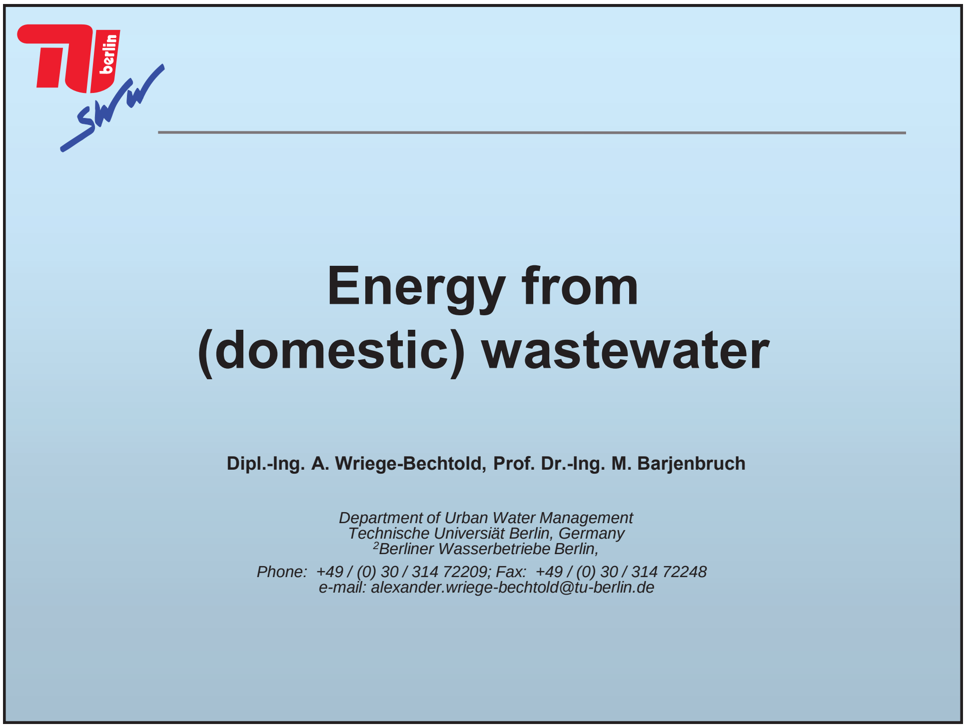
Session 3 – Rainwater, Domestic Wastewater, Energy and Nutrient Aspects

3.2 Energy from (domestic) wastewater

Alexander Wriege Bechtold, TU Berlin



Energy from (domestic) wastewater

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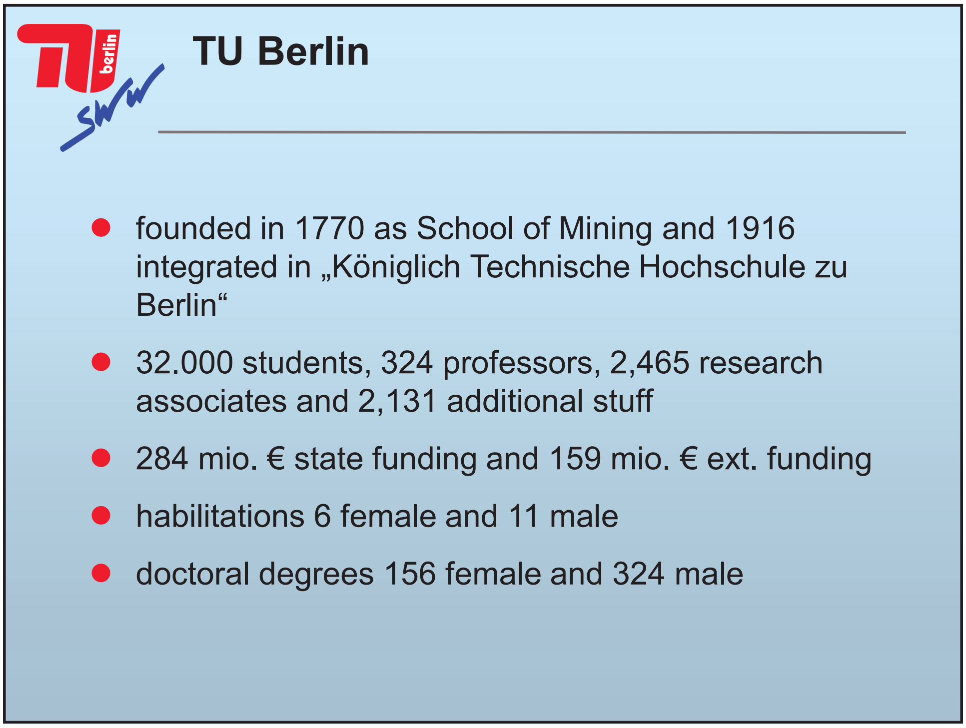


TU Berlin

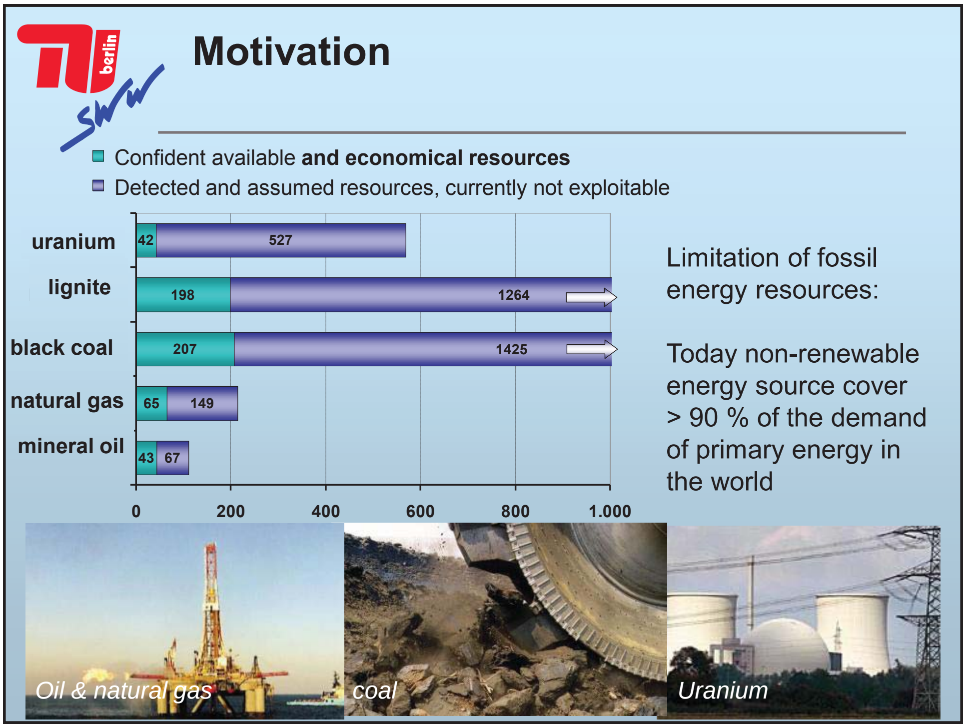
- founded in 1770 as School of Mining and 1916 integrated in „Königlich Technische Hochschule zu Berlin“
- 32.000 students, 324 professors, 2,465 research associates and 2,131 additional stuff
- 284 mio. € state funding and 159 mio. € ext. funding
- habilitations 6 female and 11 male
- doctoral degrees 156 female and 324 male

TU Berlin

- 7 schools
- compentencies
    - Materials, Design and Manufacturing
    - Cyber-Physical Systems
    - Energy Systems
    - Sustainable Resource Management
    - Infrastructure and Mobility
    - Knowledge and Communication Systems
    - Human Health
- urban water management at school VI „planning – building – environment“

Department of Urban Water Management

- Fields of research
    - advanced wastewater treatment
    - rainwater treatment
    - energy optimisation of WWTPs
    - odour and corosion in sewers
    - energy production by sludge digestion
    - alternative sanitary systems
- Project examples
    - Blue Green Dream
      (Bringing together of urban planning and water planning)
    - Production of biogas by Brownwater treatment

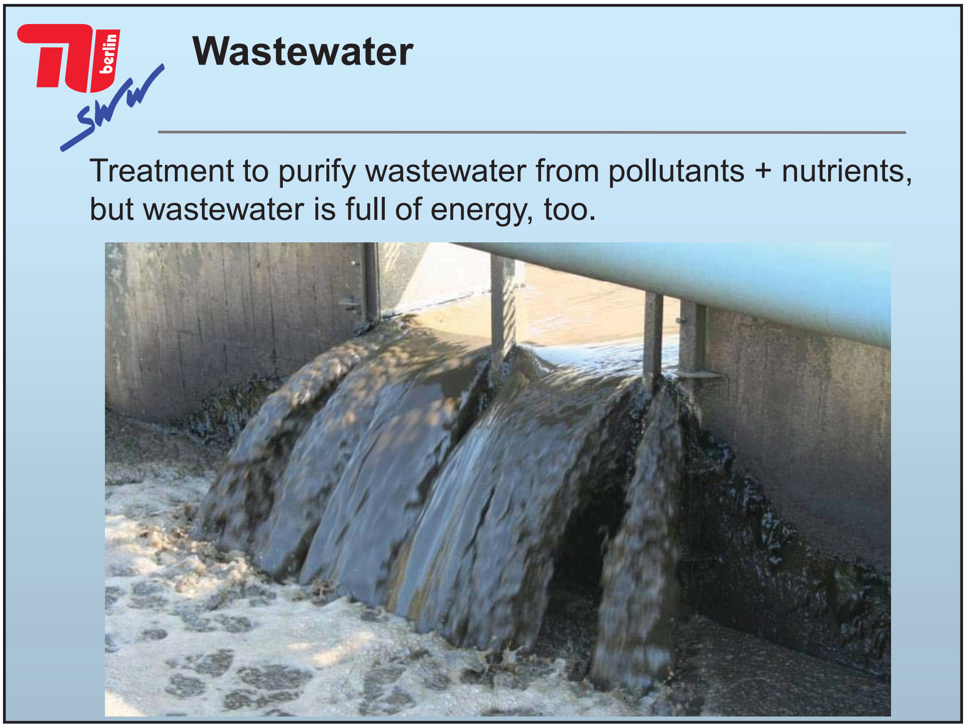


Motivation

- 🟩 Confident available **and economical resources**
- 🟪 Detected and assumed resources, currently not exploitable

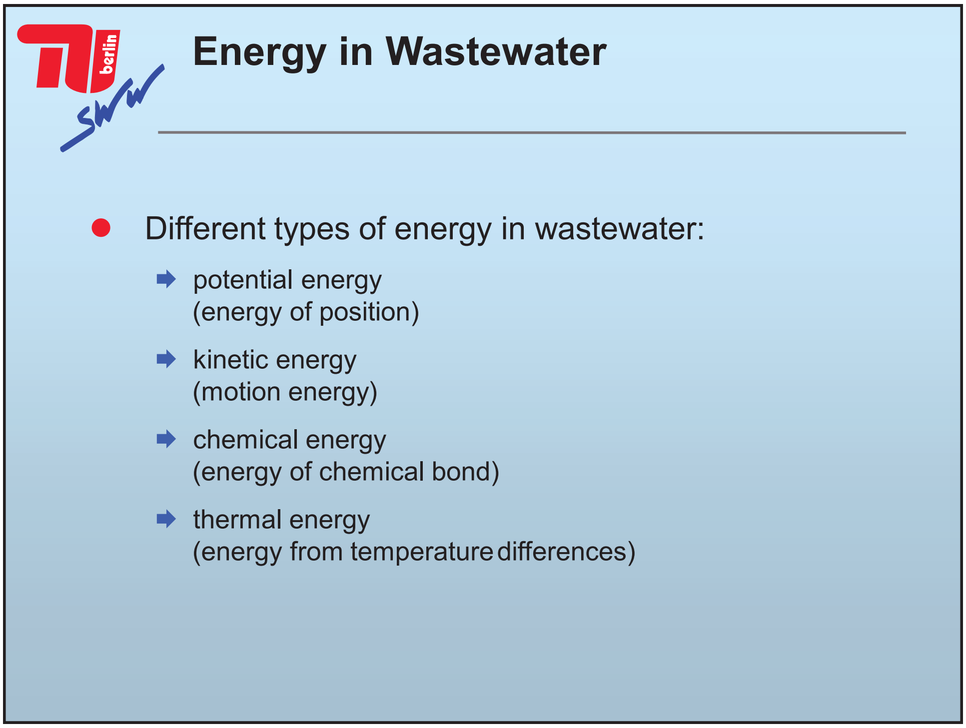
Limitation of fossil energy resources:

Today non-renewable energy source cover > 90 % of the demand of primary energy in the world



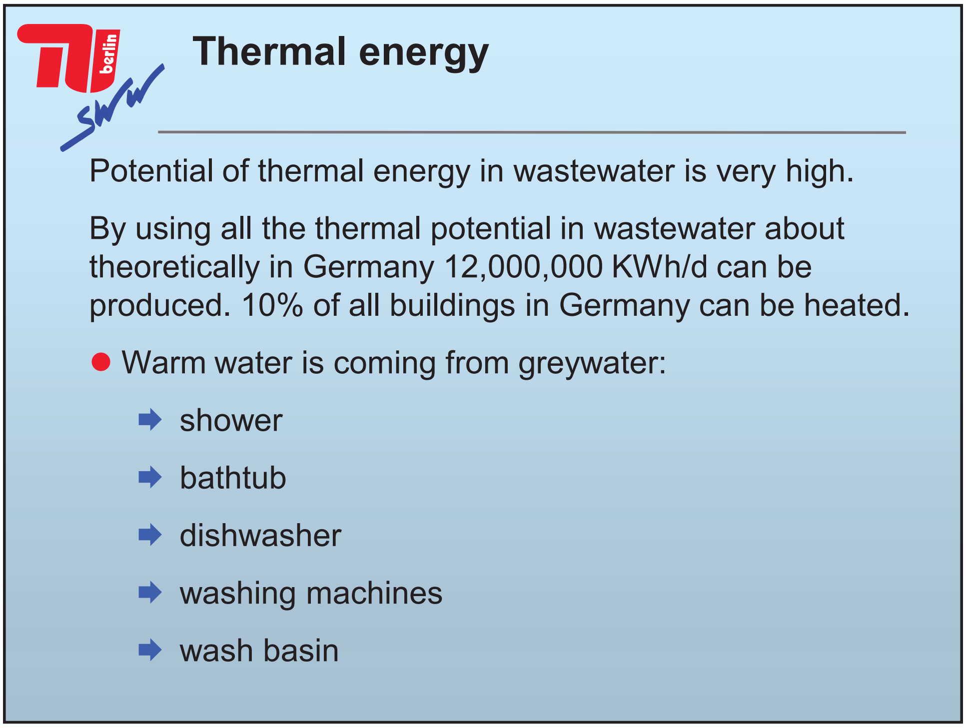
Wastewater

Treatment to purify wastewater from pollutants + nutrients, but wastewater is full of energy, too.



Energy in Wastewater

- Different types of energy in wastewater:
  - potential energy
    (energy of position)
  - kinetic energy
    (motion energy)
  - chemical energy
    (energy of chemical bond)
  - thermal energy
    (energy from temperature differences)



Thermal energy

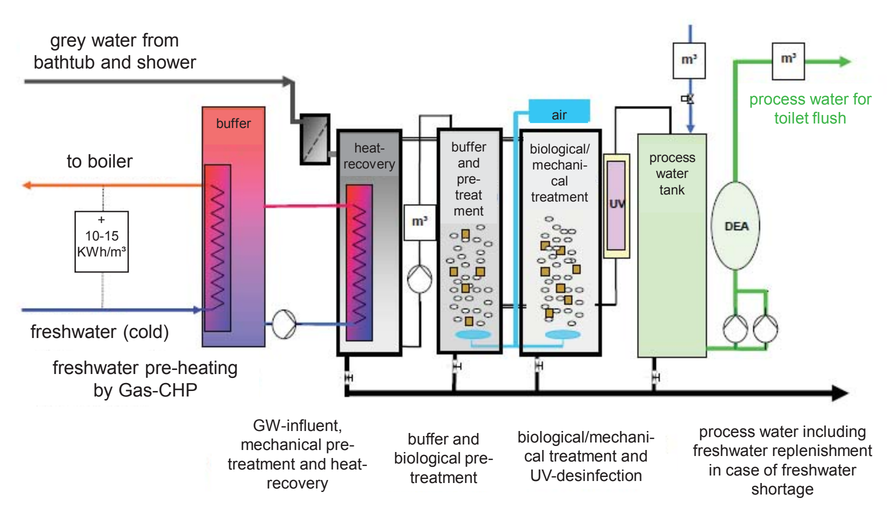
Potential of thermal energy in wastewater is very high.

By using all the thermal potential in wastewater about theoretically in Germany 12,000,000 KWh/d can be produced. 10% of all buildings in Germany can be heated.

- Warm water is coming from greywater:
  - shower
  - bathtub
  - dishwasher
  - washing machines
  - wash basin

Thermal energy

Grey water recycling with upstream heat recovery®



grey water from bathtub and shower

to boiler

+ 10-15 KWh/m³

freshwater (cold)

freshwater pre-heating by Gas-CHP

buffer

heat-recovery

m³

buffer and pre-treatment

air

biological/ mechanical treatment

UV

process water tank

m³

m³

process water for toilet flush

DEA

GW-influent, mechanical pre-treatment and heat-recovery

buffer and biological pre-treatment

biological/mechanical treatment and UV-desinfection

process water including freshwater replenishment in case of freshwater shortage

Nolde 2012, modified

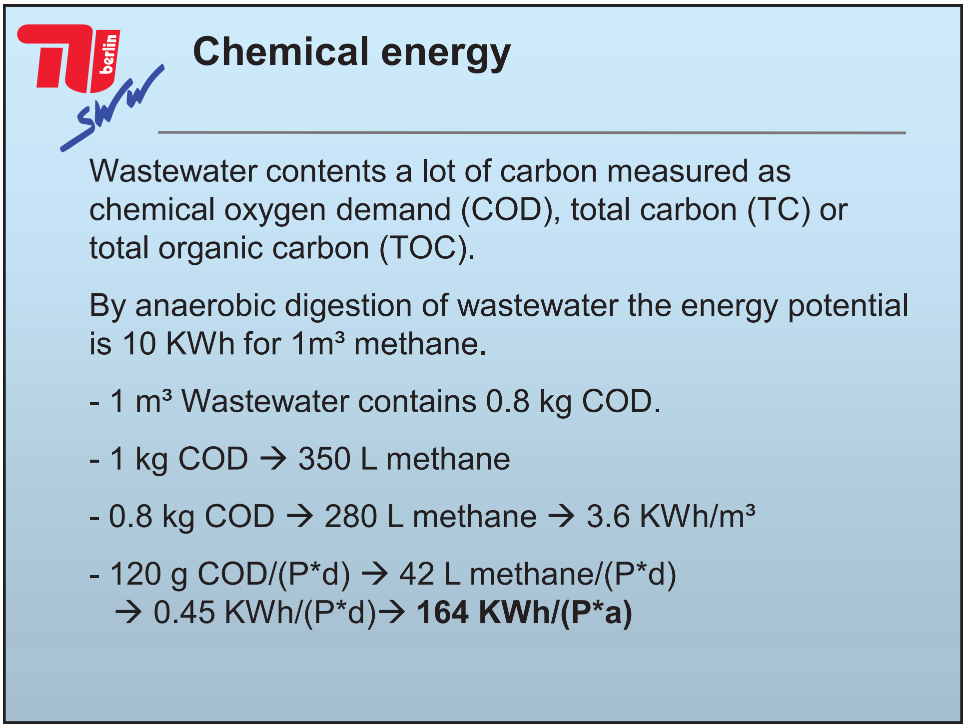
Kinetic and potential energy

Due to low speed of wastewater in sewers the kinetic energy in wastewater is very low. The potential share is more higher.

In Germany the energy potential from waterwheels is 2,500 to 17,000 MWh/a. (0.21 KWh/(P*a)=0.0005%) (PEC in Germany: 4,000 TWh/a → 49,000 KWh/(P*a))

Usually at building level use of potential energy from wastewater is according to non existing converting devices not effective.

In practise there is a small number of examples with waterwheels in wastewater treatment plant effluents.



Chemical energy

Wastewater contents a lot of carbon measured as chemical oxygen demand (COD), total carbon (TC) or total organic carbon (TOC).

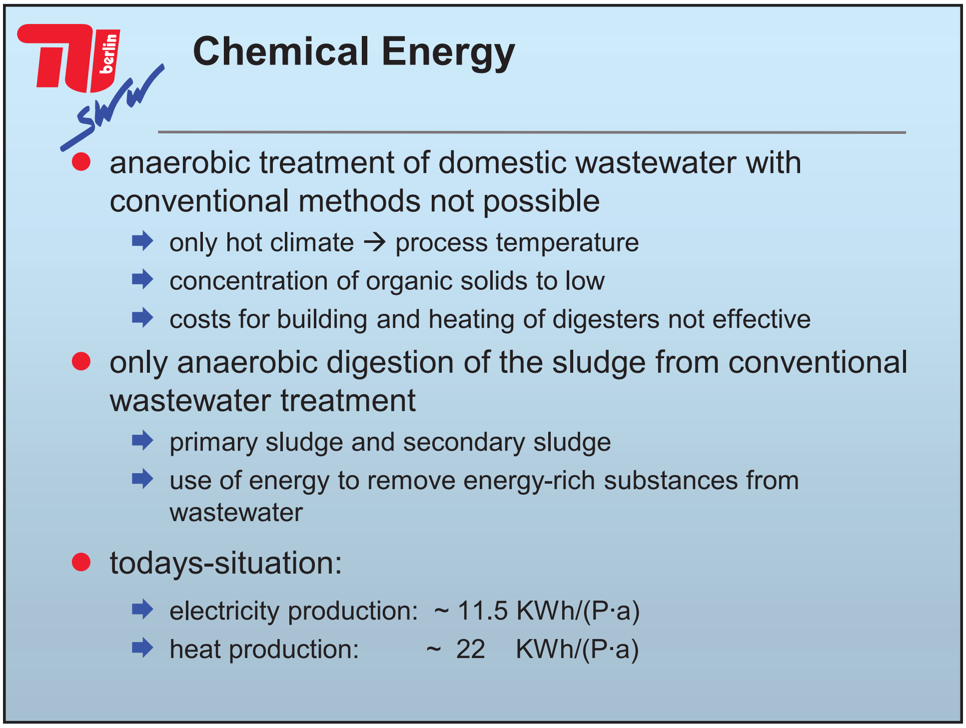
By anaerobic digestion of wastewater the energy potential is 10 KWh for 1m^3 methane.

- 1 m^3 Wastewater contains 0.8 kg COD.

- 1 kg COD → 350 L methane

- 0.8 kg COD → 280 L methane → 3.6 KWh/m^3

- 120 g COD/(P*d) → 42 L methane/(P*d)
  → 0.45 KWh/(P*d)→ **164 KWh/(P*a)**



Chemical Energy

- anaerobic treatment of domestic wastewater with conventional methods not possible
  - only hot climate → process temperature
  - concentration of organic solids to low
  - costs for building and heating of digesters not effective
- only anaerobic digestion of the sludge from conventional wastewater treatment
  - primary sludge and secondary sludge
  - use of energy to remove energy-rich substances from wastewater
- todays-situation:
  - electricity production: ~ 11.5 KWh/(P·a)
  - heat production: ~ 22 KWh/(P·a)

Chemical Energy

Conventional anaerobic sludge treatment on WWTPs

- Potential
  - ➡ In dependence of the method of biogas-utilization (Boiler, CHP, fuel cell) and degree of efficiency
  - ➡ Electricity production :
    21.2 KWh/(P·a)
  - ➡ Heat production:
    33   KWh/(P·a)
- Additional potential by implementation of biogas production on smaller WWTPs > 10,000 PE with CHP
- Co-fermentation

Schröder, 2008

State of the art in wastewater treament

combined system: domestic wastewater with stormwater

not separate:

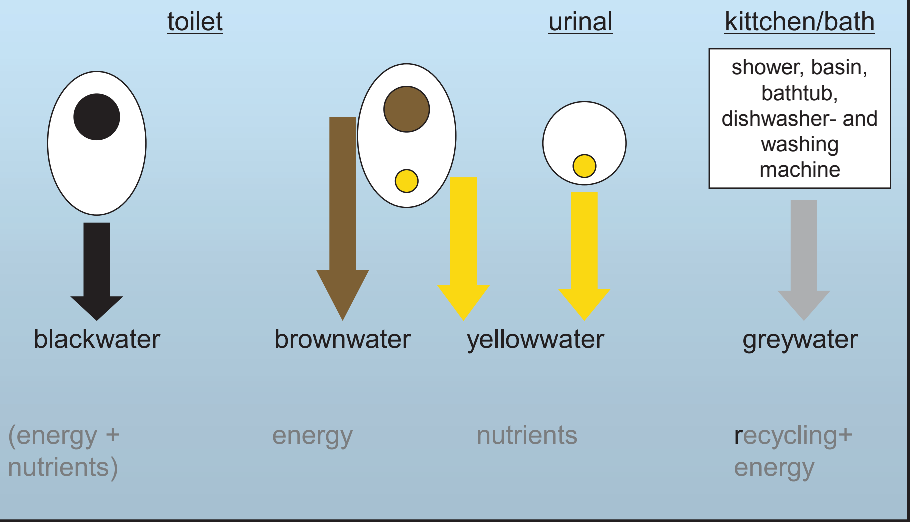
- coverage
- transport
- treatment

of wastewater

separate system: without stormwater

Different wastewater streams

- alternative wastewater treatment



toilet

urinal

kittchen/bath

shower, basin, bathtub, dishwasher- and washing machine

blackwater

brownwater

yellowwater

greywater

(energy + nutrients)

energy

nutrients

recycling+ energy

Example

Sanitation Concepts for Separate Treatment

Wastewater Treatment Plant Berlin-Stahnsdorf

Peter-Fröhlich 2005

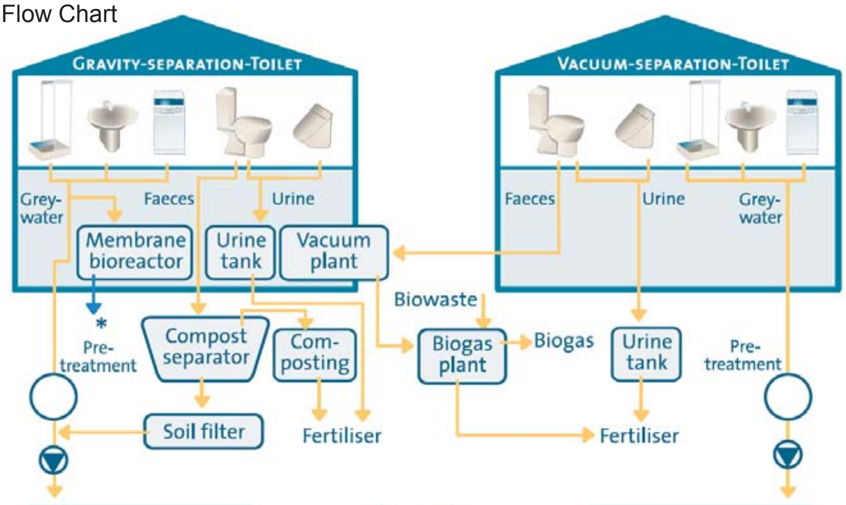
SCST Berlin-Stahnsdorf

Two types of toilet systems have been installed: gravity separation toilets and vacuum separation toilets. Different methods are taken into consideration for treatment of urine, faeces and greywater.

- Main research topics:
  - Urine: extraction of nutrients
  - Faeces: composting and **digestion**
  - Greywater: constructed wetlands and membrane bio reactor
  - Treated urine and faeces → fertiliser
  - Reuse options for treated greywater → irrigation, washing machine
  - Cost calculation and cost comparison
- Duration of the Project: 2003 - 2006
- Total costs 2.22 Mio Euro (BWB + Veolia: 80 %, EU: 20 %)
- Funded by the European Union (Life financial Instrument)

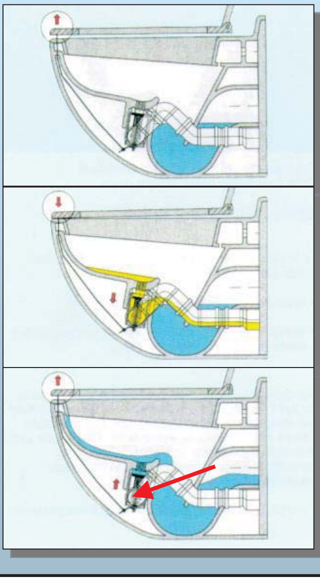
SCST Berlin-Stahnsdorf

Flow Chart



KWB 2005

SCST Berlin-Stahnsdorf



Vacuum Separation Toilet

vacuum
for faeces

gravity
for urine

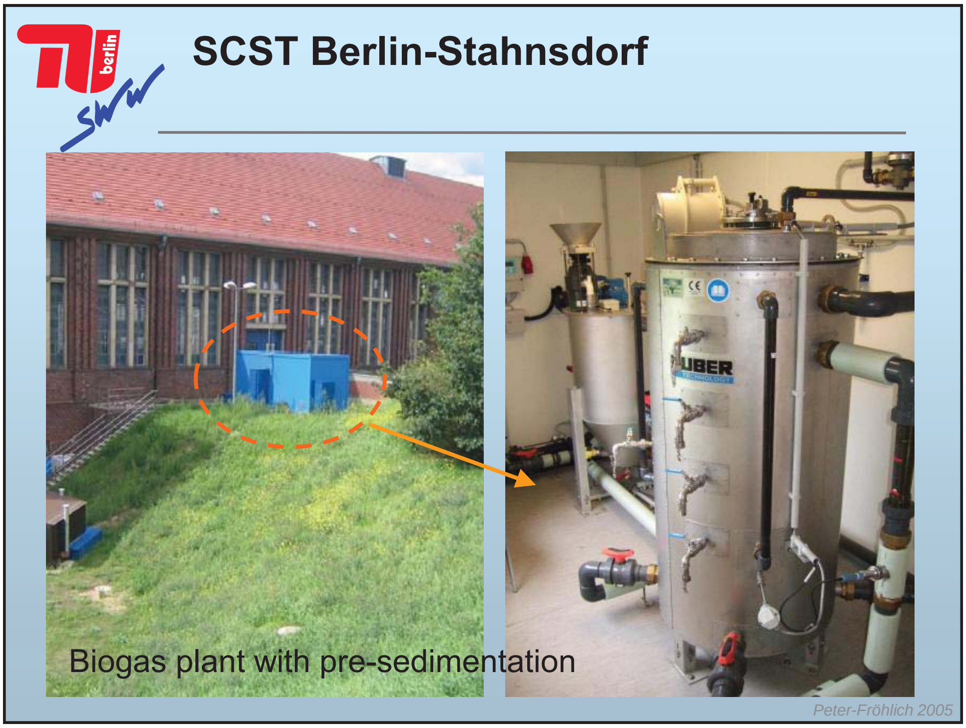
1.0 L/flush

Peter-Fröhlich 2005

SCST Berlin-Stahnsdorf

Vacuum Plant for Vacuum Toilets

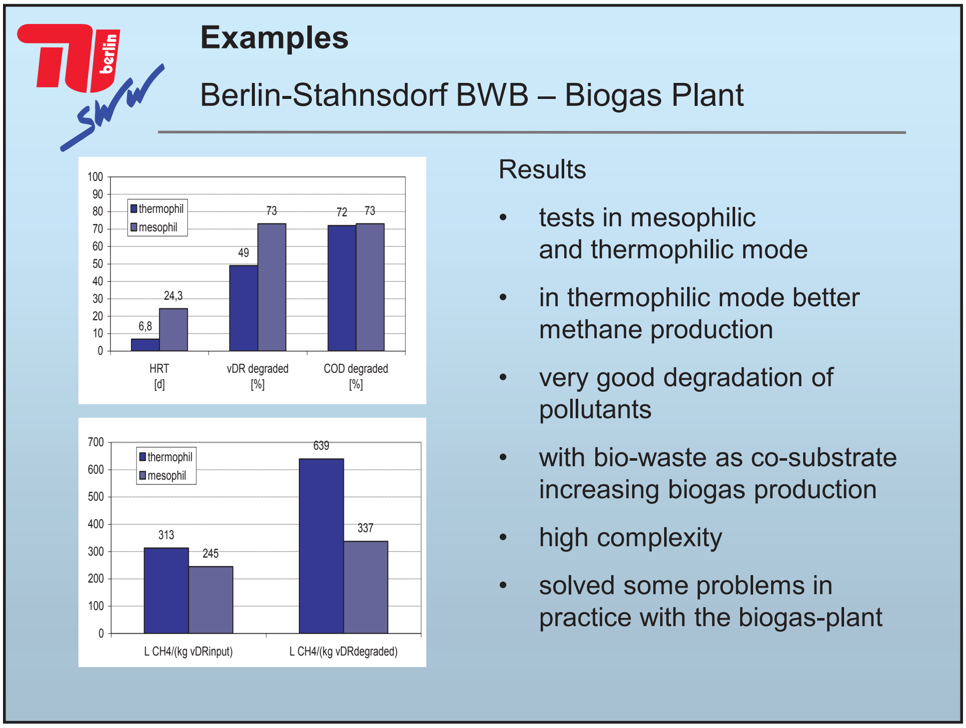
Peter-Fröhlich 2005



SCST Berlin-Stahnsdorf

Biogas plant with pre-sedimentation

Peter-Fröhlich 2005



Examples

Berlin-Stahnsdorf BWB – Biogas Plant

Results

- tests in mesophilic and thermophilic mode
- in thermophilic mode better methane production
- very good degradation of pollutants
- with bio-waste as co-substrate increasing biogas production
- high complexity
- solved some problems in practice with the biogas-plant

Abstract and future prospects

- wastewater is full of energy
- production of biogas from brownwater/blackwater is a good possibility to use the energetic potential of wastewater
- heat energy from greywater
- on the household or building lever some optimisation work is needed
- important is: to have a good general concept but the components have a deep impact to the success of the projects
- some successful pilot plants
- has not yet become established at all in practice
- depends on different factors
  - ➡ regulations and stakeholders
  - ➡ available techniques and costs

Thank you for your attention.

Session 3 – Rainwater, Domestic Wastewater, Energy and Nutrient Aspects

3.3 Elements of Sustainable Sanitation Systems

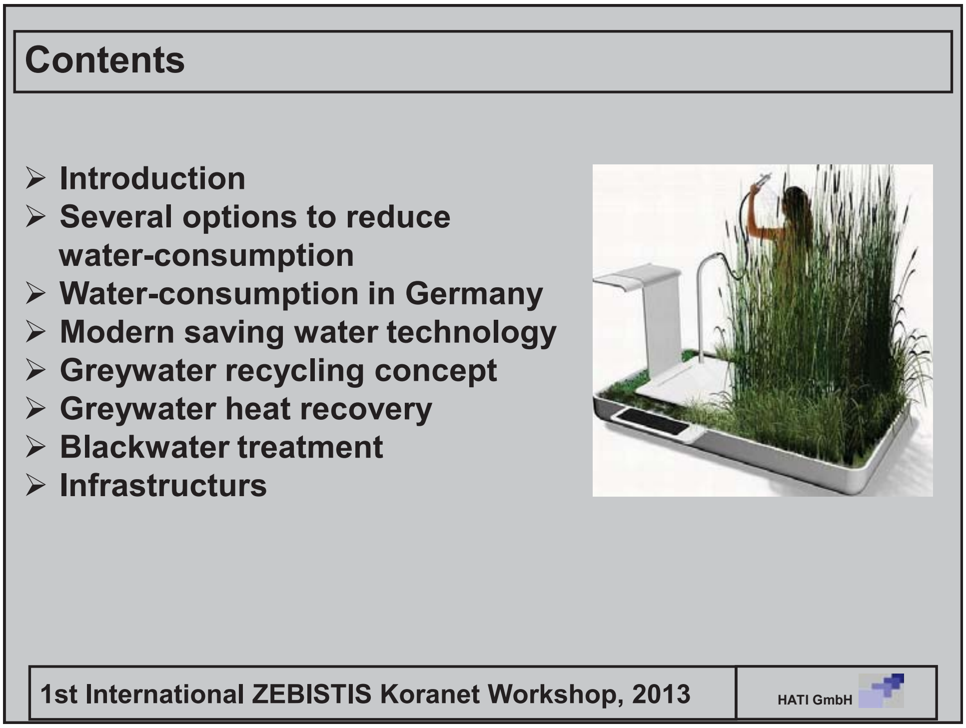
Joachim Zeisel, HATI consulting

1st International ZEBISTIS Koranet Workshop, 2013

HATI consult

Peter Thomas, Joachim Zeisel, Berlin

elements
of
sustainable
sanitation
systems



Contents

- Introduction
- Several options to reduce water-consumption
- Water-consumption in Germany
- Modern saving water technology
- Greywater recycling concept
- Greywater heat recovery
- Blackwater treatment
- Infrastructurs

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The demographic, climate and economic conditions are changing fast and profound. Dealing responsibly with water is one of the most important global aims of our times. With the modernisation or retrofitting of the water infrastructure systems, it is ought to integrate the potentials of the within-building technology. On the following pages we will inform about elements and strategies in the field of sustainable sanitary systems.

Source: letro-foto.de

Options to reduce water consumption

The sanitary industry offers several options to reduce the everyday water consumption without affecting the hygiene or comfort:

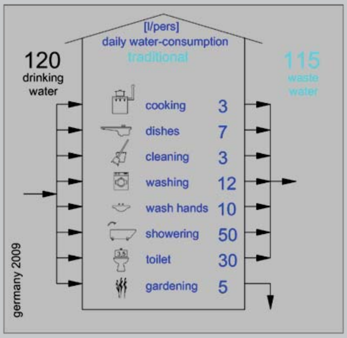
- → saving taps
- → flow limiters
- → especial saving showers
- → water saving toilets
- → personalized water meter

Traditional water-consumption

The water-consumption in Germany declined since 1995 about 22 liters per day and person:

2009 = 120 liters/day person

- → saving taps and toilets
- → better house appliances
- → higher fees



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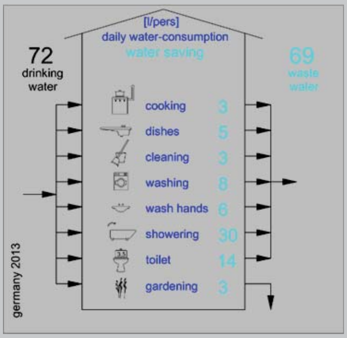
Water saving consumption

In sustainable sanitation systems the water-consumption could be reduced with saving elements to:

72 liters per day and person.



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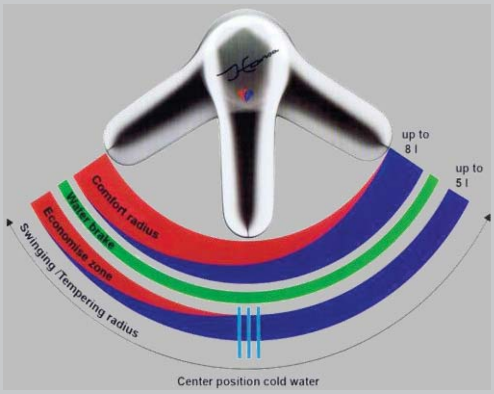
Intelligent tap - 1

Source: HANSA Metallwerke AG

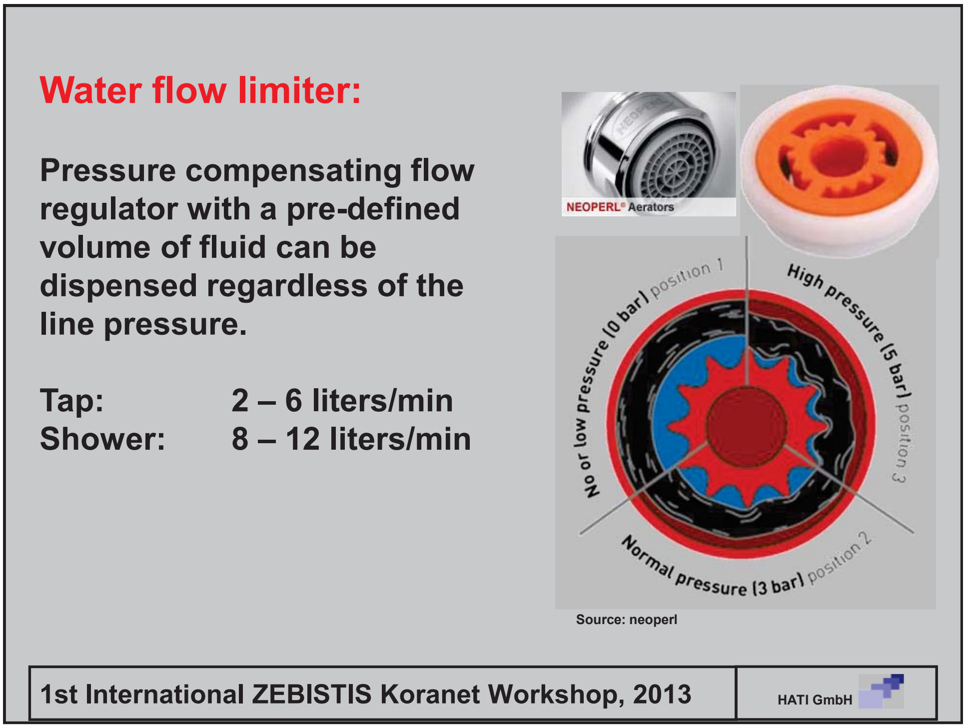
The modern saving technology is hidden in the “two-gear-system” at the cartridge. Until the resistance (water brake) only 6 liters/min flow out of the cartridge. If the lever is moved over the water brake 8 liters/min are flowing.

Intelligent tap - 2



Source: HANSA Metallwerke AG

The lever in the mostly used center position releases the cold water. To look for warm water, to have to move it to the left side.



Water flow limiter:

Pressure compensating flow regulator with a pre-defined volume of fluid can be dispensed regardless of the line pressure.

Tap:	2 – 6 liters/min
Shower:	8 – 12 liters/min

Source: neoperl

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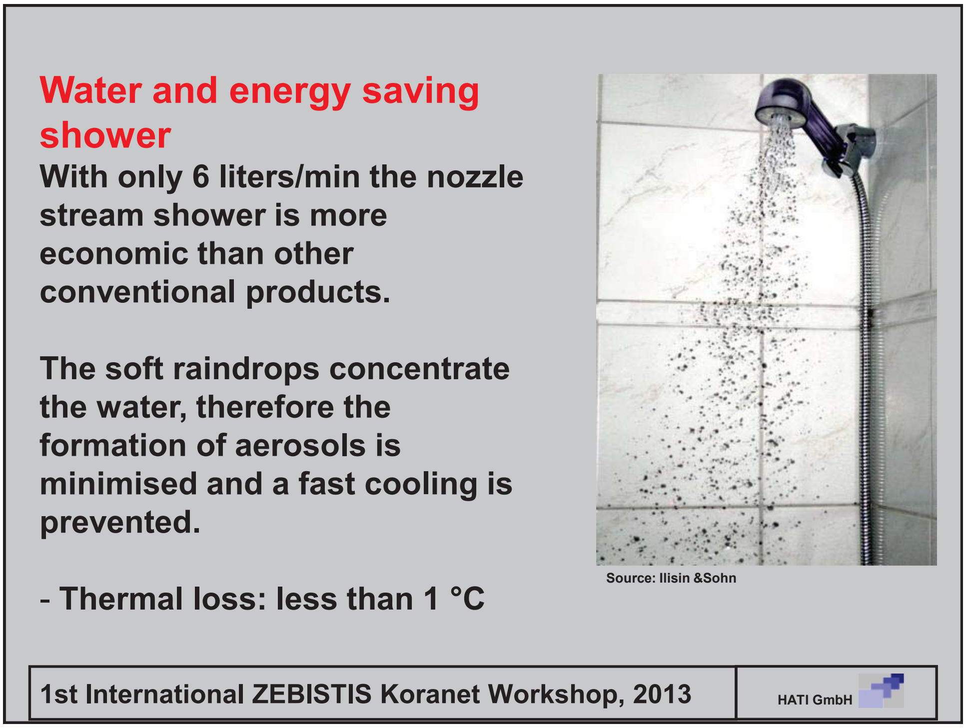

Water and energy saving shower

With only 6 liters/min the nozzle stream shower is more economic than other conventional products.

The soft raindrops concentrate the water, therefore the formation of aerosols is minimised and a fast cooling is prevented.

- Thermal loss: less than 1 °C

Source: Ilisin &Sohn

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Waterless urinals

Waterless urinals are normally using barrier liquids.

The new KERAMAG urinal has a special rubber membrane, which is located in the urinal to avoid any smell. The urine drains off completely and seals automatically.

Source: Keramag, 2004

Watersaving toilet - 1

Commercially available water-closets mostly use 6 liters of water per usage.

In the development of the GreenGain-Toilet the hydraulic performance had been improved consistently.
The result is a water-closet that only uses 3,5 liters for flushing out faeces and only 2 liters for the urine-flush.

Source: Villeroy & Boch AG

Watersaving toilet - 2

With conventional toilets the ingress is laid by one conduction. For achieving an excellent flushing the GreenGain-Toilet has three inlets.

The main stream runs parallel on the right and left side into the front area at flushing.

Source: Villeroy & Boch AG

Saving water by installing a water meter

A water meter serves as a guideline for handling water responsibly.

The installation of a water meter is necessary for a consumer equitable billing of water and sewage charges.

Source: Georg Fischer JRG AG

Rainwater use

The subject of rainwater management has reached the leading companies. Because of the engineering standard DIN 1989 part 1 and 4 there exists a planning and legal certainty.

- Flushing toilets
- Washing machine
- Watering gardens

Source: Georg Fischer JRG AG

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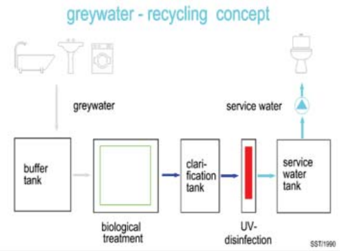
Greywater recycling concept

The greywater from wash basin, shower and laundry is collected in a buffer tank.
The mainly cleaning process contents:
- biological treatment
- clarification
- UV-disinfection

The service water is used for toilet flushing, water gardening, (laundry)



Source: Sanitärsystemtechnik, 1990

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BCR-biological compact rotator

Source: K. Zeisel

The cleaning biomas settled down on the high surface of the rotator-filters. The aeration is continous. With the compact bio-flake resulted a good sedimentation.

- BOD7 less than 5 mg/l
- O2 saturated
- bacteria under the limit of public swimming water

Cleaning with foam rubber cubes

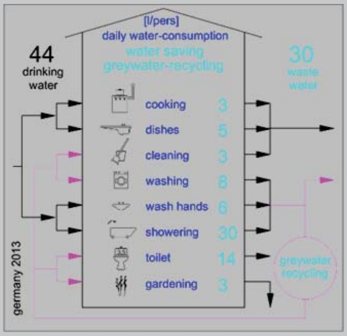
Source: E. Nolde

The cleaning biomas settled down on foam rubber cubes. They are floating in aerated tanks.

106 flats are situated in a housing “Block 6” in Berlin and connected to the foam rubber cube water cleaning system with good results since 10 years.

Water-consumption with greywater recycling

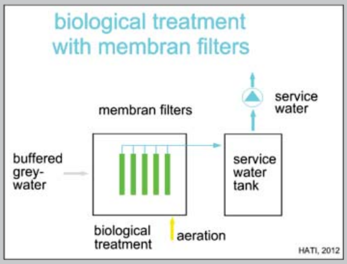
The drinking water consumption could be reduced up to 44 liters per day and person with an outflow of waste water from 30 liters.



Cleaning with membran filters

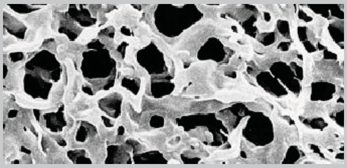
The membran filters are oriented in the treatment tank. The service water is pumped out directly disinfected.

- high age of the biomas
- great diversity of bacteria
- no need of sedimentation



Characteristic of membrane filters

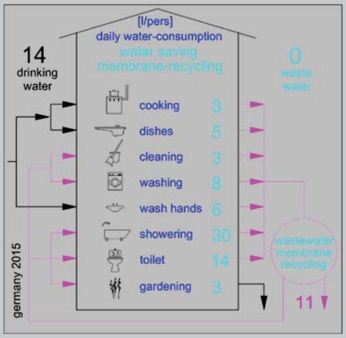
The size of the pors are between 0,1 µm and 0,01 µm. This allows to retreat bacteria and vires.
The grade of the disinfection is very high.
The membranes are made of organic or ceramic material.



Result of the membrane recycling

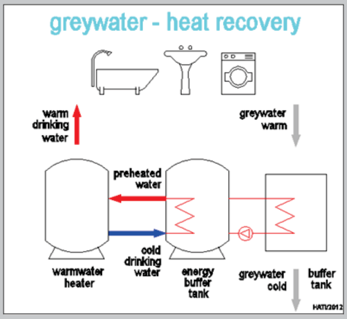
In the future we could reduce the water consumption about a factor 5 (Weizsäcker, vice-president of the Club of Rome).

The drinking water supply is reduced to 14 liters per person an day.



Greywater heat recovery 1/3

The energy of the greywater could be used for the preheating of the cold drinking water.
To minimize the hygienic risk, we need an energy buffer tank and a second heat circle.



Greywater heat recovery 2/3

In the project “Arnimplatz” in Berlin (Nolde), there was reached a recovery of about 10 – 15 kWh per cbm drinking water.

Greywater heat recovery 3/3

The heat exchanger is a flexible ripped stainless steel pipe, directly installed in the greywater buffer tank.

Blackwater treatment

Blackwater is indicated as a mixture of faeces, urine, toilet paper and rinsing water.

To deconcentrate the black- water, the solid material is separated by a spiral conveyor from the black water stream and transported to a storage tank.

1. Black water inflow
2. Separator
3. Barrel for solid material
   (Bio-Char, faeces, toilet paper)
4. Outlet of the liquid phase

Source: TECE

Faeces seperator

A spiral conveyor transports the solid material automatically to a storage tank and is mixed there with a specific portion of porous charcoal powder.

Waste material becomes a resource.

Advantages are:
- High cost savings for disposal;
- Nucleus for new services

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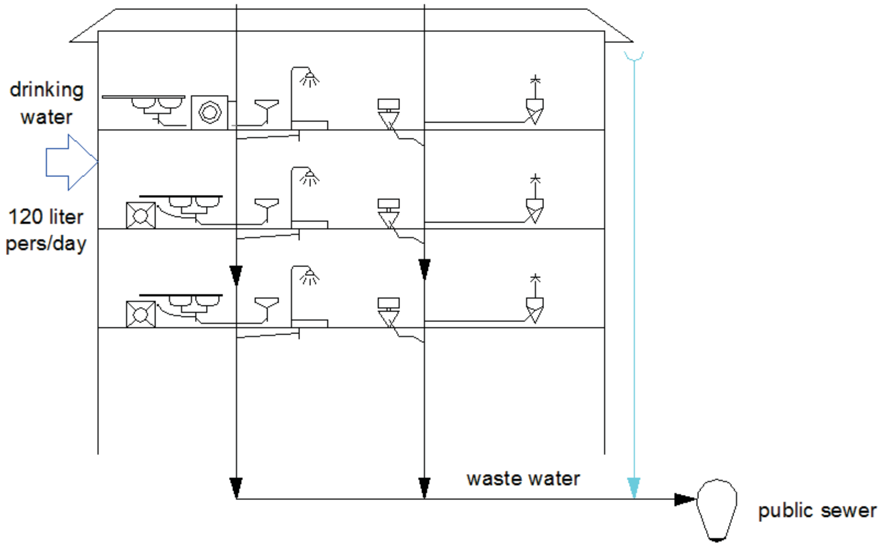

traditional urban infrastructure HATI GmbH 10.01.2013

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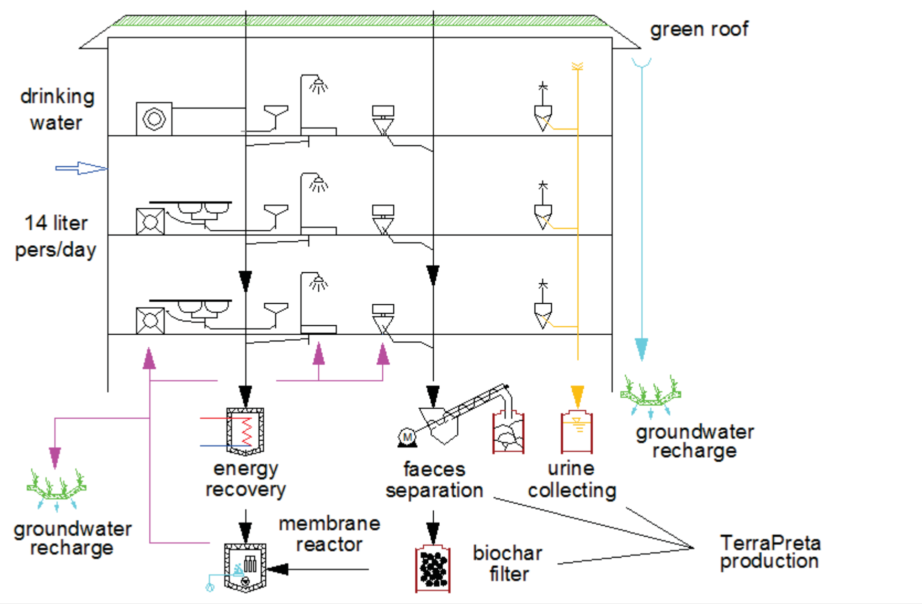

green roof

drinking water

14 liter pers/day

groundwater recharge

energy recovery

faeces separation

urine collecting

groundwater recharge

membrane reactor

biochar filter

TerraPreta production

TerraPreta sanitation

HATI GmbH

10.01.2013

Thanks for your attention

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Session 3 – Rainwater, Domestic Wastewater, Energy and Nutrient Aspects

3.4 Resource management Terra Preta-Technology

Nadine König, Botanical Garden Berlin

New challenges of ressource management in the Botanic Garden Berlin by using the Terra Preta- technology

TerraBoGa

Prof. Dr. Konstantin Terytze,
Dr. Robert Wagner, René Schatten,
Nadine König, Kathrin Rößler,
Karin Friede, Dr. Ines Vogel

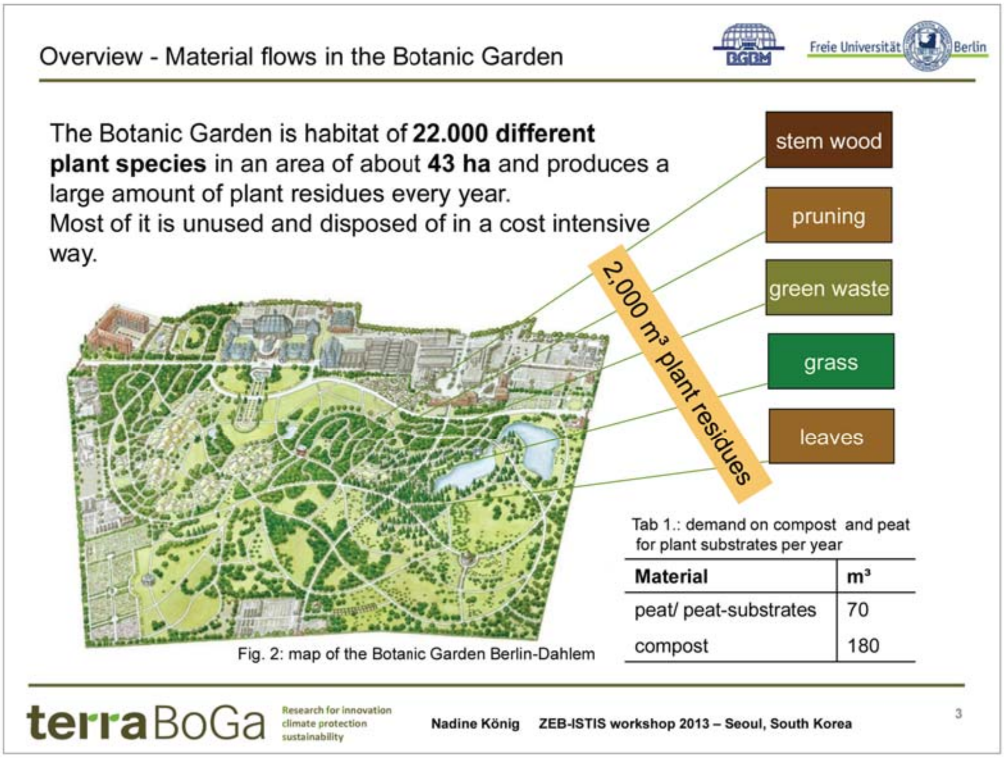
Freie Universität Berlin
Botanic Garden Berlin-Dahlem

ZEB-ISTIS workshop 2013 – Seoul, South Korea

Overview – The Botanic Garden Berlin-Dahlem

The Botanic Garden is located in the southwest of Berlin.

Fig. 1: map of the Botanic Garden Berlin-Dahlem



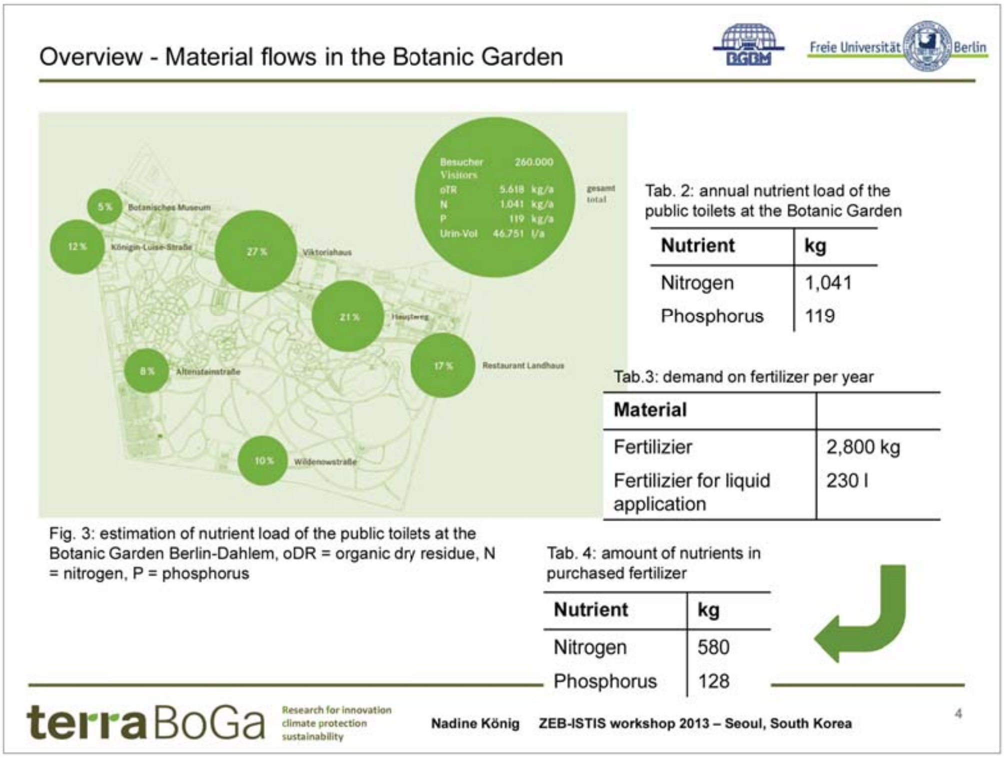
Overview - Material flows in the Botanic Garden

The Botanic Garden is habitat of **22.000 different plant species** in an area of about **43 ha** and produces a large amount of plant residues every year.
Most of it is unused and disposed of in a cost intensive way.

Fig. 2: map of the Botanic Garden Berlin-Dahlem

Tab 1.: demand on compost and peat for plant substrates per year

Material	m³
peat/ peat-substrates	70
compost	180



Overview - Material flows in the Botanic Garden

Fig. 3: estimation of nutrient load of the public toilets at the Botanic Garden Berlin-Dahlem, oDR = organic dry residue, N = nitrogen, P = phosphorus

Tab. 2: annual nutrient load of the public toilets at the Botanic Garden

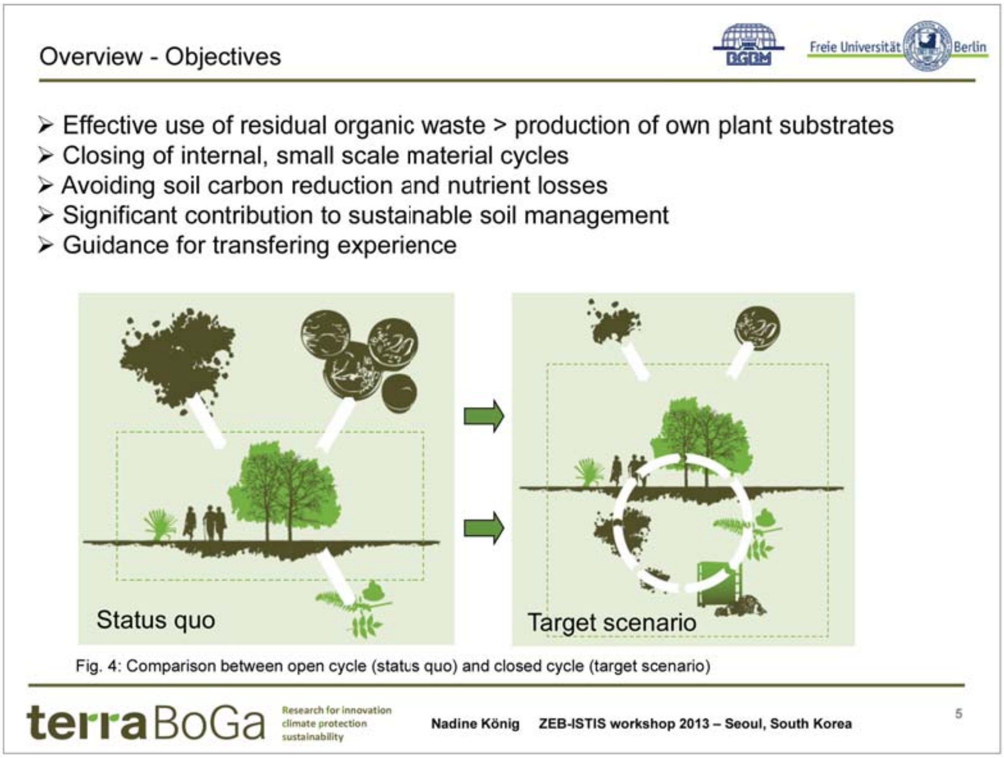
Nutrient	kg
Nitrogen	1,041
Phosphorus	119

Tab.3: demand on fertilizer per year

Material	
Fertilizier	2,800 kg
Fertilizier for liquid application	230 l

Tab. 4: amount of nutrients in purchased fertilizer

Nutrient	kg
Nitrogen	580
Phosphorus	128



Overview - Objectives

BGBM Freie Universität Berlin

- Effective use of residual organic waste > production of own plant substrates
- Closing of internal, small scale material cycles
- Avoiding soil carbon reduction and nutrient losses
- Significant contribution to sustainable soil management
- Guidance for transfering experience

Fig. 4: Comparison between open cycle (status quo) and closed cycle (target scenario)

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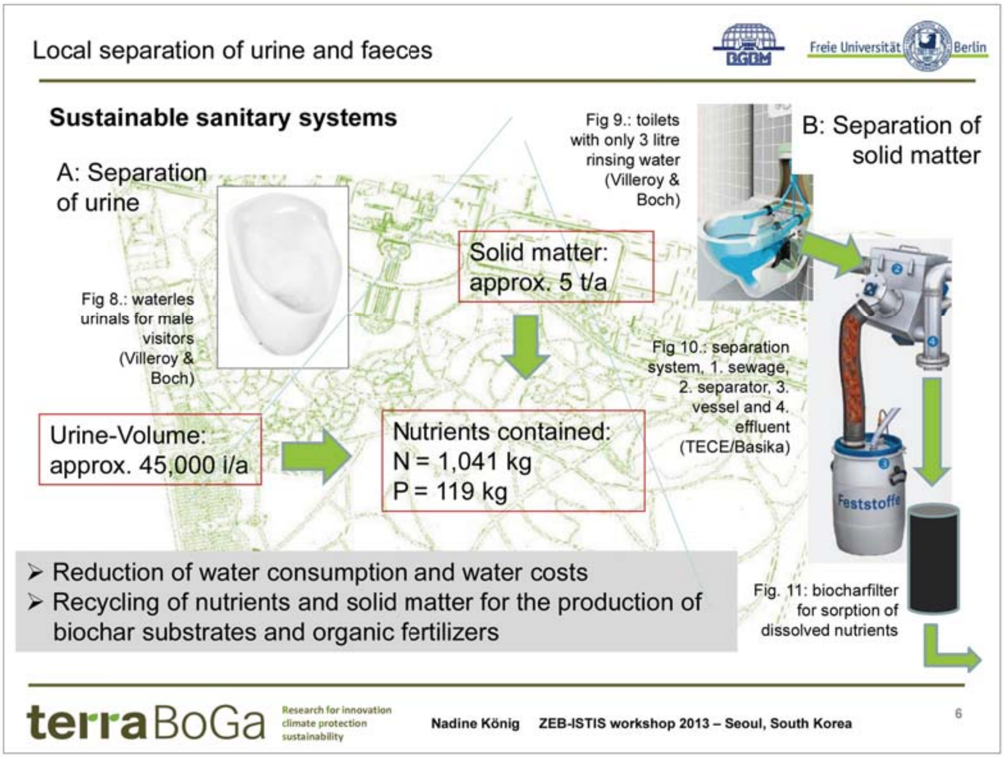

Local separation of urine and faeces

BGBM Freie Universität Berlin

Sustainable sanitary systems

A: Separation of urine

Fig 8.: waterles urinals for male visitors (Villeroy & Boch)

Urine-Volume: approx. 45,000 l/a

Fig 9.: toilets with only 3 litre rinsing water (Villeroy & Boch)

B: Separation of solid matter

Solid matter: approx. 5 t/a

Nutrients contained:
N = 1,041 kg
P = 119 kg

Fig 10.: separation system, 1. sewage, 2. separator, 3. vessel and 4. effluent (TECE/Basika)

- Reduction of water consumption and water costs
- Recycling of nutrients and solid matter for the production of biochar substrates and organic fertilizers

Fig. 11: biocharfilter for sorption of dissolved nutrients

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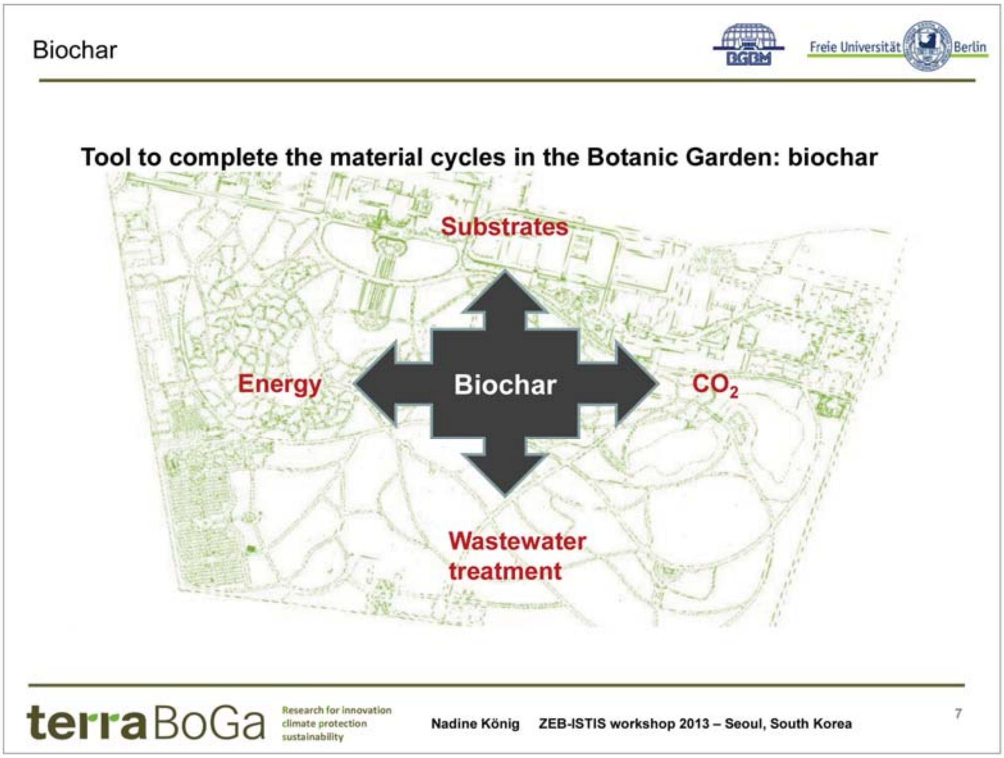

Biochar

Tool to complete the material cycles in the Botanic Garden: biochar

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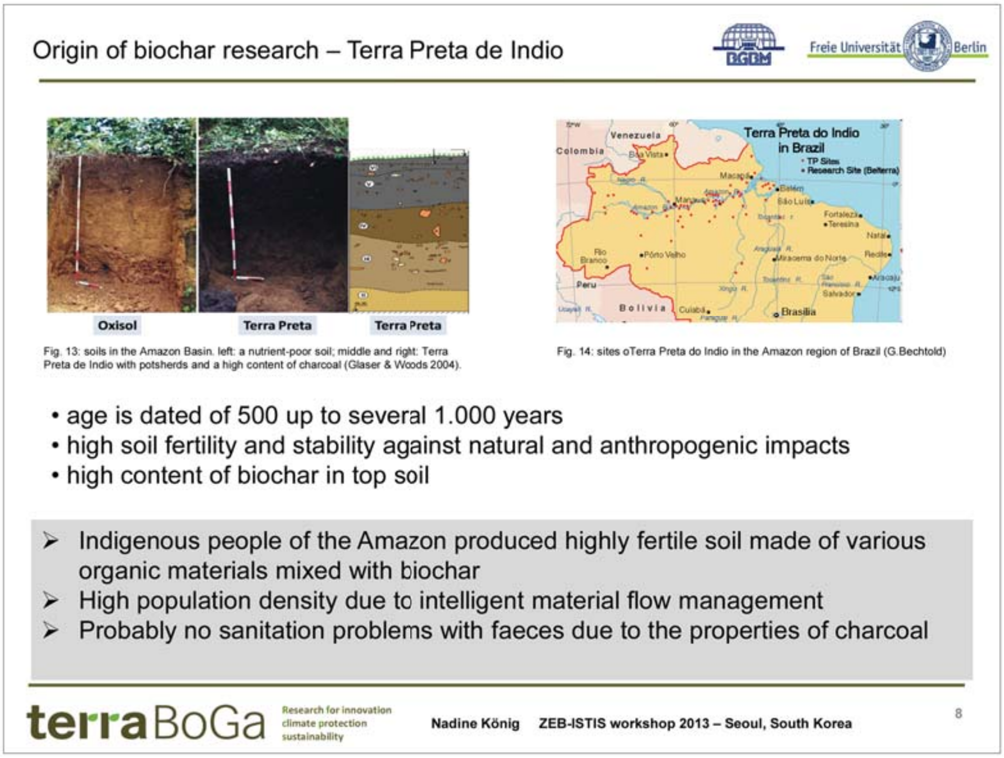

Origin of biochar research – Terra Preta de Indio

Fig. 13: soils in the Amazon Basin. left: a nutrient-poor soil; middle and right: Terra Preta de Indio with potsherds and a high content of charcoal (Glaser & Woods 2004).

Fig. 14: sites oTerra Preta do Indio in the Amazon region of Brazil (G.Bechtold)

- age is dated of 500 up to several 1.000 years
- high soil fertility and stability against natural and anthropogenic impacts
- high content of biochar in top soil

- ➢ Indigenous people of the Amazon produced highly fertile soil made of various organic materials mixed with biochar
- ➢ High population density due to intelligent material flow management
- ➢ Probably no sanitation problems with faeces due to the properties of charcoal

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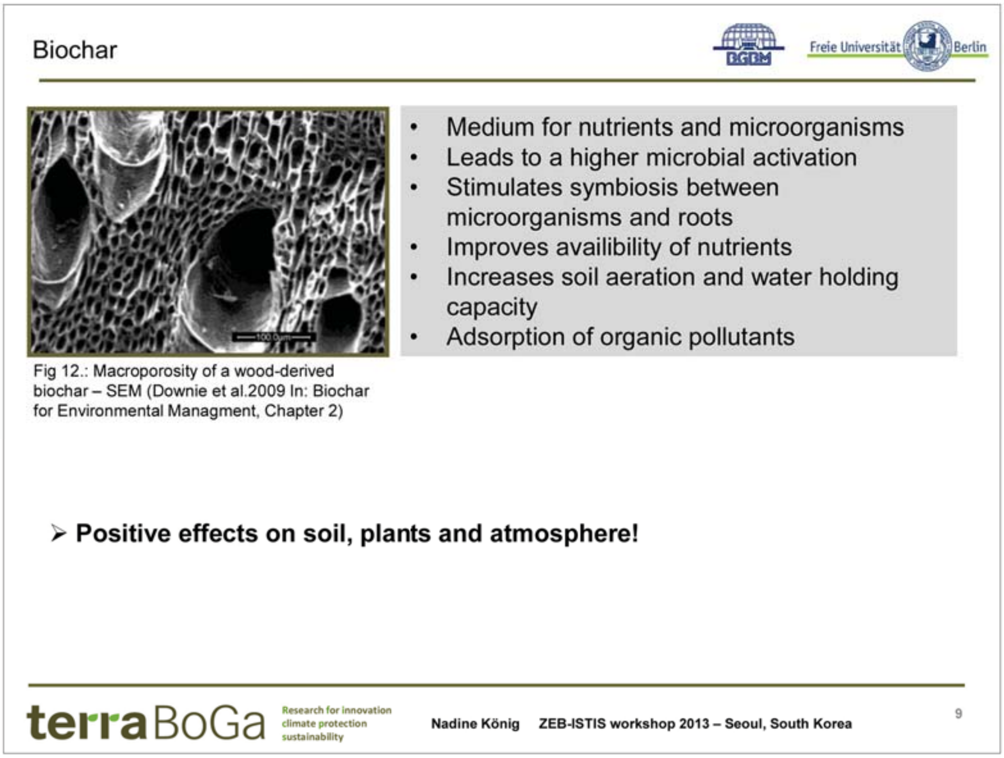
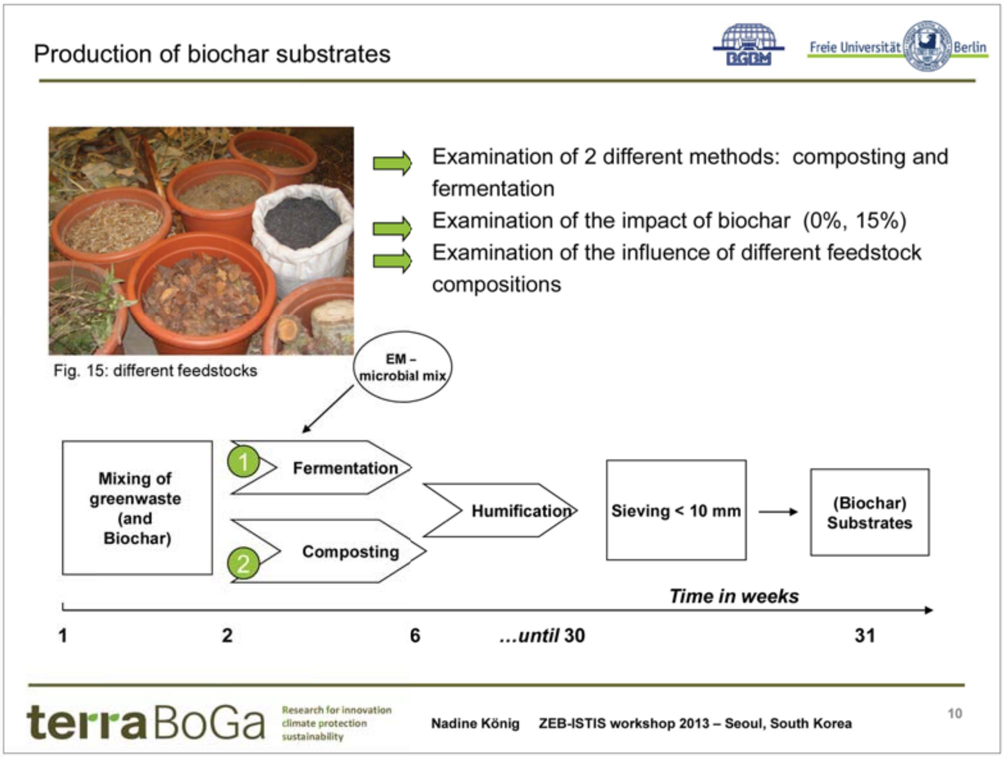


Biochar

Fig 12.: Macroporosity of a wood-derived biochar – SEM (Downie et al.2009 In: Biochar for Environmental Managment, Chapter 2)

- Medium for nutrients and microorganisms
- Leads to a higher microbial activation
- Stimulates symbiosis between microorganisms and roots
- Improves availibility of nutrients
- Increases soil aeration and water holding capacity
- Adsorption of organic pollutants

➢ **Positive effects on soil, plants and atmosphere!**



Production of biochar substrates

Fig. 15: different feedstocks

- Examination of 2 different methods: composting and fermentation
- Examination of the impact of biochar (0%, 15%)
- Examination of the influence of different feedstock compositions

EM – microbial mix

Mixing of greenwaste (and Biochar)

① **Fermentation**

② **Composting**

Humification

Sieving < 10 mm

(Biochar) Substrates

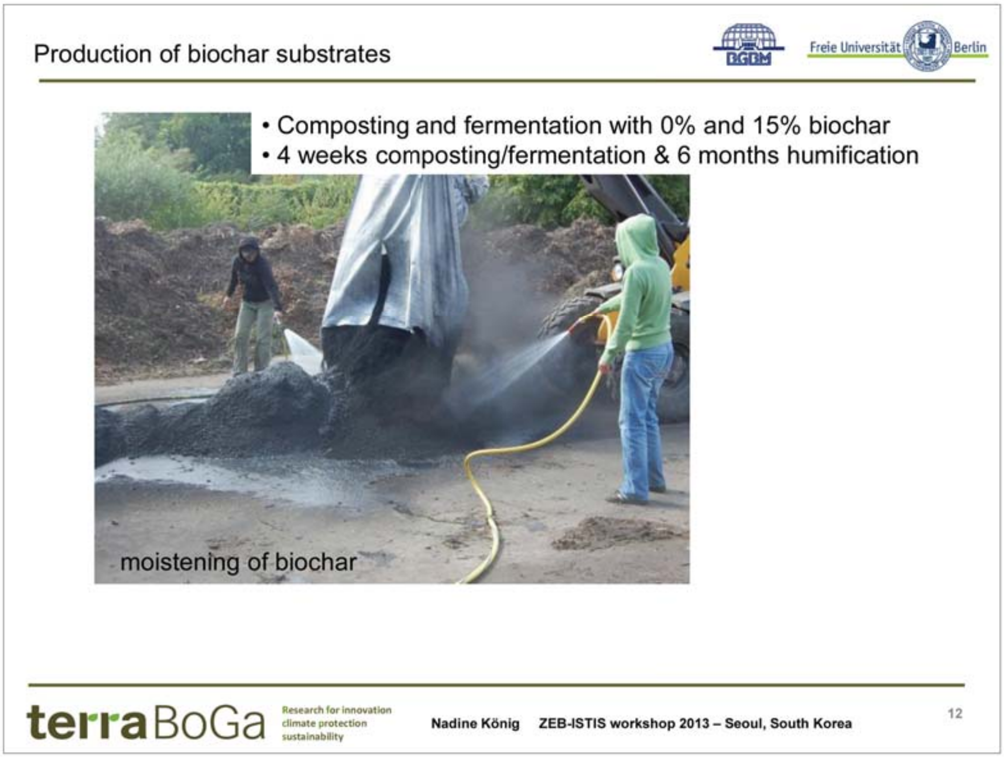
Time in weeks

1 **2** **6** ***...until* 30** **31**

Production of biochar substrates

- Composting and fermentation with 0% and 15% biochar
- 4 weeks composting/fermentation & 6 months humification

shredding of green waste



Production of biochar substrates

- Composting and fermentation with 0% and 15% biochar
- 4 weeks composting/fermentation & 6 months humification

moistening of biochar

Production of biochar substrates

BGBM Freie Universität Berlin

- Composting and fermentation with 0% and 15% biochar
- 4 weeks composting/fermentation & 6 months humification

Mixing and homogenisation

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Production of biochar substrates

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- Composting and fermentation with 0% and 15% biochar
- 4 weeks composting/fermentation & 6 months humification

Moistening with a lactic acid solution (EM)

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Production of biochar substrates

- Composting and fermentation with 0% and 15% biochar
- 4 weeks composting/fermentation & 6 months humification

Compacting the fermentation heap

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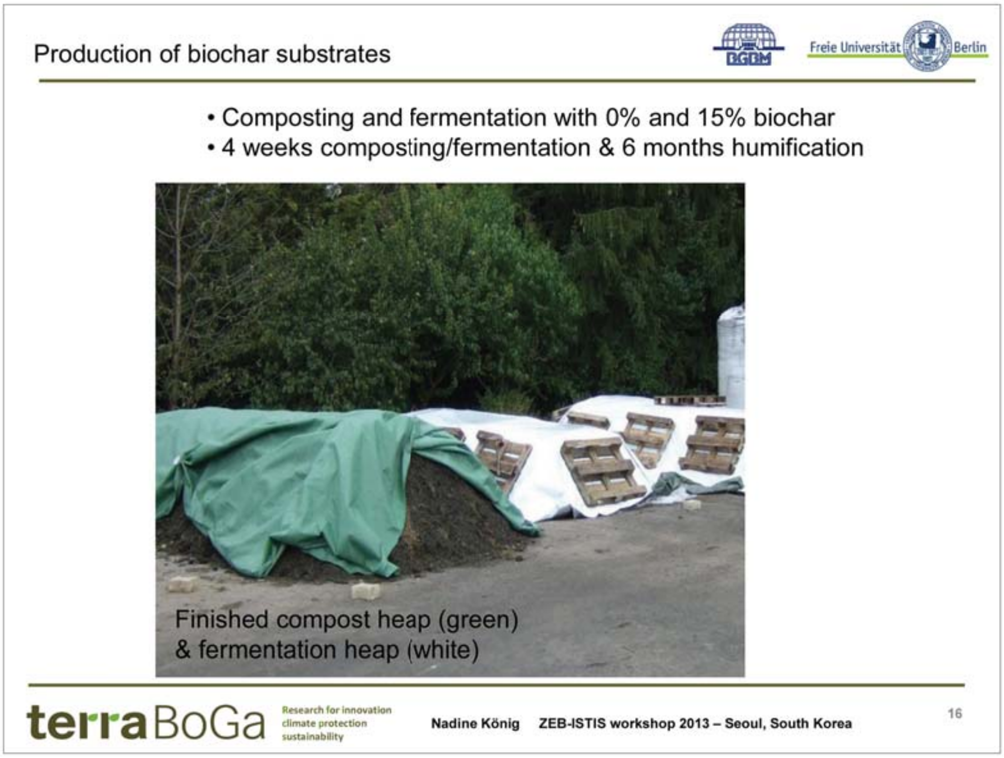

Production of biochar substrates

- Composting and fermentation with 0% and 15% biochar
- 4 weeks composting/fermentation & 6 months humification

Finished compost heap (green)
& fermentation heap (white)

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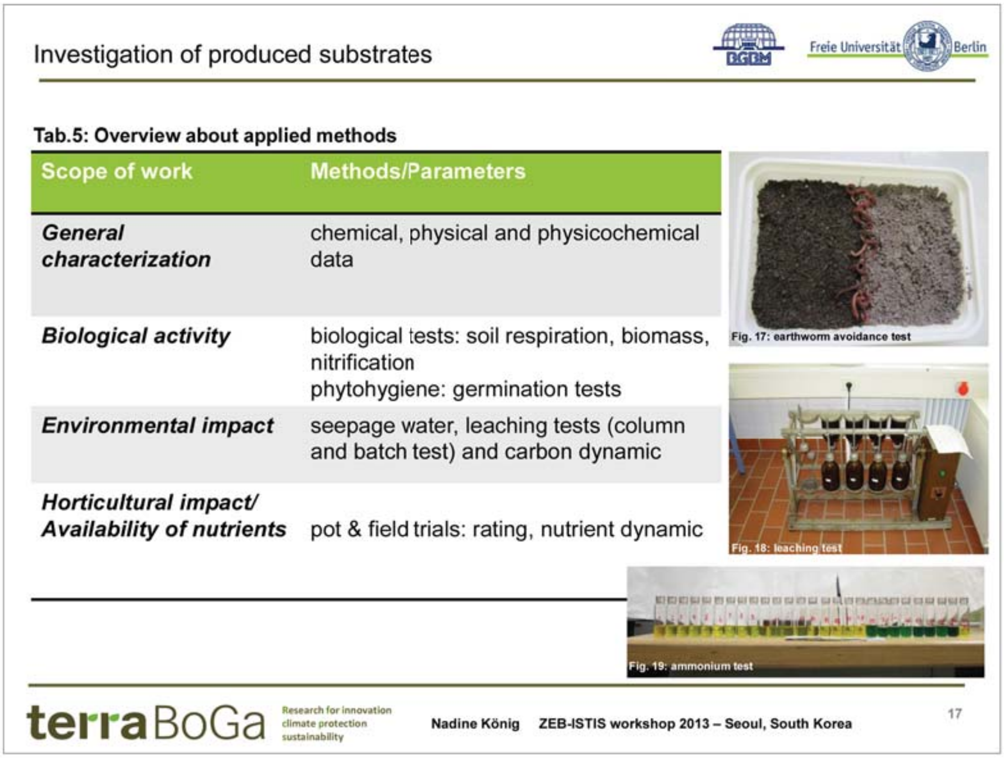


Investigation of produced substrates

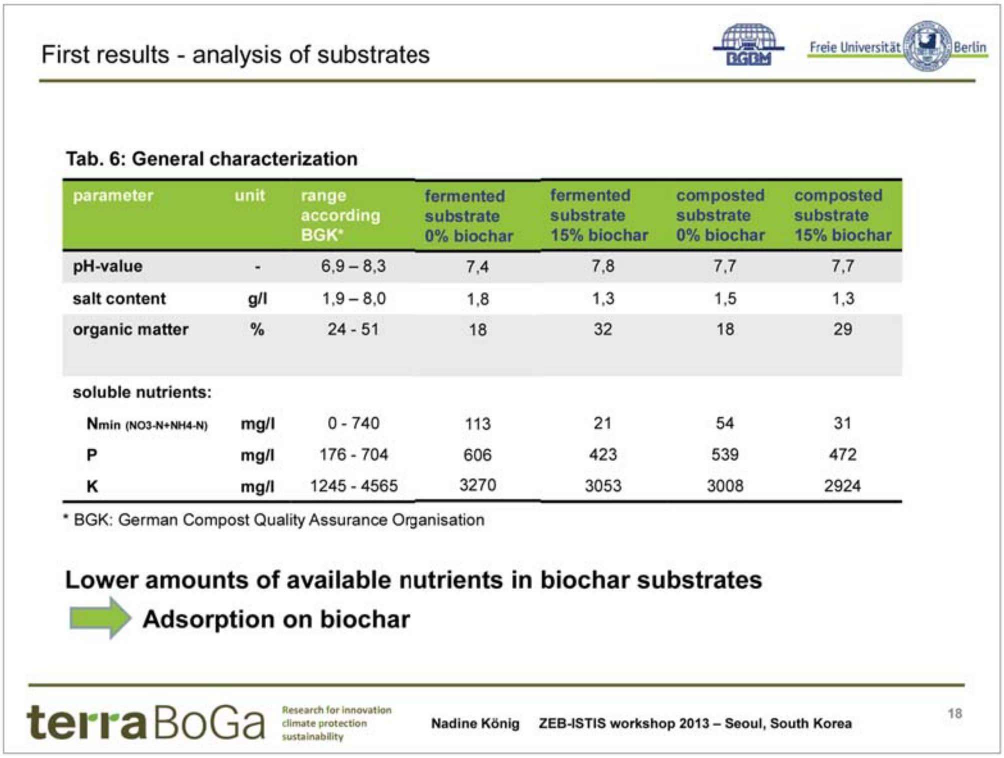
Tab.5: Overview about applied methods

Scope of work	Methods/Parameters
General characterization	chemical, physical and physicochemical data
Biological activity	biological tests: soil respiration, biomass, nitrification phytohygiene: germination tests
Environmental impact	seepage water, leaching tests (column and batch test) and carbon dynamic
Horticultural impact/ Availability of nutrients	pot & field trials: rating, nutrient dynamic

Fig. 17: earthworm avoidance test

Fig. 18: leaching test

Fig. 19: ammonium test



First results - analysis of substrates

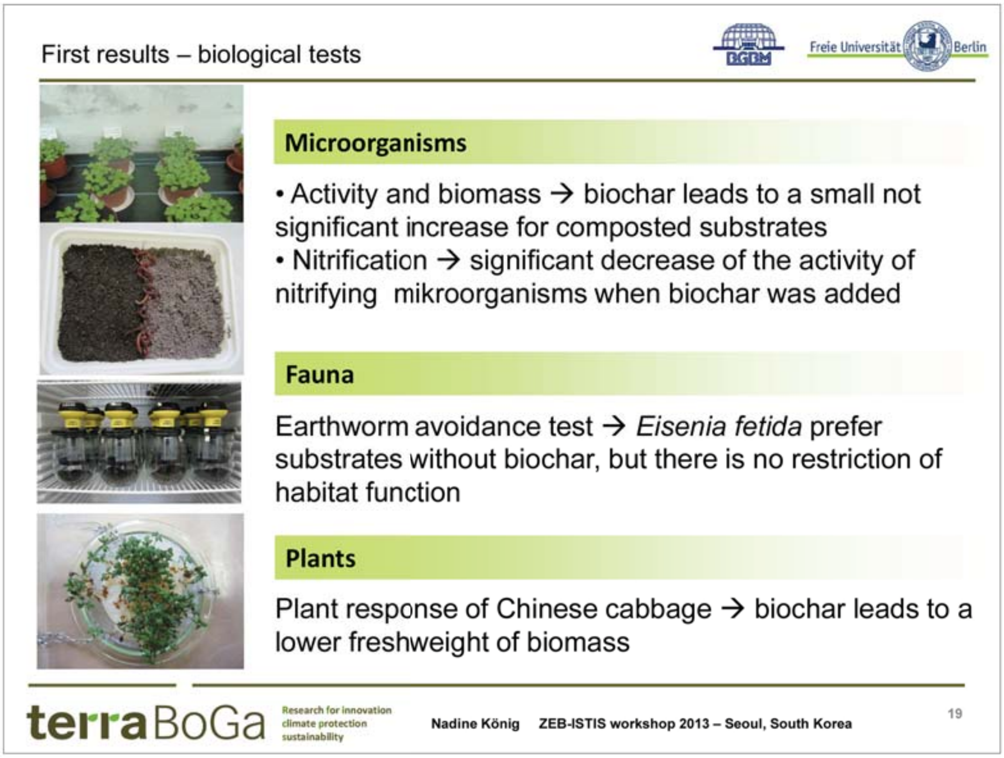
Tab. 6: General characterization

parameter	unit	range according BGK*	fermented substrate 0% biochar	fermented substrate 15% biochar	composted substrate 0% biochar	composted substrate 15% biochar
pH-value	-	6,9 – 8,3	7,4	7,8	7,7	7,7
salt content	g/l	1,9 – 8,0	1,8	1,3	1,5	1,3
organic matter	%	24 - 51	18	32	18	29
soluble nutrients:						
N_{min} (NO3-N+NH4-N)	mg/l	0 - 740	113	21	54	31
P	mg/l	176 - 704	606	423	539	472
K	mg/l	1245 - 4565	3270	3053	3008	2924

* BGK: German Compost Quality Assurance Organisation

Lower amounts of available nutrients in biochar substrates

➡ **Adsorption on biochar**



First results – biological tests

Microorganisms

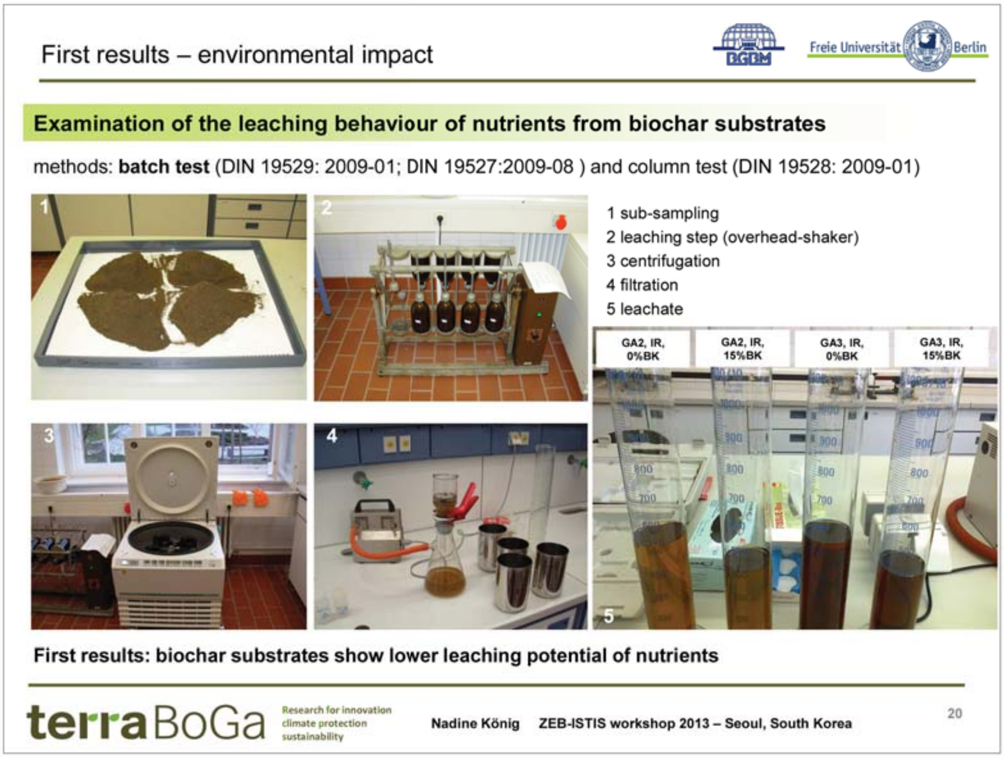
- Activity and biomass → biochar leads to a small not significant increase for composted substrates
- Nitrification → significant decrease of the activity of nitrifying mikroorganisms when biochar was added

Fauna

Earthworm avoidance test → *Eisenia fetida* prefer substrates without biochar, but there is no restriction of habitat function

Plants

Plant response of Chinese cabbage → biochar leads to a lower freshweight of biomass



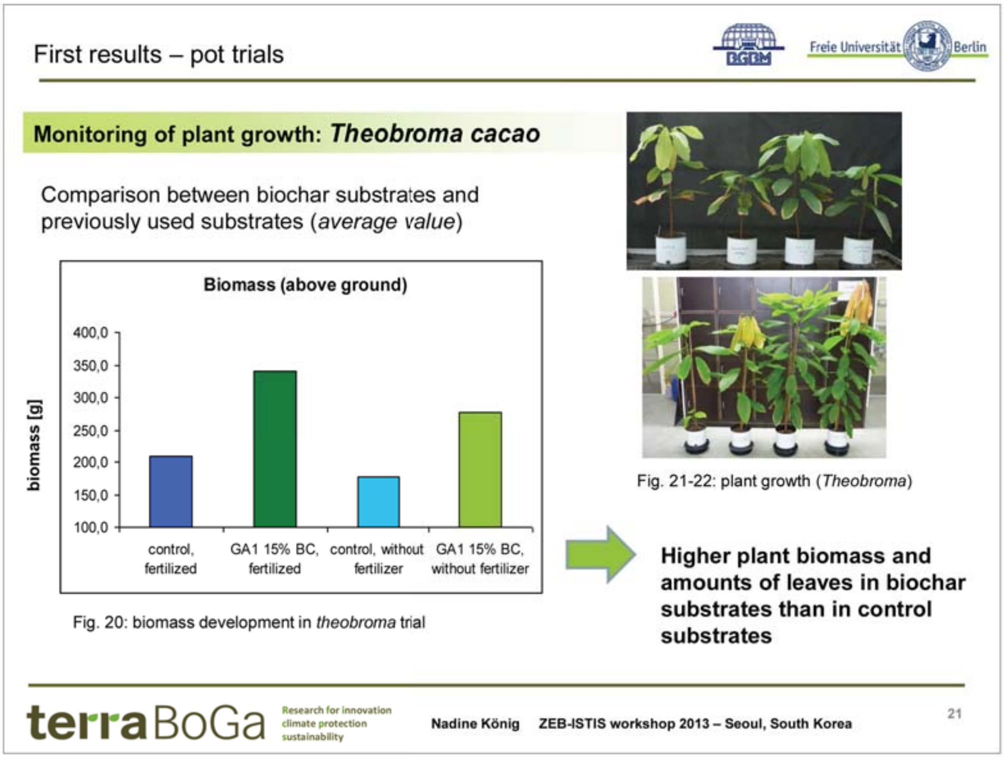
First results – environmental impact

Examination of the leaching behaviour of nutrients from biochar substrates

methods: **batch test** (DIN 19529: 2009-01; DIN 19527:2009-08) and column test (DIN 19528: 2009-01)

1 sub-sampling
2 leaching step (overhead-shaker)
3 centrifugation
4 filtration
5 leachate

First results: biochar substrates show lower leaching potential of nutrients



First results – pot trials

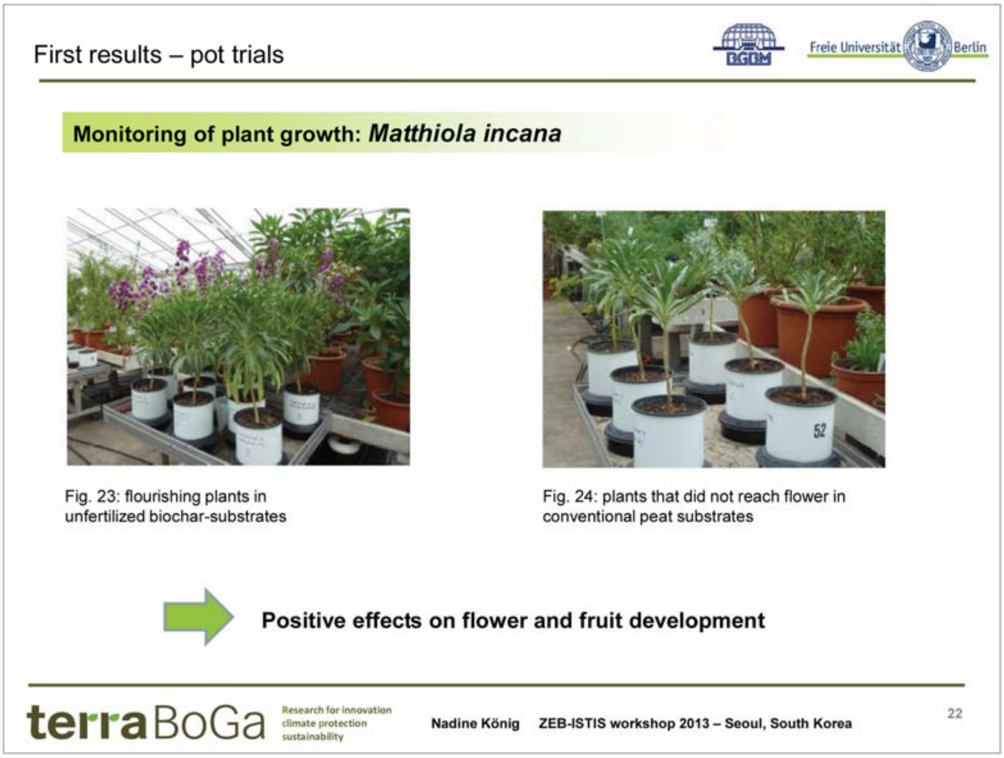
Monitoring of plant growth: *Theobroma cacao*

Comparison between biochar substrates and previously used substrates (*average value*)

Fig. 20: biomass development in *theobroma* trial

Fig. 21-22: plant growth (*Theobroma*)

Higher plant biomass and amounts of leaves in biochar substrates than in control substrates



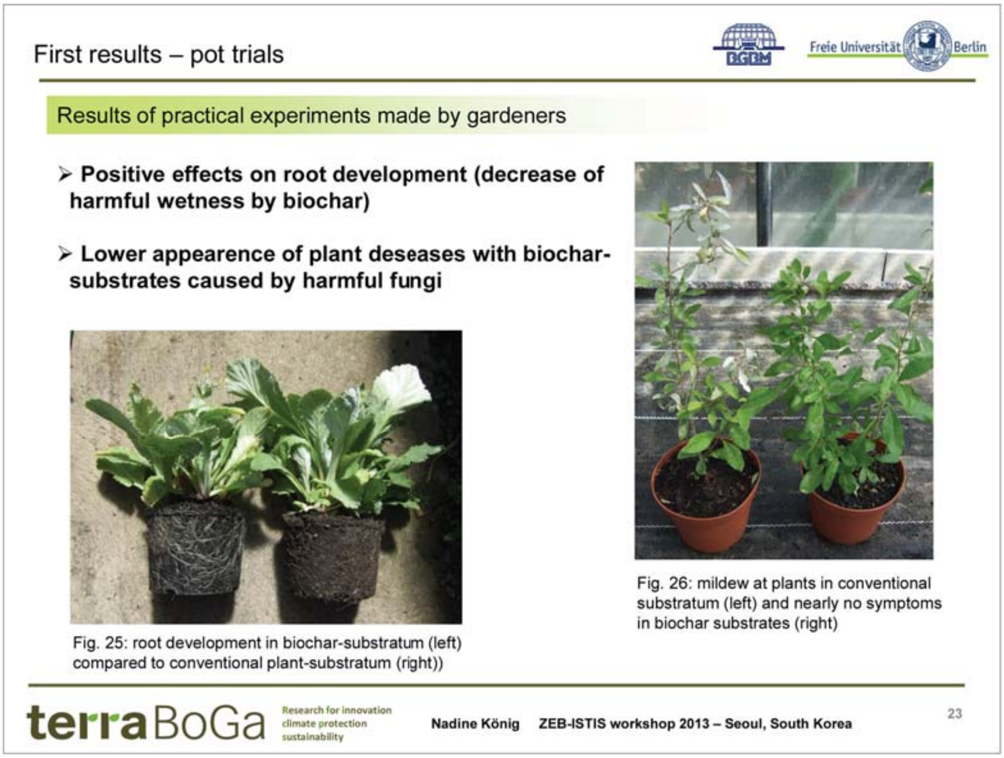
First results – pot trials

Monitoring of plant growth: *Matthiola incana*

Fig. 23: flourishing plants in unfertilized biochar-substrates

Fig. 24: plants that did not reach flower in conventional peat substrates

Positive effects on flower and fruit development



First results – pot trials

Results of practical experiments made by gardeners

- ➢ **Positive effects on root development (decrease of harmful wetness by biochar)**
- ➢ **Lower appearence of plant deseases with biochar-substrates caused by harmful fungi**

Fig. 25: root development in biochar-substratum (left) compared to conventional plant-substratum (right))

Fig. 26: mildew at plants in conventional substratum (left) and nearly no symptoms in biochar substrates (right)

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First results of outdoor experiments

Application of biochar substrates in show- and experimental garden

Fig. 29: starting with fallow ground

Fig. 30: first flower beds in spring 2012

Fig. 31: trial parcels with potatoes and strawberries

➢ **No visible effects with biochar application in field trials in the first year (known: long-term effects!)**

Fig. 32: trial parcels with zucchinis

Fig. 33: full bloom during summer 2012

Fig. 34: view of show- and experimental garden

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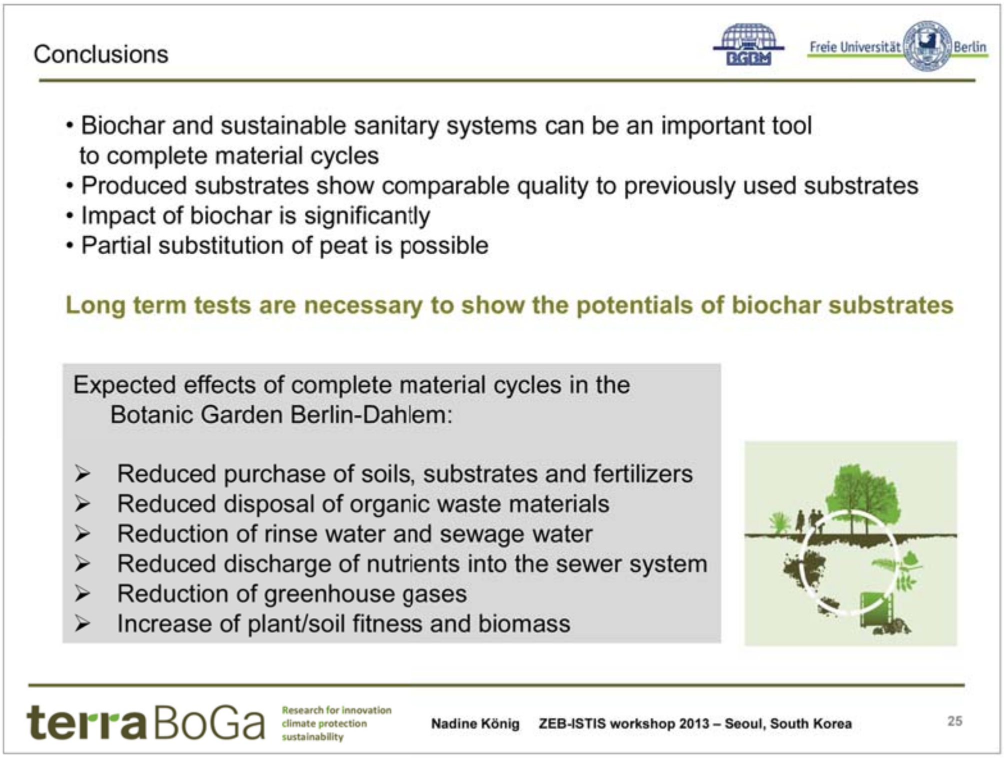

Conclusions

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- Biochar and sustainable sanitary systems can be an important tool to complete material cycles
- Produced substrates show comparable quality to previously used substrates
- Impact of biochar is significantly
- Partial substitution of peat is possible

Long term tests are necessary to show the potentials of biochar substrates

Expected effects of complete material cycles in the Botanic Garden Berlin-Dahlem:

- ➢ Reduced purchase of soils, substrates and fertilizers
- ➢ Reduced disposal of organic waste materials
- ➢ Reduction of rinse water and sewage water
- ➢ Reduced discharge of nutrients into the sewer system
- ➢ Reduction of greenhouse gases
- ➢ Increase of plant/soil fitness and biomass

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Polaterra HATI

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