Better Plants
U.S. DEPARTMENT OF ENERGY

#2: Introduction to Biological Wastewater Treatment

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October 2020

U.S. DEPARTMENT OF ENERGY

Intro to Biological Wastewater Treatment

- Objectives
- Definitions
- Role of Microorganisms
- Biological Processes

*References: Metcalf & Eddy, 4th edition
WEF training materials

Objectives

- Oxidize dissolved and particulate biodegradable constituents into acceptable end products
- Capture suspended and non-settleable colloidal solids into a biological floc or biofilm
- Transform or remove nutrients such as N and P
- Remove specific trace organic compounds

Biological Treatment

- Duplicates nature's process of stream purification
- Uses naturally occurring microorganisms
- Adapted in controlled facilities to specific conditions and time restraints
- Used to treat compatible and incompatible pollutants

Critical Aspects of Biological Treatment

- Proper nutrient balance
  - Macronutrients (N and P)
  - Micronutrients (K, Ca, S, Cl, etc.)
- General rule: BOD/N/P = 100/51
- Maintain acceptable pH range (6-9)
- Maintain acceptable temperature
- Avoid toxic substances at levels that will inhibit or interfere with microbes

Definitions: Metabolic Functions

- **Aerobic processes** – biological treatment processes that occur in the presence of oxygen
- **Anaerobic processes** – biological treatment processes that occur in the absence of oxygen
- **Anoxic processes** – process by which nitrate-N is converted biologically to nitrogen gas in the absence of oxygen

Definitions: Metabolic Functions (continued)

- **Facultative processes** – biological treatment processes in which the organisms can function in the presence or absence of molecular oxygen
- **Combined aerobic/anoxic/anaerobic processes** – processes grouped together achieve a specific treatment objectives

Definitions: Treatment Processes

- **Suspended-growth processes** – biological treatment processes in which the microbes responsible for the conversion of organic matter or other constituents in the wastewater to gases and cell tissue are maintained in the suspension within the liquid

- **Attached-growth processes** – BTPS in which the microbes are attached to some insert medium (rock, plastic, etc.). They are also known as fixed-film processes.

- **Lagoon Processes** – treatment processes that take place in ponds or lagoons with various aspect ratios and depths

Definitions: Treatment Functions

- **Biological nutrient removal** – removal of N and P in biological treatment processes
- **Biological phosphorus removal** – biological removal of P by accumulation in biomass and subsequent solids separation
- **Carbonaceous BOD removal** – biological conversion of carbonaceous organic matter to cell tissue and various gaseous end products

Definitions: Treatment Functions

- **Nitrification** – two-step biological process by which ammonia-N is converted to nitrite-N and then to nitrate-N

- **Denitrification** – biological process by which nitrate-N is reduced to nitrogen and other gaseous end products

Definitions: Treatment Functions

- **Stabilization** – biological process by which organic matter in waste sludges is stabilized, usually by conversion to gases and cell tissue (aerobic and anaerobic digestion)

- **Substrate** – the organic matter or nutrients that are converted during biological treatment or that may be limiting in biological treatment (e.g., carbonaceous organic matter in wastewater)

Roles of Microbes in Wastewater Treatment

- Oxidation of organic matter in wastewater is accomplished biologically using a variety of microorganisms, primarily bacteria

$$\text{Organics} + O_2 + NH_3 + PO_4 \xrightarrow{\text{microbes}} \text{New cells} + CO_2 + H_2O + \text{Energy}$$

- New cells are produced by the synthesis reaction (biomass produced as a result of consumption of organic matter)

Roles of Microbes in Wastewater Treatment

- Microbes are also used to remove N and P in wastewater treatment processes
- Nitrifying bacteria can convert ammonia-N to nitrite-N and nitrate-N
- Denitrifying bacteria can convert nitrate-N to gaseous nitrogen
- In biological P removal, bacteria take up and store large amounts of inorganic P

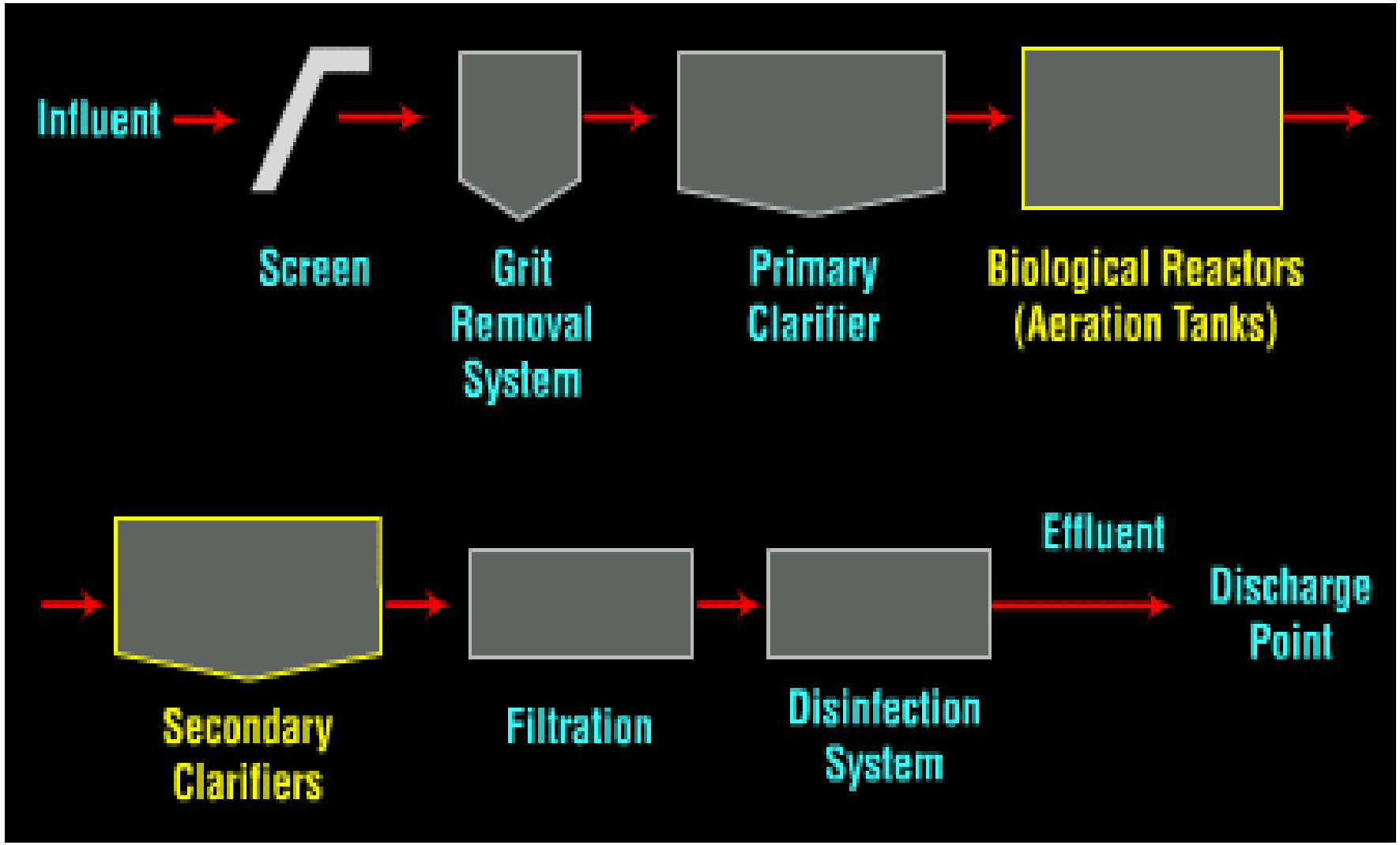
Biological Processes: Activated Sludge

- Continuous-flow, biological treatment process in which a suspension of aerobic and facultative microbes are maintained in a relatively homogenous state by the mixing and turbulence created by aeration equipment
- Microorganisms typically oxidize soluble and colloidal organic matter to CO_2 and H_2O in the presence of molecular oxygen
- Biomass is settled in final clarifier with most biomass returned to the aeration tanks, while some biomass is wasted from the process

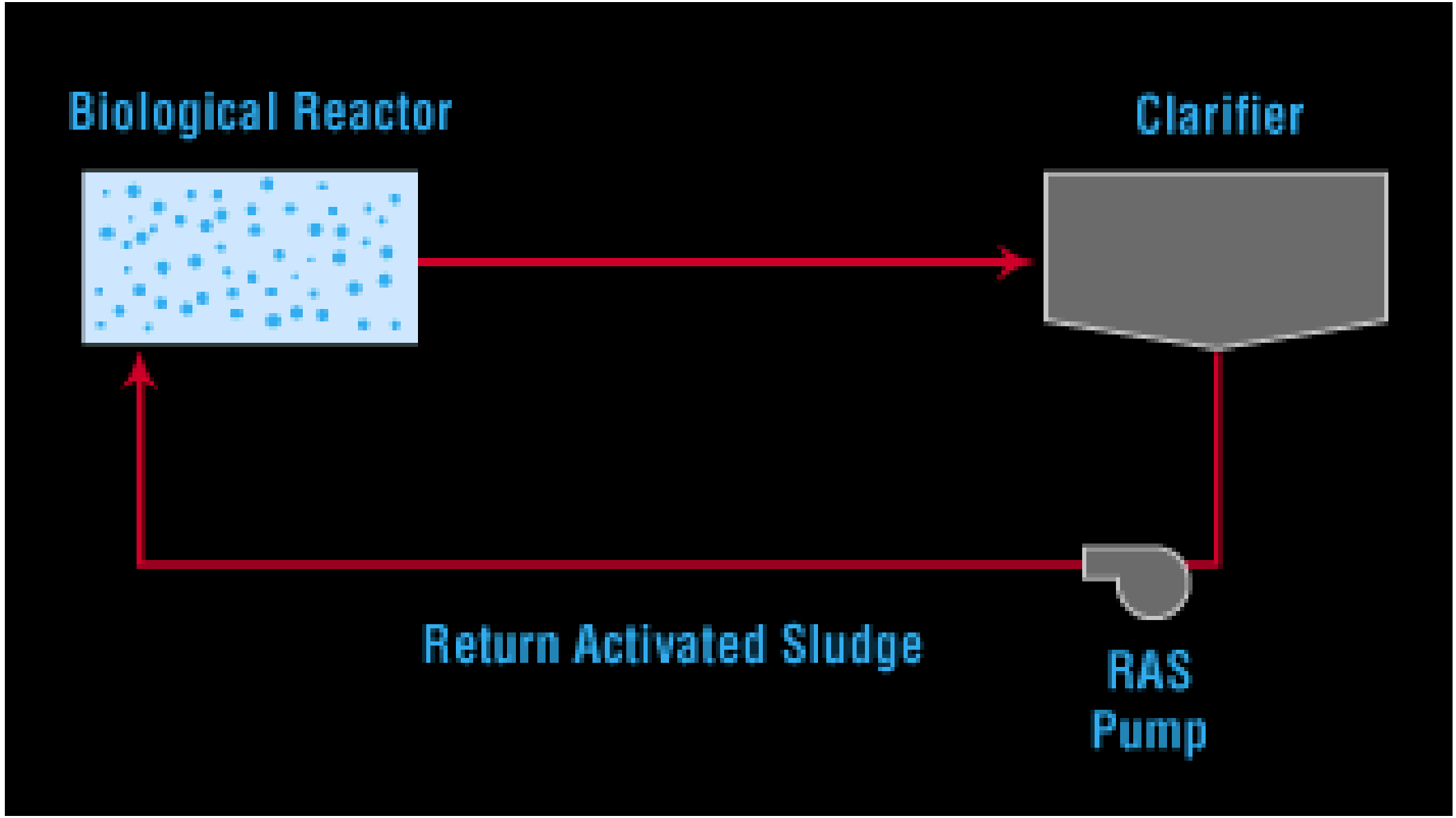
Basic Activated Sludge Process Components

- Influent pretreatment
- Aeration basic
- Secondary clarification
- Return activated sludge
- Waste activated sludge

Wastewater Process Diagram Highlighting the Activated Sludge Process Units (yellow)



Biological Reactor with Aerated Mixed Liquor



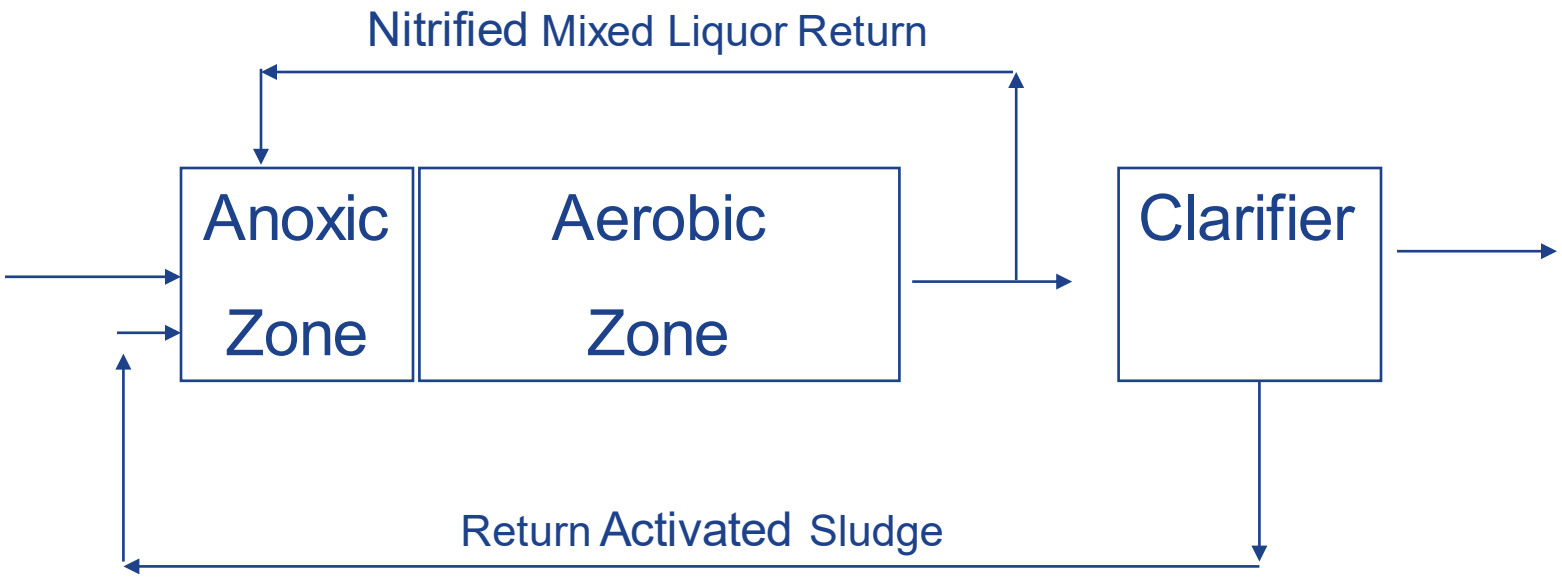
Return activated sludge (RAS) is recycled back to the biological reactor.

Secondary clarifiers are used to settle the mixed liquor solids.

Activated Sludge for N Removal

- Use anoxic zone to promote denitrification
- Better to have anoxic zone ahead of aerobic zone
- DO levels need to be ≤ 0.3 mg/L
- Readily degradable organic substrate is preferred as carbon source
- At low or zero DO, facultative heterotrophs use nitrite-N and nitrate-N as electron acceptor

Biological Nitrification/Denitrification



Activated Sludge for N Removal

- Nitrite-N and nitrate-N are converted to nitrogen gas
- Denitrification produces one-half the alkalinity consumed during nitrification
- Simultaneous nitrification and denitrification can be achieved at DO levels between 0.1 and 0.3 mg/L
- For anoxic zone ahead of aerobic zone, it is essential to recycle mixed liquor (2Q to 4Q) from end to aerobic zone to front of anoxic zone

Activated Sludge for N Removal

- Anoxic zone can be placed after aerobic zone, but this approach is less efficient
- Denitrification rate is directly proportional to level of organics available and inversely proportional to DO levels
- Denitrification rate does not depend on nitrate-N concentration

Activated Sludge for P Removal

- Need an anaerobic zone ahead of the aerobic zone to promote P removal
- Under anaerobic conditions, certain bacteria will take up organics and store them as polyhydroxybutyrate (PHB) and release P into solution
- In the subsequent aerobic zone, the stored PHB is rapidly oxidized with significant uptake of dissolved P into cell mass

Activated Sludge for P Removal

- Most of the P will be removed from the process in the waste biomass

- Where N and P removal are required, the sequence of bioreactors may be anaerobic/anoxic/aerobic, anaerobic/anoxic/aerobic/anoxic/aerobic, etc., to achieve the desired metabolism and desired effluent quality

Thank you!

For Questions or Comments please reach out to the following:

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