Purpose and Function

- Natural treatment system
- Three types classified by environmental conditions and the types of biological processes occurring within them: aerobic, anaerobic, and facultative
- Facultative ponds are the most common type
- Used for secondary treatment
- Naturally or mechanically aerated
- Mechanically aerated ponds treat a greater mass of five-day biochemical oxygen demand (BOD₅) in less space than naturally aerated ponds
- Continuous, intermittent, or zero discharge
- Anaerobic ponds primarily used by industry for pretreatment

Figure 1 Facultative Pond with Subsurface Aerators
(Reprinted with permission by Paul Krauth P.E.)
### Theory of Operation — Facultative Ponds

- Typically consist of three ponds operated in series or in parallel
- Single, two, and multiple pond systems also exist
- Treatment improves with more ponds in series; reduces opportunities for short-circuiting
- Primary ponds receive raw influent; tertiary, settling, or polishing ponds act as clarifiers to settle solids prior to discharging treated wastewater
- Uppermost pond layer is aerobic; bottom of pond contains sludge and is anaerobic; anoxic conditions may exist in some ponds
- Algae produce oxygen during the day, which is used by bacteria to consume BOD$_5$
- Algae consume oxygen and produce carbon dioxide (CO$_2$) at night and in low light conditions
- Cycles of taking up and releasing CO$_2$ increase pH, dissolved oxygen (DO), and alkalinity during the day; decrease at night
- Aerobic bacteria release nutrients as they break down BOD$_5$
- Anaerobic bacteria convert settleable BOD$_5$ and settled biomass into CO$_2$, methane, soluble BOD$_5$, and nutrients
- Some nutrients are incorporated into biomass; nitrifying bacteria convert ammonia to nitrite and nitrate; ammonia volatilizes to the atmosphere when pH is high; most nutrients pass through to the final effluent
- Pond colors reflect the dominance of different microorganisms and other environmental conditions

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<th>Design Parameters — Facultative Ponds</th>
<th>Expected Performance — Facultative Ponds</th>
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| Pond size is determined by coldest expected water temperature, BOD$_5$ load, and availability of oxygen | Facultative ponds meet secondary treatment standards for BOD$_5$
| Ponds treating colder water must be larger than ponds treating warmer water | Facultative ponds often discharge total suspended solids (TSS) in excess of 30 mg/L resulting from algae growth
| In naturally aerated ponds; dissolved oxygen is produced by algae | Many states have alternative discharge limits for TSS for ponds
| Wind and wave action transfers oxygen from the atmosphere | Spring and fall turnover can result in solids loss, increasing effluent TSS
| BOD$_5$ loading rates are limited for both the entire system and to the primary pond | Nutrient removal is inconsistent
| Switch from series to parallel pond operation when DO concentrations can’t be maintained in primary ponds; parallel operations typically used in winter | Nitrogen removal is primarily through assimilative uptake and volatilization
| Phosphorus removal is primarily through assimilative uptake | |
Equipment and Routine Maintenance

- Constructed from earth; cut and fill used to build dikes
- Length to width ratios vary: 1:1 for complete mix and 3:1 or greater for plug flow ponds
- Earthen dikes sloped for stability; kept at 3:1 or flatter to permit mowing; steeper inside the pond
- Grass, riprap, and gravel used to prevent erosion
- Tops of dikes are typically wide enough for a road; reduce erosion by varying driving habits and by staying off wet, muddy dikes
- Trees, shrubs, and burrowing animals can compromise dike stability
- Keep grass mowed and riprap in good repair to prevent erosion and deter animals
- Liners prevent wastewater from contaminating groundwater
- Liners may be natural earth, clay, asphalt, concrete, or synthetic waterproof materials
- Inlet, outlet, and transfer structures allow water to flow into, out of, and between ponds
- Inlet, outlet, and transfer structures may be a single pipe or a diffuser with multiple openings
- Gate valves are used to close pipes to take ponds in and out of service
- Stop logs, flashboard risers, or weir gates are used to control pond water level
- Baffles (walls or curtains) are used to divide ponds into smaller sections and to direct the flow of water through the pond
- Algae, recirculation of oxygen-laden water, and/or mechanical aeration devices provide oxygen for treatment
- Briefly operate mechanical aeration systems weekly when not in use to keep parts functional and lubricated

Process Variables

- Organic loading rate expressed as kg BOD$_5$/ha•d or lb BOD$_5$/ac/d
- Oxygen must be matched to the organic load or the pond will become anaerobic; oxygen concentrations increase during the day and decrease at night and on cloudy days
Supersaturation can occur when excess oxygen, produced by algae, increases the oxygen concentration beyond the saturation concentration for the current operating temperature and pressure; turning on mechanical aeration devices when the pond is supersaturated will strip oxygen from the water; the oxygen concentration will decrease.

Hydraulic detention time required depends on water temperature and availability of oxygen; naturally aerated ponds may require 180 days or longer to meet secondary treatment standards.

Alkalinity and pH change diurnally in response to CO₂ uptake and production by algae.

Sludge accumulates in the bottoms of all ponds; it contains settleable solids from the influent wastewater and biomass; eventually, approximately 60% of the organic matter will be converted to CO₂ and methane.

Differences in water temperature between the influent and the pond can cause short-circuiting.

**Process Control**

- Daily observation of pond appearance; color is a key indicator.
- Balance the influent organic load with the amount of oxygen available; operators may:
  - Switch between series and parallel operation.
  - Recirculate oxygenated water from one pond to another.
  - Increase surface aerator run speed or time.
- Monitor influent and effluent parameters.
- Monitor sludge buildup and remove excess sludge as needed.
- Control algae growth, especially in polishing ponds, to keep effluent TSS concentrations below discharge permit limits; methods of algae control include limiting growth by restricting access to light, introducing predators like daphnia, barley straw, and ultrasound.

**Sampling and Analysis**

- Minimum and ideal measurement frequencies given.
- Dissolved oxygen in each pond should be measured daily along with water temperature.
- Sampling frequencies for BOD₅, TSS, and fecal coliforms are set forth in the discharge permit; minimum frequencies are recommended for process control.
- Sludge blanket depth should be measured at least annually.
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