Wastewater Treatment Processes

(Sep 12th-15th, 2016)
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Objective: To learn about processes used in wastewater treatment plant

Courtesy: Dr. Irene Xagoraraki, MSU, USA
Minor 1 copies

• Minor 1 copies next week Monday afternoon in different slots
• Slot timings will be emailed.
# Characteristics of Domestic Wastewater

## Typical Composition of Untreated Domestic Wastewater

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Wastewater characteristics

- Compare wastewater (WW) characteristics of
  - Domestic WW
  - Industrial WW (for ex: tannery industry; distillery industry)
Wastewater Management

Different sources

http://dnr.metrokc.gov/WTD/homepage/process.htm
Wastewater Management

www.oconomowocusa.com/wastewater.gif
Municipal Wastewater Treatment Systems

- **Preliminary treatment** (removes materials that can cause operational problems, equalization basins are optional)
- **Primary treatment** (remove ~60% of solids and ~35% of BOD)
- **Secondary treatment** (remove ~85% of BOD and solids)
- **Advanced treatment** (varies: 95+ % of BOD and solids, N, P)
- **Final Treatment** (disinfection)
- **Solids Processing** (sludge management)
Pre-Treatment of Industrial Wastewaters

• Industrial wastewaters must be pretreated prior to being discharged to municipal sewer system
• Pretreatment requirements set by regulatory agencies
• Why: remove materials that will not be treated by municipal system, remove materials that inhibit the biological processes in secondary treatment
• For example: silver ions are toxic to bacteria which might affect biological process. Thus silver ions are removed at pre-treatment before biological process so that bacterial performance do not get affected.
Basic Wastewater Treatment

Note down parameters removed in different unit processes and order of their removals

Preliminary Treatment → Primary Treatment → Secondary Treatment → Final Treatment and Solids Processing
Sludge Disposal

- Method depends on RCRA regulations

- Land Spreading
  - lawns, gardens
  - agricultural land
  - forest land
  - golf courses and other public recreational areas

- Municipal Solid Waste Landfill

Utilization in other materials

\[ Q_0, C_0 \]

\[ Q_{w}, X_{w} \]

\[ Q_{0,=} \text{flow rate} \]
\[ C_{0,=} \text{initial concentration} \]
\[ X=\text{biomass concentration} \]
\[ Q_{w}=\text{sludge withdrawal rate} \]
\[ X_{w}=\text{biomass concentration in secondary settling tank} \]
Preliminary treatment

Upon arrival via the sewer system, the wastewater is sent through a bar screen, which removes large solid objects such as sticks and rags.

Leaving the bar screen, the wastewater flow is slowed down entering the grit tank, to allow sand, gravel and other heavy material that was small enough not to be caught by the bar screen to settle to the bottom. All the collected debris from the grit tank and bar screen is disposed of at a sanitary landfill.
Primary treatment

Primary treatment is the second step in wastewater treatment. It allows for the physical separation of solids and greases from the wastewater. The screened wastewater flows into a primary settling tank where it is held for several hours allowing solid particles to settle to the bottom of the tank and oils and greases to float to the top.
Secondary treatment

- biological treatment process that removes dissolved organic material from wastewater. The partially treated wastewater from the settling tank flows by gravity into an aeration tank.

- mixing of water to solids containing that use oxygen to consume the remaining organic matter in the wastewater as their food supply (use of air bubble for mixing and oxygen supply)

- liquid mixture (i.e., solids with micro-organisms and water) is sent to the final clarifier.
- In clarifier, solids settle out to the bottom where some of the material is sent to the solids handling process and some is recycled back to replenish the population of micro-organisms in the aeration tank to treat incoming wastewater.
Final treatment

Treated water is disinfected and then it is send out for wastewater reuse activities or for discharging in river/streams. mostly chlorination and/or ultra violet irradiation is used for disinfection purposes.
Solids processing

The primary solids from the primary settling tank and the secondary solids from the clarifier are sent to a digester. Micro-organisms use the organic material present in the solids as a food source and convert it to by-products such as methane gas and water.

Digestion results in a 90% reduction in pathogens and the production of a wet soil-like material called “biosolids” that contain 95-97% water.

In order to remove some of this water, mechanical equipment such as filter presses or centrifuges are used to squeeze water from the biosolids to reduce the volume prior to being sent to landfill, incinerated or beneficially used as a fertilizer or soil amendment.
Wastewater Treatment

• **Preliminary Treatment (screening)**
• Primary Treatment (primary settling)
• Secondary Treatment (e.g. activated sludge)
• Advanced Treatment (e.g. P removal)
• Final Treatment (disinfection)
• Solids Processing (sludge treatment)
Bar racks

- Purpose: remove larger objects
- Solid material stored in hopper and sent to landfill
- Mechanically or manually cleaned
Grit Chambers

- Purpose: remove inert dense material, such as sand, broken glass, silt and pebbles
- Avoid abrasion of pumps and other mechanical devices
- Material is called “grit”
Equalization Basins

- Wastewater flow has daily fluctuations
- Purpose: To dampen the variation in wastewater flow into a WWTP
- Flow equalization is not a treatment process
- Improves effectiveness of primary & secondary treatment
- Usually achieved by large basins to collect wastewater and pumped to treatment plant at a constant rate
- Adequate aeration and mixing need to be provided to prevent odors and deposition of solids

Source: Davis and Cornwall, Introduction to Environmental Engineering, 2008
Wastewater Treatment

- Preliminary Treatment (screening)
- **Primary Treatment (primary settling)**
- Secondary Treatment (e.g. activated sludge)
- Advanced Treatment (e.g. P removal)
- Tertiary Treatment (disinfection)
- Solids Processing (sludge treatment)
Primary Treatment (settling)

- Primary treatment separates suspended solids and greases from wastewater. Wastewater is held in a tank for several hours allowing the particles to settle to the bottom and the greases to float to the top.
- The solids drawn off the bottom and skimmed off the top receive further treatment as sludge. The clarified wastewater flows on to the next stage of wastewater treatment.
Settling/Sedimentation

• Solid liquid separation process in which a suspension is separated into two phases –
  – Clarified supernatant leaving the top of the sedimentation tank (overflow).
  – Concentrated sludge leaving the bottom of the sedimentation tank (underflow).

• **Purpose of Settling**
  – To remove coarse dispersed phase.
  – To remove coagulated and flocculated impurities.
  – To remove precipitated impurities after chemical treatment.
  – To settle the sludge (biomass) after activated sludge process / tricking filters.
Some basic definitions

• **Sedimentation**, also known as **settling**, may be defined as the removal of solid particles from a suspension by settling under gravity.

• **Clarification** is a similar term, which usually refers specifically to the function of a sedimentation tank in removing suspended matter from the water to give a clarified effluent. In a broader sense, clarification could include flotation and filtration.

• **Thickening** in sedimentation tanks is the process whereby the settled impurities are concentrated and compacted on the floor of the tank and in the sludge-collecting hoppers.

• Concentrated impurities withdrawn from the bottom of sedimentation tanks are called **sludge**, while material that floats to the top of the tank is called **scum**.
Primary Settling Basins
Primary Settling Tank Design Example

- **Size:**
  - rectangular: 3-24 m wide x 15-100 m long
  - circular: 3-90 m diameter
- **Detention time:** 1.5-2.5 hours
- **Overflow rate:** 25-60 m$^3$/m$^2$·day
- **Typical removal efficiencies:**
  - solids: 50-60%
  - BOD$_5$: 30-35%
Example 1

Question: A rectangular primary clarifier (2.4 m deep & 4.0 m wide) is designed to settle a flow of 2000 m$^3$/day and have an overflow rate of 32 m$^3$/m$^2$.day

I) How long should it be?
II) What detention time will it have?
I) Length:

$$\text{Overflow rate} = \frac{\text{flow rate}}{\text{area}} = \frac{2000 \, \text{m}^3}{4 \, \text{m} \times \text{Length}} = 32 \, \frac{\text{m}^3}{\text{m}^2 \cdot \text{day}}$$

Solve for length: \[ \text{Length} = \frac{2000}{4 \times 32} = 15.6 \, \text{m} \]
II) Detention time:

\[
\text{Detention time} = \frac{\text{volume}}{\text{flow rate}} = \frac{2.4 \text{ m} \times 4 \text{ m} \times 15.6 \text{ m}}{2000 \frac{\text{m}^3}{\text{day}} \times \frac{\text{day}}{24 \text{ hr}}} = 1.8 \text{ hr}
\]
Wastewater Treatment

- Preliminary Treatment (screening)
- Primary Treatment (primary settling)
- **Secondary Treatment (e.g. activated sludge)**
- Advanced Treatment (e.g. P removal)
- Final Treatment (disinfection)
- Solids Processing (sludge treatment)
Secondary Treatment

- Secondary treatment is a biological treatment process that removes dissolved organic matter from wastewater.
- Sewage microorganisms are cultivated and added to the wastewater. The microorganisms use organic matter from sewage as their food supply. This process leads to decomposition or biodegradation of organic wastes.
Secondary Treatment

• Basic approach is to use **aerobic biological degradation:**

\[
\text{organic carbon} + \text{O}_2^{\text{microorganisms}} \rightarrow \text{CO}_2 + \text{new cells}
\]

• Objective is to allow the BOD to be exerted in the treatment plant rather than in the stream
How is this accomplished?

Create a very rich environment for growth of a diverse microbial community
Basic Ingredients

- High density of microorganisms (keep organisms in system)
- Good contact between organisms and wastes (provide mixing)
- Provide high levels of oxygen (aeration)
- Favorable temperature, pH, nutrients (design and operation)
- No toxic chemicals present (control industrial inputs)
Dispersed (suspended) growth vs Fixed growth

• Two approaches of secondary treatment
  – fixed film, and suspended film systems
• Dispersed Growth (suspended organisms)
  – Activated sludge
  – Oxidation ditches/ponds
  – Aerated lagoons, stabilization ponds
• Fixed Growth (attached organisms)
  – Trickling filters
  – Rotating Biological Contactors
Activated Sludge

• Process in which a mixture of wastewater and microorganisms is agitated and aerated
• Leads to oxidation of dissolved organics
• After oxidation, separate sludge (mostly microbial cells, water, and other contaminants) from wastewater
• Induce microbial growth
  – Need food, oxygen
  – Want Mixed Liquor Suspended Solids (MLSS) of 3,000 to 6,000 mg/L
Activated Sludge Process

http://www.geocities.com/RainForest/5161/wwtps.htm
Activated Sludge Process

- Raw wastewater enters the Mixed Liquor tank.
- Air is added to promote biological activity.
- Return Activated Sludge (RAS) is circulated for treatment.
- Waste Activated Sludge (WAS) is also utilized for treatment.
- Treated wastewater is produced and can be discharged to the River or used for Land Application.

Key terms:
- Activated Sludge Process
- Mixed Liquor
- Secondary clarifier
- Discharge to River or Land Application
Activated Sludge Process with secondary clarifier

East Lansing WWTP

East Lansing WWTP
F/M Parameter

• Low F/M (low rate of wasting)
  – starved organisms
  – more complete degradation
  – larger, more costly aeration tanks
  – more $O_2$ required
  – higher power costs (to supply $O_2$)
  – less sludge to handle

• High F/M (high rate of wasting)
  – organisms are saturated with food
  – low treatment efficiency
Activated Sludge Design

- **Detention time**: $t_d$ = approximately 6 - 8 hr
- Long rectangular aeration basins
- Air is injected near bottom of aeration tanks through system of diffusers
- Aeration system used to provide mixing
- MLVSS and F/M controlled by wasting a portion of microorganisms
Other options
Low-tech solutions

- Aerobic ponds
- Facultative ponds
- Anaerobic ponds
1. Aerobic ponds

- Shallow ponds (<1 m deep)
- Light penetrates to bottom
- Active algal photosynthesis
- Organic matter converted to CO₂, NO₃⁻, HSO₄⁻, HPO₄²⁻, etc.
2. Facultative ponds

- Ponds 1 - 2.5 m deep
- $t_d = 30 - 180$ days
- Not easily subject to upsets due to fluctuations in $Q$, loading
- Low capital, O&M costs
3. Anaerobic Ponds

- Primarily used as a pretreatment process for high strength, high temperature wastes
- Can handle much high loadings
- 2 stage:
  - Acid fermentation: Organics $\rightarrow$ Org. acids
  - Methane fermentation Org. Acids $\rightarrow$ $\text{CH}_4$ and $\text{CO}_2$
Example 1: Performance of a “AA” WWTP

*(Grit chamber → PST → Activated sludge unit → SST → Nitrification unit → Effluent)*

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**Question:** Find out efficiency of different unit processes; remaining conc. of different parameters? Is it meeting the standards of river? How much is sludge generation? What information are required?
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<td>=(300-250)*100/300</td>
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<td><strong>Conc. Of bacteria in SST</strong></td>
<td>10000mg/L</td>
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<td><strong>Sludge withdrawal rate from SST</strong></td>
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September 27, 2016
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