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BIOLOGICAL TREATMENT CONTROL PARAMETERS

To ensure a favorable environment to promote the reactions involved in the biological treatment process, the following parameters must be controlled:

- pH and alkalinity
- Temperature
- Oxygen requirements
- Solids separation
- Biological solids recirculation
- Aeration capacity
- Mixing energy
- Hydraulic retention time
- Solids retention time

Biological waste treatment removes organic matter in wastewater in much the same manner as the naturally occurring stream biota would in surface receiving waters. However, there is usually not as much time to break down solid organic matter in biological treatment. Generally, microorganisms in biological waste treatment work most efficiently on dissolved organic matter. These active microorganisms are a relatively small fraction of the total biological process biomass. Certain constituents will adversely affect the biological treatment process. The major constituents and their effects on the biological treatment process are listed in Table 2:

Table 2 - Biological treatment systems critical constituents

Constituent	Condition*
Ammonia nitrogen	Too low a level can inhibit growth
Calcium and magnesium	Hardness and dissolved solids add to loadings on aeration equipment and clarifiers
Chloride	Corrosive; toxic to microorganisms at very high levels
Mercury	Toxic to microorganisms at designated levels
Other heavy metals	Toxic to microorganisms at designated levels
Phosphate	Needed for growth
Sulfate	Needed in small amounts
Sulfide	Corrosive, depletes oxygen
Petrochemicals	Toxic to microorganisms when high concentrations are experienced
Phenolic compounds	Toxic to microorganisms when high concentrations are experienced
Surfactants	Cause foaming
	* Toxicity levels are dependent upon average or normal loadings and peak loadings.

Certain substances present in municipal and industrial wastewaters are more biodegradable than others. A relative comparison of the biodegradability of various constituents commonly found in wastewater is shown in Table 3:

Table 3 - Relative biodegradability of organic compounds

Easily Degradable			**Slower and/ or Moderately Biodegradable**	**Less Easily Biodegradable**
Sugars Alcohols	Ketones Phenolic compounds	Organic acids	Esters Ethers	Cellulose Fats Lignins Polymeric Compounds Hydrocarbons • Aliphatic • Aromatic • Alkyl, aryl Chlorinated aromatics

pH and Alkalinity

The pH of the wastewater is not always a problem; however, in biological treatment the alkalinity of the wastewater is altered because of the production of carbon dioxide and other conversion products. Low alkalinity wastewaters may require pH control as a result of this conversion.

Operation of most biological processes is limited to a pH range of 5-9 (optimum pH is 6.5-8.5). In general, because of the buffering capacity of the system, the pH in the aeration tank is independent of the feed pH. Bacterial oxidation of BOD produces carbon dioxide, and a bicarbonate buffer system results. This system can neutralize 0.5-1.5 pounds (0.23-0.68 kg) of acidity or alkalinity for every pound of BOD removed.

Temperature

Temperature affects all biological consumption processes. Biological oxidation rates increase to a maximum at about 35°C for most treatment systems. Higher temperatures decrease efficiency. Temperatures in excess of 37°C show a definite effect on biological systems. It is possible, however, in certain wastes to operate efficiently at somewhat higher temperatures. Low temperatures also affect performance.

The rate of biological activity will also be influenced by temperature because of the depth of penetration of oxygen into the floc or film. Oxygen penetration or solubility increases as the temperature decreases, since oxygen is not used as quickly at the floc surfaces and greater numbers of organisms per unit surface can react.

Oxygen Requirements

Oxygen is required both for the synthesis of new cells and to meet their continuing energy requirements. Theoretically, an oxygen demand of 1.42 grams is exerted by each gram of biological solids produced.

The classical biochemical oxygen demand exerted by a waste flow consists of two oxygen demand curves known as carbonaceous demand and nitrification, as shown in. Oxygen consumption to assimilate the carbonaceous organic material begins almost immediately, while oxygen consumption for conversion of organic nitrogen compounds does not begin until the carbonaceous material in the waste has been oxidized. At this point the carbon reducing microorganisms present have begun to die off (endogenous respiration), allowing the less competitive nitrification micro-organisms to grow using ammonia as an energy source. "Nitrification" also exerts an oxygen demand on the system. The combined total oxygen demand is the sum of the two demand curves.

Sludge Production

Sludge production in a biological treatment system is expressed as the net effect of the following two processes:

1. Synthesis of new organisms resulting from assimilation of organic matter removed

2. Reduction of the mass of organisms under aeration by the process of die-off and oxidation over an extended period of time (known as "endogenous respiration").

Nutrient Requirements

Several mineral elements are essential for the proper metabolic activity of the microorganisms involved in waste treatment. Table 4 summarizes the known nutrient requirements of most biological treatment processes. In general, natural water provides virtually all of the required materials (except nitrogen and phosphorus) considered being principal nutrients. The concentration of these materials varies widely, depending on the particular wastewater. Because each wastewater is different, the population of microorganisms will tend to adapt to the available supply of nutrients.

Table 4 - Typical substrate and nutrient requirements of biological organisms

Limiting Substrate	Substantial Excess Nutrients Required for Growth	Required Micro-Nutrients
Organic Carbon Nitrogen as NH_4^+ Orthophosphates Oxygen (For aerobic organisms)	Na^+, K^+ Mg^{+2} SO_4^{-2} HCO_3^-	Fe^{+2}, Cu^{+2} Mn^{+2}, Zn^{+2}

In general, a ratio of BOD/nitrogen/phosphorus of 100/5/1 will provide sufficient nutrients to ensure adequate biological activity.

Not all organic nitrogen compounds are available for synthesis. Ammonia is the most readily available form, and other nitrogen compounds must generally be converted to ammonia. Nitrite, nitrate, and about 80% of organic nitrogen compounds are also available.

Endogenous respiration releases nitrogen from cellular material, and the nitrogen is again available for synthesis. Based on non-biodegradable residue of 23% of the cellular material formed, the maximum recovery of nitrogen typically may be 80-90%.

Solids Separation

One of the most important aspects of biological waste treatment is the design of the facilities used to separate the biological solids from the treated wastewater.

Secondary sedimentation must perform two functions:

1. Separate mixed liquor suspended solids from the treated wastewater.

2. Thicken the return sludge.

Both functions will be affected by the depth of the sedimentation basin. Ample volume must be provided for storage of the solids during periods in which sustained peak plant loadings are experienced. Also, peak daily flow-rate variations must be considered because they affect the sludge removal requirements. In general, the area required for clarification must be based on the overflow rate equivalent to the smallest particle that is to be removed from the clarified liquid in the upper portions of the settling tank.

Return Sludge Requirements

The purpose of the return of settled solids is to maintain a sufficient concentration of activated sludge, in the aeration tank so that the required degree of treatment can be obtained in the time interval desired. The return of activated sludge from the clarifier to the inlet of the aeration tank is essential to the process.

The solids tend to form a sludge blanket in the bottom of the tank which varies in thickness from time to time and may fill the entire depth of the tank at peak flows if the solids thickening capacity of the secondary clarifier is inadequate. Return-sludge pump capacities vary between 25% to over 200%, depending upon the operational strategy designed.