CHAPTER 1: INTRODUCTION TO WASTEWATER CHARACTERISTICS & TREATMENT

THE DEFINITION OF wastewAtEr
What is wastewater? We might understand this question better by first answering the question; what is water? Water is a compound made up of two parts hydrogen and one part oxygen. This is true, however, only for “pure” water. The water of our everyday lives contains many substances in addition to hydrogen and oxygen. These substances, since they are not found in “pure” water, may be considered impurities. In fact, the water that we drink every day contains many substances that can be considered impurities. Wastewater can be defined as a community’s spent water. Wastewater contains the impurities that were present when the water was obtained, and any impurities added through human uses. The term “sewage” is often used to refer to wastewater but is more properly applied to domestic (household) wastewater. Operators refer to the raw wastewater coming into a treatment plant as influent. The treated water discharged from a wastewater treatment plant is known as effluent.

SOURCES OF wastewAtER
Wastewater can originate from many sources such as; homes, businesses and industries. Storm water, surface water and ground water can enter the wastewater collection system and add to the volume of wastewater. The source of a wastewater will determine it’s characteristics and how it must be treated. For example, wastewater from homes and businesses (domestic wastewater) typically contains pollutants such as; fecal and vegetable matter, grease and scum, detergents, rags and sediment. On the other hand, wastewater from an industrial process (industrial wastewater) may include; toxic chemicals and metals, very strong organic wastes, radioactive wastes, large amounts of sediment, high temperature waste or acidic/caustic waste. Wastewater could even come from streets and parking lots during a rainstorm (storm wastewater) that could contain; motor oil, gasoline, pesticides, herbicides and sediment.

Most modern wastewater treatment facilities are designed to treat domestic wastewater. Industrial wastewaters that contain high strength waste, toxic waste or acid/caustic waste may have to be pretreated to make them safe to discharge to the collection system. If not, the processes at the wastewater treatment plant receiving the waste could be disrupted. Storm wastewater should be collected and treated (when necessary) separately from domestic and industrial wastewater.

TYPES OF WASTE DISCHARGES
The purpose of treating wastewater is to prevent pollution problems in receiving waters. Pollution can be defined as the impairment of water quality to the degree that the water is no longer suitable for beneficial use (use as a drinking water source, fish habitat, irrigation, recreation, etc.). The degree and type of pollution is related to the type of waste discharged. Waste discharges can be placed into two broad categories: organic wastes and inorganic wastes.

Organic Wastes are those substances that contain the element carbon and are derived from something that was once living. Examples include: vegetable and fecal matter, grease, proteins, sugars and paper.

Inorganic Wastes are those substances that do not contain carbon and are not derived from something that was once living. Examples include: metals, minerals, salts, acids and bases.

EFFECTS OF DISCHARGING WASTES
There are two routes by which pollutants enter receiving waters: point sources, such as a wastewater treatment plant discharges from an outfall pipe, and non-point sources, such as agricultural and industrial pollution that originates from a widespread discharge. In New Mexico, point source discharges can be made to streams, rivers and lakes or can be made to underground aquifers, because both surface and ground water discharges are common. Wastewater treatment plants, and wastewater treatment plant operators, control point source pollution. Non-point source discharges also occur to both surface and ground waters in New Mexico. Because non-point source pollution is not limited to a single outfall pipe, it is very hard to control.

The type of pollution, and the impairment of the receiving water are related to the type of waste being discharged. The following section discusses some common wastes and what effect they have upon receiving waters if not properly treated.

Sludge and Scum
Sludge and scum are a component of domestic wastewater and some industrial wastewaters. They are primarily organic in nature. If not removed by the wastewater treatment plant, sludge and scum will accumulate on river bottoms and stream banks. Sludge deposits on river bottoms can prevent fish (particularly trout) from being able to spawn. Scum accumulated on stream banks can
cause odor problems, can harbor infectious diseases and is unsightly.

**Organic Waste (in general)**

Organic waste, such as fecal and vegetable matter, toilet paper and sugars can cause a series of problems in receiving waters. One problem is oxygen depletion. Many aquatic organisms, including fish, need dissolved oxygen ($O_2$) to survive. These types of organisms are referred to as aerobes and the environment they live in as aerobic. Much like you and I, aerobic bacteria breath in $O_2$ and produce carbon di-oxide ($CO_2$) as a by-product. Natural surface waters typically contain enough dissolved oxygen to support aerobic organisms. Oxygen depletion can occur when aerobic bacteria use excess organic waste discharged into a receiving stream as food. As the aerobic bacteria multiply, they require more and more dissolved oxygen to sustain their growing numbers. When the population of aerobic bacteria grows large enough, they utilize more oxygen than is available in the river. After this happens, they (and most other aerobic organisms) in the river, die.

**Figure 1.1 - Oxygen Depletion**

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When all of the dissolved oxygen in a river has been consumed, another type of organism begins to grow in the altered environment. Anaerobic bacteria live in conditions where there is no dissolved oxygen (septic). Anaerobic bacteria breathe by using the oxygen that is chemically combined with other elements, such as sulfate ($SO_4$). When anaerobic bacteria use the oxygen from sulfate for respiration, hydrogen sulfide ($H_2S$) gas is released as a byproduct. Hydrogen sulfide, sometimes called sewer gas, smells like “rotten eggs” and is very dangerous due to its explosive, toxic and suffocating characteristics. Oxygen depleted conditions lead to the growth of anaerobic bacteria, which results in odors in receiving waters. Furthermore, anaerobic bacteria release other objectionable by-products, such as organic acids, methane gas and nutrients, all of which can further harm the natural environment in the receiving stream. Because of the chain of events that the discharge of organic waste sets into motion, one of the principal goals of wastewater treatment is to prevent as much of it from getting into receiving waters as possible.

**Nutrients**

Nutrients are substances that are required for the growth of living plants and animals. Some major nutrients are nitrogen and phosphorous. Both are found in wastewater in various forms. Nitrogen is typically present in influent in the forms of ammonia ($NH_3$) and organically bound nitrogen. Both nitrogen compounds can be measured by the Total Kjeldahl Nitrogen (TKN) test. Nitrogen may be present in effluent as ammonia, organically bound nitrogen or even nitrite ($NO_2$) and nitrate ($NO_3$). Phosphorous is present in influent and effluent primarily in the form of phosphates ($PO_4$). When large amounts of nutrients are allowed to enter into rivers and lakes, they can cause problems by increasing the growth of plants, such as algae. If the algae growth is extensive, it can choke up the water body. As the lower layers of algae are blocked off from the sun, they die and end up as food for bacteria. This begins the cycle described earlier under “organic waste discharges”, which leads to oxygen depletion.

**Toxins**

Several substances in wastewater can be toxic if not properly treated. One of these is ammonia. Ammonia is usually the main form of nitrogen present in domestic wastewater, while industrial wastes may or may not contain ammonia. Most people that have owned a fish tank are aware that even small amounts of ammonia can kill aquarium fish. Similarly, large-scale fish kills can occur when effluent-containing ammonia is discharged into receiving waters. In the case of point source discharges, ammonia toxicity depends upon the pH and temperature as well as the dilution factor in the receiving water. Warm temperatures and high pH make ammonia much more toxic to fish. If the discharge is to a small stream where only a little dilution occurs, ammonia can cause serious problems.

Another toxin of concern is the residual chlorine that is left over from the disinfection process (this process is discussed further on in this text). If residual chlorine is discharged into a receiving water, even in small amounts, it can also be toxic to fish. For this reason, chlorinated effluents must often be dechlorinated to eliminate all of the measurable residual chlorine.

Last, with regard to toxins, is the problem of ground water contamination from nitrogen compounds such as nitrate (and ammonia that is converted into nitrate by soil bacteria). If nitrate contamination occurs in an aquifer that is used for drinking water, the nitrate could cause methemoglobinemia, also called blue babies syndrome, in infants that drink the water. Methemoglobinemia is a condition where the blood’s ability to carry oxygen is greatly reduced. Recent research has also linked long term consumption of high levels of nitrate to other health problems.
**Suspended Solids**
Inorganic suspended material like sand, dirt and silt and organic material like sludge both deposit on river bottoms and prevent fish from spawning. In New Mexico, one of the largest non-point source pollution problems is habitat loss caused by suspended solids silting up river bottoms. Point source discharges of sludge and sediment can cause the same problem.

**Pathogenic Organisms**
Wastewater can potentially contain any disease causing organism, or pathogen, that the people contributing waste to the collection system are infected with. Common diseases caused by water borne pathogens include; typhoid, hepatitis, cholera, dysentery and polio. Pathogens fall into the following categories:

<table>
<thead>
<tr>
<th>Pathogen Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>Cholera, Shigella, Salmonella</td>
</tr>
<tr>
<td>Viruses</td>
<td>Norwalk, Rotavirus, Adenovirus</td>
</tr>
<tr>
<td>Protozoa</td>
<td>Giardia lamblia, Cryptosporidium parvum</td>
</tr>
</tbody>
</table>

**Table 1.1 - Types of Pathogens**

If pathogens are discharged without treatment into the natural environment, they will pose a danger to anyone that is exposed to them. For this reason, one of the primary goals of wastewater treatment is to disinfect the effluent before it is discharged. This can be accomplished by several different methods that rely upon very different principals. These are discussed later in Chapter 9 - Disinfection.

The group of microorganisms that we use to indicate the level of pathogenic contamination is the Fecal Coliform group. Fecal Coliform are a group of organisms that live in the intestinal tract of all warm blooded animals, including man. If Fecal Coliform are detected in water, it indicates that a warm-blooded animal has defecated into the water and therefore pathogens could be present. Although some members of the Fecal Coliform group are harmful to humans, such as toxin producing strains of Esterichia Coli (E. coli), they are not pathogens. As a whole, we all live quite comfortably as host to the billions, if not trillions, of Fecal Coliform in our intestines.

**Temperature Effects**
High temperature discharges can disrupt the natural ecology in surface waters by encouraging the growth of algae and aquatic plants that would not normally be as abundant. In addition, seasonal temperature changes can cause the treatment plant to operate less efficiently. This is most evident during cold weather because the growth and activity of the microorganisms in the treatment plant slows down considerably.

**pH**
pH is a measurement of water’s acid or alkaline condition. pH is measured on a scale that spans from 0 to 14 with 7 being the middle, or neutral value. pH values lower than 7 are progressively acidic while pH values that are higher than 7 are progressively basic, (also called caustic or alkaline). Most living organisms live in a narrow pH range that is near neutral. If an effluent has a pH that is higher or lower than that of the receiving water, the organisms in the receiving water may be killed off. In addition, if the pH of the influent coming into a wastewater treatment plant changes rapidly and significantly, the plant treatment processes may be disrupted.

**MEASURING THE STRENGTH OF WASTEWATER**
Because wastewater contains an unknown mixture of organic and inorganic pollutants, it is generally difficult to characterize. One test that is used to measure the overall strength of wastewater is the Biochemical Oxygen Demand (BOD) test. The BOD test measures the amount of oxygen that is consumed while a sample of wastewater is incubated...
at a temperature of 20 °C. During the test, bacteria consume oxygen as they metabolize the organic material in the sample. Oxygen scavenging chemical compounds in the wastewater sample also consume oxygen, although this is typically only a small contribution to the overall oxygen demand. The more organic material and oxygen scavenging chemicals in a sample, the more oxygen will be consumed during the test. The more oxygen consumed, the higher the BOD. This test offers a particularly good way to measure the strength of wastewater because the test determines how much dissolved oxygen will be required to stabilize the waste, thus giving us an indication of what will be needed to treat an influent or what effect an effluent will have upon a receiving stream. (For more information on the BOD test, refer to Chapter 14, Laboratory Procedures).

**MEASURING SOLIDS IN WASTEWATER**

We have discussed the different types of pollution and even discussed how we measure some of the different aspects of waste, such as BOD and Fecal Coliform. Now we will discuss how we measure solids and how we express their concentration. As we will see, the concentration of solids in typical domestic wastewater is actually quite small when compared to the amount of water present. Because of this, we express concentration in units that are practical to work with - milligrams per liter (mg/L). (See note.)

When we speak of solids in wastewater, we categorize them according to Table 1.2 opposite:

<table>
<thead>
<tr>
<th>SOLIDS GROUP</th>
<th>CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids (TS)</td>
<td>Everything that is not water</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>All the solids that cannot be filtered out of the water</td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>All the solids that can be filtered out including: settleable solids and non-settleable solids (colloids)</td>
</tr>
</tbody>
</table>

When we speak of solids in wastewater, we categorize them according to Table 1.2 opposite:

To actually measure the TS of a sample of wastewater we have to evaporate off the water in an oven and then weigh the residue. This residue represents everything (except gasses) that was in the sample, other than water. To determine the TDS we would do the same thing except that we would first filter the sample through a very fine mesh fiberglass filter and then perform the same test on the liquid that passed through the filter. To determine the TSS, we would dry and weigh the filter with the residue trapped on it and then subtract the weight of the filter. We might also want

**NOTE:**

One million milligrams is equal to one kilogram (2.2 lbs). One liter of pure water weighs one kilogram (at 60° F). Therefore, when you have one milligram of a solid in one liter of water the concentration is one part solid per million parts water (1 ppm). That is why we can use the units of mg/L and ppm interchangeably.

It is important to note that some of the TSS will not settle, even when given days or weeks. This non-settleable TSS is known as colloidal material. Colloids will not settle because they are very small and carry similar charges that keep them separated. The like charges on the colloids, which repel each other, overcome gravity’s ability to settle them out.
SOLIDS COMPOSITION IN TYPICAL DOMESTIC WASTEWATER

If we could collect a sample of typical domestic wastewater the solids concentrations would be close to the levels shown in Figure 1.5.

As you can see, most of what makes up wastewater is water. In fact, 99.9% of typical domestic wastewater is water. The total solids represent only about 1/10th of one percent (0.1%), or 1000mg/L. You can also see that about 20%; (200mg/L) of the solids are made up by the TSS, of which 130mg/L are settleable and 70 mg/L are non-settleable. THE VAST MAJORITY, (80% OF THE SOLIDS), ARE DISSOLVED.

Some of the dissolved solids in domestic wastewater are organic and some are inorganic. The dissolved organic solids are often measured as dissolved, or soluble, BOD. The majority of this material was added to the wastewater through human use. Most of the dissolved inorganic solids were present when the water was obtained and treated for human consumption (before it became wastewater). The difference between the two types of dissolved solids is important because modern wastewater treatment plants are designed to remove almost all of the organic portion of the TDS but not the inorganic portion of the TDS, which usually passes right through the treatment plant. Generally, inorganic TDS does not cause pollution problems, although there are rivers in New Mexico that have limitations to the amount of overall TDS that can be discharged into them.

TYPICAL WASTEWATER TREATMENT PROCESSES

As we have already discussed, the processes used in a modern wastewater treatment plant are designed to remove most if not all suspended material, including settleable solids and colloidal particles. In addition, dissolved organic solids are removed to a high degree. Finally, pathogenic microorganisms are reduced to prevent the spread of water borne diseases. Separate units within the treatment plant accomplish the removal of different types of solids as well as pathogen reduction. Not all treatment plants employ the same units or treatment methods because there are many ways to accomplish the treatment goals. Location, economics and even historical precedent affect which types of treatment processes are employed.

Table 1.3 - Typical Influent Pollutant Concentrations

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONCENTRATION</th>
<th>EFFLUENT GOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD5</td>
<td>200 mg/L</td>
<td>&lt; 30 mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>200 mg/L</td>
<td>&lt; 30 mg/L</td>
</tr>
<tr>
<td>TDS</td>
<td>800 mg/L</td>
<td>&lt; 1000 mg/L</td>
</tr>
<tr>
<td>Settleable Solids</td>
<td>10 ml/L</td>
<td>&lt; 0.1 ml/L</td>
</tr>
<tr>
<td>pH</td>
<td>6 – 9</td>
<td>6 – 9</td>
</tr>
<tr>
<td>Fecal Coliform</td>
<td>Too Numerous to Count</td>
<td>&lt; 500 cfu/ 100ml</td>
</tr>
<tr>
<td>(Ammonia + Organic Nitrogen)</td>
<td>30 mg/L</td>
<td>&lt; 10 mg/L Total Nitrogen</td>
</tr>
<tr>
<td>Nitrate/ Nitrite</td>
<td>&lt; 1.0mg/L</td>
<td></td>
</tr>
<tr>
<td>Phosphorous</td>
<td>2.0 mg/L</td>
<td>&lt; 1.0 mg/L</td>
</tr>
<tr>
<td>Fats, Oils and Grease</td>
<td>Varies Greatly</td>
<td>None Visible</td>
</tr>
</tbody>
</table>

Figure 1.6 - Treatment Plant Process Schematic, on the following page shows the common treatment processes and their location in the treatment train. Your treatment plant may differ considerably.

PRETREATMENT

Wastewater plant pretreatment processes are the first treatment to occur to the wastewater as it enters the plant. Pretreatment usually includes screening, grit removal, flow measurement and pumping.

Screening is accomplished by a barscreen which, as the name implies, is a screen made up of a number of bars arranged in such a way that the trapped material (screenings) can be easily removed. It is important that the screening material be removed so that it does not get caught up in mechanical equipment further on in the treatment plant. The importance of adequate screening for any size wastewater treatment facility CAN NOT be over-emphasized.

Grit removal can be accomplished in several ways. Grit refers to inorganic settleable solids, such as sand, rocks and eggshells. It is an important step in the treatment process because if not removed, grit will accumulate in pipes and tanks later on in the treatment plant. Grit can also cause excessive wear to lift pumps and valves. For this reason, grit removal should take place before the lift pumps whenever possible. The grit and screenings that are removed from the wastewater should be disposed of in...
**Treatment Plant Process Schematic**

**TREATMENT PROCESS**

**Influent**

**Pretreatment**

- **Screening**
- **Grit Removal**
- **Flow Measurement**
- **Lift Pumps**

**Primary Treatment**

- **Sedimentation & Floatation**
  - **Solids Handling**

**Secondary Treatment**

- **Biological, Chemical & Physical Processes**

**Disinfection**

- **Chemical & Physical Processes**

**Effluent Flow Measurement**

**Function**

**Influent**

Raw Wastewater entering the plant.

**Pretreatment**

- **Screening**
  - Removes large debris such as roots, rags, grease and plastic products.

- **Grit Removal**
  - Removes inorganic settleable solids such as sand, gravel and eggshells.

- **Flow Measurement**
  - Measures and records incoming flow.

- **Lift Pumps**
  - Pumps influent to an elevation high enough to allow gravity flow through the rest of the treatment plant. Best if located after screening and grit removal (protects pumps).

**Primary Treatment**

- **Sedimentation & Floatation**
  - Removes settleable and floatable solids.

**Secondary Treatment**

- **Biological, Chemical & Physical Processes**
  - Treats solids removed by other processes.

**Disinfection**

- **Chemical & Physical Processes**
  - Converts dissolved organic solids into suspended solids and then removes the suspended solids through flocculation and settling.

**Effluent Flow Measurement**

- **Discharge**
  - Kills pathogenic organisms.

- Measures and records discharge flow.

- Effluent discharged from the treatment plant.

*Figure 1.6 - Treatment Plant Process Schematic*
an approved landfill after passing a paint filter test, which ensures no liquid is draining from them.

**Flow measurement** should be included on the influent side of all treatment plants but is most common in plants with a daily flow of 100,000 gallons or more. It is important to measure not only the daily flow but also the high and low flows so that the true maximum and minimum hydraulic loading is known. This information helps the operator understand what is happening in the treatment plant. Be aware that the flow does not come into most treatment plants at a constant rate. Instead, the flow arrives as peaks and lows that relate to the activity of the people contributing wastewater to the system. The largest peak is typically experienced during the morning hours (following the time when every body wakes up, showers, starts laundry etc). Smaller peaks usually occur after lunch and after dinner. At 3:00 AM there is generally very little flow entering the plant.

**Lift pumping** is necessary in many treatment plants although some plants receive their flow at a grade that eliminates the need for pumping. If possible, the design engineer should eliminate lift pumps whenever it is practical and cost effective. This is because pumps require significant maintenance and are prone to failure.

**Primary Treatment**
Primary treatment includes sedimentation and floatation. These processes are probably the oldest water treatment methods known to man. In a modern treatment plant, they are accomplished in a primary clarifier. A primary clarifier is a tank, (usually round), where the flow velocity of the wastewater is lowered to the point that suspended solids will settle out and floatable solids will rise to the surface where they can be skimed off.

The advantage of primary clarification is that 30 – 50% of the influent BOD₅, most of the suspended solids and much of the grease and floatable rubber and plastic product found in influent are removed. The main disadvantage is that the material that has been removed by a primary clarifier, (sludge and scum), must be continuously dealt with.

The sludge removed from primary clarifiers is raw and will create odor problems very rapidly unless stabilized (digested). The scum must also be removed and discarded or it will attract vectors (birds, mice, etc.) that could spread infection.

**Secondary Treatment**
Secondary treatment involves physical, chemical and biological processes that convert the dissolved organic component in the wastewater into settleable solids. Essentially, in secondary treatment we use the dissolved organic material in the influent as food for microorganisms. As the microorganisms consume the organic matter, they convert it into more microorganisms that are then separated from the water by gravity settling. This can be accomplished in many different types of secondary treatment systems such as; trickling filters, rotating biological contactors (RBCs), activated sludge and even lagoons. When using trickling filters, RBCs and activated sludge systems, the microorganisms are grown in one unit and the solids separation occurs in a secondary clarifier. In lagoon systems, the microorganisms grow and settle out all in the lagoon cells.

**Effluent Flow Measurement**
As discussed earlier, it is desirable to measure the influent flow so that the operator will know the plant hydraulic loading. Measurement of the effluent flow is not only desirable but is a requirement of almost any discharge permit. This is because the discharge volume must be known in order to allow the pollutant loading rates to the environment to be calculated. If you discharge one million gallons of effluent with a pollutant concentration of 10 mg/L, those one million gallons contain a total of 83.4 lbs. of the pollutant. The discharge volume (flow) must be known in order to make this calculation. Because the volume of influent and effluent can be very large, flow is usually expressed as millions of gallons per day (MGD) rather than gallons per day.

**Disinfection**
After the effluent has been clarified, it is typically disinfected to lower the number of pathogenic microorganisms. This can be done in several ways including; chlorination, ozonation, ultra violet light exposure and even long detention times in lagoon cells. Chlorination is one of the most popular methods of disinfection. However, when chlorine is used to disinfect effluent that is discharged into surface water the effluent must often be de-chlorinated to prevent residual chlorine from harming organisms in the surface water body. This is most often accomplished by adding a sulfur compound that reacts with the chlorine to form inert salts.
components: thickening, digestion, dewatering and sludge disposal or re-use.

**Thickening** is performed to reduce the volume of sludge that must be stored in a digester. Thickening is accomplished by gravity thickeners, centrifuges, belt presses and diffused air floatation (DAF) units.

**Digestion** involves the breakdown of the solids by aerobic or anaerobic microorganisms. Digestion is done in aerobic (aerated) or anaerobic (heated, mixed, not aerated) digesters.

**Dewatering** is just as it sounds, removing water from the solids so they occupy less storage space. Dewatering can be accomplished in many ways including; gravity thickeners, drying beds, centrifuges, belt presses and diffused air floatation (DAF) units.

**Disposal or Re-use** of the solids after they have been digested and dewatered is the final step in the wastewater treatment process. If it is of a high quality and has undergone proper treatment, sludge generated from municipal wastewater treatment plants can be used beneficially as a resource to improve soil quality in various areas including; crop land, landscaping areas and land reclamation sites. If a beneficial use cannot be found, sludge may be disposed of in municipal landfills, surface disposal sites or, as a last resort, incinerated. Various state and federal regulations exist that pertain to sludge disposal and re-use.

**Overview of Basic Biological Principals Related to Wastewater Treatment**

Three main oxygen conditions exist that will sustain life and there are three classes of bacteria that survive in these oxygen conditions. Many of the processes in wastewater treatment involve manipulating oxygen conditions to grow certain types of bacteria or to make bacteria function in a specific way. The three oxygen conditions are as follows:

- **Aerobic** - Dissolved oxygen (O₂) is available. Aerobic bacteria survive by breathing O₂, producing carbon di-oxide (CO₂) and water are the primary by-products.

- **Anaerobic** – No dissolved oxygen is available, but oxygen is present in the form of sulfate (SO₄). Anaerobic bacteria can utilize the oxygen bound up in sulfate to breath. Hydrogen sulfide (H₂S), carbon di-oxide and water are the main by-products.
Anoxic - No dissolved oxygen is available, but oxygen is present in the form of nitrate (NO$_3$). Facultative bacteria, which normally breath dissolved oxygen, can utilize the oxygen bound up in nitrate for breathing, releasing nitrogen gas (N$_2$) as a by-product.

Elements are continually transformed into various compounds by living things as they are used for respiration, food and cell material. These transformations occur in cycles. The most important cycles to understand with regard to wastewater treatment are the carbon, nitrogen and sulfur cycles.

**Nitrogen Compounds in Wastewater**

- Total Kjeldahl Nitrogen (TKN)
  - TKN is the sum of the organically bound nitrogen and the ammonia
- Ammonia (NH$_3$)
  - Almost always present in raw domestic wastewater
- Nitrate (NO$_3$) and Nitrite (NO$_2$)
  - Rarely present in raw domestic wastewater

**References**

Office of Water Programs, California State University, Sacramento, *Operation of Wastewater Treatment Plants*, Volume 1, 4th ed., Chapters 1, 2 and 3