Lecture 1

Introduction to water and wastewater treatment processes

Significant dates in public water supply

97  Inhabitants in ancient Rome use about 38 gpcd
1619 New River Company first to supply each home directly with its own water for a few hours per day
1854 John Snow establishes source of cholera epidemic in London as a contaminated supply well – first understanding of water and health
1873 Continuous supplies in general use in London
1900 Most cities have a water supply with service pipes to homes


Per capita use (l/d/cap)


Domestic water use by state


Water Consumption (gpd/cap)


Figure by MIT OCW.

Figure by MIT OCW.
Daily min-max temperature, precipitation & water use in New York City for 1982. Precipitation
Total water use mgd

Deviations from annual average water use versus average daily temperature for 1982 & 1983

Figure by MIT OCW.

Figure by MIT OCW.


Daily water use - 1940


Figure by MIT OCW.

Figure by MIT OCW.

**Chattahoochee Water Treatment Plant – Intake Structure**

**Chemical Addition / Disinfection**

- Alum: Promote flocculation
- Sodium Hypochlorite: Disinfection

**Chemical mixing**

**Flocculation / Sedimentation**

Courtesy of Joe Lin. Used with permission.
Flocculation tank

Sedimentation tank (clarifier)

Sedimentation tank collection troughs

Filtration

Courtesy of Joe Lin. Used with permission.
Post-Treatment Chemical Addition

Fluoride: To prevent tooth decay
Lime: To raise the pH
Phosphoric acid: To prevent corrosion of piping in the distribution system
Sodium hypochlorite: To maintain disinfection residual in distribution system

Ground-water drinking water treatment plants

Disinfection and fluoridation

Iron and manganese removal

Softening

West Bridgewater, MA water distribution system

Image removed due to copyright reasons.


Figure by MIT OCW.


Figure by MIT OCW.
### Pollutants in domestic wastewater

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>High strength</th>
<th>Medium strength</th>
<th>Low strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS, Total suspended solids (mg/L)</td>
<td>120</td>
<td>210</td>
<td>400</td>
</tr>
<tr>
<td>BOD, 5-day biochemical oxygen demand (mg/L)</td>
<td>110</td>
<td>190</td>
<td>350</td>
</tr>
<tr>
<td>Ammonia nitrogen (mg/L as N)</td>
<td>12</td>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>Organic nitrogen (mg/L as N)</td>
<td>8</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Total phosphorus (mg/L)</td>
<td>4</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Oil and grease (mg/L)</td>
<td>50</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>Total coliform bacteria (number/100 ml)</td>
<td>$10^6 - 10^8$</td>
<td>$10^7 - 10^9$</td>
<td>$10^8 - 10^{10}$</td>
</tr>
<tr>
<td>Fecal coliform bacteria (number/100 ml)</td>
<td>$10^5 - 10^8$</td>
<td>$10^7 - 10^{10}$</td>
<td>$10^8 - 10^{10}$</td>
</tr>
<tr>
<td>Cryptosporidium oocysts (number/100 ml)</td>
<td>0.1 - 1</td>
<td>0.1 - 10</td>
<td>0.1 – 100</td>
</tr>
<tr>
<td>Giardia lamblia cysts (number/100 ml)</td>
<td>0.1 – 10</td>
<td>0.1 - 100</td>
<td>0.1 - 1000</td>
</tr>
</tbody>
</table>


![Typical wastewater treatment plant](image)

**Figure by MIT OCW.**


Can also have tertiary treatment to remove nutrients and other pollutants.
Lynn, MA wastewater treatment plant

Primary clarifiers

Primary clarifiers – sludge scrapers

Primary clarifiers – effluent weir
**Virtual tours of wastewater plants**

- Lynn, Massachusetts – [http://members.aol.com/erikschiff/prelim.htm](http://members.aol.com/erikschiff/prelim.htm)
LECTURE 1
INTRODUCTION TO WATER QUALITY AND TREATMENT, OVERVIEW OF WASTEWATER AND TREATMENT PROCESSES

Water supply

Slide 2 - Volumetric water use in the United States
US is in a relatively water-rich part of the world, although there are obviously local exceptions

Slide 3 - Per capita use for domestic water supply
US is one of largest water users – using 600 l/cap/day = 160 gal/cap/day

Slide 4 – Significant events in history of water supply
Most of the world still does not have centralized water supply with connections to individual households
According to the World Health Organization roughly 1 billion of the world’s 6 billion people do not have access to an improved water supply.
Access to water-supply services is defined as the availability of at least 20 litres per person per day from an "improved" source within 1 kilometre of the user's dwelling. An "improved" source is one that is likely to provide "safe" water, such as a household connection, a borehole, etc.
An improved water supply is defined as:
• Household connection
• Public standpipe
• Borehole
• Protected dug well
• Protected spring
• Rainwater collection
Only 48% of the world’s population is connected at the household level.

Slides 5, 6, & 7 – Dr. John Snow’s analysis of cholera deaths in London in 1854.
First study to show connection between contaminated water and impaired public health
Slides 8 & 9 - Patterns of water use
Total US water use increased steadily until 1980s, but largely due to cooling water use for electric power
Rate of increase exceeded rate of population increase
Since 1980s water use has leveled off despite population increase
Slide 9 – increase of public water supply has been slower but unabated

Slide 10 - Sources of drinking water in US
Ratio of 3:1 surface water:ground water for overall use but heavier reliance on ground water for public water supply

Slides 11 & 12 – Large geographical variation within US
Greater domestic water use in arid areas – mostly for landscaping
Note low use in Virgin Islands – established practice of conservation: “In this land of fun and sun, we don’t flush for number 1"
Maine - ???
Slide 12 – large variation also holds true for cities – Las Vegas has high water use for outdoor watering, not hotels as one might expect (Carmen Roberts, Vegas heading for ‘dry future’. BBC News, July 29, 2005. http://news.bbc.co.uk/1/hi/sci/tech/4719473.stm)

Slides 13, 14, & 15 – Johns Hopkins study of water use
Classic study completed in 1960s by Johns Hopkins University
Conducted 1961-66
Continuous monitoring of water use by 41 homogenous residential areas with 44 to 410 dwelling units and several apartment areas
Covered: 16 different water supply utilities, 11 metropolitan areas; 6 different climatic regions
Slide 13
Winter graph shows household usage – morning and early evening peaks
Summer graph shows potentially profound effect of sprinkling
Slide 14 shows summer usage with and without rainfall
Factors affecting water use:
Income – rich people use more water
Climate – more water is used in dry climates (for watering lawns)
Season – less water is used in winter than summer
Metering – metered customers used less water for watering lawns than those on flat rates
Slide 15 shows effect of metering on water use: little effect on household use but major effect on sprinkling

Slide 16 – Relation of water use to metering is not a new story – this graph is from textbook dated 1940
After the change in economic systems in eastern Europe, there was concern about how to bring wastewater treatment systems up to western standards. Many were highly overloaded before the change, but once the authorities started to charge for water, usage went down, wastewater went down, and overloaded plants were no longer overloaded

Slides 17, 18, & 19 – Study of effect of weather on New York City supply
Slide 17 – use during 1982 shows fairly constant use until it gets hot – above 72°F water use increases linearly with temperature
Slide 18 – shows same pattern in 1983
Slide 19 – pattern is absent in 1985 – why? Mandatory water conservation measures imposed by city

Slide 20 – pattern of daily water use has not changed appreciably over the years – curve for 1940 shows morning and afternoon peaks in usage

Slide 21 – shows that total usage increased, at least until around 1980

Slide 22 – despite prevalence of public water supply systems, about 20 percent of the US population is self supplied – usually by a ground-water well. This fraction has not changed appreciably for many decades.

Slides 24-33 - Walk-through of typical water treatment process

Slides 34&35 – Ground-water systems
Slide 34a – often minimal treatment is required
Slide 34b – Ground waters often high in iron and manganese (particularly in New England)
  Removed by oxidizing to insoluble iron oxide (rust) or manganese oxide, which precipitate and can be removed by filtration
  If not removed in treatment plant, iron and manganese precipitate in distribution system and cause staining of laundry, fixtures, etc.
Slide 35 – Deep, old ground waters are often highly mineralized and “hard” (high concentrations of Ca and Mg)
  Water is softened by adding lime (Ca(OH)\(_2\)) and soda ash (Na\(_2\)CO\(_3\))
  Recarbonation removes excess lime and prevents scaling of equipment and pipes

Slide 36 – Water distribution systems brings treated water to homes and businesses – not covered in this course

Wastewater

Slides 37 and 38 – water supply begets wastewater generation, usually with a pretty close correlation
Slide 37 – Exceptions are:
  water supply > wastewater when sprinkling use is great (e.g., Las Vegas, Los Angeles) and/or exfiltration from sewers is high
  water supply < wastewater when infiltration into sewers is high (perhaps Greenville County?)
Slide 38 – Johns Hopkins study confirms this on day with little sprinkling

Slide 39 – Most water used in the household becomes wastewater via various routes
  Consumption (drinking, cooking) is pretty negligible
  Toilets use the most, hence low-flow toilets are a good water conservation measure

Slide 40 – Daily flow curves are averages over many households – the flow from individual household is very episodic
  Under some circumstances, flow from individual homes can be coordinated:
    wastewater treatment plant workers in New York City claim to be able to tell the popularity of TV shows by the wastewater surge seen during commercials

Slide 41 – Wastewater quality
  BOD, TSS – for short-term effect on receiving water
N, P – for long-term effect (eutrophication) on receiving water
Oil and grease – for short-term effect
Pathogens – for effects on human health

Slide 42 – Variation in flow also causes variation in strength of wastewater – Why?
  At low flow, solids settle, reducing BOD concentration
  At high flow, solids get scoured from pipes, increasing BOD concentration

Slides 43-49 – Walk-through of typical wastewater treatment process

Slide 50 – Virtual tours of WWTPs: (really should be “scratch and sniff”)
  Lynn, Massachusetts – http://members.aol.com/erikschiff/prelim.htm
  Lexington, Kentucky – http://www.lfucg.com/sewers/TBTour.asp