Wilson Environmental
ENGINEERED WATER & WASTEWATER SYSTEMS

# Biological Oxidation of Organics In Industrial Applications

The intent of this paper is to provide general information to assist in understanding biological treatment systems and in determining the feasibility of using a biological oxidation process, more commonly known as biological wastewater treatment, to treat an industrial wastewater stream. This paper will help you understand the difference between a domestic biological wastewater system and an industrial biological system and help you avoid purchasing a treatment unit that will not work in your industrial application.

It is important to understand the differences between domestic and industrial wastewater treatment. A quick search on the Internet will show a wide selection of off-the-shelf biological units for sale. Many of these systems do not differentiate between domestic and industrial wastewater. These off the shelf biological wastewater units are presented as being able to treat wastewater in terms of gallons per day without any qualification. Many of these off-the-shelf systems are incorrectly designed and will not work well in either application, domestic or industrial.

## Basic Biology

Biological treatment uses microorganisms for the destruction of the anticipated organic compounds in the wastewater. The most common microorganisms are bacteria. Bacteria make up 90 to 95 % of the living microorganisms in a treatment plant. The bacteria convert the unwanted organic material to carbon dioxide and water. For this to occur, there must be sufficient substrate (food), oxygen, nutrients and the proper environment.

Bacteria can be classified into three general groups as follows:

**Anaerobic Bacteria**- Anaerobic bacteria do not require free oxygen for life. In fact free oxygen will kill them. The presence of anaerobic bacteria is usually indicated by a rotten egg odor, Hydrogen Sulfide (H2S). Also referred to as septic conditions.

**Aerobic Bacteria**-Aerobic bacteria require free oxygen for their life.

**Facultative Bacteria**- Facultative bacteria can live in either anaerobic or aerobic conditions.

# Biological Treatment Dynamics

Aerobic bacteria are a selective oxidant. For example, if glycol is present in the wastewater the bacteria will select the glycol over oils and greases. Which could result in the pass though of oils and greases. Biological reaction rates to eliminate the unwanted organics are limited by the respiration rate and the reproduction rate of the bacteria. Which is further controlled by the presence of oxygen, nutrients and the water conditions. The actual reactions in a mixed organic wastewater stream involve a complex series of chemical reactions.

# Domestic Wastewater

Domestic wastewater is composed of a small amount of organic waste carried by a large volume of water. By weight, domestic wastewater is about 99.9% water and 0.1% solids. The solids are from homes and restaurants and include body waste, food waste, bathing and laundry waste. The carbohydrates, fats, and proteins that comprise domestic waste support the biological treatment processes.

# Industrial Wastewater

Industrial wastewater may be composed of various chemicals, toxins, heavy metals, pharmaceuticals, petroleum based oils and greases. By weight industrial wastewater varies considerably and may have as much as 5 % solids.

All industrial users are subject to general and specific prohibitions identified in the Code of Federal Regulations identified in 40 (CFR) 403.6 which prohibits the discharge of any pollutant that may impair worker or public health and safety, or that might upset or pass through the wastewater treatment plant untreated.

# Dynamics of Biological Treatment

Bacteria and other microorganisms will exhibit changes in population that affect their growth. A typical growth curve will show a lag phase of several days to 30 days for the bacteria to acclimate. The most important factors to acheiving acclimation are availability of food, pH, temperature, nutrients and dissolved oxygen.

In the treatment tank the bacteria will do their job and remain healthy as long as food and environmental conditions are carefully controlled. In a healthy treatment system the amount of Food to the number of Microorganisms is called the F/M ratio. This ratio must stay balanced. This is a major concern in industrial applications. In industrial applications the F/M ratio can be easily upset if proper equalization is not used. Even with equalization, plant shutdowns, holiday closures, cleaning operations, use of degreasers and heavy soaps can adversely impact a biological treatment system.

# Controlling Factors

To determine if a biological treatment process is operating efficiently the following terms shuld be understood.   These are a minimum.

- BOD
- TSS
- TDS
- DO
- Temperature
- pH

**Biochemical Oxygen Demand (BOD)-** Biochemical Oxygen Demand (BOD) (sometimes called Biological Oxygen Demand) is the quantity of dissolved oxygen, expressed as milligrams per liter, required (used up) to partially stabilize the degradable organic matter in a waste water stream by biological and chemical action over a 5 day period.    BOD is a measure of the amount of substrate (food) that is in the wastewater.  BOD is also know as the “strength” of the wastewater.

BOD in raw domestic wastewater varies from 100 to 350 mg/l.

BOD in industrial wastewater varies over a wide range and may be as high as 20,000 mg/l.

**Total Suspended Solids (TSS):** These are suspended solids that can be filtered out

**Total Dissolved Solids (TDS):** These are dissolved solids that can not be filtered out.

**Dissolved Oxygen:** Dissolved Oxygen (DO) is free oxygen available for aerobic and facultative bacteria to live.   DO levels must be present in all parts of the aeration tank in sufficient concentration (2 – 3 mg/l).

DO is rapidly consumed in the aeration tank and must be replaced continuously.

**Temperature:** Wastewater temperature influences growth rate and the DO level.   As temperature rises DO decreases.   Excessively high or low temperature can limit or kill the bacteria.

**pH:** pH is a measure of how acidic or basic a solution is,  The pH scale runs from 0 to 14.   From 0 to 7 is acidic and from 7 to 14 is basic also called alkaline.   A pH of 7 is neutral.

The pH range for good biological growth is 6.5 to 8.0.

**Nutrients:** Nutrients are Nitrogen, Potassium and Phosphorous (NKP).

In domestic wastewater, nutrients are in abundance.

In industrial waste, nutrients are generally not present and must be added. Without NKP microbes will not live.

**Characteristics of Matter in Wastewater**

**Fats, Oils and Greases:** Fats, oil and greases are the most common constituents of wastewater and they are classified as either saponifiable or nonsaponifiable.

**Saponifiable**: Sources of saponifiable fats, oils and greases include body waste, fecal matter, wash water, kitchen wastes, restaurant wastes, food processing wastes, milk processing wastes, meat-packing wastes and soaps. Aerobic bacteria oxidize these organic fats oils and greases to carbon dioxide and water, while anaerobic bacteria reduces them to organic acids and methane gas.

**Nonsaponifiable**: Nonsaponifiable fats oils and greases are derived from petroleum products and will respond poorly to bacterial action. Many municipalities prohibit petroleum based oils and greases from being discharged to the sewer.

**Metals**: Metals are inorganic and biological wastewater systems will not remove metals from the wastewater. Metals may appear as soldis that can be filtered or as dissolved solids.

**Soaps and Cleaners**: Soaps and cleaners may be biodegradable or sanitizing. Sanitizing soaps and most degreasers are toxic to microorganisms.

# Wash Bay Applications

Industrial wash bay applications are difficult to manage. This is because the items being washed vary from day to day and may involve the use of chemicals such as degreasers in vehicle cleaning or disinfectants in food processing washrooms. Both are toxic to microorganisms.

In vehicle washing most of the wastewater will contain dirt and grit. Biological systems do not treat dirt and grit.

# Water Reuse

When reuse of the treated water is desired the treated water must be disinfected before use for worker health and safety. There are numerous ways to achieve this. Chlorine disinfection is common. But the chlorine will kill the bacteria if it is not consumed in the disinfection process. Ozone can also be used for disinfection as well as UV light. Disinfection should be addressed on a case by case basis.

# Biological Wastewater Treatment Sizing Requirements

The aeration tank provides the space and time necessary to mix, aerate and hold the wastewater long enough to be treated. Aeration tanks are often called reaction tanks or biological reactor tanks because they provide the environment and the time for the biological process to occur. The bacteria doing the work require adequate time for food gathering (biosorption) and for digestions (utilization). In biosorption the organisms collect the waste products as their food supply and adsorb it into their bodies. In utilization the bacteria convert the food to carbon dioxide and water. This process requires time and that time is know as the Hydraulic Retention Time.

While many factors are involved in the design and proper sizing of a biological wastewater treatment system, determining the proper Hydraulic Retention Time (HRT) can be used to determine system size and for obtaining a budgetary estimate.

HRT is defined as the length of time that the wastewater stays in the aeration tank or pond. In domestic wastewater treatment this ranges from 8 to 12 hours. This is sufficient to reduce BOD by up to 95%. However, in industrial applications where nonsaponifiable oils and greases are present this is much longer.

HRT = Tank Volume in Gallons / flow rate in gallons per minute

For example, a recent bench scale test for a wastewater stream from a food processing plant required an HRT of seven days. The plant was producing 20,000 gallons per day and therefore required 7 X 20,000 gallons = 140,000 gallon aeration tank to lower the BOD from its initial value of over 3,000 mg/l BOD to 300 mg/l BOD, or a 90% reduction. This size was used to produce a budgetary estimate of the cost to install a treatment system.

**Stock Designs**: Off-the-shelf, stock design, biological systems are often specified in gallons per day. This works well for domestic wastewater treatment because there is little variability in domestic sewage.

However, stock designs do not translate to industrial applications. This can be very confusing when shopping for a system.

For example: One Biological Wastewater Treatment unit readily found on-line from various vendors is advertised as a 0 to 35 gallon per minute (gpm) system, with no qualifying statements as to applicability of the system. The referenced system is advertised as 0 to 35 gpm and has an aeration tank size of 2,244 gallons. At 35 gallons per minute, the wastewater is staying in the aeration chamber (HRT) only 64 minutes. This is not long enough to accomplish much, and at the maximum flow rate the system is basically a wide spot in the line. Since off-the-shelf units are advertised as 0 to some maximum, one should ask the question, what type of loading or strength (BOD) are they basing the flow rates on. When flow rates are given as 0 to X, the HRT can be anything you want, as long you keep reducing the flow. Off the shelf units have their place, but one should never purchase an industrial system on the basis of the advertised maximum flow rate. In many cases the maximum flow rate is determined based on pump capacity using clean water.

# Using Bench Scale and Pilot Testing

When designing a biological system for domestic wastewater, standard designs based on flow rate can be used to successfully size a treatment system.

When designing a biological system for industrial wastewater, a standard design criterion will most likely not work.

**Bench Scale**: Bench scale testing is needed in industrial applications to first; determine if the wastewater stream is even treatable by biological process and to determine how long it takes to achieve the desired results. From the bench scale testing results, an estimate of HRT can be determined and the feasibility of using a biological process determined. A budgetary estimate can be made at this point before going to pilot study or to the design and build phase of the project.

**Pilot Testing**: Pilot testing is recommended if favorable results are obtained from the bench scale testing. A pilot test is generally the next step.

Pilot testing can be described as on site testing at the actual location under actual conditions. This is accomplished by taking a real time side stream of the wastewater and testing the actual biological process that is being considered before going to full-scale construction.

# Equalization Tanks

Equalization Tanks are required for most wastewater treatment systems to provide a consistent flow rate and consistent characteristics. Equalization tanks are used to collect wastewater over a period of time that is sufficient to "equalize" the flow so that the wastewater system receives a wastewater stream that is as consistent as possible.

As a rule of thumb. If the total flow occurs in less than 10 hours a day or if the characteristics of the wastewater varies from day to day an equalization tank is required. The actual size will of course be based on a case by case basis.

# Odor Problems

The most common odor problem is the smell of rotten eggs. Anaerobic decomposition of organic matter produces hydrogen sulfide ($H_2S$) which has an objectionable odor. Please note: The problem goes beyond the odor issue. $H_2S$ gas is poisonous, makes sulfuric acid when water is present, corrodes metal, will attach and destroy concrete pipes and tanks.

Odor problems occur when anaerobic (no oxygen) conditions exist. This can also occur in aerated systems when the amount of air is not enough or when sludge accumulates and is not aerated.

# Sludge (microbial) Age

The microbial mass that is produced in the treatment tank has an average age. In domestic applications the ideal sludge age is 30 days. In some of the more recent designs sludge of 8 to 12 days is ideal. This means that at start up it will take about 8 to 12 days or 30 days, depending on the type of system, to reach an operational balance. When an upset occurs the recovery time can result in pass though of contaminates.

# Conclusions

Domestic wastewater systems can be purchased based on anticipated flow rate or on the number of persons utilizing the system.

For Industrial biological wastewater treatment, off-the-shelf designs seldom work as desired. Bench scale testing and pilot testing are generally required for the proper design of an aerated biological system in an industrial setting.

Beware of vendor claims based on gallons per minute when purchasing a unit for industrial applications.

Biological systems require monitoring and proper operation. The level of operational expertise in industrial applications is often beyond what is available in terms of both man power and operational expense including monitoring for compliance.

A permit and monitoring is required to operate either type of system.

In wastewater reuse systems the treated water must be disinfected prior to use.