A Brief History of Wastewater

Tom O’Connor, PE
Overview

Wastewater Characteristics
Wastewater Past
Outhouses and Toilets
Wastewater Treatment
Wastewater in India and Japan
Wastewater Future
What is Wastewater?

Wastewater *n.* Water that has been used, as for washing, flushing, or in a manufacturing process, and so contains waste products; sewage.
Hydrologic Cycle

Condensation
Moist Air

Evaporation from rivers, soils, lakes

Transpiration

Condensation

Precipitation

Precipitation

Evaporation from Ocean

Interception

Runoff

Infiltration

Soil Moisture

Throughflow

Seepage

Groundwater
Safe Drinking Water Act - Protecting America's Public Health

MULTIPLE RISKS REQUIRE MULTIPLE BARRIERS

Safe drinking water is essential to the health of American citizens and the economic health of our communities. However, drinking water is vulnerable to contamination from many potential threats. There are programs and activities that, when operated effectively, can help protect the safety of drinking water sources. The success of these programs relies on the involvement and vigilance of local, state, and federal officials, the private sector, public interest groups, and individual citizens.

This poster identifies examples of:
1. Surface and groundwater sources of drinking water in the area;
2. Potential threats to these drinking water sources, and;
3. The multiple technologies that together protect our nation's public health (in order):
   - Source Water Protection
   - Water Treatment
   - Water Distribution
   - Adequate Service Areas

Safe Drinking Water Hotline: (800) 426-4791
Safe Drinking Water Web Site: www.epa.gov/safewater
Water and Stuff

**Molecular formula**  \( \text{H}_2\text{O} \)  
**Structural formula**  \( \text{H} - \text{O} - \text{H} \)

<table>
<thead>
<tr>
<th><strong>H\textsubscript{2}O</strong></th>
<th>Pure Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Waters</td>
<td>Water + Stuff</td>
</tr>
<tr>
<td>Drinking Water</td>
<td>Natural Waters - Stuff</td>
</tr>
<tr>
<td>Wastewater</td>
<td>Drinking Water + Stuff</td>
</tr>
</tbody>
</table>
What is the Stuff in Municipal Wastewater?

Stuff we put down the toilet or drain…
• Water
• Poop, urine, toilet paper, condoms, tampons…
• Food scraps, toothpaste, soap, hair, paint, chemicals…

…and stuff that just finds its way in.
• storm water
• wee beasties
What is the Stuff in Municipal Wastewater?

- Water (> 95%)
- Pathogens (bacteria, viruses, prions and parasitic worms)
- Non-pathogenic bacteria
- Organic particles (feces, hairs, food, vomit, paper fibers, plant material)
- Soluble organic material (urea, fruit sugars, soluble proteins, drugs)
- Inorganic particles (sand, grit, metal particles, ceramics)
- Soluble inorganic material (ammonia, salt)
- Animals (protozoa, insects, arthropods, small fish)
- Macro-solids (sanitary towels, diapers, condoms, needles, children's toys, dead pets, body parts)
- Gases (hydrogen sulfide, carbon dioxide, methane)
- Emulsions (paints, adhesives, mayonnaise, hair colorants, emulsified oils)
- Toxins (pesticides, poisons, herbicides)
How Do We Measure Stuff in Wastewater?

Biochemical Oxygen Demand
Total Suspended Solids
Nitrogen
Phosphorous
Chloride
<table>
<thead>
<tr>
<th></th>
<th>Mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical Oxygen Demand</td>
<td>200</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>200</td>
</tr>
<tr>
<td>Nitrogen (total)</td>
<td>40</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>10</td>
</tr>
<tr>
<td>Chloride</td>
<td>50</td>
</tr>
</tbody>
</table>
Evolution of Waste Management
Evolution of Waste Management:
Driving Issues

#1. Smell
#2. Infectious Disease
#3. Chronic Health Risks
#4. Environmental Concerns
Waste Management:
10,000 BC

Nomadic Tribes: MOVE
City of Ur (Mesopotamian Capital in Iraq):
Swept waste into the streets

When street level rises, raise the doors
2500 BC

Indus Valley (Pakistan): Ahead of Their Time

- Drainage systems
- Some houses had water-flushing toilets
- Houses had rubbish chutes, and there were rubbish bins placed around the city for refuse disposal
- Great leap in waste management
2100 BC

City of Hierakopolis (Egypt)

Waste generally swept into streets, but rich & religious people put waste into rivers
1700 - 1500 BC

King Minos of Crete, also ahead of his time--
Running water in palace bathrooms,
Baths filled & emptied w/ clay pipes
320 BC

Athens (Greece):
First known edict banning disposal of refuse in the streets

300 BC: City collects waste, charges landowners

The early Greeks understood the relationship between water quality and general public health. This concern was passed onto the Romans.
600 BC - 400 AD

Ancient Rome

Aqueducts
Cloaca Maxima (the Great Sewers)
Waste to Rivers (Tiber, Rome)
Public Baths
Flush Toilets (not seen again until ~1600)
Romans Raise the Bar

- 11 public baths
- 1300 public fountains
- 856 private baths
- 144 public water-flushed toilets
The Fall of the Roman Empire

- End of running water in Europe for the next thousand years
- Depopulation, deurbanization
- Return to throwing waste into the streets
500 - 1500 AD: Bad Times

Drinking Water and Wastewater: Together Again

Raging epidemics, rampant disease and death

- dysentery, typhus, typhoid fever
- rats, ticks, fleas

Linkage between waste and disease forgotten

Rivers became sewers
14th Century: Time to Do Something, But What?

Following the major plagues of the 12th century, waste management became a priority.

1388: Act of English Parliament “forbade the throwing of filth and garbage into ditches, rivers, and water”

Legislation was ineffective, as offenders and offended alike were unable to devise adequate alternatives to the available methods of collection and disposal.

Except for those in heavily polluted areas, popular opinion was very much against such measures.
**Renaissance: 1500-1700**

- Renewed awareness of the link between sanitation and human health
- More laws about polluting streams
- Development of the Cesspool (pit that allows solids to settle and liquid to seep into the ground)

- Asphyxiation common due to hydrogen sulfide, oxygen deficiency
- Methane explosions
- Used "night soil" for fertilizer
- Small children harvested cesspit wastes
1700 - 1860

Increases in Awareness, Stagnation of Options

Chamber Pots into Street Gutters
Outhouses
Cesspools
Get it to the River
Chamber
Pot
Chamber Pots
The Outhouse

Latrine
Privy
Earth-closet
Dunny
Loo
Jake
Comfort Station
Earth-Pit
Privy

Design Criteria
6 feet deep
50 cu. ft.

“... lean-to roof has two less corners for the wasps to build their nests in...”
“..dig her deep and dig her wide..”
Two-Story Outhouse

for two-storied houses with two families
Sears Roebuck Catalogs, Newspapers, and Corn Cobs

packaged toilet paper, introduced in 1857, sold poorly
Privy is 8’ from well & 10’ from kitchen. Spring rains eroded deep hole around well which was then used for disposal of rubbish.
Outhouses in Australia
1950
New Zealand 2004 - Loo with a View
The Jet-Propelled Outhouse
The Space Shittle
The Space Shittle
The Out-in-the-Open Outhouse
• Say before entering the toilet: In the name of Allah, O Allah! I seek refuge with You from all offensive and wicked things
• One should enter the toilet with the left foot and leave with the right foot.
• It is not permissible to enter the toilet whilst carrying or wearing anything bearing the name of Allah, such as the Quran, or any book with the name of Allah in it, or jewelry such as bracelets or necklaces engraved with the name of Allah.
• One should remain silent whilst on the toilet. Talking, answering greetings or greeting others is forbidden.
• One should not face nor turn your back on Mecca whilst relieving yourself. One should sit at 90 degrees.
• One should be out of sight of people when going to the toilet.
• It is forbidden to relieve oneself whilst standing up, lying down or if you are completely nude.
• One should avoid going to the toilet anywhere where people may take rest or gather for any purpose.
• Do not raise clothes until you get close to the ground and do not uncover the body any more than is needed.
• One should sit on the feet (e.g. squat) keeping thighs wide apart with the stress on the left foot.
• Do not look to the private parts of the body nor the waste matter passed from the body.
• Do not sit more than needed.
• Do not spit, blow nose, look hither and thither, touch the body unnecessarily nor look towards the sky but relieve oneself with the eyes downcast in modesty.
• After relieving oneself it is essential to perform Istinjaa (washing with water) of the anus and/or genitals with the left hand and water. The precise mode of performing Istinjaa has also been defined by religious leaders.
• Other than toilet paper, water and the left hand Istinjaa can be performed with earth, grit, stones and worn-out cloths provided they are all clean. It is forbidden to perform Istinyaa with bone, any edible item, dry dung, baked brick, potsherd, coal, fodder, writing paper and anything which has even a small value.
• After this process the hands should also be washed.
• When leaving the toilet one should say the following prayer: Praise be to Allah who relieved me of the filth and gave me relief.
Meanwhile,
Back in the 19th Century...
Cholera
Worldwide epidemic in 19th Century

1832 in New York
1854 in London
Wastewater Treatment

- Screen
- Settle
- Skim
- Accelerate Natural Biological Processes
- Destroy Pathogens
1860 Louis Moureasa invents the septic tank

- Allows solids to settle out before liquid is discharged to the nearest stream or river
- Used for communities
- People also experimented with sand filters
Septic Tank

Invented by Louis Moureas in 1860

- Large scale: used to treat sewage from communities
- Purpose: “To remove gross solids before discharge into the nearest stream or river.”
**Septic Tank**

Unit Capacity:
- 4 to 16 people
- 500 - 2000 gallons
- 90 – 300 cubic feet

1–3 compartments

L/W: 3/1; D: 4-6 ft.

Scum, gas baffles

PVC Filter Vault

Fig. 51. A single-compartment septic tank.
Sub-Surface Disposal

- Gravel-filled Trenches
- Open-Joint Tiles
- Infiltration to Ground
- Biological Slime Formation
- Mineral Precipitates, FeS
- Release of Gases, H$_2$S, CH$_4$
- Soil Acceptance Rate
  - 0.3 to 0.5 gpd/sf
New York City: Early 1800’s

Drinking water from wells and cisterns

Private waste disposal (privies for temporary storage) “vault and haul”

Belief: *running water purifies effluent*

Potential for water pollution not recognized
Sewers initially developed for storm water
Limited water supply made water-based disposal unworkable
Water brought in by aqueduct
Sewers improved to handle new influx created by more water use
Connecting all houses to sewers took awhile
Connections achieved by public funding pushed by public health concerns

New York City: Late 19th Century
1900

Toilets and Water Carriage: The Birth of Sewage

Valveless Water Waste Preventer (aka toilet)
Indoor Plumbing
Demise of the Outhouse
Early Disposal of ‘Flushings’
Indoor Plumbing

circa 1900

to eliminate disease, fumes, explosions

T. J. Crapper’s Valveless Water Waste Preventer

“Pull and let go!”
Ventilation of House Drains
Air Pump and Smoke Generating Machines
Disconnecting Traps for Safety Purposes
Self-Rising Closet Seats
Cantilever Toilet
Flusherette Valve
Stair Treads
United States Population

1910: 92 million
38% sewered
89% of waste discharged untreated

1968: 197 million
70% sewered
11% untreated
Sewered Population

- U.S. Population
- Sewered Popul.

Graph showing the increase in U.S. population and sewered population over time from 1840 to 1980.
Disposal Systems – 1910
Unsewered Households

Residential Waste Disposal
Waste Quantities and Strength

Evolution of the Septic Tank

Soil Absorption Systems
# Residential Flow Rates

<table>
<thead>
<tr>
<th>Residences*</th>
<th>gallons/person/day</th>
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</thead>
<tbody>
<tr>
<td>Low Income</td>
<td>50</td>
</tr>
<tr>
<td>Median</td>
<td>60</td>
</tr>
<tr>
<td>Luxury</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Peak Flow Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
</tr>
<tr>
<td>Day</td>
</tr>
<tr>
<td>Hour</td>
</tr>
</tbody>
</table>

* Average: 3 residents per household
## Residential Water Use

<table>
<thead>
<tr>
<th>Category</th>
<th>Gallons / Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Use</td>
<td></td>
</tr>
<tr>
<td>Laundry</td>
<td>25</td>
</tr>
<tr>
<td>Dishwashing</td>
<td>10</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5</td>
</tr>
<tr>
<td>Personal (per capita) Use</td>
<td></td>
</tr>
<tr>
<td>Bathing</td>
<td>20</td>
</tr>
<tr>
<td>Toilet Flushing</td>
<td>17</td>
</tr>
<tr>
<td>Cooking and Drinking</td>
<td>3</td>
</tr>
</tbody>
</table>
Unsewered Systems

On-Site Treatment and Disposal
Flow Range: 0.2 to 2 m³/ day

Septic Tanks (Settling; Fermentation)
1 to 2 day retention; 2 meters deep
scum, sludge removal every 6 to 12 months
sludge to lagoons, earth-covered trenches
or plowed into land after partial drying on surface
Soil absorption systems for tank overflow
Waste Disposal
1920-1950

Sewage Collection (Sewerage)

Sewage Treatment:
Imhoff Tanks
Primary Treatment
Chemical Precipitation
Karl Imhoff

Sewers: Open ditches with concrete slabs
Two-Storied Settling and Digestion Tanks
The Arithmetic of Sewage Treatment Works
US Public Health Service Training Slides from 1950
Imhoff Tank Treatment Plant

Population: 1000

40,000 gpd
RAW SEWAGE → BAR SCREEN → IMHOFF TANK → SLUDGE DRYING BED
Manually-Cleaned Bar Rack
Imhoff Tank
Settling Compartments and Gas Vents
Gas Rising from Gas Vent
Raw Sludge Drying Beds
Sewage Effluent entering Stream

50% Suspended Solids Removal
50% Reduction in Oxygen Demand
Primary Settling and Disinfection
PRIMARY SETTLING WITH SEPARATE SLUDGE DIGESTION

RAW SEWAGE → BAR SCREEN → SETTLING TANK → CHLORINATOR

SLUDGE DRYING BEDS → SLUDGE DIGESTER
Primary Treatment 4,500 / 0.5 mgd

- Prechlorination (odor control)
- Primary Clarifiers
- Chlorine Contact Chamber
- Heated Sludge Digester
- Sand Drying Beds
Prechlorination and Sampling
Dual, Manually-Cleaned Bar Screens
Rectangular, Mechanically-Cleaned Clarifiers
Scum Removal
Effluent Sampling
Imhoff Cones
Heated Sludge Digester
• Anaerobic conditions
• Volatile solids converted to CO$_2$ and methane
Digested Sludge Goes to Sand Drying Beds
Chemical Treatment
Grit Removal, Comminution

Diagram:
- Raw Sewage
- Grit Chamber
- Fill
- Bar Screen
- Bypass
- Comminutor
Lime + Ferric Chloride

Chemical Treatment

Coagulants

Coagulating Basin

Settling Basin

Chlorine

Flash Mixer
Sludge Treatment

- Fertilizer
- Covered Drying Beds
- 2nd Stage Secondary Digester
- 1st Stage Primary Digester
Lime Feeder
Ferric Chloride
FeCl₃ + Lime Feed
Chemical Treatment Basin
Coagulated Sewage
Physical Treatment

Solids Removal
Activated Sludge Plant
Aeration Tanks
Covered Drying Beds
Return Sludge, Mixed Liquor
Plant Performance
Pollution Control Legislation

1948  Water Pollution Control Act
1956  Fed. Water Pollution Control Act
1961  Amendments to FWPCA
1965  Water Quality Act
1966  Clean Water Restoration Act
1970  USEPA Established
1972  FWPCA Approved
1981  Construction Grants Amendments
1987  Water Quality Act
Secondary Treatment

Activated Sludge

Trickling Filters

Rotating Biological Contactors
Trickling Filters
Trickling Filters

- Bed of rocks, fist size (lots of air spaces)
- Water from primary treatment trickles over rocks
- Rocks coated with slime of aerobic organisms
- Bacteria aerobically digest organic solution
Rotating Biological Contactors

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Rotating Biological Contactors

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After 1972:  
Process Optimization

Complete Mix Activated Sludge  
Step Aeration  
Contact Stabilization  
Extended Aeration  
Oxidation Ditch  
Kraus Process  
Pure-Oxygen Activated Sludge
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-Oxygen Activated Sludge

Organic load and oxygen demand are uniform throughout the tank

Standard plug flow activated sludge
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-Oxygen Activated Sludge
  • Influent introduced at multiple points
  • Equalizes the food to microorganism ratio (F/M)
  • Lowers peak oxygen demand
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-Oxygen Activated Sludge

• Separate aeration of activated sludge
• Aeration requirements reduced by 50%
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-Oxygen Activated Sludge

- low organic loading
- long aeration time
- small, prefabricated package plants
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-O

- Ring or oval-shaped channel
- Mechanical aeration and circulation devices
- Extended aeration
- Long detention times
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-Oxygen Activated Sludge

- Variation of Step Aeration process
- Used for WW with low nitrogen levels
- Sludge digester supernatant added to RAS as nutrient source
Process Optimization

Complete Mix Activated Sludge
Step Aeration
Contact Stabilization
Extended Aeration
Oxidation Ditch
Kraus Process
Pure-Oxygen Activated Sludge
• High-purity oxygen is used instead of air in the activated sludge process
• Series of complete mix reactors with gas recirculation compressors
• Used with high-strength waste and limited available space
New Treatment Goals and Advanced Waste Treatment

- Disinfection
- Dechlorination
- Trickling Filters
- Rotating Biological Contactors
- Phosphorous Removal
- Ammonia Removal
Advanced Waste Treatment

Phosphorus Removal
Ammonia Removal
Wetlands
Phosphorus Removal

Biological Removal

Lime Precipitation

Aluminum Sulfate Flocculation and Precipitation
Phosphorus Removal
Phosphorus is Food for Algae

Biological Removal: Manipulation of conditions to maximize biological uptake of phosphorus ("luxury uptake")

Lime Precipitation
Aluminum Sulfate Flocculation and Precipitation
Phosphorus Removal

Biological Removal

Lime Precipitation: High pH precipitates CaCO$_3$, P

Aluminum Sulfate Flocculation and Precipitation
Phosphorus Removal

Biological Removal

Lime Precipitation

Aluminum Sulfate Flocculation and Precipitation:
Precipitates aluminum phosphate
Ammonia (Nitrogen) Removal
It’s Algae Food, Too

Physical Removal
- sedimentation
- gas stripping

Chemical Removal
- breakpoint chlorination
- ion exchange

Biological Removal
- activated sludge process
- trickling filter
- rotating biological contactor
- oxidation pond
- land treatment processes (overland flow)
- wetland treatment systems (Hyacinth cultures)
Wetlands

- Water flows through ponds (wetland cells)
- Nutrients are taken up by cattails
Effluent Disinfection

To inactivate waterborne pathogens
(typhoid, dysentery, cholera, etc.)

1900: 25,000 typhoid deaths
1960: 20 typhoid deaths
Disinfection of Wastewaters

- Chlorine
- Ultraviolet Light
- Chlorine Dioxide
- Ozone
- Bromine
# Chlorine Dosages

**MDNR Design Guide**

<table>
<thead>
<tr>
<th>Type of Treatment</th>
<th>Chlorine, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trickling Filter Plant</td>
<td>10</td>
</tr>
<tr>
<td>Activated Sludge Plant Effluent</td>
<td>8</td>
</tr>
<tr>
<td>Tertiary filtration effluent</td>
<td>6</td>
</tr>
<tr>
<td>Nitrified Effluent</td>
<td>6</td>
</tr>
</tbody>
</table>

(15 minutes minimum contact time)
Why Dechlorinate?
To protect aquatic life

Persistent chloramine - toxicity to fish:
Resistant species < 0.01 mg Cl/l
Trout, salmon < 0.002 mg Cl/l
Dechlorination

Reducing agents:

- sulfur dioxide: $\text{SO}_2$
- sodium bisulfite: $\text{NaHSO}_3$
- sodium sulfite: $\text{Na}_2\text{SO}_3$
- sodium thiosulfate: $\text{Na}_2\text{S}_2\text{O}_3$
UV Disinfection

I already talked about it this morning.
It’s pretty cool.
GENTS TOILET

पुरुषांकरीता प्रसाधनगृह
Japan
Lake Biwa Environmental Monitoring Station

Lake Biwa
• Japan’s largest lake
• Water source for 14 million people
• Ordinance Concerning the Prevention of Eutrophication of Lake Biwa (1979)
Ordinance Concerning the Prevention of Eutrophication of Lake Biwa (1979)

- prohibited detergents containing phosphorus
- regulated wastewater from factories
- expansion and improvement of sewer system
- advanced treatment of sewage to remove nitrogen and phosphorus
Hello, Toto
Konan-Chubu Water Reclamation Plant
Built on a reclaimed island using dredged soil


Present Capacity: 50 MGD
Design Capacity: 209 MGD
## Plant Performance

<table>
<thead>
<tr>
<th>mg/l</th>
<th>INFLUENT</th>
<th>EFFLUENT</th>
<th>REMOVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>180</td>
<td>0.7</td>
<td>99.6%</td>
</tr>
<tr>
<td>TSS</td>
<td>184</td>
<td>0.6</td>
<td>99.7%</td>
</tr>
<tr>
<td>COD</td>
<td>94.5</td>
<td>5.6</td>
<td>94.0%</td>
</tr>
<tr>
<td>Total N</td>
<td>31.1</td>
<td>5.4</td>
<td>82.6%</td>
</tr>
<tr>
<td>Total P</td>
<td>3.38</td>
<td>0.04</td>
<td>98.8%</td>
</tr>
</tbody>
</table>
Konan-Chubu Plant
Flow Diagram
Control Room
指南呼叫
急速砂ろ過池（Rapid Sand Filter）

砂の層を通ることによって最終処理池で除去されてなかった懸濁物（一層小さな砂）が取り除かれます。

①ろ材構成

最終処理池の上澄水は、①のろ材を通過して急速砂ろ過池へ導入します。導入水は、下向きに流れることの砂を通過し、ポンプにより最終処理へ導かれます。導入水は、導入した砂を通過させ、ろ材が通過した時の懸濁物を除去します。ろ材が通過した懸濁物を通過させ、最終処理へ導かれます。
Covered Gravity Thickener
Sludge Dehydrator
Kerosene Furnaces
Slag

- Strength equivalent to natural stone
- TCLP (Leaching test) < detection levels
Slag

Concrete pipes
Blocks
Bricks
Pavers
Aggregate
Backfill
“Advanced waste treatment techniques in use or under development range from biological treatment capable of removing nitrogen and phosphorus to physical-chemical separation techniques such as filtration, carbon adsorption, distillation, and reverse osmosis.”

-EPA, May 1998
The Future of Wastewater Management

Don’t make so much?
How to Not Make So Much

Graywater Recycle Systems
Composting Toilets
Solar Toilets
Sawdust Toilets (bucket and chuck it)
Incinerating Toilets
Urine Diversion Toilets
Graywater Recycle Systems: Water from bath, shower, washing machines, bathroom sinks is used for irrigation
Bucket and Chuck It

Sawdust Toilets
Solar Toilet
The Future of Wastewater Management

Don’t make so much?

When we’re forced to.