On-Site and communal
Greywater treatment for Reuse

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Hamburg University of Technology, Germany

TUHH
Hamburg University of Technology
City

- Water
- Food
- Energy
- Household Chemicals
- Efficiency!
- Mineralize!
City

Efficiency!

Water

Food

Energy

Household Chemicals mineralize!

Wastewater

Solid waste
Freshwater demand: 10 to 20 litres / person/d

- **Tap water**
- **Greywater**
  - Evaporation losses
  - RO-Tap water processing
  - Bath, kitchen, washing
- **Blackwater**
  - Toilets, kitchen waste grinder
  - LooLoop plant (MBR)
  - Pumping station
  - Compost, fertilizer
  - Biogas
- **Flushing water**
  - Infiltration, irrigation
  - Extraction
  - 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
Biochemical degradation in rivers

Biofilm or attached Biomass

O₂

org.C

Bio- mass
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 Aerobic

COD ➔ 60% + O₂ ➔ 40% ➔ CO₂ ➔ sludge
COD Balance Anaerobic Biodegradation

COD Balance Anaerobic

COD

10%

sludge

90%

CH₄
UASB reactor

- biogas
- influent
- effluent
- gas cap
- weir
- settling basin
- baffles
- gas bubble
- sludge granule
- sludge bed
- 3 phase separator
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.
Simplified sewerage installation, Sri Lanka

Prof. Dr. Duncan Mara
Univ. of Leeds
“Slum Networking” in India

Prof. Dr. Duncan Mara
Univ. of Leeds
In this case, simp. sewerage cheaper than on-site san. at densities \( > \sim 160 \) pers/ha.
why greywater reuse?

- Less nutrients, pathogens and pharmaceuticals, easier treatment than mixed wastewater
- 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
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
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

<table>
<thead>
<tr>
<th>No.</th>
<th>Rapid Mixing</th>
<th>Slow Mixing</th>
<th>Dosage Used (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>30sec, 200 rpm</td>
<td></td>
<td>0, 50, 100, 250, 500, 750</td>
</tr>
<tr>
<td>1-2</td>
<td>3min 200 rpm</td>
<td>5min 20 rpm</td>
<td></td>
</tr>
<tr>
<td>1-3</td>
<td>Best of 1-3 on 200 rpm</td>
<td>25min, 20 rpm</td>
<td></td>
</tr>
<tr>
<td>1-4</td>
<td>Best of 1-3 on 200 rpm</td>
<td>40min, 20 rpm</td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>Best of 1-3 on 200 rpm</td>
<td></td>
<td></td>
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</table>

2nd SERIES

(Using best combination of Rapid and Slow Mixing)

<table>
<thead>
<tr>
<th>No</th>
<th>Coagulant Type</th>
<th>Dosage Used (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>2-1</td>
<td>MO powder</td>
<td>0, 50, 100, 150, 200, 250</td>
</tr>
<tr>
<td>2-2</td>
<td>MO solution</td>
<td></td>
</tr>
<tr>
<td>2-3</td>
<td>Aluminum Sulfate</td>
<td></td>
</tr>
</tbody>
</table>

3rd SERIES

(Using best combination of Rapid and Slow Mixing)

<table>
<thead>
<tr>
<th>No</th>
<th>Coagulant Type</th>
<th>Dosage Used (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-1</td>
<td>MO powder</td>
<td>0, 10, 20, 50, 100</td>
</tr>
<tr>
<td>3-2</td>
<td>MO solution</td>
<td></td>
</tr>
</tbody>
</table>

Note: all experiment set up repeated 3 times.
<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Unit</th>
<th>Raw Grey water</th>
<th>Treated w/ Moringa powder</th>
<th>Efficiency (%)</th>
<th>Treated w/ Alum</th>
<th>Efficiency (%)</th>
<th>Requirement for irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Turbidity</td>
<td>NTU</td>
<td>480.00</td>
<td>198.00</td>
<td>58.75</td>
<td>130.00</td>
<td>72.92</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TSS</td>
<td>mg/L</td>
<td>189.00</td>
<td>80.00</td>
<td>57.67</td>
<td>58.00</td>
<td>69.31</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>pH</td>
<td>-</td>
<td>7.06</td>
<td>7.10</td>
<td>6.80</td>
<td></td>
<td></td>
<td>6-9*</td>
</tr>
<tr>
<td>4</td>
<td>Temperature</td>
<td>Deg Celcius</td>
<td>20.10</td>
<td>20.10</td>
<td>20.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Conductivity</td>
<td>mS/cm</td>
<td>1.10</td>
<td>1.12</td>
<td>1.18</td>
<td></td>
<td>&lt;1,3**</td>
<td></td>
</tr>
</tbody>
</table>

BOD removal not relevant as the powder adds natural BOD (before and after around 200)

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<th>Treated w/ Alum</th>
<th>Efficiency (%)</th>
<th>Requirement for irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Zinc</td>
<td>mg/L</td>
<td>0.80</td>
<td>0.28</td>
<td>65.00</td>
<td>&lt; 0.15</td>
<td>&gt; 81.25</td>
<td>&lt;2**</td>
</tr>
<tr>
<td>8</td>
<td>Total Coliform</td>
<td>/100 ml</td>
<td>2 x 10^6</td>
<td>10^4</td>
<td>2 x 10^6</td>
<td></td>
<td></td>
<td>&lt; 200</td>
</tr>
<tr>
<td>9</td>
<td>Average Oil &amp; Grease</td>
<td>g/L</td>
<td>0.65</td>
<td>0.22</td>
<td>65.84</td>
<td>0.30</td>
<td>53.84</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Detergent (MBAS)</td>
<td>mg/L</td>
<td>11,55</td>
<td>9,81</td>
<td>15,06</td>
<td>8,97</td>
<td>22,34</td>
<td></td>
</tr>
</tbody>
</table>

*Indonesian Water Classification, Class D, Water for Irrigation
**Mara, 2003
Determination of Slow mixing time

Turbidity Removal

Efficiency (%) vs Dosage (mg/l)

5 minutes of 20 rpm mixing time
Comparison between coagulants

Turbidity Removal

![Graph showing efficiency of different coagulants at various dosages.](image-url)

- **M. Olifeira Powder**
- **M. Olifeira Solution**
- **Alumunium Sulfate**
Design example

[Diagram of a water treatment system with labeled parts: Influent, PUMP, and Effluent]
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
Greywater Treatment with a constructed wetland / reedbed filter for 200 PE
Lübeck-Flintenbreite, Germany (2 m²/ person)
Constructed wetland – vertical flow
Simplified diagram of a filter planted with reeds, developed by Cemagref.

The system comprises two stage filters in-series, where the second refines the treatment prior to discharge to the natural environment.
Queige (73) – 500 p.e. – Phragmifilter® wastewater treatment plant

CEMAGREF, France
Greywater biofilter in Mali, West Africa
Biological Aquatic System Warrah School, Dural
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 source 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
Woodgas Stoves: Clean and very Efficient by Jörg Fingas  Climatefarming, Germany
Options for Terra Preta Sanitation 1

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

Cleansing with Spray Bottle or Spray Shower LAB can be added (Food Quality)

Tanc Transport 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

INTAQUA™ AG
worldwide patents
City

Water

Greywater recycling

Food

Solar & Woodgas

Soil Fodder

Biowaste & Excreta for reforestation