Environmental Leverage® Inc.
Turning Liabilities into Leverage
EnvironmentalLeverage.com
812 Dogwood Drive, Suite A
North Aurora, IL 60542

Typical Recommended Operator Testing:

The following analytical items should be performed by the operator(s) for process control purposes;

1. **Flows – record daily:** surge tank, primary clarifier, total from ASB, Wasted Underflow from clarifiers.

2. **Spins (solids by volume) – record daily:** ASB, sludge judge contents from clarifier,

3. **Depth of Bed (DOB)** – record daily: clarifier. ASB

4. **Settled Sludge Volume (SSV_{30}) – record daily:** from ASB effluent end.

5. **pH** – daily: Surge tank, ASB, clarifier.

6. **Temperature – daily**: ASB, clarifier
7. **Ammonia (NH_3-N) – record daily:** ASB

8. **Soluble PO_4 – record daily**: ASB
9. **Dissolved Oxygen – daily during aeration and after decant**: ASB
10. **Respiration Rate – daily:** Effluent end of ASB.

Load Factor – as needed:

Recommended Testing for Main Lab (Bioengineering Lab)

Location of Sample			Frequency		
	Test	When	Daily	Weekly	Monthly
Surge Tank (EQ)	Total Carbon (COD),	Main lab	X		
Clarifier	Solids in / Solids out (TSS), (COD),	Main lab	X		
ASB	TSS, filtered COD, MLSS, NH_3-N, PO_4	Main lab	X		
ASB	WW Biomass Analysis	**Environmental Leverage**			X
Final Effluent (18F)	Flow, COD, TSS,	Main lab	X		

Measure

- **Influent Flow, weekly**
- **Influent TSS, weekly to start**
- **Influent pH, daily**
- **Influent Temperature, daily**

ASB: Measure

- **Dissolved Oxygen, daily**
- **BOD Loading, weekly (calculate using COD ratio)**
- **MLSS, mg/l weekly, spins daily**
- **MLVSS, mg/l weekly (calculate %)**
- **Respiration Rate, daily**
- **Hydraulic Retention, daily (calculate)**

SSV_{30} / SVI, daily

Overall Performance Data: Calculate monthly to begin,
- Solids generated to BOD degraded ratio
- O_2 consumed per unit of BOD degraded

1) **Key Formula's Used:**

a). BOD Loading = pounds BOD to SBR ÷ (000)ft³ volume in SBR.
Volume in SBR = gallons volume ÷ 7.48
Note: pounds/(000)ft³/day x 0.01602 = kg/m³/day

b). Hydraulic Retention Time (HRT) = SBR (gal. or m³) ÷ (Q + R in gal. or m³).

c). F/M ratio = pounds (kg) BOD to SBR ÷ MLVSS (pounds or kg)

d). MCRT (sludge age) = solids inventory (MLSS + CSS in pounds or kg) ÷ (TSS + WAS pounds or kg)

e). %RAS = R ÷ Q (solids held before fill)

f). Surface Overflow Rate (SOR) = Q ÷ secondary clarifier surface area in ft²

g). "Flux" (solids loading on secondary clarifier) = {(Q+R) x MLSS} ÷ clarifier surface area

h). Solids Balance is based on (Q + R) x MLSS = R x RASS
therefore; %RAS = MLSS ÷ (RASS – MLSS)
RASS mg/l = MLSS mg/l x {(Q + R) ÷ R}

Summary of Process Control Factors

Aerobic System:

	Original Design Criteria	Current Actual (+/-)	Recommended
Flow (Q), m^3/day			To be determined
BOD Loading, #BOD/(000)ft^3/day			
COD:BOD ratio			
BOD Loading, #/(000)ft^3/day			
MLSS, mg/l			
%VSS			
F/M ratio			
Hydraulic Retention,hrs			
MCRT, days			
Dissolved O_2, mg/l			
Temperature, ^{o}C			
pH			
% RAS(solids to remain after decant)			
RASS, mg/l			
WAS, m^3/day			To maintain MLSS
SVI			
SOR / Flux, gpd/ft^2, #/ft^2			
SSV$_{30}$ ml/L			
DOB in 1^o, feet			

APPENDIX

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

- Acceptable environmental parameters for biological activity including:

PARAMETER	ACCEPTABLE	OPTIMUM
Dissolved Oxygen	**>0.5 mg/l**	**1.0 - 2.0 mg/l**
Temperature	**50 - 95° F**	**77 - 95 ° F**
pH	**7.0 - 9.0**	**7.5 - 8.5**
Ammonia Residual	**1.0 - 3.0 mg/l**	**2.0 - 3.0 mg/l**
Ortho-phosphate Residual	**0.5 - 2.0 mg/l**	**1.0 - 2.0 mg/l**

* Residual should be measured in the final effluent.

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
	Toxic to microorganisms at designated levels
Mercury	
	Toxic to microorganisms at designated levels
Other heavy metals	Needed for growth
	Needed in small amounts
Phosphate	
	Corrosive, depletes oxygen
Sulfate	
Sulfide	Toxic to microorganisms when high concentrations are experienced
Petrochemicals	Toxic to microorganisms when high concentrations are experienced
Phenolic compounds	Cause foaming
Surfactants	

* 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	Ketones	Organic acids	Esters	Cellulose
Alcohols	Phenolic compounds		Ethers	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.

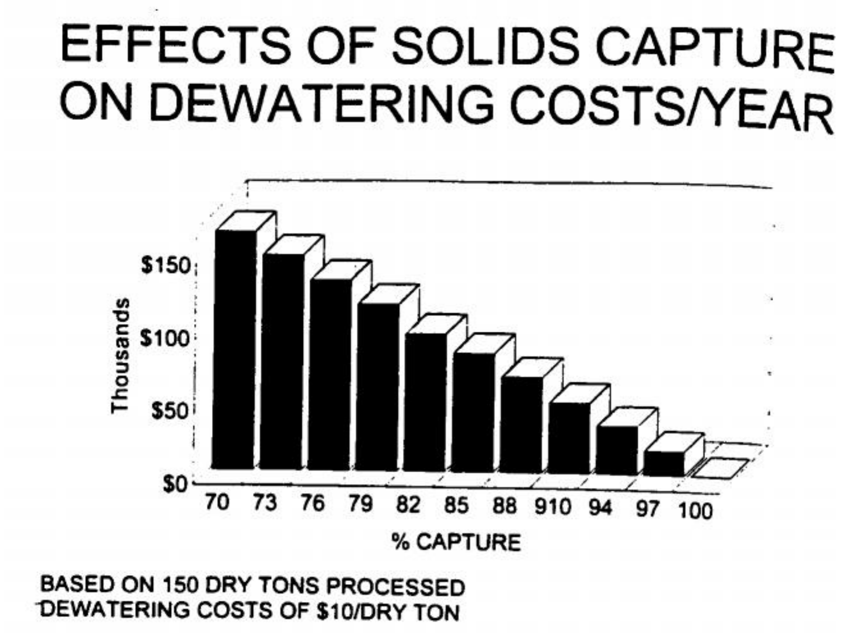
The rate of biological activity will also be influenced by temperature because of the depth of penetration of oxygen into the floc or film. Oxygen penetration or solubility increases as the temperature decreases, since oxygen is not used as quickly at the floc surfaces and greater numbers of organisms 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 to be 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	Na^+, K^+	Fe^{+2}, Cu^{+2}
Nitrogen as NH_4^+	Mg^{+2}	Mn^{+2}, Zn^{+2}
Orthophosphates	SO_4^{-2}	
Oxygen (For aerobic organisms)	HCO_3^-	

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 nonbiodegradable residue of 23% of the cellular material formed, the maximum recovery of nitrogen typically may be 80-90%.

Wastewater Treatment Operations
Nutrient Supplement

Ammonia & Ortho-Phosphate

Within a biological (Secondary) wastewater treatment system, heterotrophic bacteria (bacteria which utilize/degrade carbon molecules as a food substrate, i.e.; BOD) require a number of nutrients in their diet to maintain growth and reproduction. A typical bacteria cell contains;

Bacteria Cell
↓
↓ ↓
80% Water 20% Dry Matter
↓
90% organic / 10% inorganic
↓ ↓

53% carbon
29% oxygen
12% nitrogen
6% hydrogen

50% P_2O_5
15% SO_3
11% Na_2O
9% CaO
8% MgO
6% K_2O
1% Fe_2O_3

Therefore, it is obvious that the major nutrient requirements for a bacteria in addition to the carbon and water (H2O) are nitrogen (12% of the 90% organic = 10.8% of the total dry weight), and phosphorus (21.5% of 50% x 10% = 2.15% of the inorganic content). The other micronutrients are generally not a limiting factor as they are usually available in the trace amounts needed.

The general rule is that a system will need 5 parts of Nitrogen and 1 part of phosphorous for every 100 parts of BOD to be degraded. This is true for a conventional activated sludge system (such as a municipal sanitary WWTP), however, with a young sludge age (such as during a plant start-up or a BOD shock loading) the ratio would be 100 to 7 to 3 and for an extended aeration system (such as in an industrial treatment facility) the ratio would be closer to 100 to 3 to 0.5.

Therefore, when operation a secondary wastewater treatment system;

Step 1. Determine the influent average BOD loading, ammonia nitrogen and ortho-phosphate levels. If insufficient nitrogen or phosphorous appear to be available, calculate the amount in pounds of each that will be required for the system.

$$\text{Specific Nutrient Needed} = \frac{\text{Influent BOD (mg/l)}}{\text{Carbon :Nutrient Ratio } (100 \div \text{Nutrient ratio})}$$

Example: 170 mg/l BOD ÷ (100 ÷ 5 = 20) = 170 ÷ 20 = 8.5 mg/l of N needed

Step 2. Determine the nutrient shortage. If in this example the system has 4.5 parts of ammonia in the influent wastewater, the amount of nutrient shortage would be;

Amount Required - Amount in Influent = Amount Needed for this system.

Example: If 8.5 mg/l is required and 4.5 mg/l is in the influent, the amount we need to add to the system would be 8.5 mg/l - 4.5 mg/l = 4.0 mg/l of N.

Step 3. Calculate the pounds of the respective nutrient to be added.;

Nutrient shortfall in mg/l x flow in MGD (millions of gallons per day) x 8.34

Example: If the flow is 1.5 MGD and the N shortfall is 4.0 mg/l;

1.5 x 4.0 x 8.34 = 50 pounds of N needed per day

Step 4. Determine pounds of a specific chemical containing the needed nutrient;

$$\text{Chemical lb/day} = \frac{\text{Nutrient lb/day required x Nutrient atomic weight ratio}}{\text{concentration of the nutrient in the chemical (as a \%)}}$$

Example: The atomic weight ratio for urea is 2.14 {urea is $CO(NH_2)_2$}
atomic wt. of C = 12 x 1 = 12
atomic wt. of O = 16 x 1 = 16
atomic wt. of N = 14 x 2 = 28
atomic wt. of H = 1 x 4 = 4
total atomic wt. = 60 ÷ 28 (N) = 2.14

Therefore; if 50#/day of N is needed, (50 x 2.14) ÷ 46% N (0.46) concentration in Urea product = 233#/day of this particular grade of urea.

Some typical products that can be used as additives for N or P include;

Chemical Name	Formula .	Nitrogen atomic weight ratio	Phosphorous atomic weight ratio
Anhydrous Ammonia	NH_3	1.21	-
Phosphoric Acid	H_3PO_4	-	3.16
Ammonium Phosphate	$NH_4H_2PO_4$	8.21	3.71
Urea	$CO(NH_2)_2$	2.14	-
Trisodium Phosphate	Na_3PO_4	-	5.29
Disodium Phosphate	Na_2HPO_4	-	4.58
Monosodium Phosphate	NaH_2PO_4	-	3.87

Note: Do not use a polyphosphate or hexametaphosphate as a source for P, as they are very slow to hydrolyze, requiring a week or more to become an available source of PO_4 for the bacteria.

Also, be certain that PO_4 is measured as soluble PO_4 as phosphate tends to react very rapidly with iron (ferric chloride), aluminum (alum) or calcium to form stable complexes which again are unavailable to the bacteria (i.e.; filter the sample through a 0.45µ filter before testing.

Common Design Criteria Used in USA

	Loading Range Rate	Type of Aeration	BOD_5 Loading	HRT hours	MCRT days	F/M ratio	MLSS mg/l	R/Q %
Plug Flow	Conventional-low rate	Diffused / Mechanical	20 - 40# / (000) ft^3	4 - 8	5 - 15+	0.2 - 0.4	1500-3000	25 - 50%
Complete Mix	High rate Conventional	Diffused / Mechanical	15 - 120# / (000) ft^3	3 - 5	5 - 15+ 15 - 30	0.2 - 0.4 0.05 - 0.2	3000-6000	25 - 100%
Contact Stabilization	Conventional	Diffused / Mechanical	30 - 50# / (000) ft^3	0.5 - 1.0 3.0 - 6.0	5 - 15+	0.2 - 0.4	1000-3000 4000-10000	25 - 100%
Step Feed	Conventional	Diffused	40 - 60# / (000) ft^3	3 - 5	5 - 15+	0.2 - 0.4	2000-3500	25 - 75%
Extended Aeration	Low Rate	Diffused / Mechanical	10 - 30# / (000) ft^3	18 - 36	20 - 30 + NH_3	0.05 - 0.2	3000-6000	75 - 150%
Oxidation Ditch	Low Rate	Brush H. Rotor	10 - 40# / (000) ft^3	18 - 36	20 - 30 + NH_3	0.05 - 0.2	3000-5000	75 - 150%
Pure O_2 (UNOX^D)	High rate - Conventional	Pure O_2 Diffused	100 - 250# / 000) ft^3	1 - 3	3 - 20	0.25 - 1.0	3000-8000	25 - 50%
Sequential Batch Reactor	Conventional - Low Rate	Diffused, sometimes Mechanical	10 - 50# / (000) ft^3	8 - 50	15 - 80	0.03 - 0.18	per F/M ratio	None, Uses DOB at % total vol.

On the secondary clarifiers, use the flux rate- re: pounds of solids loading per square foot surface area on the clarifier(s) = {Q + R x $MLSS_{mg/l}$ x 8.34} ÷ {π r^2}. HRT is usually 3 to 5 hours.

Note: Sanitary Systems should have a flux within the 15 to 25 pound/ft^2 range, Pulp mills in approximately a 20 to 35 pound/ft^2 range.

The term BOD5 refers to a 5-day test at 20°C. BOD is the Biodegradable organic carbon, and under certain conditions oxidizable nitrogen present in the waste. When the nitrogen oxidation is suppressed, the term CBOD is used.

Chemical Oxygen Demand - Measures all organic carbon with the exception of certain aromatics (benzene, toluene, phenol, etc.) which are not completely oxidized in the reaction. COD is a chemically chelated/thermal oxidation reaction, and therefore, other reduced substances such as sulfides, sulfites, and ferrous iron will also be oxidized and reported as COD. NH3-N (ammonia) will NOT be oxidized as COD.