Decentralized Urban Waste Water Treatment: Hamburg Water Cycle in Indian Context

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Outline

- Water Availability in India – Projections
- Water Supply in India – Status
- Waste Water Collection and Treatment in India – Status & Issues
- Need for an Alternative Approach?
- Hamburg Water Cycle – Original
- A Case for Segregation of Wastewater – IDEA
- Hamburg Water Cycle – Indian Context
- Implementation Environment – Conducive Factors
- Technology – Suitability
- Implementation Case Study – Mumbai
- INDIA – Potential
Water Availability in India

- India consumes 230 km$^3$ ground water per year – Quarter of the world
- India consumes more Ground Water than China
- 40% Leakage in Piped water supply
- Over 50% of Urban Water needs are met by Ground Water
- 61% reduction in Ground water levels in between 2007 to 2017 (CGWB)
- Water Demand two exceed Water Supply by a factor of 2 by 2030
- Per capita (theoretical) availability projected to reach 1140 m$^3$ by 2050 (Officially water scarce at 1000 m$^3$)
State of Water Supply in India

- Population: 1,324,171,000 (Urban: 33%)
- 68.65% Piped water supply: National
- 18.3% of rural households have piped water supply
- Per capita supply: 135 lpcd (As per CPHEEO)
- India Water Use: 56,000 BL (UNEP: Natural Resource Efficiency Indicators, 2018)

Investment needed for Water Supply - $94 Billion for 100% piped supply

*It is safe to assume that people without Piped Connection do not have sewer connection*
Waste Water Collection and Treatment in India – Status & Issues

- Piped Sewer Connection: 32.7% of Urban Household (25.78 million HH, Census 2011)
- On Sanitation (Urban): 47% of Urban Households (35.69 million HH, Census 2011)
- Per capita wastewater generation: 80% of water supply (CPHEEO)

- Total wastewater generation (CPCB, 2009)
  - Class I cities (498) – 35,558 MLD
  - Class II cities (410) – 2,696 MLD
- Total wastewater generation – 76,465 MLD (2031)
Waste Water Collection and Treatment in India – Status & Issues

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Unit</th>
<th>Benchmark</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coverage of Toilets</td>
<td>%</td>
<td>100</td>
<td>69.5</td>
</tr>
<tr>
<td>2</td>
<td>Coverage of Sewage Network Services</td>
<td>%</td>
<td>100</td>
<td>12.2</td>
</tr>
<tr>
<td>3</td>
<td>Collection Efficiency of Sewage Network</td>
<td>%</td>
<td>100</td>
<td>10.3</td>
</tr>
<tr>
<td>4</td>
<td>Adequacy of Sewage Treatment Capacity</td>
<td>%</td>
<td>100</td>
<td>5.3</td>
</tr>
<tr>
<td>5</td>
<td>Reuse and Recycling</td>
<td>%</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Quality of Sewage Treatment</td>
<td>%</td>
<td>100</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Source: MoHUA, 2010
Waste Water Collection and Treatment in India – Status & Issues

- Total Sewage Treatment Capacity (CPCB, 2009)
  - 816 STPs – 23277 MLD
  - 522 Operational STPs – 18883 MLD
  - 294 Non Operation/ Under Const. / Proposed – 4394 MLD

- Only 33% states reported treating more than 50% of wastewater generated on FY 2017-18 (Niti Aayog, CWMI 2019)

An estimated investment (opportunity) of $78.8 Billion (WSP, 2016) over up to 2031 capture 74% waste water and treat 86% of wastewater generated
Priority of Urban Development
Who gets the funds?

EXTERNALLY AIDED URBAN INFRASTRUCTURE PROJECT

1. Roads
2. Electricity
3. Water Supply
4. Urban Transport
5. Sewerage
6. Storm Water Drainage
7. Solid Waste Management

AMRUT (INDIA’s FLAGSHIP PROGRAM)

1. Water Supply
2. Sewerage & Septage Management
3. Drainage
4. Urban Transport
5. Others
Conventional Sewer Systems and STPs

- Use of drinking (potable water) for Toilet Flushing
- Waste water from all kind of sources are mixed
- High Organic and Nutrient Load mixed with Low Organic Load Grey water and Rain water
- Increases the volume of waste water to be treated due to mixing
- High Energy consumption in pumping and STP operation
- Expert operation and maintenance is required (often lacking)
- Usually end of pipe treatment (In Indian context a lot of it remains untreated)
- Old school approach of “Out of Sight, Out of Mind” – People unaware and uncaring
Problems – Specific to India (Developing Nations)

- Often there is no wastewater collection system
- Non-functional or non-existent drainage system
  - (Guwahati, My current residence city is a case in point)
- Lack of Sewage Treatment Systems
- Lack of functioning STPs (Inadequate flow, Improper maintenance, Lack of expertise or funds)
- Lack of Institutional Know-How and Capacities
- Feasibility to find investment of this scale?
- Feasibility of Successful Project Implementation? (COLLECTION AND TREATMENT)
NEED FOR AN ALTERNATIVE APPROACH?

The right answers are Fuzzy!

Important to invest the multi-billion dollars in the right way!
Hamburg Water Cycle - Germany

- Developed by Hamburg Wasser – One of the most successful companies
- Implemented in Jenfelder AU, Hamburg, Germany
  - (Transformation of former military barracks in Urban settlement)
- 35 ha land area and 770 houses
- Segregation of Grey, Black and Storm Water
- Water consumption reduction (Recycling - Black/ Grey/ Storm Water)
- Possibility to reuse water (upto 75 %)
- Energy Generation from Black Water
- Proven to be a success in the local community
- Scalable on large scale
Hamburg Water Cycle - Germany

- Rainwater Harvesting
- Residential Area
- Greywater Treatment (Separated Treatment) No Reuse
- Blackwater Treatment (Energy Generation)
Hamburg Water Cycle – INDIAN CONTEXT

RAINWATER HARVESTING (OPTIONAL) (RECHARGE PITS) (LOCAL TANK / POND STORAGE)

GREY WATER TREATMENT (SEPARATED TREATMENT)
- REUSE FOR TOILET FLUSHING
- GARDENING
- OTHER NON POTABLE USAGE

BLACKWATER
- TO SEWER SYSTEM
- TO SEPTAGE MANAGEMENT
Grey Water Reuse

Source: commonfloor.com
A Case for Segregation of Wastewater – Northeastern Capital City (293,416, Census 2011)
A Case for Segregation of Wastewater – Personal Experiences

- Average rainfall >2300 mm per year well distributed over the year
- Settlements on hill/ mountain tops
- Partial coverage of piped water supply (Average cost Rs. 300 per month flat)
- Heavy Reliance on Water Tankers (Rs. 2.5 -3.5 per Litre cost)
- High energy demand for water supply (500 m – 1000 m pumping heads)
- Reliance on rainwater for meeting water demand
- Grey Water already discharged in a segregated manner

- STP Commission Ready in 2018 (Lying IDLE)
- Sewer Collection Pipe Project End – Likely 2021
- Bio-digesters used for decentralized system however not satisfactory functioning

Possibility (Small Sewer – Decentralized To treat Grey Water)
Waiting to be Commissioned Since early 2018

10 MLD SEWAGE TREATMENT PLANT
Decentralized Grey Water Collection & Treatment – Gravity based supply for non potable usage

- Grey Water collected via gravity lines and treated
- Supply to Lower Distribution Zone

SUPPLY ZONE BOUNDARIES

- Reduced Water demand/ supply vis-à-vis energy demand
- Community Based functioning
- Low cost operation maintained at Ward Level
- Treatment of Wastewater (Partial)
- This water ends up downstream in the rivulets
A Case for Segregation of Wastewater – Guwahati, Capital of Assam (957,352, Census 2011)
A Case for Segregation of Wastewater – Personal Experience

- Only 34% of the city has Piped Water Supply or 35 lpcd availability
- The city has long way to reach 100% coverage (Min. 10 years)
- No plans in view for next decade for wastewater collection and treatment (Low Priority)
- OTHER ISSUES – Narrow Streets, Lack of Capital and O & M funds
- Continued Water Pollution for a Decade ??

- DECENTRALIZED APPROACH –
  - WASTEWATER SEGREGATION, LOW COST TREATMENT AND REUSE
  - Start of pollution control
  - Environmental Protection
A Case for Segregation of Wastewater – Personal Experience

MUMBAI, CAPITAL OF MAHARASHTRA, (12,478,447, 2011)

- Water supply from 80 km from the Western Ghats, Hills
- Water cuts in Summer months is common
- Water Supply 30 – 50 min
- Intermediate Storage in HH Tanks is often used

SOUND OF 8 – 10 litres of Fresh Water Down the drain

Daily 390 MLD of fresh potable water is used for this purpose

- Housing Societies in Mumbai (Flats/ High Rises issue notices to reduce water usage, avoid vehicle washing)

- Sufficient for water needs of a city of 2,600,000 mill. Inhabitants
- More than combined water projects under implementation for Guwahati
- More than sufficient for water needs of all 7 capital cities of North East India except Guwahati
What's the right approach?

**CENTRALIZED**
- Suitable for new densely populated areas
- Important to have operating institutions with know how to run large system
- Revenue collection for financial sustainability *(Often a challenge)*
- High Capital Costs at the onset – **Affordability?**
- Expensive for high ground water table areas

**DECENTRALIZED**
- Small Scale
- Faster Implementation
- Learn as we go
- Scaled up once successful
- Low Investments
- Possible to instill ownership and increase awareness
- Can be difficult for reasons like lack of suitable land and community participation

* ANSWERS ARE FUZZY – Partly True/Partly False
Need for Wastewater Reuse in Urban India – Decentralized Approach

- Water Saving – Reduction in Fresh Water Demand
- More fresh water at customer’s disposal
- Specially relevant in areas getting water supply from Tankers
- Reduction in ground water depletion where it is the main source
- Beginning wastewater treatment even where functioning STPs are still a distant reality
- Environmental Protection
- Alternative model to conventional model
  - STPs tend to be defunct due to lack of proper sewer system
  - Improper Design (High Flows or no flows)
  - Lack of funds for operation (No sustainable model yet to levy wastewater fees)

Wastewater – A Resource / An alternate water source
Indirect but Tangible Impacts

- Unlocking of private (decentralized) financing of wastewater reuse
  - Given the humongous investment requirement for centralized systems it is unlikely to be met fully by government financing
  - Decentralized Approach allows for cost transferring to consumer (Albeit with rebates) and also allows more ownership

- Reduced working loads on wastewater collection systems
  - Savings in pumping costs (Intermediate pumping stations)
  - Reduced working load on STPs
  - If implemented on large scale in cities lacking STPs it can be factored during planning of STPs
Favorable Factors for Implementation

- **Water Problems**
  - Areas of water scarcity - Need for Water Tankers/ Deep bore wells
  - Lack of good quality water sources

- **Water Expenditure**
  - Water tariff are rationalized (and Implemented)

- **Enabling Regulations**
  - Regulations and statutory laws requiring implementation
  - Lack of a proven/ functioning sewer system with end of line STP

- **Potential for Financial Savings**
  - Property Tax are applicable and there are tax rebates for implementing such measures
  - Water Tariff savings

- **Relative availability of land for small scale set up**
- **Community awareness and institutional support**
Hamburg Water Cycle – INDIAN Implementation in Existing Buildings

CRITERIA:

1. **PIPING AND STORAGE SYSTEM**
   - Twin type plumbing for grey and black water separation
   - Plumbing for reusing for toilet flushing
   - Overhead Storage tanks for treated grey water

2. **SUITABLE TECHNOLOGY**
   1. LAND REQUIREMENT
   2. CAPEX
   3. OPEX

3. **GOVERNMENT SUPPORT (PROPERTY TAX REBATES)**
   1. Property Tax Rebates
   2. One time technology and partial funding

4. **RAINWATER HARVESTING**

5. **DIRECT BENEFITS (INFORMATION AND EDUCATION CAMPAIGN)**
   1. More fresh water availability throughout the year

<table>
<thead>
<tr>
<th>New Buildings</th>
<th>Existing Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRITERIA</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PIPING AND STORAGE SYSTEM</strong></td>
<td></td>
</tr>
<tr>
<td>Twin type plumbing for grey and black water separation</td>
<td>Optional</td>
</tr>
<tr>
<td>Plumbing for reusing for toilet flushing</td>
<td>Incentivize</td>
</tr>
<tr>
<td>Overhead Storage tanks for treated grey water</td>
<td>Incentivize</td>
</tr>
<tr>
<td><strong>SUITABLE TECHNOLOGY</strong></td>
<td></td>
</tr>
<tr>
<td>LAND REQUIREMENT</td>
<td>Low</td>
</tr>
<tr>
<td>CAPEX</td>
<td>May be high</td>
</tr>
<tr>
<td>OPEX</td>
<td>Low</td>
</tr>
<tr>
<td><strong>GOVERNMENT SUPPORT (PROPERTY TAX REBATES)</strong></td>
<td></td>
</tr>
<tr>
<td>Property Tax Rebates</td>
<td>Recommended</td>
</tr>
<tr>
<td>One time technology and partial funding</td>
<td>Recommended</td>
</tr>
<tr>
<td><strong>RAINWATER HARVESTING</strong></td>
<td></td>
</tr>
<tr>
<td><strong>DIRECT BENEFITS (INFORMATION AND EDUCATION CAMPAIGN)</strong></td>
<td></td>
</tr>
<tr>
<td>More fresh water availability throughout the year</td>
<td>Recommended</td>
</tr>
</tbody>
</table>
What is Grey Water?

- Grey water mainly consists of discharges from bathtubs, shower, kitchen sinks (optional) and washing.

- Due to low organic and nutrient content, the grey water can be relatively easily specially for non-potable usage.

- The grey water reuse will substantially reduce groundwater abstraction since majority of water demand for toilet flushing and gardening in Ashram school can be met from treated grey water.

<table>
<thead>
<tr>
<th>Chemical properties</th>
<th>Laundry</th>
<th>Bathroom</th>
<th>Kitchen sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>9.3-10Å</td>
<td>5-8.1Å,B,D,E</td>
<td>6.3-7.4Å</td>
</tr>
<tr>
<td>EC [µS/cm]</td>
<td>190-1400Å</td>
<td>82-20'000Å</td>
<td></td>
</tr>
<tr>
<td>Alkalinity [mg/l]</td>
<td>83-200 as CaCO₃Å</td>
<td>24-136 as CaCO₃Å</td>
<td>20.0-340.0Å</td>
</tr>
<tr>
<td>Hardness [mg/l]</td>
<td>-</td>
<td>18-52 as CaCO₃Å</td>
<td>-</td>
</tr>
<tr>
<td>BOD₅ [mg/l]</td>
<td>48-380Å,C</td>
<td>76-200Å</td>
<td>387-1000Å</td>
</tr>
<tr>
<td>BOD₇ [mg/l]</td>
<td>150Å</td>
<td>170Å</td>
<td>26-1600Å,F,G</td>
</tr>
<tr>
<td>COD [mg/l]</td>
<td>375Å</td>
<td>280Å up to 8000 COD₅</td>
<td></td>
</tr>
<tr>
<td>TOC [mg/l]</td>
<td>100-280Å</td>
<td>15-225Å</td>
<td>2.2-5.8Å</td>
</tr>
<tr>
<td>Dissolved oxygen [mg/l]</td>
<td>-</td>
<td>0.4-4.6Å</td>
<td></td>
</tr>
<tr>
<td>Sulfate [mg/l]</td>
<td>-</td>
<td>12-40Å</td>
<td></td>
</tr>
<tr>
<td>Chloride (as Cl) [mg/l]</td>
<td>9.0-88Å</td>
<td>3.1-18Å,B</td>
<td>-</td>
</tr>
<tr>
<td>Oil and grease [mg/l]</td>
<td>8.0-35Å</td>
<td>37-78Å</td>
<td></td>
</tr>
</tbody>
</table>

A, (Christova Boal et al., 1996); B, (Rose et al., 1991); C, (Siegrist et al., 1976); D, (Santala et al., 1998); E, (Burrows et al., 1991); F, (Shin et al., 1998); G, (Hargelius et al., 1995)
# Technology Comparison Matrix

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>LAND (sqm./ KLD)</th>
<th>ORGANIC LOAD REMOVAL**</th>
<th>CAPEX (INR./KLD)</th>
<th>OPEX</th>
<th>REUSABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reed Bed System</td>
<td>15-17</td>
<td>35-100%</td>
<td>Lower than TF</td>
<td>Low</td>
<td>Flushing and Gardening</td>
</tr>
<tr>
<td>Trickling Filter</td>
<td>0.65</td>
<td>70-100%</td>
<td>Lower than SBR</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>SBR*</td>
<td>0.40</td>
<td>&gt;90%</td>
<td>10638</td>
<td>Medium</td>
<td>All except drinking, cooking and floor washing</td>
</tr>
<tr>
<td>MBBR*</td>
<td>0.45</td>
<td>&gt;90%</td>
<td>9645</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>SBR/MBBR + UF+RO*</td>
<td>0.55</td>
<td>90-100%</td>
<td>16310</td>
<td>V. High</td>
<td>Technically up to drinking</td>
</tr>
</tbody>
</table>

*CPCB 2013
**De Koening, 2005
*Data Deficient
Which one to choose?

- **LOW COST SYSTEM** (up to Secondary)
  - Meets only flushing requirement and gardening, agriculture

- **HIGH COST SYSTEM** (Tertiary Treatment)
  - Flushing, gardening, cleaning of floor, washing clothes, GW Recharge, Vehicle washing,
Favorable Laws – Future trends

- Chennai promotes grey water recycling
- Bangalore is also expected to support such measures due to growing water pollution and scarcity
Implementation - 8 FLOOR x 4

No. of households – 100 Household – 500 people
Water Demand @ 135 lpcd – 67.5 KL
Grey Water Generation – 22.5 KL (Washing/Bathing only)

Flushing Water Demand – 37.5 KL (Washing, Bathing, Kitchen Sink)
Gardening/ Cleaning demand – 20 KL (@ 40 lpcd)
Size of Plant required – 5 KL

Size of Plant required – 25 KLD
Implementation – 8 FLOOR x 4

**Investments**
- Plant Installation Cost – INR. 230,000 (one time)
- Treated Water Storage Cost – INR. 80,000 (one time)
- Plumbing Modification Costs* – INR. 193,000 (one time)
- **Total** – INR. 503,000 (one time)

**Recurring Costs**
- Annual Plant O & M Cost – INR. 125,925 p.a. (INR. 0.015/KLD/p.a)

**Savings**
- Saving of fresh water – 23 KLD or 8.34 Million litre
- Saving of Water Tariff – INR. 42,814 p.a.
- Property Tax Rebates – INR. 100,475 p.a. (BMC, Mumbai)

(*Saved if already twin type)
Implementation Case Study – Direct Cost Benefits

8 FLOOR x 4

Saving of fresh water

- 23 KLD
or 8.34 ML per annum

Indirect Benefits
1. Reduced water supply/ reduced energy/ reduced leakage losses
2. Reduced future capacity Augmentation
3. Environmental benefits
4. Increased public awareness
5. Increased rate of reuse
6. Reduced Sewer Sizing/STP sizing/ Centralized O & M Costs

- Water Requirement for 62000 people/12500 HH for a day
- Water requirement of 34 years for HH of 5
- Water requirement for 2 long lifetime of an individual (170 years)
POTENTIAL OF REUSE INDIA

- Chennai
- Bengaluru
- Mumbai
- Hyderabad
- New Delhi
- Guwahati
- All cities which has High Rise/ Apartment Society Model
- Lack existing waste water collection and treatment infrastructure
- Face water scarcity
- 893 Class I and II cities
THANK YOU!

Cảm ơn bạn

धन्यवाद

Terima kasih

Dankeschön