Game Changing Education

- Based on ABC’s Need-to-Know criteria
- Utilizes WEF publications
- Reflects current knowledge
- Peer-reviewed
- Represents the expertise of hundreds of water quality professionals.
Real World Photos
All in full color!
Accessible Language

- Nitrification is the two-step biological oxidation of ammonia nitrogen to nitrite and nitrate using oxygen as a terminal electron acceptor.
- Some bacteria obtain energy from ammonia (NH₃) or nitrite (NO₂). This process is called nitrification.
CHAPTER 1

Introduction to Wastewater Treatment

Introduction
This chapter discusses the need for wastewater treatment, presents a brief overview of some of the pollutants in wastewater, reviews the various laws and regulations applicable to the permitting of water resource recovery facilities (WRRFs), describes the typical unit processes used to provide safe and acceptable treatment of wastewater, and discusses treatment and disposal alternatives for the solids removed from wastewater. To be consistent with the evolution of federal and state terminology, this manual uses the term sludge to refer to solids separated from wastewater during treatment and the term biosolids to refer to sludge after processing criteria have been achieved (i.e., at the outlet of the stabilization process).

LEARNING OBJECTIVES
Upon completing this chapter, you will be able to:
- Understand the need for wastewater treatment.
- List some of the components of domestic wastewater.
- Identify major unit processes of domestic WWTP.
- Understand the linkages between the liquid stream and solids handling sides of a WRF. Label appropriately.
- Draw an example WRF, clearly label the main unit processes, and give the function of each.
- Draw a typical natural treatment system and a typical mechanical treatment system.
- Describe the permitting requirements of the Clean Water Act (CWA) and the biosolids S03 regulations.

What’s in a Name?
When the CWA was passed in 1972, it referred to publicly owned treatment works (POTWs). The term POTW didn’t just include the treatment facility, but also all of the upstream infrastructure necessary to convey wastewater to the facility, including collection system pipes and lift stations. The CWA and legislation in many states still use the term POTW. Over the years, as our industry has worked to convey to the public the valuable services we provide, the name of a treatment facility has evolved from POTW to wastewater treatment plant or wastewater treatment facility to water reclamation facility and, finally, to water resource recovery facility (WRRF). The term WRRF was officially adopted by the Water Environment Federation in 2014 because it

Unit processes are a way of talking about distinct treatment steps within a treatment facility. An example of a unit process is a grit basin. A grit basin is a tank where the velocity of incoming wastewater is slowed down to approximately 0.3 m/s (1 ft/sec) to allow large particles of sand and gravel to settle by gravity.
Tons of Practice Questions!

• True/False
• Multiple Choice
• Fill in the Blank
• Matching
• Label a Diagram
• Perform Calculations

13. This term is used to describe a collection of microorganisms growing on and attached to a media surface such as a rock.
   a. Floc
   b. Slime
   c. Biofilm
   d. Algae

14. In a pond treatment system, what is the purpose of the last pond in the series?
   a. Increases the risk of short-circuiting
   b. Removes the biological solids produced in the first two ponds
   c. Warms the wastewater before discharge
   d. Acts as a primary clarifier or grit basin

15. What is the primary difference between a pond treatment system and an activated sludge system?
   a. Activated sludge recycles settled solids to the beginning of the process.
   b. Pond treatment systems use specialized, cold-tolerant bacteria.
   d. Pond treatment systems perform better at higher elevation.

16. For an activated sludge system, which of the following statements is FALSE?
   a. Activated sludge requires less time to treat wastewater than ponds.
   b. Activated sludge is a suspended growth biological process.
   c. Activated sludge uses fungus to treat wastewater.
   d. Activated sludge holds the biological solids longer than the wastewater.

17. An example of a fixed-film treatment process is
   a. Activated sludge
   b. Pond
   c. Rotating biological contactor
   d. Clarifier

18. Which two methods of disinfection are most commonly used in domestic WRRFs?
   a. Ozone and chlorine
   b. Chlorine and UV light
   c. Bleach and ozone
   d. Ultraviolet light and boiling

19. Match the unit process to its place in the liquid treatment side.
   1. Collection system
   2. Gravitation basin
   3. Primary clarifier
   4. Activated sludge
   5. Chlorine addition

20. Draw a line from the liquid treatment type to its treatment goal.
   1. Primary treatment
   2. Primary treatment
   3. Secondary treatment
   4. Tertiary treatment
   5. Disinfection

   a. Reduce number of bacteria and pathogens
   b. Increase particle size for separation step
   c. Protect downstream equipment
   d. Remove nitrogen and phosphorus
   e. Decrease size and cost of secondary treatment
1. Shaft
2. Media Support
3. Bearing
4. Baffle
5. Tank
6. Media
CHAPTER 4

Primary Treatment of Wastewater Outline

► Learning Objectives
► Part I – Purpose
► Part II – Theory of Operation
► Part III – Design Parameters and Expected Performance

► Part IV – Circular Clarifier Components
  • Equipment Tank and Component Overview
  • Inlet and Feedwell
  • Outlets (Weirs)
  • Sludge Removal
  • Skimming System
  • Clarifier Drive
CHAPTER 4

Primary Treatment of Wastewater Outline

► Part V – Rectangular Clarifier Components
  • Equipment Tank
  • Inlet and Outlet (Weirs)
  • Sludge Removal and Clarifier Drive
  • Skimming System

► Part VI – Gates and Valves
► Part VII – Process Variables
► Part VIII – Process Control
► Part IX – Operation
CHAPTER 4

Primary Treatment of Wastewater Outline

► Part X – Process Control Data
► Part XI – Maintenance and Troubleshooting
► Part XII – Records and Safety
► Chapter Exercise
► Chapter Test
Learning Objectives

• Describe the purpose of primary clarification
• Categorize influent parameters according to whether they can be removed by primary clarification
• Label all components of circular and rectangular primary clarifiers and describe the function of each
• Inspect and maintain clarifier equipment
Learning Objectives

• Place a primary clarifier into service or remove one from service
• Calculate hydraulic detention time (HDT) and surface overflow rate (SOR)
• Determine the optimum number of clarifiers to place into service to maintain a desired SOR and HDT
• Estimate the quantity of sludge produced given primary influent and effluent total suspended solids (TSS) concentrations
Learning Objectives

• Calculate sludge pumping time required for a given sludge thickness and volume
• Collect process control samples, conduct settleable solids analysis, and evaluate results
• Anticipate seasonal changes and make appropriate process control changes
• Troubleshoot common mechanical and process control problems
Primary Treatment

- Removes readily settleable material by gravity in quiescent tanks
- Velocity of wastewater is reduced to a fraction of a meter per second (foot per second)
- Grease and floatable material is skimmed off
- Reduces chemical oxygen demand (COD), biochemical oxygen demand (BOD), and TSS load to the secondary treatment process
- Reduces size, energy use, and operating cost of secondary treatment process
Settleability

- Settleability is affected by a particle’s
  - Density
  - Size and shape (surface area and drag)
- Differences in density used to separate particles from water
- Particles that are more dense than water settle to the clarifier bottom
Flocculation

- Particles are granular (sand and silt) or flocculent
- Flocculent particles can increase in size through the process
- Detention time, in part, determines the amount of flocculation that can take place
- Chemicals may be added to increase flocculation
Forces at Work

- Gravity pulls particles down
- SOR is the velocity of water as it moves through the tank and over the weirs
- SOR pushes particles up and out
- For effective settling, SOR must be less than the settling velocity
Design Parameters

- Detention time of 1.5 to 2.5 hours
- Average SOR of 24.4 to 48.9 m³/m²·d (600 to 1200 gpd/sq ft)
- Peak hour SOR of 102 to 122 m³/m²·d (2500 to 3000 gpd/sq ft)
- Sludge blanket depth of 0.6 to 0.9 m (2 to 3 ft)
- Sludge concentration of 3 to 6% total solids
Expected Performance

• Highly dependent on influent characteristics
• Performance is also affected by SOR and HDT
• Typical removal rates for domestic wastewater:
  • 50 to 70% TSS
  • 25 to 40% BOD
  • 5 to 10% total phosphorus
• Primary clarifiers cannot remove soluble or colloidal material
Component Overview

• Feedwell and inlet – slows the influent current and directs flow toward the tank bottom to prevent short-circuiting

• Rake mechanism – pushes settled sludge toward a discharge pit called a sludge hopper, typically located near the clarifier center

• Skimmer arm – rotates on the surface to push floatables to a scum trough
Component Overview

- Clarifier drive – rotate the rake and skimmer
- Scum baffle – prevents floatable material from escaping over the weir
- Leaving the clarifier, cleaner water flows under the scum baffle, over the weirs, and into the effluent launder
Circular Claroifiers

Equipment Tank

- Circular tank up to 100 m (300 ft) in diameter
  - Usually less than 50 m (150 ft) to avoid the adverse effects of currents wind on the surface
- Depths of 3 to 4 m (10 to 12 ft)
- Floor slope of 1 on 12
- 0.5 to 0.7 m (1.5 to 2 ft) of freeboard typical
Figure 4.5

Circular Primary Clarifier Schematic

Reprinted with permission by Monroe Environmental [Monroe, MI] www.mon-env.com
Placing a Clarifier into Service

1. Remove any debris from the tank floor and sludge hopper
2. Inspect all equipment for wear and proper operation
3. Be sure the sludge collection drive mechanism is properly lubricated; for chain-and-flight mechanisms, ensure flights have not adhered to the bottom of the tank
4. Drain condensate from the clarifier drive; verify proper lubrication levels; check drive alignment
Placing a Clarifier into Service

5. Start the sludge collection mechanism in a dry tank
   • With a circular mechanism, observe several full rotations; check for scraping, binding, or jerking
   • With rectangular tanks, it may be necessary to add enough water to cover the flights and lower the sprockets before starting the mechanism; some rectangular tanks use water to lubricate the lower shaft bearings rather than oil
Placing a Clarifier into Service

6. Adjust plows or flights if necessary
7. Be sure ancillary equipment is in good operating condition
8. Open slide gates or valves at the clarifier outlet followed by the clarifier inlet
9. When the sludge hopper is full, start the primary sludge pumps and allow them to operate for one full cycle; verify that the pumps are functioning properly
10. Continue filling the tank and place all equipment into automatic operation
Records and Reports

- Number of tanks in operation
- Equipment run times
- Sludge blanket levels
- Pumping time
- Operator and shift
- Housekeeping checklist
- Chemicals used (if applicable)
- Primary influent and effluent suspended solids concentrations
- COD or $\text{BOD}_5$ concentrations of primary influent and effluent
- Total solids and TVS concentrations in the sludge
- Flowrates of the influent, effluent, and sludge
- pH
- Temperature
Maintenance Overview

- Daily observation for visual and audible indications of malfunction
- Regular maintenance should be performed in accordance with the manufacturer’s recommendations
- Dewater the clarifier and perform a complete inspection of all equipment annually
- Perform other maintenance tasks daily, weekly, monthly, or as required by the manufacturer
- Maintain an inventory of spare parts
## Sample Drive Maintenance Log

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Interval</th>
<th>Initials</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Break-In Maintenance Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drain and Fill Oil Cavity/Cavities</td>
<td>0 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drain and Replace Oil</td>
<td>500 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Preventive Maintenance Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease Cyclo Reducer</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease Upper Bearing</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease Main Bearing</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Main Gear/Lower Bearing</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Torque Box Plunger</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inspection Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspect Fasteners for Tightness</td>
<td>M/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visually Inspect Drive Mech. for Wear</td>
<td>W/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Torque Box Limit Switches</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check/Drain Condensate</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check/Drain Particulates</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspect/Repair Drive Unit Paint</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspect Torque Control Device</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** This maintenance information is provided by WesTech Engineering Inc. as an example. It is not intended to be utilized as is by any plant. Each plant should develop its own schedule and log, specific to the equipment at the facility.

- A – Annually
- S – Semiannually
- M – Monthly
- W – Weekly
- D – Daily
# Troubleshooting Guide for Primary Clarifiers

<table>
<thead>
<tr>
<th>Indicators / Observations</th>
<th>Probable Cause</th>
<th>Check or Monitor</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floating Sludge</td>
<td>Excessive sludge accumulating in the tank</td>
<td></td>
<td>Remove sludge more frequently or at a higher rate</td>
</tr>
<tr>
<td></td>
<td>Scrapers worn or damaged</td>
<td>Inspect scrapers</td>
<td>Repair or replace as necessary</td>
</tr>
<tr>
<td></td>
<td>Return of well-nitrified waste activated sludge</td>
<td>Effluent nitrates</td>
<td>Reduce age of returned sludge or move point of waste sludge recycle</td>
</tr>
<tr>
<td></td>
<td>Sludge withdrawal line plugged</td>
<td>Sludge pump output</td>
<td>Flush or clean line</td>
</tr>
<tr>
<td></td>
<td>Damaged or missing inlet baffles</td>
<td>Damaged baffles</td>
<td>Repair or replace baffles</td>
</tr>
</tbody>
</table>
Hydrogen sulfide is poisonous, corrosive to concrete and metal, and potentially explosive. Methane gas, which is even more explosive, may accompany hydrogen sulfide. These gases demand extreme caution and rigorous application of safety procedures.
Biological activity in sludge continues even when the sludge is within pumps and pipelines. This activity can generate hydrogen sulfide and methane gas. Sludge should never be allowed to sit undisturbed in pipelines and pumps. It is extremely important to be flush all lines and pumps to be sure they are clean before taking them out of service. This includes pump rotation where a pump may only be out of service for several days. Failure to properly clean and store equipment can result in excessive gas buildup, which may explode.
Operator Tip

• Most drives have two limit switches and may have a shear pin as a third level of protection.

• High-high torque warning switch will turn off the drive motor to protect it from overload.

• If the limit switches do not engage, the shear pin will break.
**NOTE**

*Colloidal solids* are particles that are between 1 and 1000 µm in diameter. They are too small and light to settle to the bottom of the clarifier in the time allowed. Colloidal particles are measured in the total dissolved solids test even though they are not truly dissolved.
Surface Overflow Rate, \[ \frac{\text{m}^3}{\text{m}^2 \cdot \text{d}} = \frac{\text{Flow, m}^3/\text{d}}{\text{Surface area, m}^2} \]

*Example calculation in the Chapter 4 handouts*
Surface Overflow Rate, \( \frac{\text{gpd}}{\text{sq ft}} = \frac{\text{Flow, gpd}}{\text{Surface area, sq ft}} \)  

EQUATION 4.3

*Example calculation in the Chapter 4 handouts*
4.6
Test Your Knowledge

Chapter 4: Primary Treatment of Wastewater
Fillets are used to fill in the corners of square and octagonal clarifiers.

- True
- False
One potential disadvantage of an inboard launder is

a) Weir length is increased compared to an inset launder
b) Lack of a mounting location for the weir plate
c) Floatable material can become trapped under the launder
d) Difficulty in reaching both weir plates for cleaning
Label the components of the rectangular clarifier.
Find the SOR for a primary clarifier with a diameter of 36.6 m (120 ft) and an influent flow of 30.3 ML/d (8 mgd).
Chapter 4: Primary Treatment of Wastewater

CHAPTER EXERCISE
Water Resource Recovery Facility Information:

- The influent flow to the WRRF is 28.4 ML/d (7.5 mgd).
- The influent contains:
  - 315 mg/L of TSS, of which 50% is settleable
  - 280 mg/L of BOD, of which 84 mg/L is soluble
  - 7 mg/L of total phosphorus, of which 50% is soluble
- Assume that 50% of the particulate BOD and 50% of the particulate phosphorus are settleable.
Water Resource Recovery Facility Information:

- There are three primary clarifiers.
- Each clarifier is 24.4 m (80 ft) in diameter and 3.66-m (12-ft) deep.
- Each clarifier has a dedicated sludge pump with a capacity of 265 L/min (70 gpm).
- The settled sludge has an average total solids concentration of 3.5%.
Chapter Exercise

Estimate primary effluent BOD, TSS, and total phosphorus concentrations from laboratory data.
Chapter Exercise

STEP 1

Draw it out.

157.5 mg/L TSS

315 mg/L TSS
280 mg/L BOD
84 mg/L soluble BOD
7 mg/L TP
3.5 mg/L soluble P

84 mg/L soluble BOD
3.5 mg/L soluble P
Fifty percent, or half, or the TSS are settleable.

\[
\left(315 \frac{\text{mg}}{\text{L}} \text{TSS}\right)(50\%) = 157.5 \text{ mg/L}
\]
Half of the particulate BOD is settleable. Because the total BOD includes the soluble BOD, the soluble BOD must be subtracted from the total before the percent removal can be applied.

\[
\left( \frac{280 \, \text{mg}}{\text{L}} - \frac{84 \, \text{mg}}{\text{L}} \right) \times (50\%) = \frac{98 \, \text{mg}}{\text{L}} \text{ of Particulate BOD}
\]

Total BOD = Particulate + Soluble

Total BOD = \( \frac{98 \, \text{mg}}{\text{L}} + 84 \, \text{mg/L} \)

Total BOD = 182 mg/L
Chapter Exercise

SOLUTION

STEP 4

Find the effluent phosphorus using the same method.

\[
\left(7 \frac{mg}{L} - 3.5 \frac{mg}{L}\right) \times (50\%) = 1.75 \frac{mg}{L} \text{ of Particulate P}
\]

Total P = Particulate + Soluble

Total P = 3.5 \frac{mg}{L} + 1.75 mg/L

Total P = 5.25 mg/L