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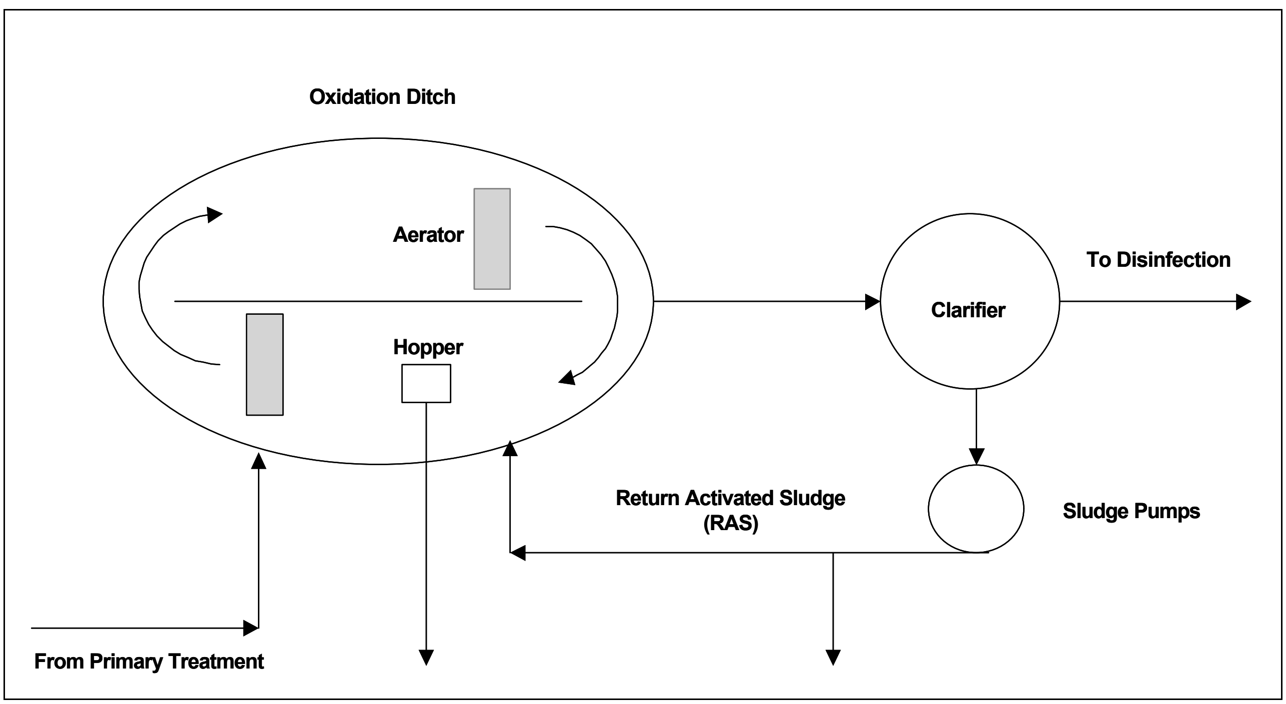
Wastewater Technology Fact Sheet
Oxidation Ditches

DESCRIPTION

An oxidation ditch is a modified activated sludge biological treatment process that utilizes long solids retention times (SRTs) to remove biodegradable organics. Oxidation ditches are typically complete mix systems, but they can be modified to approach plug flow conditions. (Note: as conditions approach plug flow, diffused air must be used to provide enough mixing. The system will also no longer operate as an oxidation ditch). Typical oxidation ditch treatment systems consist of a single or multi-channel configuration within a ring, oval, or horseshoe-shaped basin. As a result, oxidation ditches are called "racetrack type" reactors. Horizontally or vertically mounted aerators provide circulation, oxygen transfer, and aeration in the ditch.

Preliminary treatment, such as bar screens and grit removal, normally precedes the oxidation ditch. Primary settling prior to an oxidation ditch is sometimes practiced, but is not typical in this design. Tertiary filters may be required after clarification, depending on the effluent requirements. Disinfection is required and reaeration may be necessary prior to final discharge. Flow to the oxidation ditch is aerated and mixed with return sludge from a secondary clarifier. A typical process flow diagram for an activated sludge plant using an oxidation ditch is shown in Figure 1.



Source: Parsons Engineering Science, Inc., 2000.

FIGURE 1 TYPICAL OXIDATION DITCH ACTIVATED SLUDGE SYSTEM

Surface aerators, such as brush rotors, disc aerators, draft tube aerators, or fine bubble diffusers are used to circulate the mixed liquor. The mixing process entrains oxygen into the mixed liquor to foster microbial growth and the motive velocity ensures contact of microorganisms with the incoming wastewater. The aeration sharply increases the dissolved oxygen (DO) concentration but decreases as biomass uptake oxygen as the mixed liquor travels through the ditch. Solids are maintained in suspension as the mixed liquor circulates around the ditch. If design SRTs are selected for nitrification, a high degree of nitrification will occur. Oxidation ditch effluent is usually settled in a separate secondary clarifier. An anaerobic tank may be added prior to the ditch to enhance biological phosphorus removal.

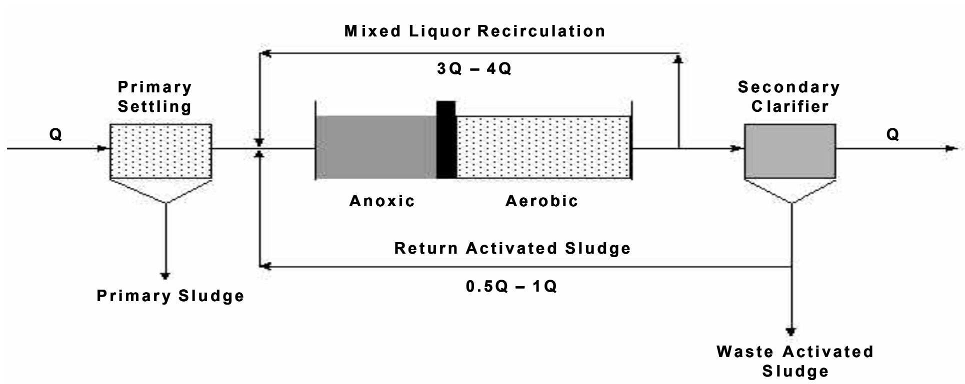
An oxidation ditch may also be operated to achieve partial denitrification. One of the most common design modifications for enhanced nitrogen removal is known as the Modified Ludzack-Ettinger (MLE) process. In this process, illustrated in Figure 2, an anoxic tank is added upstream of the ditch along with mixed liquor recirculation from the aerobic zone to the tank to achieve higher levels of denitrification. In the aerobic basin, autotrophic bacteria (nitrifiers) convert ammonia-nitrogen to nitrite-nitrogen and then to nitrate-nitrogen. In the anoxic zone, heterotrophic bacteria convert nitrate-nitrogen to nitrogen gas which is released to the atmosphere. Some mixed liquor from the aerobic basin is recirculated to the anoxic zone to provide a mixed liquor with a high-concentration of nitrate-nitrogen to the anoxic zone.

Several manufacturers have developed modifications to the oxidation ditch design to remove nutrients in conditions cycled or phased between the anoxic and aerobic states. While the mechanics of operation differ by manufacturer, in general, the process consists of two separate aeration basins, the first anoxic and the second aerobic. Wastewater and return activated sludge (RAS) are introduced into the first reactor which operates under anoxic conditions. Mixed liquor then flows into the second reactor operating under aerobic conditions. The process is then reversed and the second reactor begins to operate under anoxic conditions.

APPLICABILITY

The oxidation ditch process is a fully demonstrated secondary wastewater treatment technology, applicable in any situation where activated sludge treatment (conventional or extended aeration) is appropriate. Oxidation ditches are applicable in plants that require nitrification because the basins can be sized using an appropriate SRT to achieve nitrification at the mixed liquor minimum temperature. This technology is very effective in small installations, small communities, and isolated institutions, because it requires more land than conventional treatment plants.

The oxidation process originated in the Netherlands,



Source: Parsons Engineering Science, Inc., 1999

FIGURE 2 THE MODIFIED LUDZACK-ETTINGER PROCESS

with the first full scale plant installed in Voorschoten, Holland, in 1954. There are currently more than 9,200 municipal oxidation ditch installations in the United States (WEF, 1998). Nitrification to less than 1 mg/L ammonia nitrogen consistently occurs when ditches are designed and operated for nitrogen removal.

ADVANTAGES AND DISADVANTAGES

Advantages

The main advantage of the oxidation ditch is the ability to achieve removal performance objectives with low operational requirements and operation and maintenance costs. Some specific advantages of oxidation ditches include:

- An added measure of reliability and performance over other biological processes owing to a constant water level and continuous discharge which lowers the weir overflow rate and eliminates the periodic effluent surge common to other biological processes, such as SBRs.
- Long hydraulic retention time and complete mixing minimize the impact of a shock load or hydraulic surge.
- Produces less sludge than other biological treatment processes owing to extended biological activity during the activated sludge process.
- Energy efficient operations result in reduced energy costs compared with other biological treatment processes.

Disadvantages

- Effluent suspended solids concentrations are relatively high compared to other modifications of the activated sludge process.
- Requires a larger land area than other activated sludge treatment options. This can prove costly, limiting the feasibility of oxidation ditches in urban, suburban, or other areas where land acquisition costs are relatively high.

DESIGN CRITERIA

Construction

Oxidation ditches are commonly constructed using reinforced concrete, although gunite, asphalt, butyl rubber, and clay have also been used. Impervious materials, are usually used to prevent erosion.

Design Parameters

Screened wastewater enters the ditch, is aerated, and circulates at about 0.25 to 0.35 m/s (0.8 to 1.2 ft/s) to maintain the solids in suspension (Metcalf & Eddy, 1991). The RAS recycle ratio is from 75 to 150 percent, and the mixed liqour suspended solids (MLSS) concentration ranges from 1,500 to 5,000 mg/L (0.01 to 0.04 lbs/gal) (Metcalf & Eddy, 1991). The oxygen transfer efficiency of oxidation ditches ranges from 2.5 to 3.5 lb./Hp-hour (Baker Process, 1999).

The design criteria are affected by the influent wastewater parameters and the required effluent characteristics, including the decision or requirement to achieve nitrification, denitrification, and/or biological phosphorus removal. Specific design parameters for oxidation ditches include:

Solids Retention Time (SRT): Oxidation ditch volume is sized based on the required SRT to meet effluent quality requirements. The SRT is selected as a function of nitrification requirements and the minimum mixed liquor temperature. Design SRT values vary from 4 to 48 or more days. Typical SRTs required for nitrification range from 12 to 24 days.

BOD Loading: BOD loading rates vary from less than 160,000 mg/1000 liters (10 lb./1000 ft^3) to more than $4x10^7$ mg/1000 liters (50 lb./1000 ft^3). A BOD loading rate of 240,000 mg/1000 liters per day (15 lb./1000 ft^3/day) is commonly used as a design loading rate. However, the BOD loading rate is not typically used to determine whether or not nitrification occurs.

Hydraulic Retention Time: While rarely used as a basis for oxidation ditch design, hydraulic Retention Times (HRTs) within the oxidation ditch range from

6 to 30 hours for most municipal wastewater treatment plants.

PERFORMANCE

As fully-demonstrated secondary treatment processes, oxidation ditch processes are readily adaptable for nitrification and denitrification. As part of an *Evaluation of Oxidation Ditches for Nutrient Removal* (EPA, 1991), performance data were collected from 17 oxidation ditch plants. The average design flow for these plants varied between 378 to 45,425 m^3/day (0.1 to 12 MGD). The average performance of these plants, summarized in Table 1, indicates that oxidation ditches achieve BOD, suspended solids, and ammonia nitrogen removal of greater than 90 percent. Likewise, Rittmann and Langeland (1985) reported nitrogen removals of greater than 90 percent from oxidation ditch processes.

The following section discusses the performance of two recently designed oxidation ditch facilities.

TABLE 1 PERFORMANCE OF CASA GRANDE, AZ WWTP

	Average Monthly Influent (mg/L)	Average Monthly Effluent (mg/L)	Percent Removal (%)
BOD	226	8.86	96
TSS	207	5.23	97
Total N	35.4	1.99	94

Source: City of Casa Grande, AZ, 1999.

Casa Grande Water Reclamation Facility

The City of Casa Grande, Arizona, Water Reclamation Facility began operation in February 1996. The system was designed to treat 15,142 m^3/day (4.0 MGD) and uses an anoxic zone preceeding the aerobic zone of each train to provide denitrification. With influent design parameters of 270 mg/L BOD (0.002 lbs/gal BOD), 300 mg/L TSS (0.003 lbs/gal TSS), and 45 mg/L TKN (3.8×10^{-4} lbs/gal TKN), the plant has consistently achieved effluent objectives of 10 mg/L BOD (8.34×10^{-5} lbs/gal BOD), 15 mg/L TSS (1.2×10^{-4} lbs/gal TSS), 1.0 mg/L ammonia (8.34×10^{-6} lbs/gal ammonia), and 5.0 mg/L nitrate-nitrogen (4.2×10^{-5} lbs/gal nitrate-nitrogen). Table 1 summarizes the plant's performance between July 1997 and July 1999.

Edgartown, Massachusetts WWTP

The Edgartown, Massachusetts WWTP, located on the island of Martha's Vineyard, is designed to treat 757 m^3/day (0.20 MGD) in the winter months and 2,839 m^3/day (0.75 MGD) in the summer. Two Carrousel® denitIR basins are installed and the plant has achieved performance objectives since opening. Table 2 summarizes average monthly influent and effluent data.

TABLE 2 PERFORMANCE OF EDGARTOWN, MA WWTP

	Average Monthly Influent (mg/L)	Average Monthly Effluent (mg/L)	Percent Removal (%)
BOD	238	3.14	99
TSS	202	5.14	97
Total N	27.1	2.33	90

Source: Town of Edgartown, 1999.

OPERATION AND MAINTENANCE

Oxidation ditches require relatively little maintenance compared to other secondary treatment processes. No chemicals are required in most applications, but metal salts can be added to enhance phosphorus removal.

Residuals Generated

Primary sludge is produced if primary clarifiers precede the oxidation ditch. Sludge production for the oxidation ditch process ranges from 0.2 to 0.85 kg TSS per kg (0.2 to 0.85 lb. TSS per lb). BOD applied (Sherwood Logan and Associates, 1999). Typical sludge production is 0.65 kg TSS per kg of BOD (0.65 lb TSS per lb. of BOD). This is less than conventional activated sludge facilities because of long SRTs.

Operating Parameters

The oxygen coefficient for BOD removal varies with temperature and SRT. Typical oxygen requirements range from 1.1 to 1.5 kg of O_2 per kg of BOD removed (1.1 to 1.5 lbs of O_2 per lb. of BOD removed) and 4.57 kg of O_2 per kilogram of TKN oxidized (4.57 lbs of O_2 per lb. of TKN oxidized) (EPA, 1991; Baker Process, 1999). Oxygen transfer efficiency ranges from2.5 to 3.5 lb./Hp-hour (Baker Process, 1999).

COSTS

The basin volume and footprint required for oxidation ditch plants have traditionally been very large compared with other secondary treatment processes. Larger footprints result in higher capital costs, especially in urbanized locations where available land is very expensive. Vertical reactors, in which process flow travels downward through the reactor, are generally more expensive than traditional horizontal reactors. However, because they require less land than more conventional horizontal reactors, they can significantly reduce overall capital costs where land costs are high.

The cost of an oxidation ditch plant varies depending on treatment capacity size, design effluent limitations, land cost, local construction costs, and other site specific factors. Construction capital costs for ten plants were evaluated by EPA in 1991, with construction costs ranging from \$0.52 to \$3.17/liter per day (\$1.96 to \$12.00/gpd) treated. These costs have been updated with the ENR construction cost index (ENR = 5916).

Recent information obtained from manufacturers on facilities ranging 3,785 to 25,740 m^3/day (1.0 MGD to 6.8 MGD) indicates that construction capital costs of oxidation ditch plants range from \$0.66 to \$1.10/liter per day (\$2.50 to \$4.00 per gpd). For example, the Blue Heron Water Reclamation Facility in Titusville, Florida-- a 15,142 m^3/day (4.0 MGD) oxidation ditch and sludge handling facility which began operation in 1996, was constructed for about \$0.80/liter per day (\$3.00 per gpd) (Kruger, 1996). The facility features a multi-stage biological nutrient removal process and a sophisticated Supervisory Control and Data Acquisition System (SCADA) control system.

Oxidation ditches offer significantly lower operation and maintenance costs than other secondary treatment processes. Compared to other treatment technologies, energy requirements are low, operator attention is minimal, and chemical addition is not usually required. For example the Tar River Wastewater Reclamation Facility in Louisburg, North Carolina has documented energy savings of 40 percent compared with conventional activated sludge plants (Ellington, 1999). The oxidation ditch has also eliminated chemical costs and plant staff are available for other facility needs (Ellington, 1999).

REFERENCES

Other Related Fact Sheets

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

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ADDITIONAL INFORMATION

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