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

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Conclusions

„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

References:
- United Nations 2011, World Urbanization Prospects
- Burdett & Rode 2007, The Speed of Urban Change
From challenges to demand

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

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

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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

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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

Comparing energy consumption of different option:
- Seawater Desalination: 3 - 4 kWh/m³
- intra-urban Water Reuse: < 1 kWh/m³
Double water reuse

1. Water reuse
   - Greywater treatment
     - kitchen
       - shower, wash basin, washing machine
   - toilet flushing

2. Water reuse
   - Blackwater treatment
     - irrigation

Resource Recovery Center

-excess: discharge

Tolksdorf et al. 2016

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Semicentralized Resource Recovery Center (RRC) – a modular approach

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
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 

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Introduction – framework conditions in Outapi

Dynamic development of urban settlements

→ sanitation system needs to be flexible
→ connection of additional households should be possible

Project area in Outapi 2008
(project earth 2008)

Project area in Outapi 2015
(project earth 2015)
Improved Sanitation?
Participation

„Community health clubs“

Outapi Town Council
Implementation: Goal

- **Health**
- **Jobs**
- **Nutrition**
- **Environment**
- **Irrigation Water**
- **Wastewater**

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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

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

<table>
<thead>
<tr>
<th>Capacity: 90 m³/d!!!</th>
<th>Influent (actual)</th>
<th>Effluent</th>
<th>Removal Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q [m³/d]</td>
<td>30 – 50⁽¹⁾</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CODₜₜ [mg/L]</td>
<td>742</td>
<td>56</td>
<td>92%</td>
</tr>
<tr>
<td>BOD₅ [mg/L]</td>
<td>236</td>
<td>6</td>
<td>97%</td>
</tr>
<tr>
<td>TS [mg/L]</td>
<td>781</td>
<td>383</td>
<td>51%</td>
</tr>
<tr>
<td>EC [µS/cm]</td>
<td>617</td>
<td>527</td>
<td>-</td>
</tr>
<tr>
<td>TN [mg/L]</td>
<td>58</td>
<td>34</td>
<td>-</td>
</tr>
<tr>
<td>TP [mg/L]</td>
<td>10</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>E.Coli [MPN/100 mL]</td>
<td>17·10⁶</td>
<td>34</td>
<td>7-log</td>
</tr>
</tbody>
</table>

⁽¹⁾ Depending on the tariff

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## Multi-barrier Approach

### Approximate concentrations per 1 Liter of water

<table>
<thead>
<tr>
<th>Source</th>
<th>E.coli</th>
<th>Rotavirus</th>
<th>Hookworm eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitation facilities</td>
<td>100,000,000</td>
<td>500,000</td>
<td>Up to 3¦000</td>
</tr>
<tr>
<td>Treatment Plant</td>
<td>200</td>
<td>10^{-3}</td>
<td>1 – 770(^{(1)})</td>
</tr>
<tr>
<td>Storage Pond</td>
<td>70</td>
<td>-</td>
<td>None detected</td>
</tr>
<tr>
<td>Drip Irrigation</td>
<td>2</td>
<td>10^{-5}</td>
<td>None detected</td>
</tr>
<tr>
<td>Fruits</td>
<td>0.02</td>
<td>10^{-7}</td>
<td>None detected</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Depending on performance of micro-strainer
Improved Hygiene and Health

- 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)
3 case studies

1. Semizentral Qingdao / China
   - ...
   - ...

2. Cuve waters Outapi Namibia
   - ...
   - ....

3. EPoNa Outapi Namibia
   - Enhancement of existing Ponds in Outapi Namibia
   - 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

- 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

Source: Google Earth, 2016
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

!! 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

- **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
1. Sludge rich in nutrients

![Bar chart showing nutrient content in sludge]

- N, g/kg
- P, g/kg
- K, g/kg
- Ca, g/kg
- Mg, g/kg

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1. Sludge far below heavy metal standards

<table>
<thead>
<tr>
<th>Element</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>As, mg/kg</td>
<td>10</td>
<td>9,3</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Cd, mg/kg</td>
<td>1,4</td>
<td>1,3</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Cr, mg/kg</td>
<td>9</td>
<td>8,6</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>Pb, mg/kg</td>
<td>4,2</td>
<td>4,3</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Cu, mg/kg</td>
<td>64</td>
<td>63</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>Zn, mg/kg</td>
<td>156</td>
<td>143</td>
<td>2800</td>
<td></td>
</tr>
<tr>
<td>Zn, mg/kg</td>
<td>133</td>
<td></td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Ni, mg/kg</td>
<td>9</td>
<td>8,9</td>
<td>420</td>
<td></td>
</tr>
<tr>
<td>Na, g/kg</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co, mg/kg</td>
<td>2,2</td>
<td>2,1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sludge is used in agriculture as soil enhancer / fertilizer
2. Pretreatment for solids removal – 2 options investigated

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

- **Micro screen**
  solid removal by screens (like household sieve)
3. Flow optimization
4. Effluent filtration – algae removal
Expected results

- 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

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Conclusions

„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