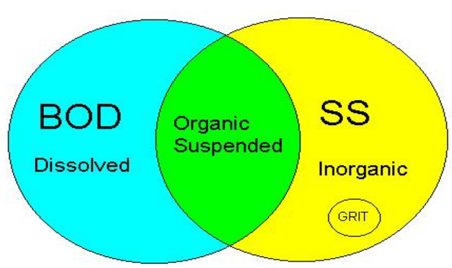
INTRODUCTION TO WASTEWATER TREATMENT

The term wastewater is commonly used to describe liquid wastes that are collected and transported to a treatment facility through a system of sewers. Wastewater is generally divided into two broad classifications: domestic wastewater and industrial wastewater. Domestic wastewater comes from communities of homes, businesses, and institutions. Domestic wastewater is 99.9% water and only 0.1% solids. Milligrams per liter (mg/L) is the metric equivalent of parts per million (one part in a million parts). One percent (1%) is equal to 10,000 mg/L. So a 0.1% solids concentration is equal to 1000 mg/L. The solids in domestic wastewater are both dissolved and suspended solids. Suspended solids can be settled out or filtered but dissolved solids will have to be converted to suspended solids during the treatment process.

BOD AND SUSPENDED SOLIDS

The strength of the wastewater is determined by measuring the amount of suspended material in the water and the amount of organic material in the water. The suspended, filterable solids in the waste flow are known as Suspended Solids or SS. They can be trapped on a filter, dried, and weighed to determine the concentration. The organic strength of the wastewater is determined indirectly. The microorganisms in the biological treatment processes decompose or stabilize the raw organic material in the waste flow. As they do this, they use oxygen as part of the respiration process. Instead of directly measuring the strength of the organics, the amount of oxygen that the "bugs" use as they eat it is determined. This is known as the Biochemical Oxygen Demand or BOD. If these organics are not stabilized in the treatment process they will deplete dissolved oxygen from the receiving water. This oxygen depletion can result in fish kills and damage to the aquatic ecosystem.

Some of the suspended solids are organic, but most of the organics in the wastewater are dissolved. About 40% of the BOD will be suspended particles and most of them will settle out without further treatment. But 60% of the BOD is dissolved and must be used as "Bug Food" to grow a culture of microorganisms that become "suspended solids" that are again removed by settling. Suspended solids are classified as "Suspended" and "Settleable". About 60-70% of the Suspended Solids in raw wastewater are settleable. The rest will have to be made settable in the biological processes. Domestic wastewater will have a BOD of between 150-300 mg/L and SS in the 100-400 mg/L range. Nitrogen, in the form of ammonia, will also be present in domestic wastewater. Ammonia concentrations usually run from 10-40 mg/L.



INDUSTRIAL WASTEWATER

Industrial wastewater characteristics vary with each type of discharge. Food processing, dairy operations and meatpacking all have wastes that are very high in BOD, sometimes over 1000 mg/L. This BOD is high in dissolved sugars, fats, and proteins and low in suspended material. It will dramatically increase the loading on the secondary treatment processes. Some food process wastes can also have a high pH, like potato processing and some vegetable canning, or a low pH, like green chili processing or fruit canning.

Toxins, like heavy metals coming from metal plating, battery shops, and heavy equipment manufacturing, and solvents from industries like body shops, dry cleaners, and furniture manufacturing can kill the microorganisms that are needed to treat the waste. Copper, chrome, lead, and cyanide are all chemicals that are commonly found in heavy industrial manufacturing discharges. Hospitals and other medical facilities have the potential to discharge wastes that are radioactive or represent a biohazard.

In some cases, pretreatment of these industrial discharges may be required. Systems that deal with industrial discharges should adopt a pretreatment ordinance to cover conditions that the system may need to impose on the industrial dischargers in order to maintain their NPDES requirements on the treatment plant effluent. If local ordinances are different from specific categorical limits imposed in the Federal Regulations, the most stringent limits of the two must be followed. Pretreatment ordinances can require actual treatment of the industrial waste prior to discharge to the system, or it may levy a monetary surcharge based on the addition loading that results from the discharge.

Any industrial discharger is considered to be a "Significant Industrial User" or SIU if:

A) The discharge requires pretreatment
B) The flow is over 25,000 gpd or
C) The flow is more than 5% of total average plant BOD or hydraulic load.

COLIFORM GROUP OF BACTERIA

Another issue that must be addressed in wastewater treatment is the removal of pathogenic bacteria that can cause water-borne diseases. Wastewater operators need to be mindful of the potential contact with organisms that are responsible for typhoid, cholera, dysentery, and hepatitis. Blood-borne pathogens responsible for illnesses like HIV are also a concern in wastewater. Wastewater must be disinfected to kill these harmful organisms before it can be discharged. The effluent must be tested for coliform bacteria to confirm proper disinfection.

Coliform bacteria are enteric bacteria. This means that they are found in the intestinal tract of warm-blooded animals, including humans. These bacteria, known as E. Coli in humans, do not cause disease but are necessary for the digestion of food. The waterborne pathogens are also enteric bacteria and are part of the coliform family. Therefore, if coliform bacteria are present in the water supply, pathogens may also be present. The coliform bacteria live longer in water and are easier to detect by laboratory testing. This is the reason the coliform group has been chosen as the indicator organism for waterborne pathogens. If coliform bacteria are not present it is assumed there are no pathogens present either.

OVERVIEW OF WASTEWATER TREATMENT PROCESSES

Wastewater treatment processes are broadly classified in one of five categories. The first step in wastewater treatment is physical separation of solids from the flow by screening, grinding rags and other debris, and settling out heavy inert grit. This is known as pretreatment or preliminary treatment. Rags and grit make up a small portion of the total amount of solids that must be removed from the waste flow. It is important to remove them first because their presence downstream can create operational and mechanical problems in the other processes.

Primary treatment follows pretreatment. Primary treatment is also a physical removal process. Gravity settling in primary clarifiers removes some of the suspended organic material and most of the total suspended solids or TSS. Most of the BOD is either too small to settle easily or dissolved. If it is not removed in the primary clarifiers it will pass on the secondary treatment process.

The settled sludge is removed to from the clarifier and sent to solids handling facilities for further processing. The sludge may be digested to stabilize it and reduce its volume. After the sludge is properly digested, it is de-watered by mechanical means or sludge drying beds and then composed or landfilled. Some large systems thicken and de-water raw sludge and burn it in furnaces. Although incineration is very expensive from an energy consumption standpoint, it provides the greatest reduction in solids volume for disposal.

Secondary treatment processes are biological processes that use bacteria and other microorganisms to "eat" the organic material that was not removed in primary clarification. This type of process will stabilize the raw organic material that poses a threat to the receiving water. The organics are stabilized because they are converted in microorganisms (suspended solids) that can be removed or harvested from the process. Secondary treatment processes include trickling filters, lagoons and stabilization ponds, rotating biological contactors (RBC's), and several different kinds of activated sludge processes. A food chain is developed in a secondary treatment process. Bacteria accomplish most of the organic stabilization. As the bacteria reproduce the organics are converted into suspended solids. The bacteria represent the bottom of the secondary food chain. These bacteria are eaten by small single celled water creatures, called protozoa, which are in turn eaten by larger multi-celled organisms. These larger organisms can be removed in a clarification process as secondary sludge.

Tertiary treatment processes follow secondary treatment. They cover a wide range of treatment options. Polishing ponds for bacteria and BOD removal have been added to secondary trickling filter plants to improve the overall plant removal efficiency. Tertiary filter processes can be used to remove suspended solids. Nutrient removal processes are also considered to be tertiary treatment processes. Nitrification/denitrification, ammonia stripping, phosphorous precipitation, and land application/overland flow processes may be used in cases where nutrient removal is required to meet a system's discharge permit.

The final process in wastewater is disinfection. Disinfection is required to destroy pathogenic organisms in the wastewater effluent. Chlorination is the most common means of disinfecting wastewater. The problem is that chlorine will also harm aquatic life in the receiving water. Many systems that chlorinate are also required to dechlorinate to remove the chlorine residual before the effluent is discharged. More and more systems have implemented alternative methods of disinfection to get away from the chlorinate/dechlorinate issues. These include polishing ponds, ultra-violet (UV) radiation, and ozonation.

NPDES Regulations

The Clean Water Act of 1970, and the Federal Water Pollution Control Act Amendments of 1972, established the National Pollutant Discharge Elimination System or NPDES in an effort to assure that wastewater discharges would not adversely affect recreation or wildlife. The Clean Water Act was legislated at the federal level and it is administered through the United States Environmental Protection Agency (USEPA). However, the responsibility for enforcement of the regulations, or primacy, is given to the individual states. Each state must identify a primacy agency to handle these duties. The primacy agency in New Mexico is the New Mexico Environment Department (NMED). In Arizona, the primacy agency is the Arizona Department of Environmental Quality (ADEQ). Tribal systems may report directly to the USEPA or an internal primacy agency like the Navajo EPA for the Navajo Nation.

The NPDES permit identifies monthly averages and maximum levels of BOD, Suspended Solids, and Fecal Coliform allowed in the treatment plant effluent. In larger systems, and systems that discharge into sensitive receiving waters, NPDES permits may also require reporting of the temperature and pH of the discharge and mandate removal of nitrogen or phosphorous. The NPDES permit will also specify the frequency of sample collection and methodology for reporting the results.

Wastewater Treatment Bacteria

The stabilization of organics in wastewater is accomplished bacteria in both secondary and tertiary treatment processes and in sludge digestion. There are three types of bacteria responsible for the decomposition of BOD in wastewater.

Aerobic bacteria are used in secondary treatment processes. They must have dissolved oxygen present in the water to survive. As they break down the organic material they release carbon dioxide (CO_2). When wastewater has dissolved oxygen for aerobic activity, it is sometimes called "fresh sewage". It has a dishwater gray appearance and few objectionable odors.

Anaerobic bacteria cannot reproduce in wastewater that has dissolved oxygen present. In the absence of DO, the anaerobic bacteria will break down organics and release carbon dioxide (CO_2), methane (CH_4) and hydrogen sulfide (H_2S). These three gases are referred to as "sewer gases" because they are often found in wastewater collection systems. Methane is explosive. Hydrogen sulfide is a deadly nerve agent that can cause paralysis and death.

Carbon dioxide is a safety hazard because it will displace oxygen in the atmosphere in confined spaces. Anaerobic decomposition is most commonly used in anaerobic sludge digesters. The methane that is produced can be used as an energy supply to heat the digester and sometimes generate electricity. Other objectionable odors that result from anaerobic decomposition include sulfur compounds called mercaptans and thiols.

Facultative bacteria can act like aerobic bacteria in the presence of oxygen or anaerobic bacteria if there is no DO available. They can be found in all types of biological treatment processes because of their adaptability. They are usually associated with facultative stabilization ponds.

pH AND WASTEWATER

The pH of the water is the measurement of the acidity of the water. Water, or wastewater, is considered to be acidic when it has more hydrogen ions (H^+) in it than hydroxide ions (OH^-). Some of the chemicals that add hydrogen ions (H^+) to the water are hydrochloric acid, HCl, sulfuric acid, H_2SO_4, nitric acid, HNO_3, and carbonic acid, H_2CO_3.

Water is considered to be alkaline when there are more hydroxide ions (OH^-) present than hydrogen (H^+) Sodium hydroxide, NaOH, calcium hydroxide, $Ca(OH)_2$, and magnesium hydroxide, $Mg(OH)_2$, all add hydroxide ions (OH^-) to the water. When the number of hydrogen ions and hydroxide ions are the same the water has a neutral pH. Pure water, H_2O or H-OH, has a neutral pH because the number of hydrogen ions (H^+) and hydroxide ions (OH^-) are equal.

pH SCALE

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
							^							
		More Acid					Neutral				More Alkaline			

The pH of water is measured on a scale that reads from 0 to 14. The midpoint of the scale is 7. Water with a pH of 7 is neutral. If the water has a pH less than 7, the water is acid and if the pH is greater than 7 it is alkaline. For every whole number that the pH changes the strength of the acid or alkaline properties of the water will change by a factor of ten times. Water that goes from a pH of 9 to a pH of 10 becomes 10 times more alkaline and water at pH of 5 is 10 times more acid than water at a pH of 6.

EFFECTS OF TEMPERATURE AND pH ON BIOLOGICAL ACTIVITY

Most biological activity occurs when the water temperature is between 50-85^{o}F. Some anaerobic digestion processes operate at temperatures of over 100^{o}F. Wastewater bugs are kind of like the rest of us in that the colder it is, the less active they become. A temperature drop of 10^{o}C (18^{o}F) will cause a 50% reduction in biological activity. This means that process adjustments must be made during the winter months to compensate for the drop in water temperature in the treatment processes.

All three types of the wastewater treatment bacteria operate most efficiently at a pH of 6.8-7.2 (somewhere around neutral). When the pH drops below 6.0 or rises above 8.5, activity drops off dramatically. The tendency in wastewater treatment is to lower the pH. This occurs because carbon dioxide that is released in the decomposition process reacts with water to make carbonic acid. Industrial wastes that create abrupt changes in pH can cause serious upsets of the secondary processes.

DAILY FLOW FLUCTUATIONS

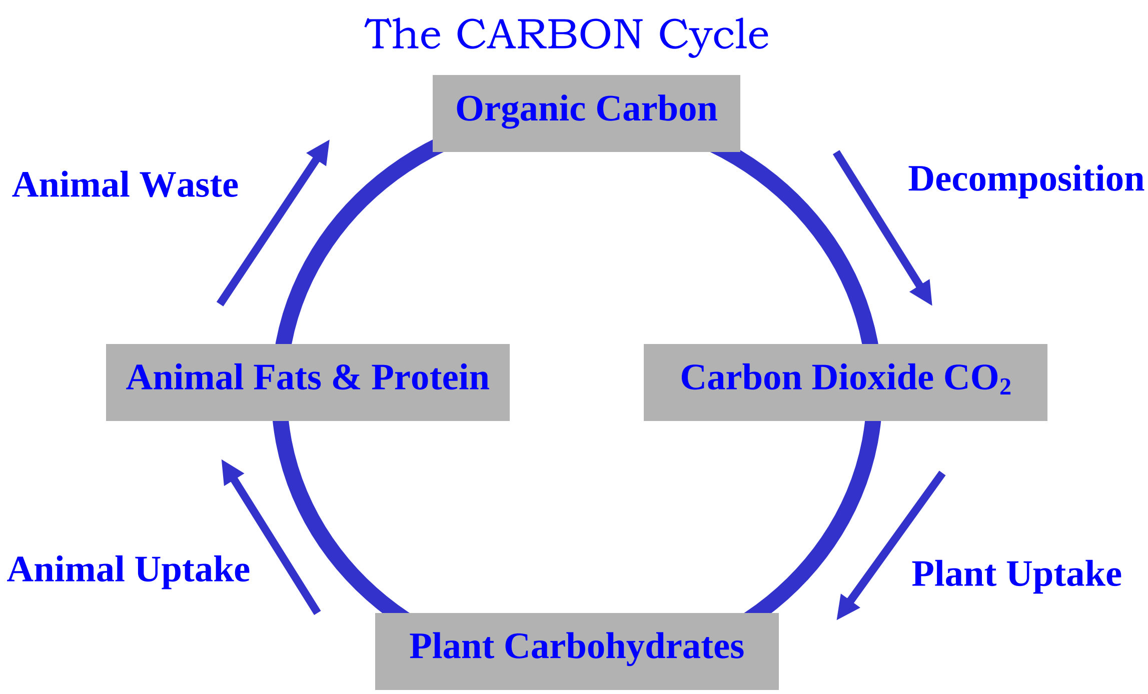
The flow at the treatment plant will fluctuate with the changes in water usage by the domestic customers. At night water usage is low and so is the flow at the treatment plant. In the morning, usually between 6-8am, water usage increases and so does the flow to the plant. But it takes several hours for the wastewater to make its way through the collection system. So the peak flow usually hits the treatment plant between 9-10:30am. This peak flow can be as much as twice the daily average flow. The flow will spike again between 6-8pm, which correspond with the evening peak water usage. Treatment process adjustments must be made to compensate for the high and low flows that will affect the hydraulic loading on the plant. A higher flow rate will result in decreased detention time in treatment processes and can adversely affect treatment as the surface loading rate in clarifiers increases.

Some systems are designed with equalization basins in the headworks. The purpose of flow equalization is to retain water during higher flow periods. The stored water can be treated later in the day when the plant flows drop. This reduces the hydraulic “bump” from sudden flow surges that can cause a loss of solids from the system.

THE CARBON CYCLE

Decomposition of organic matter in wastewater involves the oxidation of the raw organics into stable compounds. The two most important cycles of decay are the cycles for carbon and nitrogen. Organisms that feed on carbon based organics and nitrogen based organics require oxygen for the respiration process. If this is not accomplished in the treatment process, the result will be oxygen depletion of the receiving waters and harm to the aquatic life that also needs dissolved oxygen to survive.

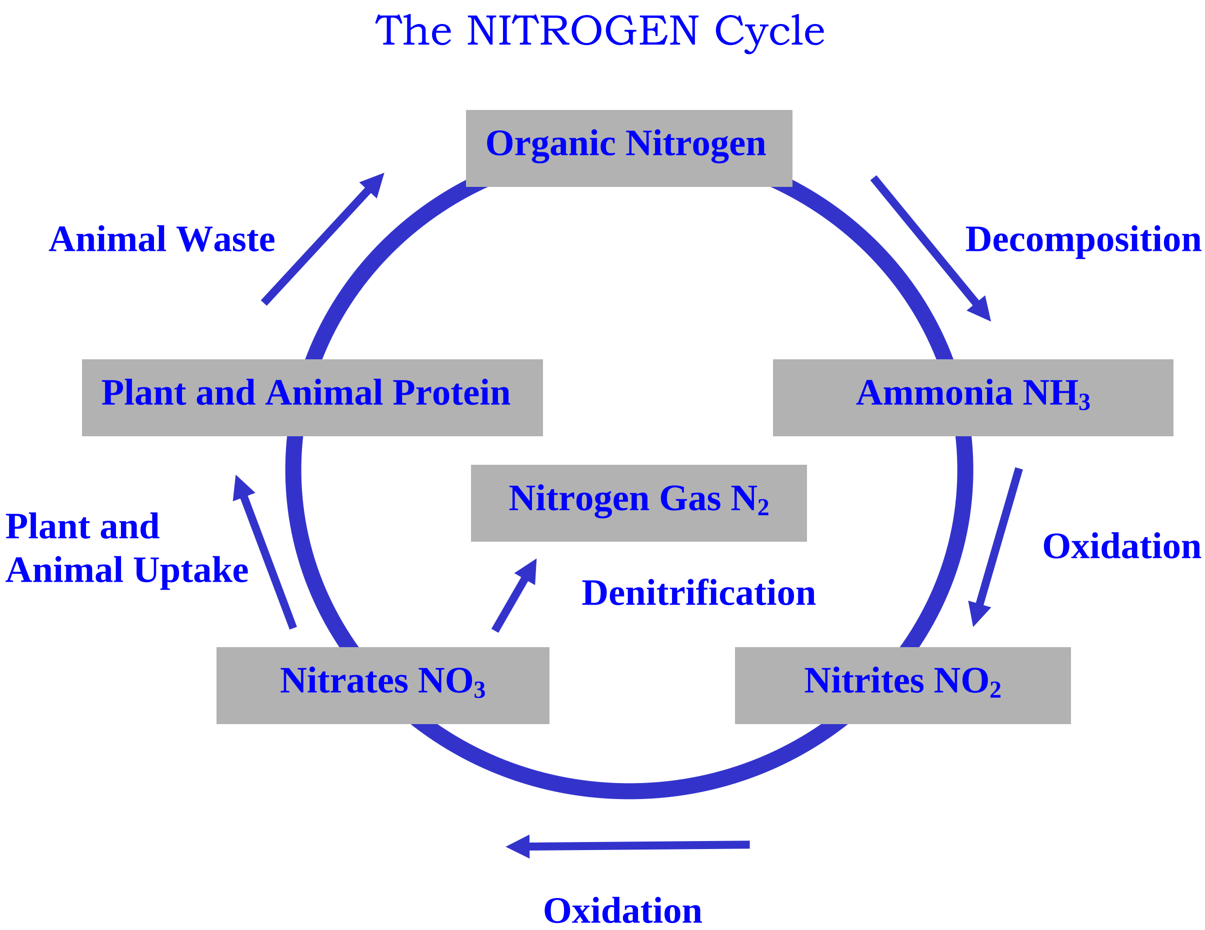
The carbon cycle begins with organic carbon that is in the waste stream. Bacteria decompose the organic carbon as they eat it and release carbon dioxide. Plants take in carbon dioxide to make plant sugars, starches, and other plant carbohydrates through photosynthesis. Animals eat the plants and use the carbohydrates to make animal fat and protein. The animal waste products are the organic carbon that we started with at the top of the cycle. Most of the BOD in wastewater treatment is made up of carbon-based organics.



THE NITROGEN CYCLE

The nitrogen cycle is more complex than the carbon cycle. The first step in the stabilization of nitrogen-based organics (primarily proteins) is the decomposition of organic nitrogen into ammonia (NH_3). Ammonia levels in domestic wastewater are normally between 10-40 mg/L. In the second step nitrogen bacteria oxidize the ammonia and change it to nitrites (NO_2). Nitrite nitrogen is still unstable and will create an oxygen demand in the receiving water. The third step is further oxidation to create nitrates, which are the most stable form of nitrogen. Plants and animals will use the nitrates to form plant and animal proteins and their waste products again become organic nitrogen.

Nitrate is a nutrient that can encourage plant growth in the receiving waters. Some tertiary treatment systems are designed to denitrify or remove the nitrates. Facultative bacteria in anoxic conditions remove the oxygen for respiration and release nitrogen gas to the atmosphere.



BASIC STUDY QUESTIONS

1. How do the three types of bacteria in wastewater treatment differ?

2. What is the normal range for BOD and SS in domestic wastewater?

3. What is the difference between primary treatment processes and secondary treatment processes?

4. What are the three sewer gases released during anaerobic decomposition?

5. What does NPDES stand for?

BASIC SAMPLE TEST QUESTIONS

1. The peak flow period at the treatment plant will be between

   A. 3:00-5:00am
   B. 6:00-8:00am
   C. 9:00-10:30am
   D. 9:00-11:00pm

2. What effect do colder temperatures have on biological activity?

   A. Bioactivity decreases
   B. Bioactivity increases
   C. Temperature does not affect bioactivity

3. Most wastewater "bugs" like a pH around:

   A. 3.5-5.5
   B. 6.8-7.2
   C. 8.3-9.5

4. Most secondary processes make use of which type of bacteria:

   A. Anaerobic
   B. Aerobic
   C. Nitrogen fixers
   D. Methane fermenters

ADVANCED STUDY QUESTIONS

1. What is the most stable form of nitrogen?

2. What parameters can be included in an NPDES discharge permit?

3. What are some of the characteristics of different industrial wastes?

ADVANCED SAMPLE TEST QUESTIONS

1. Ammonia discharged to receiving streams is a problem because:

   A. It represents BOD
   B. It will cause oxygen depletion in the stream
   C. It increases the suspended solids

2. Normal biological activity in treatment processes tends to:

   A. Cause an increase in DO
   B. Raise the pH
   C. Lower the pH
   D. Has no effect on pH