The Short History of Wastewater Treatment

Dr. John Snow
1813-1858
British

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Political controversy
After the cholera epidemic had subsided, government officials replaced the Broad Street pump handle. They had responded only to the urgent threat posed to the population, and afterward they rejected Snow's theory. To accept his proposal would have meant indirectly accepting the fecal-oral route of disease transmission, which was too unpleasant for most of the public to contemplate.

It wasn't until 1866 that William Farr, one of Snow's chief opponents, realised the validity of his diagnosis when investigating another outbreak of cholera at Bromley by Bow and issued immediate orders that unboiled water was not to be drunk.
Broad Street pilgrimage
London

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Excreta Safely Managed

2.9 billion people used safely managed sanitation services in 2015

Fig. 38  Proportion of population using safely managed sanitation services, 2015

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Centralized Treatment

- Community wastewater collected and sent to a centralized location for treatment
Community wastewater is not collected but rather is treated at the point of generation.
Fecal Sludge Management

Goal: Convert sludge into biosolids with beneficial reuse as fertilizer/soil conditioner

- Reduce Pathogens
- Reduce Heavy Metals
- Nutrients: N–P–K
- Organic Material
Nutrient Loop

“the movement and exchange of organic and inorganic matter back into the production of matter”
Why does this matter?

Earth is 40% beyond its carrying capacity due to fertilizers

Low-Cost, Alternative Wastewater Treatment Systems

- Waste stabilization ponds (a.k.a. lagoons and oxidation ponds)
- Aerated lagoons
- Oxidation ditches
- Constructed wetlands (reed beds)
- Wastewater bioremediation
- Land treatment
- Upflow anaerobic sludge blanket (UASB) reactors
Types of Wastewater Treatment Ponds

- **Waste Stabilization Ponds (WSPs)**
  - Natural bio–photosynthetic treatment
  - Earthen basins
  - No electricity–powered aeration is required
  - Four processes or types of WSPs:
    - Anaerobic ponds
    - Facultative ponds
    - Maturation ponds
    - High-rate aerobic ponds

- **Aerated Lagoons**
  - WSPs with powered aeration

- **Oxidation Ditches**
  - Oval channel shape with powered aeration
Key Design Aspects of Lagoons

- Hydraulic detention time
- Organic loading rate
  - Usually measured as mass of organic waste in $\text{BOD}_5$ added per day to a unit volume OR unit area
  - $\text{BOD}_5$ is a quantity of oxygen-depleting organic matter: “milligrams of oxygen needed to break down the organic matter contained in a liter of water over five days”
- Depth

Reference books give average design parameters, BUT real conditions vary widely around the world – testing!!
Wastewater Stabilization Ponds

Anaerobic

Facultative Photosynthetic Aerobic-anaerobic

Tertiary Maturation

Stabilization  Oxidation  Polishing

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Anaerobic Ponds

- Preliminary pond treatment stage (to reduce the organic load and allow algae to grow in the following stage)
- Deep pond, anaerobic throughout, no algae
- Bacteria break down organic matter and nutrients, and create CO$_2$ and CH$_4$
- Treats high-strength wastewaters with high solids content
- Maintains a surface cap of fresh water to seal in odors (may need powered aeration)
- $\approx$ 60 – 70% BOD removal
Anaerobic Ponds

Effluent In
Organic matter and nutrients
High BOD

Inlet Pipe
From farm dairy

Effluent Out
Higher quality
70% less BOD

Overflow Pipe
To aerobic pond

Bottom Sludge
Solids
Some organic N and P

Crusting
Solids

Gases
Carbon dioxide
Methane
Ammonia

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Facultative Ponds

- Solids settle out on the bottom in an anaerobic sludge layer and create odorous gases
- Bacteria in the middle take in $O_2$, oxidize organics/nutrients, and create $CO_2$
- Algae on the top take in sunlight and $CO_2$, oxidize organics/nutrients, and create $O_2$
- 20% BOD removal
Facultative Ponds
Facultative Ponds

![Diagram of Facultative Ponds]

Figure 22-2. A Facultative Lagoon Consists of Three Zones for Wastewater Treatment.

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Maturation Ponds

- Stage of treatment following the facultative pond (polishing step)
- Shallow pond (1–1.5m), aerobic throughout, sunlight penetrates entire depth
- Destruction of pathogens
- Wastewater effluent can be reused for agriculture or aquaculture
- 15% BOD removal (small) by N & P removal is significant (< 50% P, 80+% N)
WSP Evaluation

- WSPs are simple, low-cost, and highly effective!

- WSPs are limited by the following factors:
  - Land availability and cost, siting constraints
  - Temperature (non-ideal in cold climates)
  - Wastewater quality (natural systems that cannot handle toxic shocks, highly variable loading, industrial waste)
What can we do with this water?

Table 22-2. Types of Lagoons That Correspond to Particular Water Reuse Scenarios

<table>
<thead>
<tr>
<th>Type of Reuse</th>
<th>General Rule on Types of Lagoons Required to Meet Water Quality Guidelines</th>
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</thead>
<tbody>
<tr>
<td>Restricted irrigation—Includes irrigation of crops, except salads and vegetables eaten uncooked</td>
<td>Anaerobic lagoon followed by facultative lagoon</td>
</tr>
<tr>
<td>Unrestricted irrigation—Includes salads and vegetables eaten uncooked</td>
<td>Anaerobic lagoon followed by facultative lagoon and maturation lagoon</td>
</tr>
<tr>
<td>Wastewater-fed fish ponds</td>
<td>Anaerobic lagoon followed by facultative lagoon to maintain total nitrogen load into fish ponds of 4 kg N/ha-day. It is important to check pathogen and ammonia concentrations in the facultative lagoon effluent.</td>
</tr>
</tbody>
</table>
Constructed Wetland

- Plant varieties are restricted or a monoculture
- Impermeable liner
- Preceded by a septic tank or oxidation pond
- Water flow may be controlled below the plant-growing surface or not
- Effective at reducing pathogens, BOD, and total suspended solids
Evapotranspiration Beds

- A type of subsurface flow wetland
- Water evaporates from the soil and is transpired by the plants growing there
- Use when the soil cannot treat the wastewater before it percolates to groundwater, or where soil prevents it from percolating correctly (very clay-ey soil)
- Cannot work in areas where rainfall rate is higher than evapotranspiration rate!