Chapter 1 Introduction

In early 1972, Congress enacted the Clean Water Act providing funds for construction and operation of wastewater treatment systems, and the training of professional wastewater operators. The nation's rivers and lakes had become major wastewater disposal sites and had turned healthy ecosystems into septic and stench filled dump areas. Congress implemented the NPDES (National Pollutant Discharge Elimination System) self-monitoring program requiring industrial and municipal systems to clean up their discharge or face financial and criminal penalties. Operator certification began to be enforced to develop professional operators who understood the importance of the operation, maintenance, and management of wastewater treatment plants. Wastewater systems were required to have a permit to discharge and that permit established limits on the levels of contaminants that could be discharged. Laboratory analysis was required to document the level of these contaminants. Previously, in many instances, laboratory personnel, the operator, and management never communicated and treatment was poor. The NPDES system helped bring the parties together since they all now became responsible for the effluent quality.

Effects of Discharging Wastes

There are two routes by which pollutants enter receiving waters: point sources, such as a wastewater treatment plant discharge pipes, and non-point sources, such as runoff from feedlots and agricultural fields. 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. For example, heavy rains may wash animal waste from feedlots and dairies or fertilizer and pesticides from agricultural fields into the river.

The NPDES discharge permit system was established to help minimize the environmental devastation and health effects caused by poor treatment. One environmental problem caused by poor treatment is *oxygen depletion* in the receiving streams. Many aquatic organisms, including fish, need dissolved oxygen (O2) to survive. These types of organisms are referred to as **aerobes** and the environment they live in as **aerobic.** If untreated non-toxic waste is discharged into receiving streams, rivers, or lakes it becomes food for the microorganisms. In a normal ecosystem, the microorganisms will utilize the naturally occurring dissolved oxygen in the water to stabilize the waste and convert it into energy and more microorganisms. As the aerobic bacteria multiply, they require more and more dissolved oxygen to sustain their growing numbers. When the waste is consumed, most microorganisms will die and the oxygen level will return to its original level. However, if the waste concentration is very high or additional waste is added downstream, the digestion process will continue. When the population of aerobic bacteria grows large enough, the oxygen available in the river will be depleted. If this happens, the aerobic microorganisms (and most other aerobic organisms) in the river, die. If all of the dissolved oxygen in a river has been consumed, another type of organism begins to grow in the oxygen depleted 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 nitrate (NO_3), and sulfate (SO_4). When anaerobic bacteria use the oxygen from nitrate and sulfate for respiration,

nitrogen gas (N_2) and 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. 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 the waste from getting into receiving waters as possible.

Sources of Wastewater

Wastewater consists of two things- waste and water. Wastewater treatment plants are designed to treat the waste. Operators and laboratory technicians are responsible for effectively operating, maintaining, and monitoring the system. Waste originates from a wide variety of industrial, commercial, and residential sources and its characteristics determine what treatment is required. Most commercial and residential wastewaters contain normal "domestic" contaminants such as fecal matter, plant and animal waste, oil and grease, detergents, rags, and sediments such as sand. On the other hand, industrial waste is very unpredictable and can contain toxic chemicals and metals, very strong organic wastes, radioactive wastes, large amounts of sediment, acidic/caustic waste or high temperature waste. Industrial users often have pretreatment permits which limit the type and amount of contaminants that can be discharged into the collection system. These pretreatment limitations help prevent overloading or interfering with the operation of the municipal system.

Additional contaminants can enter the collection system from line breaks, or storm water runoff from streets and parking lots. This wastewater often contains motor oil, gasoline, pesticides, herbicides, and sediment (sand and gravel).

Wastewater Characteristics

The term wastewater characteristic is used to describe the components and condition of the waste stream. Wastewater is a very complex mixture of all sorts of materials having different characteristics. Wastewater components can be identified specifically but more commonly the mixture is characterized using general characteristics. One way to describe the waste is to divide it into two broad categories: ***organic*** wastes and ***inorganic*** wastes. **Organic Wastes** are those substances that *contain the element carbon (C)* and are derived from something that was once living. Examples include: vegetable and animal food waste, fecal matter, grease, proteins, sugars and paper. **Inorganic Wastes** are those substances that *do not contain carbon* and are derived from something that was not living. Examples include: metals, minerals, sand, acids and bases. Common wastewater tests used to measure the organic concentration is Biochemical Oxygen Demand (BOD) / Chemical Oxygen Demand (COD). These tests will discussed in a later chapter.

Solids

Another method used to describe waste is to divide it into different solid classifications. Wastewater is 99.9% water and only 0.1% solid but this small solids concentration can be classified by its physical and chemical characteristics. The common categories of solids include:

Total Solids: All the solids present after evaporation of the water.

Total Dissolved Solids (TDS): Solids which pass through a 0.45 micron glass fiber filter. Dissolved solids represent primarily minerals and small organic molecules such as sugar. Most of the TDS is inorganic.

Total Suspended Solids (TSS): Solids which do not pass through a 0.45 micron glass fiber filter. Total suspended solids represent large materials such as plant and animal debris, microorganisms, fecal material and sand. TSS is primarily organic.

Settleable Solids (SS): Settleable solids are part of the total suspended solids and a defined as solids which settle within 1 hour. These solids are generally very large and have a specific gravity that allows them to settle to the bottom of an imhoff cone within 1 hour. These solids usually represent sand, large plant and animal debris and some fecal material. Microorganisms are too light to settle.

Non-Settleable Solids (Colloidal): Non-settleable solids are the suspended solids which do not settle after 1 hour. The majority of these solids don't weigh enough to settle quickly. Within this group is a subgroup called colloids. These solids may be large enough to get caught on the glass fiber filter but do not settle because they carry similar charges. The charges on the colloids repel each other and interfere with settling. Most of these solids are fecal material and microorganisms.

Volatile Solids (VS): Solids which burn off at 550°C. This would be similar to burning logs in a fireplace. The organic material making up the logs is combusted to carbon dioxide which blows away. The material remaining after the fire goes out is called ash or fixed solids and represents the inorganic materials present.

Fixed Solids (Ash): Solids which do not burn off at 550°C.

Solids analysis will be discussed in a later chapter.

Nutrients

Nutrients are substances that are required for the growth of living plants and animals. Major nutrients include nitrogen (N) and phosphorous (P). Both are found in wastewater in various forms. Nitrogen is typically present in the influent in the forms of ammonia (NH3) 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 oxygen depletion cycle again.

Temperature

Influent wastewater temperature can effect the operation of the wastewater treatment plant. Temperature effects solid settling velocity in clarifiers, microorganism activity and oxygen solubility in aeration basins and receiving stream environments. 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. 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.

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. The microorganisms used by the wastewater treatment plant to digest the organics may also be killed off.

Microorganisms

The foundation of wastewater treatment is the use of microorganisms to digest the waste. The microorganisms convert the waste into new cells which then form a settleable solid called floc. This floc settles in the secondary clarifier hopefully leaving a clear liquid called supernatant. The clear wastewater effluent can be discharged to the receiving stream after any remaining microorganisms are disinfected. The vast majority of microorganisms used in waste treatment originate in the intestines of warm blooded animals. These microorganisms are called fecal coliforms. The most famous fecal coliform and the one common to human intestines is E. coli. E. coli are beneficial bacteria and are not typically **pathogenic.** However, pathogens may be present in wastewater and the laboratory technician should always take precautions to avoid direct contact with wastewater. There are no "kind" pathogens!!!

Pathogenic Organisms

Any wastewater can potentially contain disease causing organisms, or **pathogens**. Pathogens can cause extreme illness and even death and should be killed prior to effluent discharge. The operator and laboratory technician are always potentially exposed to these organisms. Common diseases caused by water borne pathogens include; typhoid, hepatitis, cholera, dysentery and polio. Pathogens fall into the following categories:

Pathogen Type

Bacteria - Cholera, Shigella, Salmonella
Viruses - Norwalk, Rotavirus, Adenovirus
Protozoa -Giardia lamblia, Cryptosporidium

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. Regardless of the method of disinfection, the test used to measure the effectiveness of disinfection is the same. Because so many different types of pathogens could be present, it is not practical to perform laboratory tests to detect each pathogen. Instead, non-pathogenic microorganisms are used to indicate the possible presence of pathogens. The microorganism used to indicate the possible presence of pathogens is E. Coli in the Fecal Coliform group. If E. Coli are detected in water, it indicates waste from humans is present and therefore pathogens could be present. If E. Coli are not present, it is likely all the pathogens have been killed and the wastewater is safe to discharge.

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 raw 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. The laboratory may be required to perform a bio-monitoring test to show the effluent is not toxic to organisms in the receiving stream.

Another toxin of concern is the residual chlorine left over from the disinfection process. 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. Many systems have gone to UV light for disinfection to eliminate chlorine residual problems.

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. In New Mexico, wastewater treatment plants that discharge to the land are required to have a groundwater discharge permit. This permit usually monitors for total dissolved solids, chloride, nitrate and total kjeldahl nitrogen (TKN).

Wastewater Treatment Overview

Water that has been discharged by various residential, commercial, and industrial users into a collection system is defined as wastewater. Wastewater consists of every conceivable contaminant from dirty bath water to radiological waste. A treatment system uses different physical, biological, and chemical processes to remove contaminants to avoid harming the receiving stream and downstream users.

Pretreatment

In a typical municipal treatment system, the first treatment process is the physical process of screening. A set of steel bars spaced about 1/2" to 2" apart removes large objects such as rags, rocks, rubber products and any other large screwball things put down the sewer. These materials interfere with downstream equipment operation and are collected and removed to the landfill. The next process is generally a grit chamber designed to remove heavy inorganic materials such as sand, eggshells, and coffee grounds. This chamber reduces flow to 1 foot per second to separate grit from heavy organic settleable solids. This gritty material is abrasive to downstream pumps and valves and takes up valuable space in tanks and digesters. Grit is also hauled off to the landfill. The lab technician can measure the volatile solids present in the grit chamber to determine if the grit chamber velocity is acceptable. A high volatile solids concentration would indicate heavy organics are settling and the grit chamber is too slow.

Primary Treatment

Following grit removal, the wastewater enters a large tank called a primary clarifier. The flow through the primary clarifier is slowed down even further to allow the heavy organic suspended solids (sludge) to separate from the light suspended solids and floatable solids (scum). The heavy settleable solids (sludge) settle to the bottom of the clarifier, where they are eventually pumped to the digester. The floatable solids (scum) are taken to the landfill. Because the remaining solids are small and light, physical settling is no longer effective because it would take too long. The lighter suspended solids move on to the secondary treatment unit. The lab technician can measure the settleable and suspended solids to determine the tank removal efficiency. The primary clarifier should remove:

90-95% of the settleable solids
40-60% of the suspended solids
20-50% of the BOD

Changes in the % removal may indicate broken clarifier flights or short circuiting.

Volatile solids could also be run to validate that the grit chamber is working correctly. The presence of high fixed solids may indicate the grit chamber was flowing too fast and not allowing the grit time to settle.

Secondary Treatment

Secondary treatment involves physical, chemical and biological processes that convert the incoming light suspended solids and dissolved organic components into settleable solids. In secondary treatment the incoming suspended solids and dissolved organic material represent food for microorganisms. As defined earlier, this organic food material is called BOD. As the microorganisms consume the BOD, they convert it into more microorganisms that are then separated from the water by gravity settling. This conversion is accomplished using 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.

It becomes the lab technician's responsibility to monitor the environment in the secondary treatment unit to make sure the microorganisms are "happy". The lab technician will monitor the temperature, the pH, and the dissolved oxygen to make sure the microorganisms are not environmentally stressed. The lab technician will also measure the amount of food present (TSS /BOD) and determine how many microorganisms are needed to digest the food. This would be much like determining how many pizzas to order if you know how many people are coming to dinner. It may be the lab technician's responsibility to observe and identify different types of microorganisms. Using a microscope to identify the different microorganism provides the lab technician with a tool to help control the biological processes. At the end of the secondary process the organics should be fairly well stabilized, the effluent water should be clean, and the water almost ready for discharge into the receiving stream.

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 common methods of disinfection. However, chlorine has the undesirable potential of causing carcinogens that effect fish and other aquatic life. To reduce the carcinogen potential, chlorine must often be de-chlorinated to prevent residual chlorine from harming organisms in the receiving stream. This is accomplished by adding sulfur dioxide to destroy the chlorine residual. The lab technician will be responsible for monitoring both the fecal coliform and chlorine residual to assure the effluent is acceptable to discharge.

SOLIDS HANDLING

The major function of a wastewater treatment plant is to stabilize the waste and clarify the water prior to disposal. Often overlooked is solids handling. The solids that settled in the primary and secondary clarifier must be treated and also disposed of. This aspect of the treatment plant is separated from the liquid wastewater treatment processes and is known as solids handling. Solids handling may involve four 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 solids handling process. If the sludge 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, stabilized 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.

Lab Technician Responsibilities

In New Mexico, certified operators are responsible for the treatment and disposal of wastewater according to various state and federal regulations. Lab technicians help operators monitor the system. In many small systems, the operator is also the lab technician. In either case, the lab technician has to be able to complete core competencies. The lab technician must

- Collect and preserve samples
- Prepare samples for analysis
- Analyze samples and interpret results
- Operate and maintain equipment and instruments
- Handle chemicals and wastes
- Quality assurance/quality control
- Manage laboratory
- Laboratory safety
- Understand how volumetric, gravimetric, colorimetric and electrometric analysis are performed.

Levels and Classification

To assure the lab technician has the core competencies, a laboratory certification plan has been implemented. Based on the results of the job analysis of laboratories in New Mexico the certification classes are as follows:

Level 1	Laboratory Technician/Operators performing wastewater lab tests and lab functions; pH, Dissolved Oxygen, Chlorine residual, Temperature, Total Solids, Total Suspended Solids, and Settleability tests. General duties in the laboratory that incorporate glass care, and lab safety.
Level 2	Laboratory Technician/Operators performing wastewater lab tests and lab functions; all Class 1 analysis plus BOD, COD, Nitrogen, Phosphorus, Coliform bacteria, metals, Inorganic, Organics, and Oil and Grease.
Level 3	Laboratory Technician/Operators performing wastewater lab tests and lab functions; all Class 2 analysis listed above in Class 1and 2 plus Bioassay, Laboratory Management, and NPDES Permit preparation.

The remaining chapters will address these competencies and help prepare the lab technician for the certification exam.