Basics of Wastewater Treatment

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PDH: 1

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Module 1: Basics of Wastewater Treatment

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary biological aeration processes used in pre-manufactured package treatment facilities.
- **Evaluate** the design criteria and performance capabilities of Extended Aeration, Sequencing Batch Reactors (SBR), and Oxidation Ditches.
- **Select** appropriate package plant technologies based on site-specific hydraulic loads and effluent requirements.

Executive Summary: Package plants are pre-manufactured facilities designed for small-scale wastewater treatment (typically 0.002 to 0.5 MGD), primarily utilizing biological aeration processes like extended aeration, SBRs, and oxidation ditches to serve remote or limited-flow applications.

Design Fundamentals of Package Plants

Package plants are pre-manufactured treatment facilities used to treat wastewater in small communities or on individual properties. Manufacturers design these plants to handle flows as low as **0.002 MGD** or as high as **0.5 MGD**, though the most common range is between **0.01 and 0.25 MGD**.

While several types of package plants exist, including contact stabilization and rotating biological contactors, industry focus remains on three primary biological aeration processes:

- **Extended Aeration Plants**
- **Sequencing Batch Reactors (SBR)**
- **Oxidation Ditches**

Extended Aeration Plants

The extended aeration process is a modification of the activated sludge process designed for the biological removal of biodegradable organic wastes under aerobic conditions.

Operational Requirements

- **Aeration:** Oxygen is supplied via mechanical or diffused aeration to sustain the biological process.
- **Mixing:** Required to maintain microbial contact with dissolved organics.
- **Process Control:** pH must be monitored, and essential nutrients must be present to facilitate biological degradation.

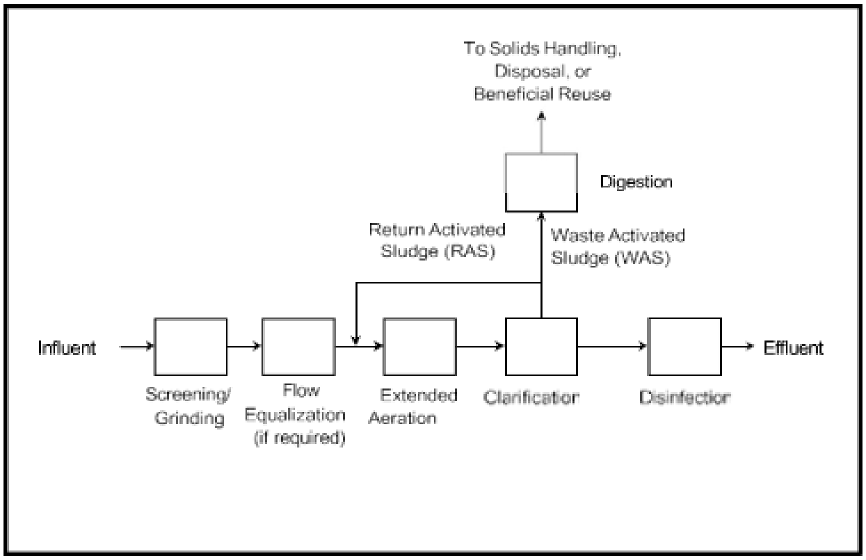

Figure 1: Process Flow Diagram for a Typical Extended Aeration Plant

Process Sequence

1. **Screening/Grinding:** Wastewater is screened to remove solids that could damage downstream equipment; a grinder may follow for further particle reduction.

2. **Equalization:** If flow regulation is required, effluent enters equalization basins to regulate peak rates.

3. **Aeration Chamber:** Microorganisms mix with oxygen to degrade waste.

4. **Clarification:** Mixed liquor flows to a settling chamber where microorganisms settle.

5. **Sludge Return:** Settleable material is either returned as **Return Activated Sludge (RAS)** or removed as **Waste Activated Sludge (WAS)**.

6. **Disinfection:** Clarified wastewater flows over a weir to the disinfection system.

⚠️ **Safety Constraint:** Extended aeration plants typically require **two to four weeks** from initial seeding with "seed sludge" to achieve full stabilization.

Sequencing Batch Reactors (SBR)

An SBR is a variation of the activated sludge process operated as a **fill and draw** batch system. Unlike conventional systems, all biological treatment phases occur in a **single tank**, eliminating the need for separate clarifiers.

SBR Treatment Cycle Phases

- **Fill:** Raw wastewater enters the basin and mixes with settled biomass.

- **React:** The basin is aerated to allow oxidation and nitrification.
- **Settle:** Aeration and mixing are suspended to allow solids to settle.
- **Decant:** Treated wastewater is discharged from the basin.
- **Idle:** The basin waits for the next cycle; excess solids are removed as waste sludge.

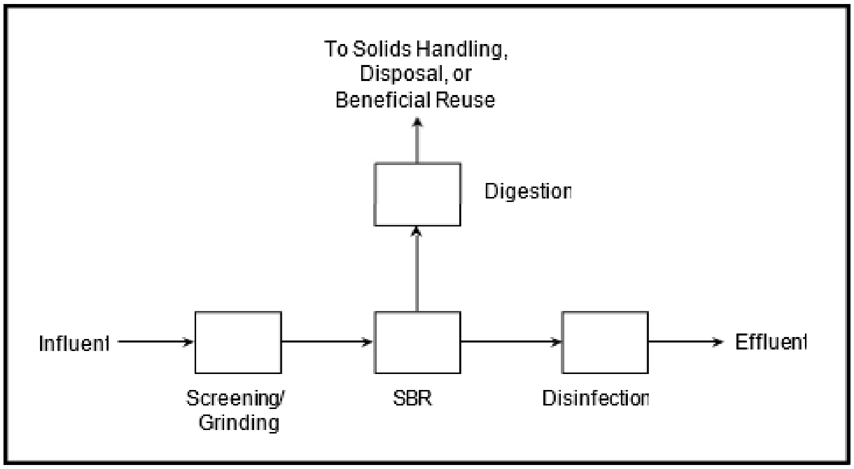

Figure 2: Process Flow Diagram for a Typical SBR

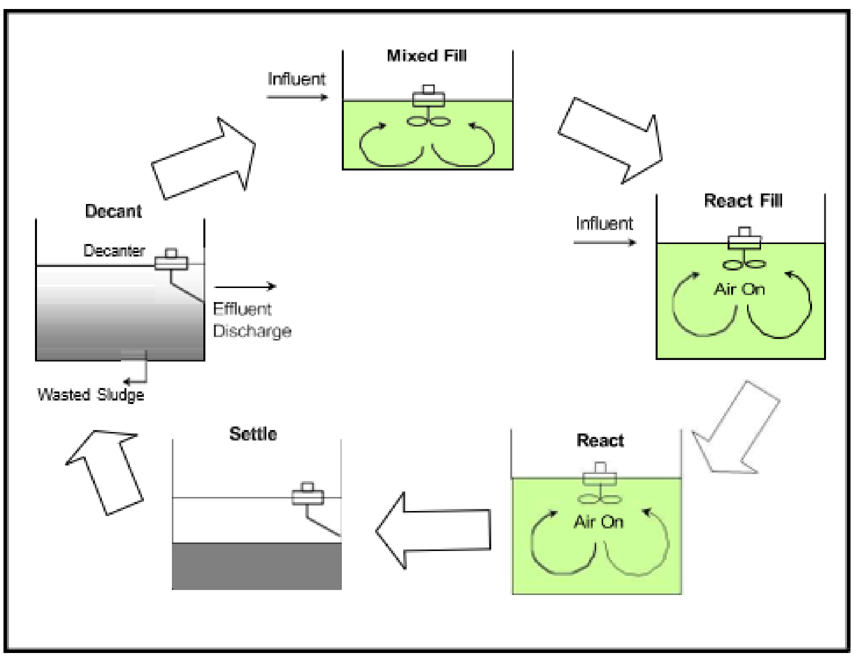

Figure 3: SBR Sequence of Operation

💡 **Design Tip:** SBR systems provide tremendous flexibility for changing effluent requirements; however, economic advantages may be lost if advanced downstream treatment requires intermediate equalization.

Oxidation Ditches

An oxidation ditch is a modified activated sludge process characterized by an aerated, long-term, complete mix environment. It typically utilizes a ring, oval, or horseshoe-shaped basin.

Key Characteristics

- **Aeration:** Horizontally or vertically mounted aerators provide circulation and oxygen transfer.
- **Flow Rates:** Typically manufactured for rates between **0.01 and 0.5 MGD**.
- **Retention:** Long hydraulic and solids retention times allow for extensive organic matter breakdown.

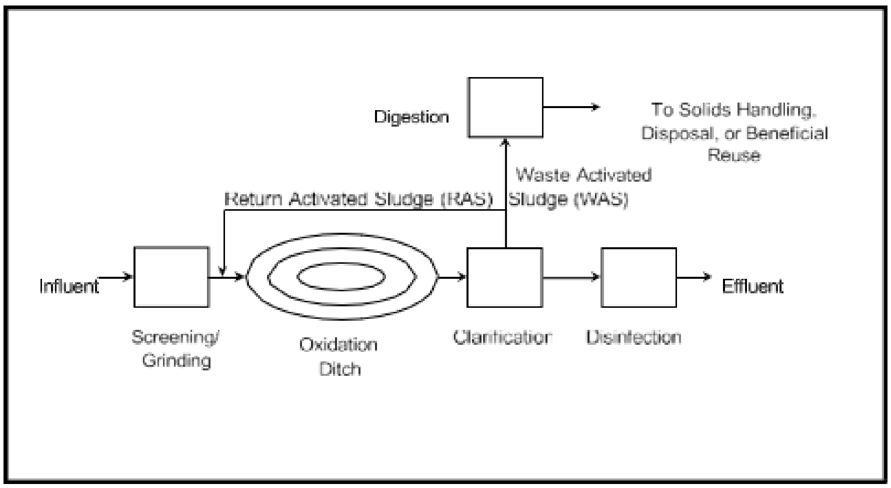

Figure 4: Process Flow Diagram.

Applicability and Selection Criteria

Package plants are most applicable for remote locations, small municipalities, and sites with limited wastewater flows.

System Suitability

- **Extended Aeration:** Ideal for small subdivisions, highway rest areas, and sites requiring nitrification with flows below **0.1 MGD**.
- **SBR:** Best for areas with little land, stringent requirements, or high BOD loadings (e.g., breweries, pharmaceutical plants).
- **Oxidation Ditches:** Suitable for nutrient removal and energy-saving goals; most applicable where a large amount of land is available.

Technical Design Criteria

Table 1. Typical Design Parameters for Package Plants

	Extended Aeration	SBR	Oxidation Ditch
BOD_5 loading (F:M) (lb BOD_5/ lb MLVSS)	0.05 - 0.15	0.05 - 0.30	0.05 - 0 30
Oxygen Required Avg. at 20EC (lb/lb BOD_5 applied)	2 - 3	2 - 3	2 - 3
Oxygen Required Peak at 20EC (value x avg. flow)	1.5 - 2.0	1.25 - 2.0	1.5 - 2.0
MLSS (mg/L)	3000 -6000	1500 -5000	3000 -6000
Detention Time (hours)	18 - 36	16 - 36	18 - 36
Volumetric Loading (lb BOD_5/d/ 10^3 cu ft)	10 - 25	5 - 15	5 - 30

Source: Adapted from Metcalf and Eddy, 1991 and WEF, 1998.

Calculation Note: SBR cycle sequences are time-controlled; if incoming flow is significantly less than design flow, aeration periods can be reduced to save energy.

Performance and Effluent Quality

System performance is influenced by temperature changes, grease removal efficiency, and hydraulic shock loads.

Table 2. Extended Aeration Performance

	Typical Effluent Quality	Aldie WWTP (monthly average)
BOD (mg/L)	< 30 or <10	5
TSS (mg/L)	< 30 or <10	17
TP (mg/L)	< 2*	**
NH_3-N (mg/L)	< 2	**

* May require chemicals to achieve.
** DEQ does not require monitoring of these parameters.

Source: Sloan, 1999 and Broderick, 1999.