Sanitation in a Crowded (and Water-short) World

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Toilets Around the World 2016
What is the greatest invention of the last 150 years?

Edward Luce, Financial Times, 20 February 2016
Toilets make the density of cities possible.
Lack of toilets makes the density of cities miserable.

Kibera, Kenya
Global Sanitation Delivery: How big is the problem?

- 2.4 billion people (out of 7 billion – 32%) are without access to any kind of improved sanitation.
- Singapore, Japan, and Korea are the only countries in Asia with near complete coverage of the population with adequate sanitation. China is improving, but not there yet.
- South Africa has extensive sewage treatment, but much of the rest of Africa has little or none. “Flying toilets” are more common than community sanitation in poor urban settings.
- Latin America and the Caribbean have widespread delivery of potable water, but sanitation has lagged.
- Some progress is being made, but in general things are not improving very fast.
Millennium Development Goals

**Goal 7: Ensure Environmental Sustainability** Targets

- Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources
- Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss
- Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation
- Achieve, by 2020, a significant improvement in the lives of at least 100 million slum dwellers
Millennium Development Goals

Goal 7: Ensure Environmental Sustainability

Progress

- The world met the drinking water target by 2015.
- With half the population of developing regions lacking basic sanitation, the 2015 target was not met.
- The world missed the 2010 target to slow the decline in biodiversity.
- The target of improving the lives of at least 100 million slum dwellers has already been achieved three times-over.
Sanitation Goal Not Met

“Between 1990 and 2015, the proportion of the global population using an improved sanitation facility has increased from 54 per cent to 68 per cent. This means that 2.1 billion people have gained access to improved sanitation since 1990, and the proportion of people practising open defecation globally has fallen almost by half, from 24 per cent to 13 per cent. However, in 2015, 2.4 billion people are still using unimproved sanitation facilities, including 946 million people who are still practising open defecation.”

Water and Sanitation in Uttar Pradesh India* (2008)

“As per latest survey carried out in the year 2004, out of the 2,60,110 habitations (sic) in the State, 7993 were found to be ‘not covered’ habitations, 18,776 ‘partially covered’ and remaining ‘fully covered’ habitations as per Government of India norms.” (90 per cent coverage?)

“As per census 2001, there are about 2.58 crore (26 million) households in the State and only 28 per cent households have individual household toilets.”

A Typical Sewage Outfall in India (2006)
Endangered Rivers:
The Ganga at Varanasi (2006)
Prime Minister Modi has vowed to improve matters.

- “PM Modi's 'Namami Gange Programme': Cabinet approves a massive Rs 20,000-crore ($3 billion) budget.***”


Inappropriate Sewage Pollution Control in India

• Ganga Action Plan (GAP) funded sewage pump stations and activated sludge treatment plant upstream of Varanasi.

• Unreliable power supply led to complete failure of the pump stations and treatment plant and raw sewage pollution of tube wells.
Advanced Integrated Pond System (AIPS) Proposed for Varanasi

- Site downstream of Varanasi
- Low or no-power secondary treatment system
- Effluent coupled with irrigation and/or infiltration
- Disadvantage: Relatively large land area (but a site has been identified)
Endangered Rivers:
Yamuna River between Downstream of New Delhi, India (2006)
## Water and Sanitation Coverage in Nepal* (2011)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Urban</th>
<th>Rural</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of population using an improved drinking water</td>
<td>93.5</td>
<td>87.8</td>
<td>88.6</td>
</tr>
<tr>
<td>Percentage of population with access to improved sanitation</td>
<td>58.1</td>
<td>36.1</td>
<td>39.5</td>
</tr>
</tbody>
</table>

Endangered Rivers:
Kathmandu Valley, Nepal (2008)

Bagmati River between Kathmandu and Patan

Treatment Tank in a small village

### Urban Water Supply

<table>
<thead>
<tr>
<th>Year</th>
<th>Population Served</th>
<th>Coverage Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>117.58</td>
<td>51.3</td>
</tr>
<tr>
<td>2003</td>
<td>291.25</td>
<td>86.15</td>
</tr>
</tbody>
</table>

### Urban Wastewater Treatment

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (m³/day)</th>
<th>Coverage Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2003</td>
<td>42.5</td>
<td>42.9</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Year</th>
<th>Population Served (Millions)</th>
<th>Coverage Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
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<td>51.3</td>
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<td>291.25</td>
<td>86.15</td>
</tr>
</tbody>
</table>

### Rural Sanitary Latrine Development

<table>
<thead>
<tr>
<th>Year</th>
<th>Households (1,000 households)</th>
<th>Coverage Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>???</td>
<td>39.8</td>
</tr>
<tr>
<td>2003</td>
<td>247,898</td>
<td>50.9</td>
</tr>
</tbody>
</table>

Endangered Rivers:
The Yangtze at Chengdu (2004)
Excreta Management in Szechuan Province (2004)
Modern Sewage Treatment in Singapore (2011)
Rooftop Gardens at the Miwakashima WWTP in Tokyo (late 1980s)

<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved water source, rural (%)</td>
<td>77</td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Improved water source, urban (%)</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Improved sanitation facilities, rural (%)</td>
<td>68</td>
<td>69</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Improved sanitation facilities, urban(%)</td>
<td>97</td>
<td>97</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
</tbody>
</table>

But as of 2013 “only 20 % of Caracas sewage is intercepted.”*

* Source: Inter American Development Bank
(http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=35073918)
As of 2008, only 33 percent of sewage flows received treatment*!

Sewage Pollution Control Solution in Venezuela (circa 1997)

The Beetham Lagoons in Port of Spain, Trinidad (1997)
A Success Story: New Treatment Plant at Beetham Lagoon Site (2001)
Decision Tree for Appropriate Wastewater Collection
Decision Tree for Appropriate Treatment

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United Nations Environment Programme
APPROPRIATE TECHNOLOGY FOR SEWAGE POLLUTION CONTROL IN THE WIDER CARIBBEAN REGION

Figure 6.2: DECISION TREE FOR APPROPRIATE DOMESTIC SEWAGE TREATMENT
EAWAG Compendium of Sanitation Systems and Technologies
EAWAG Sanitation System Diagram

Sanitation System 8: Sewerage System with Urine Diversion

Input Products | User Interface | Collection and Storage/Treatment | Conveyance | Treatment | Output Products | Use and/or Disposal
---|---|---|---|---|---|---
Stormwater | | | | | | Disposal/Recharge
Greywater | | | | | | 
Toilet Flushing | | | | | | 
Urine Diverting Urinal | | | | | | 
Brownwater | | | | | | 
C.6 | | | | | | 
Composted Urine | | | | | | 
Stormwater Drains | | | | | | 
ABR, Anion, Filter | | | | | | 
WSP, Aerated Pond | | | | | | 
FWS, CW, MBR, LGW, VFB, CW | | | | | | 
T.1 | | | | | | 
Thickening Filter | 
T.9 | | | | | | 
Activated Sludge | 
T.10 | | | | | | 
Emulsion | 
D.10 | | | | | | 
Disposal/Recharge
Urine | | | | | | 
Storage Tank | | | | | | 
C.1 | | | | | | 
Decentralized Enzyme Bioreactor | | | | | | 
C.7 | | | | | | 
Biogas Reactor | 
C.11 | | | | | | 
Treated Sludge | 
D.11 | | | | | | 
Land Application | 
D.12 | | | | | | 
Surface Disposal
C.8 | | | | | | 
Application | 
D.13 | | | | | |
The Economy of Scale Issue

Wastewater treatment plants are sensitive to economy of scale: As plant size gets bigger, the unit cost goes down
Density Impacts on Unit Cost

As density increases, the cost of centralized collection decreases compared to on-site or decentralized treatment.
Is water carriage a problem?

• Water carriage is convenient and a symbol of development (and makes cities possible!)
• But there would be no water pollution (or much less) without water carriage!
• It is not justified in every context
• In many contexts ventilated pit latrines or composting toilets are more appropriate
• The economics and sociology are as important as the sanitary engineering in selecting appropriate technology
Ecosan Example
Erdos Project

- Water-short new town in Erdos in Inner Mongolia
- Urine Diverting, composting toilets
- Grey water treatment
- Installed in 3,000 person apartment complex
Erdos Technology

“Improved” UD Toilet

Dry Compost Bins
Erdos Results

• 30% savings in water use
• “Materials input for the Ecosan system is higher than for the waterborne one by about USD 920 for each household (in 2003).”
• Problems:
  – More complex than water carriage
  – Viewed as backward
  – Odors
• Residents voted in 2010 to replace all of the Ecosan toilets with flush toilets
The Gates Foundation: Reinvent the Toilet (2011)

“The Reinvent the Toilet Challenge aim(ed) to create a toilet that:

- Removes germs from human waste and recovers valuable resources such as energy, clean water, and nutrients.
- Operates “off the grid” without connections to water, sewer, or electrical lines.
- Costs less than US$.05 cents per user per day ($5 per month for four)
- Promotes sustainable and financially profitable sanitation services and businesses that operate in poor, urban settings.
- Is a truly aspirational next-generation product that everyone will want to use—in developed as well as developing nations.”

See: http://www.gatesfoundation.org/What-We-Do/Global-Development/Reinvent-the-Toilet-Challenge#AbouttheReinventtheToiletChallenge
Reinvent the Toilet: The Winners (2012)

• Cal Tech: Solar toilet that generates hydrogen and electricity.
• Loughborough University: Produces biological charcoal, minerals, and clean water.
• University of Toronto: Sanitizes feces and urine and recovers resources and clean water.
Reinvent the Toilet: $5 per month? (2016)
Reinvent the Toilet: More Questions

• Doesn’t this idea cut off individuals from the community?
• How could this be cost-effective in urban areas?
• How does this address waste water from cleaning, bathing, and cooking?
• Where will the water go?
And now for something completely different:
The Peepoo Bag.

“Recognising consumer needs, Peepoo is formulated from a bottom-up perspective that puts the user’s need first. Ergonomically designed to be easy and hygienic to use, simple to produce, and thus possible to be sold to groups with the weakest purchasing power, Peepoo offers a sanitation choice for both individuals and society at large.”

http://www.peepoople.com/
Sanitation Delivery
What technical process should be followed?

- Evaluate alternatives (!)
  - That are culturally appropriate
  - Manage all potential pollution streams (feces, urine, blackwater, greywater, and sludges)
  - Are sensitive to economies of scale
  - Are sensitive to density impacts
  - Are sensitive to local costs and capabilities
  - Are sensitive to local operational skill levels
  - Are consistent with local energy sources
  - Consider nutrient recovery potential, and
  - Make best use of current technological development
The challenge for the future: How to deliver sanitation here?

Petare (Caracas), Venezuela
... or here?

Kibera, Kenya
What is preventing improved sanitation in the developing world?

• The biggest obstacle is urbanization without economic development,
• Followed by lack of institutional development.
• Technical development is way down the list of obstacles.
• The pessimist’s view: Truly widespread sanitation development will only come with economic development.
• The optimist’s view: We don’t have to repeat the mistakes of the developed world. Appropriate technology can help us sidestep them.
For More Information

- UNEP, Appropriate Technology for Sewage Pollution Control in the Wider Caribbean Region (http://www.cep.unep.org/pubs/Techreports/tr40en/index.html)
- IWA Urban Sanitation Programs: (http://www.iwa-network.org/projects2/urban-sanitation)
- Sustainable Sanitation Alliance: (http://susana.org/)
- EAWAG Compendium: (http://www.eawag.ch/forschung/sandec/publikationen/compendium_e/index_EN)
Questions?
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