Intra-Urban Water Reuse – Case Studies

Closing urban water cycles – transforming urban water solutions

***Wednesday 29 August** | 16.00-17.30 | Room: FH Congress Hall A*

Dr. Peter Cornel, Prof. Emeritus

TU Darmstadt, Institute IWAR, Wastewater Technology and Water Reuse

Conclusions

TECHNISCHE UNIVERSITÄT DARMSTADT

„Cities of the Future“ will differ from those of yesterday and today

Water and Sanitation Infrastructure will be diverse

Water reuse will be a key element of urban water solutions

Wastewater is a resource, not a waste

Major challenges

	1950 → 2025	
1. World Population Growth	2.5 → 8.0	Billion people
2. Urbanization	30% → 60%	
	0.75 → 4.8	Billion people

3. Dynamic of urban growth

- Delhi, Shanghai, Beijing, Dhaka and Lagos grow by more than 500,000 people /year

4. Limited Resources

- Water
- Energy
- Nutrients

Shanghai 1990

Shanghai 2010

United Nations 2011, World Urbanization Prospects ; United Nations 2012: World Popu
Burdett & Rode 2007, The Speed of Urban Change

From challenges to demand

TECHNISCHE UNIVERSITÄT DARMSTADT

Components of urban water management

- **High flexibility and adaptability**
  - a system being able to react to changes in development-reality
  - „growing" system for growing cities

- **Resource recovery**
  - water reuse
  - energy recovery and transfer (heat, biogas, power, ..)
  - Nutrients recovery

- **Integrated treatment** (water, used water, solid waste)

- Water conservation
- Stormwater management

3 case studies

TECHNISCHE UNIVERSITÄT DARMSTADT

1. Semizentral Qingdao / China

- Fast growing megacity
- Separated grey and blackwater treatment
- Water reuse up to 140%
- Integrated waste treatment → Energetically self sufficient
- Semicentralized

2. Cuve waters Outapi / Namibia

- Informal settlement in fast growing village in arid area
- Sanitation units, vacuum sewer, treatment incl. disinfection and helminth eggs removal, intra-urban agriculture

3. EPoNa Outapi / Namibia

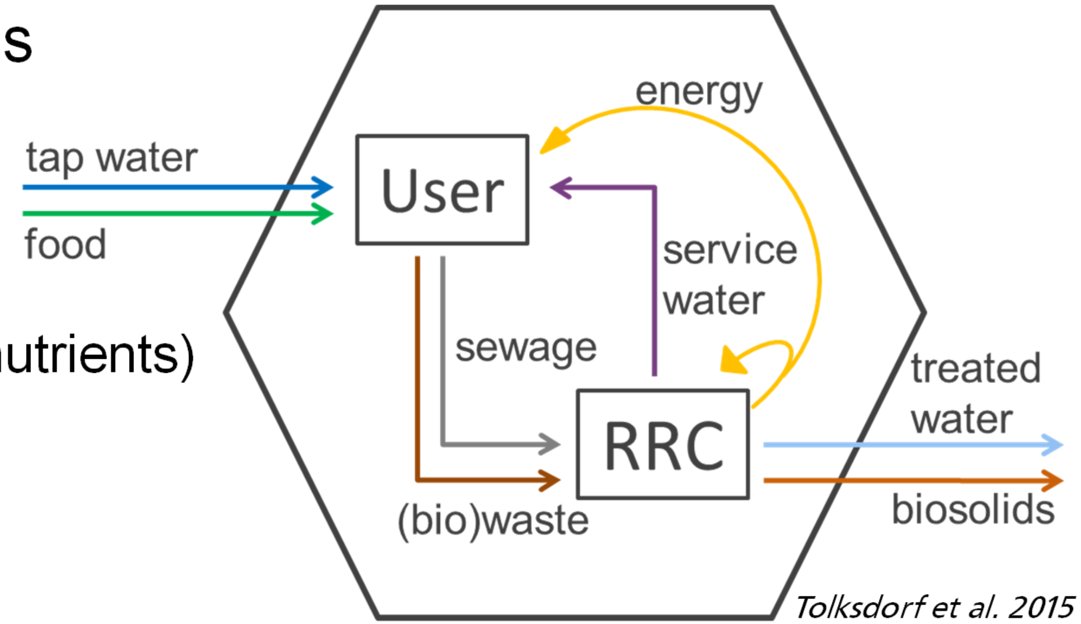
- Enhancement of existing ponds in Outapi Namibia
- Multiplying the capacity by pre-treatment, upgrading and post-treatment
- Production of irrigation water for fodder plants

Idea of „SEMIZENTRAL“
Resource Recovery Center (RRC)

- Waste water as a resource for
  - Water
  - Energy
  - Nutrients

- Products instead of wastes
  - Non-potable service water
  - Irrigation water
  - Biogas/electricity
  - Biosolids (stabilized / rich in nutrients)

- Flexible and adaptable



Tolksdorf et al. 2015

SEMIZENTRAL:
Integrated treatment on district level

- adaptable to growth rate
- flexible
- adjusted
- integrated
  (water, wastewater, waste, energy)
- enclosed construction → low-emission

- „As small as possible, as large as necessary“
- **Infrastructure on demand**

Tolksdorf et al. 2015

Realization in Qingdao, P.R. China

- Emerging metropolis at China's east coast in ShanDong Province
- Limited water resources
- Fast growing population

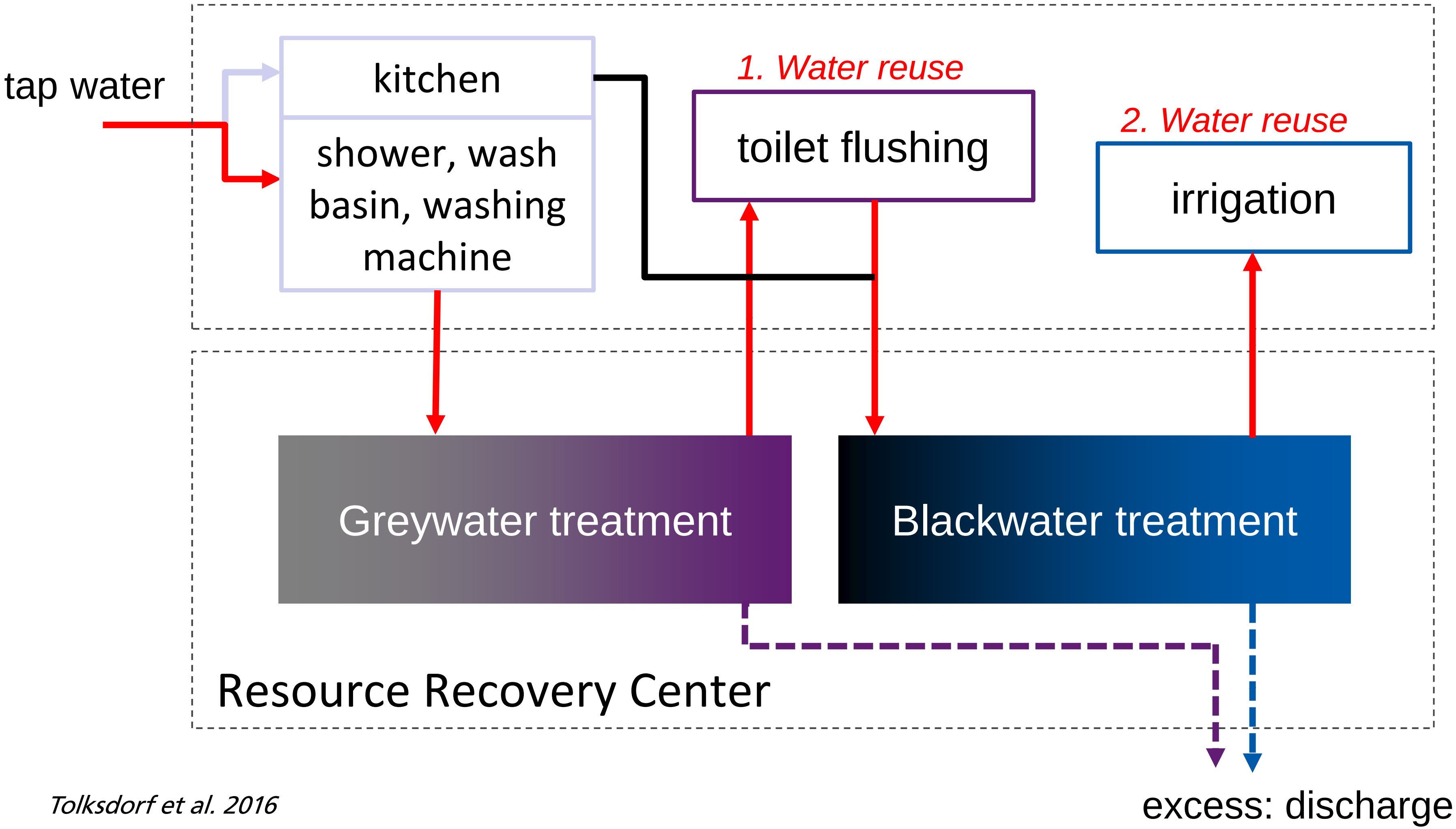
SEMIZENTRAL GERMANY

Comparing energy consumption of different option:

- Seawater Desalination: **3 - 4 kWh/m³**
- intra-urban Water Reuse : **< 1 kWh/m³**

CorbisImages

Double water reuse



Tolksdorf et al. 2016

Semicentralized Resource Recovery Center (RRC) – a modular approach

TECHNISCHE UNIVERSITÄT DARMSTADT

Technical basics

Greywater treatment

- Non-potable service water production with MBR

Blackwater treatment

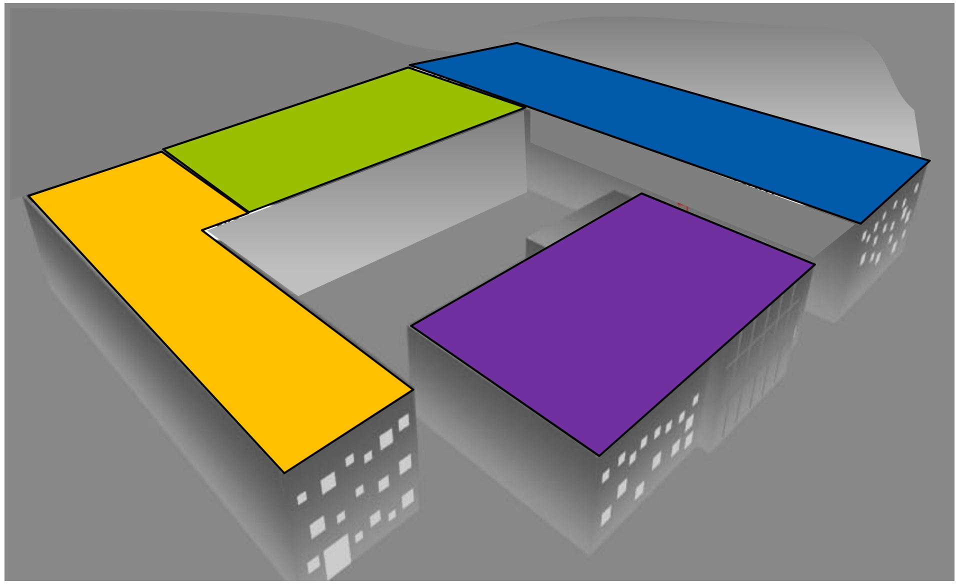
- Irrigation water with MBR

Foodwaste pre-treatment

- Mechanical pre-treatment

Energy-Center

- Anaerobic thermophilic treatment
- Electric energy by CHP station

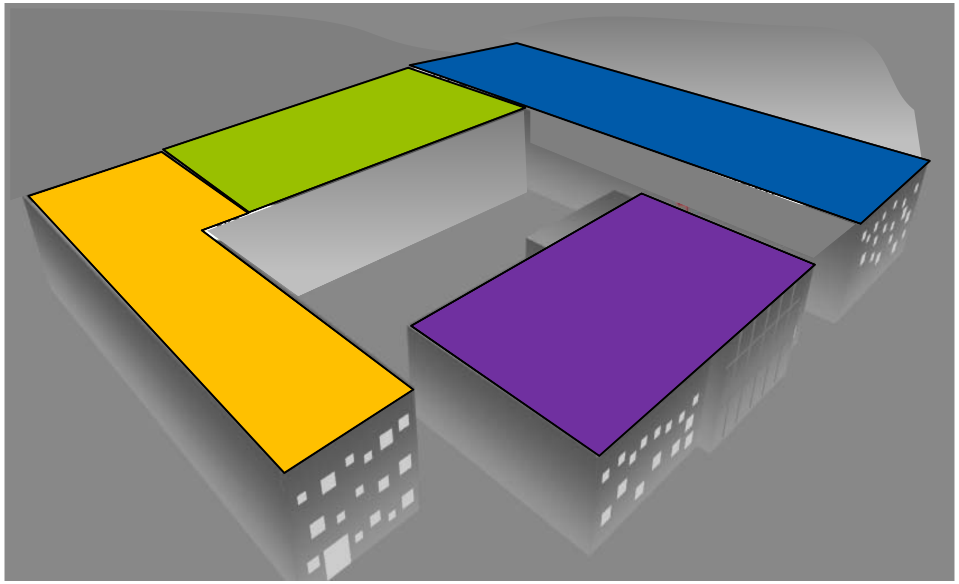


Advantages

On the water side

Water recycling rates between

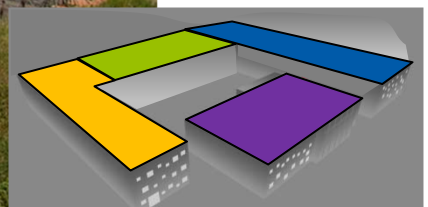
40% (greywater only) and 140% (grey- and blackwater)



On the energy side

Energy self-sufficient operation possible

RRC in Qingdao ShiYuan, 2014



RRC in Qingdao ShiYuan, May 2015

RRC in Qingdao ShiYuan
2017

Service water is sought after

TECHNISCHE UNIVERSITÄT DARMSTADT

IWAR

Take home messages “Semizentral”

1. **(Multiple) water reuse fosters decentralization**

2. **Energy (heat) recovery fosters decentralization**

3. **Fulfilling high quality standards foster professional operation**
   → rather *partly- (semi)-* centralized than *de*-centralized at household level

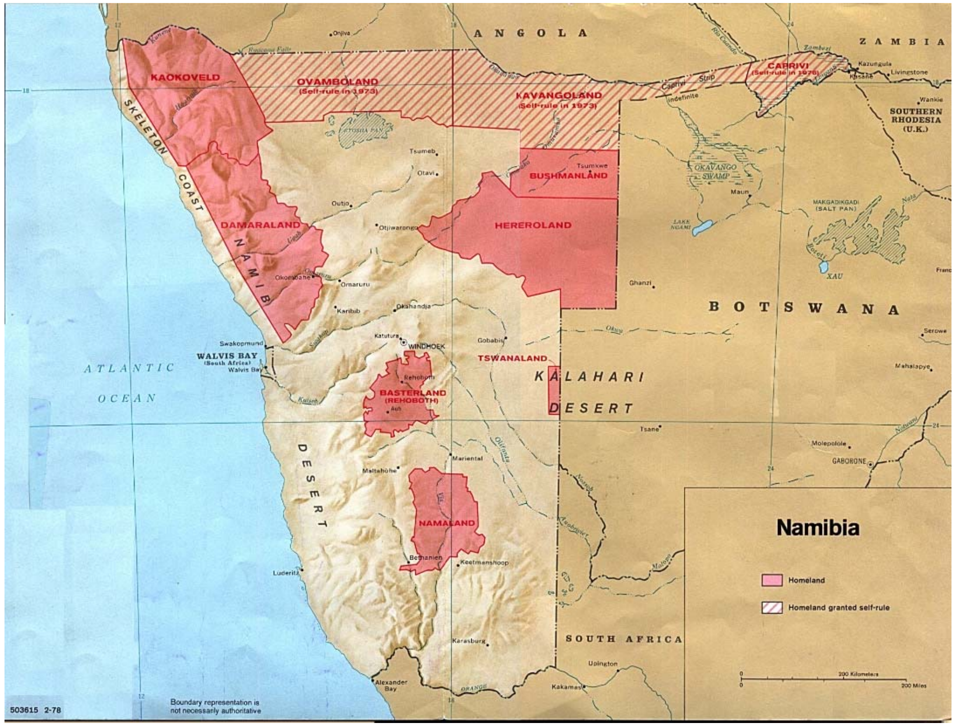
4. **“smaller “ infrastructure is more flexible and reduces vulnerability**
   (natural hazards, terrorism, …)

5. **Energy self-sufficiency fosters combination of different sectors**
   (water supply, wastewater treatment and waste treatment)

3 case studies

1. Semizentral Qingdao / China
   - …..
   - …..
2. **CuveWaters Outapi Namibia**
   - Informal settlement in fast growing village in arid area
   - No receiving water available
   - Flooding during rainy season
   - Sanitation units, vacuum sewer, treatment incl. disinfection and helminth eggs removal, intra-urban agriculture
3. EPoNa Outapi Namibia
   - Enhancement of existing ponds in Outapi Namibia
   - Multiplying the capacity by pre-treatment, upgrading and post-treatment
   - Production of irrigation water for fodder plants

Namibia



ANGOLA
ZAMBIA
KAOKOVELD
OVAMBOLAND
(Self-rule in 1973)
KAVANGOLAND
(Self-rule in 1973)
CAPRIVI
SOUTHERN RHODESIA (U.K.)
BUSHMANLAND
HEREROLAND
DAMARALAND
SKELETON COAST
NAMIB
BOTSWANA
WALVIS BAY
WINDHOEK
TSWANALAND
ATLANTIC OCEAN
KALAHARI DESERT
BASTERLAND (REHOBOTH)
DESERT
NAMALAND
SOUTH AFRICA
Namibia
Homeland
Homeland granted self-rule
Boundary representation is not necessarily authoritative
503615 2-78

Introduction – framework conditions in Outapi

TECHNISCHE UNIVERSITÄT DARMSTADT

Dynamic development of urban settlements

→ sanitation system needs to be flexible

→ connection of additional households should be possible

*Project area in Outapi **2008***
(google earth 2008)

*Project area in Outapi **2015***
(google earth 2015)

Improved Sanitation ?

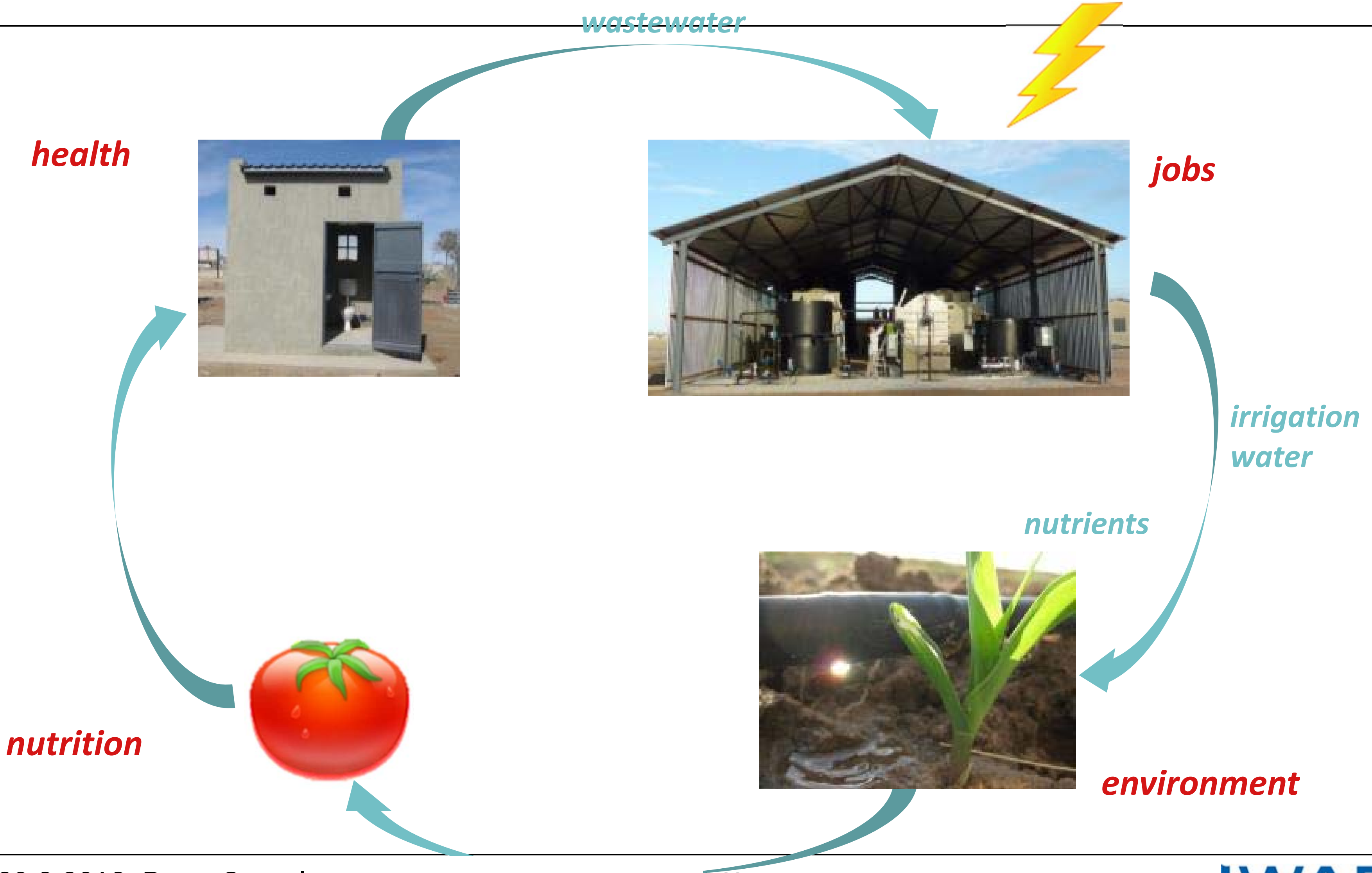
Participation

„Community health clubs"

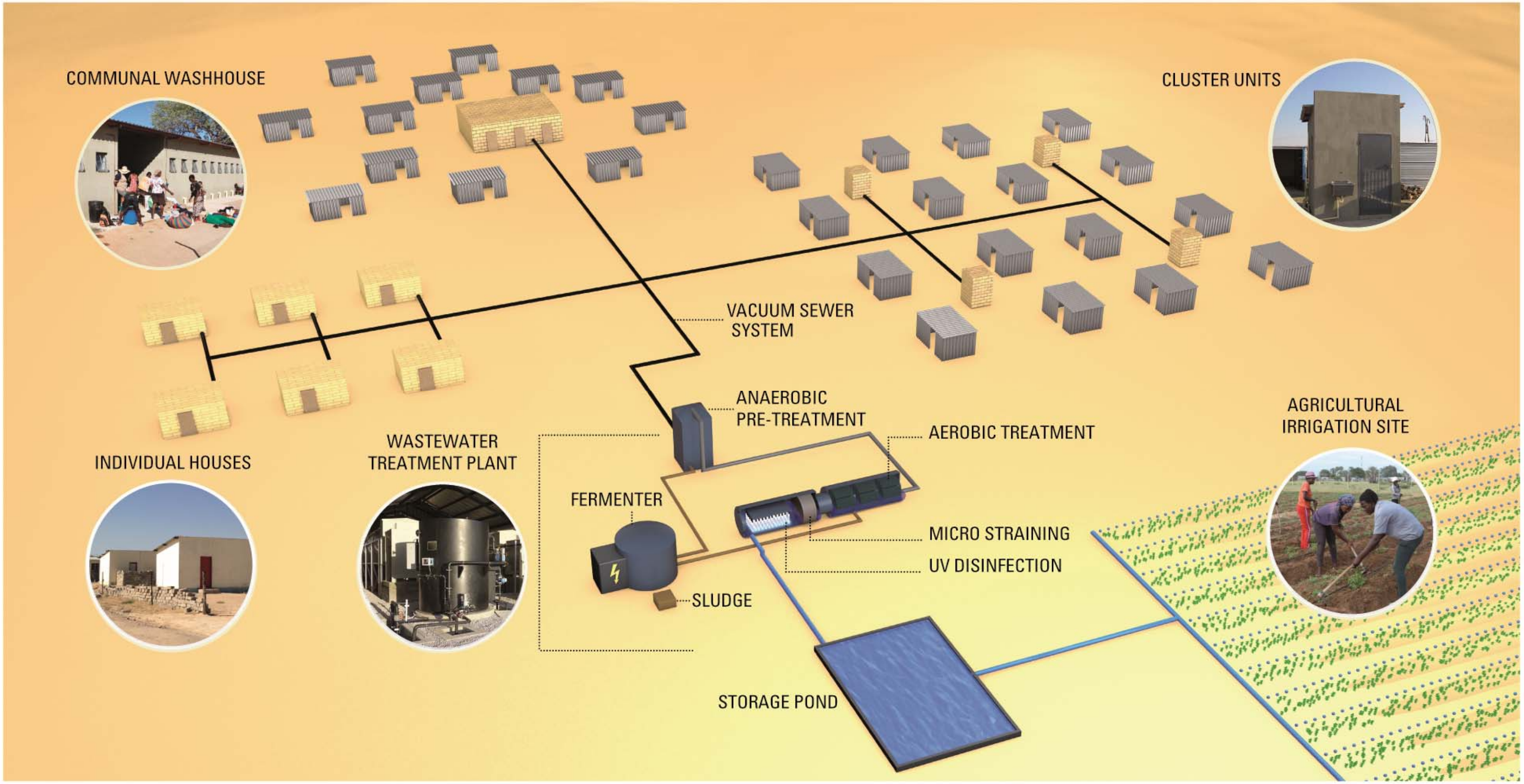
Outapi Town Council

IWAR

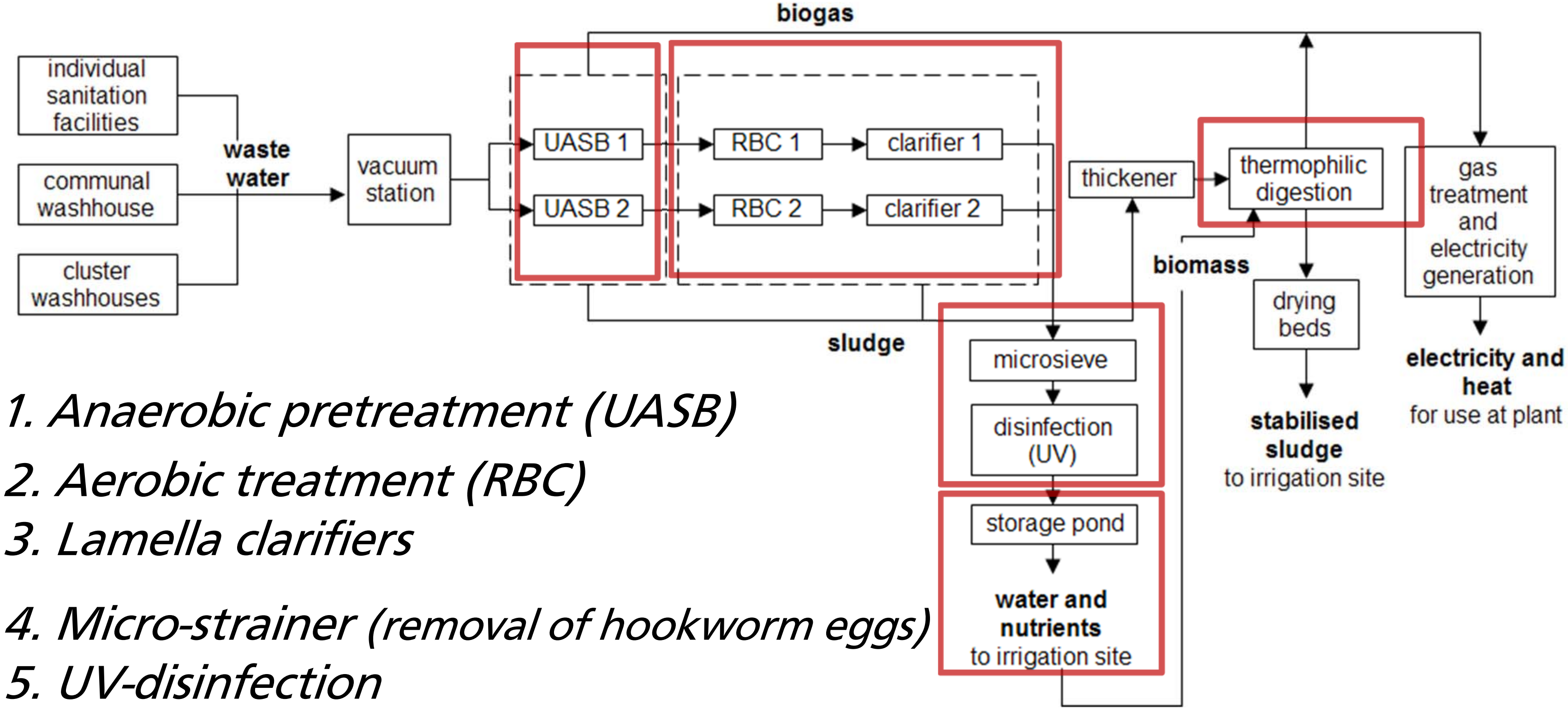
Implementation: Goal



Implementation



Treatment steps



1. Anaerobic pretreatment (UASB)

2. Aerobic treatment (RBC)

3. Lamella clarifiers

4. Micro-strainer (removal of hookworm eggs)

5. UV-disinfection

6. Storage pond

7. Irrigation site

8. Fermenter

Results – Effluent Water Quality

TECHNISCHE UNIVERSITÄT DARMSTADT

- *Average values for the monitoring period June'14 – June'15*

Capacity: 90 m³/d!!!	Influent (actual)	Effluent	Removal Efficiency
Q [m³/d]	30 – 50[1]		
COD_{tot} [mg/L]	742	56	92%
BOD_5 [mg/L]	236	6	97%
TS [mg/L]	781	383	51%
EC [µS/cm]	617	527	-
TN [mg/L]	58	34	-
TP [mg/L]	10	8	-
E.Coli [MPN/100 mL]	$17 \cdot 10^6$	34	7 [illegible]

(1) [illegible] tariff

Fit for purpose!!!

IWAR

Multi-barrier Approach

Approximate concentrations per 1 Liter of water		**E.coli**	**Rotavirus**	**Hookworm eggs**
	Sanitation facilities	100,000,000	500,000	Up to 3‘000
	Treatment Plant	*200*	10^{-3}	1 – 770[1]
	Storage Pond	70	-	None detected
	Drip Irrigation	2	10^{-5}	*None detected*
	Fruits	0.02	10^{-7}	*None detected*

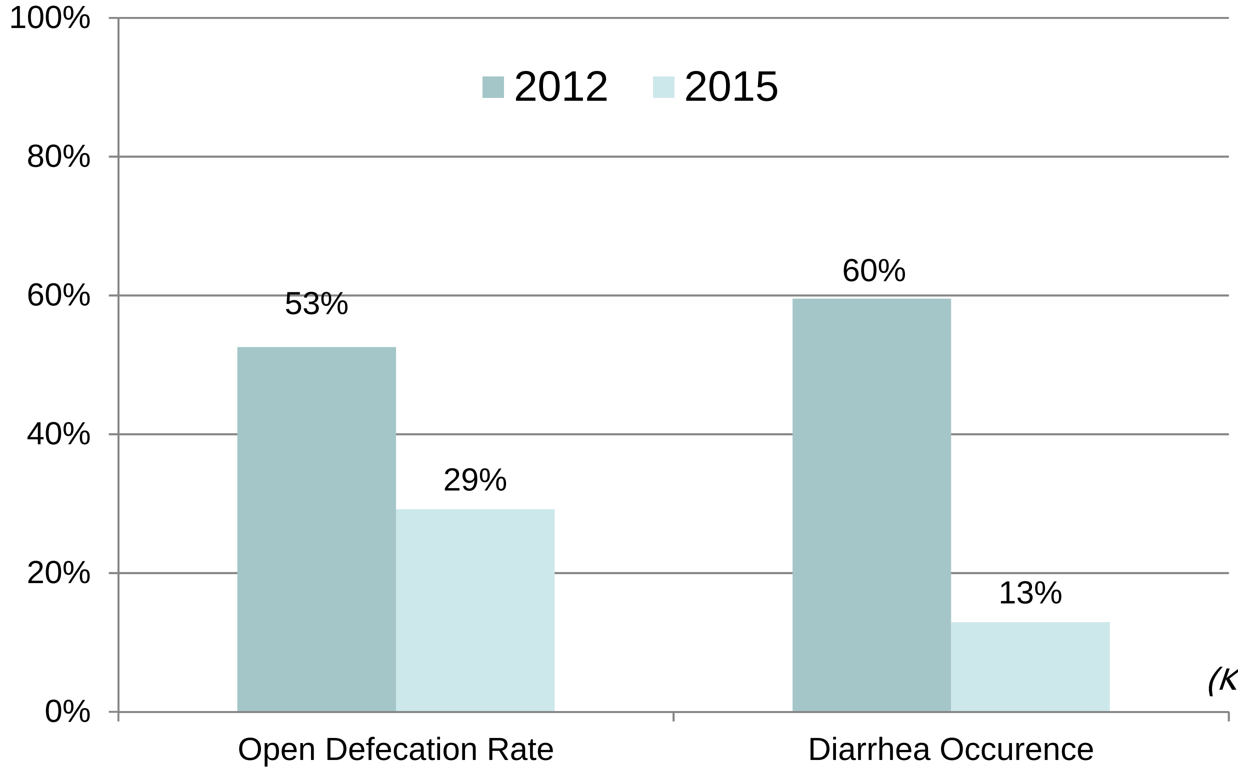
[1] Depending on performance of micro-strainer

Improved Hygiene and Health

TECHNISCHE UNIVERSITÄT DARMSTADT

- *Households performing open defecation and reporting diarrhea problems in the family within the past 2 weeks*

→ *Reduction shows that CHC program and toilet usage made a difference*



(Kramm & Deffner, 2016)

TECHNISCHE
UNIVERSITÄT
DARMSTADT

3 case studies

TECHNISCHE UNIVERSITÄT DARMSTADT

1. Semizentral Qingdao / China
   - …
   - …
2. Cuve waters Outapi Namibia
   - …
   - ….
3. **EPoNa Outapi Namibia**
   - **E**nhancement of existing **Po**nds in Outapi **Na**mibia
   - Existing ponds are overloaded
   - No receiving water available
   - Overflow in environment / Oshanas
   - Multiplying the capacity by pre-treatment, upgrading and post-treatment
   - Production of irrigation water for fodder plants

Status quo

TECHNISCHE UNIVERSITÄT DARMSTADT

- existing “evaporation” ponds (2004)
- 2 parallel lines with 4 ponds each
  - Surface 35,000 m²
- 1 evaporation pond (37,000 m²)
- Waste water 700 m³/d
- No discharge options
- Overloaded and overflowing
- No reuse of the treated effluent
- Insufficient effluent quality
- No sludge removal ever

IWAR

Challenges

- Outapi is growing fast
- Sewer is expanded continuously
- three to four times more people connected to the ponds than planned
- No receiving water, that is no effluent for treated water

Challenges:

- **Amount of waste water**
- **Quality of treated wastewater**

Concept

TECHNISCHE UNIVERSITÄT DARMSTADT

!! Solutions without discharge required

- ~~larger ponds?~~
  - ~~~20 m²/person needed for evaporation~~
  - ~~water is lost by evaporation~~

- **Water reuse for irrigation** (transpiration instead of evaporation)

- **Water reuse requires improved quality of treated water**

- **Current effluent quality is far away to be used for irrigation**

- **Improvements have to been taken**

Objectives

TECHNISCHE UNIVERSITÄT DARMSTADT

- Engineering
  - Improvement of one line to produce irrigation water
  - Reduction of methane emissions through preliminary sludge management
  - Increase of plant capacity
  - Adopted irrigation and cultivation techniques
- Management
  - Governance structures – neighbour ship of treatment plants – federation of operators
  - Support of management structures on macro, meso and micro level
  - Development of irrigation agriculture and socio-economic impact assessment
- Economy
  - Appraisal of macro economic framework conditions and impacts
- Social economic impact assessment and transfer
  - Concepts for the transfer in other regions

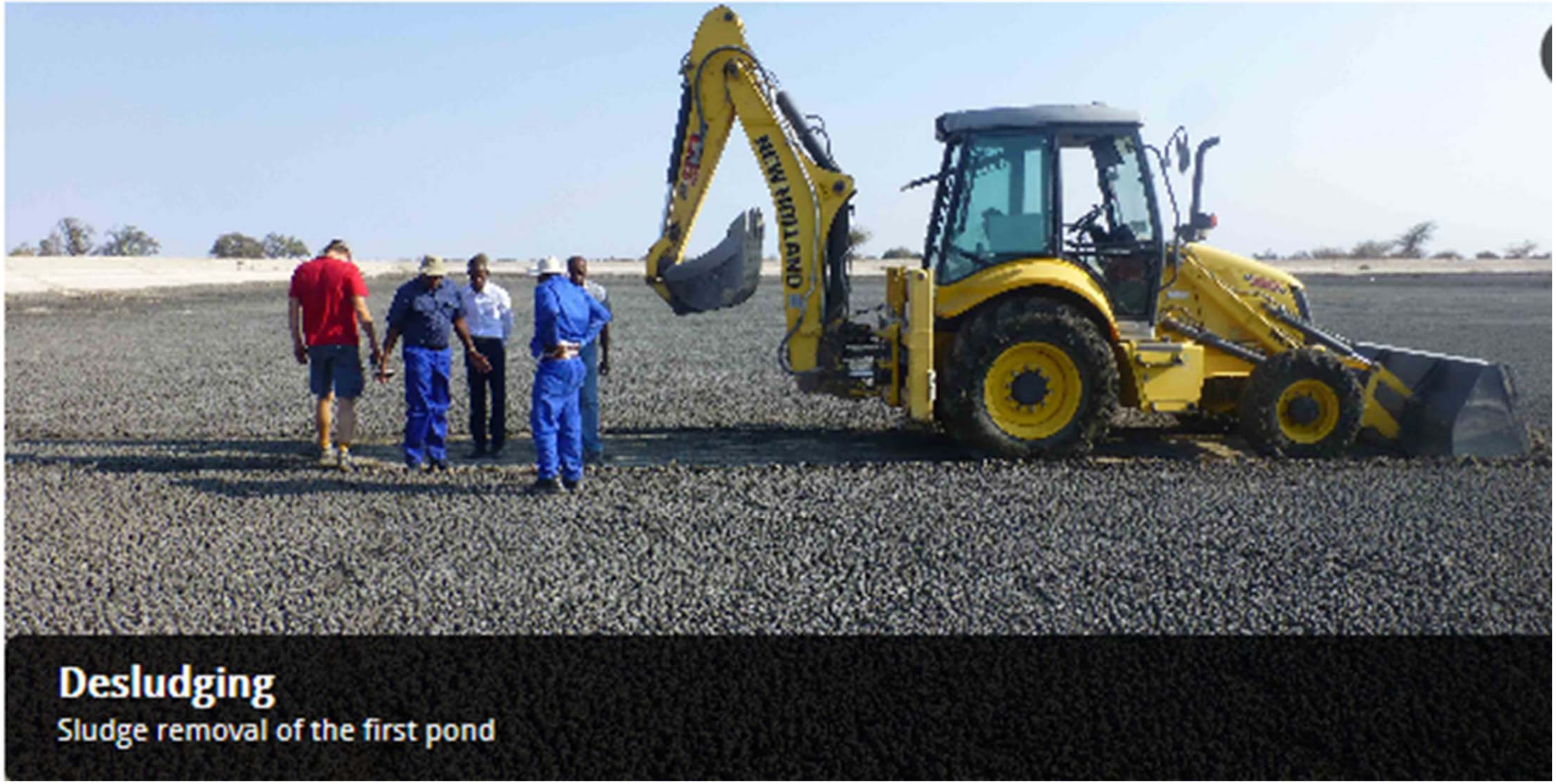
Technical improvement steps

1. Desludging of existing ponds to gain treatment volume
2. Pre-treatment to remove solids
3. Optimizing flow in ponds
4. Filtration of effluent

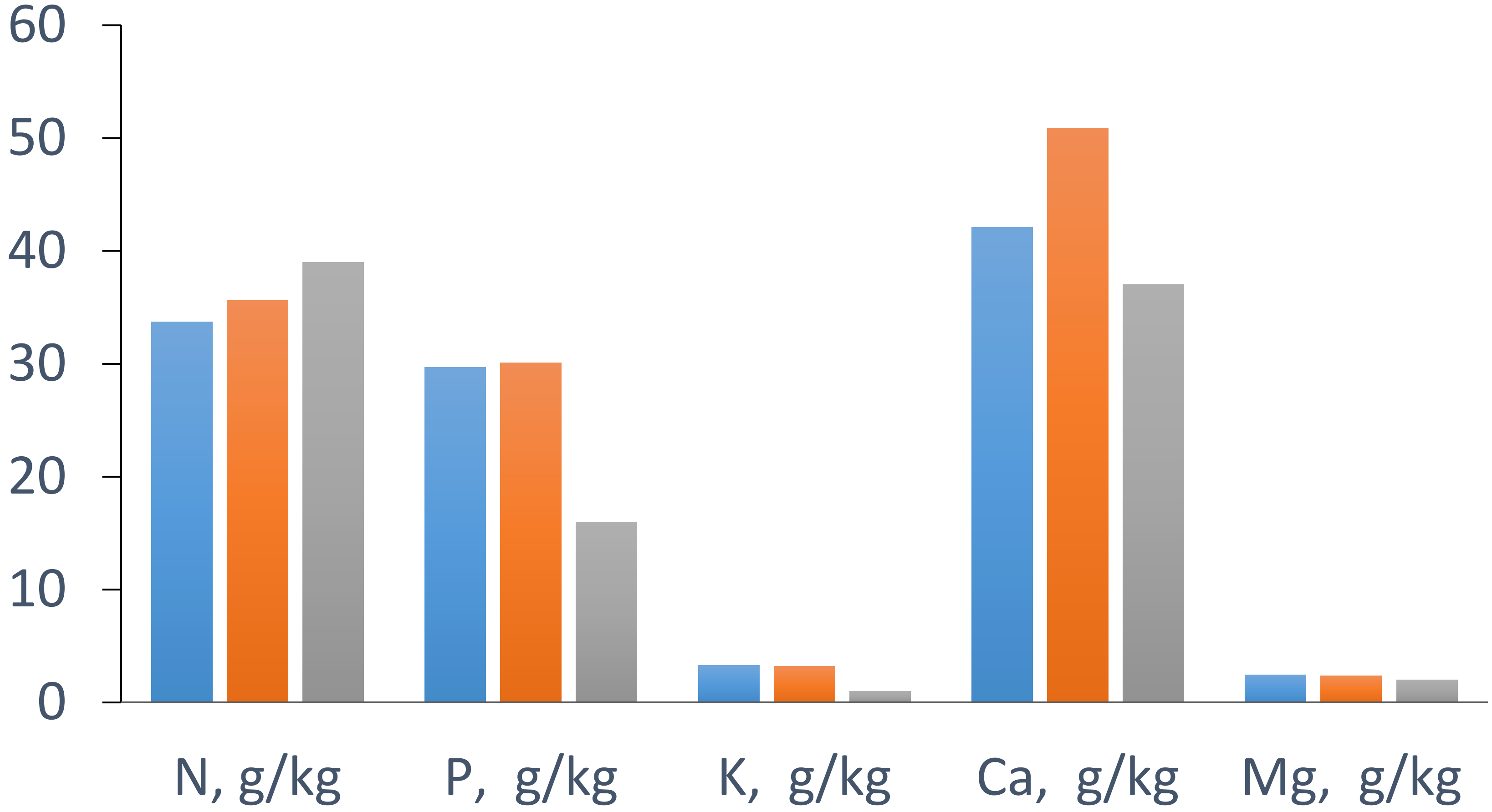
1. Sludge removal from ponds

1. Sludge removal from ponds

TECHNISCHE UNIVERSITÄT DARMSTADT



1. Sludge rich in nutrients



1. Sludge far below heavy metal standards

As, mg/kg	10	9,3	40
Cd, mg/kg	1,4	1,3	40
Cr, mg/kg	9	8,6	1200
Pb, mg/kg	4,2	4,3	300
Cu, mg/kg	64	63	1500
Zn, mg/kg	156	143	2800
Zn, mg/kg	133		200
Ni, mg/kg	9	8,9	420
Na, g/kg	2		
Co, mg/kg	2,2	2,1	

Sludge is used in agriculture as soil enhancer / fertilizer

2. Pretreatment for solids removal – 2 options investigated

TECHNISCHE UNIVERSITÄT DARMSTADT

- **UASB**
  solid removal by sedimentation and digestion

- **Micro screen**
  solid removal by screens (like household sieve)

3. Flow optimization

TECHNISCHE UNIVERSITÄT DARMSTADT

4. Effluent filtration – algae removal

Expected results

TECHNISCHE UNIVERSITÄT DARMSTADT

- Better effluent quality
- Water reuse for irrigation all year long possible
  - →no discharge,
  - →no unintended overflow,
  - →beneficial for fodder cultivation.
  - →reducing fertilizer demand (due to the use of the fertilizer in the water)
- Use of sludge as soil-enhancer
  - Humus
  - Nitrogen, Phosphorus, Potassium

Further improvement steps

1. Desludging of existing ponds to gain treatment volume
2. Pre-treatment to remove solids
3. Optimizing flow in ponds
4. Filtration of effluent
5. Quality assurance
6. Governance and management structures
7. Irrigation and agriculture
8. Economical assessment
9. Socio-ecological impact assessment and transfer

Conclusions

TECHNISCHE UNIVERSITÄT DARMSTADT

„Cities of the Future“ will differ
from those of yesterday and today

Water and Sanitation
Infrastructure will be diverse

Water reuse will be a key element
of urban water solutions

Wastewater is a resource, not a waste