Wastewater Treatment Operations

State of Oklahoma
Certification Study Guide

OKLAHOMA
Environmental
Quality

This Study Guide is Dedicated to the

Certified Wastewater System Operators

Of the State of Oklahoma

"Protectors of Public Health"

For information concerning Oklahoma operator certification requirements or application procedures, please contact

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WASTEWATER CERTIFICATION STUDY GUIDE
2ND EDITION 2017

WASTEWATER CERTIFICATION STUDY GUIDE CREDITS AND ACKNOWLEDGEMENTS
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Introduction

This study guide has been prepared for persons interested in obtaining or upgrading their Oklahoma wastewater system operator certification. The chapters in this guide offer information designed to help with each level of certification. Class D is entry level, and Class A is the most advanced of the certifications.

This guide is not intended to be a reference manual for technical information. Its purpose is to help guide operators in their studies of each of the major subject areas. Each chapter in this guide covers a different subject. Suggested guidelines for each subject area are listed by certification level at the beginning of each chapter. A brief discussion is then provided primarily for the benefit of entry level operators, followed by suggested references, other study suggestions and sample questions. The study guide is used by both instructors and students of approved operator training classes.

Components of Each Chapter in this Study Guide

Suggested Study Guidelines

The *Suggested Study Guidelines* describe knowledge that may be needed by operators of community wastewater systems. These suggestions are designed to help direct study but do NOT address every item of information that an operator may need to know when taking a certification exam or when performing actual job duties. The guidelines are designed to be used as a "checklist" when studying for a certification exam to help ensure sufficient preparation. **Operators preparing to take a Class C, B, or A level certification exam should follow the guidelines listed for their exam as well as those listed for all lower levels of certification**.

Entry Level Discussion

The *Entry Level Discussion* is offered only as an introduction to the chapter subject. It should be used as a starting point for all persons preparing to take an exam. The answer to all of the questions that may be on the Class D exam can be found within these readings. Persons studying for higher levels of certification should concentrate most of their efforts on the Suggested References for Study in each chapter. **Please remember that the *Entry Level Discussion* should never be used as a reference for actual system operating or maintenance**.

Suggested References for Study

These are the primary references for questions found on Oklahoma operator certification exams. A complete listing of all the *Suggested References for Study* and a "Reference Source Sheet" can be found at the back of this study guide. References listed in *Italics* are needed for certification purposes only if preparing to take a Class A exam. Although many reference manuals are worthwhile and helpful, most of the references listed are taken from the manuals prepared by California State University at Sacramento (CSUS) for the U.S. Environmental Protection Agency.

Other Study Suggestions

These suggestions include individual exercises that will help the operator fully understand the material referenced in the *Suggested Study Guidelines*. Operators who can perform these various exercises, in addition to studying all the suggested materials, should be well prepared for their exam.

Sample Questions

These are questions representing the approximate difficulty level and format of the questions found on certification exams. The answers to the questions can be found within either the Entry Level Discussion or the *Suggested References for Study* for the chapter. Answers to the *Sample Questions* are listed near the back of this guide. Additional practice questions can be found within many of the *Suggested References for Study*.

How to Use this Study Guide to Prepare for State Certification Exams

Class D Certification

Preparation for the Class D exam should include the use of this guide for both personal study and during attendance at an approved standard entry level class. Begin studying by familiarizing yourself with the entire study guide. Next, completely read the *Entry Level Discussion* offered within each chapter. Finally, read the *Suggested Study Guidelines* for Class D operators listed at the beginning of each chapter and read the *Entry Level Discussion* for the chapter again.

All operators are encouraged to obtain and read additional study material whenever possible. Some of the *Other Study Suggestions* listed in each chapter may also be helpful. APPENDIX A includes practice problems and explanations that may help to refresh basic math skills.

Other Levels of Certification

Students preparing to take a Class C, B, or A level operations exam are strongly encouraged to use the *Suggested References for Study* listed in each chapter. The higher the level of certification being sought, the more important these references become. Although there are many excellent reference books available, the suggested references should be used whenever possible as these are the primary references used to prepare state certification exams.

It is recommended that persons preparing to take these certification exams utilize extensive personal study to become knowledgeable in all the items listed in the appropriate *Suggested Study Guidelines*. Also recommended is attendance at training classes including an approved standard intermediate level and/or advanced level class shortly before taking the exam. APPENDIX B should be reviewed to become familiar with the math formulas that will be provided with the certification exam. APPENDIX C is a starting point for those needing an introduction to chemistry.

Oklahoma Certification Exam Qualifications

Water and Wastewater Works Operator Examination Applications are available online at the DEQ website from the DEQ Operator Certification Unit, and the County DEQ offices. Examination sessions are offered throughout the State on a regular basis. The dates and locations of all examination sessions as well as most approved training classes are published on the DEQ website www.deq.state.ok.us/.

Properly completed and signed exam applications must be received by the Operator Certification Unit at least three weeks before the exam is to be taken. An examination fee is charged for each exam taken. Payment of the exam fee must be made by check, money order, or credit card made payable to the Operator Certification Unit, and must be submitted with the exam application.

Minimum qualifications for operator certification exams are listed in the table below.

MINIMUM QUALIFICATIONS FOR CERTIFICATION EXAMS		
CLASSES	TRAINING [1]	EXPERIENCE [2]
WATER/WASTEWATER OPERATOR		
D Operator	16 hrs of DEQ approved training	None
C Operator	36 hrs of DEQ approved training	(a) For water works or wastewater works operators, one year of waterworks or wastewater works operation
B Operator	100 hrs of DEQ approved training or its approved equivalent	3 years of waterworks or wastewater works operation including one year actual hands-on operating experience
A Operator	200 hrs of approved training, including at least 40 hrs of DEQ approved courses in advanced treatment and managerial training or its approved equivalent[3]	5 years of waterworks or wastewater works operation including 2 years actual hands-on operating experience
OPERATOR		
Technician	8 hrs of DEQ approved training	None
C Operator	36 hrs of DEQ approved training	1 year distribution collection operations

[1] Training credit will be granted only for courses or workshops listed as approved by the DEQ or for courses, workshops, or alternative activities which have been approved in writing by the DEQ in advance.

[2] Experience that is used to meet the experience requirement for any class of certification may not be used to meet the education or training requirements.

[3] Approved equivalents are listed in 252:710-36

All approved training hours are cumulative. **All certified operators should keep permanent records of all approved training they have received**. Any requests for experience credit for completion of classes in higher education must be accompanied with an official transcript.

Oklahoma Operator Certification Exam Information

All certification examinations consist of 100 multiple-choice questions. Each question on the exam is worth one point. At least 70% of the questions must be answered correctly in order to pass the exam. When you take your exam, you are given an exam booklet, and answer sheet, and scratch paper. Most math formulas needed are provided in the exam booklet (see APPENDIX A and APPENDIX B for more information). The only items you should bring into the exam session are a calculator, two no. 2 pencils, and the approval notification for your exam.

Each exam is divided into 12 subject areas or "areas of competency" which correspond with the chapters in this study guide. **All levels of certification exams include questions from each area**. However, because potential job duties will change as higher level certifications is achieved, the priority and number of questions for each subject area will vary between certification levels. The chart below shows the suggested emphasis or priority to use when studying for certification exams.

AREA OF COMPETENCY	SUGGESTED STUDY EMPHASIS			
Study Guide Chapter	Class D	Class C	Class B	Class A
Sections I				
1. Basic of Wastewater Treatment	High	Low	Low	Low
2. Characteristics of Wastewater	High	Medium	Low	Low
3. General Regulations and Management	High	High	High	High
Section II				
4. Collection Systems	High	High	Medium	Medium
5. Maintenance	Medium	Medium	Medium	Medium
6. Operators Safety	High	High	High	High
Section III				
7. Preliminary and Primary Treatment	Medium	High	High	High
8. Secondary Treatment	Medium	High	High	High
9. Advanced Treatment (Tertiary)	Low	Low	Medium	Medium
Section IV				
10. Sludge Digestion and Solids Handling	Low	Medium	High	High
11. Wastewater Treatment Ponds	High	High	Low	Low
12. Disinfection	Medium	Medium	Medium	Medium

Immediately following your exam completion, you will receive a report of your results. Your exam report will specify the number of questions which were include for each category on the exam taken and the percentage that were answered correctly. Exam categories correspond directly to the chapters and/or sections in this study guide. **Your exam report is designed to help direct your future studies and professional development**. For example, if you passed the exam but scored only 60% in the category of Operator Safety, you would be encouraged to review the corresponding chapter (Chapter 6) in this study guide.

If you did not pass your exam, you should carefully re-study all categories in which you scored below 70%. You may also want to review all the chapters in this study guide and/or attend additional training before retaking your exam. You must wait at least 30 days before retaking a certification exam unless additional approved training has been completed in the interim.

Chapter 1

Basics of Wastewater Treatment

Suggested Study Guidelines

All certification levels

Be prepared to answer questions concerning:

The purpose of wastewater treatment

The importance and role of the wastewater operator

The definitions of each of the following terms

aerobic	anaerobic	community wastewater system
digester	disinfection	preliminary treatment
facultative pond	influent	inorganic
stabilize	effluent	water pollution
organic	sludge	primary treatment
secondary treatment	tertiary treatment	wastewater collection system

National Pollutant Discharge Elimination System (NPDES)

Oklahoma Pollutant Discharge Elimination system (OPDES)

The average domestic wastewater production per person per day.

The common conversion factors used in wastewater systems and how to use them.

How to perform area and volume calculations for cylindrical and rectangular basins.

How to convert between different volume/time units.

Figuring dose of chemicals commonly used, both lbs. and ppm or mg/L.

The most commonly used metric system units in wastewater systems and their values.

Basic chemistry terms.

Entry Level Discussion

All over America and the world, people want and deserve clean water, and this need creates an intense responsibility to ensure that wastes be disposed of in a manner that reduces pollution, prevents the spread of waterborne diseases, and keeps our rivers suitable for both wildlife and recreational use. Therefore, it is the responsibility of the wastewater system operator to maintain, or exceed, current standards for wastewater treatment, to constantly learn more about his or her profession, and to operate the systems in a cost effective and safe manner. All certified wastewater system operators are considered **Public Health Professionals** who have a very important role in protecting the public health in their communities.

The Municipal Sanitary Sewer Collection System (SSCS), and conveyance systems are an extensive, valuable, and complex part of the nation's infrastructure. Distribution systems consist of pipelines, conduits, pumping stations, force mains, and all other facilities used to collect wastewater. The proper functioning of these wastewater and water systems are among the most important factors responsible for the general level of good health in the United States. Most members of the general public take a well-operated SSCS for granted, without being aware of its design and technical workings. The public expects these systems to function effectively at a reasonable cost.

According to the Environmental Protection Agency (EPA), of the more than 19,000 collection systems, about 4,800 are satellite collection systems. There are also private satellite collection systems, which are associated with a wide range of entities such as trailer parks, residential subdivisions, apartment complexes, and commercial complexes such as shopping centers, industrial parks, college campuses, and military facilities. In addition, commercial complexes, homeowner associations, and other entities may retain ownership of collector sewers leading to the municipal sanitary SSCS. In some situations, the municipality that owns the SSCS may not provide treatment of wastewater, but only send its wastewater to the municipal entity for treatment. Collection systems of this nature are also referred to as satellite systems.

The EPA estimates that the more than 19,000 collection systems in the U.S. would have a replacement value of $1 trillion to $2 trillion dollars. Another source estimates that wastewater treatment and collection systems represent about 10 to 15 percent of the total infrastructure value in the U.S. The collection system of a single, large municipality can represent an investment worth billions of dollars. Usually, the asset value of the collection system is not fully recognized, and the collection system operation and maintenance programs are given low priority compared with wastewater treatment needs and other municipal responsibilities.

For example, the Federal Water Pollution Control Act Amendments of 1972 were passed by Congress to regulate and improve the quality of effluents discharge into the streams and rivers of this country. The contaminants identified by the EPA as harmful to human health are called primary contaminants. In order to protect public health, a primary contaminant must not exceed a certain specified level known as the Maximum Contaminant Level (MCL). If an MCL is exceeded, public notification is required. Such processes cost a lot of money, so it is common to see both public and private ownership of the current infrastructure.

A large number of public and private entities may own different pipes and other components of the entire municipal SSCS. The customers of a municipal SSCS typically retain ownership of building laterals and are responsible for their maintenance. However, municipalities can have differing regulations pertaining to lateral ownership. These regulations should be revised on a case-by-case basis and incorporated into any management plan.

Brief History of Collection System Regulatory Activities

The EPA has been working for a number of years on enhancing existing regulations to reduce or eliminate the occurrence of **sanitary sewer overflows (SSOs),** and to preserve the substantial investment in infrastructure that collection systems represent. In 1995, the EPA convened an Urban Wet Weather Flows Advisory Committee and an SSO Subcommittee. Both the Committee and the Subcommittee included municipal representatives, advocacy groups, states, and the EPA. The SSO Subcommittee examined the need for national consistency in permitting and enforcing effective sewer operation and maintenance principles, public notification of SSOs with potential health and environmental dangers, and other public policy issues.

On May 29, 1999, President Clinton directed the EPA to "improve protection of public health at our nation's beaches by developing, within one year, a strong national regulation to prevent the over 40,000 annual sanitary sewer overflows from contaminating our nation's beaches and jeopardizing the health of our nation's families. At a minimum, the program must raise the standard for sewage treatment to adequately protect public health and to provide full information to communities about water quality problems and associated health risks caused by sanitary sewer overflows."

Optimizing Operation, Maintenance, and Rehabilitation of Sanitary Sewer Collection

The current performance of many collection systems is poor, and many systems have received minimal maintenance for many years. Many systems are maintained by a "public works" department charged with various functions, such as street, sidewalk, storm drain, and sometimes water utility maintenance. However, many times people want the convenient function of these functions without spending the money; as a result, the wastewater collection systems suffer because officials and the public like to spend the money where the public can most see the results.

Wastewater collection systems also suffer from a history of inadequate investment in maintenance and repair. This problem is also due to simply being forgotten by both the public and officials of the industry. Because the inner workings are primarily underground and hidden from view, they are often forgotten about and are allowed to weaken, break, or block before repairs are made. This causes an "out-of-sight, out-of-mind" view of the wastewater collection system, which poses an inherent problem.

The lack of proper maintenance has resulted in deteriorated sewers with subsequent basement backups, overflows, cave-ins, hydraulic overloads at treatment plants, and other safety, health, and environmental problems. As one of the most serious and environmentally threatening problems**, sanitary sewer overflows** are a frequent cause of water quality violations and are a threat to public health and the environment. Beach closings, flooded basements, closed shellfish beds, and overloaded treatment plants are some symptoms of collection systems with inadequate capacity and improper management, operation, and maintenance.

The poor performance of many sanitary sewer systems and the resulting potential health and environmental risks highlight the need to optimize operation and maintenance of these systems.

Wastewater treatment is the "last line of defense" against water pollution.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – **Operation of Wastewater Treatment Plants–Vol. 1**

Chapter 1	The Treatment Plant Operator
Chapter 2	Why Treat Wastes?
Chapter 3	Wastewater Treatment Facilities
Appendix	How to Solve Wastewater Treatment Plant Arithmetic Problems

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems–Vol. 1**

Chapter 1	The Wastewater Collection System Operator
Chapter 2	Why Collection System operation and Maintenance?

OTHER STUDY SUGGESTIONS

Draw a simple diagram of a typical secondary wastewater treatment facility which includes:

Collection system   Plant pretreatment   Primary sedimentation

Secondary treatment   Disinfection

Solids going to an anaerobic sludge digester followed by sludge drying beds

Identify typical influent characteristics (see also Chapter 2) and determine where they are removed in the process train that you have drawn.

For a review of basic math skills, read and work the problems in the APPENDIX A Practice Math section of this study guide.

To help prepare for all exams, practice using the appropriate formula sheets found in APPENDIX B in this study guide.

SAMPLE QUESTIONS

Class D

The Federal Water Pollution Control Act Amendments was passed in what year?

A. 1968
B. 1972
C. 1974
D. 1975

Class C

The term "Public Health Professional" is used to describe.

A. The superintendent
B. The DEQ inspector
C. An Operator

Class B

A high quality effluent from a treatment plant:

A. is the only goal of a good operator.
B. will mean that the public will always appreciate all that you do.
C. means that the plant is being operated safely and exactly as it should be.
D. may mean little to the public if the plant doesn't appear clean and well maintained.

Class A

Your community has voted to issue a bond to finance a new or improved wastewater treatment plant. The consulting engineers have submitted their plans and specifications for the project. You as the supervisor of this plant should?

A. participate in the ground floor planning and be present or available during the construction period but never consider yourself an actual member of the team of experts in your community.

B. participate in the ground floor planning and be present or available during the construction period to become familiar with the system and to offer advice to the consulting engineer.

C. try to stay out of the way during planning and construction but make sure that you get a good set of the final plans to study when the plant is put on-line.

D. advise the consulting engineer to not include any processes or treatment concepts that you and the other operators are not currently familiar with.

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Chapter 2

Characteristics of Wastewater

Suggested Study Guidelines
Be prepared to answer questions concerning:

<u>Class D</u>
Be prepared to answer questions concerning:
Physical, chemical, and microbiological characteristics of wastewater.
The definitions of each of the following terms and their significance:

pH	Bacteria	Acid
Pathogenic	Base	Non-Pathogenic
Neutral	Microbiology	Total Alkalinity
Phenolphthalein Alkalinity	Fecal Coliform	Phosphorus
Nitrogen	Nutrients	Total Solids
Total Dissolved Solids	Settleable Solids	Total Suspended Solids
Non-Settleable Solids	Dissolved Oxygen	Aerobic Bacteria
Fresh Wastewater	Coliform	Carbon Dioxide
Anaerobic Bacteria	Chemical Oxygen Demand (COD)	
Facultative Bacteria	Biochemical Oxygen Demand (BOD)	
Septic Bacteria		

The proper units of measurement for each of the general characteristics of water.
The most important factors in properly collecting wastewater samples.
The two basic types of wastewater samples based on how they are collected.

Class C
Be prepared to answer questions concerning guidelines listed for Class D certification and:
The chemical symbols for the various chemical constituents of wastewater.
The differences in the characteristics of treated versus untreated domestic wastewater.
The average concentration of BOD and solids in domestic wastewater.
How temperature effects DO values.
What gases are produced under septic conditions.
What gases are produced under fresh conditions.
The effects carbon dioxide has on pH levels.
Be prepared to answer other questions that require additional personal study.

Class B and Class A
Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

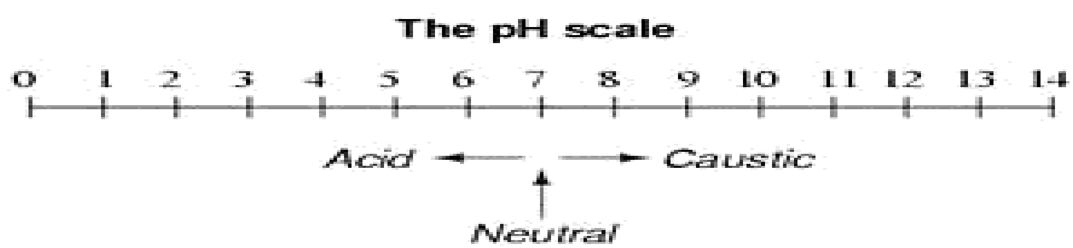
The different types of sampling and the proper way to sample for each parameter.
How to evaluate a BOD worksheet, including when you can and cannot use the results.
Which methods of chlorine residual measurement are acceptable.
The names of different methods used to measure wastewater parameters.

Be prepared to answer other question that require a combination of actual experience and additional personal study.

Entry Level Discussion:

A good basic understanding of the characteristics of wastewater is essential to the understanding of why and how wastewater treatment is formed. Because wastewater contains many different substances, it is characterized by its physical, chemical and biological aspects. These substances are expanded by the 3 main sources; (1) homes, (2) industries, and (3) storm runoff and groundwater that enters through inflow, infiltration (I & I), and exfiltration**.**

pH Potential of **H**ydrogen:
The **pH** is a measurement of how acidic or basic, (sometimes referred to as alkaline) the item being tested is. The **pH scale** is from 0.0 to 14.0. pH values less than 7.0 are progressively **acidic** while pH of greater than 7.0 are progressively **basic, (also called caustic or alkaline).** A pH of exactly 7.0 is considered **neutral.** Each **pH unit** on the scale is very significant because it actually represents a ten-fold increase or decrease in how acidic or basic the water is. It is for this reason that pH measurements are always reported in tenths of a pH unit instead of just "rounding off" to the nearest whole number. pH measurements should never be averaged together. The most common method used for pH measurement is pH meter using a hydrogen ion-sensitive electrode.



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.

As a chemical component of the wastewater, pH has direct influence on wastewater treatability — regardless of whether treatment is physical/chemical or biological. Because it is such a critical component of the makeup of the wastewater, it is therefore critically important to treatment.

By chemically adjusting the pH, we can remove heavy metals and other toxic metals from water. In most runoff of wastewater, metal and other contaminants are dissolved and will not settle out. If we raise the pH, the amount of negative hydroxide ions, the positively charged metal ions will form bonds with the negatively charged hydroxide ions. This creates a dense, insoluble, metal particle that can settle out of wastewater given time or be filtered out manually using a filter press.

At an acidic pH, the excess of positive hydrogen and metal ions have nothing to bond with and float around in the water, never settling. At a neutral pH, the hydrogen ions are bonded with the hydroxide ions to form water while the metal ions remain. At a basic pH the excess hydroxide ions bond with the metal ions to form metal hydroxides which can be removed through filtering or settling.

The pH of water can be used to kill off bacteria in wastewater in addition to the treatment mentioned above. Most organic matter and bacteria we are familiar with, and contact daily, are best suited to a neutral or slightly basic environment. At an acidic pH, the excess hydrogen ions begin to form bonds with and break down the cell, slowing their growth, or killing them outright. After a wastewater treatment cycle, the pH must be raised back to neutral by use of additional chemicals or it will continue to damage any living cell it contacts.

The water molecule (H_2O) has a tendency to disassociate or "split apart" into two parts; the **hydrogen ion** (H^+) and the **hydroxide ion** (OH^-). The hydrogen ion (H^+) is related to acidic conditions while the hydroxide ion (OH^-) is related to basic conditions which determines the pH levels.

The presence of different types of impurities in water causes differences in pH. If there are high concentrations of impurities in the water that combine with or "tie up" hydroxide ions, a surplus of hydrogen ions will be left over or "free." This condition will cause the pH to be less than 7.0 (acidic). On the other hand, if the impurities tend to "tie up" the hydrogen ions, a surplus of hydroxide ions will be "free" and the pH will be greater than 7.0 (basic). If a water sample contains equal concentrations of OH^- and H^+, the pH will be exactly 7.0 (neutral).

This hydrogen ion concentration expressed as pH, is a valuable parameter in the operation of biological units. The pH of the fresh sewage is slightly more than the water supplied to the community. However, decomposition of organic matter may lower the pH, while the presence of industrial wastewater may produce extreme fluctuations. Generally, the pH of raw sewage is in the range of 5.5 to 8.0.

Alkalinity:

Alkalinity can be defined as the ability to resist changes in pH in response to dilute acids or dilute bases. In other words, the alkalinity in the wastewater is caused by certain chemicals that act as a **buffer.** It should be noted that the presence of alkalinity does not necessarily indicate basic pH conditions. Although the chemicals producing alkalinity in wastewater do tend to keep the wastewater at a high pH, it is possible to have acidic pH conditions and still have some alkalinity present or to have basic pH conditions, but not have a significant amount of alkalinity present.

There are two types of alkalinity measurements. These measurements are referred to as total alkalinity and p-alkalinity.

Just as it sounds, the **total alkalinity** test measures the total amount of alkalinity present. Total alkalinity is usually called t-alkalinity or **T-alk.** Total alkalinity only exists between pH range of 4.5 to 14.0. This means that if a wastewater sample has a pH of less than 4.5, the alkalinity content is zero which is why pH of 4.5 is referred to as the "endpoint" for T-alk.

Another alkalinity measurement is the **p-alkalinity** or **p-alk** test. The "p" in p-alkalinity is an abbreviation for phenolphthalein, a chemical used in the lab test. p-alk only exists between pH range of 8.3 to 14.0. Where the endpoint for T-alk is 4.5 the endpoint for p-alk is 8.3. p-alk represents 100% alkalinity where T-alk will also have hardness, (within the range of 4.5 to 8.3). The p-alk test is often performed to help determine the relative concentrations of hydroxide, carbonate, and bicarbonate in the sample. It should be remembered that p-alkalinity (if it is present) is only part of the total alkalinity, not an entirely separate measurement.

The most common method used for alkalinity analysis is **titration**. In alkalinity titrations, a dilute acid is added to the sample until the pH reaches the "**endpoint"** as indicated by a pH meter or a color indicator. The amount of dilute acid that was needed to reach the endpoints is then noted and calculated in a formula to determine alkalinity values. Alkalinity values are reported in mg/L (milligrams per liter) or ppm (parts per million).

Solids:

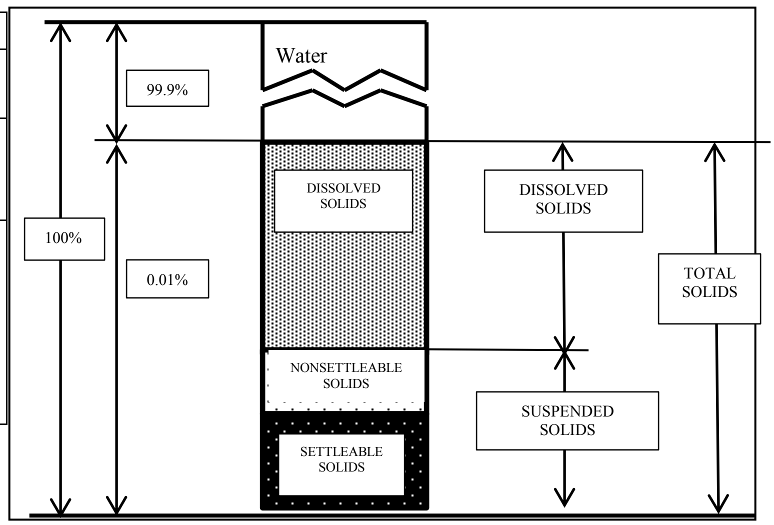
Domestic wastewater will normally consist of 99.9% water with only 0.1% total solids, (equivalent to 1000 mg/L total solids content). Total solids in wastewater consist of both dissolved solids and suspended solids.

The **total suspended solids** (TSS) is the portion of the total solids that can be removed by filtration. Total suspended solids can be further categorized as either settleable or nonsettleable solids. The nonsettleable TSS is known as colloidal material. Colloids will not settle because they are very small and carry similar charges that keep them separated. An important example of a settleable solid is grit. Grit is a heavy inorganic settleable solid that consists of sand and silt and is usually removed very early in the treatment process. The total dissolved solids (TDS) is the portion of the total solids that CANNOT be removed by simple filtration. About 80% of the solids in typical domestic wastewater are dissolved solids.

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.

Solids analysis is performed by use of a drying oven set at a specific temperature and a very sensitive weighing scale. After prescribed sequences of initial weighing, oven drying, cooling, and re-weighing have been completed, the final weight of the dry residue is recorded. The results are reported in mg/L or ppm.

SOLIDS GROUP	CONTENTS
Total Solids (TS)	Everything that is not water
Total Dissolved Solids (TDS)	All the solids that cannot be filtered out of the water
Total Suspended Solids (TSS)	All the solids that can be filtered out including: settleable solids and non-settleable solids (colloids)



Microbiology:

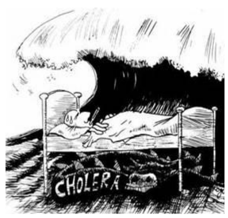
Domestic wastewater comprises of countless numbers of living organisms, most of them too small to be visible except when viewed under a microscope, which is why they are called "microorganisms." These organisms include bacteria, virus, protozoa, rickettsia, fungi, algae, and other forms of microscopic life. Domestic wastewater prior received by the treatment plant via collection system will contain from 100,000 to 1,000,000 microorganisms per milliliter. The two sources for these are through sanitary wastes and the soil. They serve a primary function in the degradation of wastes in biological wastewater treatment. It is for this reason that the successful operation of a biological wastewater treatment plant is dependent on the knowledge of the activities of the microorganisms. Efficient treatment then depends on understanding the requirements for optimal growth as well as recognizing unfavorable conditions.

Pathogenic Organisms:

While the majority of the microorganisms found in wastewaters are not harmful to man -- that is non-pathogenic (do not cause disease), some microorganisms are pathogenic (disease causing) and always are of great concern in wastewater treatment. Among the diseases that are associated with wastewaters are typhoid, cholera, dysentery, polio, and hepatitis. Other diseases that could be spread by wastewater include giardiasis (giardia) and cryptosporidiosis (crypto).

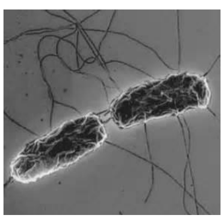
Pathogens fall into the following categories:

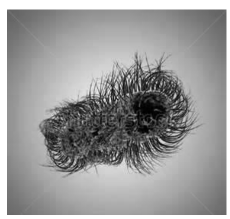
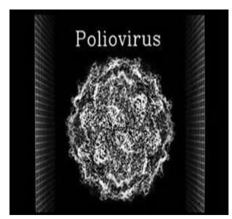
Pathogen Type	**Examples**
Bacteria	Cholera, Shigella, Salmonella
Viruses	Norwalk, Rotavirus, Adenovirus
Protozoa	Giardia lamblia, Cryptosporidium parvum

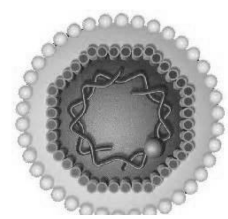



A
B
C

TYPHOID CHOLERA DYSENTERY POLIO HEPATITIS





The microorganisms found in wastewaters are commonly classified by their appearance (morphology). While all microorganisms found in wastewater treatment plants have some role in the decomposition of wastes, probably the three most significant microbial groups in biological treatment are the **bacteria**, **fungi**, and **protozoa**. Bacteria have the primary role of decomposing wastewater compounds, forming settleable solids, and at times are the source of operational problems. The general group called fungi are significant since many operational problems are caused by members of this group. Protozoa are microorganisms that play a key role as predators and help control the bacterial populations.

Bacteria are living organisms, microscopic in size. They consist of a single-cell organism, and are capable of growth in suspended masses, as in the activated sludge process or attached as in trickling filters. There are many different kinds of bacteria, too numerous to elaborate. The group best known to those in the wastewater field are the fecal coliforms -- a group of bacteria commonly associated with human excretions. Bacteria have the ability to reproduce rapidly when in intimate contact with their nutrient material (e.g., wastes) and feed readily by taking in food directly through their cell wall. Bacteria occur in three basic shapes: rods (or bacilli), spheres (or cocci) and spirals. While all of these forms are found in wastewaters, quite often they are found individually enmeshed or associated in masses, slimes or "flocs" as in the activated sludge process. While bacteria have a principal role in biological treatment, under some conditions certain bacterial forms (e.g. filamentous bacteria) can cause serious operational problems, especially in settling

Parasitic Bacteria:

Parasitic bacteria are those which normally live off of another living organism, known as the host, since they require a food supply already prepared for their consumption, and generally do not develop outside the body of the host. The parasitic bacteria are of importance in wastewater. They originate in the intestinal tract of human beings and animals and reach the sewage by means of body discharges. Included among the parasitic bacteria are certain specific types which, during their growth within the body of the host, produce toxic or poisonous compounds that cause disease in the host. These bacteria are called pathogenic bacteria. They may be present in sewage receiving the body discharges of persons ill with such diseases as typhoid fever, dysentery, cholera, or other intestinal infections.

Saprophytic Bacteria:

The saprophytic bacteria are those which feed on dead organic matter, thus decomposing organic solids to obtain their needed nourishment, and producing in turn waste substances which consist of both organic and inorganic solids. By this activity they are of utmost importance in sewage treatment methods designed to facilitate or hasten natural decomposition of the organic solids in sewage. Such processes of decomposition will not progress without their activity. In the absence of bacterial life, aka "sterility," decomposition will not take place. There are many species of saprophytic bacteria, each of which plays a specific role in the breakdown of the organic solids of sewage. Each species tends to die away following completion of its part in the process of decomposition.

Oxygen Requirements of Microbiological Organisms:

All of the bacteria, parasitic and saprophytic, require in addition to food, oxygen for respiration. Certain types of them can use only oxygen dissolved in water, termed dissolved oxygen and sometimes called free or molecular oxygen. These organisms are known as **aerobic bacteria** and the process of degradation of organic solids which they carry out is termed aerobic decomposition, oxidation, or decay. This type of decomposition proceeds in the presence of dissolved oxygen without the production of foul odors or unsightly conditions. Other types of bacteria cannot exist in the presence of dissolved oxygen, but must obtain the required supply of this element from the oxygen content of organic and some inorganic solids, which is made available by their decomposition as well as chemical compounds found in the wastewater such as sulfate (sulfur and oxygen). When the oxygen is removed from sulfur compounds, hydrogen sulfide (H2S) is formed giving off a rotten egg smell. Such microorganisms are termed **anaerobic bacteria,** and the process of degradation of solids which they bring about is called anaerobic decomposition or putrefaction, that is, decomposition in the absence of dissolved oxygen, which results in the production of foul odors and unsightly conditions.

To complicate the reactions involved in the decay of organic matter, certain aerobic types can adjust themselves to live and function in the absence of dissolved oxygen and are termed

facultative aerobic bacteria. Conversely, some varieties of anaerobic bacteria can become accustomed to live and grow in the presence of dissolved oxygen and are thus termed **facultative anaerobic bacteria.**

Total Coliform Bacteria:

Members of two bacteria groups, coliforms and fecal streptococci, (a subset of total coliform bacteria, are more fecal-specific in origin), are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff.

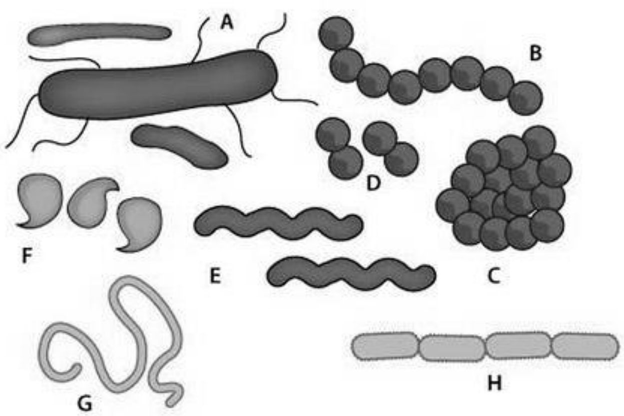
In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand

The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli*, fecal streptococci, and enterococci. All but *E. coli* are composed of a number of species of bacteria that share common characteristics such as shape, habitat, or behavior; *E. coli* is a single species in the fecal coliform group. *E. coli* is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals.

Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood and in other places outside the human body. Thus, the usefulness of **total coliforms as an indicator** of fecal contamination depends on the extent to which the bacteria species found are fecal and human in origin. For drinking water, total coliforms are still the standard test because their presence indicates contamination of a water supply by an outside source.

One of the most common procedures used by microbiological laboratories to detect fecal coliform or total coliform bacteria is referred to as the **MF (membrane filter) method.** In this method, a measured portion of the sample is passed through a very fine filter using sterile handling techniques. The filter has such a small pore size that the organisms are caught on the filter as the water passes through. The filter is then placed in a small dish which contains a fluid especially formulated to grow coliform bacteria. The dish containing the filter is then incubated at precise temperatures for a specific period of time. After incubation, the number of coliform colonies (groups of bacteria) that grew on the filter are counted. Each colony represents one coliform bacteria present in the original sample. The results of this coliform test are reported as the number of organisms present per 100 mls of sample.

In some situations, other laboratory tests are used to check for coliform bacteria. One of these is known as the **MPN** (most probable number) method. This method uses several tubes which are each "inoculated" with sample. They are then incubated at 35°C for 48 hours. If a gas bubble is produced in one of the tubes, the sample may be positive for coliform bacteria. A separate procedure to confirm the results is then performed. A "most probable number" of coliform is reported based on the number of tubes that tested positive.



The different shapes of bacteria enable us to place them in different family groups:

A Bacilli with and without flagella
B Streptococci
C Staphylococci
D Diplococci
E Spirochete
F Club rod
G Filamentous
H Streptobacilli

Viruses:

Among the other microbiological components that are found in domestic wastewaters in smaller numbers are viruses. Viruses are very small and can be seen only by use of a sophisticated tool called an electron microscope. Viruses are significant since they all must derive their energy and reproduce from living tissue and are thus parasitic.

Among the viruses found in domestic wastewaters which cause diseases in man are: hepatitis, polio, as well as a variety of intestinal viruses such as ECHO, coxsackie and adenovirus. A common virus found in domestic wastewater that does not infect man but does attack bacteria is a phage or a bacteriophage. Viruses pathogenic to man are usually present in small numbers in relation to coliform bacteria, for example, it is estimated that for approximately every million coliform bacteria there is one infective virus present. Viruses are of special concern in wastewater treatment since many are not destroyed by conventional chlorination procedures.

Dissolved Oxygen:

Fresh domestic wastewater will usually be grayish in color with only a slight fecal odor. Generally speaking, for wastewater to be considered fresh (aerobic) it will have at least 2.0 mg/L of dissolved oxygen (DO). Some aerobic treatment processes are designed to allow the DO to go as low as 0.5 mg/L. In any case, if the DO level is allowed to drop below what is required for that particular aerobic treatment process, the **aerobic** organisms will die and **facultative** organisms will convert to the **anaerobic** state. At this point, the wastewater is no longer fresh and is considered septic. **Septic** wastewater contains very little or no DO. It has a dark brown to black color and a rotten-egg odor.

The rotten egg odor in septic or anaerobic wastewater is caused by the presence of **hydrogen sulfide** (H_2S) gas which is produced as a result of anaerobic decomposition (septic conditions). Another gas produced by anaerobic decomposition is methane. Methane gas is flammable and explosive.

The dissolved oxygen content of the water can be directly affected by the temperature of the water. The colder the water, the more dissolved oxygen it can contain. Heat drives the dissolved oxygen out of the water contributing to possible anaerobic conditions. Thus, it is much more difficult to maintain aerobic conditions during the summer than it is during the winter.

Common methods of determining DO levels include using a DO meter equipped with a special membrane covered probe or a specific titration procedure known as the Winkler-Azide method. DO levels are reported in mg/L or ppm.

Biochemical Oxygen Demand (BOD):

The parameter used to estimate the organic content of wastewater is referred to as **biochemical oxygen demand (BOD).** Microorganisms use oxygen dissolved in the water when they degrade the organic material. As the microorganisms metabolize the organic matter, they use up the available oxygen. BOD is the amount of oxygen required to decay a certain amount of organic matter. In simple terms, BOD is a measurement of the strength of the wastewater. Actually, the BOD lab test measures the amount of oxygen that is consumed by aerobic bacteria while the sample is incubated in the dark for a five-day period at 20° Celsius (C) +or- 1 °C. Because it takes five days to get the results of this test is sometimes written as BOD_5. BOD results are very important to operators because BOD is the primary guideline used to determine the efficiency of the plant. Raw BOD levels at domestic wastewater treatment plants are normally between 150 and 300 mg/L.

Chemical Oxygen Demand (COD):

A measure of the amount of oxygen, in ppm or mg/L, chemically (rather than biologically) consumed under specific conditions in the oxidation of organic and oxidizable inorganic materials in water is **chemical oxygen demand (COD)**. COD is an alternative to BOD for measuring the strength of the wastewater. The primary advantage of COD test is time, as it only takes two (2) hours to get results. The primary disadvantage of the COD test is that chloride may interfere with the chemical reactions. So, wastewaters containing high-salt concentrations cannot be readily analyzed without modification.

Carbon Dioxide:

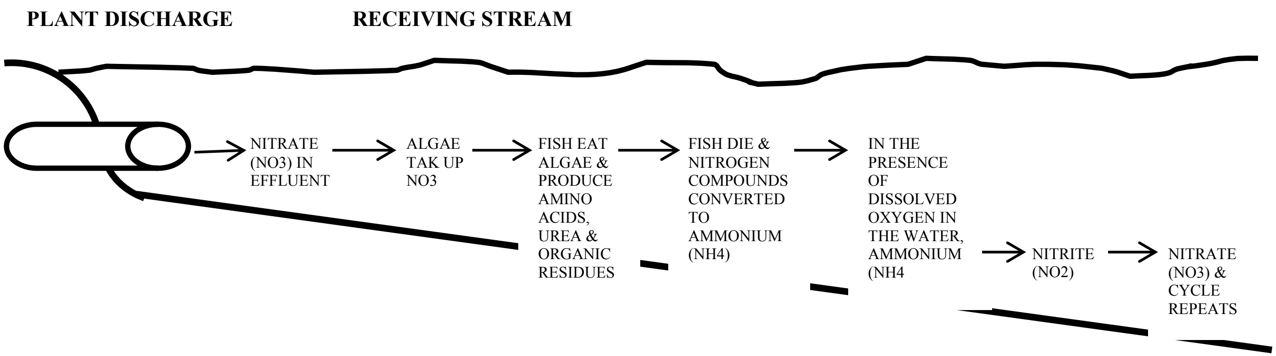
Carbon Dioxide (CO_2) is a common constituent of both air and wastewater, and is produced by both aerobic and anaerobic conditions. Carbon Dioxide will have a tendency to lower pH because carbonic acid (H_2CO_3) is produced when carbon dioxide reacts with water.

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.

An illustration of nitrogen cycle



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.

Some heavy metals and compounds such as chromium, copper, cyanide, which are toxic may be found in municipal sewage if there is industrial discharges. The concentration of these compounds is important if the sewage is to treat by biological treatment methods or disposed of in stream or on land. In general these compounds are within toxic limits in sanitary sewage however; with receipt of industrial discharges they may cross the limits in municipal wastewaters.

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.

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.

General Procedures for Samples:

Sampling is a vital part of wastewater operations. A major source of error in the overall process control or effluent quality information often occurs during sampling. In any type of testing program where only small samples ate withdrawn from perhaps millions of gallons, there is potential uncertainty because of possible sampling errors. Decisions based upon incorrect data may be made if sampling is performed in a careless manner. Obtaining accurate results will depend to a great extent upon the following factors:

1. Ensuring that the sample taken is truly representative of the water under consideration.

2. Using proper sampling techniques.

3. Protecting and properly preserving the samples until they are analyzed by the lab technician.

The two basic types are grab samples and composite samples. A **grab sample** is a single water sample collected at no specific time, but within a total period of less than 15 minutes. Grab Samples will show the characteristics at the time the sample was taken. Grab Samples are usually taken when testing for parameters such as dissolved oxygen, pH and alkalinity.

A **composite sample** is a sample consisting of portions of several samples each taken one hour apart. The hourly portions are mixed together. The size of each portion used is in proportion to the flow rate when the sample was collected, as well as the total size of the sample needed. Typical composite samples might be taken over a period of 3 hours, 6 hours, or 12 hours. Composite sampling is often utilized for tests such as biochemical oxygen demand (BOD) and total suspended solids (TSS).

TYPICAL INFLUENT POLLUTANT CONCENTRATIONS		
PARAMETER	CONCENTRATION	EFFLUENT GOAL
BOD5	200 mg/L	< 30 mg/L
TSS	200 mg/L	< 30 mg/L
TDS	800 mg/L	< 1000 mg/L
Settleable Solids	10 ml/L	< 0.1 ml/L
pH	6 – 9	6 – 9
Fecal Coliform	Too Numerous to Count	< 500 cfu/ 100ml
TKN (Ammonia + Organic Nitrogen)	30 mg/L	< 10 mg/L Total Nitrogen
Nitrate/ Nitrite	< 1.0mg/L	
Phosphorous	2.0 mg/L	< 1.0 mg/L
Fats, Oils and Grease	Varies Greatly	None Visible

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – Operation of Wastewater Treatment Vol.1
    Chapter 2   Why Treat Wastes?
California State University, Sacramento – Operation of Wastewater Treatment Vol.2
    Chapter 13   Effluent Disposal
    Chapter 16   Laboratory Procedures and Chemistry
    Note: Questions concerning step-by-step lab procedures are NOT on operation exams.

OTHER STUDY SUGGESTIONS

Become familiar with typical values of the influent and the effluent of the wastewater treatment plant for each of the wastewater characteristics.
Identify wastewater characteristics and identify what happens to each characteristic as it goes through each process unit (see also Chapter 1)
Study APPENDIX C of this study guide
Using any good chemistry or laboratory textbook, study the fundamentals of chemistry.
Using any good microbiology or bacteriology textbook, study the characteristics of different microorganisms, including their oxygen requirements and pathogenicity.

SAMPLE QUESTIONS

Class D
A pH of 9.1 is considered:

A. acidic.
B. basic.
C. neutral.

Class C
BOD is an estimate of the:

A. organic content of wastewater.
B. inorganic content of wastewater.
C. solids content in wastewater.

Class B
A COD test is preferred over a BOD-5 test for the following reasons?

A. Test results are quickly obtained.
B. The test is more exact.
C. The test gives more information.
D. The test is less expensive.

Class A
Dissolved solids are also correctly called:

A. settleable solids.
B. filterable residue.
C. Imhoff cone results.
D. nonfilterable residue.

Chapter 3

General Regulations and Management

INTRODUCTION TO CHAPTER 3

There are many references made throughout this study guide to legal requirements regarding the proper treatment and handling of wastewater and treatment equipment. The requirements are designed to protect public health and to help ensure operator safety.

This chapter is designed to serve as an introduction to some of the more fundamental legal requirements of system operation and to provide sources for additional information concerning regulation. The suggested references for this chapter also address the management related skills especially needed by the supervisors and superintendents of community wastewater systems.

SUGGESTED STUDY GUIDELINES

Class D

Be prepared to answer questions concerning:

Who must be certified and how to renew a certificate.
The basic requirements for certification including temporary certification.
The regulations concerning Monthly Operational Reports (MORs) and Discharge. Monitoring Reports (DMRs).
How long to keep records at wastewater systems.
The importance of and need for records.
The penalties for falsification.
The definition of an un-permitted discharge (bypass).
The reporting requirements for un-permitted discharges and the possible penalties if not met.

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

The basic criteria concerning the classification of wastewater works.
The levels of certification required for supervisors and superintendents at different systems.
The rules and regulations concerning laboratory technician certification requirements.
The parameters and frequencies of laboratory tests required at different types of facilities.
The proper way to fill out and submit a DMR.

Be prepared to answer other questions that require additional personal study.

Class B and Class A
Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

- The basic differences in responsibility between wastewater works owners and operators.
- The different types of records that should be kept.
- How to organize and write a report.
- How to implement and maintain safety programs.
- Common uses of computers in wastewater systems.
- How to recognize questionable data on operational reports and laboratory data.
- How to calculate wastewater parameter effluent concentrations for reporting on the DMR.
- How to perform a variety of management related calculation and analyze and present data using, charts, graphs, tables, and numbers.
- How to manage an organization to operate and maintain wastewater collection systems.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

ENTRY LEVEL DISCUSSION

Operator Certification Requirements
State law requires that all operators of community wastewater systems be certified within 10 days of employment or appointment as an operator (252:710-3-32(b)). An **operator** is a person who is at any time responsible for the operation of a wastewater works in part or in whole and shall include any person who can through direct act or command, affect the quality of the wastewater. **"Wastewater works"** means wastewater treatment systems and facilities used in the collection, transmission, storage, pumping, treatment, or disposal of liquid or waterborne wastes.

Every certified operator should understand the operator certification requirements found in DEQ's **Title 252:710 Waterworks and Wastewater Works Operator Certification Rules**.

This document may be obtained from the Department of Environmental Quality (DEQ) Operator Certification Unit. Some of the more important rules and policies concerning operator certification are discussed here.

Level of Certification Required
Operators who are not supervisors or superintendents may hold any level of current certification. All operators are encouraged to obtain the highest level of certification for which they qualify.

The **superintendent/supervisor** must hold a certification equal to or greater than the classification level of the wastewater system that he or she is responsible for including each treatment facility and collection system. The manager/superintendent/supervisor is the operator in direct responsible charge of an entire plant or collection system. This is true even if other official titles are sometimes assigned by employers.

The **assistant supervisor, and line maintenance supervisors** must hold a certification no less than one class less than the facility for which they are responsible for.

Persons who **supervise superintendents** are required to have a certification level equal to or higher than that required for the superintendent if they give commands which can affect the quality of the water or wastewater.

Persons who **program or maintain telemetry/SCADA systems** and also make process control/system integrity decisions must hold a certification no less than one class less than the facility for which they are responsible for.
(252:710-3-34)

Determinations concerning classification of wastewater works are made by the Operator Certification Unit based on complexity and population served. Population categories are listed in the box below.

Class "D"	1,500 or less
Class "C"	>1,500 - <15,000
Class "B"	>15,000 - <50.000
Class "A"	>50,000

All **discharging** wastewater works serving a population <15,000 must be operated by a superintendent with at least a Class C certification. A population over 15,000 requires a Class B or A certification, depending on the specific population and/or complexity of the wastewater plant. Temporary certification is not available to superintendents, assistant superintendents, supervisors, or managers of superintendents who make decisions regarding the daily operational activities of water/wastewater works.

Wastewater Works Operator
A certified wastewater operator may perform all duties relating to the operation and maintenance of wastewater treatment plants, lagoon systems and collection systems. Laboratory work can be performed as long as it is under the general supervision of a properly certified laboratory operator.
(252:710-5-52)

Collection Operator
A certified collection operator may perform all duties relating to the operation and maintenance of total retention lagoons systems and collections systems
(252:710-5-58)

Collection Technician
A certified collection technician may perform all the duties relating to operation and maintenance of total retention lagoon systems and collection systems under the general supervision of an appropriately certified operator.

Note: This is the only available certification which is the only certification test that can be given as an oral exam. This oral exam is only available by DEQ and only with proof provided to them that the person applying for this method has justified need. (252:710-5-59)

Temporary Certification

If permanent certification is not already held, **temporary certification** must be applied for within **ten days of employment** or appointment as an operator. Applications are available at the Operator Certification Unit. Individuals who have temporary certificates must work under the **general supervision** of a permanently certified operator. Direct, constant supervision is not required. Temporary certificates expire one year from the date of initial employment and cannot be renewed.

After receiving temporary certification, the operator should immediately begin to make plans to attend an approved entry level standard wastewater operations training course and an exam session in order to obtain at least Class D certification before the temporary certificate expires.

Temporary certification is not available to superintendents, assistant superintendents, supervisors, or managers of superintendents who make decisions regarding the daily operational activities of wastewater works.
(252:710-3-32(b)&(e)) & (252:710-5-54)

Helpers

When a helper is employed the helper's name and address must be submitted on a registration application when each helper is employed and thereafter by July 1st of each year the helper is in the employed. Helpers must work under the direct supervision of a permanently certified operator.
(252:710-5-55)

Laboratory Operators

All discharging wastewater facilities must have a properly certified designated laboratory operator. All of the laboratory analysis must be performed by or under the general supervision of a laboratory operator certified by DEQ. The designated certified lab operator is required to give general supervision of all laboratory tests performed and is held responsible for all test results. Certified laboratory operators are authorized to work in laboratories only. They are not certified to operate or make decisions concerning the operation of the plant. However, many individuals are certified as both operators and laboratory operators and perform work in both areas at their facilities.

Owners of water facilities that contract for laboratory services must notify the Operator Certification Unit within ten (10) days of the contract and state the analyses to be performed. Also, the contracting laboratory must notify the Operator Certification Unit within ten (10) days of the contract and state what analyses are performed by them.

One of the requirements of the laboratory operator certification program is that the results of all laboratory analyses shall be recorded in a bound volume at the time of the analysis. Each entry in this volume shall be signed and dated by the person who performed the analysis. These volumes will be kept on file at the laboratory for three (3) years for wastewater systems.

Laboratory operator certification is not required for wastewater works laboratory operators performing the minimum analyses required by rules of the Department for total retention lagoon facilities unless the Department has determined that additional laboratory test are required.
(252:710-5-53)

Annual Renewal of Certifications
All permanent certifications expire on June 30 of each year and must be renewed by no later than July 30 to remain current. Operators are responsible for renewal of their certifications regardless of notification. Before renewing a certification, the operator must have completed at least four hours of approved training within the last fiscal year (July1-June30). The renewal application should not be submitted until the training requirement has been met. Renewal application/invoices are mailed to all certified operators during late spring of each year. The application must be completed and then submitted with payment of renewal fees. Expired (delinquent) certifications may be reinstated for up to two years after the expiration date.
A temporary certification is valid for one year from the date of employment and is not renewable.
(252:710-1-7(f))

Reinstatement
If your certification is **suspended** it may be reinstated by the DEQ upon proper application, payment of all back fees and a satisfactory demonstration that all reinstatement requirements of the DEQ have been met. A person holding a suspended certification may work as a helper under the supervision of a person certified by the DEQ.

If your certification is **revoked** by the DEQ you must wait one year from the date of revocation before filling an application for a any new certification.

Anyone who has allowed the certification to expire for a period exceeding two years must re-apply and take a validated exam in order to be **reactivated** as a certified operator. Previous experience and training would be taken into consideration.

To satisfy **reinstatement requirements** you must satisfy again the training requirements as well as take the certification exam at a level not to exceed the prior level of certification with a score of 70% or higher. If you are not able to pass the exam you are required to wait 30 days before you can retake exam.
(252:710-1-8)

Other Requirements
It is the responsibility of the operator as well as the employer to see that his or her certification is the proper certification according to operator certification regulations. Owners of wastewater works must give their operators reasonable opportunity to obtain the necessary hours of training for their required certification upgrades and renewals. Owners must also furnish the necessary equipment and materials for adequate maintenance and operation of the treatment plant, laboratory, and supporting facilities. Possible penalties for violation of the Operator Certification Act are loss of certification, a fine, and/or jail term.
(252:710-1-7(a)) & (252:710-5-57)

Operational Rules and Standards

There are several other documents that every operator should be familiar with which specify legal requirements involved in the operation of wastewater systems. These are:

Oklahoma Pollutant Discharge Elimination System Standards (Chapter 606)
(includes Land Application of Biosolids)

General Water Quality (Chapter 611)

Non Industrial Impoundments and Land Application (Chapter 621)

Water Pollution Control Facility Construction (Chapter 656)

Underground Injection Control (Chapter 652)

Rules For Oklahoma Hazard Communication Standard

If you are not the operator-in-charge (superintendent) at your system. IT IS PROBABLY NOT NECESSARY THAT YOU HAVE YOUR OWN PERSONAL COPIES OF THESE DOCUMENTS. However, you should have access to them at your facility or local Public Works Department. All superintendents should have their own current copies of these documents and be very familiar with the requirements found therein. (see the "Reference Source Sheet" for information on how to obtain them). A brief summary of some of the documents is offered below.

Discharge – OPDES (Chapter 606)
This program regulates discharge into Oklahoma's waters from point sources, including municipal, industrial, commercial and certain agricultural sources. They include the basic provisions for the operation and maintenance or systems with lagoons.

General Water Quality (Chapter 611)
This chapter contains the requirements for TMDL's and other wastewater planning issues. Also, requirements for groundwater monitoring and remediation, and requirements for non-point source pollution under the DEQ's jurisdiction.

Non Industrial Impoundments and Land Application (Chapter 621)
These regulations list many requirements related to the actual operation of wastewater systems. These regulations are implemented by the Water Quality Division of the Oklahoma Department of Environmental Quality.

Water Pollution Control Facility Construction (Chapter 656)
These standards list requirements generally related to construction an/or modification of the physical system of wastewater systems. This document is also implemented by the Water Quality Division of the Oklahoma Department of Environmental Quality.
Rules for Oklahoma Hazard Communication Standard

These rules include several requirements applicable to publicly-owned systems regarding the transmission of necessary information to employees about the properties and potential hazards of hazardous substances in the workplace. These rules are implemented and enforced by the Public Employees Health and Safety Division of the Oklahoma State Department of Labor (ODOL).

Reports

All community wastewater systems must keep **Monthly Operational Reports (MOR)**. The MOR is a day-by-day record of the total plant operation. Entries should be made daily. It is the superintendent's responsibility to make sure that the MOR is kept up-to-date. Blank MOR forms are available from the DEQ Water Quality Division.

All discharging wastewater systems must also complete another important report called the **Discharge Monitoring Report (DMR)**. The DMR is a form which is completed monthly that summarizes the volume and nature of all discharges by the system. All discharging systems must hold a discharge permit issued under the Oklahoma Pollutant Discharge Elimination System or ODES.

The DMR must be submitted by the tenth day of the following month to the County DEQ office and the State DEQ office. For facilities that have not been delegated to the DEQ, a copy must also be submitted to EPA Region 6. For example, a copy of the DMR for the month of May would be due by June 10. DMR forms are obtained through the Water Quality Division. Some facilities may submit these reports electronically.

Reports of Unpermitted Discharges

A bypass or **unpermitted discharge** is any discharge from a wastewater treatment facility or collection system other than exactly what was allowed in the OPDES discharge permit. ALL UNPERMITTED DISCHARGES MUST BE PROPERLY REPORTED. An unpermitted discharge or diversion of wastes from any part of the treatment facilities or collection system is prohibited unless each of the following conditions are met:

1. It is unavoidable to prevent loss of life, personal injury or severe property damage.
2. There are no feasible alternatives.
3. The system must submit notice by telephone within 24 hours to the DEQ Water Quality Division, a brief description of the discharge and cause of the noncompliance; the period of noncompliance, including exact dates and times (or the anticipated time the noncompliance is expected to continue); and steps taken to reduce, eliminate and prevent the recurrence of the non-complying discharge.

A written submission must follow within five (5) days. When it is known in advance that an unpermitted discharge will occur, notification must be submitted ten (10) days or as long a time as possible before the discharge. Failure to report an unpermitted discharge can result in administrative actions or criminal charges filed against operators and/or owners.

Records
According to regulations, the records of all laboratory checks and control tests, including a copy of the MOR and DMR, should be kept on file at the facility for at least three years. Other records concerning the system operation should also be kept. These include plant performance records, personnel records, budget records, inventory records, maintenance records, and others.

Generally speaking, the more records that are kept and the greater the accuracy of those records, the better the chances of the system being properly operated and maintained. Records help operators see current problems and anticipate upcoming problems. Thorough and accurate records are also important from a legal standpoint to protect the system (and the operator) from accusations or inquiries based on incorrect or incomplete information.

Safety Records
Another very important category of records that must be kept by all systems are those concerning safety. These records include – but are not limited to- **accident records** and **safety checklists**, as well as **emergency guidelines and procedures.**

One of the most important sets of safety records required is the Material Safety Data Sheets (MSDS). An **MSDS** is required for each chemical used or stored in your system. These are available from the manufacturer or distributor of the product. Each MSDS should be fully understood and readily available to all operators working at the system.

Note: MSDS are now known as SDS (Safety Data Sheets) as explained in Chapter 6.

Falsification
Sometimes frustration levels reach such a high point for some operators that they resort to a very dangerous practice known as **falsification**. This practice endangers public health and also puts the operator in personal jeopardy of criminal prosecution, and/or loss of certification. The best advice when frustrated is to inquire (and even complain when necessary) as you seek a positive, safe, and legal way to solve problems. Some may think that by falsifying records they are protecting their system from "getting into trouble". Actually, they are making the situation much, much worse. If there is something that has not been done, or has not been done properly, the best choice by far is to simply note the problem and the reason why it occurred in the remarks column on the required reports, NEVER FALSIFY RECORDS OR REPORTS.

Falsification of system records or reports is considered gross inefficiency and incompetence under the Oklahoma Operator Certification Act and is punishable by loss of certification, a fine, a jail term or all three of these penalties combined. Federal penalties for falsification of records may reach up to one year in prison and $25,000 per violation.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – **Operation of Wastewater Treatment Plants Vol.2**

Chapter 14	Plant Safety and Good Housekeeping (especially sections 14.6 through 14.9)
Chapter 17	Applications of Computers for Plant O & M
Chapter 18	Analysis and Presentation of Data
Chapter 19	Records and Report Writing

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems Vol.2**

Chapter 12	Administration
Chapter 13	Organization for System Operation and Maintenance

Oklahoma Operator Certification Rules ***(Chapter 710)***
Discharges ***(Chapter 606)***
Water Pollution Control Facility Construction ***(Chapter 656)***
Rules for Oklahoma Hazard Communication Standard

OTHER STUDY SUGGESTIONS

If you have any questions concerning system requirements, contact the office that has been assigned to implement them or your county sanitarian for more information.

As you work, think about the various requirements placed on wastewater systems and why you believe they are considered necessary for proper operation.

Using any good management textbook, study the various theories of organization, management, planning, public relations, and human resource development.

STUDY QUESTIONS

Class D

You are unable to provide the laboratory data required for the MOR. You should:

A. write in the numbers you think that the regulatory officials want to see.
B. write in numbers based on the appearance of the effluent.
C. provide what accurate data you can and use the remarks column as needed.

Class C

The superintendent of a discharging system treating the wastes of 1000 persons must hold at least:

A. Class D certification.
B. Class C certification.
C. Class B certification.

Class B

BOD_5 testing was performed weekly for a total of four times in one month. The results of the tests and the flow measurements from the six-hour composite samples are shown below. What is the average loading and maximum loading of BOD in lbs/day to be reported on the DMR?

	BOD_5	Flow
Sample #1	22.2 mg/L	2.52 MGD
Sample #2	20.9 mg/L	2.55 MGD
Sample #3	23.1 mg/L	2.59 MGD
Sample #4	23.9 mg/L	2.54 MGD

A. The average loading is 479.1 lbs/day and the maximum loading is 506.3 lbs/day.
B. The average loading is 429.7 lbs/day and the maximum loading is 454.1 lbs/day.
C. The average loading is 479.1 lbs/day and the maximum loading is 1916.4 lbs/day.
D. The average loading is 429.7 lbs/day and the maximum loading is 1718.7 lbs/day.

Class A

Given the following BOD values, determine the mean, the median, and the mode.
BOD_5 results, mg/L: 230, 205, 280, 190, 215, 180, 160, 150, 170, 190, 205, 205, 195, 220

A. The mean is 200, the median is 205, and the mode is 280.
B. The mean is 205, the median is 195, and the mode is 190.
C. The mean is 200, the median is 205, and the mode is 280.
D. The mean is 200, the median is 195, and the mode is 205.

CHAPTER 4

Wastewater Collection Systems

Suggested Study Guidelines

Class D
Be prepared to answer questions concerning:

- The basic design and operation of wastewater collection systems.
- The required minimum and recommended maximum velocity of wastewater in the collection system and the reasons for these limits.
- The proper distances of separation between potable water lines and wastewater collection lines.
- Basic practices used when laying pipe, including pipe bedding and backfill requirements.
- The minimum size lateral line required under normal conditions.
- Typical problems with lines and types of repairs.
- General cleaning methods including flushing, rodding, and high velocity cleaners.
- The definitions of inflow, infiltration, rodding, cross connection, and galvanic corrosion.

Class C
Be prepared to answer questions concerning guidelines listed for Class D certification and:

- The basic design, operation, and maintenance of lift stations.
- Troubleshooting typical problems with lift stations.
- What types of pipe construction materials are resistant to corrosion.
- How to identify the cause of line stoppages.
- Which cleaning method to use for each type of stoppage.
- The preventive maintenance requirement/recommendations for collection lines.
- The regulations concerning collection systems including minimum soil cover, and the required placement of manholes.

Be prepared to answer other questions that require additional personal study.

Class B and Class A
Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

- How to develop a program for regular collection line cleaning and maintenance.
- The advantages and disadvantages of different types of lines.
- The recommended methods of achieving proper grades.
- How to calculate advance problems involving hydraulics, flow rates, line slopes, and dosages.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

Entry Level Discussion:

The first step in the treatment and disposal of wastewater is the collection system. This system consists of piping which is used to transport wastes to the treatment facility, manholes which provide access for cleaning, flushing and inspection, and lift stations which assist the gravity flow when a change in elevation occurs.

Components of the Collection System:

The different sections of the wastewater collection system each have specific roles to play. The **lateral sewer** or **gravity sewer** collects wastes only from sources such as houses or businesses. A **sub-main line** or **branch** sewer receives flow from two or more lateral lines. The **main line** receives flow from the sub-mains. The mains connect to the larger trunk sewers. The **trunk sewer** is the line that carries the collected wastes to the treatment plant. Throughout the collection system are **manholes** which are necessary for cleaning and inspection. Manholes might be constructed from brick, concrete block, pre-cast or poured concrete, or fiberglass materials.

Generally speaking, collection systems are gravity flow. As a result, each size (diameter) of pipe has a minimum slope which must be used to maintain proper velocities. If there is a change in the natural topography, or any other cause of preventing sufficient gravity flow, a **lift station** (pump station) is used to "lift" the wastewater, so it can continue along its way to the treatment plant.

Design capacity

Design sewers for the ultimate future population that may be served.
(1) Consider the maximum hourly domestic flow, industrial flow, inflow and infiltration and the topography regarding the slope and pumping needs.
(2) Design for an average daily per capita flow of 100 gpd, which includes normal infiltration. Peak design flow must be based on an acceptable infiltration/inflow (I/I) study or, for new sewer extensions, the ratio of peak to average daily flow from a widely recognized engineering standard.
(3) Exclude storm water from roof drains, streets and other areas.
DEQ 252:656-5-1. Design capacity

The national average of wastewater generated per person per day is about 70-100 gallons. Many factors may alter this "average" amount. Industry may contribute more flow depending on the nature of the business. Seasonal variations effect flow rates, with increases of as much as 30 percent during the summer months. People in warmer climates or in affluent communities tend to use more water. Also, in some communities, the higher cost of water may lower water usage.

In the early 1900s, the same piping system was used to collect storm water runoff and wastewater. This practice caused many serious problems, including the fact that treatment plants would lose treatment efficiency or be damaged by large flows after a storm. CURRENT STATE AND FEDERAL REGULATIONS PROHIBIT THE COMBINATION OF STORM SEWERS AND SANITARY SEWERS. The definitions of these two types of collection systems are listed below:

1. **Storm water collection systems** (sometimes called storm sewers) are specifically designed to carry the storm runoff from pavement and roof drains into drainage ditches.
2. **Wastewater collection systems** (often called sanitary sewers) carry domestic and industrial municipal wastes to the wastewater treatment plant.

Piping Materials Collection System

PIPES & PIPE COUPLINGS COLLECTION SYSTEM

Many different materials are used for distribution & collection system construction, including different types of piping used at different systems and situations. Each type of piping has advantages and disadvantages and serious consideration should be given before making decisions involving material selection.

One consideration when selecting piping is the C-factor of the pipe. The C-factor, also called the coefficient of roughness, is an indication of how much friction (slowing down of the flow) is caused by the pipe material itself. The higher the C-Factor, the smoother the inside of the pipe. Even when brand new, all piping materials have some roughness which resists water flow and causes a drop in pressure.

The pressure rating of a pipe is also an important consideration. The pipe must be adequate to handle the pressures that it may encounter in the system. Generally, only four classes of pressure ratings will be encountered - 100, 150, 200, and 250 psi (pounds per square inch). Pipes may rupture or be crushed when subjected to internal or external pressures that exceed its ratings. Another characteristic of pipe is the pipe schedule. The pipe schedule indicates the pipe's wall thickness. The higher the number, the thicker the wall.

Materials

- **ASTM.** All pipe, materials and construction must meet ASTM standards. List the standard for all materials and methods in the detailed specifications.
- **Bedding.** Specify the applicable ASTM material class of bedding, which must be matched to the proper strength pipe to support the anticipated loads.
- **Backfill.** Specify the applicable ASTM standard for the backfill material and its placement.
- **Manholes.** Specify the applicable ASTM standards for the manhole material, manhole installation, and manhole testing to be used in the construction of the manholes. Bricks and/or concrete blocks will not be approved for manhole construction.

DEQ 252:656-5-3. Materials

Construction standards:

(a) **Sewer.** Lay sewers in straight alignment with uniform grade between manholes. Protect all pipe from traffic load damage. Install metal tracer wire and color code all pipe constructed.

(b) **Trench.** The width of the trench must be ample to allow the pipe to be laid and joined properly and to allow the backfill to be placed and compacted as needed.
   (1) Trench sides must be kept as nearly vertical as possible. When wider trenches are dug, appropriate bedding class and pipe strength must be used.
   (2) Provide a minimum clearance of 4 inches between all pipe and any large stones, ledge rock, or boulders.
   (3) Except for ductile iron pipe, provide 30 inches of soil cover as protection from traffic load damage to the pipe. Specify the applicable ASTM standards for ductile iron pipe. DEQ 252:656-5-4. Construction standards

Gray Cast Iron Pipe (CIP):
Gray cast iron pipe (CIP) offers a long service life and is relatively strong. Its main disadvantage is the brittleness of the pipe. Where corrosive soils are a problem, the outside of cast iron pipe should be protected by encasing it in a sleeve of polyethylene plastic or by using standard cathodic protection methods. The interior of unlined cast iron pipe is subject to tuberculation (the pitting and growth of nodules), which reduces the inside diameter and increases the pipe roughness. Methods of preventing tuberculation include a cement or bituminous tar lining as well as reducing the corrosivity of the water. Flanged or mechanical joints are used to connect lengths of pipe. New installations are using bell and spigot push-on joints which provide a more watertight seal.

Ductile Iron Pipe (DIP):
Ductile iron pipe (DIP) is very malleable (easily worked) as compared to CIP and has roughly twice the strength. DIP is particularly useful for buried water lines exposed to heavy loads, shocks and unstable pipe bedding. Because of its strength it is sometimes used for transmission lines. Also, because of its strength, DIP is easier to install than CIP, and is easily drilled and tapped for service lines.
The disadvantage of DIP is similar to CIP in that it is subject to corrosion from both inside and outside often requiring preventative measures.

Steel Pipe:
Steel pipe has been in use in the United States since the mid-1800s and is still often used where pressures are high and large diameter pipe is required. Steel pipe is much stronger than CIP and is slightly stronger than DIP. In addition, it is somewhat lighter than iron pipe. It is relatively inexpensive, easy to install, and is easier to transport. Steel pipe is resistant to shock loads and is somewhat flexible. However, steel pipe will not withstand the external loads that iron pipe will. A negative pressure, or vacuum caused by rapidly emptying steel pipe could result in distortion or total collapse.

Corrosion of steel pipe can often be more severe than in iron pipe. In fact, special linings and coatings may be required to prevent the thin walls of steel pipe from corroding. Bitumastic enamel, a coal-tar material, is commonly used to coat steel pipe for corrosion control. Cement-mortar lining and epoxy lining may also be used for corrosion protection. Caution should be taken to prevent damage to the coatings. Small scars or chips in the coating will result in accelerated corrosion rates in the area of the damage.

Plastic Pipe
Plastic pipe is one of the most versatile types of pipe use in collection and distribution systems. Lateral and sub-main lines are especially common uses for plastic pipe because they are shallow. **Polyvinyl chloride** (PVC) is one of the most popular plastic pipes. Since PVC is non-metallic, it will not corrode from electrolysis or electrochemical action. Soil corrosion will also have very little effect on PVC. Therefore, corrosion resistant coatings, cathodic protection, and other corrosion protection devices are unnecessary. Plastic pipe is generally considered to be the piping material most resistant to corrosion. Another advantage of plastic pipe is that it is relatively light and is easily cut and assembled without the need for special tools.

Disadvantages of PVC include its relatively thin wall design, sometimes causing deflection in larger size pipe. Another drawback to plastic pipe is that ultraviolet rays will cause it to deteriorate. For this reason, plastic pipe should never be stored where it can come into direct contact with sunlight. If it is necessary to leave plastic pipe in an open trench for more than a few days, the pipe should be covered with a small amount of backfill or with black, heavy, plastic sheeting. Plastic pipe can also be damaged by rocks or other rough material if it is not properly bedded.
Finally, because of its composition, petroleum products will cause severe deterioration in plastic pipe. Therefore, it must be kept at a distance from gasoline storage tanks. The two joints used for PVC are solvent welds for smaller sizes (up to six inch diameter) and the rubber ring push-on joints for larger sizes.

ALL PLASTIC PIPING USED IN DISTRIBTUION SYSTEMS MUST HAVE THE NATIONAL SANITATION FOUNDATION (NSF) STAMP INDICATNG THAT IT IS APPROVED FOR USE WITH POTABLE WATER.

Reinforced Concrete Pipe (RCP):
Reinforced concrete pipe (RCP) has been widely used in wastewater systems since the turn of the century and is widely used for large distribution and transmission lines. RCP can be classified into tow general types: non-steel cylinder type and steel cylinder type.

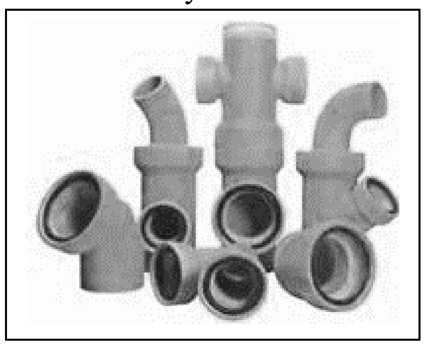
- NON-STEEL CYLINDER RCP-Non-steel cylinder RCP is constructed by forming from one to three cages of reinforcing steel. The cage(s) are then placed in a mold and are coated with concrete. This type of pipe is designed for low pressure applications. Because concrete is a somewhat porous material, non-steel cylinder RCP has a tendency to leak.

- STEEL CYLINDER RCP-Steel cylinder RCP, sometimes referred to as pressure pipe, is constructed with a steel cylinder lined with cement mortar. Wire is then wrapped around the structure and a mortar coating is added over it. This pipe is capable of being used in high pressure applications.

RCP is used in large lines due to its high compressive strength and capability of being used under high backfill loads. It is also a low maintenance pipe and is usually not subject to tuberculation, although corrosive water can harm it. Many types of specialized interior coatings are available to ensure water tightness and to prevent any tuberculation. Because of its composition, RCP is resistant to electrolysis and corrosive soil conditions. It is somewhat difficult to tap and may be hard to repair if damaged. Bell and spigot or push-on joints are used for connections.

Asbestos Cement Pipe (ACP):
Asbestos-cement pipe (ACP) was a relatively popular pipe material until people became concerned about breathing asbestos fibers. Because of this serious health concern, ACP is no longer being installed in distribution systems. It is very important for operators to take special care to avoid health hazards when working with any existing ACP in their system, especially if it is being cut or machined. Respirators must be worn whenever there is a possibility of inhaling airborne asbestos fibers.

Vitrified Clay Pipe (VCP):
Vitrified Clay Pipe (VCP) has been used in wastewater collection systems for over 100 years. It is made from a combination of clays and shales which is then fired. VCP is used in lateral lines, sub-mains, and trunk lines. Its main advantage is that it is not damaged by hydrogen sulfide gases. The main disadvantages of VCP is that it is very rigid. Therefore, proper and very even bedding and backfill must be maintained to prevent cracking. Bell and spigot joints with a rubber seal are used for connections.



Joints:

a. Packing and jointing materials used in the joints of pipe shall meet the latest standards of the AWWA.
b. Pipe having mechanical joints or slip-on joints with <u>rubber gaskets is preferred.</u>
c. Gaskets containing lead shall not be used.
d. Manufacturer approved transition joints shall be used between dissimilar piping materials.

<u>ELEVATION AND GRADE</u>
In years past, many sewer lines were laid on the premise that a quarter "bubble" was all that was needed for adequate fall. This method utilized a straight edge level or string level to determine the grade or "fall" of the sewer. Whenever possible, sewer lines are constructed, so that one end of the pipe is higher than the other so that gravity keeps the flow going downhill. If there is not enough fall, and the flow is too slow, less than 2 fps, then solids are settled in the line. If grade is too steep, the flow exceeds 10 fps and the flow is too fast. Fast flows scourge pipe and erodes lines.

Modern means of determining grade include surveyor's level and rod and or laser transits.

Design Standards:

Standard- Design and construct sewers with hydraulic slopes sufficient for obtaining a velocity of 2 fps (feet per second) or greater. Base the design on Manning's formula using an "n" value of 0.013. Gravity sewers shall not be smaller than 8-inch diameter, except those sewer lines meeting the requirements that can be found in DEQ 252:656-5-2. Design standards Subchapter (c) under **exceptions**.

Slope. The depth of flow and the slope of the conduit affects the velocity of a liquid flowing under gravity conditions. The following table gives minimum slopes for different sizes of pipe to meet the required flow velocity.

(1) 4" sewer: 1.00 feet/100 feet	(2) 6" sewer: 0.50 feet/100 feet
(3) 8" sewer: 0.40 feet/100 feet	(4) 10" sewer: 0.29 feet/100 feet
(5) 12" sewer: 0.22 feet/100 feet	(6) 14" sewer: 0.17 feet/100 feet
(7) 15" sewer: 0.15 feet/100 feet	(8) 16" sewer: 0.14 feet/100 feet

DEQ 252:656-5-2. Design standards

Procedure for surveying a sewer line is as follows:

1. Surveyor locates the level instrument at a location where backward and forward sightings can be made. Level the instrument.

2. The surveyor assistant holds the rod plumb on a point of known elevation called a benchmark.

3. The surveyor back sights the telescope of the surveyor's level on the rod. Record the distance on the rod that the cross hair is above the benchmark.

4. To determine the height of the instrument above the benchmark, add the distance sighted in the cross hairs to the benchmark. If referencing a manhole invert then add that depth for the total elevation. This may be referred to as station 0+00.

5. For the Fore Sight mark, move the rod and hold plumb on the foresight side of the level. Turn level telescope and sight on rod. Read distance on cross hair.

6. Ground level is Instrument height minus reading on rod. Upstream manhole invert elevation would be ground level minus manhole depth. This may be referred to as Station 1+00.

7. Sometimes when objects are in the way a secondary benchmark or turning mark has to be made.

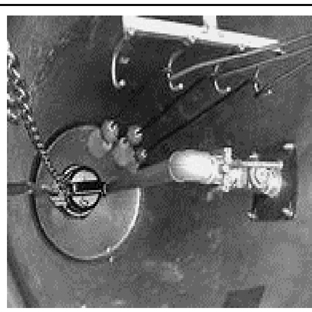
The **slope** of a sewer is defined as the rise over the run. In other words, the difference in height from Station 0+00 to Station 1+00 is divided by the distance. Many times this may be expressed as a percent slope. Multiply percent slope by 100 to get feet of fall per one hundred feet.

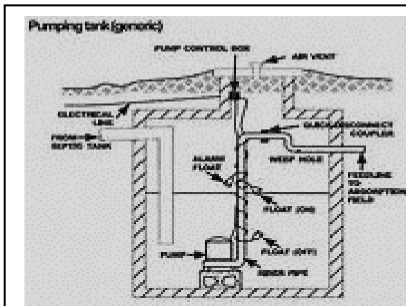
An example is when the station is 0+00, the stake elevation is 105.60, the invert grade is 100, and the cut is 5.60. At station 0+50 the stake elevation is 106.12, the invert grade is 100.25, and the cut is 5.87.

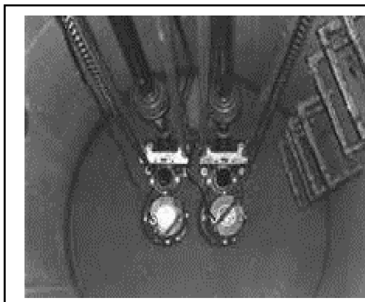
Manholes:
Manholes shall be installed at the end of each line, at all changes in grade, size, or alignment, at all intersections, and at distances not greater than 400 feet apart for sewers 15 inches in diameter or less, and 500 feet for sewers 18 to 30 inches in diameter. Greater spacing may be permitted in larger lines, those carrying a settled effluent or where adequate modern cleaning equipment for such spacing is provided.

- **Lampholes and cleanouts** shall not be substituted for manholes nor installed at the end of laterals longer than 250 feet.
- **Drop manhole.** A drop pipe is required for all sewer lines entering a manhole at an elevation of 24 inches or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, the invert must be filleted to prevent solids deposition. For drop pipes constructed outside the manhole, the entire outside drop connection must be encased in concrete. Drop pipes constructed inside the manhole, must be secured to the interior wall of the manhole and provide access for cleaning.
- **Diameter.** The minimum inside diameter of manholes shall be 48 inches with a conical section at top to receive a standard manhole ring and cover.
- **Bases.** Manhole bases must be at least 8 inches thick, with a diameter 8 inches more than the largest outside diameter of the manhole. Construct with leakproof joints between the base and manhole.
- **Inverted siphons.** Inverted siphons must have at least two barrels with a pipe size at least 6 inches in diameter. Provide necessary appurtenances for convenient flushing and maintenance. Construct manholes with adequate clearance for rodding the pipes. Provide sufficient head and select a pipe size for a velocity of at least 3.0 fps for average flows. Arrange the inlet and outlet details so normal flow is diverted to one barrel and either barrel may be taken out of service for cleaning. The vertical alignment must permit cleaning and maintenance.
- *DEQ 252:656-5-4 Construction standards*

<u>**Lift Stations: (Pump Stations)**</u>







At some points in the system, the waste has flowed by gravity to a low point. A **lift station** is installed to pump the wastewater up to an elevation where it may again flow by gravity. There are <u>**two**</u> types of lift stations: drywell and wet well installations:

1. **Drywell stations** have the pumps and controls housed in a separate dry compartment and the wastewater flows into a separate wet well. This type of station is better protected from corrosion and is easier to ventilate when checking controls, valves, and pumps.
   Two types of pumping systems are used in drywell stations: centrifugal pumps and, less commonly, pneumatic ejectors. Centrifugal pumps should be capable of passing objects up to three inches in size. A pneumatic ejector allows waste to flow into a large pot. When the liquid level in the pot reaches a set point, a solenoid opens and allows compressed air into the pot. The air displaces the wastewater up and out. Pneumatic ejectors work well in systems with flows less than 150 gpm.

2. **Wet wells** utilize one compartment with submersible pumps in the wet well or suction lift pumps above the wet well and enclosed in a housing or cover. Disadvantages of some wet well installations are difficult access to service pumps and difficulties in ventilating gases. If designed and constructed properly, the pumps should be easy to remove and replace without having to dewater the lift station. Submersible pumps used in wet wells must be especially designed for pumping raw wastewater. Wet well stations have the advantage of lower construction costs. Suction lift pumps are either self-priming or vacuum-priming. The pumping equipment compartment must be isolated from the wet well by being above or offset from it. These pumps are generally limited to a suction lift of 22 feet.

Regardless of which type of pumping system is used, there must always be a stand-by. All lift stations should include at least two pumping units to allow for maintenance and repair. In the case of the pneumatic ejector, in a drywell lift station, backup is provided by a stand-by air compressor.

Equipment accessibility and safety: Provide a suitable stairway or ladder for dry wells and for wet wells with bar screens or mechanical equipment. Adequate provision must be made to effectively protect maintenance personnel from hazards. Equipment for confined space entry in accordance with OSHA and regulatory agency requirements must be provided for all wastewater pumping stations.

Pump requirements are:

1. **Multiple units.** Provide at least two pumps. With any pump out of service, the remaining pump(s) must have the capacity to handle maximum sewage flows.
2. **Protect against clogging.** Pump stations with screening devices shall provide for the storage and disposal of the collected material. Provide a suitable bypass where screening is installed.

Ventilation:
Adequate ventilation shall be provided for all pump stations. Where the pump room is located below ground surface, mechanical ventilation is required. There shall be no interconnection between wet well and dry well ventilation systems. If the wet well must be entered to service mechanical equipment, forced ventilation is required, independent of dry well ventilation. Ventilation equipment switches shall be well marked and located at the entrance to the dry well.

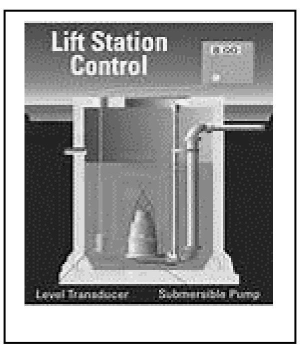
Intermittent operation ventilation systems shall be interconnected with the lighting system. The fan wheel(s) shall be fabricated from non-sparking material.

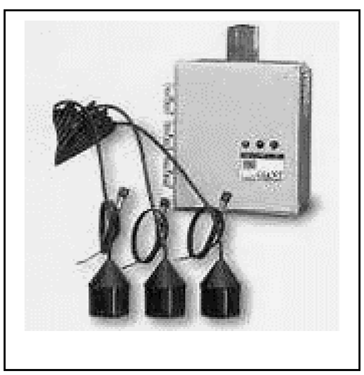
Wet wells- Ventilation may be either continuous or intermittent. Mechanical ventilation is required if screens or mechanical equipment requiring maintenance and/or inspection are located in a wet well. Continuous ventilation shall provide at least 12 complete air changes per hour. Intermittent ventilation shall provide at least 30 complete air changes per hour. Air shall be forced into, rather than exhausted from, the wet well. Wet wells not designed for access shall have provision for air displacement to the atmosphere. The top of the pumping station shall be located higher than the 100-year flood.

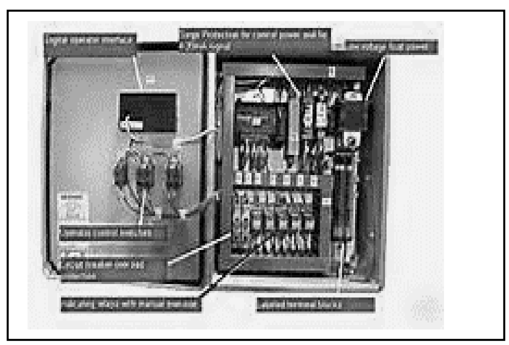
Dry wells- Provide adequate ventilation for all dry wells. Ventilation may be either continuous or intermittent. Continuous ventilation shall provide at least six complete air changes per hour; intermittent ventilation shall provide at least 30 complete air changes per hour. Ventilation equipment switches shall be marked and located at the entrance to the dry well.
DEQ 252:656-7-1 pump station design & standards

<u>Lift Station Control Systems</u>:
Alarm systems are required for all lift stations to report any malfunction that might allow a bypass (an unpermitted discharge) of wastewater to occur. All lift stations will also include backup methods to prevent an overflow or bypass. These methods include the use of holding ponds, portable pumps, or emergency generators.

The control system of the lift station should start and stop the pumps at pre-set levels. Failure of the control systems will burn up the pump motors, cause wastewater to back up in the collection system and/or cause a bypass. Pump performance can be monitored by taking regularly spaced kilowatt readings. Unusual readings may indicate the need for maintenance.







The controls may work off pressure (air bubblers), encapsulated floats, or by flow measurement. The pressure system requires an air compressor, storage tank, pressure regulator, and bubbler tube. The pressure is created against the compressed air flow in the bubbler tube when the water rises in the tube as wastewater fills the wet well. When the pressure <u>reaches</u> a pre-set point, the pump kicks on. When the pressure <u>drops</u> to a pre-set point, the pump shuts off. **Floats** are suspended in the wet well. When the wastewater touches a point on the float, the float tips and activates a mercury switch inside the float. A bottom float will shut the pump off. Scum is a problem with most water level controls that operate pumps and it must be removed on a regular basis.

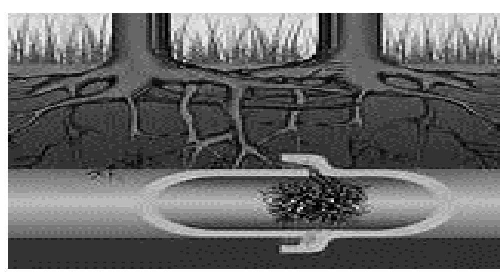
Emergency operation:
Design- Design pumping stations to prevent bypassing of raw sewage during periods of power outage or mechanical failure. The pumping station must meet one of the following design conditions:

1. An on-site standby generator with automatic means of activation in the event of a power failure.
2. A portable engine-driven pump with a quick connection to the force main; four hours of emergency storage at the average design flow above the alarm level, and telemetry to the city office during working hours and to the home of the person(s) in responsible charge of the lift station during off-duty hours.
3. 24 hours of emergency storage at the average design flow above the alarm level with an audio/visual alarm system.
4. An on-site engine-driven pump with one hour of emergency storage at design flow above the alarm level and an automatic means of activation, or
5. A portable engine-driven generator with four (4) hours of emergency storage at the design flow above the alarm level, a telemetry alarm system that communicates to the person in charge of the lift station, and a transfer switch with electrical system components that comply with the National Electrical Code requirements that is pre-wired to allow for a ready connection between the lift station and the portable generator.

   252:656-7-4. Emergency operation

<u>Preventing Stoppages:</u>
Stoppages are a major problem in the collection system. Routine preventive maintenance including proper construction practices can eliminate most stoppages from ever developing. In fact, some operators claim that as many 85% of these problems can be avoided by a good preventive maintenance program. Even when there is not a complete stoppage, poor construction will result in less flow capacity and lower velocity. This can lead to settling of solids and septic (anaerobic) conditions causing undesirable odors and the formation of toxic gases.
Industries can sometimes cause stoppages by overloading the system with **grease.** A strong pretreatment enforcement program can be effective in reducing these types of stoppages. Another cause of stoppages are **rags** or other large materials. **Roots** are probably the single most common cause of stoppages in collection systems.

<u>Removing and Preventing Roots in Lines:</u>
The best way to control roots is to install sewer lines that don't leak. Modern pipe materials can be installed without leaks so roots can't enter a sewer line. In older sections of the collection system where there is a potential for root intrusion several methods are sometimes used. Some of these methods include:



1. Clearing roots from the sewer using rodding equipment with a cutting tool attached. Rodding is a method of opening a blocked pipe by pushing or pulling a steel rod through a pipe. It should be kept in mind that every time a root is cut, it will add new growth and increase in diameter which can break the pipe or open the joint even more.

2. Using root control chemicals. Root control using chemicals is not as fast as removing roots by cutting them off by a rodder, but it is more permanent. Use of chemicals must be very carefully researched and planned to avoid danger to the environment, the treatment plant, or the operator. With proper chemicals and application, root control is a very desirable cost effective preventative maintenance program and can control roots in a sewer for as long as five years.

3. Removing roots and then using internal sealing techniques such as grout sealing. Internal sealing is one of the most widely used methods of rehabilitating old collection systems. Internal sealing is effective when the sewer line to be repaired is in an area that is unsuitable for excavation and has leaking joints, cracks, or small holes.

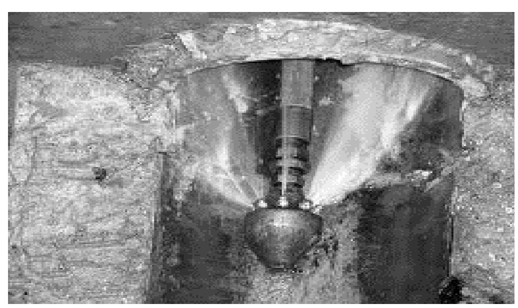
4. Inserting a liner in the collection line. This method is normally used only on sections of lines with very few or no service connections.

5. Eliminating deep rooted trees and not allowing trees to be planted over wastewater collection lines. Poor construction practices can also allow **solids** in the wastewater to settle out or let **sand** and other materials to enter and stop up the collection system. Examples of poor construction in collection systems include flat or below grade sections, misaligned joints, collapsed lines, and illegal traps.

General Cleaning Methods:

Preventing and clearing stoppages can be performed by either hydraulic or mechanical methods. Both methods should be used to help maintain the collection system in good working condition and to help reduce odors.

Hydraulic cleaning methods are methods that use water under pressure to produce high velocities that will wash most grit, grease, and debris through the sewer line, and leave the pipe clean. One type of hydraulic cleaning equipment used is a "jet cleaner" or "jet rodder." This instrument uses jets of high velocity water sprayed into wastewater collection lines through a nozzle at the end of a hose.



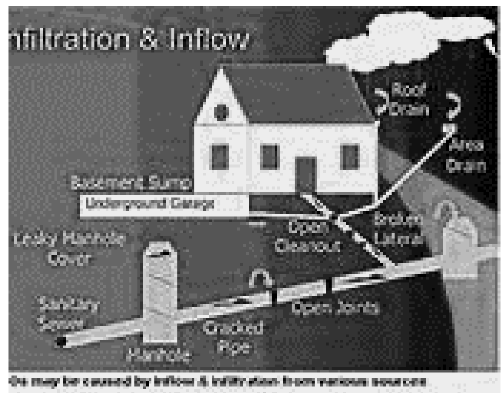
Another type of hydraulic cleaning method is to use a ball or other device with a large volume of water behind it to push it along. The volume of water creates a flushing action as it picks up velocity when it moves around the ball. The ball bounces and rotates in the flow which further breaks loose debris.

Simply flushing with large amounts of water is the easiest, but the least effective hydraulic cleaning method. This may break loose some of the debris, but often it merely moves it to the next bend in the line. This can work if the debris can be caught at the next manhole.

Mechanical cleaning methods use equipment that scrapes, cuts, pulls, or pushes the material out of the pipe. Mechanical cleaning equipment includes power rodders and hand rods. Special machines and winches are sometimes used for pulling buckets or scrapers through a line. Mechanical devices are more effective at clearing than at cleaning and the sewers sometimes still have to be flushed after being cleared.

Before clearing a large stoppage that may have gone septic (anaerobic), the operator should notify the treatment plant downstream. When a large volume of septic wastewater reaches the treatment plant without special preparations being made to minimize the impact, the plant operation could become "upset" and fail to perform adequately.

Common Problems in Collection Systems:



Inflow is water that flows into a wastewater collection system. Inflow is usually caused by holes in manhole covers, yard drains connected to the wastewater collection system, and other cross connections with storm water systems.

Infiltration refers to the ground water that has entered a wastewater collection system through defective pipes, pipe joints, connections or manhole walls. Both inflow and infiltration, abbreviated "**I & I**" are considered undesirable because of the added hydraulic load placed on the system and the plant.

Exfiltration is wastewater that is similarly leaking out of a collection system and into the environment.

Smoke testing is a common method used to discover sources of "I & I." This method can be very effective in finding cross connections and "holes" in the system. However, it should NEVER be performed without advance public notification, and the assistance of a specially trained and experienced smoke testing crew.

A **cross connection** is the connection between a potable (drinking) water supply and water from an unsafe or unknown source. This term is also used to describe a connection between a wastewater collection system and a storm water system. The best prevention of all cross connections is an **air gap**. A good "rule of thumb" is to provide a gap at least two times the width of the inside diameter of the discharge pipe.

A **bypass** or **unpermitted discharge** is any discharge from a collection system or wastewater treatment facility other than exactly what was allowed in the NPDES discharge permit. One example of an unpermitted discharge occurring in the collection system is when a manhole overflows due to a line stoppage or high inflow. ALL UNPERMITTED DISCHARGES MUST BE PROPERLY REPORTED.

State Construction Standards:
According to Oklahoma standards, all wastewater lines must be laid to provide a **minimum horizontal separation** of 10 feet from any existing or proposed water line and a **minimum vertical separation** of 24 inches (two feet) from the outside of the collection line to the outside of the water line. If it is impossible to obtain the minimum vertical or horizontal separations, the sewers must be constructed of special pipe and pressure tested to the highest pressure under the most severe head (pressure) conditions of the collection systems. Leakage test for newly constructed sewer lines (PVC pipe) must not exceed 10 gallons/inch of pipe diameter/mile/day. Wastewater lines must also be located a minimum of 50 feet horizontally from all petroleum storage tanks or any existing or proposed water well and a minimum of 10 feet horizontally from all other utilities.

Gravity sewer lines should never be less than eight inches in diameter except that six inches may be used where the run of the line is less than 400 feet. In order to help prevent seepage at the joints, lines should be laid with the bell pointing upgrade. To prevent freezing, a **minimum earth cover** of 30 inches is required for all collection lines constructed of any material other than cast/ductile iron.

State standards require that bedding materials meeting specific standards must be used below the pipe to support the anticipated load. Select **backfill material**, free of large clods or stones or other unstable material must be used for the first 24 inches (two feet) of backfill above the pipe.

The required **minimum velocity** of wastewater in collection lines is two feet per second (fps). The recommended **maximum velocity** in sewer lines is 10 fps. When velocities exceed 10 fps, special provisions must be made to prevent movement and damage of the pipes. **Manholes** should be installed at the end of each line, and at all changes in grade, size, or alignment. They must also be installed at all intersections or at distances no greater than every 400 feet for lines with a diameter of 15 inches or less and every 500 feet for lines 18 to 30 inches in diameter. Remember, the purpose of manholes is to provide easy access to the collection system for inspection and maintenance.

All collection system maps should show the system "**as built**." This means that whenever there is any change whatsoever in the original construction plans, the maps should be updated to clearly reflect these changes.

Special Safety Considerations
Probably the two most likely causes of serious injury or death to collection system workers are contact with dangerous gases and trench cave-ins. Chapter 6 of this study guide provides a brief introduction to these, and some of the other many potential dangers present in the collection system as well as basic guidelines on how to avoid these dangers. However, additional study and on-the-job training (OJT), in conjunction with strict obedience to all safety-related requirements, is absolutely essential to reduce the chances of injury or death among collection system workers.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems–Vol. 1**

Chapter 3	Wastewater Collection System (Purpose, Components and Design)
Chapter 4	Safe Procedures
Chapter 5	Inspecting and Testing Collection Systems
Chapter 6	Pipeline Cleaning and Maintenance Methods (especially sections 6.1, 6.3)
Chapter 7	Underground Repair

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems–Vol. 2**

Chapter 8	Lift Stations
Chapter 9	Equipment Maintenance
Chapter 11	Safety Program for Collection System Operators

Reference Handbook: Basic Science Concepts and Applicati*ons (American Water Works Assn.)*
Hydraulics Section

OTHER STUDY SUGGESTIONS

Through personal observation and study, be familiar with:
- Grades and positioning of lines.
- Materials used in construction and proper manhole construction.
- Service connection details.
- The operation of rodding machines and high velocity cleaners.

Be able to draw or study the diagram of a typical wastewater system lift station.
Refer to a troubleshooting chart for lift stations for information on typical problems.
Pay special attention to any detailed information that you can obtain on procedures for dealing with collection system safety problems and observe a crew to see what safety procedures are followed.

SAMPLE QUESTIONS

Class D

The minimum horizontal separation required between wastewater collection lines and drinking water lines is:

A. 2 feet.
B. 5 feet.
C. 10 feet.

Class C

Probably the easiest but least effective means of cleaning lines is:

A. using a “ball” or “pig.”
B. flushing with large volumes of water.
C. use of power rodding equipment.

Class B

A 24 inch collection line from town to the plant is 3 miles long. Assuming the flow velocity is the minimum allowed by Oklahoma law, what is the approximate time it will take the wastewater to reach the plant?

A. 4.5 hrs
B. 2.2 hrs
C. 1.6 hrs
D. 10 hrs

Class A

When performing a closed circuit television inspection (CCTV) between two adjacent manholes, the camera:

A. should never be pulled in the direction of flow.
B. should always be pulled in the direction of flow except in some cases involving new lines or very small flows.
C. should always be pulled in the direction of flow unless the sewer lines have been cleaned prior to televising.
D. should always be pulled in the direction of flow.

Chapter 5

Maintenance

INTRODUCTION TO CHAPTER 5

Maintenance procedures will vary for different pieces of equipment found at different systems. Therefore, questions regarding details of specific maintenance procedures are not asked on certification exams. Although you will not need to know specific procedures for exams, they must be understood by operators actually working with the equipment. On-the-job training (OJT) is essential for learning this information.

Questions of a general nature regarding the basic operation and maintenance of common pieces of equipment will be found on certification exams.

Suggested Study Guidelines

Class D

Be prepared to answer questions concerning:

- The importance and the basic aspects of a good preventive maintenance program.
- The names and purposes of the two types of maintenance cards that are kept for equipment.
- What information should be recorded for each piece of equipment?
- Where to find the most complete information on maintenance for a piece of equipment.
- The condition under which centrifugal pumps should never be operated.
- The condition under which reciprocating pumps should never be operated.

Know the special safety considerations when working around electrical or mechanical equipment.

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- How centrifugal and reciprocating pumps operate including starting, stopping, and valve control.
- How to identify typical problems with pumps (troubleshooting).
- The basic routine and preventive maintenance for pumps including:
    - Inspection (what to look and listen for)
    - Packing and seals
    - Lubrication
    - Replaceable parts
- The basic routine and preventive maintenance for motors including:
    - lubrication
    - ventilation
    - bearing and motor temperature
    - amperage measurement
    - controls and wiring (including how much you should do)
- The basic procedure for proper alignment and maintenance of couplings and power drives.

How to develop a comprehensive maintenance recordkeeping system that will provide information to protect equipment warranties

How to perform calculations involving volume and pumping rates

Be prepared to answer other questions that require additional personal study

Class B and Class A

Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

The descriptions, operating characteristics, and applications for the following types of pumps

- submersible pumps
- jet lift pumps
- progressive cavity pumps
- screw pumps

The types and applications of coupling and power drives

The basic descriptions and operating principles of the following controls

- control panel (diagram of simple panel)
- mercury float
- probes
- bubbler

Be prepared to answer other questions that require a combination of actual experience and additional personal study

ENTRY LEVEL DISCUSSION:

A treatment plant operator has many duties. Most of them are designed to make sure that the plant as well as all other areas, (collection systems, lift stations, manholes, etc.) of the system are able to run as efficiently as possible.

A successful maintenance program is essential for a wastewater treatment plant and system to operate continuously. This plan will cover everything from mechanical equipment, such as pumps, valves, scrapers, motors, plant grounds, buildings and structures.

For a successful maintenance program, your supervisors must understand the need for, and benefits of, equipment which operates continuously as intended. Disabled or improperly working equipment is a threat to the quality of the plant effluent, and repair costs for poorly maintained equipment usually exceed the cost of proper maintenance.

Mechanical maintenance is of prime importance as the equipment must be kept in good operating condition in order for the plant to maintain peak performance. Manufacturers provide information on the mechanical maintenance of their equipment. You should thoroughly read their literature on your plant equipment and understand the procedures. Contact the manufacturer or the local representative if you have any questions. Follow the instructions very carefully when performing maintenance on equipment. You also must recognize tasks that may be beyond your capabilities or repair facilities, and you should request assistance when needed

Preventive Maintenance Records:
Preventative programs help operating personnel keep equipment in satisfactory operating condition and aid in detecting and correcting malfunctions before they develop into major problems.

A frequent occurrence in a preventative maintenance program is the failure of the operator to record the work after it is completed. When this happens, the operator must rely on memory to know when to perform each preventive maintenance function. As days pass into weeks and months, the preventative maintenance program is lost in the turmoil of everyday operations.

The only way an operator can keep track of a preventive maintenance program is by **good recordkeeping**. Whatever record system is used, it should be kept up to date on a daily basis and not left to memory for some other time. Equipment service cards are easy to set up and require little time to keep up to date.

Equipment Service Card:
An **equipment service card** should be prepared for each piece of equipment in the plant and collection system. Each card should have the name of the piece of equipment clearly written on it, such as "Sludge Pump No.1, Primary Clarifier." In addition, each card should include the following information:

1. List each required maintenance service with an item number.

2. List maintenance services in order of frequency of performance. For instance, daily service might be shown as items #1, #2, and #3 on the card; weekly items as #4 and #5; monthly items as #6, #7, #8, and #9, and so on.

3. Describe each type of service to be performed.

Make sure all necessary inspections and services are shown. Specific references should be listed for each of the items. The frequency of service and the day or month that service is due should also be listed for each item. Service card information may be changed to fit the needs of your plant or particular equipment as recommended by the equipment manufacturer. Make sure the information on the cards is complete and correct.

The *equipment service card* tells what should be done and when to do it.

Service Record Card:
The **service record card** should have the date and work done, listed by item number and signed by the operator who performed the service. Some operators prefer to keep both cards clipped together, while others place the service record card near the equipment.

When the service record card is filled, it should be filed for future reference and a new card attached to the equipment service card.

The *service record card* is a record of what you did and when you did it.

In addition to the use of service cards for scheduling and tracking maintenance procedures, many systems now use computer programs that have been created especially for this purpose.

EXAMPLE OF EQUIPMENT SERVICE CARD

EQUIPMENT SERVICE CARD				
EQUIPMENT: #1 Raw Wastewater Lift Pump				
Item No.	**Work To Be Done**	**Reference**	**Frequency**	**Time**
1	Check water seal and packing gland	Par. 1	Daily	
2	Operate pump alternately	Par. 1	Weekly	Mon.
3	Inspect pump assembly	Par. 1	Weekly	Wed.
4	Inspect and lube bearings	Par. 1	Quarterly	1-4-7-10
5	Check operating temperature of bearings	Par. 1	Quarterly	1-4-7-10
6	Check alignment of pump and motor	Par. 1	Semiannually	4 & 10
7	Inspect and service pump	Par. 1	Semiannually	4 & 10
8	Drain pump before shutdown			

EXAMPLE OF SERVICE RECORD CARD

SERVICE RECORD CARD						
EQUIPMENT: #1 Raw Wastewater Lift Pump						
Date	Work Done (Item No.)	Signed		Date	Work Done (Item No.)	Signed
01/05/2014	1 & 2	MJ				
01/06/2014	1	JS				
01/07/2014	1-3-4-5	KK				

Other Maintenance Records:
All of the information on the nameplate of a piece of equipment including the serial and/or model numbers should be recorded and placed in a file for future reference. Many times the nameplate is painted, corroded, or missing from the unit when the information is needed to repair the equipment or replace parts. The date of installation and service startup for each piece of equipment should be logged and filed. A parts inventory is also essential for key pieces of equipment. As is an established SOP for each task.

Buildings:
Building maintenance programs depend on the age, type, and use of a building. New buildings require a thorough check to be certain essential items are available and working properly. Older buildings require careful watching and prompt attention to keep ahead of leaks, breakdowns, replacements, and changing uses of the building. Attention must be given to the maintenance requirements of many items in all plant buildings. For safety's sake, periodically check all stairways, ladders, catwalks, and platforms for adequate lighting, head clearance, and sturdy and convenient guardrails. Protective devices should be around all moving equipment. Whenever any repairs, alterations, or additions are being built, avoid building accident traps such as pipes laid on top of floors or hung from the ceiling at head height, which could create serious safety hazards.

Organized storage areas should be provided and maintained in an accessible and neat manner.

All tools and plant equipment should be kept clean and in their proper place. Floors, walls and windows should be cleaned at regular intervals. A treatment plant kept in a neat, orderly condition makes a safe place to work and aids in building good public and employee relations.

Plant Grounds:
Plant grounds that are well groomed and kept in a neat condition will greatly add to the overall appearance of the plant area. Well-groomed and neat grounds are important because many people judge the ability of the operator and the plant performance on the basis of the appearance of the plant. Management, also, tends to view well-kept grounds as evidence of an operator's ability and competence.

Control rodents and insects so they will not spread diseases or cause nuisances.

For the convenience of visitors and new operators, signs directing people to the plant, pointing the way to different plant facilities, identifying plant buildings, and indicating the direction of flow and contents flowing in a pipe can all be very helpful. Take pride in your plant grounds and you will be amazed at the favorable impression your facility will convey to the public and administrators.

Plant Tanks and Channels:
Plant tanks and channels such as grit chambers and wet wells should be drained and inspected at least once a year. Be sure that the groundwater level is down far enough so the tanks will not float on the groundwater when empty or develop cracks from groundwater pressure. Some are equipped with relief valves to prevent these developments from happening.

Schedule inspections of tanks and channels during periods of low flow. Route flows through alternate units, if available, otherwise, provide the best possible treatment with remaining units not being inspected or repaired.

Digesters should also be drained and cleaned about once every five years (actual times range from three to eight years). By measuring the depth of the sand and grit in digesters, you can determine how fast this build-up is accumulating.

All metal and concrete surfaces that come in contact with wastewater and covered surfaces exposed to fumes should have a good protective coating to prevent corrosion. The coating should be reapplied where necessary at each inspection. On surfaces where the protective coatings are flaking off, it is necessary to sand blast the entire surface before new coatings are applied. Usually two or more coats are needed for proper protection.

Periodic drainage, inspection, and repair of tanks and channels is essential. Select a time for maintenance when you can minimize the discharge of harmful wastes to receiving waters. Schedule as many concurrent events as possible during a shutdown to minimize the time that the plant or parts of the plant must be taken out of service.

Mechanical Equipment:
THIS DISCUSSION SHOULD NOT BE CONSIDERED A SOURCE OF TECHNICAL INFORMATION FOR ACTUAL OPERATION AND MAINTENANCE PROCEDURES. IT SHOULD BE USED ONLY AS A BRIEF INTRODUCTION OR REVIEW OF GENERAL INFORAMTION.

The first step for any type of mechanical equipment maintenance is to get the manufacturer's instruction book and read it completely. Each piece of equipment is different and the particular manufacturer will provide its recommended maintenance schedules and procedures. If you do not have an instruction booklet, you might obtain one by contacting the manufacturer's representative in your area.

Pumps:
Pumps serve many purposes in wastewater collection systems and treatment plants. They may be classified by the character of the material handled: raw wastewater, grit, effluent, activated sludge, raw sludge, or digested sludge, or, they may relate to the conditions of pumping: high lift, low lift, recirculation, or high capacity. They may be further classified by principle of operation, such as centrifugal, propeller, reciprocating, and turbine.

Pumps are rated by the flow they produce and the pressure they must work against. Centrifugal pumps are used for high flow and low head pressure applications. Booster pumps or primary service pumps are required to move high volumes of water and usually operated at low head pressures (200-300 feet of head for water and as little as 50 feet of head for wastewater applications). Centrifugal pumps are ideally suited to these types of applications and are much more efficient than positive displacement pumps of comparable size. Positive displacement pumps are used for low flow and high-pressure applications. High pressure water jet systems like those used for well screen or sewer line cleaning use positive displacement pumps since pressure in excess of 2500 feet of head are needed and the flows seldom exceed 100 gpm. Sludge pumps and chemical feed pumps are also likely to be positive displacement pumps. Piston pumps, diaphragm pumps, and progressive cavity screw pumps are the most common types of positive displacement pumps.

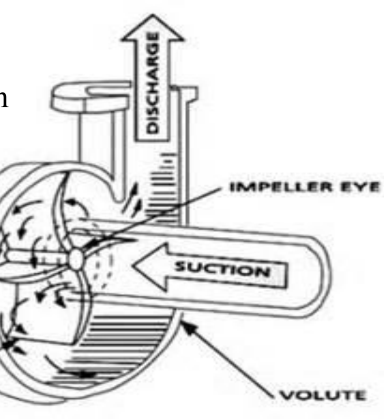
The type of material to be handled and the function or required performance of the pump vary so widely, the design engineer must use great care in preparing specifications for the pump and its controls. *Similarly, the operator must conduct a maintenance and management program adapted to the particular characteristics of the equipment.*

Two basic categories of pumps are used in wastewater operation: velocity pumps and positive-displacement pumps. Velocity pumps, which include centrifugal and vertical turbine pumps, are used for most wastewater distribution system applications. Positive-displacement pumps which include reciprocating and piston pumps are most commonly used in wastewater treatment plants for chemical metering.

TYPE OF PUMP	PRESSURE/FLOW RATING	CHARACTERISTICS
Centrifugal	Low Pressure/High Flow	Flow changes when pressure changes
Positive-Displacement	High Pressure/Low Flow	Flow doesn't change when pressure changes

Centrifugal Pumps
A centrifugal pump moves water by the use of centrifugal force. Any time an object moves in a circular motion, there is a force exerted against the object in the direction opposite the center of the circle. This would be easier to explain if we use an example consisting of a person with a bucket full of water. If the person swings the bucket in a circle fast enough, the water will stay in the bucket even when it is upside down. The force that holds the water in the bucket is called centrifugal force. If a hole is made in the bottom of the bucket, and it is swung in a circular motion, the centrifugal force will push the water out of the bucket through the hole. The same principle applies when water is moved through a centrifugal pump.

An impeller spins inside a centrifugal pump. It is the heart of the pump. Water enters the center, or suction eye, of the impeller. As the impeller rotates, the veins pick up the water and sling it out into the pump body under pressure. It is the pressure exerted by the vanes that moves the water out of the pump and into the system. The suction created as the water leaves the impeller draws more water into the impeller through the suction eye.



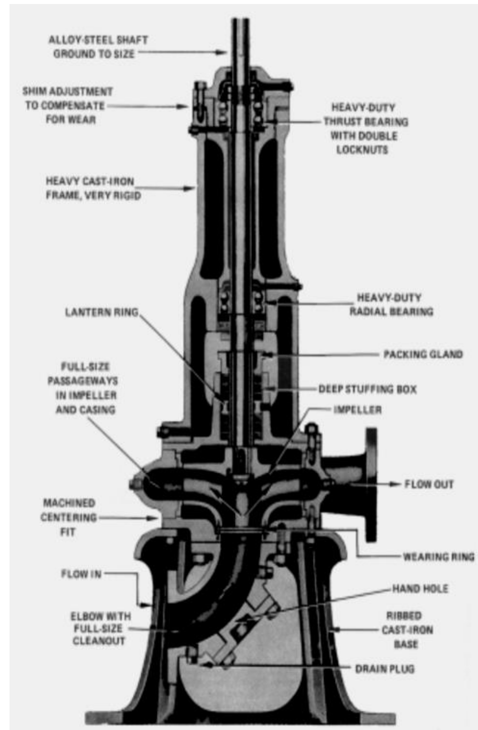
Centrifugal Pump Cross-section

Centrifugal pumps designed for pumping wastewater usually have smooth channels and impellers with large openings to prevent clogging. Impellers may be of the open or closed type. Submersible pumps usually have open impellers and are frequently used to pump wastewater from wet wells in lift stations.

Centrifugal pumps cannot operate unless the impeller is submerged in water. Therefore, they should NEVER be started until they are properly primed.

Propeller Pumps

There are two basic types of propeller pumps, axial-flow and mixed-flow impellers. The axial-flow propeller pump is one having a flow parallel to the axis of the impeller. The mixed-flow propeller pump is one having a flow that is both axial and radial to the impeller.

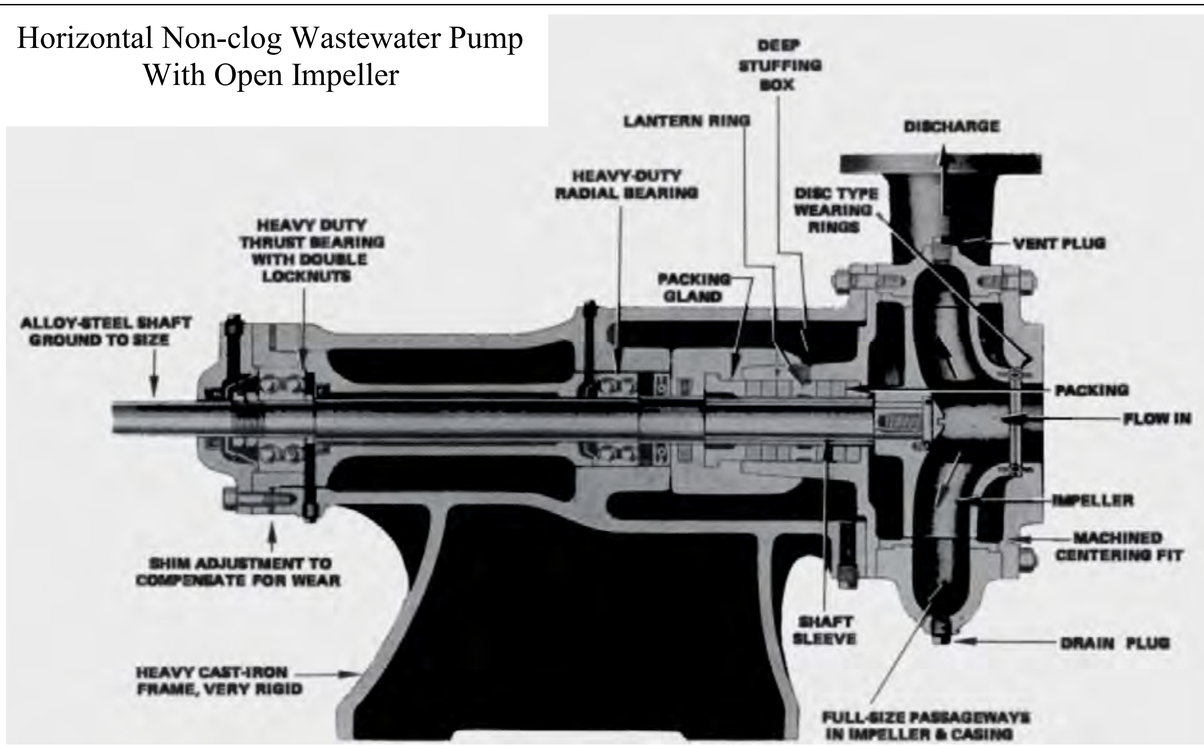


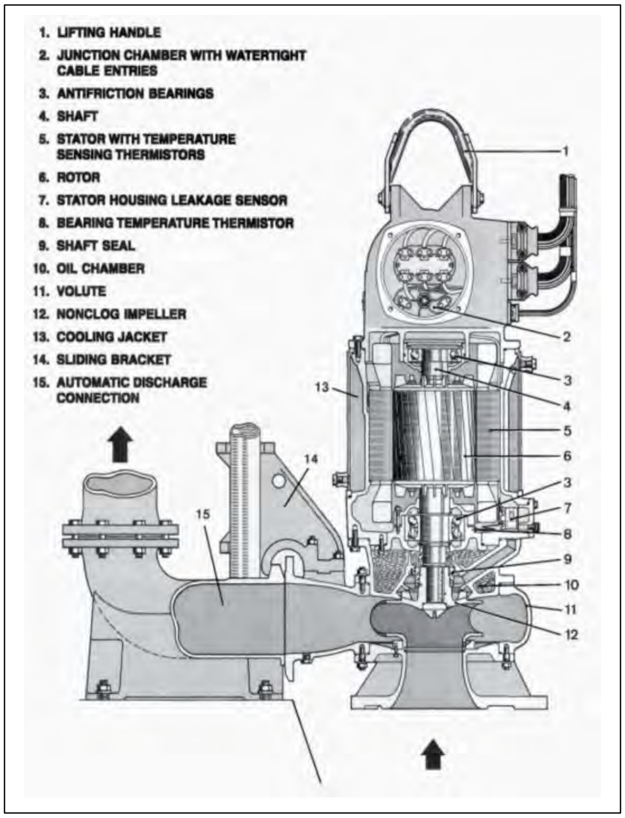
Vertical Ball Bearing Type Wastewater pump

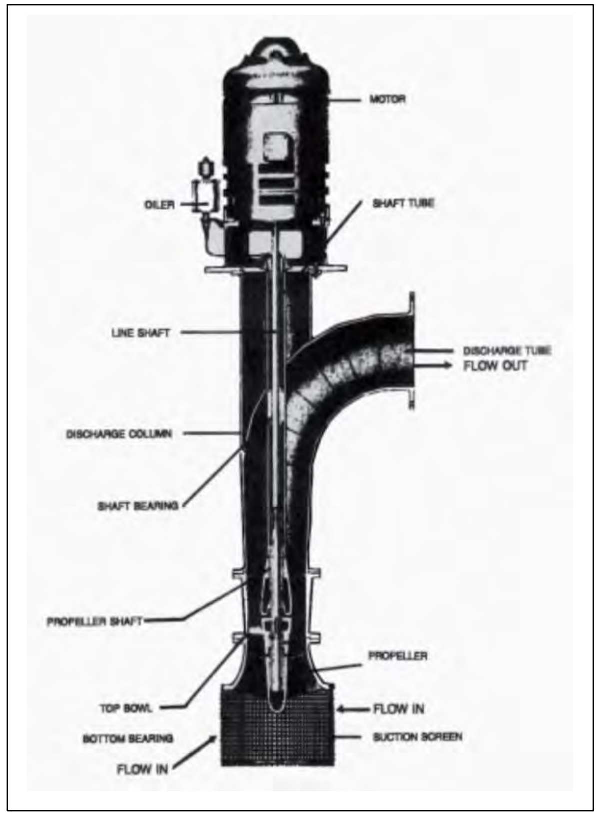
Vertical Wet Well Pumps

A vertical wet well pump is a vertical shaft, diffuser type centrifugal pump with the pumping element suspended from the discharge piping. The needs of a given installation determine the length of discharge column. The pumping bowl assembly may connect directly to the discharge head for shallow sumps, or may be suspended several hundred feet for raising water from wells. Vertical turbine centrifugal pump consists of multiple impellers that are staged on a vertical shaft. The impellers are designed to bring water in the bottom and discharge it out the top. This results in axial flow as water is discharged up through the column pipe. Staging the impellers in these pumps can create very high discharge pressures, since the pressure increases as the water moves through each stage.

Horizontal Non-clog Wastewater Pump
With Open Impeller







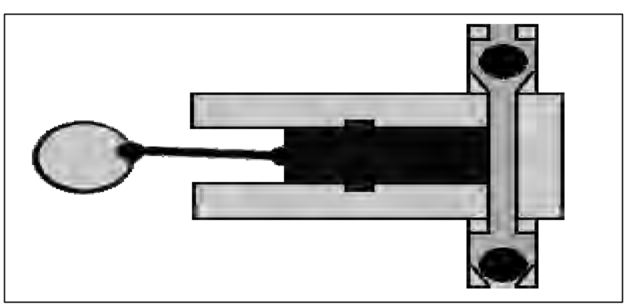
Submersible Wastewater Pump **Propeller Pump**

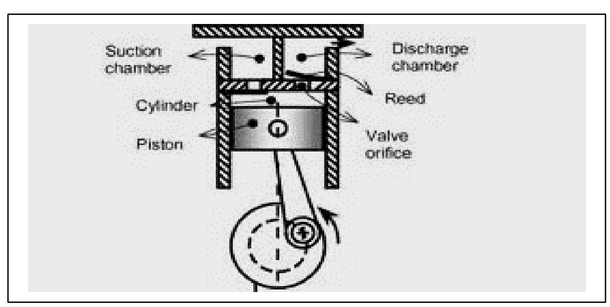
POSITIVE DISPLACEMENT PUMPS

Reciprocating OR Piston Pumps:

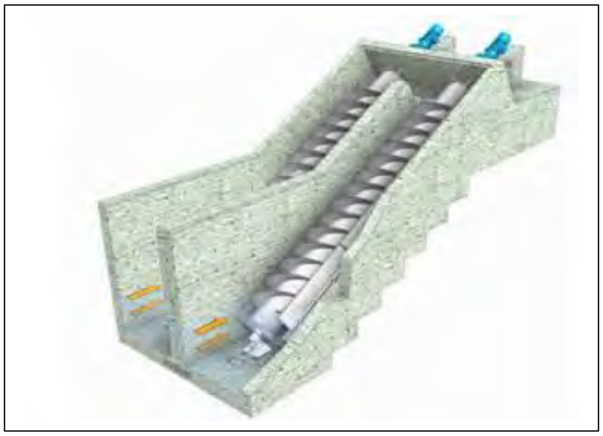
The word "reciprocating" means moving back and forth, so a reciprocating pump is one that moves water or sludge by a piston that moves back and forth. A simple reciprocating pump is shown below. If the piston is pulled to the left, check valve A will be open and sludge will enter the pump and fill the casing. When the piston reaches the end of its travel to the left, and is pushed back to the right, Check Valve A will close, Check Valve B will open, and wastewater will be forced out the exit line.

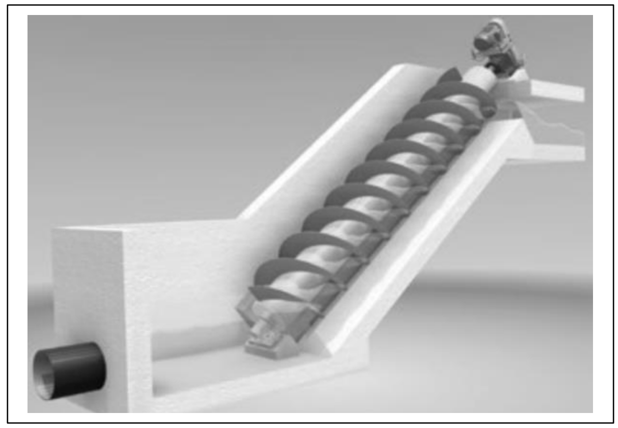
A reciprocating or piston pump is a positive-displacement pump. Never operate it against a closed discharge valve or the pump, valve, and/or pipe could be damaged by excessive pressures. Also, the suction valve should be open when the pump is started. Otherwise an excessive suction or vacuum could develop and cause problems





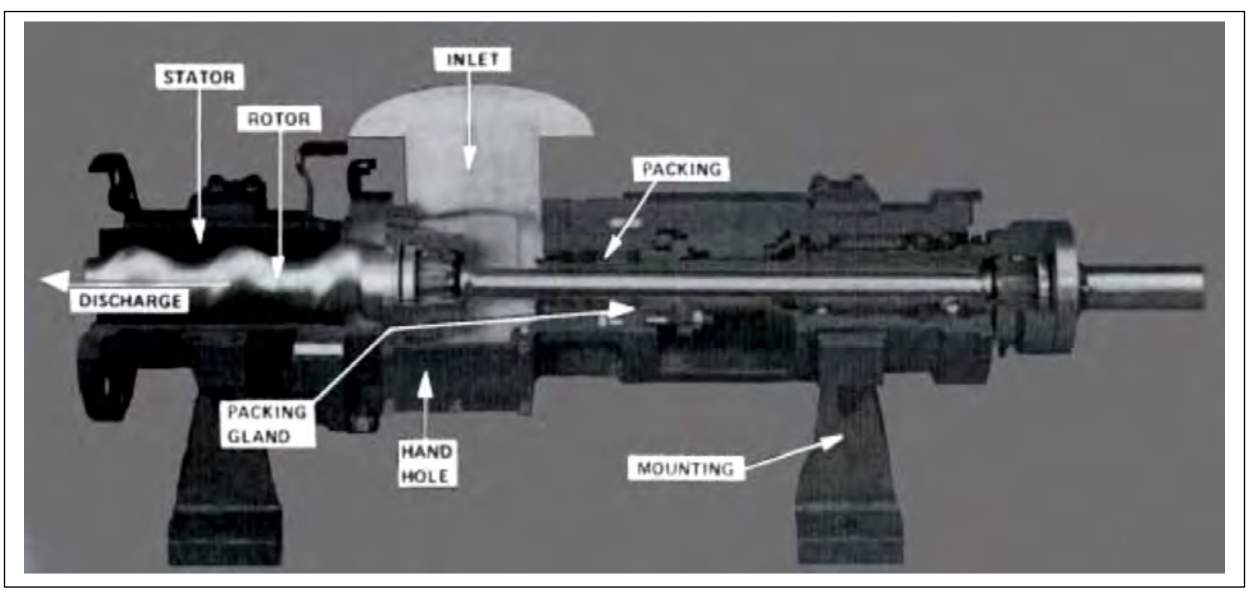
Incline Screw Pumps
Incline screw pumps consist of a screw operating at a constant speed within a housing or trough. When the screw rotates, it moves the wastewater up the trough to a discharge point. Two bearings, one on top and one at the bottom, support the screw.





PROGRESSIVE CAVITY PUMPS
Operation of a progressive cavity pump is similar to that of a precision incline screw pump. The progressive cavity pump consists of a screw-shaped rotor snugly enclosed in a non-moving stator or housing. The threads of the screw like rotor make contact along the walls of the stator (usually made of synthetic rubber). The gaps between the rotor threads are called "cavities." When wastewater is pumped through an inlet valve, it enters the cavity. As the rotor turns, the waste material is moved along until it leaves the conveyor (rotor) at the discharge end of the pump. The size of the cavities along the rotor determines the capacity of the pump.

These pumps are recommended for materials that contain higher concentrations of suspended solids. They are commonly used to pump sludge. Progressive cavity pumps should NEVER be operated dry (without liquid in the cavities), nor should they be run against a closed discharge valve.



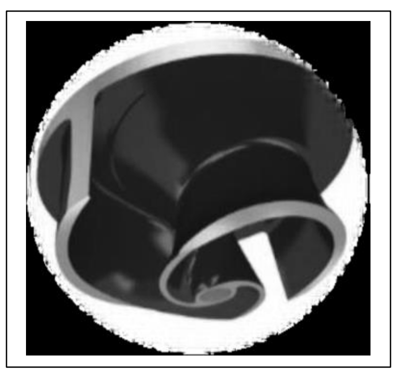
Pump Type Typical Application:

Centrifugal	Raw Wastewater Primary Sludge Secondary Sludge Effluent Wastewater	Flush Water Spray Water Seal Water
Positive Displacement	Primary Sludge Thickened Sludge Digested Sludge Slurries Chemical Feed Applications	
Progressive Cavity	All types of Sludge All types of Slurries	

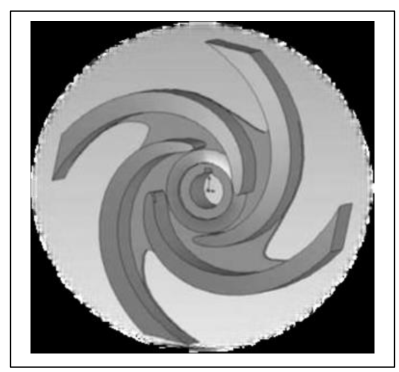
Pump Lubrication:
Pumps, motors, and drives should be oiled and greased in strict accordance with the recommendations of the manufacturer.

Pump Components
Impellers:
The heart of a centrifugal pump is the impeller. This device spins causing a centrifugal force that pumps the wastewater. There are many different types of impellers, such as propeller, turbine, mixed flow, and radial. These impellers may be open, enclosed, or semi-closed.

Enclosed



Semi-closed



Open

The most common impellers used in wastewater centrifugal pumps are semi-closed or enclosed-type radial for larger pumps and open impellers for smaller sludge pumps. These are used because they will pass solids with less chance of plugging.

Shafts:
Pump shafts are used to turn the impeller and mount the bearing; they are connected to a pump driver of some type. They are machine to exact tolerances and must be maintained this way for proper operation. There are <u>four</u> major areas to shaft:

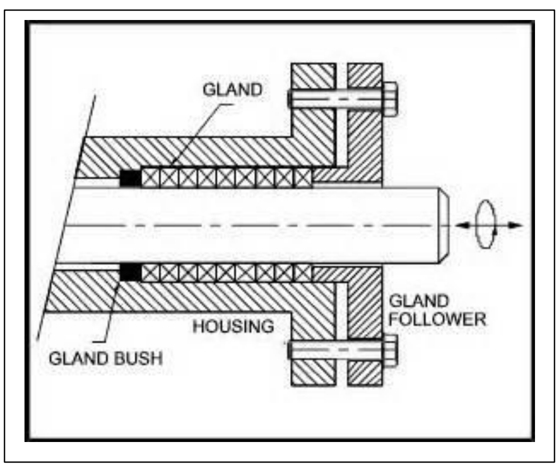
1. **Impeller end-**The impeller end is where the impeller is pressed, keyed, or secured onto the shaft.
2. **Coupling end-**The coupling end is where the coupling mounts on the shaft to connect to the driver
3. **Bearing fits-** Bearing fits or journals are where the bearings are installed on the shaft.
4. **Stuffing box area-**The most important problem section with a pump shaft is the stuffing box area. The pump packing, if not properly cared for, will cut grooves into the shaft.

Packing:
Packing is probably the single biggest problem for the maintenance operator maintaining pumps. More pumps have been damaged due to improper maintenance of packing than any other reason. If packing is not maintained properly, the following troubles can occur:

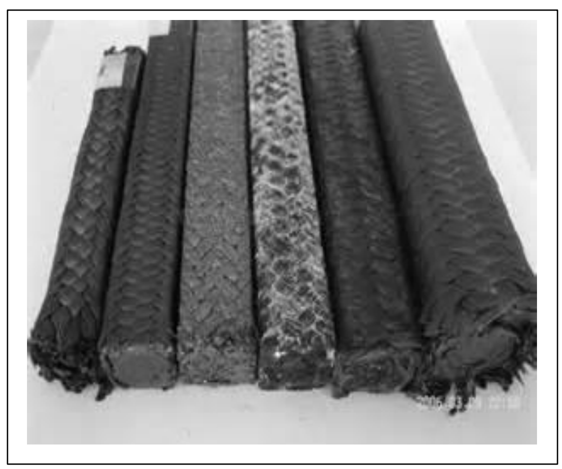
1. Loss of suction due to air being allowed to enter pump
2. Shaft or shaft sleeve damage
3. Water or wastewater contaminating bearings
4. Flooding of pump station
5. Rust corrosion and unsightliness of pump and areas

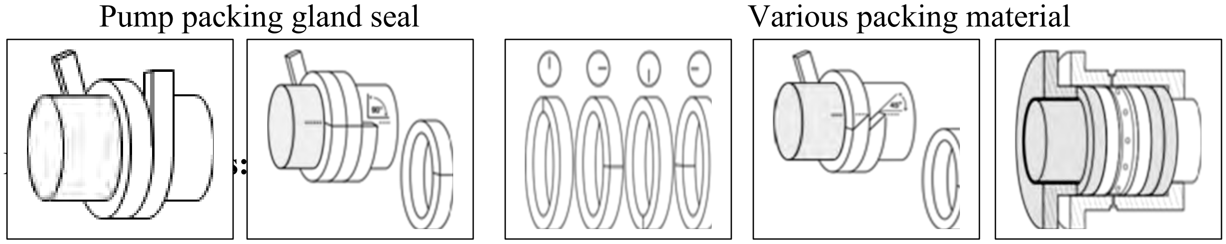
Packing is used to provide a seal where the shaft passes through the pump casing in order to keep air from being drawn, or sucked, into the pump, and/or the water being pumped from coming out.

If a clear water seal is used on the packing, the pressure of the clear water at the packing box should be maintained at least 5 psi greater than the maximum pump suction pressure.



Pump packing gland seal


Various packing material



Many pumps use mechanical seals in place of packing. Mechanical seals serve the same purpose as packing. They prevent leakage between the pump casing and shaft. Like packing, they are located in the stuffing box where the shaft goes through the volute; however, they should not leak. Mechanical seals are gaining popularity in the wastewater field.

Mechanical seals have two faces which "mate" to prevent water from passing through them. One half of the seal is mounted in the pump or gland with an "O" ring or gasket, thus providing sealing between the housing and seal face. This prevents water from going around the seal face and housing. The other half of the mechanical seal is installed on the pump shaft. This part also has an "O" ring or gasket between the shaft and seal to prevent water from leaking between the seal part and shaft. There is a spring located behind one of the seal parts which applies pressure to hold the two faces of the seal together and keeps any water from leaking out. One half of the seal is stationary, and the other half is revolving with the shaft.

Bearings:
If serviced properly and used in their proper application, bearings should usually last for years There are several types of bearings used in pumps. These include: **ball bearings**, **roller bearings**, and **sleeve bearings**. The type of bearing used in each pump depends on the manufacturer's design and application. Whenever a bearing failure occurs, the bearing should be examined to determine the cause and then, if possible, eliminate the problem. An example of types of bearing failures is as follows:

1. Fatigue failure	2. Contamination	3. Brinelling*
4. False brinelling	5. Thrust failures	6. Misalignment
7. Electric arching	8. Lubrication failure	9. Cam failure

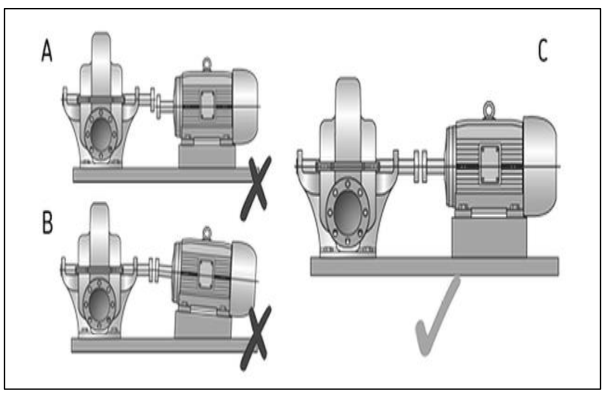
**Brinelling (bruh-NEL-ing). Tiny indentations (dents) high on the shoulder of the bearing race or bearing.*

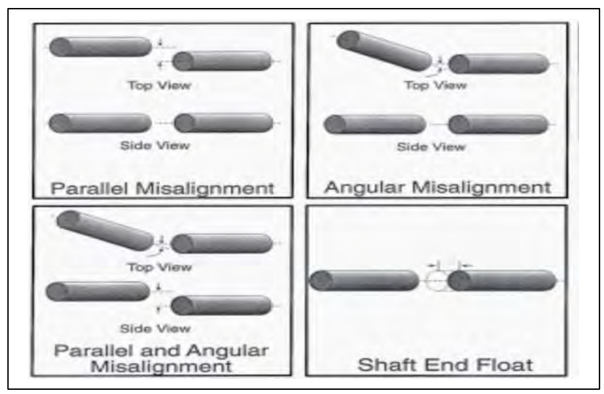
Couplings:
Whenever two pieces of rotating equipment, such as a pump and a motor, are used, there must be some means of transmitting the torque from the motor to the pump. Couplings are designed to do this. To function as intended, the equipment must be properly aligned at the couplings.

Alignment:
Misalignment of the pump and the motor can seriously damage the equipment and shorten the life of both the pump and the motor. Misalignment can cause excessive bearing loading as well as shaft bending which will cause premature bearing failure, excessive vibration, or permanent damage to the shaft. Remember that the purpose of the coupling is to transmit power and, unless the coupling is of special design, it is not to be used to compensate for misalignment between the motor and the pump.

When connecting a pump and a motor, there are two important types of misalignment: (1) **parallel** and (2) **angular**. Parallel misalignment occurs when the centerlines of the pump shaft and the motor shaft are offset. The pump and the motor shafts remain parallel to each other but are offset by some degree.

Angular misalignments occur when the shaft centerlines are not parallels, but instead form an angle, which represents the amount of angular misalignment. In reality, misalignment usually includes both parallel and angular misalignment. The goal when aligning machines is to reduce the angular and parallel misalignment to a minimum. Toward this end, it is recommended that the use of a dial indicator be employed.





Many large systems have fully-equipped machine shops staffed with competent mechanics, but for smaller plants, adequate machine shop facilities for rebuilding pumps and other mechanical equipment often can be found in the community. Most pump manufacturers maintain pump repair departments where pumps can be fully reconditioned.

COMMON OPERATIONAL PROBLEMS
The operator should check all pumps and motors every day to insure proper operation. After spending a certain amount of time with these pumps and motors an operator should be able to tell just by listening to them whether they are working properly. The vast majority of pumping problems are either a result of improperly sizing a pump for the job, or one of the three following operational problems:

1. **Cavitation:**
   One of the most serious problems an operator will encounter is cavitation. It can be identified by a noise that sounds like marbles or rocks are being pumped. The pump may also vibrate and shake, to the point that piping is damaged in some severe cases. Cavitation occurs when the pump starts discharging water at a rate faster than it can be

drawn into the pump. This situation is normally caused by the loss of discharge head pressure or an obstruction in the suction line. When this happens, a partial vacuum is created in the impeller causing the flow to become very erratic. These vacuum-created cavities are formed on the backside of the impeller vanes.

Causes of Cavitation:

- Loss of discharge pressure due to open hydrants or line breaks
- Closed suction valve
- Obstruction in the suction line
- Low suction head due to drop in water level

2. **Air Locking:**
   Air locking is another common problem with pumps. It is caused by air or dissolved gases that become trapped in the volute of the pump.

3. **Loss of Prime:**
   Loss of prime happens when water drains out of the volute and impeller. The impeller can't create any suction at the impeller eye unless it is filled with fluid.

Electricity

THIS DISCUSSION SHOULD NOT BE CONSIDERED A SOURCE OF TECHNICAL INFORMATION FOR ACTUAL OPERATION AND MAINTENANCE PROCEDURES. IT SHOULD BE USED ONLY AS A BRIEF INTRODUCTION OR REVIEW OF GENERAL INFORMATION.

ONLY QUALIFIED AND AUTHORIZED PERSONS SHOULD WORK ON ELECTRICAL EQUIPMENT OR CIRCUITRY.

When working with water and electricity, the need for safety should be apparent. If proper safe procedures are not followed in operating and maintaining the various electrical equipment used in wastewater collection and treatment facilities, accidents can happen which cause injuries, permanent disability, or loss of life. Some of the serious accidents that have happened, and which could have been avoided, occurred when machinery was **not** shut off, locked out, and tabbed properly as required by OSHA. Possible accidents include:

1. Maintenance operator could be cleaning pump and have it start, thus losing an arm, hand, or finger.
2. Electrical motors or controls not properly grounded could lead to possible severe shock, paralysis, or death.

Improper circuits created by mistakes, such as a wrong connection, bypassed safety devices, wrong fuses, or improper wiring and wires, can cause fires or injuries due to incorrect operation of machinery.

Electrical Equipment Maintenance
Fundamentals of Electricity:
In all wastewater systems, there is a need for the operators to know something about electricity. However, very few operators, even those who specialize in maintenance, ever do the actual electrical repairs or troubleshooting because it is such a highly specialized field. Unqualified persons can severely injure themselves and damage costly equipment.

Volts:
Voltage (also known as electromotive force or E.M.F.) is the electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. This pressure can be compared with the pressure or force that causes water to flow in a pipe. Pressure is required to make the water move. The same is true of electricity. A force is needed to push electricity or electric current through a wire. This force is called voltage. There are two types of current: Direct Current (D.C.) and Alternating Current (A.C.)

Direct Current:
Direct Current (D.C.) flows in one direction only and is essentially free from pulsation. Direct current is seldom used in water systems except in electronic equipment, some control components of pump drives, and stand-by lighting.

Alternating Current:
An **Alternating Current (A.C.)** is one in which the voltage and current periodically change direction and amplitude. In other words, the current goes from zero to maximum strength, back to zero, and to the same strength in the opposite direction. Most A.C. circuits have a frequency of 60 cycles per second. Alternating current may be classified as one of three types.

1. Single-Phase
2. Two-Phase
3. Three-Phase (sometimes called polyphase)

The most common of these are single phase and three phase. Single-phase power is found in lighting systems, small pump motors, various portable tools, and throughout residential homes. This power is usually 120 volts and sometimes 240 volts. Single-phase means that only one phase of power is supplied to the main electrical panel at 240 volts, and it has three wires or leads. Two of these leads have 120 volts each and the other lead is neutral.

Three-phase power is generally used with motors and transformers found in water systems. Generally, motors above two horsepower are three-phase. Three-phase power is usually brought in to the point of use with three leads. There is power on all three leads. If a fourth lead is brought in, it is a neutral lead. Incoming power goes through a meter, then through some type of disconnecting switch such as a fuse or circuit breaker.

Amps:
Amps, which is short for **amperage**, is the measurement of current or electron flow and is an indication of work being done or "how hard the electricity is working." The **amp** or **ampere** is the practical unit of electric current. The actual definition of an ampere is the current produced

by a pressure of one volt in a circuit that has a resistance of one ohm. Most electrical equipment used in water systems is labeled with nameplate information indicating the proper voltage and allowable current in amps.

Nameplate Information:

Ohm- The **ohm** is the unit of measurement for electrical resistance.

Watts and Kilowatts- **Watts** and **kilowatts** are the units of measurement of the rate at which power is being used or generated. 1000 watts is equal to 1 kilowatt. Power requirements are expressed in kilowatt hours. 500 watts for two hours or one watt for 1000 hours equals one kilowatt hour. The electric company charges so many cents per kilowatt hour.

Meters, and Testers-A wide variety of instruments are used to maintain electrical systems. These instruments measure current, voltage, and resistance. They are used not only for trouble-shooting, but for preventive maintenance as well. These instruments may have either an analog readout, which uses a pointer and scale, or a digital readout, which gives a numerical reading of the measured value.

Equipment Protective Devices

Fuses:

A **fuse** is a protective device having a strip or wire of fusible metal which, when placed in a circuit, will melt and break the electrical circuit when subjected to an excessive temperature. This temperature will develop in the fuse when a current flows through the fuse in excess of what the circuit will carry safely.

Circuit Breakers:

The **circuit breaker** is another safety device, and is used in the same place as a fuse. Most circuit breakers consist of a switch that opens automatically when the current or the voltage exceeds or falls below a certain limit. Unlike a fuse that has to be replaced each time it "blows," a circuit breaker can be reset after a short delay to allow time for cooling.

Overload Relays:

Three-phase motors are usually protected by **overload relays.** This is accomplished by having heater strips, bimetal, or solder pots which open when overheated, stopping power to the motor. Such relays are also known as "heaters" or "thermal overloads."

Motors
Equipment used to operate pumps include electric motors and internal combustion engines. In all except very large installations, electric motors are used almost exclusively. **Electric Motors** usually consist of a stator, rotor, end bells, and windings. The rotor has an extending shaft that allows a machine to be coupled to it. Motors are of many different types. The most common of these is the squirrel cage induction motor. Some pumping stations use wound rotor induction motors when speed control is needed.

Electric motors generally require little attention, and with average operating conditions, the factory lubrication of the bearing will last approximately one year. Check with the manufacturer for the average number of operating hours for bearings. Pumps, motors, and drives should be oiled and greased in strict accordance with the recommendation of the manufacturer.

Most of the trouble encountered with electrical motors results from bad bearings, shorted windings due to insulation breakdown, or excessive moisture. If single phasing occurs in a three-phase motor, one phase loses power; if the motor is running, it will tend to overheat and damage itself unless stopped. The amperage and voltage readings on motors should be taken periodically by qualified persons to ensure they are operating properly.

A **motor starter** is a device or group of devices that are used to connect the electrical power to a motor. These starters range in complexity from manually controlled starters such as on/off switches to automatically controlled magnetic starters using timers and coils. When you install a 3-phase motor, and it runs in the wrong direction, change the connections, and reverse any two lead wires.

Valves
Gate Valves:
Pump suction and discharge isolation gate valves are found immediately before and after the pump to allow isolation of the pump from the wet well and force main during pump or check valve maintenance. The most common type of valve used for this application is a gate valve in which discs or gates are used to provide a shutoff. Two types of gate valves are the **Non-Rising Stem Valve** and the **Outside Screw & Yoke Valve.**

Under no circumstances should gate valves be buried, as is common practice in drinking water distribution systems. At some point in time, a gate valve will require disassembly and maintenance.

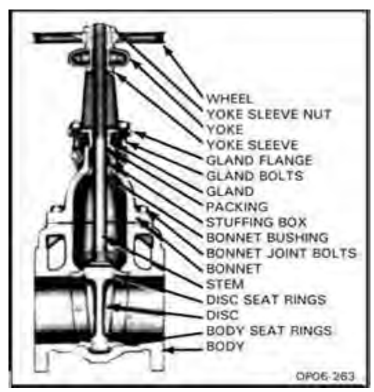
Gate valves are also commonly used in the discharge manifold and cross-connect valves in the pump station.

Plug Valves:
Plug valves are another type of valve that are successfully used as suction and discharge isolation valves in lift stations and are frequently used in wastewater plants where waste-streams with high solids content are encountered, such as in sludge pumping systems. Plug valves consist of a rotating plug within the valve body. Many systems specify plug valves as opposed to gate valves as they are less susceptible to being fouled by debris.

Check Valves:
Normally, a check valve is installed in the discharge of each pump to provide a positive shutoff from force main pressure when the pump is shut off and to prevent the force main from draining back into the wet well.
The most common type of check valve is the **swing check valve** normally installed in the discharge of pumps. This valve consists of a valve body with a "clapper arm" attached to a hinge that opens when a pump comes on and closes to seat when a pump is shut off. Each of these valves require regular maintenance as specified by the manufacturer to operate and minimize chance of failure.

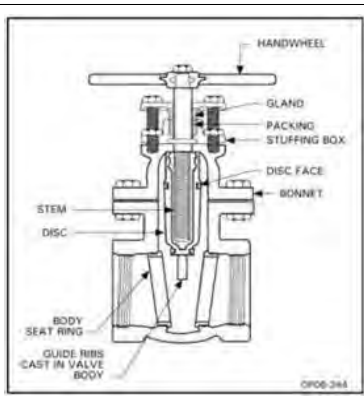
Most valves suffer from lack of operation rather than from wear. A comprehensive program of inspection, exercising and maintenance of valves on a regular basis can help systems avoid potentially serious problems when the need to use a valve arises. In general, it is recommended that all valves be exercised at least once a year. Exercising the valves verifies valve location, determines whether or not the valve works and extends valve life by helping to clean encrustations from the valve seats and gates. Valves should be exercised in both directions fully closed and fully opened and the number of turns and direction of operation recorded. Any valves that do not completely open or close should be replaced. Valves which leak around the stem should be repacked.

Non-Rising Stem Valve

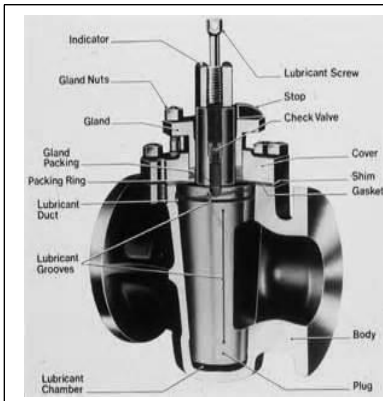


Rising Stem Valve

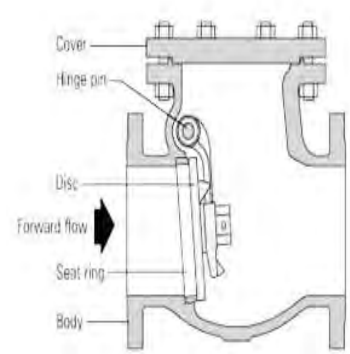
Sluice Gate



Screw and Yoke Valve



Plug Valve



Swing Check Valve

Outline of Maintenance for Some of the Valves:

Gate Valves

1. Replace Packing	2. Operate Valve
3. Lubricate Gearing	4. Lubricate Rising Stem Threads
5. Lubricate Buried Valves	6. Reface Leaky Gate Valve Seats

Check Valves

1. Inspect Disc Facing	2. Check Pin Wear

Plug Valves

1. Adjust Glad	2. Lubricate All Valves

Sluice Gates

1. Test for Proper Operation	2. Clean and Paint	3. Adjust for Proper Clearance

Chlorinators:
All **chlorinators** can give continuous trouble-free operation if properly maintained and operated. Each chlorinator manufacturer provides with each machine a maintenance and operations booklet with line diagrams showing the operation of the component parts of the machine. Manufacturer's instructions should be followed for maintenance and lubrication of your particular chlorinator. If you do not have an instruction booklet, you might obtain one by contacting the manufacturer's representative in your area.

Other Types of Mechanical Equipment
Many other types of equipment also require regular maintenance including pipelines, flow metering devices, and moving parts associated with various secondary treatment processes. Manufacturer's and/or design engineer's instructions should be consulted for specific information on proper maintenance of each piece of equipment. Also helpful are operation and maintenance manuals and/or schedules that have been developed for your water system.

Special Safety Considerations (see also Chapter 6)

DO NOT OPERATE ELECTRICAL SYSTEMS OR CONTROLS UNLESS YOU ARE QUALIFIED AND AUTHORIZED TO DO SO.

Even when qualified and authorized, caution should be used when operating electrical controls, circuits, and equipment.

- Be aware of moving equipment, especially reciprocating equipment and rotating shafts. Guards over couplings and shafts should be provided and should be in place at all times.
- Do not wear loose clothing, rings, or other jewelry around machinery.
- Long hair must be secured.
- Wear gloves when cleaning pump casings to protect your hands from dangerous sharp objects.

- Operate only those switches and electrical controls installed for the purpose of your job.

- When starting rotating equipment after a shutdown, everyone should stand away from rotating shafts. Dust and oil and loose metal may be thrown from shafts and couplings, or sections of a long vertical shaft could come loose and whip around, especially during start-up of equipment.

- All equipment that could unexpectedly start-up or release stored energy must be locked out or tagged out to protect against accidental injury to personnel.

- DO NOT OPEN OR WORK INSIDE ELECTRICAL CABINETS OR SWITCH BOXES UNLESS ABSOLUTELY NECESSARY, AND ONLY IF YOU ARE QUALIFIED TO PERFORM THESE VERY SPECIALIZED SKILLS.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – **Operation of Wastewater Treatment Plants, Vol. 2**

Chapter 15 Maintenance (especially sections 15.1, 15.2, and 15.3)

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems, Vol. 1**

Chapter 5 Inspecting and Testing Collection Systems

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems, Vol. 2**

Chapter 9 Equipment Maintenance

Chapter 11 Sewer Rehabilitation

OTHER STUDY SUGGESTIONS

Study the chapters on mechanical maintenance of pumps, motors, couplings and valves in all manuals available to you.

Be able to draw a diagram of a centrifugal pump with its internal components, valves and pressure gauges. Know location and function of packing/stuffing box, volute wear rings, impeller, shaft sleeves, and bearings

Be able to diagram a positive displacement pump with check valves and piping.

Know basic maintenance procedures and intervals for pumps including lubrication, packing and adjustment, priming.

Be aware of lubrication intervals for motors so that over or under lubrication is avoided.

Be able to diagram the two principle types of misalignment of couplings and power drives.

Identify specific safety practices used when working close to rotating equipment.

Trace the flow of water or pumped material through each of the types of pumps listed in the guidelines.

Observe the sequence of operation of gate valves, check valves, and pressure gauges, and electrical controls as each type of pump is started up or shut down.

Pick out frequently performed maintenance procedures, i.e. packing and seals, lubrication, and go through them in detail step by step.

Refer to trouble shooting charts in suggested references for typical problems and what to do about them.

Be familiar with section diagrams and names of valves that are used in wastewater collection and treatment.

Know the operating characteristics of these valves and typical applications.

STUDY QUESTIONS

Class D

A type of pump that utilizes positive displacement and a moving piston is called a:

A. reciprocating pump.
B. centrifugal pump.
C. screw pump.

Class C

The card that is used to record what should be done and when for each piece of equipment is called:

A. the service record card.
B. the equipment service card.
C. the repair and maintenance card.

Class B

Which of the following is NOT an advantage of using mechanicals seals instead of packing?

A. lower initial cost
B. no requirement for continual adjusting and cleaning
C. less chance of damage to the shaft sleeve when replaced
D. reduced maintenance requirements

Class A

Which of the following types of pumps utilizes a screw-shaped rotor and is commonly used to pump sludge?

A. centrifugal pumps
B. pneumatic ejectors
C. reciprocating positive displacement pumps
D. progressive cavity pumps

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CHAPTER 6

OPERATOR SAFETY

INTRODUCTION TO CHAPTER 6

Much of the information in this chapter is referred to separately within this study guide. This special chapter on safety is included to focus special attention of this very important topic.

This chapter is provided as a general guideline to operator safety, but it is not all-inclusive. Operators are required to follow the safety rules as stated by OSHA and the Oklahoma Department of Labor.

SUGGESTED STUDY GUIDELINES:

Class D and Class C

Be prepared to answer questions concerning:

- The general safety concerns and procedures as they apply to excavation and shoring.
- Where the spoil should be placed.
- When a trench or excavation SHOULD have adequate cave-in protection.
- When a trench or excavation MUST have adequate cave-in protection.
- The general safety concerns and procedures as they apply to confined space entry.
- The requirements that must be met before entering a permit-required confined space.
- The specific responsibilities for entry supervisors, attendants, entrants, and rescue personnel.
- The procedures regarding confined space entry permits including recordkeeping requirements.
- The characteristics and dangers associated with gases found in confined spaces.
- The general safety concerns and procedures as they apply to electrical hazards.
- The procedures and significance of proper lockout-tagout practices.
- The basic procedure for emergency rescue of victims of electrical shock.
- Safety concerns and procedures as they apply to other dangers operators may face including:
    - hazardous chemicals
    - noise
    - physical hazards
    - traffic
- The name of the service available in the case of an emergency involving hazardous chemicals.
- The importance of reading and understanding a Material Safety Data Sheet (MSDS).
- The general guidelines for personal protective equipment and protective clothing.

Be prepared to answer other questions that require additional personal study

Class A and Class B

Be prepared to answer questions concerning guidelines listed for lower levels of certifications and:

Know how to establish and maintain effective operator safety programs and emergency planning.

Know how to establish and maintain a hazard communication program as required by law

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

ENTRY LEVEL DISCUSSION

Have you ever wondered **why safety should be of such interest to water system operators?** Stop and think of the wide variety of hazards associated with this work. In any one working day, operators could be exposed to any or all of the following:

1. Trenching and Excavation - OSHA Regulations Title 29 (1926.650)
2. Confined Spaces - OSHA Regulation Title 29 (1910.146)
3. Electrical and Mechanical Hazards - OSHA Regulation Title (1910.147)
4. Hazardous Chemicals - Oklahoma Haz Com (O.S. 380.45)
5. Noise - OSHA Title 29 (1910.95)
6. Physical Hazards - OSHA Title 29 (1900-1926)
7. Traffic
8. Blood Borne Pathogens - OSHA Title 29 (1910.151, .1030)

The ways in which operators deal with these day-to-day hazards may be detailed in a safety program which may include the following:

1. Personal Protective Equipment - OSHA Title 29 (1910.132-134)
2. Process Safety Management - OSHA Title 29 (1910.119)
3. Chemical Hygiene Plan - OSHA Title 29 (1910.1450)

We need to be aware of the potential for injury in all our activities. The best person to prevent an injury from occurring is YOU. By thinking ahead, being aware of the potential for an accident, and developing good work habits, many injuries can, and will, be eliminated. Poor work habits, those short cuts you may take, or the messes that are left behind, ultimately do NOT pay off. Eventually, these mistakes will catch up with you, or someone else, and can and will result in injury. The trip to the doctor and the days of lost work and paid-time will consume far more time than you may have thought you were saving by taking a shortcut.

Injuries on the job have negative consequences for all involved. Injured operators not only suffer pain and discomfort, they may be unable to return immediately to work. This can result in a loss of full wages and financial and emotional hardships to both the operator and his or her family.

The water system is also affected. Injuries rob the facility of much-needed operators, and when accidents happen, it causes other possibly inexperienced, and less-skilled people to fill in for you. This is not just a problem that small work crews face; even large crews may have to face being either shorthanded or work on overtime. This creates fatigue among the operators and results in an overtime expense to the system.

Common Causes of Injuries

Most injuries involve either the back, legs, or hands. The vast majority of injuries are caused by one of the following three categories of accidents:

1. Sprains and strains resulting from improper lifting, awkward positions, pushing, and pulling.

2. Being struck by objects that are falling, moving, stationary, flying, sharp, or blunt.

3. Slips and falls from platforms, ladders, stairs, or from one level to another.

Operator Safety Training Programs

Construction work can be a safe occupation, and fatalities and injuries can be prevented when workers are aware of the hazards, and they use an affective Safety & Health Program. On-the-job training (OJT) is a very valuable tool not only to upgrade operational skills, but also to protect the worker's health. Improvements in the safety programs at water treatment and distribution systems should be a constant goal. The desire for a good safety program must start at the very top of the organization. Without this support, many efforts will not be given the authority and financial resources to carry through. Some of the aspects of a good operator safety program are listed on the following pages.

1. Develop a written Standard Operating Procedure (SOP) for routine duties or equipment operation and have regular training sessions over each SOP. This will not only point out safety aspects of the job, but will also be a way to train people in the most efficient way to work.

2. Have safety meetings for all workers at least once a month. Each supervisor should take turns presenting a meeting.

3. Form a safety committee to review accidents, inspect the facility for unsafe conditions, to post warnings, or suggest improvements to risky areas, and enforce good work habits.

4. Have all personnel learn CPR and First Aid skills. This can be done through the Red Cross, the American Heart Association, or maybe even your local fire department or ambulance service. If the Operator Certification Unit is notified in advance in writing, these classes may be approved as training credit for certified operators.

5. Recognize and reward safe workers with a certificate of some type of tangible recognition. Make safety and good work habits a part of annual evaluations and a factor in merit raises.

CALL OKIE TWO WORKING DAYS BEFORE YOU DIG!

Uniform Color Code Used for Identifying Public Works Pipe and Cables

RED =	electric power lines, lighting cables, conduit
YELLOW =	gas, oil, steam, petroleum
ORANGE =	communication cables, alarm cables, signal lines.
BLUE =	potable water, irrigation water, slurry lines.
GREEN =	sewers, drain lines
PINK =	temporary survey markings
WHITE =	proposed excavation
PURPLE =	reclaimed water

Trenching and Excavation

Trenching and excavation is recognized as one of the most hazardous construction operations. The Occupational Safety & Health Administration (OSHA) recently revised Subpart P, Excavations, to make the standard easier to understand, to permit the use of performance criteria where possible, and to provide construction employers with options when classifying soil and selecting employee protection methods.

OSHA requires that workers in trenches and excavations be protected, and that safety and health programs address the variety of hazards they face. The following hazards cause the most trenching and excavation injuries:

- No protective system.
- Failure to inspect trench and protective systems.
- Unsafe spoil-pile placement.
- Unsafe Access/Egress.

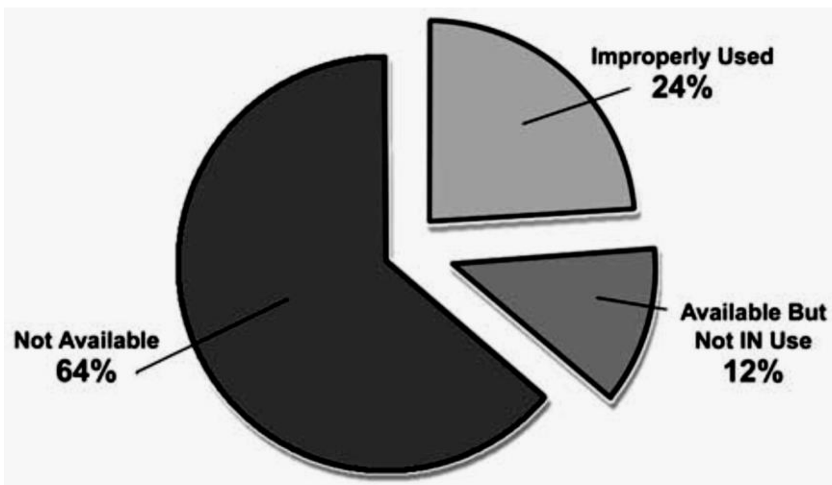
All excavations are hazardous because they are inherently unstable. If they are restricted spaces they present the additional risks of oxygen depletion, toxic fumes, and water accumulation. If you are not using protective systems or equipment while working in trenches or excavations at your site, you are in danger of suffocating, inhaling toxic materials, fire, drowning, or being crushed by a cave-in.

Cave-ins are perhaps the most feared trenching hazard and one of the most difficult hazards to control. Unsafe trenches are the greatest killers. By their nature, trenches tend to be temporary (short term) with less attention given to safe procedure. They are also extremely confining which makes escape more difficult, but other potentially fatal hazards exist, including asphyxiation due to lack of oxygen in a confined space, inhalation of toxic fumes, drowning, etc. Electrocution or explosions can occur when workers contact underground utilities.

Given the contributing factors involved in a **cave-in**, the numbers are not surprising. A cubic foot of soil weighs one hundred pounds on average. This is equivalent to each cubic yard weighing the same capacity of most backhoe-loader front buckets (which weigh twenty-seven hundred pounds) the weight of a mid-sized automobile. A person working in an unprotected excavation could be buried eight-feet deep on a sewer main which could easily have 3-6 cubic yards (8,100-16,200 lbs.) in a cave-in. The force of that impact could snap bones like matchsticks and crush soft tissue like gelatin.

Furthermore, the research has shown that now, as was the case thirty years ago, the accidents occur to employees who are either working in excavations without any protective system, or one where the protective system is clearly inadequate.

The protective measure breakdown causing fatalities:



Source: OSHA Construction Directorate Office Review of 2003 Trench Fatalities
These dramatic revisions in the OSHA Standard clearly impacted the number of excavation fatalities in the nation. Those who wished to comply finally had a standard that provided adequate resources and flexibility to allow them to do so.

Those who did not, suddenly found that the excuses for not doing so in the past had been swept away.

This, in turn, permitted the punishment for non-compliance to be more easily and severely applied. OSHA's revised penalty structure, in combination with excavations special emphasis status, allowed OSHA to assess fines of up to $70,000.00 per person at exposure in the most egregious cases.

A short overview of the OSHA Standard for Excavations

OSHA Standard 29 CFR 1926.650-652 Subpart P

OSHA is the Occupational Safety and Health Administration, which is an agency within the Federal Department of Labor. They are charged with promulgating and enforcing the safe work regulations, which are found in Title 29 of the Code of Federal Regulations, which is the Labor title. Part 1926 contains the regulations for the Construction Industry. Sections 650- 652 contain the Excavation regulations, which are also known as **Subpart P.**

Scope and Application: This standard applies to all open evacuations made in the earth's surface. Excavations are defined to include trenches.

Excavation**:** Any man made cut cavity, trench or depression in an earth surface, formed by earth removal.

Trench Excavation**:** A narrow excavation (in relation to its length). In general the depth is greater than the width, but the width of a trench (measured at its bottom) is not greater than 15 feet.

General Requirement for Protection**:** Each employee in an excavation five feet deep or deeper shall be protected from cave-ins by an adequate protective system, unless the excavation is made entirely in stable rock.

Under 5 feet**:** Under 5 feet, the requirement for a protective system is a judgment call for the "Competent Person."

Competent Person**:** Means "…one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to the employees and who has authorization to take prompt corrective measures to eliminate them."

Note: The primary candidate for the Competent Person role is the onsite supervisor, backed up by the backhoe or excavator operator.

Training Required for the Competent Person

In the preamble to the Standard, OSHA says that, "… for the purposes of this standard, one must have had specific training in and be knowledgeable about soils analysis, the use of protective systems and the requirements of the standard. One who does not have such training or knowledge cannot possibly be capable of recognizing existing and predictable hazards in excavation work or taking prompt corrective measures."

In Subpart C, OSHA also requires that all employees be trained in the "recognition and avoidance of hazards," so they will not unwittingly expose themselves to unsafe conditions.

Specific Responsibilities of the Competent Person

- Conducts tests for soil classification.
- Understand standards and any data provided.
- Determine proper protective system.
- Recognize and reclassify soil after changes in conditions.
- Determine whether damage to excavation safety equipment renders it unusable.
- Conducts tests for hazardous atmospheres.
- Design of structural ramps if needed.
- Location of underground installations/utilities.
- Monitor water removal equipment and operation if needed.
- Perform daily inspections.
- Determine the necessity for a protective system if less than 5 feet deep.

General Responsibility of the Competent Person

It is the general responsibility of the Competent Person to ensure that all aspects of the excavation process are in compliance with the excavation standard and the General Duty Clause of the OSHA Act (5a1.), which requires the employer to provide a safe, healthful workplace, free of unknown or recognizable hazards.

Options of the Competent Person:

1. Use the OSHA Standard for guidance with:
   - Sloping.
   - Shoring with timber or aluminum hydraulic shoring.
   - Shielding.

2. Use a Registered Professional Engineer to provide:
   - Tabulated data.
   - Manufacturers tabulated data.
   - A site specific design.
   - Must be registered in the state where the work is being done.

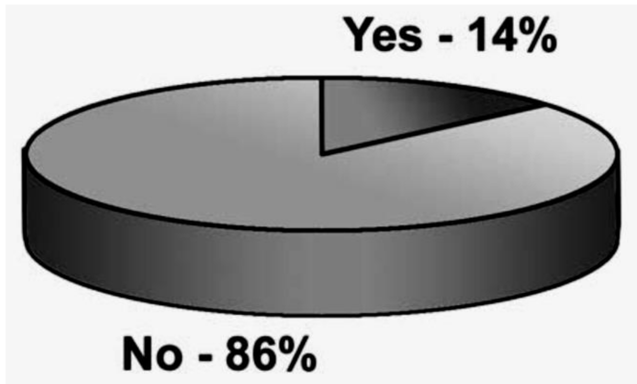
Registered Professional Engineers must be used if:

- The excavation is deeper than 20 feet.
- An "alternate system" (such as sheet piling) that the Standard does not provide guidance for is used.
- If the excavator is at "variance" with the Standard (i.e. doing less than the standard requires).

Note: OSHA expects that the engineer will be registered in a related area, such a civil, mechanical, geotechnical, or architectural engineering.

Note: Excavation protection solutions must either come from the OSHA Standard or a Registered Professional Engineer.

Does it really make a difference when a COMPETENT PERSON is in charge?
Note: that in the OSHA Construction Directorate study of excavation fatalities occurring in 2003, the competent person was not on the site 86% of the time. Clearly, the presence of a competent person when workers are at exposure is a critical element of a safe work program.



The on-site supervisor would be assigned the role of the competent person and would be supported by the excavator operator, who could assume that role if the competent person had to leave the site or was preoccupied with other duties.

Using the resources of the OSHA Standard
When OSHA revised the Excavation Standard, they knew full well that most jobs would not require a site-specific plan drafted by a registered professional engineer.

The revised Excavation Standard provides a soil classification system that allows the contractor to identify the soil "Type" present on their site. They also provide Tabulated Data for the use of sloping, timber shoring and aluminum hydraulic shoring, and guidance for the use of shield systems that would be used in conjunction with the engineered data provided by the manufacturer or designer of the shield.

Note: the competent person should not enter an unprotected excavation to test the soil. They should test freshly excavated material from the spoil pile.

SOIL TYPES = Stable Rock ⟶ Type A ⟶Type B ⟶ Type C

Stable Rock*:* Stable rock is defined as natural, solid mineral matter that can be excavated with vertical sides and remain intact while it is exposed. Most rock has stability problems. The competent person should downgrade unstable, dry rock to Type B, and unstable wet or submerged rock to Type C.

Type (A) Soil is defined as: Cohesive soil with an unconfined compressive strength of 1.5 tons per square foot or greater (these would be hard clays). Examples of cohesive soils are clay, silty clay, and sandy clay. The exclusions for Type A typically eliminate the possibility of its existence on a construction site. Practically speaking, B is the optimum soil type than can be expected. Simply stated, B is the best it can be.

Type (B) Soil is defined as: Cohesive soil with an unconfined compressive strength greater than.5 but less than 1.5 tons per square foot (this would be medium stiff clay). A common misperception is that all previously disturbed soil is Type C soil. That is simply not what the definition says. A previously disturbed soil cannot be Type A. It is automatically downgraded to Type B, but only further downgraded to Type C if other conditions require it.

Type (C) is defined as:

1. Cohesive soil with an unconfined compressive strength of .5 tsf or less (this would be a soft, wet, clay).
2. Granular soil including gravel, sand and loamy sand.
3. Submerged soil or soil from which water is freely seeping.
4. Submerged rock that is not stable.

It is perfectly fine with OSHA for the contractor to simply declare "worst case," i.e. Type C, and go forward with protective systems designed for those soils.

Layered geological strata: Where soils are configured in layers, i.e., where a layered geologic structure exists, the soil must be classified on the basis of the soil classification of the weakest soil layer. Each layer may be classified individually if a more stable layer lies below a less stable layer, i.e., where a Type C soil rests on top of stable rock.

Test Equipment and Methods for Evaluating Soil Type:
Many kinds of equipment and methods are used to determine the type of soil prevailing in an area, as described below.

Pocket Penetrometer: Penetrometers are direct-reading, spring-operated instruments used to determine the unconfined compressive strength of saturated cohesive soils. However, penetrometers have error rates in the range of ±20–40 percent.

<u>5 Soil Tests</u>:

1. Shearvane (Torvane): To determine the unconfined compressive strength of the soil with a shearvane, the blades of the vane are pressed into a level section of undisturbed soil, and the torsional knob is slowly turned until soil failure occurs. .

2. Thumb Penetration Test: The thumb penetration procedure involves an attempt to press the thumb firmly into the soil in question. If the thumb penetrates the full length of the thumb, it is Type C soil. The thumb test is subjective and is therefore the least accurate of the three methods.

3. Dry Strength Test: Dry soil that crumbles freely or with moderate pressure into individual grains is granular. Dry soil that falls into clumps that subsequently break into smaller clumps (and the smaller clumps can be broken only with difficulty) is probably clay in combination with gravel, sand or silt.

4. Visual Test: A visual test is a qualitative evaluation of conditions around the site. In a visual test, the entire excavation site is observed, including the soil adjacent to the site and the soil being excavated.

5. Plasticity or Wet Thread Test: This test is conducted by molding a moist sample of the soil into a ball and attempting to roll it into a thin thread approximately 1/8 inch in diameter (thick) by 2 inches in length. The soil sample is held by one end. If the sample does not break or tear, the soil is considered cohesive.

Protective Systems: Sloping, Shoring & Shielding

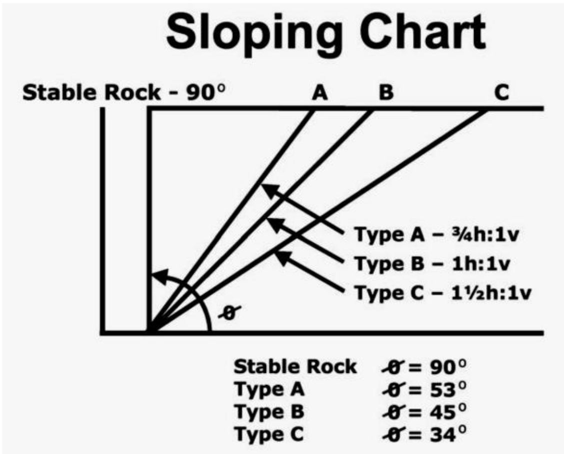
The OSHA Standard provides guidance for the use of three protective systems: sloping, shoring (with timber and aluminum hydraulic shoring systems) and shielding. After determining the soil type(s) on their construction site, the competent person can refer to the Standard for guidance in the correct use of those systems.

Sloping:
Sloping prevents cave-ins by removing the unstable wedge of soil from the walls of an excavation. Excavators are typically used to slope the walls back to a safe angle from which they will not fail. The safe angle is the angle at which the soil will stand

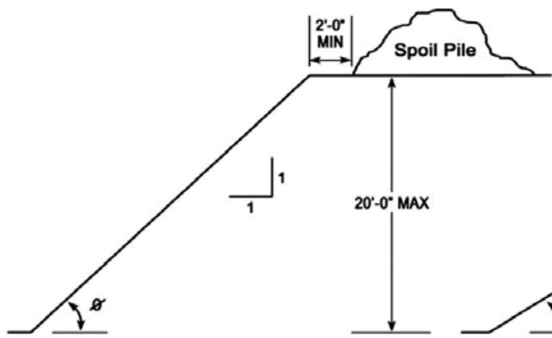
The OSHA Standard provides for four sloping options:
1. Slope the excavation 1 ½ horizontal to 1 vertical. In this case, the competent person will slope the excavation as though it were a Type C, worst case soil. If the competent chooses this option, they are not required to classify the soil, as they will be defaulting to a worst case condition.

If the excavation is sloped for Type C, they simply have to eliminate any accumulated water, inspect the excavation to ensure the slope profile is performing as intended, and return to work.

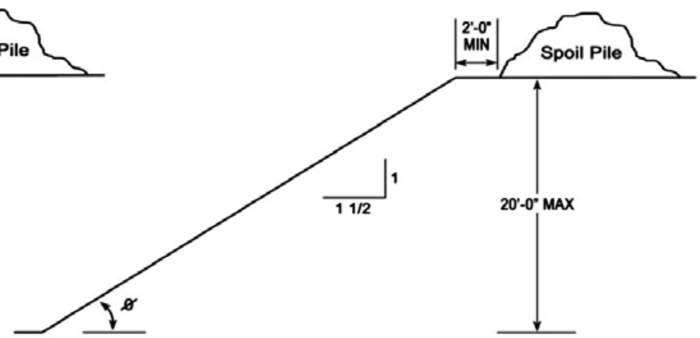
The OSHA standard assigns the following slopes to the four soil types:



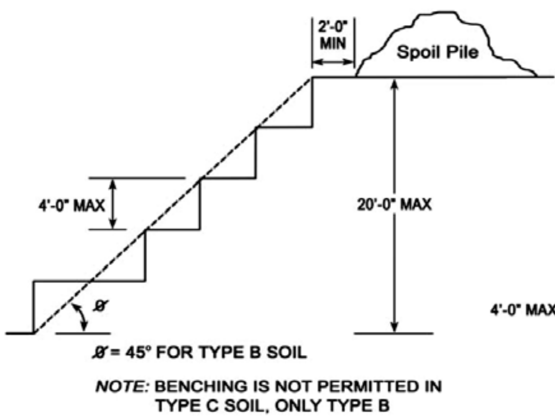
SLOPING - TYPE B SOIL



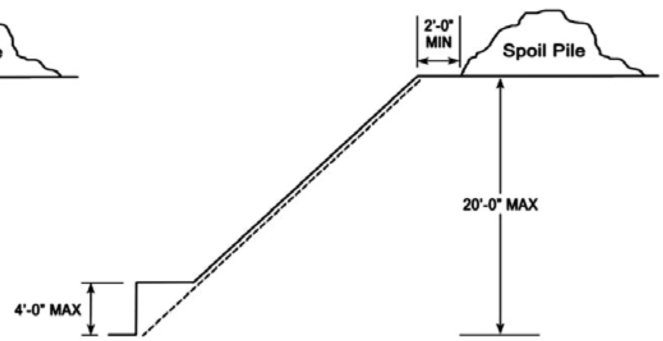
SLOPING - TYPE C SOIL



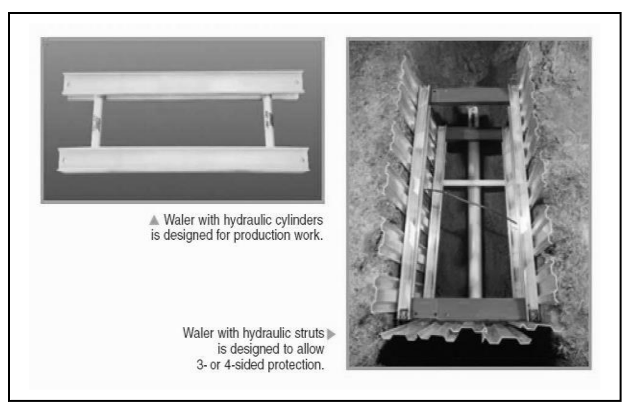
BENCHING



BENCHING AND SLOPING



Shoring:
Shoring is a complete framework of wood and/or metal that is designed to support the walls of the trench. Sheeting is the solid material placed directly against the side of the trench. Either wooden sheets or metal plates might be used. Any space between the sheeting and the sides of the excavation should be filled in and compacted in order to prevent a cave-in from starting.



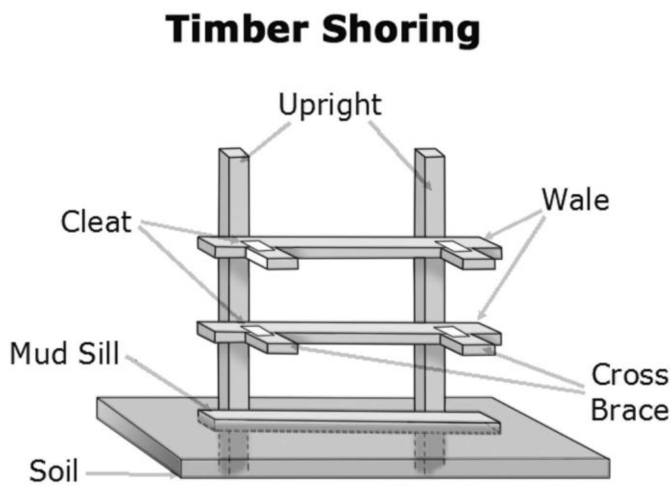
Uprights are used to support the sheeting. They are usually placed vertically along the face of the trench wall. Spacing between the uprights varies depending upon the stability of the soil. Stringers are placed horizontally along the uprights.

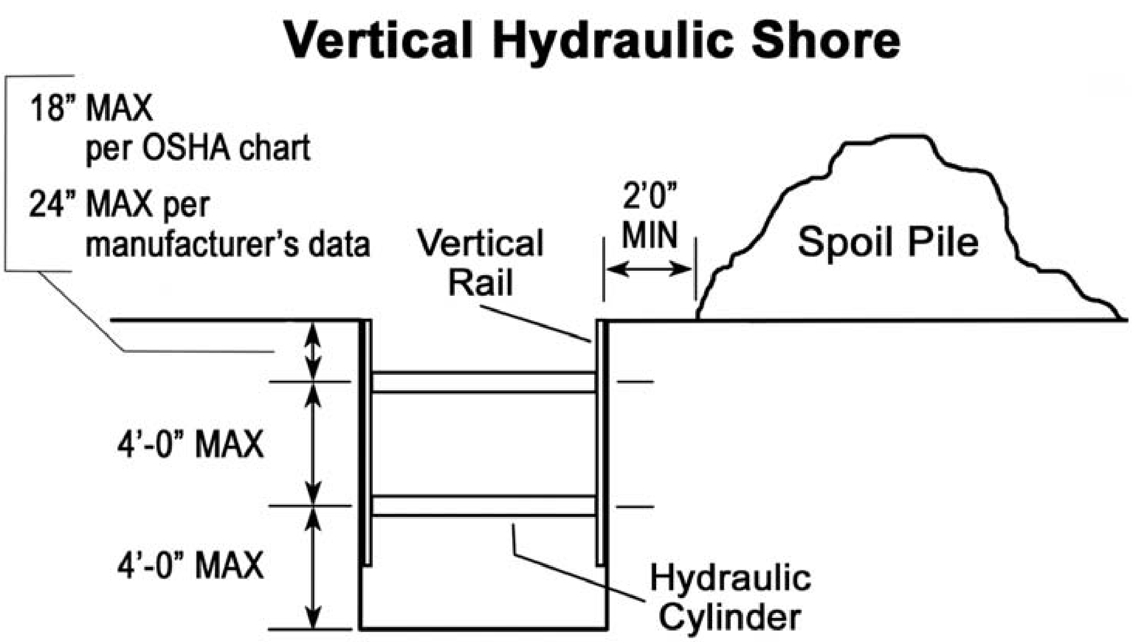
Trench braces are attached to the stringers and run across the excavation. The trench braces must be adequate to support the weight of the wall to prevent a cave-in. Examples of types of trench braces include solid wood or steel, screw jacks, or hydraulic jacks.

OSHA provides guidance for the use of Timber Shoring.

Note #1: The timber must be full dimensional Oak or normal dimensional Douglas Fir or equivalent.

Note #2: The shoring must be constructed using the dimensions and spacing required by OSHA's Shoring Charts or one designed by a registered professional engineering.





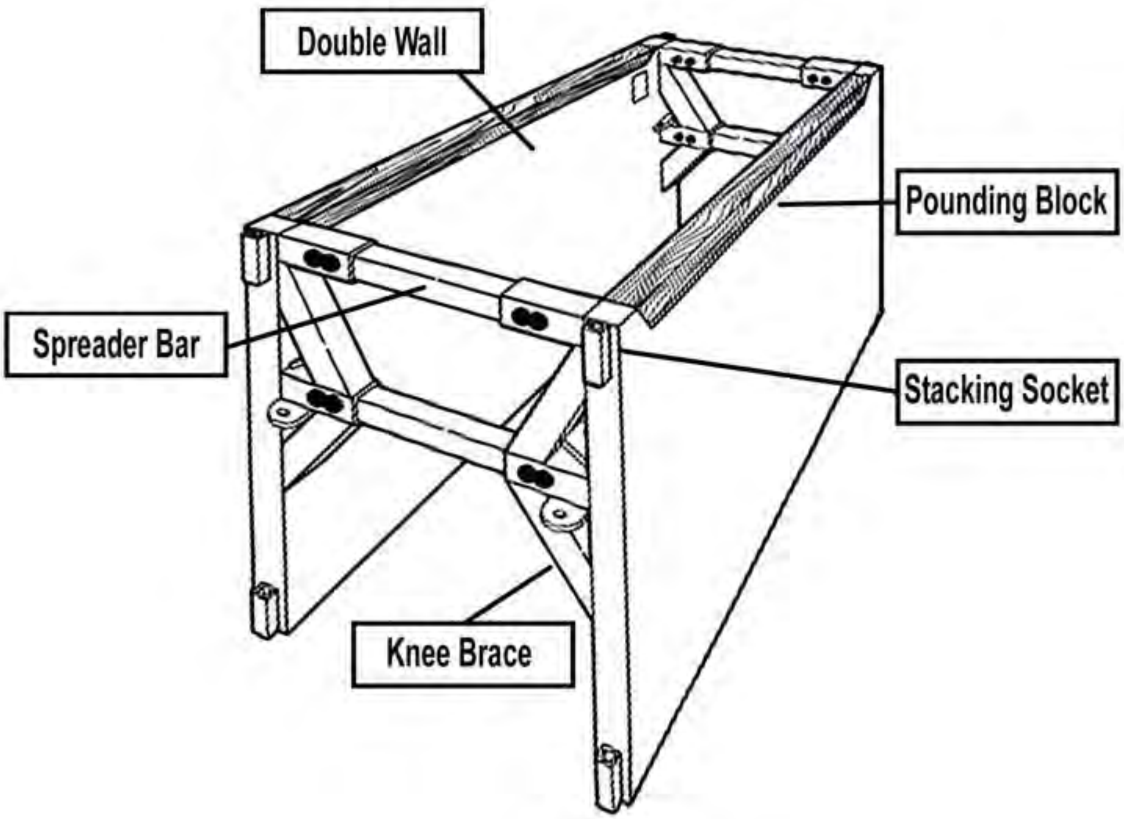
Aluminum Hydraulic Shoring
Aluminum hydraulic shoring is a system that uses extendable aluminum cylinders operated by fluid pressure to support the walls of an excavation. The walls of the excavation are literally jacked apart and supported by the cylinders. Invented in the late 1950s, they were pioneered by the Speed Shore Corporation in the 1960s. The light weight, ease of installation, multiple configurations and ability to compress the soil (which increased its stability) resulted in hydraulic shoring becoming a very popular method.

The Standard requires that the cylinders be a minimum of 2 inches in diameter, and have an axial compressional load rating of at least 17,000 pounds. The aluminum rail to which the cylinders are attached must be 6061t aircraft grade aluminum. Heavy-duty 3-inch cylinders can also be used to support trenches up to 15 feet in width.

Hydraulic shoring is installed and removed from the top of the excavation; no employee exposure is required. Special installation tools (hooks) are used to install vertical and single shores and release the hoses. Walers are typically installed by backhoes using standard rigging bridles.

Shield System
Shielding is accomplished by using a two-sided, braced steel box that is open on the top, bottom, and ends. This "drag shield," as it is sometimes called, is pulled through the excavation as the trench is dug out in front and filled in behind. Operators using a drag shield should always work only within the walls of the shield. If the trench is left open behind or in front of the shield, it could be tempting to wander outside of the shield's protection sometime during the job. In addition, the heavy equipment operator must be very careful to dig trench walls which are straight and are the same width as the drag shield, so that there is no opportunity for a cave-in to start. There have been cases where this was not done, and the shield was literally crushed by the weight of a collapsing trench wall.

One example of a shield system and its use:



Shield systems differ significantly from sloping and shoring systems in that they are not designed to prevent cave-ins, but rather to protect the workers when a cave-in occurs. In a real sense, they function like bomb shelters. They are structures, typically “box-like” in design, that are placed in the excavation to provide worker protection. If installation of a new pipe service is required, the contractor excavates the area for the installation of the first joint, and then lowers the shield in place. After the first joint is installed and aligned, the excavator backs up, excavates in front of the shield, then pulls it forward by either pulling on the spreader bars, or a pulling bridle attached to pulling lugs on the front of the shield. After the next joint of pipe is installed, the process is repeated.

Shields have become the preferred means of providing worker protection when possible, due to their ease of use, the minimum time required to install, move, and remove them, the minimum right of way requirements, and the fact that they can be used in unstable soils where vertical walls cannot be reliable.

OSHA does not provide an Appendix for the use of shield systems. What guidance they do provide is found in the General Requirements for Protective Systems in 1926.652. Those paragraphs require the following:

1. Shields must be designed by a registered professional engineer.
2. Shields cannot be used in excess of the loads they are rated for.
3. You cannot make any additions to, any subtractions from, or any alterations to any shield without written consent from the manufacturer or designing engineer.
4. Any structural damage, such as bending a spreader bar or breaking a socket weld, is cause for taking the shield out of service until repairs have been made in accordance with manufacturer's guidelines and requirements.
5. Shields must be installed in a manner to restrict lateral movement. While OSHA does not officially permit a gap between the shield wall and the excavation, they are aware that the contractor intends to raise, lower and pull the shield, so they "unofficially" allow about 4" as long as there is no danger of an employee being injured if the box were to shift the distance of that gap if a cave-in were to occur.
6. If the shield does not reach the top of the excavation, the section above the shield must be sloped to a point at least 18" below the top of the shield, or, if the shield is designed for use in a stacking configuration, a second shield may be stacked atop it.
7. Workers may remain inside a shield when it is pulled forward, but they cannot remain in it when it is installed, removed, or raised vertically.
8. Workers must enter and exit the shield in a protected area, which is to say a ladder used for that purpose must be inside the shield, not outside it in the unprotected trench.
9. Shields may be raised two feet off the bottom of the trench as long as it is rated for the full depth of the excavation, and as long as no soil caves out from under it.
10. The workers must not be exposed to walls at the end of the trench. If the trench cannot be sloped in front of the shield, end plates must be installed to protect the workers from cave-ins at the open end.

Trench Boxes or Shields:

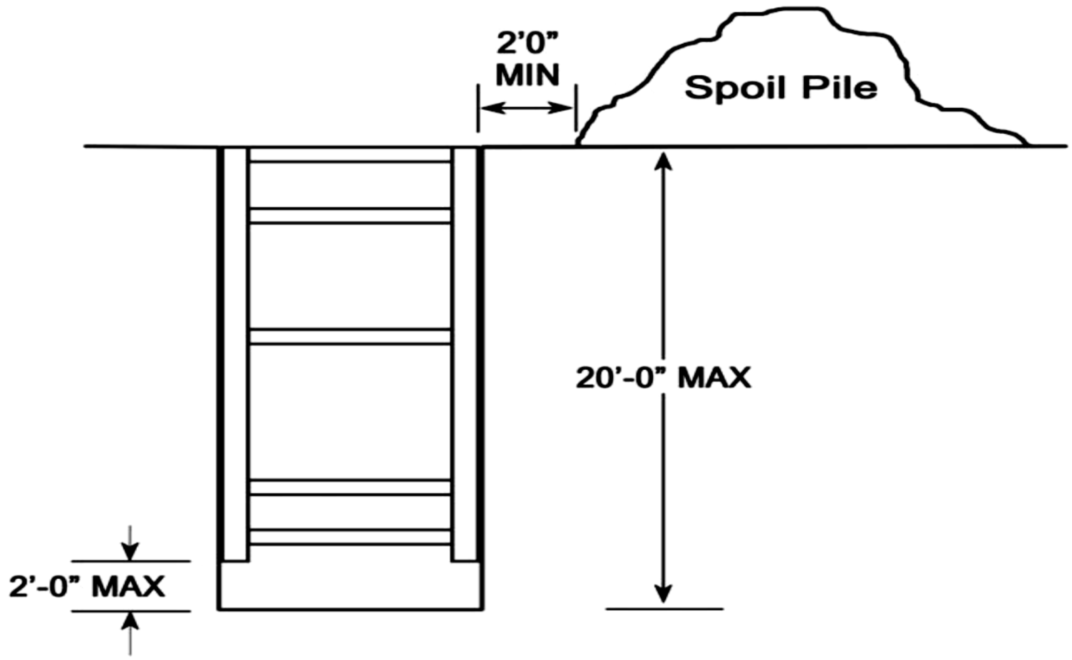
- May be production type or custom made of steel, aluminum, or other equivalent material.
- Must be regularly inspected and properly maintained.
- Must be properly used under the direction of a competent person.

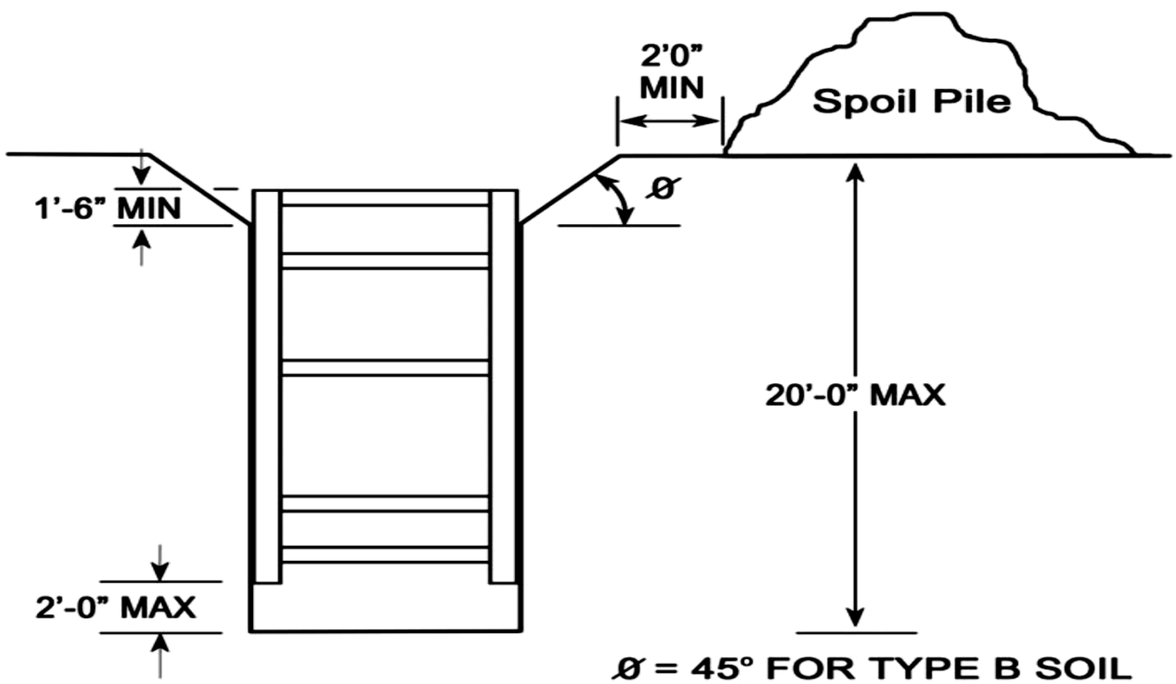
Combined use of Sloping and Benching:

Trench boxes are generally used in open areas, but they also may be used in combination with sloping and benching. The box should extend at least 18 inches (0.45 meters) above the surrounding area if there is sloping toward excavation. This can be accomplished by providing a benched area adjacent to the box.

Earth excavation to a depth of 2 feet (0.61 meters) below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench and there are no indications while the trench is open of possible loss of soil from behind or below the bottom of the support system.

Shield Installation





REMEMBER:

Pre-planning is vital to accident-free trenching; safety cannot be improvised as work progresses.

Other Hazards

Falls and Equipment

In addition to cave-in hazards and secondary hazards related to cave-ins, there are other hazards from which workers must be protected during excavation-related work. These hazards include exposure to falls, falling loads and mobile equipment. To protect employees from these hazards, OSHA requires the employer to take the following precautions:

- Keep materials or equipment that might fall or roll into an excavation at least 2 feet (0.61 meters) from the edge of excavations, or have retaining devices, or both.

- Provide warning systems such as mobile equipment, barricades, hand or mechanical signals, or stop logs to alert operators of the edge of an excavation. If possible, keep the grade away from the excavation.

- Provide scaling to remove loose rock or soil or install protective barricades and other equivalent protection to protect employees against falling rock, soil or materials.

- Prohibit employees from working on faces of sloped or benched excavations at levels above other employees unless employees at lower levels are adequately protected from the hazard of falling, rolling or sliding material or equipment.

- Prohibit employees under loads that are handled by lifting or digging equipment. To avoid being struck by any spillage or falling materials, require employees to stand away from vehicles being loaded or unloaded. If cabs of vehicles provide adequate protection from falling loads during loading and unloading operations, the operators may remain in them.

Water Accumulation:

The standard prohibits employees from working in excavations where water has accumulated or is accumulating unless adequate protection has been taken. If water removal equipment is used to control or prevent water from accumulating, the equipment and operations of the equipment must be monitored by a competent person to ensure proper use.

OSHA standards also require that diversion ditches, dikes or other suitable means be used to prevent surface water from entering an excavation and to provide adequate drainage of the area adjacent to the excavation. Also, a competent person must inspect excavations subject to runoffs from heavy rains.

Hazardous Atmospheres:

Under this provision, a competent person must test excavations greater than 4 feet (1.22 meters) in depth as well as ones where oxygen deficiency or a hazardous atmosphere exists or could reasonably be expected to exist, before an employee enters the excavation. If hazardous conditions exist, controls such as proper respiratory protection or ventilation must be provided. Also, controls used to reduce atmospheric contaminants to acceptable levels must be tested regularly. Where adverse atmospheric conditions may exist or develop in an excavation, the employer also must provide and ensure that emergency rescue equipment, (e.g., breathing apparatus, a safety harness and line, basket stretcher, etc.) is readily available. This equipment must be attended when used.

Employees must not be permitted to work in hazardous and/or toxic atmospheres. Such atmospheres include those with:

Less than 19.5 percent or more than 23.5 percent oxygen; combustible gas concentration greater than 20 percent of the lower flammable limit; and concentrations of hazardous substances that exceed those specified in the Threshold Limit Values for Airborne Contaminants established by the American Conference of Governmental Industrial Hygienists.

When testing for atmospheric contaminants, the following should be considered:

- Testing should be conducted before employees enter the trench and should be done regularly to ensure that the trench remains safe. The frequency of testing should be increased if equipment is operating in the trench. Testing frequency should also be increased if welding, cutting or burning is done in the trench.

- Employees required to wear respiratory protection must be trained, fit-tested and enrolled in a respiratory protection program. Some trenches qualify as confined spaces. When this occurs, compliance with the Permit-Required Confined Space Standard is also required.

REMEMBER TO INSPECT OFTEN:

A competent person must inspect the trench and document any findings. The following guide specifies the frequency and conditions requiring inspections:

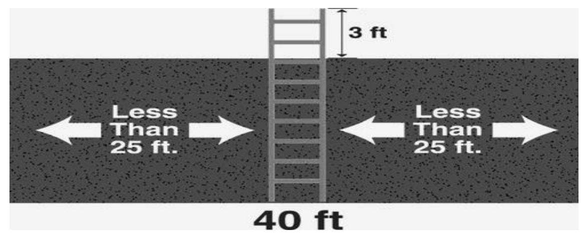
- Daily and before the start of each shift.
- As dictated by the work being done in the trench.
- After every rainstorm.
- After other events that could increase hazards, e.g. snowstorm, windstorm, thaw, earthquake, etc.
- When fissures, tension cracks, sloughing, undercutting, water seepage, bulging at the bottom or other similar conditions occur.
- When there is a change in the size, location or placement of the spoil pile.
- When there is any indication of change or movement in adjacent structures.

Accidents at the site of trenching and shoring activities are all too common. Almost anyone working for several years in this field can remember personally witnessing or being told about a real life incident where workers were injured or killed in a cave-in. It does not matter how short a time you might work in a trench, if there is no adequate cave-in protection provided you could easily be buried under tons of dirt. THERE IS USUALLY NO WARNING AND NO TIME TO ESCAPE.

OSHA REQUIREMENTS STATE THAT ADEQUATE PROTECTION IS ABSOLUTELY REQUIRED IF THE TRENCH IS FIVE (5) FEET OR MORE IN DEPTH. A trench that is less than (5) deep requirements for protection is up to the competent person in charge to determine. In addition, A PERSON DESIGNATED AS QUALIFIED AND COMPETENT TO RECOGNIZE AND EVALUATE HAZARDS MUST BE PRESENT. A COMPETENT PERSON must inspect the equipment, be able to identify the hazards, and have the authority to stop work if conditions warrant. Methods of adequate protection include shoring, shielding, and sloping.

Other Trenching Requirements:
The spoil (dirt removed from the trench) must be placed at least two feet back from the trench.

THE LADDER MUST BE PLACED WITHIN 25 FEET OF THE WORKER AND MUST EXTEND AT LEAST THREE (3) FEET ABOVE THE EXCAVATION WALL.



OVERVIEW:

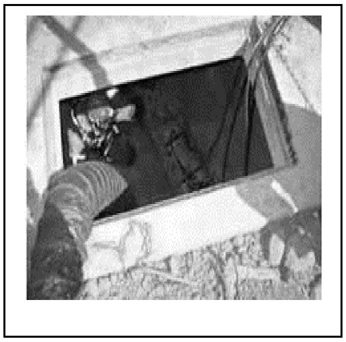
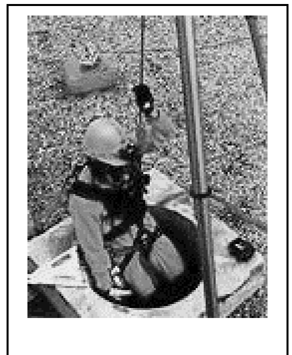
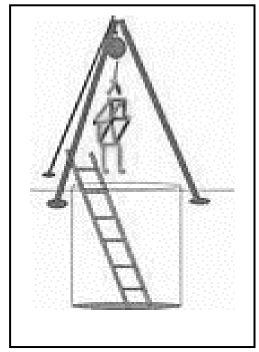
To help ensure safety in trenching and excavations, these specific conditions should be taken into account:

- Soil types and layers.
- Traffic.
- Nearness of structures and their condition.
- Surface and ground water conditions.
- The water table elevation.
- Overhead and underground utilities.
- Weather.

The cooperation of all employees requires their recognition of safety hazards and the necessary safety precautions. Employees should be trained in the following areas:

1. Hazards associated with trenching and excavating.
2. Soil identification.
3. Safe slopes for different soil types and conditions
4. Proper installation and shoring.
5. Stress patterns on trench walls from soil and spoil, equipment, and vibration caused by equipment and traffic.
6. Effects of adjacent buried utilities, building foundations, and lengthy exposure to the elements on trench side walls and other excavations.
7. Effects on trench and excavation conditions from severe weather, such as excess water, freezing temperatures, unexpected heat or prolonged drying.
8. Recognition of buried drums, containers, tanks and wells.

Confined Spaces:

The water and wastewater industry has one of the highest numbers of confined space injuries per capita in the country. The vast majority of confined space related injuries result in fatalities. Another disturbing fact is that 40% of the confined space related fatalities are people who tried to rescue someone else from a confined space.

According to **OSHA's Confined Space Entry Rule**, a confined space is defined as an area large enough for entry with a limited ability to enter and exit and that is not intended for continuous occupancy. One easy way to identify a confined space is by whether or not you can enter it by simply walking while standing fully upright. If you must duck, crawl, climb, or squeeze into the space, it is probably considered a confined space. Any open surface tank that is deeper than four feet is also considered a confined space.

Confined spaces fall into two categories; permit required and non-permit required. A confined space becomes permit required when it has potential for a hazardous atmosphere, potential for engulfment, a hazardous internal configuration, or other recognized hazards such as dangerous equipment or hot work (welding, cutting torch, etc.) that is in progress. The potential for buildup of toxic or explosive gas mixtures, and/or oxygen deficiency exists in many confined spaces found at water and wastewater systems.

Employees entering a permit required confined space must wear a harness and utilize emergency retrieval equipment. Employers must evaluate all workplaces and determine which confined spaces require an entry permit. An entry permit requiring different information might be used for some confined spaces if they are difficult to completely isolate and/or present special hazards.

Job Designations and Responsibilities:

Before entering a permit-required confined space, the **entry supervisor** must prepare and sign an entry permit. The entry supervisor must know the potential hazards of confined spaces, verify that all atmospheric tests have been conducted, and all procedures and equipment are in place before endorsing the entry permit. The entry supervisor also must determine that acceptable conditions continue until the work is completed. The entry permit is "canceled" after a significant break, work is completed or the approved duration of permit has passed, whichever comes first. All canceled entry permits must be kept for at least one year to allow for an annual review of the program.

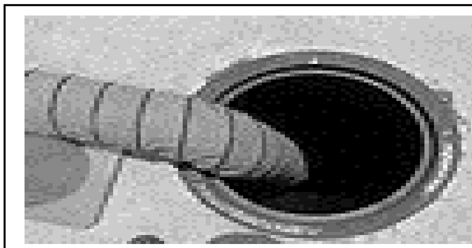
The law also requires that an attendant be stationed outside confined spaces while the work is done (also known as the buddy system). The **attendant** must know the potential hazards of confined spaces, be aware of behavioral effects of potential exposures, and communicate with entrants as necessary to monitor their status. The attendant must remain outside the space until relieved. Attendants also must monitor activities inside and outside the permit space and order exit if required, summon rescuers if necessary, prevent unauthorized entry into confined space, and perform non-entry rescues. An attendant may not perform other duties that interfere with the primary duty of monitoring and protecting the safety of authorized entrants.

All authorized **entrants** (persons entering the confined space) must be trained in the hazards they may face, be able to recognize signs or symptoms of exposure, and understand the consequences of exposure to hazards. They must also know how to use any needed equipment, communicate with attendants as necessary, alert attendants when a warning symptom or other hazardous condition exists. Entrants must exit as quickly as possible whenever ordered or alerted to do so. All contractors must be provided information by the system owner on permit spaces and likely hazards that the contractor might encounter. Joint entries must be coordinated.

Special training is necessary to provide all employees with the understanding, skills and knowledge to perform their individual duties. Training is required for all new employees and whenever duties change, the hazards in a space change, or whenever an evaluation shows a need for additional training.

Rescue services (either on-site or off-site) must be readily available and able to be summoned quickly. On-site teams must be properly equipped. They must receive the same training as authorized entrants plus additional training on how to use personal protective and rescue equipment and first aid training, including CPR. Simulated rescues must be performed at least once every 12 months. Outside rescue services must be made aware of hazards and receive access to comparable permit spaces to develop rescue plans and practice rescues.

Ventilation and Continuous Monitoring:
CONFINED SPACES MUST BE PROPERLY VENTILATED USING SPECIALLY DESIGNED FORCED-AIR VENTILATORS.
This crucial step must be taken even if gas detection and oxygen-deficiency detection instruments show the atmosphere to be safe. Because some of the likely found gases are explosive, the blowers used must be specially designed to be intrinsically safe. This means that the blower itself will not create a spark and cause an explosion.



THE ATMOSPHERE MUST BE CONTINUOUSLY CHECKED WITH RELIABLE, CALIBRATED INSTRUMENTS. Several instruments are available that check for toxic gases, flammable gases, and for oxygen deficiency.

Some of the Common Dangerous Gases Found in Wastewater Treatment Plants and Collection Systems					
Name Of Gas	**Chemical Formula**	**Specific Gravity (Air = 1.00)**	**Explosive Range (% in air) LEL UEL**	**Common Properties**	**Physical Effects**
Methane	CH_4	0.55	5.0% 15.0%	Colorless Tasteless Flammable Explosive	Asphyxia; Doesn't support life.
Hydrogen Sulfide	H_2S	1.19	4.5% 46%	Rotten-egg odor Colorless Flammable Explosive Poisonous	Death in a few minutes at 0.2%, Paralyzes respiratory center, Odor not detectable at high levels.
Carbon Dioxide	CO_2	1.53	Not flammable	Colorless Tasteless Odorless	10% can't be endured for more than 10 min. Acts on nerves of respiration.
Chlorine	Cl_2	2.5	Not flammable Not explosive	Greenish-yellow Strong odor, Highly corrosive, Highly toxic.	30 ppm coughing 40-60 ppm dangerous 1000 ppm fatal in a few breaths

Hydrogen Sulfide Issues:

Hydrogen sulfide is generated by anaerobic bacteria in slow moving wastewater such as that which sits in a long force main or a pump station wet well or conditions such as low pH or high temperature. The hydrogen sulfide is released when the wastewater undergoes turbulence or aeration. The hydrogen sulfide is converted to sulfuric acid by other bacteria on the pipe wall and corrosion of the pipe wall begins to take place. Hydrogen sulfide is a major source of odors and corrosion in collection systems. Hydrogen sulfide corrosion may cause structural failure of the affected component.

HYDROGEN SULFIDE IS AN ACUTELY TOXIC MATERIAL THAT IS DANGEROUS TO HUMAN HEALTH AND HAS BEEN RESPONSIBLE FOR THE DEATHS OF A NUMBER OF COLLECTION SYSTEM WORKERS.

Hydrogen sulfide is heavier than air and therefore can be found in the lower portion of manholes. This deadly gas, whose toxicity has been ranked with Hydrogen Cyanide, is colorless and has a characteristic rotten egg smell at low concentrations. As the level of Hydrogen Sulfide increases, workers are generally unaware of its presence. A person's ability to sense dangerous concentrations by smell is quickly lost. If the concentration is high enough, unconsciousness will come suddenly, and will be followed by death if there is not a prompt rescue. It is essential that a collection system utility's safety program contain procedures and training for monitoring for hydrogen sulfide and confined space entry.

Collection systems vary widely in their vulnerability to hydrogen sulfide corrosion. Vitrified clay and plastic pipes are very resistant to hydrogen sulfide corrosion. Concrete, steel and iron pipes are susceptible to hydrogen sulfide corrosion.

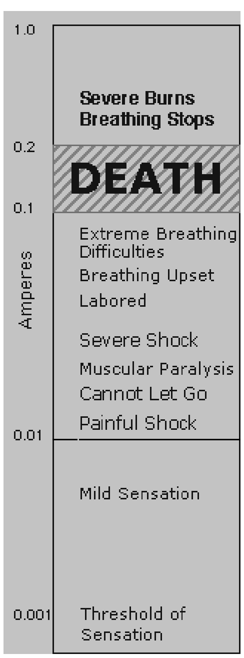
Only non-sparking tools and lamps should be used. Obviously, there should be **no smoking** anywhere near the entrance to a confined space.

Electrical and Mechanical Hazards:

- ELECTRICAL HAZARDS CAN CAUSE SERIOUS INJURY LEADING TO DEATH.
- UNDER NO CIRCUMSTANCES SHOULD PERSONS OPEN AN ELECTRICAL PANEL OR ATTEMPT ELECTRICAL REPAIRS UNLESS THEY ARE BOTH QUALIFIED AND AUTHORIZED.

The Physiological Effects of Electric Shock

The chart shows the physiological effects of various currents. Note that voltage is not a consideration. Although it takes voltage to make current flow, the amount of shock-current will vary, depending on the body resistance between the points of contact.



As shown in the chart, shock is relatively more severe as the current rises. For currents above 10 milliamps, muscular contractions are so strong that the victim cannot let go of the wire that is shocking him. At values as low as 20 milliamps, breathing becomes labored, finally ceasing completely even at values below 75 milliamps.

As the current approaches 100 milliamps (0.1 amp), ventricular fibrillation of the heart occurs - an uncoordinated twitching of the walls of the heart's ventricles which results in death.

Above 200 milliamps (0.2 amp), the muscular contractions are so severe that the heart is forcibly clamped during the shock. This clamping protects the heart from going into ventricular fibrillation, and the victim's chances for survival are good.

http://www.physics.ohio-state.edu/~p616/safety/fatal_current.html

In the event of electrical shock, the following steps should be taken:

Step 1. Survey the scene and see if it is safe to enter.
Step 2. If necessary, free the victim from a live power source by shutting power off at a nearby disconnect, or by using a dry stick or some other non-conducting object to move the victim.

Step 3. Send for help, calling 911 or whatever the emergency number is in your community. Check for breathing and pulse. Begin CPR immediately if needed.

There are several things to keep in mind whenever working on electrical equipment:

1. Always lockout and tagout any electrical equipment being serviced. NEVER remove someone else's lock or tag.

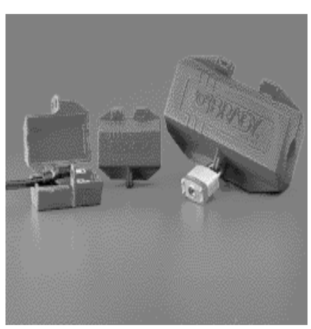
2. Use only grounded power tools.

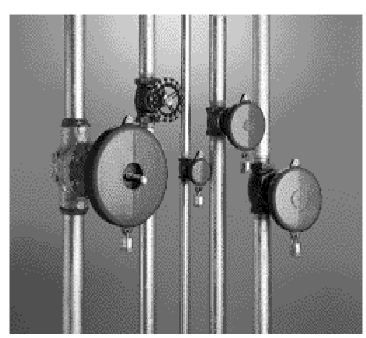
3. Do not use metal ladders when working on electrical equipment.

4. Only trained and legally licensed persons working in pairs should attempt electrical repairs.

Lock Out/Tag Out

Lock out/tag out (LOTO) According to OSHA law, all equipment that could unexpectedly start-up or release stored energy must be locked out or tagged out to protect against accidental injury to personnel. Regulations deal with the need to isolate a machine from its energy source to prevent it from starting while work is being done in, and around, the equipment. Energy sources can include electrical energy, hydraulic energy, pneumatic energy, thermal energy, and chemical energy. This can be either active energy or stored energy. Stored energy can take many forms. Some examples of stored energy are; electrical energy stored in capacitors, pneumatic energy stored in a compressor tank, and hydraulic water pressure in an isolated line. Any stored energy must be dissipated prior to working on the equipment. Employers are responsible for establishing an “Energy Control Plan” for LOTO work and supply each worker with their individual LOTO locking devices.





LOTO requires workers to isolate and de-energize these sources and lock and tag them prior to working on the equipment or process. Only trained personnel should conduct lock out/tag out procedures. Each individual involved in the work should attach their personal LOTO lock to the disconnection or isolation device. This assures that the equipment cannot be restarted until each individual is finished with their task and is clear of the equipment. Tags are used to provide information regarding the date and nature of the lockout and the individual responsible for removing the lockout. Tags are not substitutes for locks. Any isolation that can be locked must be locked and tagged. Lockout devices may also include chains, valve clamps, wedges, jacks, or key blocks.

Anyone who enters a LOTO work area must be informed that a LOTO situation exists. If they are to be involved in the work, they must also apply their own LOTO locks. Workers that leave a LOTO site must take their LOTO locks with them. If work is not completed at the end of a shift, all LOTO locks must be removed and be replaced with an equipment protection lock until work resumes. If equipment must be temporarily restarted, the LOTO must be removed during the restart and reapplied before work can continue.

A lockout device uses a positive means such as a lock, either key or combination type, to hold the switch in the safe position and prevent the equipment from becoming energized. A tagout device is a prominent warning, such as a tag, which can be securely fastened to the energy isolating device in accordance with an established procedure, to indicate that both it and the equipment being controlled may not be operated until the tagout device is removed.

The basic procedures required for proper lock-out/tag-out are listed below:

1. Notify all affected employees that a lockout or tagout system is going to be utilized and the reason why. The authorized employee should know the type and magnitude of energy that the equipment utilized and should understand the potential hazards.
2. If the equipment is operating, shut it down by the normal stopping procedure.
3. Operate the switch, valve, or other energy isolating device(s) so that the equipment is isolated from its energy source(s). Stored energy (such as that is springs, elevated machine members, rotating flywheels, hydraulic systems, and air, gas, steam, or water pressure, etc.) must be dissipated or restrained by methods such as repositioning, blocking, or bleeding down.
4. Lockout and/or tagout the energy isolating device with your assigned individual lock or tag.
5. After ensuring that no personnel are exposed, and as a check that the energy source is disconnected, operate the push button or other normal operating controls to make certain the equipment will not operate.
   CAUTION! RETURN OPERATING CONTROLS TO THE NEUTRAL OR OFF POSITION AFTER THE TEST.

6. The equipment is now locked out or tagged out and work on the equipment may begin.
7. After the work on the equipment is complete, all tools have been removed, guards have been reinstalled, and all personnel are in the clear, remove all lockout or tagout devices. Operate the energy isolating devices to restore energy to the equipment.

Hazardous Chemicals & Hazards

Hazardous chemicals are present in many areas of the system. The plant laboratory uses a wide variety of acids, bases, and other potentially dangerous compounds. Water system operators will also likely come in contact with various forms of chlorine. Each worker should be trained in safe chemical and handling procedures as required by the Rules for Oklahoma Hazard Communication Standard. These rules are based on a federal law designed to help minimize injuries among workers from chemical overexposure.

A MATERIAL SAFETY DATA SHEET (MSDS) OR SAFETY DATA SHEETS (SDS) IN COMPLIENCE OF THE NEW GLOBALLY HARMONIZED SYSTEM (GHS) FOR EACH AND EVERY CHEMICAL THAT IS PRESENT OR PRODUCED IN THE SYSTEM MUST BE READILY AVAILABLE TO ALL OPERATORS. The MSDS is reliable reference (usually provided by the manufacturer) for the type of hazards the chemical presents and what to do in the case of an emergency. All operators should be familiar with the MSDS through training provided by the employer and personal study.

NEW GLOBALLY HARMONIZED SYSTEM (GHS)

Notable Changes:

- Labels are more defined and will now require:
  - ❖ Product identifier
  - ❖ Pictogram
  - ❖ Signal word
  - ❖ Hazard statement(s)
  - ❖ Precautionary statement(s)
  - ❖ Name, address, and phone number
- Safety Data Sheet (not Material Safety Data Sheet)
  - ❖ Uses a 16 section format

Safety Data Sheets:

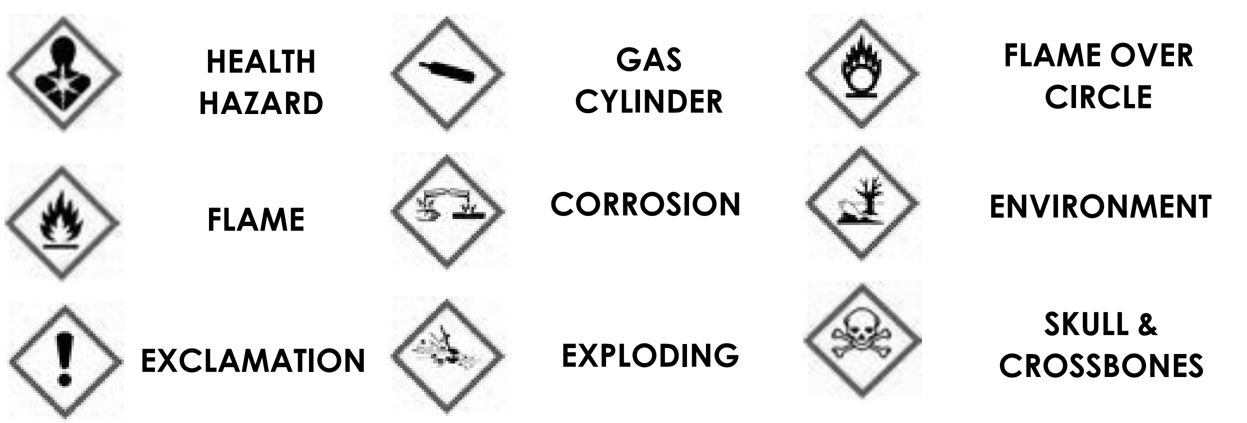
- Mandates 16-section SDS headings, order of information, and what information is to be provided under the headings.
- Will not enforce sections 12-15 that require information outside OSHA's jurisdiction.

16- Section Safety Data Sheet:

1. Identification of the substance or mixture and of the supplier
2. Hazard identification
3. Composition/information on ingredients substance/mixture
4. First aid measures

5. Firefighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure controls/personal protection
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information including information on preparation and revision of the SDS

Pictograms:



Secondary Containers:

- Are not required to be labeled if used immediately by one person.
- Must be labeled if used by more than one person.
- Must be labeled if used/left for more than one shift.

Safely handling chemicals used in daily water treatment is an operator's responsibility. However, if the situation ever gets out of hand, there are emergency teams that can respond with help anywhere there is an emergency. Chemtrec will provide immediate advice for those at the scene of an emergency and then they will quickly alert experts whose products are involved for more detailed assistance and appropriate follow-up. The toll-free Chemtrec number is 1-800-424-9300.

Hazard Communications:
OSHA established the Hazard Communication Standard in 1986. The standard was created to provide an information system on hazardous chemicals for both employers and employees. The Haz-Com Standard requires employers to ensure their employees know what hazardous materials exist in the workplace, how to safely use these materials, and how to deal with any emergencies that arise during use. Employers are required to provide the proper safety equipment, train employees in the safe use of any hazardous materials on a jobsite, and maintain records of both.

Health hazards refer to immediate or long-term harm to the body caused by exposure to hazardous chemicals. Physical hazards like flammability or corrosivity can also cause injury to skin, eyes and the respiratory system. MSDS's are divided into 8 sections:

1. Manufacturers Contact Information
2. Hazardous Ingredients/Identity Information
3. Physical/Chemical Characteristics
4. Fire and Explosion Hazard Data
5. Reactivity Data
6. Health Hazard/First Aid Information
7. Precautions for Safe Handling and Use
8. Control/Cleanup Measures

NFPA Color-Code Warning System

OSHA uses a system based on the **National Fire Protection Association (NFPA)** Diamond Warning Symbol as part of the MSDS information. This code is also required for all container labels. The NFPA symbol has FOUR color-coded, diamond-shaped sections:

The top	(Red) diamond is the Flammability Hazard rating.
The left	(Blue) diamond is the Health Hazard rating.
The right	(Yellow) diamond is the Reactivity Hazard rating.
The bottom	(White) diamond contains special symbols to indicate properties not explained by the other categories.

A **number– based rating system** is used for each section, ranging from 0- least dangerous to 4 – extremely dangerous.

Noise Hazards:
Noise is a hazard often overlooked. Prolonged exposure to high noise levels (85 decibels or greater) can lead to permanent hearing loss. Excessive noise can come from motor rooms, lawn mowers, and other tools and equipment. Noise levels should be checked using a noise dosimeter. In general, if you have to shout or cannot hear someone talking to you in a normal tone of voice, the noise level is excessive. Hearing protection such as ear plugs or muffs is required if the noise cannot be eliminated.

Physical Hazards:
In addition to the common cause of injuries listed previously are physical hazards such as moving machinery, automatically operated equipment, and obstructing pipes or walkways. Some of these are called built-in hazards because they are built into the plant. Built-in hazards should be modified if possible, or clearly labeled, and personnel should be made aware of the hazard. Protective clothing is needed by all operators. Hardhats and steel-toed shoes are often appropriate.

Other ways of avoiding injuries from physical hazards are to use the proper ladder or tool for job, fill in holes, or post barricades, put additional tread on the steps, and paint slick areas with pumice paint. Emphasis should be put on good housekeeping as a way to eliminate accidents.

Oil, water, polymer, or other debris left in walkways causes many slips and falls. Cleaning up spills as they occur and using oil soak or oil soak booms can eliminate much of this. Placing trash barrels in all areas of the facility will help stop clutter. Enforcing good housekeeping habits among all workers is a must.

Traffic Hazards:

Traffic controls are absolutely essential for those working in the **distribution system**. This is important for line maintenance workers, meter readers, field samplers, and others. Some of the precautions you can take to eliminate injury from traffic are to:

1. **Avoid** working in rush-hour traffic.

2. **PUT** up warnings or post a flagman 500 FEET ahead of oncoming TRAFFIC.

3. **Always** use warnings, including VESTS AND FLASHING LIGHTS.

5. **PLACE** a barrier between the workers and the traffic, such as a truck. The general rule for effective barriers: the bigger, the better.

Infectious Agents:
Infectious agents are present in wastewater. It is commonly known that wastewater carries a host of pathogenic organisms. There are several ways that the risk of becoming infected can be reduced.

1. **Cover ALL open wounds**. Clean wounds immediately and frequently thereafter.
2. **Do NOT smoke, eat, or drink in WORK AREAS,** and wash thoroughly before doing so.
3. **Do NOT** wear work clothes or shoes home if possible. Don't wash work clothes with other laundry.
4. **Follow** your doctor's recommendations for adult immunization and boosters.

Bloodborne Pathogens:
Bloodborne pathogens are infectious materials in blood that can cause disease in humans, including: Hepatitis B (HBV), Hepatitis C (HCV), and Human immunodeficiency virus, or HIV. Workers exposed to these pathogens risk serious illness or death.

Bloodborne pathogens are spread by contact with another person's blood or bodily fluids on non-intact skin which includes any body fluid contaminated with blood. These contacts can be caused when another person's blood or bodily fluids on mucous membranes such as your eyes, nose or mouth. Contact with contaminated sharp objects such as needles, construction debris, broken glass, sharp metal, or wire.

Regulations governing exposure to bloodborne pathogens are mandated by OSHA. It is the employer's responsibility to develop an exposure control plan and provide training to those workers potentially exposed to bloodborne pathogens that may be present in body fluids.

First Aid procedures should outline the appropriate response for an employee to follow when rendering First Aid. First Aid Kits should contain disposable gloves and biohazard bags to contain contaminated bandages or gauze.

Employers must provide **post-exposure follow-up** to any worker who experiences an exposure incident, at no cost to the worker. Employers must offer this training on initial assignment, then at least annually.

Hepatitis B Vaccination:
The best defense against Hepatitis B is to be vaccinated. These vaccinations are to be provided free of charge to all employees who are exposed to blood or other potentially infectious materials as part of their job duties, and vaccinations must be offered within 10 days of initial assignment as required by the new OSHA standard covering bloodborne pathogens.

Fire Protection:
The best fire protection the plant operator can provide is fire prevention. Fire hazards can be easily removed and the local fire department can give advice on fire prevention in and around the treatment plant. Fire classification is important for determining the type of fire extinguisher needed to control the fire. Fires are classified as:

		A Wood, paper, textiles and other carbonaceous materials.	B Flammable liquids, petrols and spirits.	C Flammable gasses. For example propane and butane.	D Fires involving burning metals.	Fires caused by electrical equipment where electric current may be present.	F Cooking oil and fat. For example olive oil, maize oil, lard and butter.
Water		✓	✗	✗	✗	✗	✗
Foam		✓	✓	✗	✗	✗	ABF Foam Only
Dry Powder		✓	✓	✓	✗	✓	✗
M28/L2		✗	✗	✗	✓	✗	✗
CO2 Gas		✗	✓	✗	✗	✓	✗
Wet Chemical		✓	✗	✗	✗	✗	✓

Personal Protective Equipment:
A Personal Protective Equipment (PPE) evaluation should be completed by the employer for each task performed by the employee and adequate protection should be provided. Hazards to be analyzed and protection provided for include: eye protection, fall protection, foot protection, hand protection, head protection, hearing conservation, and respiratory protection.
PPE may be uncomfortable and increase stress, but is for your protection. When wearing PPE, the body's ability to cool is usually diminished. Nevertheless, PPE is frequently required to reduce the risk of injury. PPE includes steel-toed boots, safety glasses or goggles, face shields, earplugs, gloves and/or chemical protective clothing.

Respiratory protection equipment is commonly used because of the danger of inhalation, which provides a route of entry into the bloodstream for dangerous volatile chemicals. There are 2 types of respiratory protection devices called respirators: air purifying and air supplying. Both consist of a face piece connected to either an air source or an air-purifying device. The air-purifying respirator uses cartridges with filters to purify air before it is inhaled. This type of protection is not adequate in an oxygen deficient atmosphere.

Respiratory Protection Training Requirements in OSHA Standards and Training Guidelines:
(k) Training and information. (1) The employer shall ensure that each employee can demonstrate knowledge of this PPE
(2) Training shall be conducted in a manner that is understandable to the employee.
(5) Retraining shall be administered annually and when the following situations occur:
(i) Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly. Respirators shall not be worn when conditions prevent a good face seal. Such conditions may be a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses. Also, the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors shall be evaluated by periodic check. To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator. This may be done by following the manufacturer's facepiece fitting instructions.

Process Safety Management Plan (OSHA):
The main objective of the Process Safety Management (PSM) of highly hazardous chemicals is to prevent unwanted release of hazardous chemicals, especially into locations that could expose employees and others to serious hazards. With this objective in mind in 1992, OSHA issued one of its most comprehensive regulations - Process Safety Management of Highly Hazardous Chemicals (29 CFR 1910.119). Since PSM only has one class level it is mirrored to the EPA's RMP Level 3 Checklist.

The standard applies to water or wastewater treatment facilities that process chemicals over threshold amounts: such as chlorine gas at 1500 pounds under OSHA guidelines. It describes tasks to be performed, data to be recorded, operation conditions to be maintained, samples to be collected, and safety and health precautions to be taken.

Risk Management Program (EPA):
The purpose of a Risk Management Program is to prevent or minimize the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals. The standard applies to water or wastewater treatment facilities that process chemicals over threshold amounts: such as chlorine gas at 2500 pounds

Program Levels:
- Program 1
  No history of offsite accidents, No public receptors and ER coordinated w/ local emergency organizations
- Program 3
  Industries subject to OSHA Process Safety Management, Complex processes –NH3 refrigeration, refineries, pulp & paper mills, fertilizer manufactures, industrial gas manufacturing, water treatment plants/wastewater treatment plants
- Program 2
  Not eligible for Program 1 or 3. Bulk storage and distribution of chemicals, fertilizer wholesalers, frozen and dehydrated food manufactures, Content of Program.

Hazard Assessment
The potential worst-case and more probable accidental release scenario. 5 yr accident history. Prevention Program – Safety information, hazard review/analysis, operating procedures, mechanical integrity/maintenance, employee training. Emergency Response – Emergency response plan or program, employee training, procedures for informing the public and local responders.

Chemical Hygiene Plan
This program describes various chemicals in use in the laboratory, PPE to be used in handling them, and precautions to be used by designated personnel in case of spills or release. A primary and secondary response person shall be designated in the plan to respond to spills.

Personal Responsibility for Safety
Based on past studies, the water and wastewater industry has one of the highest injury rates in the nation. Workers in these areas are involved in construction and excavations, confined spaces, hazardous chemicals, and mechanical equipment that pose a serious injury risk when proper training, equipment, and procedures are not utilized. The final lesson to remember about safety is that it is your life and health, and that of your co-workers, which are to be protected. THE FINAL RESPONSIBILITY LIES WITHIN YOU.

The **Occupational Safety and Health Administration (OSHA)** is responsible for developing regulations regarding worker safety and protection. However, DENIAL OF REQUESTS FOR LEGALLY REQUIRED SAFETY GEAR OR OTHER UNRESOLVED SAFETY VIOLATIONS VILATIONS SHOULD BE REPORTED TO THE:

Oklahoma State Department of Labor
Public Employees Health and Safety Division
(405) 528-1500 ext. 226

ADDITIONAL SAFETY INFORMATION
The 2002 Keller's Official OSHA Safety Handbook, 5th Edition, is provided for general safety information. Additional operator safety information is summarized below.

Most importantly, always approach each job with the question, "HOW CAN I DO THIS SAFELY?"

Environmental Hazards

Heat Stress

Heat stress is caused by a number of interacting factors, including environmental conditions, clothing, workload, etc., as well as the physical and conditioning characteristics of the individual.
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Heat Rashes

Heat rashes are one of the most common problems in hot work environments. Prickly heat occurs in skin that is persistently wetted by unevaporated sweat, and heat rash papules may become infected if they are not treated. In most cases, heat rashes will disappear when the affected individual returns to a cool environment.

Heat Cramps

Heat cramps are usually caused by performing hard physical labor in a hot environment. Thirst cannot be relied on as a guide to the need for water; instead, water must be taken every 15 to 20 minutes in hot environments.

Heat Exhaustion

Heat exhaustion occurs from increased stress on various body organs due to inadequate blood circulation, cardiovascular insufficiency, or dehydration. Signs and symptoms include pale, cool, and moist skin; heavy sweating; dizziness; nausea; headache; vertigo; weakness; thirst; and giddiness

Heat Stroke

Heat stroke is the most serious form of heat stress. Heat stroke occurs when the body's system of temperature regulation fails and the body's temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. Heat stroke is a medical emergency. The primary signs and symptoms of heat stroke are confusion; irrational behavior; loss of consciousness; convulsions; a lack of sweating (usually); hot, dry skin; and an abnormally high body temperature

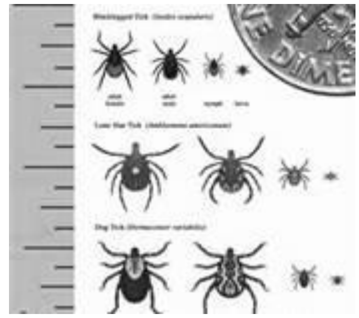
Cold Stress

Cold stress normally occurs in temperatures at or below freezing, or under certain circumstances, in temperatures of 40°F.

Frostbite

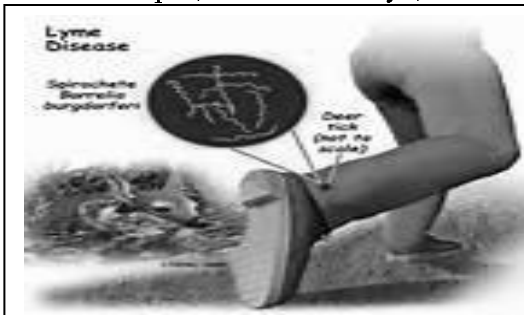
Frostbite is the generic term for a local injury resulting from cold. Several degrees of tissue damage are associated with frostbite.

Biological Hazards
Portions of the field work will be conducted in grassy and wooded areas along the river. Numerous biological hazards may be present, including poison ivy, snakes, thorny bushes and trees, ticks, mosquitoes, and other pests.



Tick-Borne Disease
The following tick-borne diseases may present hazards when conducting field work. These diseases are transmitted primarily by the deer tick, which is smaller and redder than the common wood tick. The disease may be transmitted by immature ticks, which are small and hard to see. The tick may be as small as a period on this page.

Lyme Disease
The disease commonly occurs in the spring and summer and is transmitted by the bite of infected ticks. Symptoms of Lyme disease include a rash or a peculiar red spot, like a bull's eye, which expands outward in a circular manner. The victim may have headache, weakness, fever, a stiff neck, swelling and pain in the joints, and eventually, arthritis.



Tick repellant containing **diethyltoluamide (DEET)** should be used when working in tick-infested areas, and pant legs should be tucked into boots. In addition, workers should search the entire body every three or four hours for attached ticks. Ticks should be removed promptly and carefully without crushing, since crushing can squeeze the disease-causing organism into the skin. A gentle and steady pulling action should be used to avoid leaving the head or mouth parts in the skin.

Poisonous Plants Hazards
Poisonous plants may be present all along the river. Personnel should be alerted to their presence, and instructed on methods to prevent exposure.

Snakes
The possibility of encountering snakes exists, specifically for personnel working in grassy, wooded, and vegetated areas. If a snake bite occurs, an attempt should be made to safely kill the snake for identification. The victim must be transported to the nearest hospital within 30 minutes; first aid consists of applying a constriction band and washing the area around the wound to remove any unabsorbed venom.

Spiders
Personnel may encounter spiders during work activities along the river. Two spiders are of concern, the black widow and the brown recluse. Both prefer dark sheltered areas such as basements, equipment sheds and enclosures, and around woodpiles or other scattered debris. The black widow is shiny black, approximately one inch long, and found throughout the United

States. There is a distinctive red hourglass marking on the underside of the black widow's body. The brown recluse is smaller than the black widow and gets its name from its brown coloring and behavior. The brown recluse is more prevalent in the southern United States. The brown recluse has a distinctive violin shape on the top of its body. The bite of the brown recluse is painful and the bite site ulcerates and takes many weeks to heal completely. If a spider bite occurs, the victim must be transported to the nearest hospital as soon as possible; first aid consists of applying ice packs and washing the area around the wound to remove any unabsorbed venom.

PERSONAL SAFETY:
Sometimes you may be working in remote areas that could potentially put you at risk of getting lost or hurt. You should take the following steps to ensure you can work safely when conducting sanitary surveys and field visits in remote locations:

Plan Ahead:

- Notify your supervisor or a fellow worker that you will be working in a remote area.
- Carry a fully charged cell phone (available for checkout at the regions).
- Always wear your ID badge to clearly identify yourself.
- If you are injured or involved in an accident, report to your supervisor immediately and submit an Accident/Incident Report Form.

Vehicle Safety:

- Always drive defensively and safely. Obey all driving laws, including wearing your seat belt. Be aware of other vehicles and surroundings.
- Know who to call if your vehicle breaks down.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – **Operation of Wastewater Treatment Plants, Vol.1**

Chapter 10 Disinfection and Chlorination
(especially sections 10.3 and 10.4)

California State University, Sacramento – **Operation of Wastewater Treatment Plants, Vol.2**

Chapter 14 Plant Safety and Good Housekeeping

California State University, Sacramento – **Operation and Maintenance of Wastewater Collection Systems, Vol. 1**

Chapter 3 Wastewater Collection Systems
(especially sections 3.700, 3.701, 3.702)

Chapter 4 Safe Procedures
(especially sections 4.4 through 4.7)

Chapter 7 Underground Repair
(especially sections 7.10 through 7.15 and 7.38

Rules for Oklahoma Hazard Communication Standard

Title 40 – Oklahoma Statutes for General Safety and Health

OSHA Confined Space Entry Rule

OTHER STUDY SUGGESTIONS

Study the guidelines from a current OSHA or Oklahoma State Department of Labor bulletin for excavation safety and confined space entry.

Be familiar with local rules for work site setup and traffic control in streets.

For the best information on chlorine handling and safety, obtain the Chlorine Manual from the Chlorine Institute.

SAMPLE QUESTIONS

Class D
The presence of dangerous gases in confined spaces can only be detected by using:

A. the sense of smell.
B. knowledge from past experiences.
C. properly calibrated atmospheric testing and monitoring equipment.

Class C
Before working on a newly installed piece of mechanical equipment, it should be:

A. tagged out only, because the old equipment couldn't take a lock-out device.
B. locked out using all the proper procedures.
C. tagged out only, because it is more convenient and quicker.

Class B
Electrical equipment fires are considered:

A. Class A fires.
B. Class B fires.
C. Class C fires.
D. Class D fires.

Class A
Which of the following should NOT be included in a good operator safety program?

A. total support from the system's top officials and organized from the top to the bottom
B. training at all levels from initial employment to retirement
C. freedom for the immediate supervisor to decide appropriate enforcement action for each case
D. training program which only address general issues

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Chapter 7

Preliminary and Primary Treatment

Suggested Study Guidelines

Class D

Be prepared to answer questions concerning:

- The functions and processes of bar screens, comminutors, and grit chambers.
- The typical locations of primary treatment processes in the sequence of wastewater treatment.
- What is removed from the flow stream as it goes through preliminary treatment processes?
- The location of primary treatment in a typical wastewater treatment sequence.
- What is removed in the sedimentation and flotation processes and how it is removed?
- The basic descriptions of clarifiers.
- How to calculate the detention time for tanks and basins.

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- The operating characteristics and typical problems of
    - bar screens and bar racks
    - comminutors and barminutors
    - grit chambers
    - aerated grit chambers
    - primary clarifiers
    - secondary clarifiers
- How to identify normal and abnormal operating conditions in clarifiers.
- The removal efficiencies associated with primary clarifiers.
- The problems associated with too much sludge detention time in a primary clarifier.
- The ideal detention time for a primary clarifier.
- The special maintenance procedures for preliminary and primary treatment equipment.
- How to calculate surface loading and organic loading rates.
- The special safety hazards and procedures involving preliminary and primary treatment.

Be prepared to answer other questions that require additional personal study.

Class B and Class A

Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

- The process controls available to the operator from sampling and testing information.
- How to troubleshoot causes of poor performance in primary clarifiers.
- The typical design loading rates for primary clarifiers.
- How to calculate weir overflow rates.
- How to calculate the percent of solids removed using data from laboratory test.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

Entry Level Discussion

Purpose of Preliminary Treatment

All types of debris can make its way through collection systems and into wastewater treatment plants. Bottles, sticks, rocks, plastic lids, aluminum cans, rags, sand and silt, etc. These materials must be removed in order to prevent damage to mechanical systems. An important part of a wastewater treatment plant is the equipment used to remove these rough materials before they can do damage to valuable machinery. Equipment used to remove this rough material includes bar screens, comminutors, and grit removal devices. These units are commonly located in the wastewater plant **preliminary treatment** facilities.

Bar Screens

When raw wastewater enters the treatment plant, the first treatment device that it will encounter is the **bar screen**. The bar screen is a set of parallel bars placed in a channel, and they are designed to allow the wastewater to flow through the bars, but with large pieces of debris and solids will be caught on the bars. Bar screens are used to screen the influent flows on a continuous basis, and might be manually or mechanically cleaned. The spaces between the bars on manually cleaned screens will usually be about one inch. Bar spacing on mechanically cleaned bar screens may be somewhat narrower. In addition to the bar screen, some plants may have a **bar rack**. The bar rack is sometimes included in the plant design to be used when the bar screen is being cleaned or serviced.

An important consideration when working with bar screens is the proper disposal of the material that is removed from bar screens. This material must be disposed of quickly using only approved procedures. The screenings should be well drained and taken to a landfill approved to receive such material. Many modern screen designs include equipment used to wash the screening, often with final treated plant effluent, and then to squeeze or otherwise dewater the screenings prior to disposal. These processes reduce both the amount of organic material in the screenings and landfill disposal fees. Landfill tipping fees are usually based on weight of the disposed material.

Manually-Cleaned Bar Screen with Bypass Channel

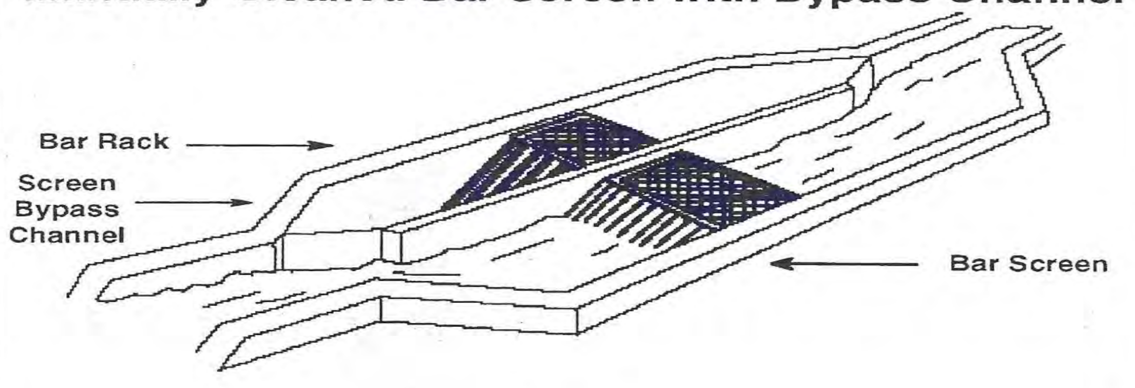


Figure 7.1

Comminution

A **comminutor** is a mechanical device that acts as both a screen and a cutting device. The purpose of the comminutor is to cut solids that were small enough to pass through the bar screen into smaller pieces. Like the bar screen, comminutors are mounted in wastewater flow channels. The material is shredded by the cutters until it is small enough to pass through the opening in the comminutor, and continue on through the system for further treatment. Debris that cannot be cut by the comminutor is rejected and remains on the water surface in front of the comminutor. This debris is removed manually and is disposed of in the same manner as the bar screen material. Most comminutor units have a shallow pit in front to catch heavy debris such as rocks and metal. Periodically, the flow should be shut off to the comminutor so this debris can be removed.

There are many variations of comminuting devices. One type of comminutor has a trade name of "barminutor." This device consists of a bar screen made of U-shaped bars and a rotating drum with teeth and "shear bars." In a barminutor, the rotating drum travels up and down the bar screen shredding the material into smaller pieces.

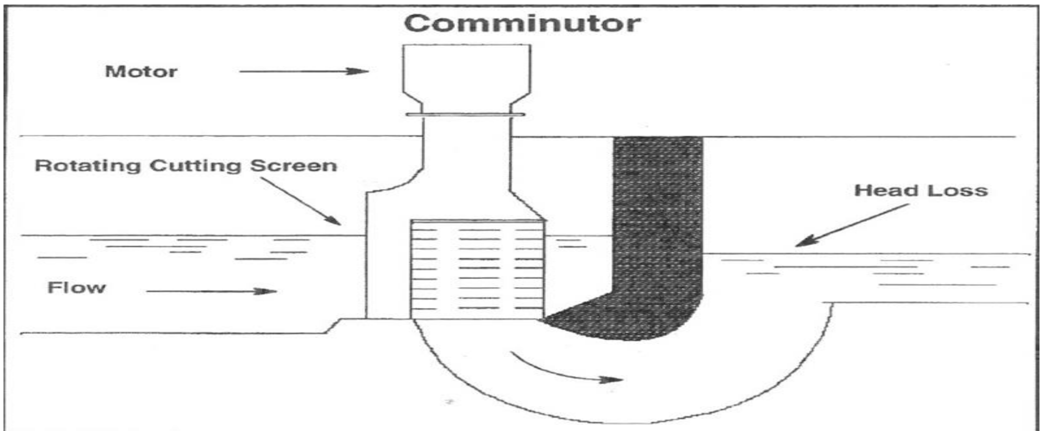


Figure 7.2

Grit Removal

Grit is heavy, mostly inorganic suspended solids that will settle out readily when wastewater flow is slowed down. Grit consists mostly of sand and silt. Eggshells, cinders, snail shells, and other small dense materials are also classified as grit. If grit is not removed, it can cause excessive wear in pumps and damage other treatment process equipment in the treatment process.

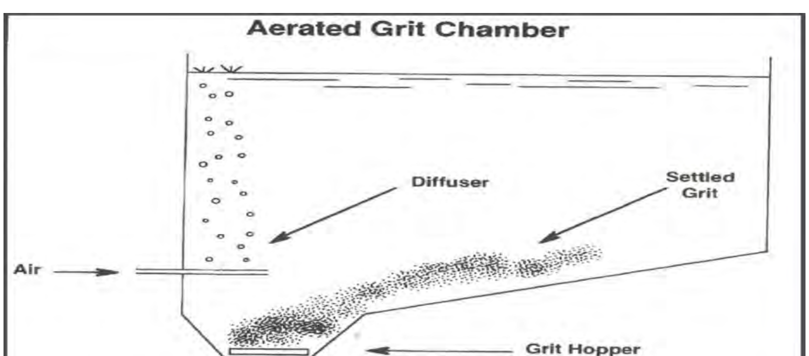


Figure 7.3

The most common method of removing grit is to use channels or basins that reduce the wastewater flow velocity to somewhere between 0.8 and 1.3 feet per second (fps). A velocity of one foot per second is often considered ideal. Velocities in this range will allow the grit to settle out while keeping the lighter organic solids moving along to the next treatment stages. If the velocity is too slow organics will settle with the grit. If the velocity is too fast, inorganic grit will not settle in the grit chamber.

One of the most effective grit removal systems is the aerated grit chamber. The aerated grit chamber is a tank with a sloping bottom and a hopper or collection trough in the lower end. Air is introduced to the water through diffusers located along the wall of the tank above the trough. Utilizing aeration in the grit chamber has two primary advantages, one of which is the reduction of the density of the wastewater. When air is introduced to water, the result is a reduction in the density of the water. This means particles will settle through the water at a faster rate.

Photo of a working aerated grit chamber

Another important advantage of aeration is an increase in dissolved oxygen levels. Aerated grit chambers are frequently constructed at activated sludge plants where there is a readily available air supply, and the pre-aeration is needed to help freshen the wastewater. The older wastewater becomes, the more difficult it is for aerobic organisms to treat the organic wastes present. Increasing the dissolved oxygen content of the wastewater will make the treatment process downstream more effective by reducing the chances of a shock load from anaerobic wastewater.

Although grit consists mainly of inorganic material, it will have organic material on its surface. Therefore, the grit must be disposed of quickly, usually in the same manner as the bar screen material. Many current grit removal system designs often include equipment used to wash grit, often with final treated plant effluent, and then to squeeze, or otherwise dewater, removed grit prior to disposal. These processes reduce both the amount of organic material in the grit and landfill disposal fees. Landfill tipping fees are usually based on weight of the disposed material.

Photo of a grit removal system

Vortex grit removal systems have also proven effective. Eutek describes the operation of their Teacup™ system: Flow enters the stainless steel vessel tangentially at a controlled rate and velocity. The flow regime established in the device forms a free vortex which results in high centrifugal forces and a thin predictable boundary layer. Grit is forced to the outside perimeter or held in suspension until it falls by gravity into the boundary layer which sweeps the grit, but not volatile solids, into the collection chamber at the bottom of the unit. The concentrated slurry is collected in the chamber at the bottom of the unit. Periodically, fluidizing water is added, and the grit is purged from the system. The slurry discharged is clean and ready for dewatering. The water containing the volatile solids exits the top and returns to the WWTP for treatment (courtesy of Eutek).

Eutek Grit Removal "Teacup™"

Flow Measurement
Other devices used at wastewater treatment plants to measure wastewater flow include magnetic flow meters and **rotameters**. Magnetic flowmeters use Faraday's Law of Electromagnetic Induction which states that the voltage generated is Flow Measurement.

Although flow measuring devices do not treat wastewaters, it is necessary to know the quantity of wastewater flow, so adjustments can be made on pumping rates, chlorination rates, and other processes in the plant. Flow rates must also be known for calculating loadings on treatment processes and treatment efficiency. Many treatment plants have a measuring device at the plant headworks.

The most common measuring device found at wastewater facilities is a Parshall flume. Basically, a **Parshall flume** is a narrow place in an open channel which allows the flow to be determined by measuring the depth of flow at a specific point in the flume. The method is widely used for measuring wastewater because its smooth constriction does not offer any protruding sharp edges or areas where wastewater particles may catch or collect behind the metering device.

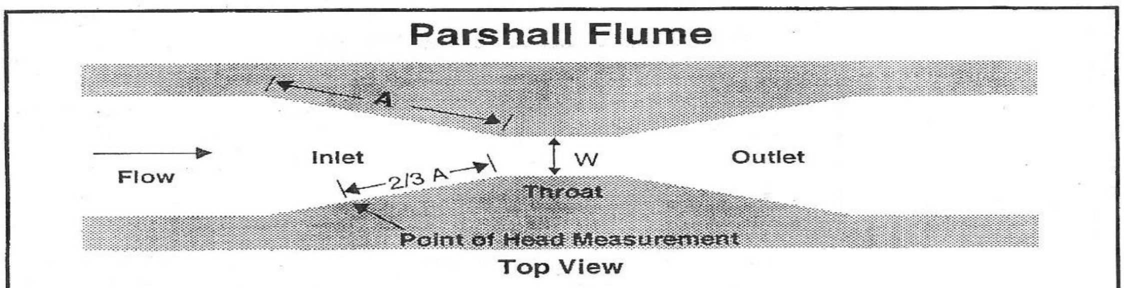


Figure 7.4

Another measuring device used in open channels is a weir. The **weir**, which is placed across the channel, is a wall over which the wastewater may fall. Weirs are usually made of thin metal and may have either a rectangular or V-notch opening. The flow rate over the weir is mathematically determined from the depth (the head) of the wastewater going through the opening. A disadvantage of a weir is the relatively dead water space that occurs just upstream of the weir. If the weir is located before primary treatment (sedimentation and flotation), organic solids will likely settle out in this area. If solids settle out, odors and unsightliness may occur. Also, as the solids accumulate, the flow reading may become incorrect.

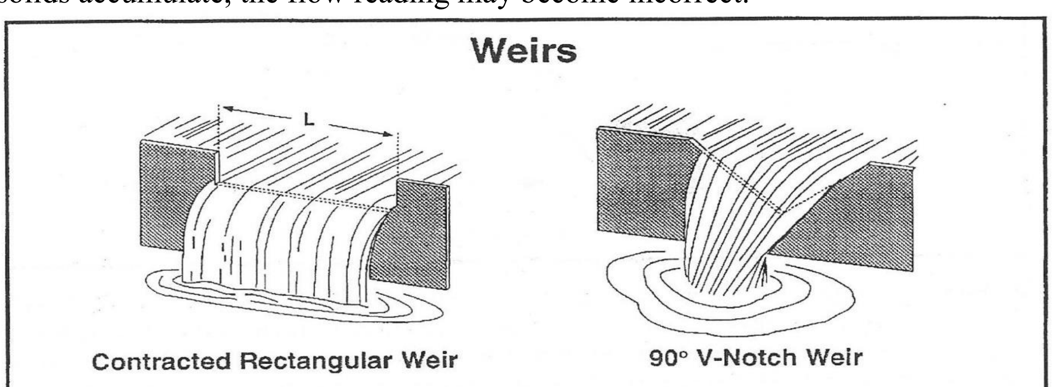


Figure 7.5

Other devices used at wastewater treatment plants to measure wastewater flow include magnetic flow meters and **rotameters**. Magnetic flowmeters use Faraday's Law of Electromagnetic Induction to establish the flow of the liquid in a pipe; a magnetic field is generated and moved into the liquid flowing throughout the pipe. The flow of a conductive liquid into the magnetic field will start a voltage signal to be sensed by electrodes positioned on the flow tube walls, and when the fluid moves faster, additional voltage is generated. Faraday's Law says that the voltage generated is proportional to the progress of the flowing liquid. The electronic transmitter processes the voltage indicator to establish liquid flow. Magnetic flowmeters calculate the velocity of conductive liquids in pipes, such as water, acids, caustic, and slurries, and also they can calculate properly when the electrical conductivity of the liquid is higher than approximately 5mS/cm. You should be careful because using magnetic flow meters on liquids with little conductivity, like de-ionized water, boiler feed water, or hydrocarbons, can resolute in flow meter turning off and measuring zero flow. Since this type of flow meter doesn't block flow it can be applied to clean sanitary, dirty, corrosive, and harsh fluids.

A rotameter is a device that measures the flow rate of liquid or gas in a closed tube. It belongs to a class of meters called variable area meters, which measure flow rate by allowing the cross-sectional area the fluid travels through, to vary, causing a measurable effect.

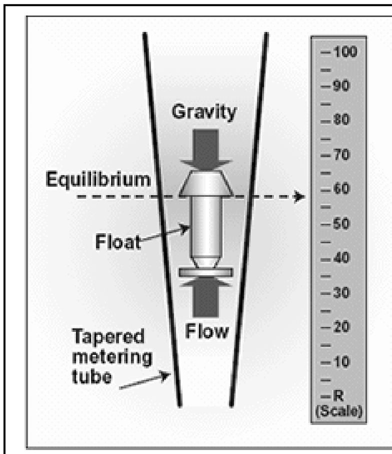


FIGURE 1. A float of given density, establishes an equilibrium position in a tapered tube. At a given flowrate, the upward force of the flowing fluid equals the downward force of gravity

Examples of Rotameters

Sedimentation and Flotation

In most municipal wastewater plants, the phase that immediately follows preliminary treatment is **sedimentation and flotation**, usually referred to as the **primary clarification**. The primary clarifier is a settling basin that is designed to remove settleable solids from the wastewater via sedimentation and to remove materials such as oil and grease by flotation.
Typically, wastewater treatment plants will have clarifiers located at two different locations in the treatment system. The clarifiers that immediately follow preliminary treatment processes are

called primary clarifiers. Clarifiers designed to remove solids after secondary treatment processes are called **secondary clarifiers**.

One of the major differences between primary and secondary clarifiers is the density of the sludge handled. Sludge that settles out in the primary clarifier has not been biologically treated. Therefore, it is usually denser, and will have a higher solids content than sludge that settles out in the secondary clarifier. The effluent from the secondary clarifier will also be much cleaner and clearer than the primary effluent.

The term "sedimentation and flotation" refers to the fact that in primary clarifiers solids float to the top as well as settle to the bottom. The solids that settle out in a clarifier are referred to as the **raw sludge**. The raw sludge is usually scraped to one end if the clarifier is rectangular or to the middle if it is a circular clarifier. A sump will then move the sludge to the sludge handling or sludge disposal system.

The solids that float to the surface of a primary clarifier are referred to as **scum** and are removed by mechanical skimming devices called **skimmers**. Disposal methods for the skimmed solids will vary from plant to plant. If this material is sent to the digester along with the raw sludge, it may cause problems for the digester.

Primary clarifier in service.

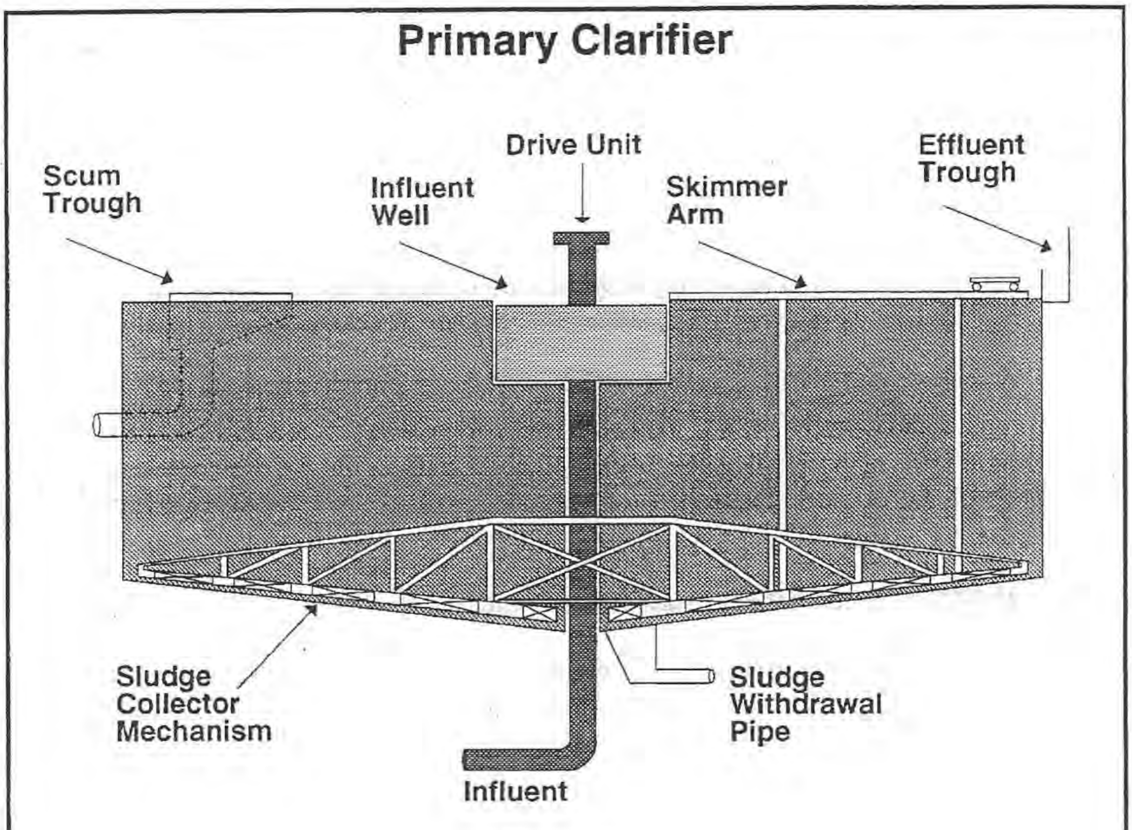


Figure 7.6

Removal Efficiencies for Primary Sedimentation

Primary clarifiers are designed to remove as much of the settleable suspended solids as possible, and will also remove a significant percentage of the total solids and BOD in the wastewater influent. If a primary clarifier is operated properly, you should expect to obtain the approximate removal efficiencies shown below.

Settleable Solids	90% to 99%
Total Suspended Solids (TSS)	50% to 70%
Total Solids	10% to 15%
Biochemical Oxygen Demand (BOD)	20% to 40%
Bacteria	25% to 75%

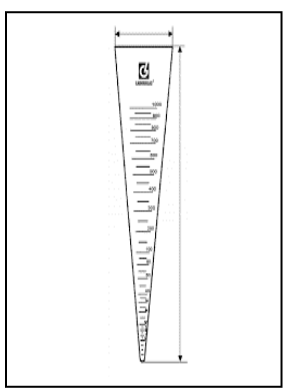
If a plant is not obtaining these removal efficiencies, it indicates that it is overloaded or improperly operated and /or maintained. A primary clarifier should have a minimum detention time of about two hours. The velocity of the water through a clarifier should be no more than about 0.05 feet per second (fps) in order to allow good settling and achieve optimum removal efficiencies. The surface settling rate for primary tanks should not exceed 1,000 gpd/ft^2 at design average flows.

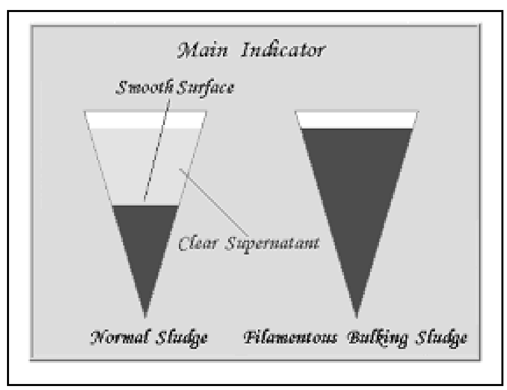
Sludge Pumping Rates
A common operational problem associated with primary clarifiers is inadequate sludge removal from the primary clarifier. Experience at many plants has demonstrated that a given amount of settled sludge should not be allowed to remain in the clarifier for more than four hours to avoid having the sludge go septic. Septic conditions will result in the production of gases which attach to the particles of sludge causing them to float back to the surface. This is called **sludge gasification** or burping, and can result in solids carryover as well as a reduction in overall treatment efficiency.

Sludge pumping rates from a clarifier should be slow in order to prevent pulling too much water with the sludge. Operators usually have to learn from experience to recognize the differences between thin or concentrated sludges. There are several observations that can sometimes aid the operator in determining when the sludge is too thin:

1. Sound of the sludge pump. The pump will usually have a different sound when the sludge is thick than when it is thin.
2. Pressure gauge readings. Pressure will be higher on the discharge side of the pump when the sludge is thick.
3. Visual observation of a small quantity of sludge.
4. Watch sludge being pumped through a sight glass in the sludge line.

The appropriate waste pumping rates from the primary clarifier can be calculated by measuring the volume of settleable solids in the wastewater. This measurement utilizes a one-liter, cone shaped container called an **Imhoff Cone**. This container is marked with graduations (in ml/L) that allow operators to observe how many milliliters of solids can be expected to settle out of each liter of wastewater. This ratio is then used to calculate the settleable solids (raw sludge) expected to settle out in the entire volume of wastewater passing through the primary clarifier. This calculation helps to determine what the waste pumping rates in the primary clarifier should be.





SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento**- Operation of Wastewater Treatment Plants-Vol. 1**

Chapter 4 Racks, Screens, Communitors, and Grit Removal

Chapter 5 Sedimentation and Flotation

Oklahoma Guidance Manual for the Management of Municipal Wastewater Sludge *(587-A).*

OTHER STUDY SUGGESTIONS

Study drawings or photographs of bar screens and communitors.
See if you can identify those parts of the mechanisms which are most subject to wear, and which will need replacing, and where lubrication will be required in the mechanism.
Write out the sequence of safety procedures that you would go through before, during, and after performing maintenance on a communitor or barminutor.
Study photographs and schematics of grit channels and aerated grit chambers. Be familiar with the operating principles of both.
Refer to current regulatory agency recommendations for proper disposal of grit and screenings.
Study diagrams of clarifiers, circular, and rectangular.
Be familiar with all component parts.
Be able to identify which parts need maintenance and replacement.
Be able to draw a picture of the flow as it moves through the clarifier and identify what is removed in the sediment process and where they go.
List five or six problems which can occur in operation of clarifiers and what their remedies would be.
Make a list of the major safety considerations when working around sedimentation basins.
Be able to locate primary and secondary sedimentation in a typical secondary treatment plant process sequence.
Study cross section diagrams of clarifiers.
Be able to trace what is removed in the process and where it goes.
Be able to calculate removal efficiencies for BOD and TSS.
Identify operational controls for the process.
Practice hydraulic loading calculations.
Be able to recall standard design numbers for detention time and hydraulic loading rates.

SAMPLE QUESTIONS

Class D

What is the common name for the material that is skimmed from the surface of a primary clarifier?

A. Grit
B. Screenings
C. Scum

Class C

Removal of almost all of the settleable solids in the primary clarifier also removes a large percentage of the:

A. total suspended solids.
B. total dissolved solids.
C. total colloidal solids.

Class B

A primary clarifier is 60 feet in diameter and 15 feet deep receives a flow of 3.2 MGD. What is the surface loading in gallons per day per square foot?

A. 654 gpd/ft^2
B. 833 gpd/ft^2
C. 1132 gpd/ft^2
D. 1397 gpd/ft^2

Class A

The weir overflow rate in a secondary clarifier will be somewhere in the range of:

A. 500-1,500 gpd/linear ft.
B. 1,500-3,000 gpd/linear ft.
C. 3,000-5,000 gpd/linear ft.
D. 5,000-15,000 gpd/linear ft.

Chapter 8

Secondary Treatment

SUGGESTED STUDY GUIDELINES

Class D

Be prepared to answer questions concerning:

- The main purpose of secondary treatment.
- The typical locations of secondary treatment processes in the sequence of wastewater treatment.
- The definitions of fixed media and liquid media.
- The basic process involved in the various types of secondary treatment including:
  - trickling filters
  - activated sludge
  - oxidation ditches
  - sequential batch reactors (SBR's)

The basic advantages and disadvantages of various types of secondary treatment.
The definitions of pooling, ponding, sloughing, and humus.
The definition of recirculation and its basic purpose at a trickling filter.
The definitions of return activated sludge (RAS) and waste activated sludge (WAS).

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- How to remedy common problems associated with trickling filters.
- The process controls available to the operator of a trickling filter and how to use them.
- The likely indicators and results of clogged distributors.
- The typical BOD reduction ranges for trickling filters.
- The basic process controls for activated sludge including dissolved oxygen in aeration and solids levels in the system.
- Which laboratory tests and information are needed to determine loading rates and performance of secondary treatment processes.
- The basic definitions and significance of process control factors including:
  - food/microorganism ratio (F/M ratio)
  - mixed liquor suspended solids (MLSS)
  - mixed liquor volatile suspended solids (MLVSS)
  - sludge age (SA)
  - sludge volume index (SVI)
- The proper sampling procedures and sampling locations for laboratory and process control tests at secondary treatment systems.
- The special basic maintenance procedures for various secondary treatment processes.
- How to keep proper maintenance records for secondary treatment equipment.
- The special safety considerations when operating or maintaining secondary treatment processes.
- How to perform *F/M* ratio and aeration basin detention time calculations.

Be prepared to answer other questions that require additional personal study.

Class B

Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

How to identify normal and abnormal operating conditions (troubleshooting) in the various secondary treatment processes.

The different types of media used in trickling filters and how they compare.

When and how to calculate soluble BOD for trickling.

How to identify some of the common microorganisms found in a trickling filter.

The basic operating differences of standard rate, high rate, and two stage trickling filters.

The typical process schematics and process variations for conventional activated sludge and extended aeration (including package plants and oxidation ditches).

The common ranges of *F/M* ratio, ML VSS, SA, and SVI for conventional activated sludge and extended aeration.

How to remedy typical problems at activated sludge plants using process control techniques.

The description of the WAS and RAS processes including typical amounts and frequencies.

The characteristics of organisms found in the activated sludge process

The effects of bacterial activity and solids level on DO in the activated sludge process.

How to identify the different types of scum found in an aeration basin and what they mean.

How to perform the 30 minute settleability test and interpret the results by observation.

How to determine the reasons for problems with sludge in the settling basin.

How to calculate BOD reductions of various secondary treatment processes.

How to perform hydraulic and organic loading calculations for secondary treatment processes.

How to perform calculations involving SA, SVI, and pounds of solids wasted per day.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

Class A

Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

The definition and significance of Mean Cell Residence Time (MCRT).

When, where, and how nitrification and denitrification occur in secondary treatment processes and in what amounts.

How to convert settleable solids reading into other forms of data.

The methods of process control changes in activated sludge processes including time limits.

How to determine RAS and WAS rates and the effects of these changes.

The advantages and disadvantages of different process control techniques using F/M Ratio, MCRT, MLVSS, SVI, sludge age, and the settleability test.

When and where the use of polymers is recommended in the activated sludge process.

The correlation between COD and BOD measurements.

The advantages and disadvantages of COD and BOD as determinants of organic loading.
How to perform calculations involving MCRT.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

ENTRY LEVEL DISCUSSION

Although primary treatment is very efficient at removing settleable solids, it is not capable of removing BOD and non-settleable solids (colloids) or dissolved solids. In order to remove BOD and non-settleable solids, virtually all modem wastewater treatment facilities include some form of **secondary treatment**. Secondary treatment facilities follow primary treatment processes and always involve some form of aerobic biological activity. Most forms of secondary treatment can reduce final effluent BOD levels by up to 90 percent or more.

The most common types of secondary treatment processes in the state of Oklahoma today are trickling filters, and various activated sludge processes. Trickling filters are considered fixed media systems. This means that the microorganisms providing the treatment are "fixed" (attached) to a solid surface. Activated sludge processes use **liquid media**. In this type of treatment the microorganisms providing the treatment are mixed directly with the wastewater and do not attach themselves to any solid surface.

Description of the Trickling Filter Process

The name **trickling filter** does not do a very good job of describing the actual nature of the process. The so-called trickling filter does not actually utilize physical filtration at all. Instead, the treatment is provided by biological consumption. Microorganisms attach (fix) themselves to the media and consume the organic material in the wastewater being applied.

Most trickling filters are large diameter, shallow, cylindrical structures filled with stone and have an overhead rotary distributor. Trickling filters consist of these three basic parts.

1. The media and retaining structure.

2. The underdrain.

3. The distribution system.

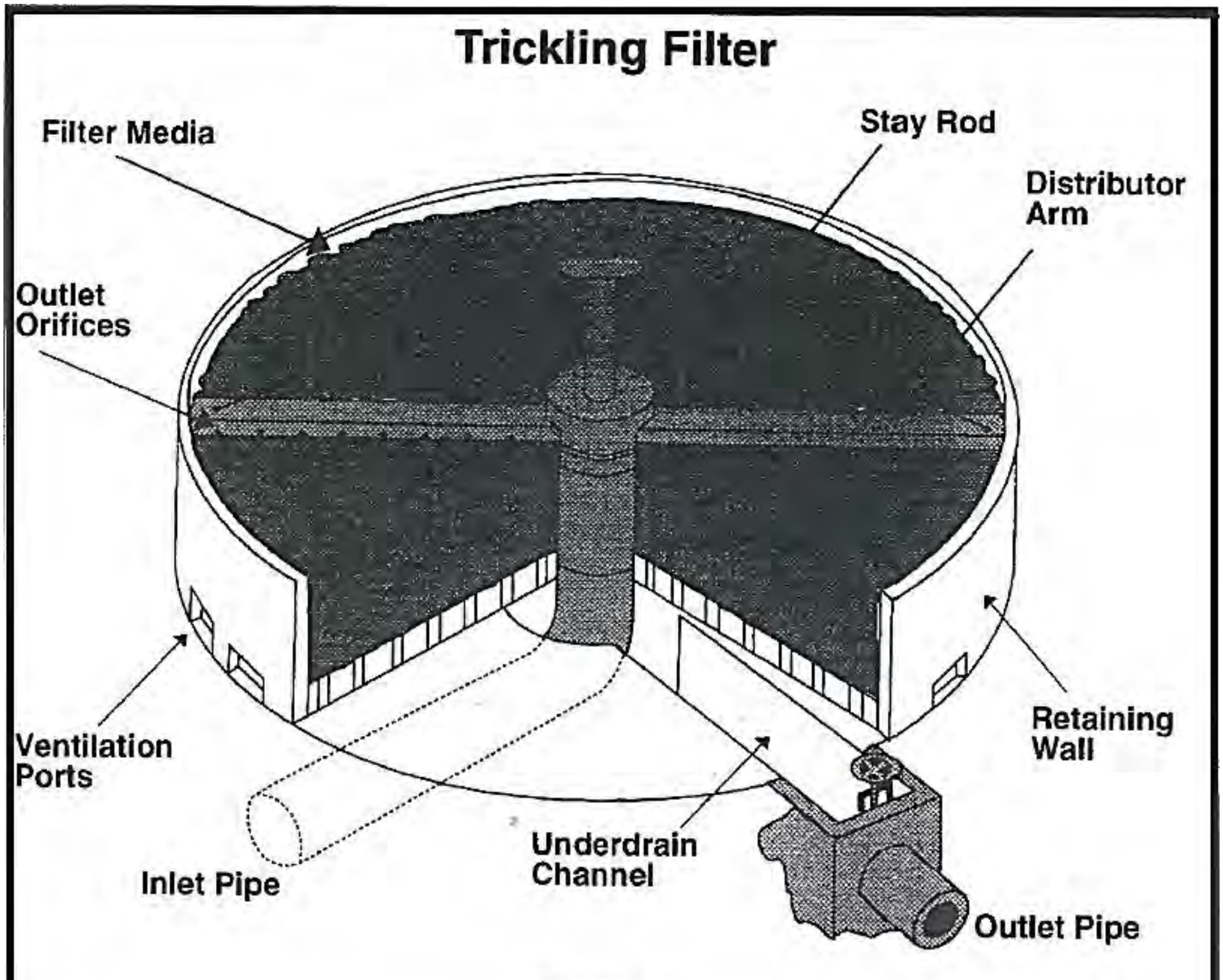


Figure 8.1

A typical trickling filter will consist of rock or plastic **media**. When rock is used the individual stones are of uniform shape and size, usually round or oval and about two to four inches in diameter. To make sure aerobic conditions are maintained in the filter, the spaces between the media must be large enough for sufficient oxygen to be supplied by circulating air.

The media provides a large surface area upon which biological slime growth develops. The slime growth is sometimes referred to as **zoogleal** or biological film. This film contains the organisms that aerobically break down or decompose the organic material in the wastewater, reducing the BOD in the final effluent. The organisms in the film use the organic matter in the wastewater that passes through the trickling filter as food breaking the organic material down into simpler substances.

Trickling filter with plastic media.

The organisms found on trickling filters are mostly bacteria, algae, and fungi. As these organisms grow, reproduce, and die, the dead remains fall away from the media. This material will eventually wash or slough off and then settle out in the secondary clarifier. This process is often referred to as **sloughing**. The sludge that results from the sloughing process is referred to as **humus**.

The trickling filter's **retaining structure** will usually be cylindrical with a diameter of about 40 to 100 feet and a depth of around 5 to 8 feet. When plastic media is used, trickling filters may be much deeper. The **underdrain system** of a trickling filter has a sloping bottom leading to a central channel which collects the trickling filter effluent. The underdrain is sloped to allow filter media to remain well ventilated.

The majority of trickling filter systems in the state of Oklahoma have been constructed with a **rotary distributor** consisting of two or more horizontal pipes mounted a few inches above the filter media by a central column. The wastewater is fed from the column through the horizontal pipes and is distributed evenly over the media through orifices along one side of the pipes. Rotary distributor motion is due to the hydraulic power from the wastewater flow similar to a lawn sprinkler. Occasionally the rotary distributor may be powered by some mechanical or electrical means. A **fixed nozzle** distributor utilizes spray nozzles at fixed locations over the surface of the media, arranged in such a way that the entire surface of the media receives wastewater.

Common Problems with Trickling Filters

Ponding and Pooling

Ponding and Pooling is often caused by inadequate sloughing of trickling filter growth resulting in a clogged condition with ponds or pools of wastewater forming. These pools can produce septic conditions accompanied by odors and may experience reduced treatment efficiency. Ponding usually results from excessive organic loading, but may also be caused by poor media design. Another common cause of ponding conditions is the growth of excessive amounts of algae on the media surface. Proper maintenance, such as frequent cleaning of the distributor orifices, will help prevent ponding by maintaining a steady flow of water over the trickling filter's entire surface.

Ponding can usually be corrected by spraying with high-pressure water or by raking. If these methods are not successful in correcting the ponding problem more drastic measures may have to be used. The following is a list of strategies sometimes used for correcting ponding conditions in order of preference depending on the severity of the condition. The last solution, No 5, listed here is used only as a last resort when all other methods have failed.

1. Spraying the filter with a high pressure water stream.

2. Hand turning or stirring the filter surface with a rake, fork, or bar.

3. Submerging the media for 24 hours in order to promote sloughing.

4. Shutting off the flow to the filter for several hours allowing the growth to dry and then manually cleaning. Most of the remaining material will be flushed out when the unit is put back into service.

5. Dosing the filter with 5 mg/L of chlorine for several hours.

Psychoda

Small flying insects often called filter flies or **psychoda** are the primary nuisance insect connected with trickling filter operations. They are sometimes found in great numbers and can be an extremely difficult problem to operators as well as nearby neighbors. Because psychoda prefer an alternately wet and dry environment, their numbers will be reduced by keeping the orifice opening on the distributor clear, including the end gates of the distributor arms to obtain a flushing action on the inside walls of the filter. This helps keep the fly larvae washed out of the rock media.

Another important factor in controlling filter flies is to maintain a continuous high hydraulic loading. A common way to increase the hydraulic loading in trickling filters is a strategy called recirculation.

Recirculation

Recirculation is a process in which filter effluent is recycled back into the trickling filter unit. This is a commonly used method for increasing trickling filter efficiency and helps to control some common problems.

Recycling some of the filter effluent increases wastewater contact time with the biological film and helps to seed the lower portions of the filter with active organisms. Recirculation increases the flow rate per unit of surface area, which means higher velocities will occur causing more continuous and uniform sloughing of excess or older growths. This increase in the sloughing process is important because this provides space for new biological growth which helps to keep the biological growth active.

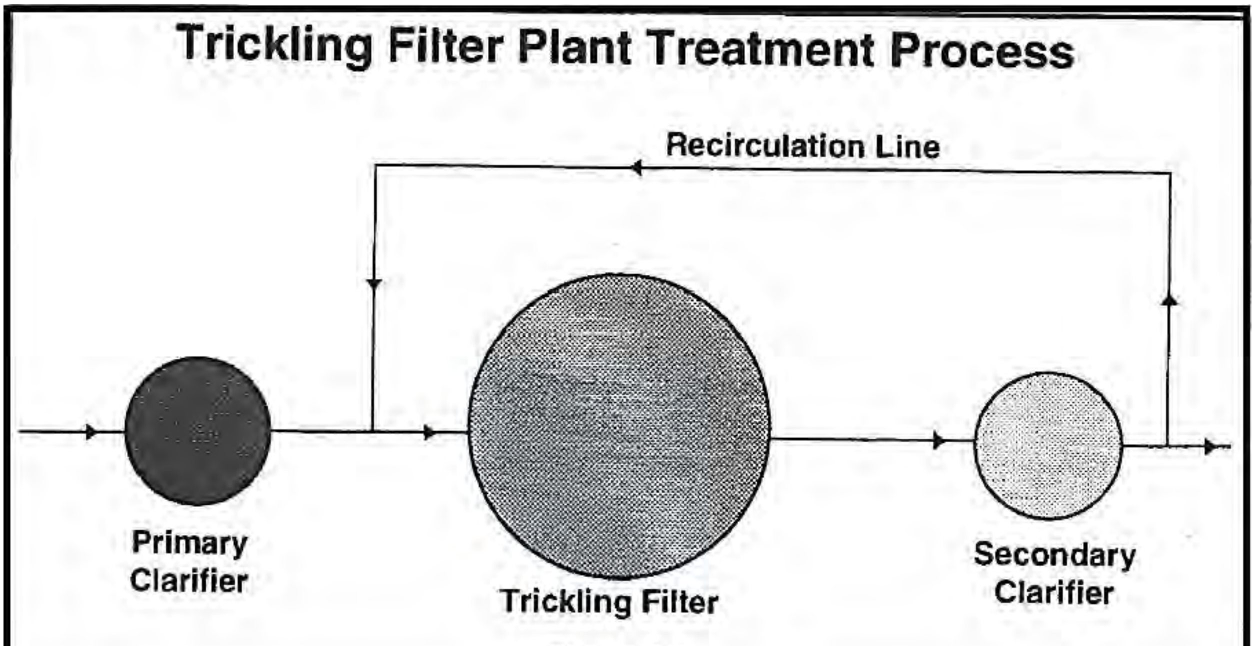


Figure 8.2

Sloughing of biological growths also improves ventilation through the filter and therefore helps prevent ponding and pooling. An increase in hydraulic loading caused by recirculation may also help reduce the populations of filter flies by reducing breeding opportunities, and increase the DO in the effluent.

The thickness of biological growth on a trickling filter is directly related to the organic strength of the wastewater being applied to the filter. Higher BODs in the incoming wastewater will result in a thicker biological growth on the trickling filter media. By the use of recirculation, the strength of wastewater applied to the filter can be reduced, thus helping to prevent excessive build-up of biological growths.

Recirculation may be constant or intermittent and at a steady or fluctuating rate. Occasionally recirculation is utilized only during periods of low flows to keep rotary distributors in motion and to prevent drying of the biological growths. Recirculation in proportion to flow may be used to reduce the organic strength of the wastewater applied to the filter, while steady recirculation tends to even out the highs and lows caused by the differences in organic loading. However, steady recirculation will use more energy and increase treatment costs.

As a general rule, it is a good practice to use the lowest recirculation rates that will achieve good results in the final effluent. In fact, excessive recirculation rates can actually starve the biological growth on the trickling filter by diluting the BOD content in the influent to a point where there is not enough organic material to support growth. In addition, recirculation requires pumping. Operators should keep recirculation rates as low as possible, while still achieving effective treatment, to reduce wear on pumping equipment and decrease electric power costs.

Trickling Filter Loading Rates

Trickling filters can be put into three major categories depending in their relative organic and hydraulic loadings. Filters are classified as **standard-rate, high rate,** or **roughing filters** and are summarized in the following sections.

Standard-Rate Filters

The **standard-rate filter** is operated with a hydraulic loading of 45 to 90 gallons/day/ft^2, and an organic BOD loading of 5 to 12 pounds/day/1000ft^3. These filters are designed to receive wastewater continually at these loading rates.

High-Rate Trickling Filters

High-rate filters will have hydraulic loadings of 230 to 690 gallons/day/ft^2 and BOD loadings of 30 to 100 pounds/day/1000ft^3. These filters are designed to receive wastewater continually at these higher rates. Due to the heavy flow of wastewater over the media, more uniform sloughing occurs from high-rate filters than standard-rate filters. This sloughed material is somewhat lighter than solids obtained from a standard-rate filter and therefore more difficult to settle.

Roughing Filters

A **roughing filter** is actually a high-rate filter receiving a very high organic loading. Any filter that receives a BOD loading of over 100 pounds/day/1000ft^3 of media is considered a roughing filter. Roughing filters and "bio-towers" are used in treatment of high-strength waste before the waste is sent to other secondary treatment processes such as activated sludge basins.

Trickling Filter Performance

In actual practice, the trickling filter is one of the most trouble-free types of secondary treatment processes currently in operation. Trickling filters are not easily upset by shock loads as are some of the more modern types of secondary treatment processes, such as activated sludge. As a general rule, trickling filter plants are easier to operate than activated sludge plants and are more cost effective because of lower electrical power consumption. The only real disadvantage to the trickling filter process is that other secondary treatment processes will generally have higher removal efficiencies. Although actual removal efficiencies will vary from plant to plant, most trickling filters are generally considered able to remove only about 85 percent of the BOD.

Definition of Activated Sludge

The **activated sludge** process is a secondary, biological treatment that utilizes liquid media. The activated sludge organisms are normally present in domestic sewage and are contained in large tanks filled with wastewater called **aeration basins**. The term “activated” refers to the fact that the sludge particles in this process are absolutely teeming with bacteria, fungi, protozoa, and other microorganisms. Wastewater in the aeration basins is aerated by diffused aeration or surface agitation to maintain aerobic conditions. When wastewater flows into an aeration basin containing activated sludge, the microorganisms feed and grow on the organic waste (BOD) in the wastewater, which greatly reduces the BOD level. These microorganisms also break down non-settleable solids into simpler substances.

Activated Sludge Terms and Definitions

To help understand the activated sludge process, you should become familiar with a few terms and definitions associated with activated sludge. Some of the more important terms are listed below.

Mixed Liquor – the liquid mixture of wastewater and microorganisms found in aeration basins.

MLSS – Mixed Liquor Suspended Solids. The MLSS is an estimate of the suspended solids concentration found in the aeration basin of an activated sludge plant. It is also a rough estimate of the concentration of organisms (consisting mainly of bacteria and protozoa) found in the aeration basin. MLSS concentrations can range from 800 to 5000 mg/L.

MLVSS – Mixed Liquor Volatile Suspended Solids. The term volatile refers to the organic material only. Thus the MLVSS is the organic portion of solids in the MLSS. MLVSS is a more accurate estimate of the actual concentration of organisms present in the aeration basin. On the average MLVSS will make up approximately 70 percent of the MLSS.

WAS – Waste Activated Sludge. WAS refers to the removal of excess activated sludge solids from the system.

RAS – Return Activated Sludge - RAS refers to activated sludge solids that are returned from the secondary clarifier to the aeration basin to provide an adequate supply of organisms.

F/M Ratio – Food/Microorganism Ratio - The F/M ratio is the ratio of the organic material to the microorganisms that are present. The most accurate estimate of the F/M ratio can be obtained by dividing the pounds of BOD entering the aeration basin each day by the pounds of MLVSS in the aeration basin. A proper F/M ratio is very important to successful activated sludge process operation.

SA – Sludge Age - Sludge age is a measure of the length of time a particle of suspended solids has been retained in the activated sludge process. It could be thought of as a type of sludge process. To calculate sludge age in days the pounds of MLSS are divided by the pounds per day of suspended solids that are added to the aeration basin.

MCRT – Mean Cell Residence Time - This process control factor expresses the amount of time that a microorganism will spend in the activated sludge process. To calculate MCRT in days the pounds of MLSS are divided by the pounds per day of MLSS removed from the process.

SVI – Sludge Volume Index - This is a calculation used to indicate the settling ability of activated sludge solids in the secondary clarifier. The calculation is a measure of the volume of sludge compared with its weight. A sample of mixed liquor from the aeration basin is allowed to settle. The SVI is calculated by dividing the volume of wet solids (in ml) by the weight (in mg) of that sludge after it has dried. The answer is multiplied by 1000 to obtain a whole number. A sludge with an SVI of one hundred or greater will not settle as readily because it is as light, or is lighter than, water.

Activated Sludge Process Description

Activated sludge secondary treatment processes remove BOD (organic material) in the form of dissolved and suspended materials. Aerobic organisms present in the process remove the materials as wastewater flows through the aeration basins. The organisms **oxidize** the dissolved and suspended solids forming carbon dioxide, sulfate and nitrate compounds. The solids that remain are converted into a form that can be settled and removed as sludge in the secondary clarifier.

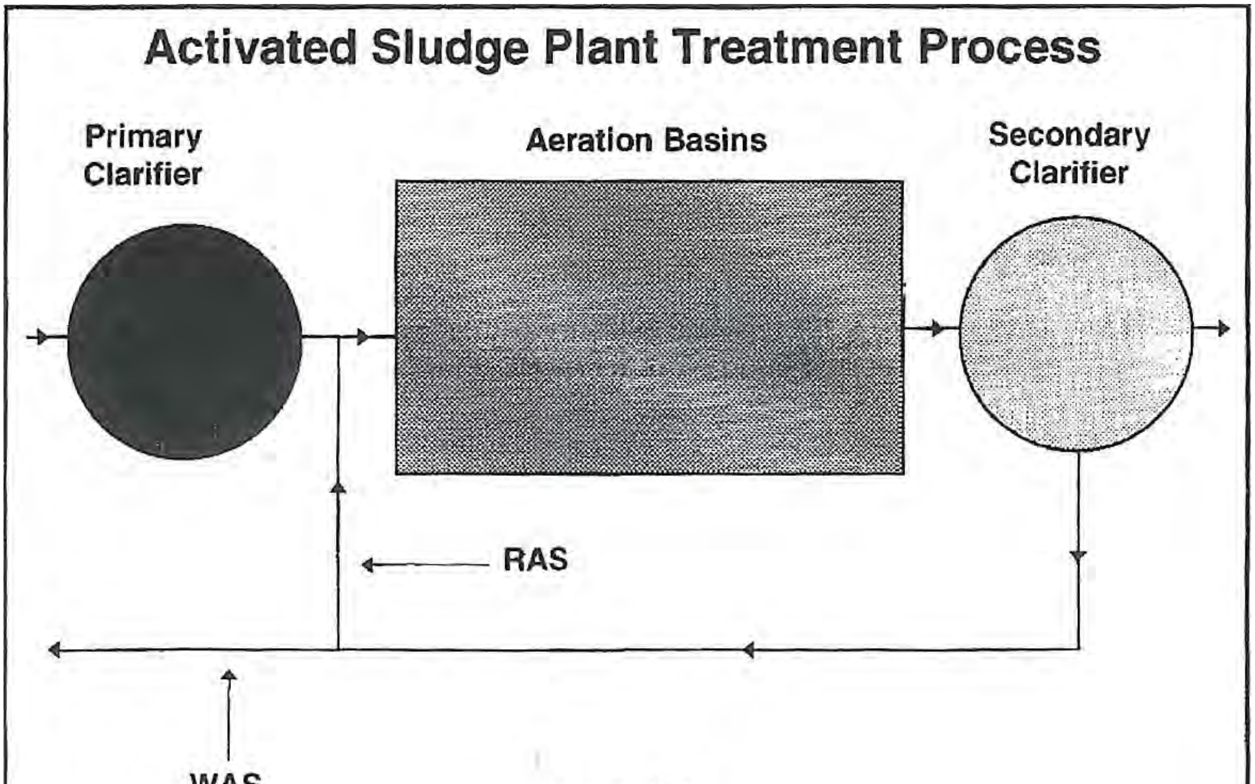


Figure 8.4

After treatment in the aeration basins, the wastewater is sent to the secondary clarifier to separate solids from the water. The activated sludge solids settle to the secondary clarifier bottom resulting in a large reduction in the final effluent solids concentration. The sludge that settles consists mostly of living organisms and most of it is quickly returned to the aeration basin as return activated sludge (RAS). At some activated sludge plants the RAS is maintained at a constant rate, thus providing a consistent supply of organisms to maintain the solids level in the aeration basin.

If some solids are not removed from the process, solids build-up will result in too high a concentration of solids in the aeration basin, and a reduction in process efficiency. This is the purpose of the waste activated sludge (WAS). When the concentration of solids in the aeration basin becomes too high the WAS is used to remove excess solids from the system. The activated sludge process can be viewed as a loop, with the loop being formed by the RAS rate. When the solids concentration becomes too high, the WAS acts as an outlet for the activated sludge loop. Never change the WAS rate more than 10-15% at a time. After making an operational change wait a full seven days to determine if the change was effective.

The ratio of food to microorganisms (F/M ratio) is of primary importance to the activated sludge process. The population of organisms will tend to increase with an increase in organic material in the incoming wastewater. When conditions are right the operator will remove the excess organisms as WAS to maintain the proper concentration of organisms. In a healthy aeration tank, the MLSS will have a reddish brown to chocolate color.

Photo of an aeration basin.

Oxygen is required by the organisms. These organisms oxidize or consume organic wastes to obtain energy for growth and reproduction. If the oxygen supply is too low, the aerobic organisms reproduction will slow down and, eventually, anaerobic activity could start producing odors and result in treatment efficiency reduction. An increase in the population of organisms in the aeration basin will require greater amounts of dissolved oxygen (DO). A higher BOD in the activated sludge process influent will promote organism population growth resulting in a dissolved oxygen demand increase. Aerobic conditions, defined as a minimum dissolved oxygen concentration of 2.0 mg/L, are required in the aeration basin for complete waste stabilization.

A minimum level of DO must be maintained to promote the growth of the favored type of organisms. If DO levels in the aeration basin are too low, **filamentous bacteria** will begin to dominate and sludge floc that will not settle efficiently will result. This condition is commonly referred to as sludge bulking. On the other hand, if the DO is too high, a fine pinpoint floc will form that will also be difficult to settle in the secondary clarifier. This is due to floc "shearing" or the floc breaking up resulting in poor solids settleability.

Types of Activated Sludge Processes

There are two major types of activated sludge systems in use today: **conventional aeration** and **extended aeration**. A conventional aeration plant will usually have a MLSS concentration of 800 to 2000 mg/L, while an extended aeration plant will usually have a MLSS concentration of 2000 mg/L to 5000 mg/L. In extended aeration plants organisms are retained in the aeration basin longer and will not receive as much food. The organisms do not get as much food because there are more of them to feed. Thus, the F/M ratio of an extended aeration plant will be much lower than a conventional aeration plant. Due to higher RAS flows, the MLSS and sludge age in an extended aeration plant will be significantly higher than in a conventional aeration process.

Oxidation Ditches

The **oxidation ditch** is a modified version of the activated sludge process that is usually operated in the extended aeration mode. Oxidation ditches are constructed by using an oval shaped channel as the aeration basin. Aeration is provided by brush type rotors that agitate the surface of the water and keep the water in motion around the oval. This is why oxidation ditches are sometimes called "racetracks". The oxidation ditch flow velocity is usually maintained around 1.0 to 1.5 feet per second.

Many small package plants utilize oxidation ditches, often without primary clarifiers and grit removal systems. Inorganic solids such as sand and silt are captured in the oxidation ditch and removed during sludge wasting or cleaning operations.

Oxidation Ditch Treatment Process

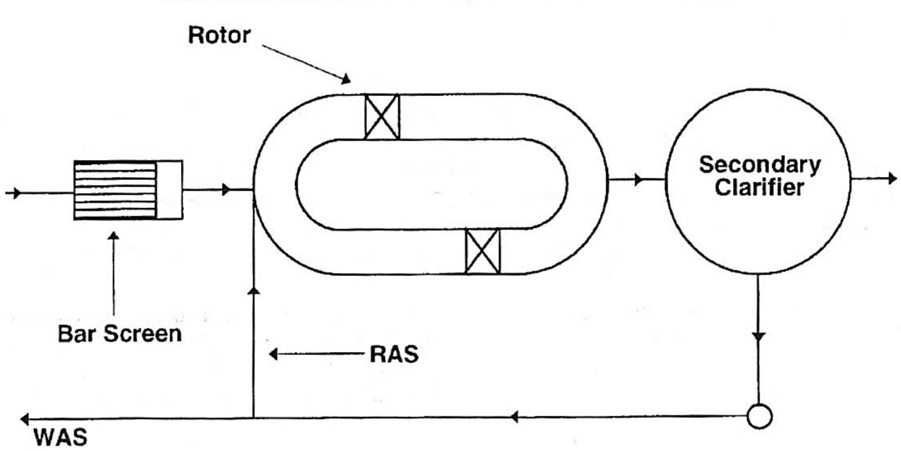


Figure 8.5

Sequential Batch Reactors

Another activated sludge treatment process modification is referred to as a **sequential batch reactor** (SBR). Many plants utilizing this secondary treatment process have been built in Oklahoma. An SBR could be described as an activated sludge process that treats wastewater in batches and provides all secondary treatment in the same tank.

Typical SBR operation involves filling a tank with raw wastewater or primary effluent, aerating the wastewater to convert the organics into microbial mass, providing a period for settling, and then discharging the treated effluent. An idle period may be provided after discharging the tank before refilling. Some SBR systems have been designed to operate in conventional mode but most are designed and operated as extended aeration plants.

For most SBR systems, a multiple tank system is required. This allows incoming flow to be switched to one tank while the other tank is going through the aeration, clarification, and discharge functions. A key element in the SBR process is that a tank is never completely emptied, but rather a portion of settled solids is left in the tank for the next cycle. The remaining portion of this residue (sludge) is wasted. The fraction wasted will depend upon the desired sludge age.

Process control for SBR systems is very similar to that used for conventional activated sludge. F/M ratio, sludge, or MCRT can be used to control the process. Lab testing is much the same, however, some sampling requirements must be met to ensure representative samples. Reactor samples should be taken:

1. At the same time in the reactor cycle;
2. At the same reactor liquid level; and
3. At the same location in the reactor.

Take sequencing cycles into account when making a sample plan for SBRs. Sludge blankets cannot be measured during reaction cycles. MLSS samples should be taken about halfway through or near the end of the reactor cycle. Take each MLSS sample when the reactor is at the same depth.

Common Problems in the Activated Sludge Process

Foaming in the aeration basins is a problem at many activated sludge plants. Usually the color of foam will help the operator diagnose its cause. If billowing white foam is observed, the sludge is probably too young. In other words, the sludge age is not long enough and the WAS rate needs to be decreased. On the other hand, if brown scummy-looking foam is observed, the sludge is probably too old. This means that the sludge age is too high (too long) and the WAS rate needs to be increased.

A common problem mentioned earlier is **sludge bulking**. Sludge bulking is usually caused by the growth of excessive amounts of filamentous bacteria. Filamentous bacteria are desirable to a point, but can reduce the settleability of activated sludge if they become dominant. This problem is caused by incorrect sludge age or nutrient imbalances. Methods of controlling filamentous growth include increasing the sludge age and maintaining higher dissolved oxygen values.

Activated Sludge Performance

The activated sludge process is considered to be one of the most efficient, if not the most efficient, modern day wastewater treatment system for BOD removal. However, there are some disadvantages to the activated sludge process. As a general rule, the activated sludge process is more complex to operate than a trickling filter or RBC and requires more skill and training on the part of the operator.

Activated sludge plants are often easier to upset by shock loads of BOD than is a trickling filter plant. In addition, the electrical power requirements are usually significantly higher than for an activated sludge plant. The primary advantage to the activated sludge process is that BOD removal rates are usually significantly higher than that obtained in a trickling filter system. BOD removal rates of 95 to 98 percent can be routinely obtained in a well operated activated sludge system.

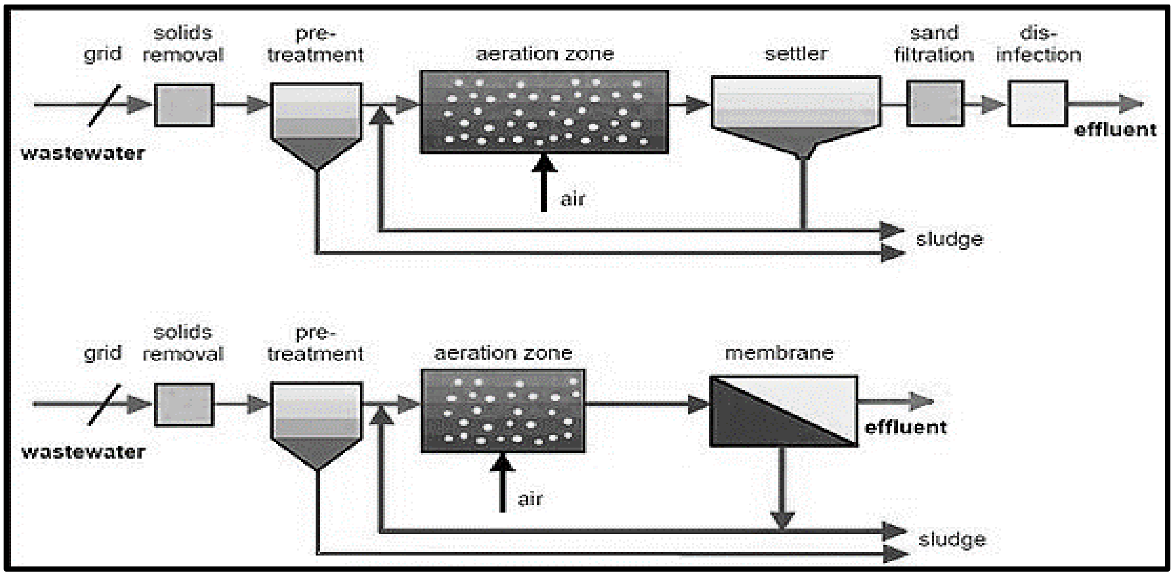
Membrane Bioreactors

When used with domestic wastewater, MBR processes can produce effluent of high enough quality to be discharged to coastal, surface, or brackish waterways, or to be reclaimed for urban irrigation. Other advantages of MBRs over conventional processes include small footprint and easy retrofit and upgrade of old wastewater treatment plants.

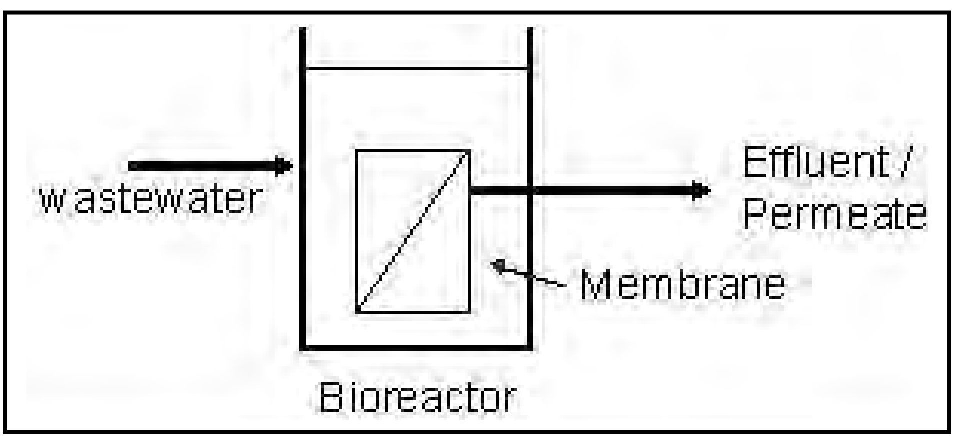
Recent technical innovation and significant membrane cost reduction have enabled MBRs to become an established process option to treat wastewaters. As a result, the MBR process has now become an attractive option for the treatment and reuse of industrial and municipal wastewaters, as evidenced by their constantly rising numbers and capacity.

It is possible to operate MBR processes at higher mixed liquor suspended solids (MLSS) concentrations compared to conventional settlement separation systems, thus reducing the reactor volume to achieve the same loading rate.

Two MBR configurations exist: internal/submerged, where the membranes are immersed in and integral to the biological reactor; and external/side stream, where membranes are a separate unit process requiring an intermediate pumping step. **Membrane bioreactor** (MBR) is the combination of a membrane process like microfiltration or ultrafiltration with a suspended growth bioreactor, and is now widely used for municipal and industrial wastewater treatment.



Schematic of conventional activated sludge process (top) and external (side stream) membrane bioreactor (bottom)



Schematic of a submerged MBR

Membrane bioreactors can be used to reduce the footprint of an activated sludge sewage treatment system by removing some of the liquid component of the mixed liquor. This leaves a concentrated waste product that is then treated using the activated sludge process.

Major Considerations in MBR Treatment

Membrane Fouling and Fouling control

The MBR filtration performance inevitably decreases with filtration time. This is due to the deposition of soluble and particulate materials onto and into the membrane, attributed to the interactions between activated sludge components and the membrane. This major drawback and process limitation has been under investigation since the early MBRs, and remains one of the most challenging issues facing further MBR development.

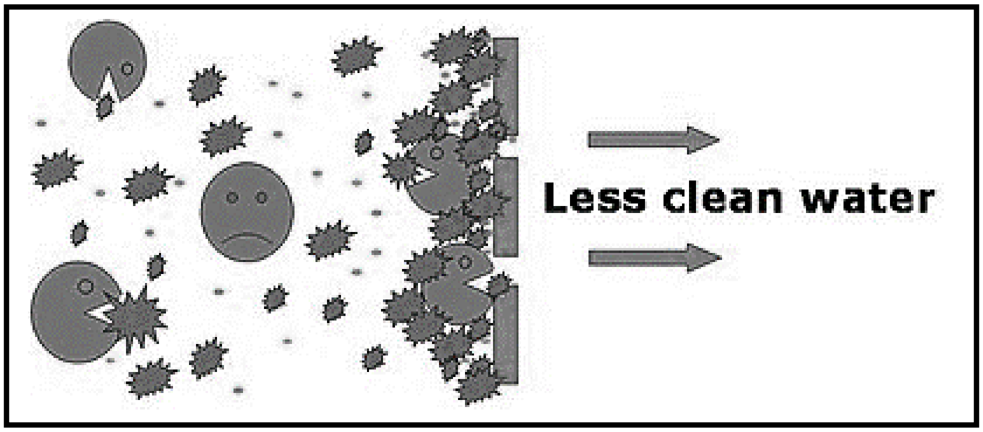


Illustration of membrane fouling

Anti-fouling strategies can be applied to MBR applications. They comprise, for example:

- **Intermittent permeation,** where the filtration is stopped at regular time interval for a couple of minutes before being resumed. Particles deposited on the membrane surface tend to diffuse back to the reactor; this phenomenon is increased by the continuous aeration applied during this resting period.
- **Membrane backwashing,** where permeate water is pumped back to the membrane, and flow through the pores to the feed channel, dislodging internal and external foulants.
- **Air backwashing,** where pressurized air in the permeate side of the membrane build up and release a significant pressure within a very short period of time. Membrane modules therefore need to be in a pressurized vessel coupled to a vent system. Air usually does not go through the membrane. If it did, the air would dry the membrane and a rewet step would be necessary, by pressurizing the feed side of the membrane.
- **Proprietary anti-fouling products,** such as Nalco's Membrane Performance Enhancer Technology.

In addition, different types/intensities of chemical cleaning may also be recommended:

- Chemically enhanced backwash (daily);
- Maintenance cleaning with higher chemical concentration (weekly);
- Intensive chemical cleaning (once or twice a year).

Intensive chemical cleaning protocols for MBR systems (the exact protocol for chemical cleaning can vary from a plant to another).

Membrane Treatment Performance

Simply due to the high number of microorganism in MBRs, the pollutants uptake rate can be increased. This leads to better treatment in a given time span or to smaller required reactor volumes. In comparison to the conventional activated sludge process which typically achieves 95 percent, BOD removal can be increased to 96 to 99 percent in MBRs. BOD_5 removal increases with MLSS concentration. Higher MLSS concentrations in MBR, however, give rise to high and non-Newtonian viscosities which impede oxygen transfer and require more energy for pumping.

Nutrient removal

Nutrient removal is one of the main concerns in modern wastewater treatment especially in areas that are sensitive to eutrophication. Like in the conventional activated sludge process, currently, the most widely applied technology for nitrogen removal from municipal wastewater is nitrification combined with denitrification. Besides phosphorus precipitation, enhanced biological phosphorus removal (EBPR) can be implemented which requires an additional anaerobic process step. Some characteristics of MBR technology render EBPR in combination with post-denitrification an attractive alternative that achieves very low nutrient effluent concentrations.

Mixing and hydrodynamics

Like in any other reactors, the hydrodynamics (or mixing) within an MBR plays an important role in determining the pollutant removal and fouling control within an MBR. It has a substantial effect on the energy usage and size requirements of an MBR, therefore the whole life cost of an MBR is high.

The removal of pollutants is greatly influenced by the length of time fluid elements spend in the MBR.

Membrane Reactor References

- S. Judd, The MBR book (2006) Principles and applications of membrane bioreactors in water and wastewater treatment, Elsevier, Oxford ISBN 1856174816
- Membrane Bioreactors. membrane.unsw.edu.au
- Z.F. Cui, S. Chang, A.G. Fane (2003). "The use of gas bubbling to enhance membrane processes". *Journal of Membrane Science* **221**: 1. doi:10.1016/S0376-7388(03)00246-1.
- Nalco. http://www.nalco.com/ASP/applications/membrane_tech/products/mpe.asp .[*dead link*]
- Drews, H. Evenblij, S. Rosenberger (2005). "Potential and drawbacks of microbiology-membrane interaction in membrane bioreactors". *Environmental Progress* **24** (4): 426. doi:10.1002/ep.10113.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento - Operation of Wastewater Treatment Plants• Vol. 1

Chapter 6	Trickling Filters
Chapter 8	Activated Sludge (Package Plants and Oxidation Ditches)

California State University, Sacramento - Operation of Wastewater Treatment Plants - Vol. 2

Chapter 11	Activated Sludge (Conventional Activated Sludge Plants)
Chapter 13	Effluent Disposal
Chapter 18	Analysis and Presentation of Data (especially section 18.94)

California State University, Sacramento – Advance Waste Treatment

Chapter 2	Activated Sludge (Pure Oxygen Plants and Operational Control Options)
Chapter 6	Nitrogen Removal

OTHER STUDY SUGGESTIONS

Be familiar with the cross section diagram of a trickling filter.
Be able to draw a complete wastewater treatment facility flow diagram including plant pretreatment, primary clarifiers, trickling filters (single and two stage), secondary clarifiers, and chlorination.
Include in the drawing all process unit overflows, underflows, return flows, and waste flows.
Include in the drawing the sampling points for process control and NPDES reporting.
Be able to list the operational controls available to the operator.
Be able to calculate removal efficiency from before the trickling filter to after the secondary clarifier.
Practice hydraulic and organic loading calculations for trickling filters.
Be able to recall standard design numbers for hydraulic and organic loading rates on a trickling filter.
For typical problems with trickling filters and what to do about them, refer to troubleshooting charts in the suggested references.
Study diagrams of Rotating Biological Contactors.
Be familiar with where RBCs are located in the sequence of process units.
Be able to draw a diagram of flows through the RBC process units.
Practice calculations for computation of hydraulic and organic loading rates to RBCs.
Be familiar with typical operational problems and troubleshooting from troubleshooting charts included in manual chapters on RBCs.
Be able to describe process differences between conventional and extended aeration activated sludge processes in terms of detention time in aeration, *F/M* ratio, solids retention time and solids return rate.
Be able to draw a schematic of a typical activated sludge system. Include process control values and practice distinguishing between conventional activated sludge and extended aeration plants.
Be familiar with diagrams of mechanical and diffused air aeration systems and be familiar with the safety considerations of working around each type.
From descriptions or actual observations, be able to identity normal and abnormal operating conditions such as bulking sludge, rising sludge, and excessive foaming.
From laboratory tests results, be able to identity normal and abnormal operating conditions such as excessive loading on the process, solids retention times, and 30 minute settleability.
Be familiar with typical problems and troubleshooting from charts in reference manuals.
Be familiar with recommended maintenance schedules for surface floating aerators, vertical and horizontal shaft aerators, and diffused air systems including components and critical replacement parts.
Practice performing calculations for *F/M* Ratio, SA, MCRT, SVI, detention time, and pounds of solids wasted per day.
Learn how to perform 30 minute settleability testing and sludge blanket measurements.
Be able to describe the basics of microbiological examination of activated sludge including desirable and undesirable organisms and what their relative populations indicate about the condition of the process.

SAMPLE QUESTIONS

Class D
A secondary treatment process that utilizes aeration basins and liquid media is:

A. trickling filters.
B. rotating biological contactors.
C. activated sludge.

***Class* C**
At a trickling filter plant, a heavy organic loading at a low hydraulic loading rate could lead to:

A. excessive aerobic digestion.
B. Ponding.
C. Bulking.

Class B
The activated sludge process that operates in the endogenous phase of microorganism growth is:

A. the Kraus method.
B. step-feed.
C. Conventional.
D. extended aeration.

Class A
Rotifers are associated with:

A. young sludge, low MCRT.
B. average age sludge, medium MCRT.
C. old sludge, high MCRT.
D. young sludge, high MCRT.

Chapter 9
Advanced Treatment and Water Reuse
(Tertiary Treatment)

STUDY GUIDELINES

Class D

Be prepared to answer questions concerning:

- The basic definition of tertiary treatment.
- The typical locations of tertiary treatment processes in the sequence of wastewater treatment.
- The names of the two substances most commonly removed in tertiary treatment processes.

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- The reasons for performing tertiary treatment.
- The definitions for nitrification and denitrification.
- Be prepared to answer other questions that require additional personal study.

Class B and Class A

Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

- The description of processes including fixed film nitrification-denitrification, suspended growth nitrification-denitrification, and breakpoint chlorination.
- The operational requirements of these processes including dissolved oxygen (DO) and mean cell residence time (MCRT).
- Other factors in these processes including food balance, alkalinity, recycle flow, and dosages.
- How tertiary treatment processes remove nitrogen and phosphorous.
- The proper procedures for using chemicals to remove solids from secondary effluent.
- How to recognize abnormal operating conditions in tertiary treatment processes, their causes, and corrective actions.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

ENTRY LEVEL DISCUSSION

Advanced treatment, also known as tertiary treatment, is a third stage of biological or chemical/physical processes used to "polish" the effluent. Many modern treatment plants are utilizing advanced treatment processes to further reduce the level of ammonia, nitrogen, and phosphorus leaving the facility. Some systems utilize advanced processes for solids removal from secondary effluents.

Advances in wastewater treatment technology and the desire for more effective use of available resources have led many municipalities and water utility providers to consider reuse of treated wastewater effluent to supplement available water supplies. Reuse projects can take many forms. The reuse of treated wastewater can provide water for inside the plant use such as wash water for plant processes and backwash water for filtration units. Outside, the plant uses include landscape irrigation, dust control, and many other opportunities to use reuse water for industrial and commercial applications.

Nitrogen Removal

It is desirable to remove ammonia in the treatment plant rather than in the receiving stream. The conversion process of ammonia to nitrate requires oxygen. If ammonia is present in the effluent going to the stream, oxygen levels in the stream would decrease and could result in septic conditions. Ammonia nitrogen can be removed by several processes including biological removal, breakpoint chlorination, and lime addition/ammonia stripping.

Biological Removal

Biological removal is usually the least expensive and the most frequently used method. Biological removal is accomplished by a two-stage process called **nitrification/denitrification**.

The first stage of this process is **nitrification.** Nitrification is accomplished by a specialized group of bacteria called nitrifiers which live in liquid and fixed media systems. The nitrifiers of interest are nitrobacter and nitrosomonas. Nitrosomonas converts ammonium (NH_4^+) to nitrite (NO_2^-).

Note: Ammonium (NH_4^+) is the natural form of ammonia in wastewater.

In a second step, nitrobacter converts nitrite to nitrate (NO_3^-). Nitrification will occur only in a limited range of conditions. Adequate amounts of free oxygen must be present. Approximately four and one-half (4.5) pounds of free dissolved oxygen are required to convert one pound of ammonia to nitrate. Optimal temperature, bacterial populations and sufficient alkalinity are also required. If there is not enough alkalinity, the pH will drop and nitrification will decrease. Finally, nitrifiers require long mean cell residence times (MCRT's) and are susceptible to "wash-out" during periods of high flow.

Biological **denitrification** is the process by which bacteria reduce the nitrate (NO_3^-) to gaseous forms of nitrogen, primarily nitrous oxide (N_2O) and nitrogen gas (N_2). Placed in a controlled environment which has no free oxygen but does have needed food sources, the denitrifying bacteria reduce nitrate to nitrogen gas because they are forced to use the oxygen found in the nitrate molecule. Denitrification is performed using specialized anaerobic processes.

Breakpoint Chlorination for Nitrogen Removal

Breakpoint chlorination removes ammonia because chlorine and ammonia readily react to form chloramines. Adding more chlorine to the breakpoint will convert chloramines to nitrogen gas. This method can suffer several disadvantages including high chlorine costs, lowered pH values requiring addition of base, high values for effluent chlorides, and increased exposure to chlorine hazards.

Ammonia Stripping

Ammonia stripping is achieved by raising the pH of the effluent to values of pH 10.8 to 11.5. The high pH effluent is then passed over a stripping tower having a large air flow over it. Ammonia is liberated from solution at the high pH values. The agitation of the water creates more surface area for ammonia to escape. The use of lime also removes phosphorous in this process. Disadvantages of this process include lowered efficiency in cold weather, formation of a calcium carbonate scale on the tower, and significant space requirements.

Phosphorus Removal

Phosphorus is an essential element to biological organisms. However, phosphorus in combination with nitrogen can create excessive algae growths in the receiving streams. Algae themselves create obnoxious tastes and odors in water and can render a body of water unusable as a drinking water source or for recreation. Large quantities of algae can radically change the pH of streams because of their intake of carbon dioxide and can also raise the DO to supersaturated levels. Additionally, when the algae die they become a source of organic material for bacteria to break down. This bacterial action can use all available DO, thus creating septic conditions. Some treatment plants are required to remove both nitrogen and phosphorus. Other plants may be designed to remove only nitrogen, since the lack of nitrogen will inhibit an algae bloom.

Probably the most common method of phosphorus removal is by biological uptake, sometimes referred to as “luxury uptake.” **Biological uptake** of phosphorus is a treatment process whereby the bacteria usually found in the activated sludge process of a secondary treatment plant are withdrawn to an anaerobic environment called a phosphate stripper. When the bacteria are faced with this extreme situation, they release phosphorus from their cell structure in large quantities. The liquid that contains the phosphorus which has been released from the bodies of the bacteria flows into a chemical clarification unit where lime is used to coagulate (form solids which clump together) and settle the phosphorus.

After the bacteria have released their phosphorus, they are placed back into an area of the aeration basin where sufficient oxygen and BOD exist. Since the bacteria are now lacking in phosphorus in their cell structure, the first thing they need is phosphorus. This is the “uptake” phase of the process in which the hungry bacteria are revived and proceed to take up the maximum amount of phosphorus that their cell structure can contain. After the aeration process, the bacteria are again withdrawn to the anaerobic phosphorus stripper and the process is repeated.

Water Reuse

A number of factors have contributed to increased stresses on water supplies. These stresses include drought, increases in population, more stringent potable water quality requirements, and increased demand for commercial and industrial water use. In order to meet water supply demands many organizations and municipalities are utilizing reuse of treated wastewater plant effluent. Water reuse can increase water supply by providing an alternative supply option.

Oklahoma has in place regulations, 252:656-27, that provide specific requirements for construction of water reuse treatment and distribution systems. In addition, regulatory parameters for reuse water quality are found in these statutes. Reuse water quality standards are based on public protection and focus on applicable methods of ensuring reuse water quality. The standards establish clear guidance for reuse water quality in various applications.

Water recycling has proven to be effective and successful in creating a new and reliable water supply without compromising public health. Non-potable reuse is a widely accepted practice that will continue to grow. However, in many parts of the United States, the uses of recycled water are expanding in order to accommodate the needs of the environment and growing water supply demands. Advances in wastewater treatment technology and health studies of indirect potable reuse have led many to predict that planned indirect potable reuse will soon become more common. Recycling waste and gray water requires far less energy than treating salt water using a desalination system (epa.gov).

While water recycling is a sustainable approach and can be cost-effective in the long term, the treatment of wastewater for reuse and the installation of distribution systems at centralized facilities can be initially expensive compared to such water supply alternatives as imported water, ground water, or the use of gray water onsite from homes. Institutional barriers, as well as varying agency priorities and public misperception, can make it difficult to implement water recycling projects. Finally, early in the planning process, agencies must reach out to the public to address any concerns and to keep the public informed and involved in the planning process (information from epa.gov).

As water energy demands and environmental needs grow, water recycling will play a greater role in our overall water supply. By working together to overcome obstacles, water recycling, along with water conservation and efficiency, can help us to sustainably manage our vital water resources.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento - **Advanced Waste Treatment**

Chapter 4 Solids Removal from Effluents
Chapter 5 Phosphorous Removal
Chapter 6 Nitrogen Removal

Aerobic Biological Wastewater Treatment Facilities*, USEPA, 430-9-77-006 (process control manual)*

OTHER STUDY SUGGESTIONS

Diagram suspended growth (activated sludge), fixed film, and breakpoint chlorination systems, mark sampling points and what to sample.

Be able to predict sampling values that you would expect to see at various stages in a well-operated removal processes for ammonium (NH4+), nitrite (NO2-), and nitrate (NO3-).

Identify the operational controls for obtaining nitrification-denitrification with different types of processes.

SAMPLE QUESTIONS

Class D
Tertiary treatment processes are generally located:

A. before secondary treatment.
B. after secondary treatment.
C. before primary treatment.

Class C
Tertiary treatment is primarily concerned with the removal of:

A. HNO_3 and HCl.
B. NH_4^+ and PO4.
C. CaO and KMnO4.

Class B
Nitrification refers to the:

A. bacterial action changing ammonia into nitrate.
B. physical addition of nitrogen gas into the effluent.
C. chemical reaction of nitrate to nitrogen gas.
D. chemical reaction of nitrate into nitrite.

Class A

A denitrification process that uses submerged sand media columns is sometimes referred to as:
A. a liquid growth reactor.
B. a suspended growth reactor.
C. a nitrification/denitrification reactor.
D. an attached growth reactor.

Chapter 10

Sludge Digestion and Solids Handling

SUGGESTED STUDY GUIDELINES

Class D
Be prepared to answer questions concerning:

The location of the digester in typical wastewater treatment process sequence.
The purposes of sludge digestion.
The basic description and processes of aerobic and anaerobic digesters.

Class C
Be prepared to answer questions concerning guidelines listed for Class D certification and:

The basic process controls in sludge digestion that are available to the operator.
The most critical process control factor for the anaerobic digestion process.
The early warning signs of digester upset.
The most common problems associated with anaerobic digesters and how to avoid them.
The definition of coning.
The most common temperature ranges for anaerobic digestion.
The predominant gases produced in anaerobic digesters under normal conditions.
The predominant gases produced in anaerobic digesters under upset conditions.
The proper maintenance procedures that are recommended for digester components.
The procedures for proper operation and maintenance of sand drying beds.
The different levels of sludge conditioning.
What level of conditioning lime stabilization achieves and how it is accomplished.
The level of conditioning that heat drying achieves.
The level of conditioning that air drying achieves.
The location of sludge thickening and dewatering processes in a typical unit sequence.
The special safety considerations for sludge digestion and management processes.

Be prepared to answer other questions that require additional personal study.

Class B and Class A
Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

The special operating characteristics of sludge handling for various types of digesters.
What information is needed to operate a digester using process controls.
How to identify normal and abnormal operating conditions from observation and lab tests.
The sampling locations, tests and information necessary to monitor digester performance.
How to perform a variety of calculations associated with sludge management including how to calculate loading rates to see if the digester is overloaded.
The characteristics of anaerobically digested sludge.
The principles and basic procedures for different methods of sludge dewatering including gravity thickening.

dissolved air flotation thickeners
belt filter press
sand drying beds

What chemicals can be used to stabilize sludge?
Why polymers are used in sludge treatment.
The effects that temperature, pH, alkalinity, and chemicals have on sludge treatment.
The requirements for the different methods of sludge stabilization.
The requirements for the handling and disposal of each level of sludge conditioning.
How to determine when to remove sludge for disposal.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

Entry Level Discussion

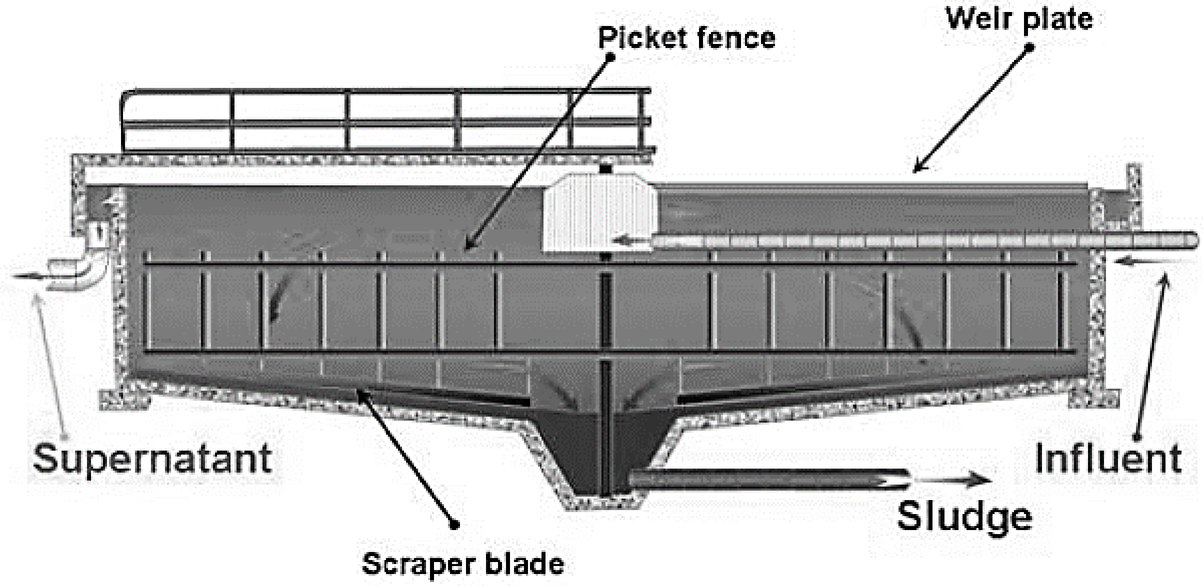
The settled sludge produced from wastewater treatment process is a highly odorous, watery mixture that must be stabilized so that it can be disposed of properly. The most common types of sludge stabilization processes used are anaerobic or aerobic digesters. In digesters, bacteria decompose the sludge to simpler forms prior to final disposal. The organic matter in the sludge is stabilized which greatly reduces both odors and pathogenic organisms. Other steps in solids handling processes include the thickening of sludge before it is sent to the digesters and the final dewatering of the digested sludge before it is disposed of. Treated sludge that can be beneficially recycled or used for productive purposes is sometimes referred to as biosolids. Composting of biosolids is one approved method used to produce very high quality biosolids that can, when properly treated, be used with no restrictions.

Sludge Thickening
The first step in treatment of sludge at some treatment plants is sludge thickening. The primary function of sludge thickening is to reduce the sludge volume to be handled in subsequent processes.

Settled solids removed from the bottom of the primary clarifier (raw primary sludge) and settled biological solids removed from the bottom of secondary clarifier (secondary sludge) contain large volumes of water. Typically primary sludge should contain approximately 95 percent water. Secondary sludge will typically contain even greater amounts of water. The less water that is removed from the sludge, the larger the size of the sludge digestion and handling equipment required.

Many facilities do not have separate sludge thickening treatment units. Even those facilities that do have these units should try to obtain maximum sludge thickening in the primary and secondary clarifiers before sending to a separate sludge thickening unit.
When a separate sludge thickening unit is used it is typically circular in design and will resemble a circular clarifier. The tank bottom is usually sloped towards the center and the settled solids move to the center of the tank where they are deposited in a sludge hopper and sent on to sludge digestion processes. In these units, the sludge being thickened is very gently stirred. This action releases trapped gases which prevents the rising of the solids and also prevents the accumulation of solids floating on the surface of the thickener.

Sludge Thickener



Anaerobic Digestion
The process of anaerobic digestion converts wastewater solids from a coarse, odorous mixture to a substance that is relatively odor free, dewaterable, and capable of being disposed of without causing serious problems. Anaerobic digestion liquefies organic solids, reducing the total solids volume, and produces valuable methane gas as a by-product.

Anaerobic digestion is accomplished by two types of organisms working together: acid formers; and methane fermenters. The acid formers consume organic waste in the wastewater and produce organic acids as a by-product. The methane fermenters then take the organic acids produced by the acid formers and break those acids down into methane and other by-products. Methane fermenters are not as numerous in raw wastewater as acid formers and require a pH range of 6.6 to 7.6 in order to reproduce.
Successful digester operation will result in a volatile solids reduction of 50 to 60 percent of the original content of raw sludge; you should try to operate an anaerobic digester so that the rate of acid formation and methane fermentation are approximately equal. In other words, you must maintain a balance between the acid formers and the methane fermenters. If this balance is not maintained, the process will get out of control resulting in poor digester performance.
The most common type of imbalance occurs when the methane fermenting bacteria fail to keep pace with the acid forming bacteria. If the activity of the methane fermenting bacteria slows down, the conversion of organic acids also slows down resulting in an increase in the acid content. If this continues, it will result in a lowered pH and a malfunctioning digester.

Description of Anaerobic Digesters
Anaerobic digesters will usually be cylindrical in shape although occasionally they may be constructed with a cubic shape. They will often have an operating depth of around 20 feet. The floor of the digester is usually sloped to remove sand, grit, and other heavy materials. There may be several tubes for removing supernatant at different levels. The supernatant is the liquid that collects above the sludge in unmixed digesters. The supernatant is usually returned in carefully

portioned quantities to the primary clarifier. All digesters will have sludge draw-off lines near the bottom of the tank for transferring treated sludge to a dewatering and/or disposal process or a second digester.

Another very important component in anaerobic digesters is a gas draw-off system for removal and subsequent handling of the large quantities of dangerous gases produced in the digestion process. This gas might be used to fuel burners that are designed to heat the digester to optimum temperatures for digestion.

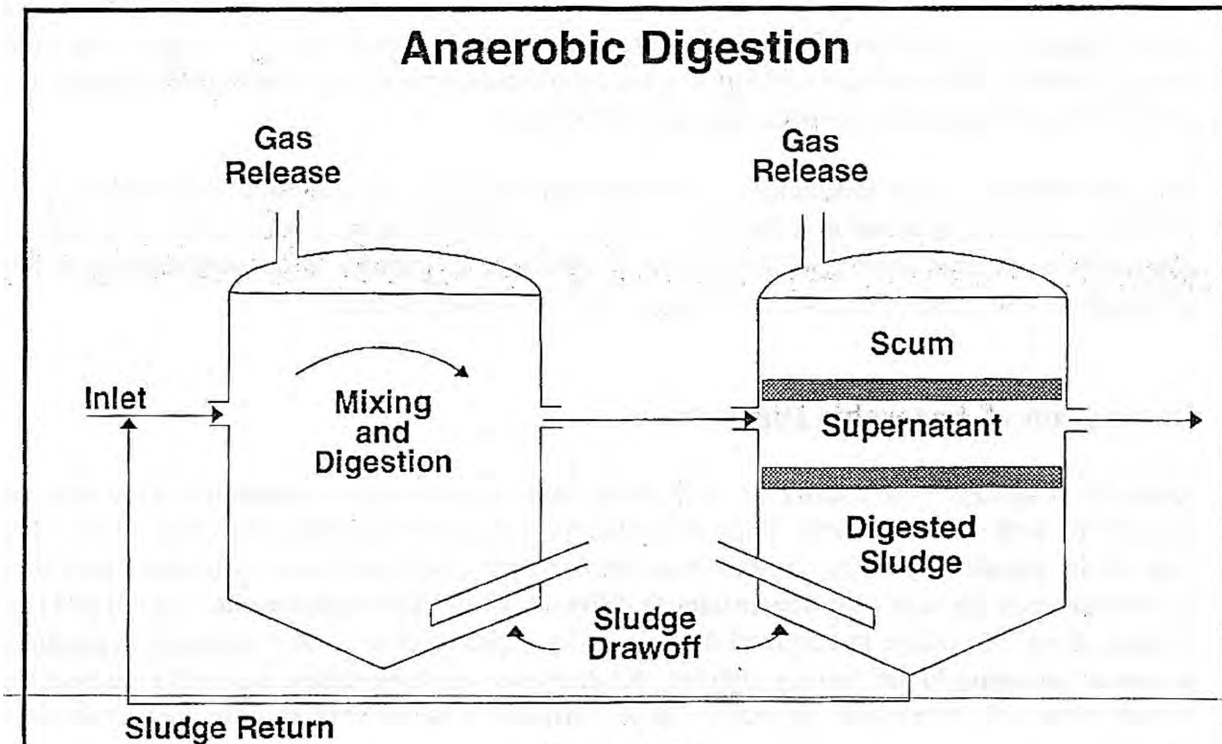


Figure 10.1

Fixed Cover Digesters
A fixed cover digester has a stationary roof that does not expand upward with an increase in gas pressure. A fixed cover digester can have an explosive mixture of gases in the tank when sludge is withdrawn if proper precautions are not taken to prevent air from being drawn into the tank. Each time raw sludge is added to the digester, an equal amount of supernatant is displaced because the tank is maintained at a fixed amount.

Floating Cover Digesters
Some digesters have a floating cover that moves up and down according to the tank level and gas pressure. For most floating cover digesters the distance of vertical travel of the cover is about eight feet. The advantages of a floating cover digester are primarily a reduction in the danger due to explosive gas mixtures in the tank, better control of supernatant withdrawal, and better control of scum blankets. The major disadvantages are higher construction and maintenance costs.

Operation and Process Control
The primary objective of good digester operation is maintaining conditions in a digester that will result in healthy populations of both acid formers and methane fermenters. This is accomplished through the following process control factors:

1. Temperature;
2. Food supply or loading rate;
3. Volatile acid/alkalinity ratio; and
4. Mixing of digester contents.

Temperature
Anaerobic digesters can theoretically be operated in one of three temperature ranges, each of which depends upon its own particular type of bacteria for digestion.

The lowest temperature ranges utilizes psychrophilic bacteria in unheated digesters. Digester temperature, as well as the sludge, tends to fluctuate along with external temperatures. Temperatures below 50°F will result in a drastic reduction in bacterial activity along with a reduction in digestion. When the temperature is above 50°F, bacterial activity increases to a measurable rate and anaerobic digestion is resumed. The upper limit for psychrophilic bacteria is about 68°F with a required digestion time of 50 to 180 days. In Oklahoma very few digesters are operated in the psychrophilic range in simply because they are slower and less efficient than heated digesters.

Digesters that operate within a temperature range between 68°F and 113°F utilize mesophilic bacteria to perform the digestion process. The ideal temperature for mesophilic digestion is about 98°F. The digestion time needed in a mesophilic digester is approximately 5 to 50 days depending in the degree of volatile solids reduction required and adequacy of mixing. The so-called "high-rate" digestion processes are usually operated in the mesophilic range. Mixing is also usually used in these digesters so that the organisms and the food can be brought together allowing the digestion process to proceed as rapidly as possible.

Mesophilic digesters must be heated to maintain the desired temperature range. They are often able to provide their own heating fuel supply in the form of methane. Methane is the most abundant gas produced by a digester operated in the mesophilic range. Hydrogen sulfide is the least abundant gas produced. In Oklahoma the mesophilic range is by far the most common temperature range utilized for sludge digestion.

The highest temperature range for sludge digestion uses thermophilic bacteria which prefer temperatures in excess of 113°F. The time required for digestion at these temperatures can range from only five to twelve days depending on the conditions. However, because there can be problems in maintaining these temperatures and the organisms are very sensitive to temperature change.

It should be noted that you cannot raise the temperature of the digester and expect it to perform successfully in another temperature range. The bacterial organisms must have time to adjust to the new temperature range before proper operations can be achieved. An important rule for digestion is never to change the temperature more than one degree Fahrenheit (F°) per day so that the organisms will have time to adjust.

Food Supply
When a new digester is put into service, naturally-occurring bacteria begin to consume the food sources that are easiest to digest, such as sugar, starches, and soluble nitrogen. Acid formers convert these foods into organic acids, alcohols, carbon dioxide, and some hydrogen sulfide. In this early stage digester contents pH will drop from about 7.0 to 6.0 or lower. At this time, the acid regression stage will begin and will last about six to eight weeks. During this stage, ammonia and bicarbonate compounds are formed, and the pH gradually increases to around 6.8, which provides conditions suitable for methane fermenting bacteria to become active. Methane fermenters, utilizing the organic acids as a food source, produce large quantities of methane gas and carbon dioxide. Once methane fermentation is established, a goal of successful digester operation is to maintain the pH within the 7.0 to 7.2 range.

If the feed rate of raw sludge to the digester is too high, the acid fermenters will become too active and begin to dominate. This results in high acid production and a drop in pH creating undesirable conditions for the methane fermenters. The activity of the methane fermenters decreases allowing excessive acid production in the digester. When the digester recovers from an acidic state, and as the breakdown of organic acids resumes, the formation of methane and carbon dioxide gas will occur very rapidly. This may result in foaming or frothing, which forces solids through water seals and gas lines which can cause serious operational problems. An upset or sour digester may require 30 to 60 days to completely recover.

The best procedure for feeding a digester is to feed it several times a day rather than just once. This avoids temporarily overloads on the digester and uses digester space more efficiently. Several pumping's a day from the primary clarifier aids in the digestion process, maintains better conditions in the clarifiers, and permits thicker sludge pumping. It is recommended that an operator pump as thick sludge as possible to the digester. Sludge is considered too thin if it contains less than five (5) percent solids content. Listed here are several reasons for maintaining sludge thickness.

1. Excess water requires more heat than may be available in the digester.
2. Excess water reduces sludge holding time in the digester.
3. Excess water forces seed and alkalinity from the digester, which can reduce the buffering capacity of the water and ultimately result in a lowered pH.

If a digester becomes upset the conditions can usually be remedied by adding alkalinity to buffer the excessive acid. This will increase the pH level to a point where normal digester processes of acid formation and methane fermentation can resume. Usually lime or soda ash and occasionally sodium bicarbonate will be used to neutralize a sour digester. The application of lime can have undesirable side effects however, such as an increase in solids handling problems. Soda ash causes less solids production but is more expensive. Sodium bicarbonate is sometimes used because it produces very little increase in solids. However, its use is also limited by the expense involved.

Volatile Acid / Alkalinity Ratio
The volatile acid/alkalinity ratio (V/A) is the single most important key to successful digester operation. As long as the volatile acid content remains low and the alkalinity stays high, anaerobic sludge digestion will occur. The proper V/A ratio will vary from plant to plant, but will usually be less than 0.1. When the V/A ratio begins to increase corrective action should be taken immediately. An increase in the V/A ratio is the first warning sign of impending trouble in an anaerobic digester. If no action is taken, the carbon dioxide content of the digester will increase, producing a decrease in the pH and a sour or upset digester.

The V/A ratio is an indication of the buffering capacity of the digester contents. Excessive feeding of sludge to the digester, removal of digested sludge, or some type of shock load such as storm flushing may upset the balance of the V/A ratio. A definite problem is developing when the V/A ratio starts increasing. When the ratio gets in the vicinity of 0.5 serious reductions in the alkalinity content of the digester will occur. When the ratio reaches 0.8 or higher, digester pH will begin to drop which can result in problems described in previous sections.

If the V/A ratio begins to increase, the operator may be able to avoid problems by using one or more of the following process controls:

1. Extending the mixture time of the digester contents;
2. Controlling heat more evenly; and
3. Decreasing sludge withdrawal rates.

Mixing
Plants constructed today are typically equipped with two separate digestion tanks or one tank with two divided sections. One tank is referred to as the primary digester and is used for heating, mixing and breakdown of sludge. The second tank, or secondary digester, is used as a holding tank for separation of the solids from the liquor. Most of the sludge stabilization work is accomplished in the primary digester, and 90 percent of the gas production occurs there. The primary tank must be very thoroughly mixed.

Gas Production in Anaerobic Digestion
During the early phases of digester startup, most of the gas consists of carbon dioxide and hydrogen sulfide. This combination of gases will not burn and is usually vented to the atmosphere. When methane fermentation starts and the methane content reaches about 60 percent, the gas can be used as a fuel source. Methane production should eventually predominate, producing a gas with a methane content of 65 to 70 percent and a carbon dioxide content of 30 to 35 percent. This gas is sometimes used as a fuel source to heat the digester.

Aerobic Sludge Digestion
At some modern aerobic biological treatment plants (including all activated sludge and trickling filter plants) an aerobic digester may be used instead of an anaerobic digester or other process for stabilizing sludge. An aerobic digester can be used to treat waste activated sludge (WAS), trickling filter sludge (humus), and primary sludge (raw sludge and scum).

Aerobic digestion tanks may be either round or rectangular, with a depth of about 18 to 20 feet. The tanks use mechanical or diffused aeration equipment to maintain aerobic conditions. Aerobic digesters are operated under a principal similar to extended aeration activated sludge processes. The aeration equipment in aerobic digesters must be turned off to allow time for the solids to separate from the supernatant.

Dewatering of Digested Sludge
After sludge has been treated through an aerobic or anaerobic digestion system, it must be dewatered before being disposed of. Most small treatment plants use drying beds for dewatering, while larger plants utilize mechanical dewatering systems.

Drying Beds
This drying process is accomplished through evaporation and percolation of the water after it is spread on a drying bed. Drying beds are usually constructed with an underdrain system covered with coarse crushed rock. Over the rock are layers of gravel and then a final layer of sand.

Sludge is carefully and properly drawn from the bottom of the second (unmixed) anaerobic digester, or the aerobic digester and applied to the drying bed. The depth to which the sludge is applied is normally around twelve inches. Thinner layers dry quicker than thicker layers. In warm weather, a good sand bed will usually have the sludge dry enough for removal within about four weeks. The water separates from the sludge and drains down through the sand. Evaporation also helps to dry the sludge and will cause it to crack. Air-dried sludge should contain a moisture content of 70% or less before removal from the bed.

Mechanical Dewatering
In plants where large volumes of sludge are handled and drying beds are not feasible, mechanical dewatering may be used. Mechanical dewatering methods include belt filter presses, vacuum filters and centrifuges. Each of these methods can be capable of reducing the moisture content of sludge by at least 60 to 80 percent leaving a wet, pasty material.

Sludge Disposal
The U.S Environmental Protection Agency (EPA) and the State of Oklahoma have strict requirements regarding the ultimate disposal of municipal wastewater sludge. In many cases, the approved sludge management plan for a treatment system allows for treated and dewatered sludge to be applied to agricultural land. The fertilizer value of treated sludge is slightly less than commercial fertilizer but it can serve as an excellent soil conditioner.

In the State of Oklahoma, one important set of criteria used to determine how and where the sludge can be disposed of is the level of conditioning that has been achieved in the treatment process. In addition to raw unconditioned, Class C, sludge, there are two levels of sludge conditioning: Class A and B.

Class C Sludge
Class C sludge is raw primary sludge and secondary sludge that has not undergone any treatment for removal of pathogens. Obviously, Class C sludge in not yet ready for disposal.

Class B Sludge
Class B sludge conditioning is defined as processes designed to significantly reduce pathogens. Class B sludge may be disposed of in landfills approved for accepting municipal sludge or applied to agricultural land in accordance with an ODEQ approved sludge management plan.

The most common methods of obtaining Class B conditioning are anaerobic digestion and aerobic digestion, each discussed earlier in this chapter. Another method of reaching Class B conditioning that is commonly used in Oklahoma is lime stabilization. Lime stabilization is achieved by adding enough lime to raise the pH to 12.0 and then maintaining this pH for a contact time of two hours. This method of stabilization is very effective for raw sludge. However, the addition of large amounts of lime greatly increases the volume of sludge material to be disposed of and the cost is generally more expensive than biological treatment or dewatering.

Class A Sludge
Class A sludge conditioning uses sludge processing to further reduce pathogens. Class A sludge may also be disposed of in landfills approved for accepting municipal sludge. If allowed by the plant's approved sludge management plan, Class A sludge may be applied to land that is used by the public such as golf courses or parks.

One method of accomplishing Class A sludge is a treatment process called heat drying. Heat drying exposes the sludge particles to temperatures greater than 80°F (176°C) which reduces the moisture content to less than 10 percent. The end by-product is odor free, contains few or no pathogenic organisms but still contains soli nutrients. However, because of the energy requirements necessary, this process is very rarely utilized in the State of Oklahoma.

Composting Sludge
Some treatment plants employ composting to produce Class B or Class A biosolids. Composting is comprised of mixing sludge with green wastes to break down sludge borne pathogens and volatile solids. Composting is recognized by EPA as one of the approved methods for Class A sludge production. Temperatures created by the green waste/biosolids mixture or "recipe" reduce pathogens and volatile materials in the sludge. The following table summarizes EPA composting time and temperature requirements treatment:

TIME AND TEMPERATURE REQUIREMENTS FOR BIOSOLIDS COMPOSTING

Product	Regulatory Requirements
Class A	Aerated static pile or in-vessel: 550 C for at least 3 days Windrow: 550 C for at least 15 days with 5 turns
Class B	400 C or higher for five days during which temperature exceed 550 C for at least four hours

Source: 40 Code of Federal Regulations, Part 503, Standards for the Use and Disposal of Sewage Sludge.

SUGGESTED REFERECES FOR STUDY

California State University, Sacramento – **Operation of Wastewater Treatment Plants Vol. 2**

Chapter 12 Sludge Digestion and Solids Handling
(especially sections 12.0, 12.1, 12.2, and 12.70)

California State University, Sacramento – **Advance Waste Treatment**

Chapter 3 Residual Solids Management

Operations Manual – Anaerobic Sludge Digestion*, USEPA 430/9-76-001*

Oklahoma Pollutant Discharge Elimination system (OPDES) STANDARDS *(Chapter 606)*

Biosolids Rule 40 *– CFR 503*

OTHER STUDY SUGGESTIONS

Be able to trace the flow of floating and settled solids from a primary clarifier to an anaerobic sludge digester and drying beds.
Study a cross section of sludge drying beds and be able to trace the flow to the beds and flow of drainage from the sludge drying beds back into the treatment process.
Know how to calculate drying beds solids handling capacity.
Know where anaerobic sludge digestion fits in the process sequence of a typical secondary wastewater treatment facility with trickling filters or activated sludge, and primary and secondary clarifiers.
Be familiar with a cross section diagram of an anaerobic and aerobic sludge digester and know the positioning of all the major components.
Trace the flow streams into and out of the digester.
Know what is removed or reduced and what is produced in the process and where it goes.
Know what your operational controls on the process are.
Be able to calculate pumping rates, detention time, organic loading rate, *VIA* Ratio, and volatile solids percent reduction.
Be able to recall standard numbers for these parameters.
Be able to recall standard design numbers for these parameters.
Know what a sour or upset digester is, and what might cause it.
Refer to troubleshooting charts in suggested references for information on typical problems with anaerobic and aerobic sludge digesters.
Study the relationship between digester health and each of the following variables:

- Temperature
- Volatile acid to alkalinity relationship
- pH
- Dissolved oxygen (aerobic digesters)
- Loading in terms of sludge volume and pounds volatile solids per cubic foot per day
- Detention time
- Carbon dioxide
- Volatile suspended solids reduction
- Detention time

Diagram each of the sludge thickening and dewatering processes
Plot flow streams into and out of each of the sludge thickening and dewatering processes with sampling locations.
Be able to identify what is happening in the sludge thickening and dewatering processes and what your expected values would be for solids concentrations and percent solids going into the processes and in the flow streams coming out of each process.
Refer to troubleshooting charts for typical problems and troubleshooting of each sludge thickening and dewatering process.

Practice performing solids and hydraulic loading calculations for each sludge thickening and de-watering process as appropriate.

Identify special safety problems when working around sludge thickening and dewatering processes.

SAMPLE QUESTIONS

Class D

Sludge digestion

A. Makes sludge more stable before disposal

B. Disposes of sludge

C. Makes sludge "stronger"

***Class* C**

Anaerobic bacteria that are especially sensitive to fluctuations in pH conditions of sludge are

A. acid formers

B. methane fermenters

C. nematodes

Class B

A solids concentration of 6 is equal to

A. 60 mg/l

B. 600 mg/l

C. 6,000 mg/l

D. 60,000 mg/l

Class A

A plant with a flow of 0:2 MGD produces 5,180 lbs/day of primary sludge and 2230 lbs/day of secondary sludge. Lime stabilization requires additions of 225 pounds of lime/ton to raise the pH to 12.0. How many pounds of lime is used per day?

A. 834 lbs

B. 927 lbs

C. 1048 lbs

D. 1202 lbs

Chapter 11
Wastewater Treatment Ponds

Suggested Study Guidelines

Class D

Be prepared to answer questions concerning:

- The type of pond used for treating domestic wastewater treatment.
- How the facultative pond treatment process works.
- Where the aerobic layer and anaerobic layer are located in a facultative pond.
- The basic types of microorganisms that are desirable in a pond and why.
- What the DO content should be in the aerobic layer of a facultative pond.
- The proper range of depth for primary ponds.
- What color a healthy facultative pond should be.
- How to recognize and remedy common operational problems.
- The difference between series operation and parallel operation.
- The difference between total retention and discharging ponds.
- The basic operation and maintenance procedures for facultative ponds.
- The special safety considerations when working around ponds.

***Class* C**

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- The basic pond parameters including loading rates, DO levels, pH, alkalinity, etc.
- The laboratory tests that are required to operate discharging ponds.
- The laboratory tests that are required in the operation of land application systems.
- How to determine if a pond is underloaded or overloaded.
- What chemical changes occur within the pond when the algae population increases.
- The most desirable ways of controlling growth of blue-green algae (cyanobacteria).
- The minimum required detention time for a discharging pond in Oklahoma.
- The maximum population loading per acre and how to calculate population equivalents.
- How to calculate pond areas, volumes, and detention times.

Be prepared to answer other questions that require additional personal study.

Class B and Class A

Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

- The special characteristics of mechanically aerated ponds.
- The hydraulic loading rate expressed in terms of detention time.
- The typical hydraulic and organic loading rates for aerated and non-aerated ponds.

Be prepared to answer other questions that require a combination of actual experience and additional personal study.

Entry Level Discussion

Shallow ponds are sometimes used to treat wastewater instead of, or in addition to, conventional treatment processes. When discharged into ponds, wastes are treated or stabilized by several natural processes happening at the same time. Heavy solids settle to the bottom where they are decomposed by bacteria. Lighter suspended material is broken down by suspended bacteria. Evaporation also helps to dispose of the wastewater**.**

Types of Wastewater Treatment Pond Systems

Wastewater treatment ponds may have different names based on their usage. For example, pond systems that receive and treat raw wastewater are referred to as **stabilization ponds** or **lagoons**. Ponds which are used after a primary clarifier are sometimes called **oxidation ponds.** Ponds that follow a secondary treatment process may be referred to as **polishing ponds**.

Regardless of their specific location in a process sequence, all wastewater treatment ponds used to treat domestic wastes in the State of Oklahoma are operated as **facultative ponds**. A facultative pond is a pond operated with both an aerobic layer and an anaerobic layer. Approximately the top 18 inches of a facultative pond will be aerobic and will contain significant amounts of dissolved oxygen. The lower layers of facultative ponds will be anaerobic and will contain very little dissolved oxygen.

Total Retention or Discharging Systems

Ponds are also categorized based on whether they are total retention or discharging. Ponds that do not discharge an effluent but dispose of water only through evaporation and/or land application are referred to as **total retention ponds**. Although it is recommended that certain lab tests (including pH, alkalinity, and dissolved oxygen) be performed regularly to serve as a warning of potential problems, total retention pond facilities are NOT actually required to conduct lab tests unless they are utilizing land application.

Ponds that discharge an effluent into a receiving stream are called **discharging ponds**. According to Oklahoma standards, the detention time for discharging ponds should be at least 120 days. Discharging pond facilities are much more complex to operate than total retention facilities. Specific lab tests and reports are required as indicated in Oklahoma rules and regulations.

Systems with multiple ponds are operated either in series or in parallel. **Series operation** refers to the use of several consecutive ponds, with the raw wastewater flowing first to a **primary pond** before being routed to the **secondary ponds**. In **parallel operation**, the raw wastewater is divided between two or more primary ponds. In this mode of operation, there may be no ponds available for use as secondary ponds.

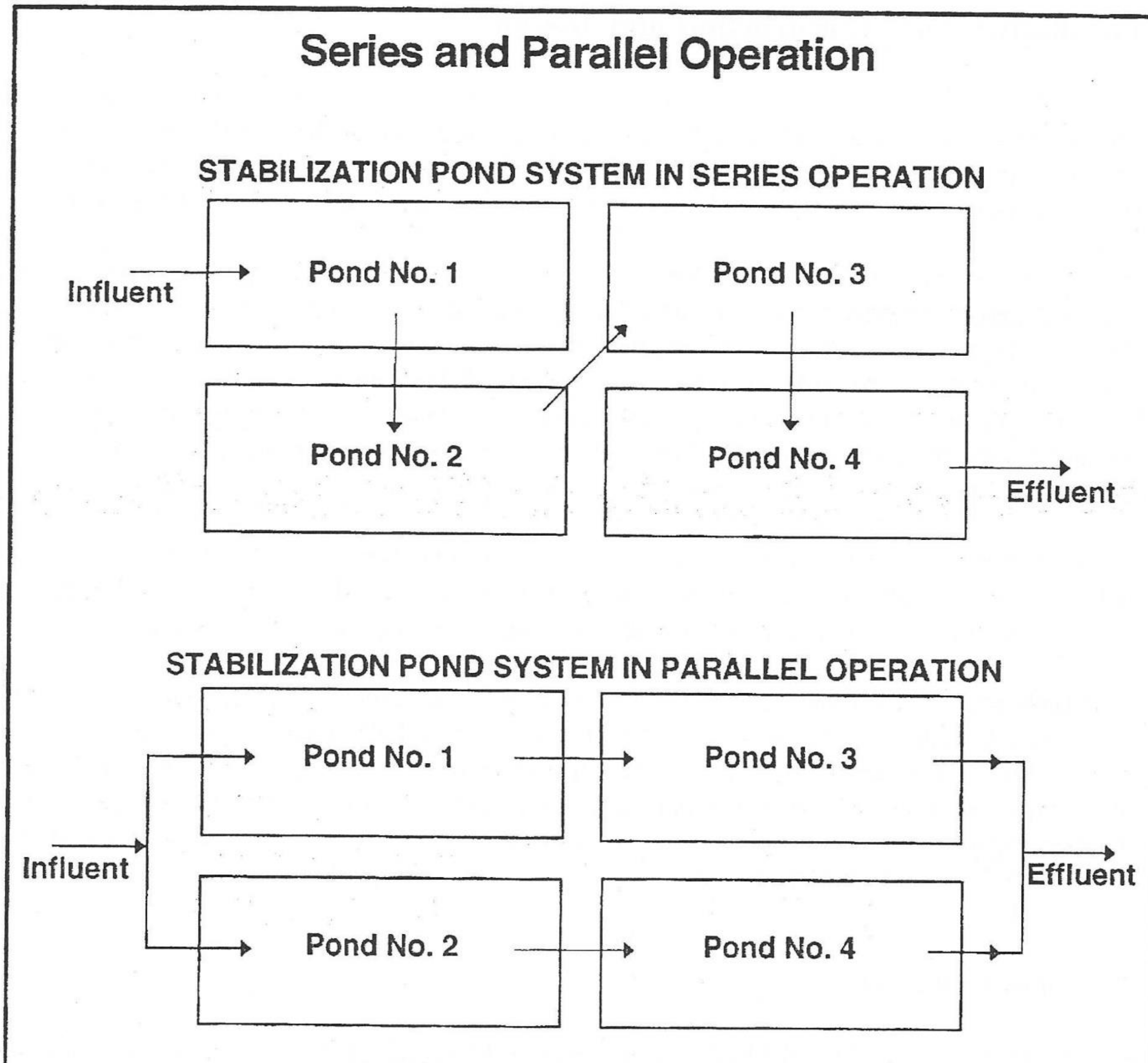


Figure 11.1

Generally speaking, the more ponds that the wastewater flows through, the better the treatment provided. For this reason, series operation is usually preferred unless the organic loading (BOD) of the raw wastewater is so high that a single primary pond would become overloaded and septic if it received all of the influent.

Facultative Pond Construction and Design

All ponds are constructed and maintained to meet rigid standards. One of these requirements is regarding the rate of seepage allowed through the bottom of the pond. The reason for this is to prevent groundwater supplies from becoming contaminated by leaking wastewater. To meet the standard, it is often necessary to install a **pond seal** of clay or synthetic material on the bottom of the pond.

Another important part of a pond's ability to properly contain wastewater is the pond dike. The **dike** is constructed of compacted material with a flat top at least eight feet wide and with sloped sides. The dike not only provides a stable wall for the pond but also permits operators access via vehicles in daily inspections and routine maintenance. The dike wall inside and outside slopes should not be steeper than 1 foot vertical rise for every 3 feet horizontal distance. Sometimes in older pond systems, erosion may have washed away some of the inside dike wall, causing it to be much steeper. This makes it very difficult for the operator to control weeds and mow the dike.

A typical primary facultative pond should have a water depth of between 3 feet and 6 feet. Secondary ponds where the water is clearer and algae are able to grow at greater depths can be even deeper. If the pond is mechanically aerated, the pond might be designed for depths of 10 to 15 feet.

The **freeboard** is the vertical distance from the surface of the water to a point which is even with the top of the dike. Pond systems are designed so that the freeboard above the average water line can be kept at 3 feet. Some very small wastewater pond systems might be designed to maintain a freeboard of only two feet. If a situation occurs that the freeboard becomes less than two feet, the system must have a pump available to provide irrigation of the inside of the dikes. Care must be taken to make sure wastewater does not flow over the dike.

Population Equivalent

Primary ponds in the State of Oklahoma are designed to handle the wastes of no more than 200 "population equivalent" or 35 pounds of BOD per surface acre. **Population equivalent** refers to the combination of the actual population served as well as all of the businesses served by the system. One population equivalent is considered to be either one person or about 0.17 pounds of organic material (BOD) per day contributed by other sources. For example, a small industry that contributed about 17 pounds of BOD each day would add about 10 population equivalent to the system. This small industry alone would therefore require at least one-half of a surface acre of primary pond for proper treatment.

It is important that operators are aware the initial design criteria of their systems. If there have been any significant changes in the amount of industry and/or the number of residents served by their system, modification of the operation or the plant design itself may be required.

Facultative Pond Treatment Process

Treatment Processes in the Aerobic Layer

In the **aerobic layer** (top layer) of the pond, organic material is converted into carbon dioxide and ammonia. These materials help to encourage the growth of **algae** (microscopic plants which contain chlorophyll and live in water). The large quantity of algae found in the aerobic layer of healthy ponds is the reason for the **sparkling green color** normally found in well-operated pond systems. The most desirable algal growth in ponds is a type of green algae called **chlorella**.

By utilizing sunlight and photosynthesis, the green algae uses the carbon in the carbon dioxide and then releases free oxygen, making it available to aerobic bacteria in the pond. The aerobic bacteria then produce carbon dioxide which the algae needs for respiration. Thus, the algae and bacteria will work together to maintain proper conditions for wastewater treatment.

The dissolved oxygen level in the aerobic portion of the pond should be maintained at a minimum of 3 mg/L or higher. Depending on the time of year and the time of day, dissolved oxygen levels in the top layer of ponds will be very high; often at near the saturation point (the point at which no more oxygen could be dissolved in the water).

Treatment Processes in the Anaerobic Layer

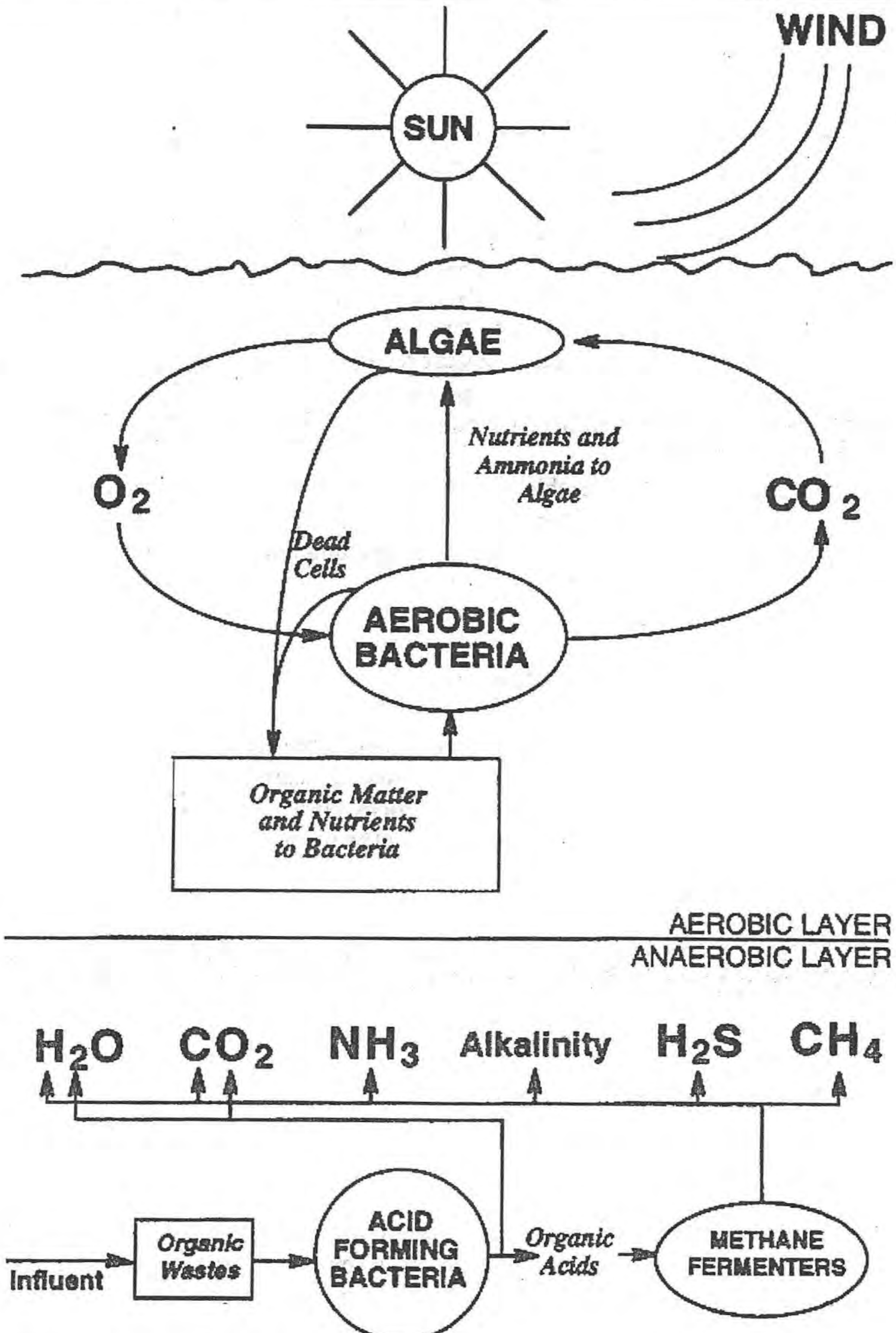
In the **anaerobic layer** (bottom layer) of a facultative pond, the organic waste entering the system at the bottom of the primary ponds will first be converted into carbon dioxide, nitrogen, and organic acids by a type of anaerobic bacteria called **acid formers**. Next, a group of bacteria called **methane fermenters** will break down the organic acids produced by the acid formers to form methane gas and alkalinity.

Due to the alkalinity produced by methane fermenters and the consumption of carbon dioxide by algae, most ponds will have pH levels in excess of pH 8.3. This means that most ponds will have at least some P-alkalinity present. The pond pH should be highest in late afternoons, when the algae are most active.

Common Problems in Pond Systems

Organic Overloading

If a pond becomes overloaded, it can result in algae die-off followed by a reduction in DO since the algae are the primary source of oxygen. Algae die-off can be controlled through proper application of ammonium nitrate (NH_4NO_3) to the pond. If ammonium nitrate isn't effective, the pond is probably under-designed and may require surface agitation by mechanical aeration to maintain adequate DO levels.



WIND
SUN
ALGAE
Nutrients and
Ammonia to
Algae
O_2
CO_2
Dead
Cells
AEROBIC
BACTERIA
Organic Matter
and Nutrients
to Bacteria
AEROBIC LAYER
ANAEROBIC LAYER
H_2O
CO_2
NH_3
Alkalinity
H_2S
CH_4
Influent
Organic
Wastes
ACID
FORMING
BACTERIA
Organic
Acids
METHANE
FERMENTERS

Figure 11.2

Undesirable Plant Growth

Effective control of undesirable plant growth is essential to proper operation of ponds. Generally, only two types of vegetation are considered desirable in or around the pond. One is the green algae needed in the aerobic layer to maintain DO levels. The other vegetation that is desirable at ponds is perennial, low growing, spreading grasses on the top and sides of pond dikes. Any other **dike vegetation,** all **emergent weeds** (those that grow from the pond bottom up through the water), and all **suspended vegetation** (floating plants) are undesirable at ponds.

Trees, shrubs, and tall grasses (such as alfalfa) are not wanted because their root systems are apt to impair the water-holding efficiency of the dike. Cattails, bulrushes and some other emergent weeds have long tap roots which can easily damage the pond seal allowing leakage of wastewater into groundwater supplies. Heavy growth of emergent weeds reduces proper mixing in the pond as well as supplying food for burrowing animals such as muskrats, badgers, squirrels, and gophers. Suspended vegetation, including duckweed and water hyacinth, will block sunlight from reaching the green algae in the pond. If the alga does not receive sunlight, the DO level in the aerobic layer will drop and the entire pond will become anaerobic. Both emergent and suspended weeds also provide a breeding place for mosquitoes and encourage the build-up of scum growth.

All weed growth tends to block wind which provides an important secondary source of oxygen in the top layer of the pond. Another problem common to all undesirable vegetation is simply an unsightly appearance. Uncontrolled weed growth shoes a lack of good housekeeping and proper upkeep of the facility.

The best method for control of undesirable vegetation is a DAILY practice of **close inspection and removal** of the young plants including their roots. Suspended vegetation usually will not flourish if the pond is exposed to a clear sweep of the wind. Dike vegetation control is aided by regular mowing and use of cover grass that will out-compete undesirable growth. Because emergent weed growth will occur only when sunlight is able to reach the pond bottom, the single best preventative measure against this type of growth is to maintain a water depth of at least three feet. Because shallow water promotes growth, there will always be a battle to keep emergent weeds from becoming established around pond banks.

Various other appropriate weed control methods can be found by studying the *Suggested References for Study* listed in this chapter. One option sometimes mentioned is the use of herbicides to kill the weeds. This option should only be used as a last resort, not only because of the chemical hazards for the operator, but also because of dangers presented to the desirable biological growth in the pond, on the dike and in the receiving, if discharging.

Blue-Green Algae

Another common problem for pond operators which sometimes prevents sunlight from reaching the pond is blue-green algae also known as cyanobacteria. **Cyanobacteria** are scum growth sometimes found on the pond surface. The appearance of cyanobacteria is usually an indicator of poor conditions in the pond. Cyanobacteria will make any pre-existing problems even worse.

Simply breaking up the cyanobacteria or other scum mats will cause them to sink to the bottom of the pond where they can be digested along with the other organic material. Appropriate methods of **physical agitation** used to break up these scum mats include the manual use of rakes, boards, paddles, or high pressure water hoses. For larger ponds, boats with outboard motors can be used to break up the mats (the motor should be the air-cooled type to avoid plugging its cooling system).

Land Application of Treated Wastewater

Land application of treated, domestic wastewater is becoming a common practice in the State of Oklahoma. Two situations often result in a decision to consider land application. One situation is when a discharging pond system is having difficulty meeting the requirements on its discharge permit. Another example of when conversion to land application is considered is when the hydraulic load of a total retention pond system has increased to the point that evaporation alone is no longer sufficient. Because so many factors must be weighed, land application is not always the best option. A decision to convert to land application is only made after careful evaluation of a completed feasibility study.

A NPDES discharge permit is not required for land application systems. However, whenever a discharging or total retention system plans to convert to land application, a construction permit must be issued by the State of Oklahoma that will specify the method of application as well as the testing requirements on both the wastewater and the soil where it will be applied. The owner of the cropland receiving the wastewater will likely require additional tests to determine the nutrient concentrations in the wastewater to be applied. This will indicate what type of supplemental fertilizer may be needed.

Probably the greatest public health concern related to land application of wastewater is **nitrate contamination** of ground water supplies. Because of this possibility, the permit may specify that all nitrogen applied to the land is accounted for on an annual basis. For some systems, this could require the drilling of ground water monitoring wells.

Siting Considerations and Application Methods

Examples of crops generally considered most desirable for receiving land applied wastewater are cotton, alfalfa grass, Bermuda grass, corn silage, and sorghum silage. Any crop that is intended for human consumption after processing must be subjected to a thirty day period between the last application of wastewater and the harvest. Wastewater should never be applied to any human foodstuff that is eaten raw.

Use of pond effluent to water grass at parks, cemeteries, golf courses, or other landscapes is sometimes allowed if the wastewater has been disinfected and if human access is restricted during spraying. A practice at smaller pond systems is to use the effluent on low traffic areas of the facility lawn.

Irrigation is by far the most common land application method approved for use in Oklahoma. Irrigation is usually performed by spraying the wastewater over the cropland. Many different types of piping and distributors are used, depending on the hydraulic load and many other factors. Probably the most common type of irrigation used are pumps feeding water cannon or rain-bird type sprayers.

Special Safety Considerations at Pond Systems

Whenever working around wastewater treatment ponds, especially when pulling weeds, such **protective gear** as waterproof gloves, boots, and goggles should be worn to reduce the chance of infection from pathogenic organisms that may be present in the water. Although many stabilization ponds are no deeper than five or six feet, there is still sufficient depth to drown a person, especially if he or she gets caught in a sticky clay liner. USING THE BUDDY SYSTEM AND LIFE PRESERVERS WILL GREATLY INCREASE THE LEVEL OF SAFETY when performing any pond maintenance, especially when using a boat.

When using heavy equipment to mow the dike, mowers especially designed for cutting slopes are preferable. Any tractor used on the dike should have a low center of gravity.

SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento–**Operation of Wastewater Treatment Plants – Vol. 1**
Chapter 9 Waste Treatment Ponds

Operations Manual, Stabilization Ponds, EPA-430/9-77-012

OTHER STUDY SUGGESTIONS

Draw out diagrams for ponds in series and in parallel.

Draw out typical process sequences which may include ponds as part of the treatment. One example of this would be pretreatment, primary sedimentation, wastewater treatment stabilization ponds, then sand filters, and effluent.

Concentrate on studying facultative ponds and aerated ponds.

Make a list of five or six of the most important operations variables which you need to monitor. Examples of these would be temperature, pH, and dissolved oxygen.

Make a diagram of where you would sample to determine loading on the pond, BOD and suspended solids removal efficiency and effluent quality, dissolved oxygen, and pH.

Refer to wastewater stabilization ponds troubleshooting charts available in EPA and California manuals for typical problems and what might be done about them.

Draw schematics of different flow patterns through a multiple pond system and identify what operational variables may occur with each flow pattern.

For mechanically aerated ponds you should be familiar with section diagrams of a surface floating aerator, a bridge mounted floating aerator, and diffused air systems.

Operation and maintenance characteristics for facultative and for aerated ponds.

Be familiar with the differing organic and hydraulic loading rates that may be applied to facultative ponds as opposed to ponds which are mechanically aerated.

Be familiar with the increased sampling schedules and locations for operational parameters such as dissolved oxygen, temperature, pH, and the solids level on the bottom of the pond.

Know how to perform sampling for operations tests and for determination of treatment efficiencies.

Be able to draw a schematic of a system which would include pretreatment, mechanically aerated ponds, secondary ponds, sand filters, and effluent disinfection.

Be able to trace the characteristics of raw wastewater through the pond system to see which characteristics such as suspended solids and dissolved solids are removed at what locations in the system.

SAMPLE QUESTIONS

Class D
Facultative ponds utilize:

A. both aerobic and anaerobic processes.
B. aerobic processes only.
C. anaerobic processes only.

Class C
Each surface acre of a primary pond is designed to treat the waste of no more than:

A. 100 persons or population equivalent.
B. 150 persons or population equivalent.
C. 200 persons or population equivalent.

Class B
As a result of excessive algal growth, discharging pond system operators may sometimes experience difficulty in meeting NPDES permit effluent limits for:

A. fecal coliform.
B. suspended solids.
C. BOD.
D. hydraulic loading.

Class A
The tests required at systems that utilize land application to dispose of the treated effluent are:

A. fecal coliform, alkalinity, and BOD.
B. pH, conductivity, and TSS.
C. fecal coliform, pH, and BOD.
D. pH, conductivity, and SAR.

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Chapter 12

Disinfection

SUGGESTED STUDY GUIDELINES:

Class D

Be prepared to answer questions concerning:

Where in the typical secondary wastewater treatment sequence chlorination and dechlorination processes are located.

The purpose of disinfection.

The basic definitions of chlorine dose, chlorine demand, chlorine residual, and breakpoint chlorination.

What concentrations of chlorine are in high-test hypochlorite (HTH) and liquid bleach.

The characteristics of chlorine gas including its color and its weight as compared to air.

The special safety considerations for working with chlorine and chlorine equipment:

- The characteristics and hazards of the different forms of chlorine.
- The proper procedures for safe storage and handling of chlorine.
- The proper procedure for changing a chlorine gas cylinder.

The most common causes of chlorine leaks and how to prevent it:

- How to check for chlorine leaks and what to do when a leak is detected.
- Where the self-contained breathing apparatus (SCBA) should be located.
- The procedures to prepare for emergencies in the chlorine room including the buddy system.

How to perform basic dosage calculations.

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- The basic processes of hypochlorinations and gas chlorination including the equipment used.
- The common operational problems involving hypochlorinators, gas ejectors, and regulators.
- The basic maintenance procedures that are recommended for chlorination equipment.
- The chemical reactions of chlorine in water.
- The major factors affecting the reaction including pH, temperature, concentration, mixing, and contact time.
- The chemical symbols for calcium hypochlorite, sodium hypochlorite, chlorine gas, sulfur dioxide, hypochlorous acid, and hydrochloric acid.

Class B and Class A
Be prepared to answer questions concerning guidelines listed for lower levels of certification and:

The related reactions of wastewater chlorination including reducing compounds and ammonia.

ENTRY LEVEL DISCUSSION:

Diseases from human discharges may be transmitted by wastewater. Disinfection is considered to be the primary mechanism for the inactivation/destruction of pathogenic organisms to prevent the spread of waterborne diseases to users of the streams as well as the environment. Typical disease-causing microorganisms include bacteria, viruses, and parasites. Disease causing organisms are known as **pathogenic organisms.** Some of the types of illnesses that these microorganisms can cause are as follows:

Bacteria-Caused:	**Internal Parasite-Caused:**	**Virus-Caused**
Anthrax	Amoebic Dysentery	Gastroenteritis
Bacillary Dysentery	Ascariasis	Heart anomalies
Cholera	Cryptosporidiosis	Infectious Hepatitis
Gastroenteritis	Giardiasis	Meningitis

NOTE: To date, there is no record of an operator becoming infected by the Human Immunodeficiency Virus (HIV) or developing Acquired Immune Deficiency syndrome (AIDS) due to on-the-job activities.

In order for disinfection to be effective, wastewater must first be adequately pretreated to remove suspended solids and organic material. Impurities, organics, and suspended solids (turbidity) can reduce the effectiveness of the disinfectant process by using up the disinfectant as well as giving the pathogenic organisms a protective barrier. If the disinfectant cannot reach the pathogen, it cannot kill it.

It is important to distinguish between disinfection and sterilization. **Sterilization** is the complete destruction of all organisms present in the wastewater. Sterilization of wastewater is not only unnecessary, it is also not cost effective. **Disinfection** is the destruction of most of the pathogenic organisms. Disinfection of wastewater is usually accomplished by using chlorine. However, ultraviolet light and, to a lesser extent, chlorine dioxide and ozone have been used as disinfectants at some wastewater treatment facilities. A brief discussion on both chlorination and alternative disinfection will be offered here.

Wastewater treatment processes usually remove some of the pathogenic microorganisms through the following processes.

1. Physical removal through sedimentation and filtration.
2. Natural die-away or die-off of microorganisms in an unfavorable environment.
3. Destruction by chemicals introduced for treatment purposes.

Effectiveness of treatment processes in removing microorganisms depends on the type of treatment processes and the hydraulic and organic loadings. Typical destruction/removals by various processes are summarized below:

Treatment Process	Microorganism Removal %
Primary Sedimentation	25-75
Trickling Filters	90-95
Activated Sludge	90-98
Chlorination	98-99
Ozone	98.5-99.5
UV Radiation	99-99.9

With all of the disinfection processes, time is a critical factor. In fact, simply allowing the organisms time to die is one way to disinfect. In cases where a disinfecting agent is used, the product of concentration of disinfectant and the time that the wastewater is in contact with the disinfectant is called the "CT" value. CT stands for concentration multiplied by time, and this product is sometimes considered as the disinfectant "dose."

Dose = Concentration of disinfectant X Time

Effective disinfection of wastewater is influenced by:

1. Contact time	2. pH	3. Concentration
4. Type of disinfecting agent	5. Wastewater demand	6. Temperature of wastewater
7. Flow rate	8. Concentration of interfering substances	

Although it is impractical to accurately identify all wastewater characteristics due to differences in location, water use, seasonal variations, waste-stream make-up, and others, it is important to have a general knowledge of the wastewater characteristics if the disinfection system is to perform its intended purpose.

Disinfection using Chlorine:

One of the main uses of chlorine in wastewater treatment is for disinfection. Chlorine is relatively easy to obtain and cheap to manufacture. Even at relatively low dosages, chlorine is extremely effective.

Today, people are living more intimately with wastewater than ever before. Wastewater treatment plants effluent may be used for irrigating lawns, parks, cemeteries, freeway planting, golf courses, college campuses, athletic fields, and other public areas. Recreational lakes used for boating, swimming, water skiing, fishing, and other water sports are frequently made up partially or, in a few cases, solely of treated effluents. As public contact has increased and diluting waters have decreased or become of poor quality, it has become obvious that more consideration must be given to disinfection practices.

FORMS OF CHLORINE*:*

There are three forms of chlorine that are commonly used as a disinfectant in the United States: chlorine gas, calcium hypochlorite, and sodium hypochlorite.

Chlorine gas (Cl_2) is 100 percent available chlorine and comes in 150 pound and one ton cylinders.

Calcium hypochlorite $Ca(OCl)_2$, is a calcium-based chlorine sanitizer and oxidizing compound. This product comes in the form of powder, 3" tablets and 1" tablets. One of the most popular brands of this compound on the market is registered in the name of **High Test Hypochlorite** (**HTH®).** For reference, oftentimes, Calcium hypochlorite and **(HTH®)** will be used to indicate this same form of sanitizer. For the purpose of math problems in this guide, as well as testing for certification, you will need to use 65 percent available chlorine as the standard concentration. However, calcium hypochlorite comes in various concentration, so to make sure you figure your dosage properly, you will need to read the available chlorine of any purchased supplies before using.

Sodium hypochlorite (NaOCl) is available in the form of **liquid bleach**. Bleach is produced in a variety of concentrations. The concentration of common household bleach is about 5.25 percent available chlorine. However, most wastewater (or water) systems that use bleach will use a 10 to 15 percent concentration.
Of the three major sources of chlorine, chlorine gas is by far the most common source used for continuous disinfection of wastewater. However, alternative methods are growing in popularity.

Characteristics of Chlorine Gas*:*
Chlorine gas must be handled with care because it is very **toxic** and **corrosive**. This gas can cause severe injury to anyone who comes into direct contact with it, especially if it is inhaled or comes into contact with the eyes. Chlorine gas is also dangerous because it is approximately **2.5 times heavier than air**, which means it has a tendency to collect in low places and will not float away without forced ventilation. Chlorine gas has a **greenish-yellow color** and a very distinctive and pungent odor. Chlorine gas cylinders actually contain very concentrated chlorine gas in a liquid form. One liter of this concentrated liquid chlorine produces 450 liters of chlorine gas upon evaporation.

In addition, chlorine gas has a very high **coefficient of expansion**, which means that it has a tendency to expand even further if the temperature increases. For example, if there was a temperature increase of 50°F (28°C), the volume of the chlorine gas in the cylinder would increase by 84 to 89 percent. This much expansion could easily cause enough pressure to rupture a chlorine cylinder or a line full of liquid chlorine. For this reason, chlorine gas cylinders are never filled to their total capacity.

Principles of Chlorination*:*
The exact mechanism of chlorine disinfection is actually not yet completely understood. One hypothesis contends that the chlorine exerts a direct action on the organism itself, thus destroying

it. Another hypothesis is that the toxic nature of chlorine destroys the enzymes that enable living microorganisms to use their food supply and the organisms die of starvation.

An important factor to consider in the effectiveness of chlorination is **contact time**. The more time that the wastewater is in contact with the chlorine, the better the disinfection. Adequate contact time is especially important for effluents that have a high pH and during colder periods of the year.

When chlorine is added to pure water, it reacts as follows;

Cl_2	+	H_2O	$\longrightarrow$	HOCl	+	HCL
Chlorine		water		hypochlorous acid		hydrochloric acid

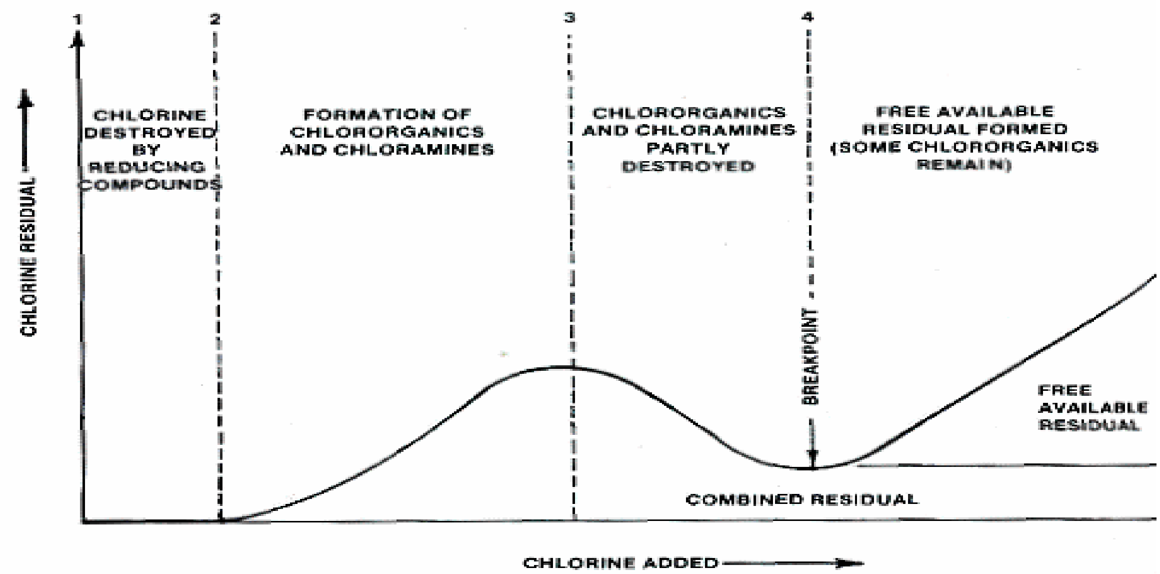
Chlorine (Cl_2) combines with water (H_2O) to form **Hypochlorous acid (HOCl),** a weak acid. This is one of the two chlorine residual forms. HOCL penetrates into and kills bacteria with little effort which if why it is the most effective form of chlorine for disinfection. **Hydrochloric acid** has very little disinfectant properties but is a very strong acid. Whenever chlorine comes into contact with moisture, this strong acid is formed.

Dose, Demand, and Residual:
When chlorine is added to water that contains organic and inorganic substances, it will immediately begin to react with them to form chlorine compounds. These compounds will in fact consume the chlorine that you add to the water until they are used up. These compounds that initially consume chlorine are referred to as the **chlorine demand**. After the chlorine demand has been "satisfied", any chlorine that remains is referred to as the **chlorine residual.** The **chlorine dose** is the total amount of chlorine added. In other words, the chlorine dose is the chlorine that is needed to satisfy the demand plus any remaining chlorine residual.

Chlorine Demand = Chlorine Dose - Chlorine Residual:
When chlorine is added to wastewater, any hypochlorous acid that is produced will immediately react with ammonia to form a group of compounds called **chloramines.** Chloramines are in fact a disinfecting residual often referred to as the **combined residual**, because they are a combination of both chlorine and ammonia. Combined residuals such as chloramines are relatively weak disinfecting agents. A much stronger disinfectant is a **free chlorine** residual. The total chlorine residual includes both the combined residual and the free chlorine residual.

Total Chlorine Residual = Combined Chlorine Residual + Free Chlorine Residual:
In order to obtain a free chlorine residual, a chlorination technique called **breakpoint chlorination** must be utilized. Breakpoint chlorination is a common practice at water treatment systems. However, due to the large amount of ammonia and nitrogen compounds found in

wastewater, breakpoint chlorination is not a common practice at wastewater systems.



Interferences

Interference	**Reaction**
Biochemical oxygen demand (BOD) ----->	exert a chlorine demand (chlorine is an oxidizer)
Suspended solids (TSS) ----------------->	exert chlorine demand, hides pathogens
Humic materials ------------------->	exert chlorine, they are organic compounds
Nitrite --------------------------->	is oxidized by chlorine add to chlorine demand
Iron, manganese, & hydrogen sulfide -->	exert chlorine demand plus will precipitate causing undesirable colors in treated wastewater

Chlorine is a disinfectant that has certain health and safety limitations, but at the same time, has a long history of being an effective disinfectant.

Advantages:
- Chlorination is a well-established technology.
- Presently, chlorine is more cost-effective than either UV radiation or ozone disinfection (except when dechlorination is required and/or fire code requirements must be met).
- The chlorine residual that remains in the wastewater effluent can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness.
- Chlorine disinfection is reliable and effective against a wide spectrum of pathogenic organisms.
- Chlorine is effective in oxidizing certain organic and inorganic compounds.
- Chlorination has flexible dosing control.
- Chlorine can eliminate certain noxious odors during disinfection.

Disadvantages:
- The chlorine residual, even at low concentrations, is toxic to aquatic life and treated wastewater discharging to aquatic environments may require dechlorination.
- All forms of chlorine are highly corrosive and toxic. Thus, storing, shipping, and handling pose a risk, requiring increased safety regulations.

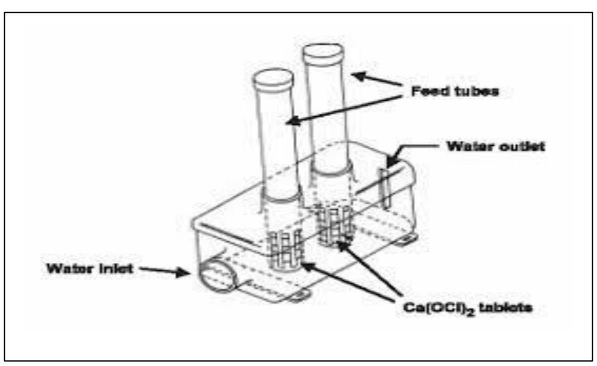
- Chlorine oxidizes certain types of organic matter in wastewater, creating more hazardous compounds (e.g., trihalomethanes (THMs).
- The level of total dissolved solids is increased in the treated effluent.
- The chlorine content of the wastewater is increased.
- Chlorine residual is unstable in the presence of high concentrations of chlorine-demanding materials, thus requiring higher doses to effect adequate disinfection.
- Some parasitic species have shown resistance to low doses of chlorine, including oocytes of *Cryptosporidium parvum*, cysts of *Endamoeba histolytica* and *Giardia lamblia*, and eggs of parasitic worms.
- Long-term effects of discharging dechlorinated compounds into the environment are unknown.

De-chlorination:
To minimize the effect of chlorinated wastewater to the receiving streams, the wastewater almost always needs to be dechlorinated to meet the requirements of the DMR.

De-chlorination is the process of removing the free and combined chlorine residuals to reduce residual toxicity after chlorination and before discharge. Sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$), sodium sulfite ($NaSO_3$), sodium metabisulfite ($Na_2S_2O_5$), hydrogen peroxide (H_2O_2), and sodium thiosulfate ($Na_2S_2O_3$) are the commonly-used de-chlorinating chemicals. Activated carbon has also been used. The total chlorine residual can usually be reduced to a level that is not toxic to aquatic life. Chlorine/de-chlorination systems are more complex to operate and maintain than chlorination systems. De-chlorination reactions occur very rapidly; therefore, no detention (contact) basin is required downstream from the de-chlorinator. The de-chlorinator can be as simple as a tablet de-chlorinator system, using exactly the same product as the chlorinator (without the contact basin), or dechlorinating chemicals such as sodium thiosulfate can be added using a metering pump and liquid solution tank similar to liquid chlorination.

Sulfur Dioxide gas (SO_2) is the most commonly used dechlorinating agent because it reacts instantaneously with chlorine on approximately a one-to-one basis (1mg/L SO_2 will react with and remove 1mg/L chlorine residual). It is fed into the effluent after the chlorine contact basin. Sulfur dioxide has hazardous properties much the same as chlorine gas. Hydrogen Peroxide is a very strong, liquid oxidizing agent which can cause serious burns. It is very expensive, the cost being several dollars per gallon for a 50% solution. Sodium meta-bisulfite is used for very small flows. The reaction of each of these dechlorinating agents with chlorine is instantaneous.

Tablet Feeder



Gas Feeder

Wastewater characteristics affecting chlorination performance. Source: EPA, 1999a.

Wastewater characteristics	Effects on Chlorine Disinfection
Ammonia	Forms chloramines when combined with chlorine
BOD	The degree of interference depends on their functional groups and chemical structures.
Hardness, Iron, Nitrate	Minor effect, if any.
Nitrite	Reduces effectiveness of chlorine and results in THM's.
pH	Affects distribution between hypochlorous acid and hypochlorite ions and among the various chloramine species.
TSS	Shielding of embedded bacteria and chlorine demand.

Chlorine Gas Safety:
When chlorine gas is inhaled, it will cause severe **lung damage** and can cause **blindness** if it comes into contact with the eyes.

One of the most common problems with chlorination equipment is leakage. In this case, the best cure is prevention. For example, **NEVER** reuse the gasket and washer when replacing a chlorine cylinder, even if they appear to be in good condition. Reusing gaskets and washers on chlorine cylinders is probably the most common source of chlorine leaks.

IT IS EXTREMELY IMPORTANT FOR ALL FACILITES WHICH USE CHLORINE GAS, OR ANY OTHER FORM OF CHLORINE, TO FOLLOW ALL SAFETY PRECAUTIONS.
Ammonia vapors can be used as a simple method of chlorine leak detection. If you place a clean rag that has been wetted with an ammonia water solution near a connection that has a chlorine leak, a visible white vapor will appear. Only a commercial grade of ammonia should be used for this purpose. Care should be taken to avoid applying the ammonia solution directly to the fittings because a strong acid will form that will corrode metal.

Improper storage temperature can contribute to the occurrence of leaks because of the high coefficient of expansion that chlorine gas possesses. Remember, chlorine will expand when heated. On the other hand, chlorine hydrate icing may occur on the connections of chlorine cylinders if the temperature in the chlorine room falls below 60°F (16°C). Chlorine containers should be stored away from heat or direct sunlight and the chlorine room should be kept in climate controlled conditions at normal room temperatures. Also, cylinders should never be connected to a common manifold unless special precautions are taken to prevent one cylinder from back-feeding to another.

As mentioned previously, chlorine gas is about 2.5 times heavier than air. That means it will have the tendency to collect in low places. For this reason, exhaust ducts for chlorine rooms are placed near the floor. Mechanical ventilation equipment (built-in fans) must be turned on, and must provide at least one complete air change per minute whenever the chlorine room is occupied.

A **self-contained breathing apparatus** (SCBA) or other respiratory air-pac protection equipment meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) must be available and stored at a location convenient to the chlorine room, but **NEVER** inside the chlorine room. This unit must contain a <u>30-minute minimum</u> air supply and be compatible with units used by the fire department. Instructions for using this equipment must be posted and comprehensive chlorine safety training including chlorine emergency drills using safety equipment should be held on a regular basis.

One of the most important safety precautions when working around chlorine gas or performing any other potentially dangerous job is to use the **buddy system.** Under the buddy system, a person is simply NEVER allowed to be left alone when performing dangerous work. Another person trained in emergency techniques and procedures must always be present and alertly watching the work being done from a safe position. All chlorine rooms must be equipped with an inspection window from which the buddy can safely observe the progress of the work without having to enter the room.

Chlorine Dioxide:
Studies have shown that chlorine dioxide is an effective wastewater disinfectant, although its use in the United States is limited. Chlorine dioxide is applied to wastewater as a gas that is generated on-site using excess chlorine. Although it is relatively easy and economical to produce chlorine dioxide is unstable and reactive and any transport is hazardous. Chlorine dioxide is effective at oxidizing phenols, but does not react with aquatic humus to produce trihalomethanes (THMs). However, any excess chlorine remaining from the generation of chlorine dioxide would react with THM precursors and form THMs. Therefore, operators must be careful to use the correct amounts of chlorine when generating chlorine dioxide. And while chlorine dioxide will not react with wastewater to form chloramines, it can produce potentially toxic byproducts such as chlorite and chlorate.

Chorine Dioxide is an effective bactericide and viricide that works over a wide range of pH values but is unstable and explosive as a gas. On-site generation of ClO_2 may be accomplished by combining sodium chlorite with either aqueous or gaseous chlorine (Reaction 1).
ClO_2 can also be produced by combining sodium chlorite with hydrochloric acid (Reaction 2).

<u>Reaction 1:</u> $2NaClO_2 + Cl_2 \div 2ClO_2 + 2NaCl$ (chlorine)
<u>Reaction 2:</u> $5NaClO_2 + 4HCl \div 4ClO_2 + 5NaCl + 2H_2O$ (hydrochloric acid)

A chlorine dioxide disinfection system requires chlorine dioxide generation on site.

12 milligrams/liter ClO_2 applied for a two-minute contact time achieved the following:

- Total coliform (TC) bacteria reduction to target levels of 1,000 colonies/100 milliliters.
- Fecal coliform (FC) and fecal streptococci (FS) bacteria reduction to 200 colonies/100 milliliters.

Proper operation and maintenance of a chlorine dioxide facility should include the following procedures:

- All tubing should be inspected every six months and faulty or corroded tubing should be replaced.
- Any gas filters should be inspected every six months.
- Chlorine dioxide pressure reducing valves should be cleaned with isopropyl alcohol or trichloroethylene.
- The valve spring should be replaced every two to five years.
- Ejectors should be disassembled and cleaned every six months.
- Chlorine dioxide analyzers (if used) should be inspected regularly. All lines should be inspected daily. Results from the analyzer should be compared with results from a manual analysis.
- Granular sodium chlorite should be stored in its own building equipped with sloped floors and equipment to hose down spills.
- Increases in temperature, exposure to light, changes in pressure, and exposure to organic contaminants should be avoided as they increase the chance of ClO2 explosions.

The following list highlights selected advantages and disadvantages of using chlorine dioxide as a disinfection method for drinking water (Masschelein, 1992; DeMers and Renner, 1992, Gallagher et al., 1994). Because of the wide variation of system size, water quality, and dosages applied, some of these advantages and disadvantages may not apply to a particular system.

Advantages:

- Chlorine dioxide is more effective than chlorine and chloramines for inactivation of viruses, cryptosporidium, and giardia.
- Chlorine dioxide oxidizes iron, manganese, and sulfides.
- Chlorine dioxide may enhance the clarification process.
- Taste and odors resulting from algae and decaying vegetation, as well as phenolic compounds, are controlled by chlorine dioxide.
- Under proper generation conditions (i.e., no excess chlorine), halogen-substituted DBPs are not formed.
- Chlorine dioxide is easy to generate.
- Biocidal properties are not influenced by pH.
- Chlorine dioxide provides residuals.

Disadvantages:

- The chlorine dioxide process forms the specific byproducts chlorite and chlorate.
- Generator efficiency and optimization difficulty can cause excess chlorine to be fed at the application point, which can potentially form halogen-substitute DBPs.
- Costs associated with training, sampling, and laboratory testing for chlorite and chlorate are high.
- Equipment is typically rented, and the cost of the sodium chlorite is high.
- Chlorine dioxide gas at concentrations over 10% can be explosive.
- Chlorine dioxide decomposes in sunlight.
- Chlorine dioxide must be made on-site.
- Can lead to production noxious odors in some systems.

Ozonation:
Ozone is a strong oxidizer and is applied to wastewater as a gas. Its use for wastewater disinfection is relatively new in the United States, and there are few facilities currently using ozone for disinfection. This can be potentially attributed to high initial capital costs associated with ozone generation equipment. Ozone is equal or superior to chlorine in "killing" power, but it does not cause the formation of halogenated organics as does chlorination.

Ozone disinfection is similar in most respects to chlorine disinfection. The major difference is that ozone is unstable, so it must be generated on site. For water treatment, ozone is produced by an electrical corona discharge or ultraviolet irradiation of dry air or oxygen. Ozone can be injected or diffused into the water supply stream.

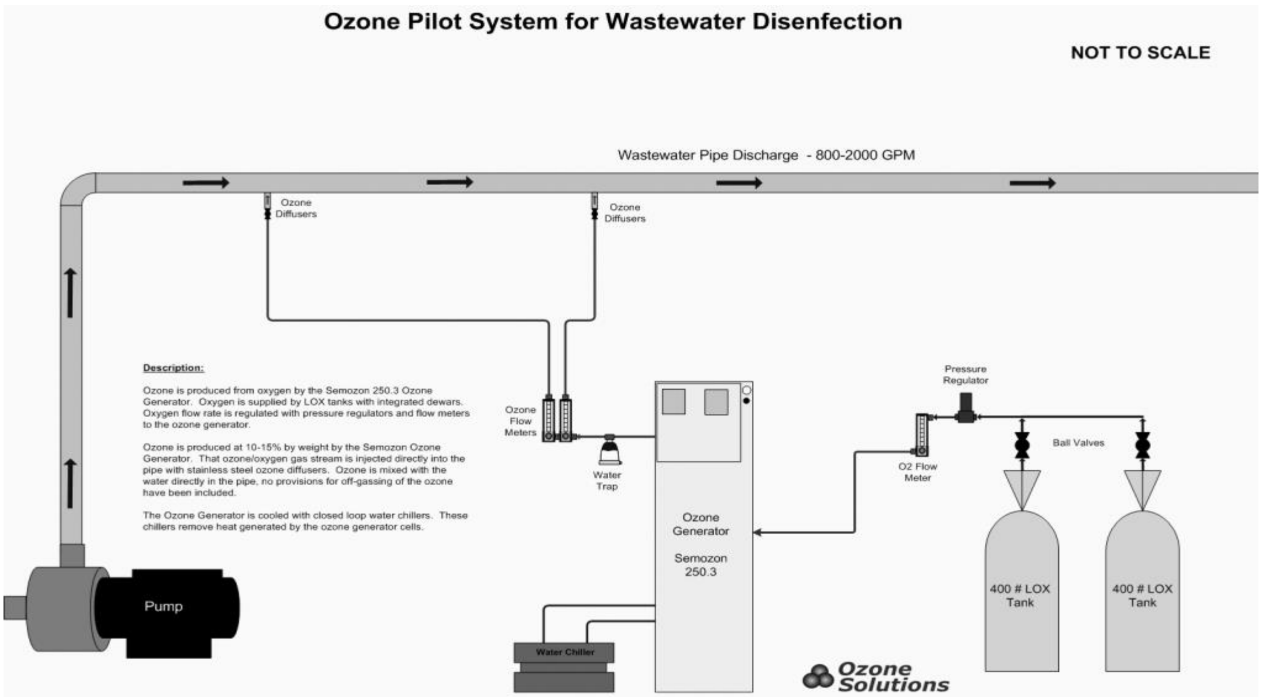
Maintenance of an ozone residual at a given concentration for a specific period (detention time) is necessary for proper disinfection. Because ozone has a tendency to decompose naturally and is consumed rapidly, it must be contacted uniformly in a near plug flow contactor. The ozone dosage must be calculated based on <u>the gas flow and the concentration</u> applied to the contactor versus the gas flow, and the concentration <u>out of the contactor and the aqueous ozone residual and flow</u>. The calculation requires consideration of gas volume and concentration versus aqueous volume and concentration.

Maintenance activities that should be addressed include:
- Prevent leaking connections or other leaks in or around the ozonator because this presents an electrical shock hazard.
- Schedule cleanings of ozonator and its parts.
- Lubricate compressor or blower as scheduled.
- Monitor ozone generator operating temperature.
- Clean the ozone generation cells periodically to maintain maximum efficiency.

Advantages:
- More powerful disinfectant than most chlorine compounds.
- Inactivates most strains of bacteria and viruses and is noted for destroying chlorine-resistant strains of both. Highly effective for cryptosporidium eradication.
- Will oxidize phenols with no negative residuals such as trihalomethane production.
- Does not produce a disinfection residual that would prevent bacterial growth.
- Degenerates into oxygen, which can elevate oxygen levels in treated water. It does not alter pH of water.
- Increases coagulation.
- Helps remove iron and manganese.
- Has taste and odor control properties.
- Requires shorter contact time than other disinfectants for the same or better results.

Disadvantages:
- More costly than traditional chlorinated disinfection techniques.
- Forms nitric oxides and nitric acid which can lead to corrosion.

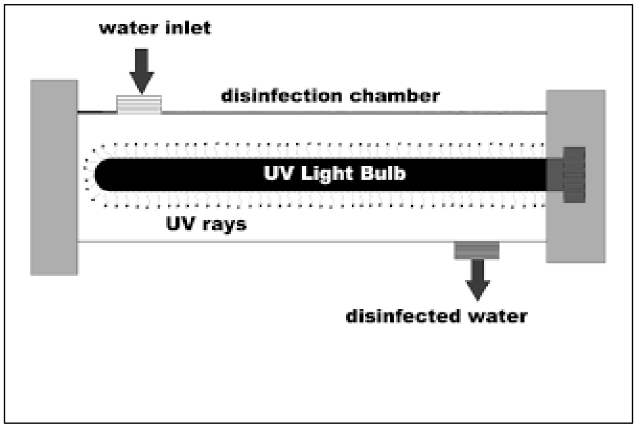
- Ozone is chemically unstable as a gas, and hazardous to transport. It must be generated on site and used immediately.

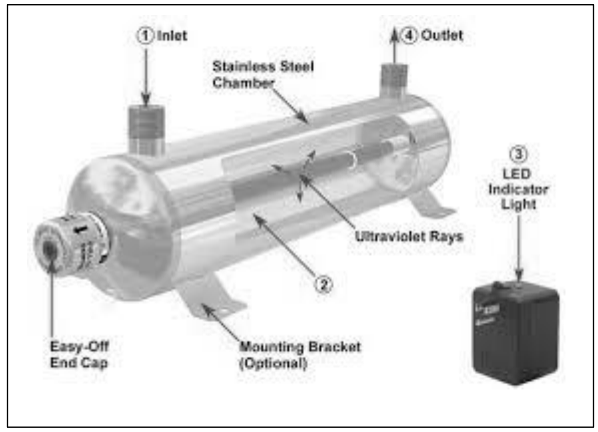


Ultraviolet (UV) Radiation:
The primary method for utilizing UV disinfection is to expose wastewater to a UV lamp. Historically, most UV disinfection facilities have been designed to utilize Low Pressure Low Intensity UV lamps for disinfection. For example, low-pressure mercury arc lamps emit approximately 90 percent of their light energy around 254 nanometers. UV disinfection works by penetrating the cell walls of pathogenic organisms and structurally altering their DNA, thus preventing cell replication and function. No hazardous chemicals are produced or released while treating wastewater with UV. Because UV is not a chemical disinfection method, it disinfects without altering the physical or chemical properties of water. However, UV efficiency is affected by suspended solids in the wastewater, which can scatter and absorb light. Thus, UV disinfection is not effective in wastewaters with a high TSS level.

The following factors must be monitored for the successful operation of a UV system: flow rate, suspended solids concentration, UV absorbency coefficient, initial and final coliform density, number of lamps in operation, average lamp output, and average transmissibility of the transmitting surface.

Maintenance for a UV disinfection facility would include area maintenance and component cleaning/repair. As with most surfaces exposed to wastewater, bacterial growth occurs in spite of the disinfecting ability of the UV radiation (the associated warmth facilitates growth). Bacterial growth on the quartz tubes surrounding the UV lamps gradually reduces the amount of UV radiation reaching, and disinfecting, the wastewater. UV systems have transmittance meters that measure the amount of UV light coming from the bulbs and passing through the wastewater. When the transmittance reading reaches a predetermined low level, the bulb covers must be cleaned, chemically and/or physically. UV examples below:





VERTICAL SYSTEM HORIZONTAL SYSTEM

Several **methods** are available for cleaning lamps including:

- In-place recirculation.
- Mechanical wipers.
- Dip tanks.
- Removing modules (rinse, clean with chemical, rinse and return).

Several **cleaning agents** available for cleaning lamps include:

- Citric acid.
- Dilute HCl.
- Phosphoric acid.
- Tile/bowl cleaner.
- Lime away.
- Detergent.
- Sulfuric acid.

Advantages:

- UV light produces no residual compounds.
- UV disinfection is effective at inactivating most viruses, spores, and cysts.
- UV disinfection is a physical process rather than a chemical process, which eliminates the need to generate, handle, transport, or store toxic/hazardous or corrosive chemicals.
- There is no residual effect that can be harmful to humans or aquatic life.
- UV disinfection is user-friendly for operators.
- UV disinfection has a shorter contact time when compared with other disinfectants (approximately 20 to 30 seconds with low-pressure lamps).
- UV disinfection equipment requires less space than other methods.

Disadvantages:

- UV light systems are relatively expensive.
- The UV lamps lose power with use.
- Any slime growth, solids, or color in the effluent will absorb UV light an minimize disinfection.
- UV radiation is not visible, but is VERY HARMFUL to the human eye. Special goggles must be worn when the lamps are operating.
- Low dosage may not effectively inactivate some viruses, spores, and cysts.
- Organisms can sometimes repair and reverse the destructive effects of UV through a "repair mechanism," known as photo reactivation, or in the absence of light known as "dark repair."
- A preventive maintenance program is necessary to control fouling of tubes.
- Turbidity and total suspended solids (TSS) in the wastewater can render UV disinfection ineffective. UV disinfection with low-pressure lamps is not as effective for secondary effluent with TSS levels above 30 mg/L.
- UV disinfection is not as cost-effective as chlorination, but costs are competitive when chlorination/dechlorination is used.

Peracetic Acid:

Peracetic acid (CH_3COOOH) (PAA), also known as ethaneperoxoic acid, peroxyacetic acid, or actyl hydroxide, is a very strong oxidant. Based on limited demonstration data for disinfection of secondary treatment plant effluent, peracetic acid appears to be an effective disinfectant and should be evaluated further for treating wastewater. The equilibrium mixture of hydrogen peroxide and acetic acid that produces PAA is too unstable and explosive to transport, and so PAA must be produced on site. The decomposition of PAA results in acetic acid, hydrogen peroxide and oxygen.

Peracetic acid has been used as a disinfectant in demonstration projects for the treatment of primary effluent such as that found in wastewater. PAA is a very strong oxidizer, and is produced by combining glacial acetic acid, hydrogen peroxide, and water. Sulfuric acid is typically used as a catalyst for the reaction. A stabilizer chemical is also added to solution to slow biodegradation.

Maintenance for a PAA facility should include periodic inspections of feed lines, storage areas, leakage detection equipment, and chemical injectors. Blocked or silted sewer lines should be flushed and cleaned on a regular basis. Spent chemical containers should be discarded in approved receptacles. Spilled chemicals should be cleaned up immediately. The chemical housing facility should be cleaned and inspected periodically to ensure structural integrity. The explosive nature of the chemical agents stored at the facility requires that the sprinkler system be inspected regularly.

Advantages:

- Higher oxidation potential than chlorine.
- Virtually unaffected by pH.
- Low cost to upgrade existing equipment.

Disadvantages:

- Unstable-will lose 1-2% of its active ingredients per month.
- A solution containing more than 15% PAA is highly volatile (explosive).
- Corrosive to rubber, galvanized iron, copper, brass, and bronze.

Electron Beam Irradiation:

Electron Beam Irradiation (E-Beam) uses a stream of high energy electrons that are directed into a thin film of water, or sludge. The electrons break apart water molecules and produce a large number of highly reactive chemical species. There are a few reactive species formed during this process and include oxidizing hydroxyl radicals, reducing aqueous electrons and hydrogen atoms.

Advantages:

Currently, there is insufficient information on the E-Beam process to make a full determination of its usefulness for CSO disinfection, but a pilot study performed for the New York City Department of Environmental Protection (NYCDEP) determined several advantages of the E-Beam system:

- No disinfectant chemicals required.
- No toxic byproducts are known to be produced.
- Short contact time required.
- Potential to deactivate a wide range of pathogens.
- Potential to penetrate waste streams with high solids concentrations.

Disadvantages

- Increased safety considerations due to use of high-voltage technology and the generation of X-ray radiation.
- No full scale application experience for CSOs.
- High capital costs.
- High O&M costs.
- Thin process flow stream.
- Abundant pretreatment straining of influent is required for this delivery system.

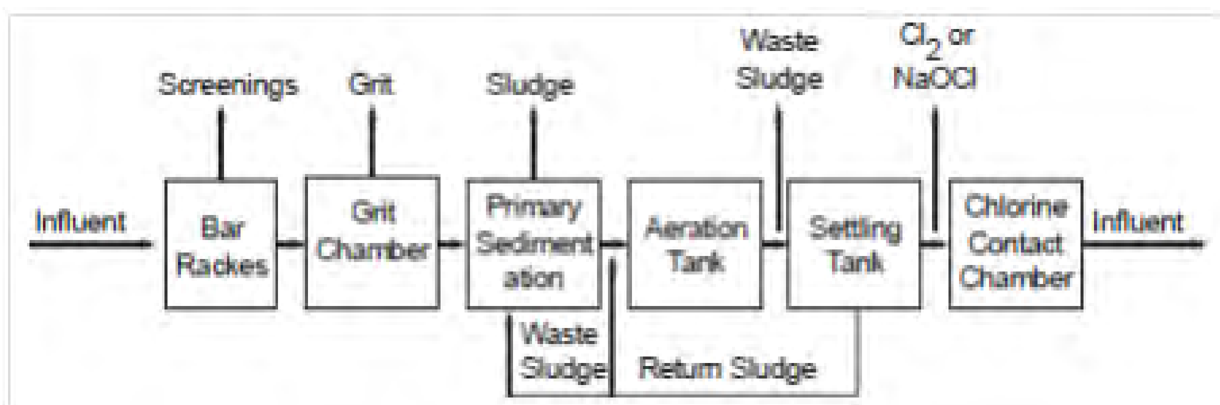
POINT OF CHLORINE APPLICATION

Collection System Chlorination:
One of the primary benefits of up-sewer chlorination is to prevent the deterioration of structures. Other benefits include odor and septicity control, and possible BOD reduction to decrease the load imposed on the wastewater treatment processes.

Prechlorination:
Pre-chlorination is defined as the addition of chlorine to wastewater at the entrance to the treatment plant, ahead of settling units and prior to the addition of other chemicals. In addition to its application for aiding disinfection and odor control at this point, prechlorination is applied to reduce plant BOD load, as an aid to settling, control foaming in Imhoff units, and help remove oil.

Plant Chlorination:
Chlorine is added to wastewater during treatment by other processes and the specific point of application is related to the results desired. The purpose of plant chlorination may be for control and prevention of odors, corrosion, sludge bulking, digester foaming, filter ponding, filter flies, and as an aid in sludge thickening. Again chlorination should be an emergency measure. Extreme care must be exercised when applying chlorine because it can interfere with or inhibit biological treatment processes.

Postchlorination:
Post-chlorination is defined as the addition of chlorine to municipal or industrial wastewater following other treatment processes. This point of application should be before a chlorine contact chamber and after the final settling unit in the treatment plant. The most effective place for chlorine application for disinfection is after treatment and on a well-clarified effluent. Postchlorination is used primarily for disinfection. As a result of chlorination for disinfection, some reduction in BOD may be observed; however, chlorination is rarely practiced solely for the purpose of BOD reduction.



SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – **Operation of Wastewater Treatment Plants, Vol. 1**
Chapter 10 Disinfection and Chlorination
(especially sections 10.0 – 10.5)

OTHER STUDY SUGGESTIONS

Be able to diagram the location of the injection point and contact basin.
Study the relationships and effects of mixing contact time, dosage, and flow on the effectiveness of chlorine.
Be familiar with diagrams of hypochlorite solution injection systems and gas chlorine regulator and ejector systems.
Be familiar with the complete gas chlorination set up including booster pump, strainers, pressure gauges, and ejector into mainline and the details of gas chlorine flow through the chlorine gas regulator and ejector.
Be able to identify and troubleshoot typical problems which may occur with the gas chlorine ejector and regulator system.
Study proper maintenance procedures, where the items are on each system that have to be maintained, and where your operational failures are likely to occur on gas chlorination systems.
For the best information on chlorine handling and safety, obtain the Chlorine Manual from the Chlorine Institute.
Practice using the dosage formulas found in APPENDIX A and APPENDIX B and in the suggested references.
Study the chemical reactions for chlorination and dechlorination in APPENDIX C.

SAMPLE QUESTIONS

Class D
Probably the most common cause of chlorine leaks is:

A. reusing gaskets and washers in chlorine connections.
B. automatic exhaust fans with too much “pull.”
C. faulty regulators.

Class C
The compound mainly responsible for the disinfecting action of chlorine is:

A. HOCl.
B. HCl.
C. SO_2.

Class B
How many pounds of 65% $Ca(OH)_2$ *(sometimes referred to as HTH)* are needed per day to achieve a chlorine residual of 0.5 mg/L if the demand is 7.6 mg/L and the flow is 0.5 MGD?

A. 22 lbs.
B. 34 lbs.
C. 41 lbs.
D. 52 lbs.

Class A
SO_4 reacts with chlorine at which of the following ratios?

A. 1 mg/L SO_2 is needed for every 0.5 mg/L of chlorine residual.
B. 1 mg/L SO_2 is needed for every 1.0 mg/L of chlorine residual.
C. 1 mg/L SO_2 is needed for every 2.0 mg/L of chlorine residual.
D. 1 mg/L SO_2 is needed for every 5.0 mg/L of chlorine residual.

Appendix A

Introduction to Basic Operator Math

This appendix offers some examples of how to work basic operator math problems. The "simplified" math formulas used in this Appendix will be provided with the test questions on the Class D exams. However, some of the conversion factors and abbreviations listed in this appendix must be memorized for the certification exam. To fine out exactly what you need to know for your Class D exam, please refer to the *Suggested Study Guidelines in each chapter of this study guide.*

Also included in this Appendix are some practice problems. It is important to practice to improve you ability to work the problems while you are actually taking your exam. Some of the basic math practice problems in this appendix may require additional explanations not offered here. A more complete explanation concerning basic operator math skills can be found within the *Suggested References for Study* listed in Chapter 1 of this study guide. Many approved operator training classes also offer help in learning how to solve math problems. It is recommended that all new operators read this appendix and work the math problems before attending an approved standard entry level class

Instructions for using APPENDIX A

1. Read completely

2. Read each section again before working the practice problems for that section

3. Compare your answers to answers on the last page of APPENDIX A. Don't be concerned if your answer is slightly different than the answer given. (how you round your numbers will change the outcome) Just remember if you have done the problem correctly you will be able to identify the correct answer in this appendix and on the actual test.

4. Review before taking you certification exam

The #1 factor in how well you do in math can be summarized by the old saying:

"If you don't use it, you lose it"

BASIC MATH EXPLAINED
WITH PRACTICE MATH

Converting (MGD) Million Gallon per Day to (gpd) gallon per day
Converting (MGD) Million Gallon per Day to (gpd) gallon per day

Two methods available to you
1st Move the decimal to the right 6 places
2nd Multiply by 1,000,000

Example: 2.3 MGD to gpd = 2,300000 = 2,300,000 gpd

Or 2.3 MGD x 1,000,000 = 2,300,000 gpd

Problems:

1. 1.6 MGD = ____________________ gpd
2. 0.04 MGD = ____________________ gpd
3. 0.002 MGD = ___________________ gpd

Converting (gpd) to (MGD)

Two methods available to you
1st Move the decimal to the left 6 places
2nd Divide by 1,000,000

Example: 1,475,000 gpd to MGD = 1,475,000 = 1.475 MGD

Or 1,475,000 gpd ÷ 1,000,000 = 1.475 MGD

Problems:

4. 100,000 gpd = _________________ MGD
5. 5,300 gpd = _________________ MGD
6. 275 gpd = _________________ MGD

Surface Area

Squares & Rectangles (A)ft^2 = (L x W) Area ft^2 = (Length x Width)

Example:
A surface dimensions are 35 ft. long by 15 ft. wide. What is the Area ft^2?

Area ft^2 = (Length 35 ft. x Width 15 ft.) Area=(35 ft. x 15 ft) Area = 525 ft^2

Problems:

7. L = 40 ft. W = 20 ft. Surface Area = _________________ ft^2
8. L = 15 ft. W = 5 ft. Surface Area = __________________ ft^2

Volume

Squares & Rectangles (V)ft^3 = (L x W x Third dimension)

Third dimension = Height or Depth

Example:

A Sedimentation basin dimensions are 40 ft. long 20 ft. wide and 14 ft. deep.

What is the Volume ft^3?

Volume ft^3 = (Length 40 ft. x Width 20 ft. x Depth 14 ft.)

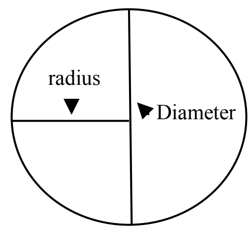
= (40 ft. x 20 ft. x 14 ft.)

= 11,200 ft^3

Problems:

9. L = 40 ft. W = 20 ft. D = 10 ft. Volume = ________________ ft^3
10. L = 15 ft. W = 5 ft. D = 8 ft. Volume = ________________ ft^3

Surface Area



Cylinders (Round Tanks, Pipe, Clarifiers, etc)

Surface Area $ft^2 = \pi r^2 = \pi$ x radius ft. x radius ft.

$\pi = 3.14$ r = Radius = ½ Diameter

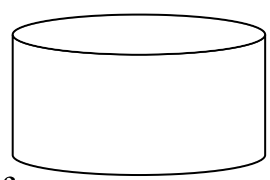
Example: A Clarifier has a diameter of 40 ft. What is the Surface Area ft^2?

Surface Area = π x 20 ft. x 20 ft. = 3.14 x 20 ft. x 20 ft. = 1,256 ft^2

Problems:

11. Diameter = 30 ft. Surface Area = __________________ ft^2
12. Diameter = 75 ft. Surface Area = __________________ ft^2

Volume



Cylinders (Round Tanks, Pipe, Clarifiers, etc)

Volume ft^3 = πr^2 x third dimension

= π x radius ft. x radius ft. x third dimension ft.

$\pi = 3.14$ r = Radius = ½ Diameter Third dimension = Height or Depth

Example:

A Clarifier has a diameter of 40 ft. and a depth of 14 ft. What is the Surface Area ft^3?

Surface Area = π x 20 ft. x 20 ft. x 14 ft.

= 3.14 x 20 ft. x 20 ft. x 14 ft. = 17,584 ft^3

Problems:

13. Diameter = 30 ft. Depth = 10 ft. Volume = __________ ft^3
14. Diameter = 75 ft. Depth = 14 ft. Volume = __________ ft^3

Volume ft^3 to Volume gallons

Volume ft^3 x gal/ft^3 Gallons = Volume ft^3 x 7.48 gal/ft^3

Example:

Volume of a tank = 17,584 ft^3How many gallons can this tank hold?

Gallons = (17,584 ft^3 x 7.48 gal/ft^3) Gallons = 131,528.32 or 0.13 MG

Problems:

15. 495 ft^3 = __________________ gal. = __________________ MG
16. 1,295 ft^3 = __________________ gal. = __________________ MG

Volume gallons to (lbs) Pounds

lbs = gallons x 8.34 lbs/gal

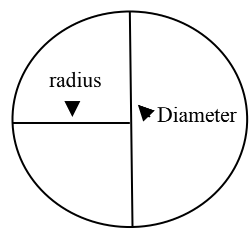
Example:

131,528 gallons to lbs = 13l,528 gal x 8.34 lbs/gal = 1,096,943.52 lbs. or 1.1 Mlbs

Problems:

17. 595 gallons = __________________ lbs. = __________________ Mlbs
18. 1,397 gallons = __________________ lbs. = __________________ Mlbs

CIRCUMFERENCE
Measurement of the circle



Circumference

Circumference of a circle = π x diameter ft.

= 3.14 x diameter ft.

Example:

The Diameter = 40 ft. What is the Circumference ft.

Circumference ft. = π x 40

= 3.14 x 40

= 125.6 ft.

Problems:

19. Diameter = 30 ft. = __________________ Circumference ft.
20. Diameter = 75 ft. = __________________ Circumference ft.

Convert psi to ft.

2.31 ft of head = 1 psi 1 ft of head = 0.433 psi

Example: 30 psi = how many ft of head

ft. = 30 x 2.31ft./psi ft. = 69.3 ft.

or ft. = 30 ÷ 0.433psi/ft. ft. = 69.3 ft.

Problems:

21. psi = 53 = ________________ ft.
22. psi = 125 = ________________ ft.

Convert ft. to psi

Example: 100 ft. of water is in the tower. What would the psi gage read?

psi = 100 ft. ÷ 2.31 ft./psi

psi = 43.3

or psi = 100 ft. × 0.433psi/ft.

psi = 43.3

Problems:

43. ft. = 125 = ________________ psi
44. ft. = 55 = ________________ psi

Review

- **Area of square or rectangle = (L × W) = ft^2**
- **Area of a circle = ("π" 3.14 × r^2) = ft^2**
- **Volume of sq or rectangle = (L × W × H) = ft^3**
- **Volume of cylinder = ("π" 3.14 × r^2 × H) = ft^3**
- **Volume gal = (ft^3 × 7.48 gal/ft^3) = gallons**
- **Diameter to Circumference = π × diameter**
- **lbs = (gallons × 8.34 lbs/gal)**
- **From Volume to lbs**
- **(L x W x H)(7.48 gal/ft^3)(8.34 lbs/gal) = lbs**
- **(π 3.14 × r^2 × H)(7.48 gal/ft^3)(8.34 lbs/gal)=lbs**

Remember radius must be in FEET to work for the purpose of the equations listed above

- **Flow MGD × 8.34 = Mlbs**
- **Volume MG × 8.34 = Mlbs**
- **Volume gal × 8.34 = lbs**

Volume Gallons:

Example:

You have just laid a section of pipe which is 18" in diameter and 2,850 ft. long. How many gallons does this section of pipe hold?

Formula (πr^2ft. x length ft. x 7.48 gal/ft.^{3})

1st. you have to convert the diameter from inches to feet.

18" ÷ 12"/ft. = 1.5 ft. DIAMETER Be sure to remember this is still DIAMETER

2nd now you have to divide the DIAMETER by 2 to get to radius

1.5 ft. ÷ 2 = 0.75 ft. RADIUS

3rd work the formula

Formula (πr^2ft. x length ft. x 7.48 gal/ft.^{3})

(3.14 x 0.75 ft. x 0.75 ft. x 2,850 ft. x 7.48 gal/ft3) =

37,652.9175 gallons ROUND TO 37,653 gallons

Problems:

25. You have just laid a section of pipe which is 6" in diameter and 1,200 ft. long. How many gallons does this section of pipe hold?

26. Your crew just finished laying a 18" diameter pipe 1,750 feet. How many gallons would that section of pipe hold?

Volume to drainage time:

Example:

It is time to drain your sedimentation basin for cleaning, the dimensions of the tank is 85 feet long, 40 feet wide and 15 feet deep. Using a pump that has a pumping rate of 185 gpm figure how many hours would this process take.

1st you have to figure how many gallons is in the tank.

Formula Gallons = (Length ft. x Width ft. x Depth ft. x 7.48 gal/ft.^{3})

Gallons = (85 feet long x 40 ft. wide x 15 ft. x 7.48 gal/ft.^{3})

Gallons = 381,480

2nd you need to divide the number of gallons by the pumping rate of the motor.

In this case the motor is listed as 185 gpm

Minutes = (381,480 gallons ÷ 185 gpm) = 2,062.05 minutes

3rd you still have at least one more step to convert minutes to hours

Hours = (2,062.05 ÷ 60) = 34.3675 hours rounded to 34.37 hours

NOTE THE ANSWERS MAY BE IN HOURS AND MINUTES SO YOU HAVE ANOTHER STEP

34.37 HOURS IS NOT 34 HOURS 37 MINUTES

YOU MUST MULTIPLE 60 MINUTES/HOUR BY 0.37 HOURS TO GET MINUTES

Minutes = (60 x 0.37) = 22.2 minutes rounded to 22 minutes

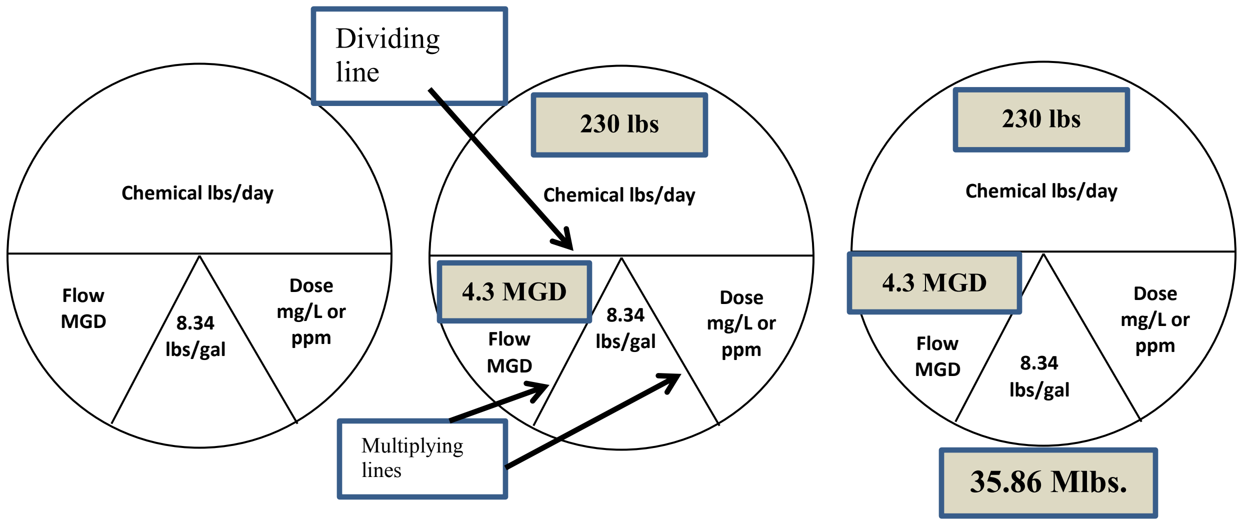
Makes your answer to be 34 HOURS and 22 MINUTES

Problems:

27. It is time to drain your sedimentation basin for cleaning, the dimensions of the tank is 120 feet long, 50 feet wide and 18 feet deep. Using a pump that has a pumping rate of 275 gpm figure how many hours this process would take.

28. It is time to drain your sedimentation basin for cleaning, the dimensions of the tank is 60 feet long, 30 feet wide and 14 feet deep. Using a pump that has a pumping rate of 185 gpm figure how hours this process would take.

Dosage Questions using 100% Chlorine Gas, Alum or any 100% Available Chemical:



Example:

The city water usage demand is 4.3 MGD from the water plant. The water plant is feeding 230 lbs./day of chlorine gas. What is the dose in mg/L?

1st Place the numbers where they belong on the pie as shown above.

2nd You need to multiply the bottom numbers on the bottom of the pie.

4.3 MGD x 8.34 lbs/gal = **35.86 Mlbs** now write this below your pie.

3rd To understand the way a pie works you need only remember that the half that needs no other information is divided by the half that is needing information to be full.

The top half needed only one piece of information to be full, which has already been given. The bottom half needed three pieces of information to be full but was only given two. So the top half is divided by the bottom half

230 lbs. ÷ 35.86 Mlbs. = **6.41 mg/L DOSE**

Now to work the same problem using the formula given to us to use by DEQ.

$$Dose, mg/L = \frac{Chemical, lbs.}{Mlbs}$$

$$Dose, mg/L = \frac{230\ Chemical, lbs.}{(4.3\ Flow, MGD\ x\ 8.34 lbs/gal)} = \frac{230\ lbs}{\mathbf{35.86\ Mlbs}}$$ = **6.41 mg/L DOSE**

Problems:

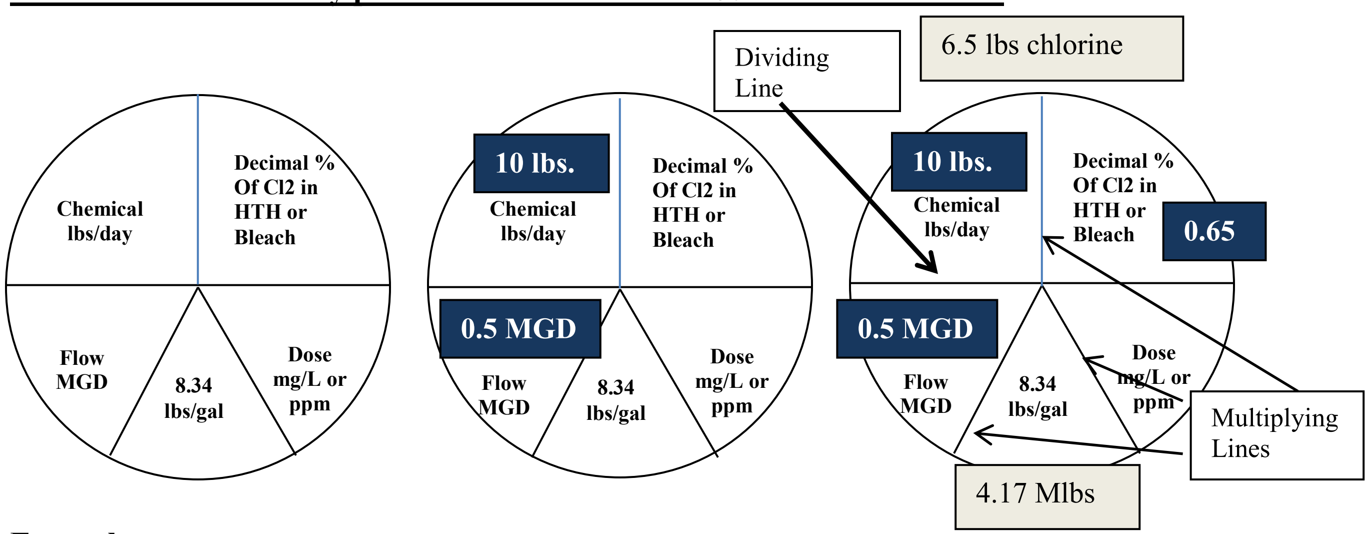
29. The city water usage demand is 2.8 MGD from the water plant. The water plant is feeding 35 lbs./day of chlorine gas. What is the dose in mg/L?

30. The city water usage demand is 10.7 MGD from the water plant. The water plant is feeding 161 lbs./day of chlorine gas. What is the dose in mg/L?

31. The city water usage demand is 1.2 MGD from the water plant. The water plant is feeding 15 lbs./day of the <u>coagulant ALUM</u>. What is the dose in mg/L?

32. The city water usage demand is 5.9 MGD from the water plant. The water plant is feeding 64 lbs./day of the <u>coagulant ALUM</u>. What is the dose in mg/L?

<u>Dosage Questions using 65% or 0.65 Calcium Hypochlorite or HTH:</u>
<u>Can also be used for any product with less than 100% available chemical</u>



Example:

The well is pumping 0.5 MGD. You are feeding 10lbs/day of HTH/day. What is your dose mg/L?

1st Place the numbers where they belong on the pie as shown above

2nd You need to realize that 10 lbs of HTH is not 10 lbs of chlorine and we are only interested in the amount of chlorine that is being fed.

HTH is only 65% chlorine which in decimal form is 0.65

So if you multiply the top half of the pie you will find out how many lbs. of Chlorine is available.
10 lbs of HTH x 0.65 = 6.5 lbs of Chlorine. Write that on the top of your pie.

3rd You need multiply the numbers on the bottom half of the pie.
0.5 MGD x 8.34 lbs/gal = 4.17 Mlbs. Write that on the bottom of your pie.

Remember the way a pie works you need only remember that the half that needs no other information is divided by the half that is needing information to be full.

4th In this case the top half has all the information it needs and the bottom half is still needing the Dose mg/L figured out so the top number is divided by the bottom number.

6.5 lbs/day chlorine ÷ 4.17 Mlbs = **1.56 mg/L dose**

Now work the same problem using the formula given to us to use by DEQ. However, you notice the formula given is only for 100% chlorine, you have to add in the difference in %.

$$Dose, mg/L = \frac{Chemical, lbs.}{Flow, Mlbs.}$$

$$Dose, mg/L = \frac{Chemical, lbs.\, x\ 0.65}{Flow, Mlbs.}$$

$$Dose, mg/L = \frac{Chemical, lbs.\, x\ 0.65}{(Flow, MGD\ x\ 8.34\ lbs/gal)}$$

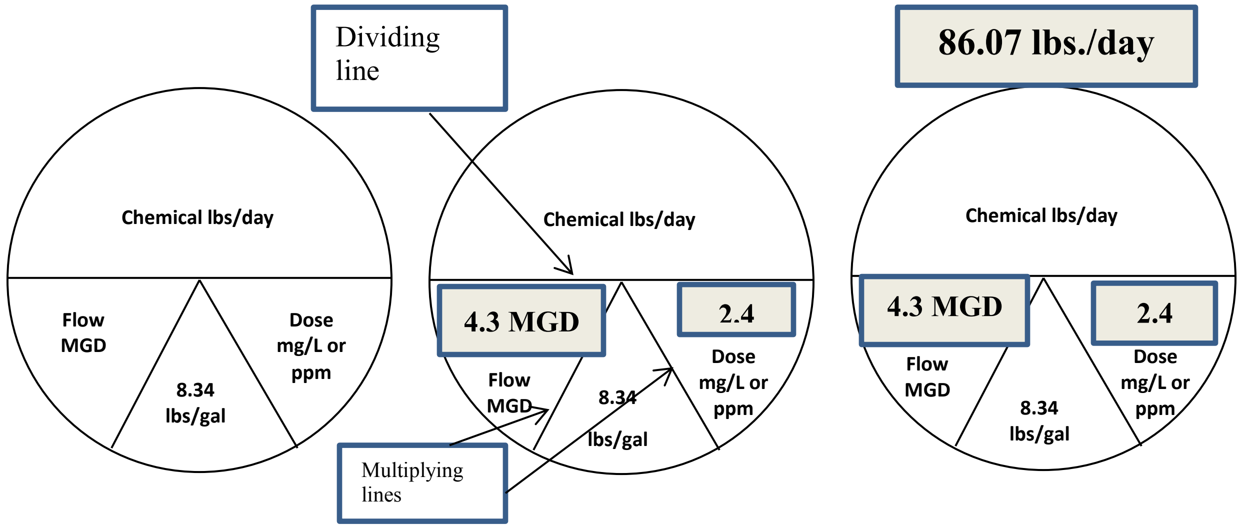
$$Dose, mg/L = \frac{10\ Chemical, lbs. x\ 0.65}{(0.5\ Flow, MGD\ x\ 8.34 lbs/gal)} = \frac{6.5\ lbs}{4.17\ Mlbs}$$ = **1.56 mg/L dose**

Problems:

33. The city water usage demand is 2.8 MGD from the water plant. The water plant is feeding 27 lbs./day of HTH. What is the dose in mg/L?

34. The city water usage demand is 250 gpm from the water plant. The water plant is feeding 7.5 lbs./day of HTH. What is the dose in mg/L?

Lbs./day Questions using 100% Chlorine Gas, Alum or any 100% Available Chemical:



Example:

The city water usage demand is 4.3 MGD from the water plant. The water plant needs to dose with a 2.4 mg/L of chlorine gas. How many lbs./day of chlorine gas would you need to feed?

1st Place the numbers where they belong on the pie as shown above.

2nd You need to multiply the bottom numbers on the bottom of the pie.

4.3 MGD x 8.34 lbs/gal x 2.4 mg/L = **86.07 lbs/day**
now write this in the upper section of the pie.

Since the bottom half of the pie had all the information it needed you can see that all you had to do is multiply those numbers to figure out how many lbs/day of 100% Chlorine was needed

Now to work the same problem using the formula given to us to use by DEQ.

$$\boldsymbol{Chemical\ Feed, lbs = (Dose, mg/L\ \ x\ Flow, Mlbs)}$$

Formula expanded:

$$Chemical\ Feed, lbs = (Dose, mg/L\ \ x\ 8.34\ lbs/gal\ x\ Flow, MGD)$$

$$Chemical\ Feed, lbs = (2.4\ mg/L\ \ x\ 8.34\ lbs/gal\ \ x\ 4.3\ MGD)$$

$$\boldsymbol{Chemical\ Feed, lbs = 86.07}$$

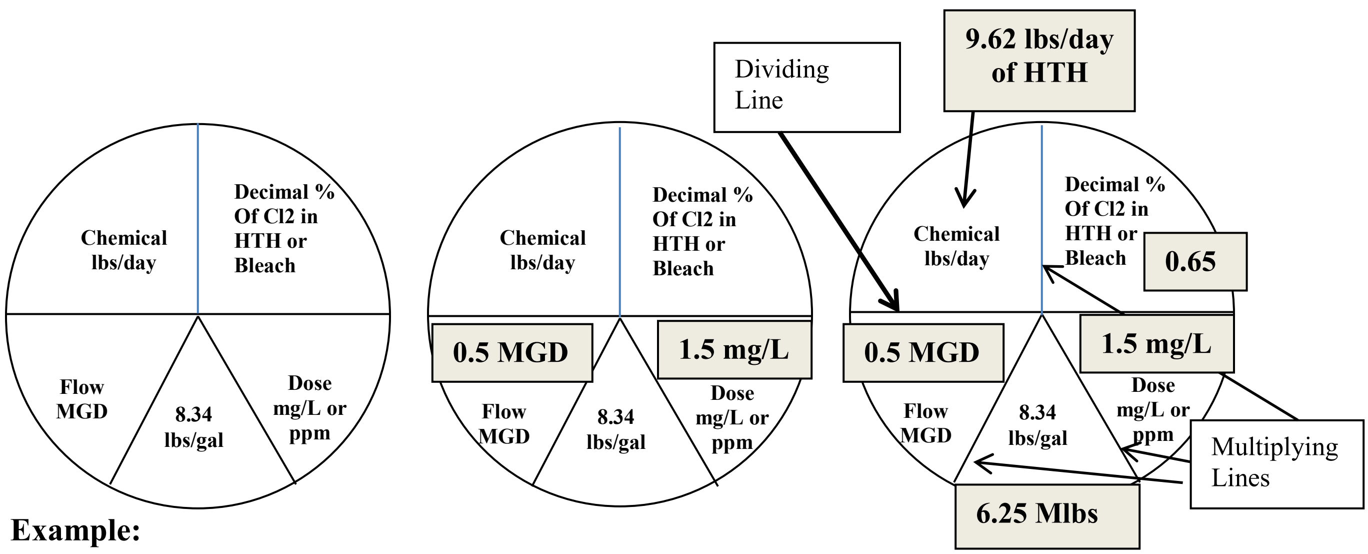
Problems:

35. The city water usage demand is 2.8 MGD from the water plant. The water plant desires a Dose of 1.5 mg/L. How many pounds of 100% Chlorine would you need to feed per day?

36. The city water usage demand is 1.2 MGD from the water plant. The water plant desires a Dose of 2.3 mg/L. How many pounds of 100% Chlorine would you need to feed per day?

37. The city water usage demand is 0.87 MGD from the water plant. The jar test results shows a Dose of 2.5 mg/L to be an ideal starting point for your coagulant. How many pounds of the coagulant ALUM would you need to feed per day?

lbs./day Questions using 65% or 0.65 Calcium Hypochlorite or HTH:
Can also be used for any product with less than 100% available chemical



Example:
The well is pumping 0.5 MGD. You desire a dose of 1.5 mg/L. How many lbs of HTH do you need to feed per day?

1st Place the numbers where they belong on the pie as shown above

You need to realize that the numbers on the bottom half of the pie represent 100% Chlorine Not HTH or any other percent of Chlorine such as bleach etc.

HTH is only 65% chlorine which in decimal form is 0.65

2nd You need to multiply all the bottom numbers to find out how many lbs of 100% Chlorine you would need.

0.5 MGD x 8.34 lbs/gal x 1.5 mg/L = 6.25 Mlbs (again this is 100% chlorine)

Remember the way a pie works you need only remember that the half that needs no other information is divided by the half that is needing information to be full.

In this case the bottom is full and the top needs information so the bottom number of 6.25 Mlbs of Chlorine is divided by 0.65.

6.25 Mlbs ÷ 0.65 = **9.62 lbs/day of HTH**

Now work the same problem using the formula given to us to use by DEQ. However, you notice the formula given is only for 100% chlorine you have to add in the difference in %.

$$Chemical\ Feed, lbs = (Dose, mg/L\ \ x\ 8.34\ lbs/gal\ x\ Flow, MGD)$$

You have to rewrite this to look like the following

$$Chemical\ Feed, lbs = \frac{(Dose, mg/L\ \ x\ 8.34\ lbs/gal\ \ x\ \ Flow, MGD)}{0.65\ HTH}$$

$$Chemical\ Feed, lbs = \frac{(1.5\ Dose, mg/L\ \ x\ 8.34\ lbs/gal\ \ x\ \ 0.5\ Flow, MGD)}{0.65\ HTH}$$

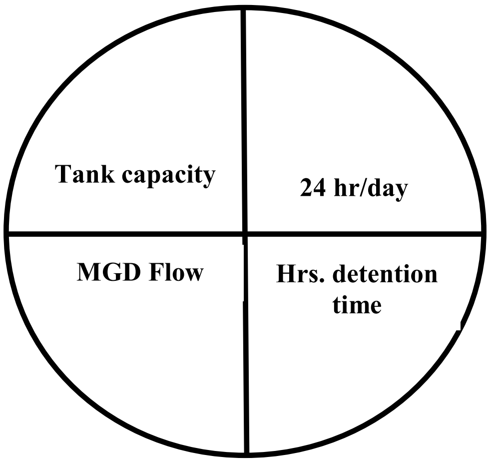
Chemical Feed, lbs = **9.62 lbs/day of HTH**

Problems:

38. The city water usage demand is 2.8 MGD from the water plant. The water plant desire a dose of 2.5 mg/L. How many lbs/day of HTH would you need to feed?

39. The city water usage demand is 0.15 MGD from the water plant. The water plant desire a dose of 1.5 mg/L. How many lbs/day of HTH would you need to feed?

Detention Time:



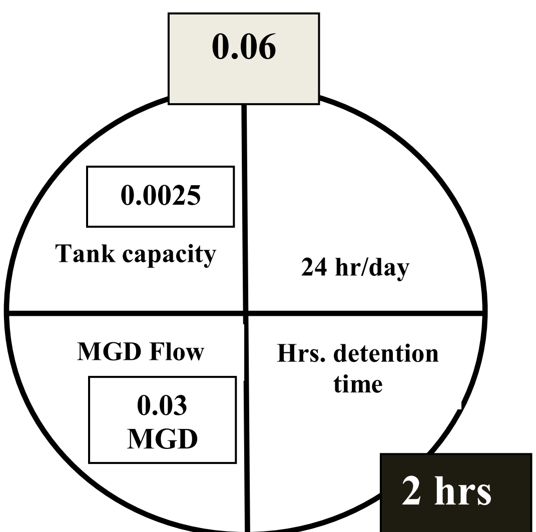
DEQ Formula:

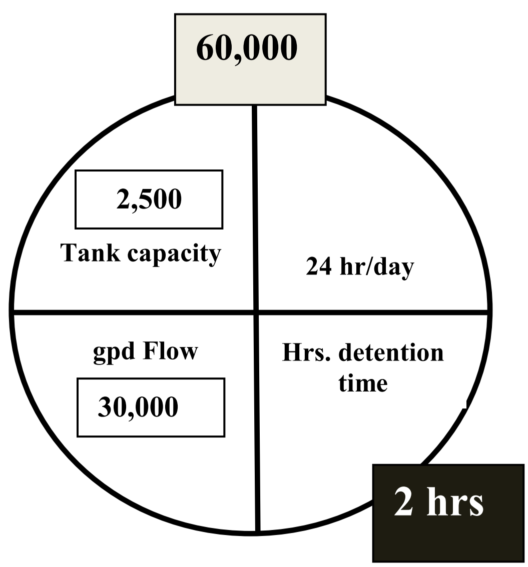
$$Detention\ Time, hr. = \frac{(Volume, gal\ x\ 24\ hr/day)}{Flow\ gpd}$$

$$Detention\ Time, hr. = \frac{(Volume, MG\ x\ 24\ hr/day)}{Flow\ MGD}$$

NOTE:
The pie on the DEQ handout sheet is formatted as MG & MGD.
The formula sheet on the DEQ handout sheet is formatted as gallons. & gpd.
It makes no difference if you use the 1st or 2nd format as long as you use the same format on the top of your equation or pie that you have on the bottom of the equation or pie.

Detention Time:





DEQ Formula:

$$Detention\ Time, hr. = \frac{(Volume, gal\ x\ 24\ hr/day)}{Flow\ gpd}$$

$$Detention\ Time, hr. = \frac{(Volume, MG\ x\ 24\ hr/day)}{Flow\ MGD}$$

EXAMPLE:

Determine the average detention time in hours for a basin that holds a volume of 2,500 gallons, that receives a flow of 30,000 gpd?

A. 2 hrs. B. 4 hrs.
C. 20 hrs. D. 9 hrs.

$$Detention\ Time, hr. = \frac{(2{,}500\ Volume, gal\ x\ 24 hr/day)}{30{,}000\ Flow\ gpd} = 2\text{ hrs.}$$

$$Detention\ Time, hr. = \frac{(0.0025\ Volume, MG\ x\ 24\ hr/day)}{0.03\ Flow\ MGD} = 2\ hrs.$$

Problems:

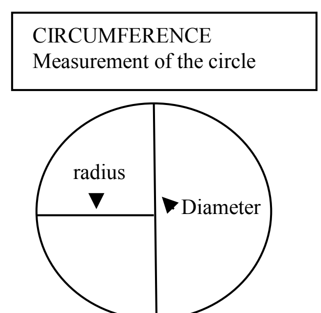
40. What is the detention time in a storage tank 20 feet high and 30 feet in diameter when the rate of flow is 500,000 gal/day?

A. 2.9 hours B. 5.1 hours C. 3.5 hours

Just as you learned earlier in this section on math the following formula will give you the ability to convert the dimensions given to volume in gallons.
(pi x r^2 x depth x 7.48 gal/ft^3) = volume in gallons

41. Basin = 38,000 gal Flow = 65,000 gpd
What is the detention time?
A. 1.4 hrs B. 15 hrs
C. 14 hrs D. 8 hrs

WEIR OVERFLOW:



Circumference

Circumference of a circle $= \pi$ x diameter ft.
= 3.14 x diameter ft.

$$Weir\ Overflow\ \ gpd/ft = \frac{Flow\ gpd}{Weir\ Length\ ft.}$$

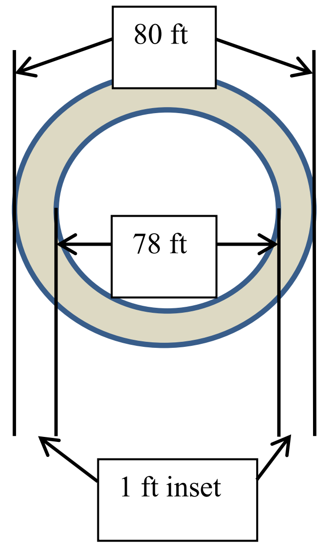
EXAMPLE:

The flow into a clarifier 80 foot diameter is 185 gpm. The weir is set back 1 foot. What is the weir overflow rate gpd/ft of weir?

Convert the information you have to fill in the information you need.
1st You were given 185 gpm but the formula is wanting gpd.
Simply convert to gpd: 185 gpm x 1440 min/day = **266,400 gpd**

2nd You need to figure out the circumference of the weir.
Diameter is 80 ft. however the weir is set in 1 ft. on each side making the actual weir diameter 78 ft.

3rd Now that you know the diameter of the weir figure the circumference by using the circumference formula from below.



Circumference of a circle = π x diameter ft.
= 3.14 x 78
= 244.92 ft of weir
Rounded to = 245 ft of weir

$$Weir\ Overflow\ \ gpd/ft = \frac{266{,}400\ Flow\ gpd}{245\ Weir\ Length\ ft.}$$ = 1,087 gpd/ft of weir

$$\boldsymbol{Weir\ Overflow = 1{,}087\ gpd/ft}$$

Problems:

42. A tank with a weir set one foot in has an overall diameter of 35 feet and a flow of 0.22 MGD. What is the weir overflow rate in gpd/ft of weir?

A. 2,189 gpd/ft of weir B. 1,000 gpd/ft of weir C. 228.6 gpd/ft of weir

43. A clarifier with a weir set one foot in has an overall diameter of 32 feet and a flow of 1.1 MGD. What is the weir loading rate in gpm/foot of weir?

A. 9,553 gpd/foot of weir B. 897 gpd/foot of weir C. 11,677 gpd/ft of weir

SURFACE LOADING:

$$Surface\ Loading\ gpd/ft^2 = \frac{Flow\ gpd}{Surface\ Area\ ft^2}$$

EXAMPLE:

A primary clarifier has a diameter of 60 feet, the primary effluent flow is 2.3 MGD. What is the surface loading rate in gpd/ft^2?

Remember to convert MGD to gpd 2.3 MGD x 1,000,000 = **Flow 2,300,000 gpd**

How to figure surface area square feet example: $A = \pi r^2$

Surface Area = 3.14 x radius x radius
= 3.14 x 30 ft x 30 ft
= 2,826 ft^2

$$Surface\ Loading\ gpd/ft^2 = \frac{2{,}300{,}000\ Flow\ gpd}{2{,}826\ Surface\ Area\ ft^2} = \mathbf{813.87\ gpd/ft^2}$$

Problems:

44. A circular clarifier has a diameter of 55 feet, the flow is 1.2 MGD.
What is the surface loading rate in gpd/ft^2?

A. 617.5 gpd/ft^2 B. 505.3 gpd/ft^2 C. 857.3 gpd/ft^2

45. Calculate the surface loading rate on a clarifier 75 ft in diameter
with a flow rate of 4.1 MGD. What is the surface loading rate in gpd/ft^2?

A. 928 gpd/ft^2 B. 1028 gpd/ft^2 C. 1440 gpd/ft^2

46. Calculate the surface loading rate on a clarifier 40 ft in diameter
with a flow rate of 1.7 MGD. What is the surface loading rate in gpd/ft^2?

A. 818 gpd/ft^2 B. 1128 gpd/ft^2 C. 1354 gpd/ft^2

FILTRATION RATE:

$$Filtration\ Rate\ gpm/ft^2 = \frac{Flow\ gpm}{Surface\ Area\ ft^2}$$

Example:

A flow rate of 0.5 MGD is being filtered by a filter with the dimensions of 15 ft. wide and 20 ft. long. What is the filtration rate in gpm/ft^2?

1st Convert MGD to gpm 0.5 MGD x 1,000,000 = 500,000 gpd
500,000 gpd ÷ 1440 min/day = **347 gpm**

2ndConvert the dimensions to ft^2 15 ft wide x 20 ft long = **300 ft^2**

$$Filtration\ Rate\ gpm/ft^2 = \frac{347\ Flow\ gpm}{300\ Surface\ Area\ ft^2}$$

$$\mathbf{Filtration\ Rate = 1.16\ gpm/ft^2}$$

Problems:

47. A flow rate of 600 gallons per minute is being filtered by 1200 square feet.
What is the filter rate?

A. 2 gpm/ft^2 B. 5.0 gpm/ft^2 C. .5 gpm/ft^2

48. What is the filter rate in gpm/ft^2 with a Flow = 3 MGD Filter area = 1400 ft^2

A. 21.4 gpm/ft^2 B. 1.5 gpm/ft^2 C. .15 gpm/ft^2

Backwash rate:

A backwash formula is not available in the DEQ handout however, it is a simple formula. The main thing to remember is the smaller of the two numbers will be divided by the larger of the two numbers.

The only two numbers you need to work this is the number of gallons that were filtered and the number of gallons you used to backwash with.

Example:
You have filtered 1.5 MG before needing to backwash. You used 35,000 gallons of water to backwash the filter. What is the backwash rate %?

1st You will need to convert MG to gpd 1.5 MG x 1,000,000 = 1,500,000 gpd
2nd Divide the smaller number by the larger number
3rd Your answer will be in decimal form so to convert it to (%) percent multiply by 100

$$Backwash\ rate\ \% = \frac{Gallons\ used\ to\ Backwash}{Gallons\ Filtered}$$

$$Backwash\ rate\ \% = \frac{35{,}000\ gal.}{1{,}500{,}000\ gpd}\ \text{x}100$$

$$Backwash\ rate\ \% = 0.023\ \text{x}\ 100$$

$$\boldsymbol{Backwash\ rate = 2.3\%}$$

Problems:
49. A filter is 30 ft wide by 15 ft long and flows 552,000 gallons before needing backwashed with 10,400 gal and the backwash rate is 1.5 gpm/ft^2. What is the percent of backwash?

A. 5.5% B. 3.5% C. 1.9%

California manual water treatment Plant Operation, Vol.1, Ch. 6, section 6.722, example 10
Equation:
Note: Always remember that the only two numbers you need for this problem is the gallons filtered and gallons used to backwash.

50. A filter has filtered 0.75 MG, you used 20,000 gallons to backwash. What is the percent of backwash?

A. 3.7% B. 2.7% C. 4.1%

VELOCITY: **Note: a number to remember 5,280 ft. = 1 mile**

$$Velocity, ft/\min = \frac{Distance, ft.}{Time, min.}$$

Example:
Water is traveling 1.5 miles in 1.75 hours. What is the velocity in ft/min?

1st Convert miles to ft. 1.5 miles x 5,280 ft/mile = 7,920 ft.
2nd Convert hours to min. 1.75 hrs. x 60 min/hr. = 105 min.
3rd Fill in the formula and calculate

$$Velocity, ft/\min = \frac{7{,}920\ Distance, ft.}{105\ Time, min.}$$

$$Velocity = 75.4\ ft/min$$

Problems:
51. Water is traveling 1 mile in 1.25 hours. What is the velocity in feet per min.?

A. 70 ft/min B. 4224 ft/min C. 0.013 ft/min

52. Water is traveling 1450 ft in .5 hours. What is the velocity in feet per min.?

A. 35 ft/min B. 48 ft/min C. 57 ft/min

Example of a more complex problem:
Water is flowing through a 10"diameter pipe at a rate of 1,375 gpm.
What is the velocity of water in ft/sec?

1st How many gallons is in 1 foot of this pipe?

Formula (πr^2ft. x length ft. x 7.48 gal/ft.^{3})

A. Figure Diameter in feet

10" ÷ 12" = 0.8333 round to 0.83 ft. DIAMETER

B. Figure Radius

0.83 ft. DIAMETER ÷ 2 = 0.4166 round to 0.42 ft. RADIUS

C. (3.14 x 0.42 ft. x 0.42 ft. x 1 ft. x 7.48 gal/ft.^{3}) = 4.143 gal. round to 4.1 gallons

2nd Figure how many ft/min.

1,375 gpm ÷ 4.1 = 335.3658 ft/min round to 335.4 ft/min

3rd Reduce to ft/sec

335.4 ft/min ÷60 = 5.5894 ft/sec round to **5.6 ft/sec**

Problems:

53. Water is flowing through a 8"diameter pipe at a rate of 1,850 gpm. What is the velocity of water in ft/sec?

54. Water is flowing through a 18"diameter pipe at a rate of 2,875 gpm. What is the velocity of water in ft/sec?

FLOW ft^3/min:

$$Flow, ft^3/\min = Area, ft^2 \; x \; Velocity, ft/min$$

This question is asking for ft^3/min. We know to get ft^3 we need 3 foot measurements. Two (2) of the foot measurements come from the Surface Area of the pipe ($A = \pi r^2$) The 3rd foot measurement simply comes from the velocity (ft/min).

Example:

What is the flow in ft3/min for a pipe that is 18 inches in diameter and the velocity is 150 ft/min.?

1st We need to find out the surface area of the pipe and to do that we need to convert some numbers to use the ($A = \pi r^2$) formula.

The pipe is 18 inches in diameter, but we need ft. to make this work.
To do this we divide 18 inches by 12 inches/ft.

$$Diameter = \frac{18 \; inches}{12 \; inches/ft} = 1.5 \; ft.$$

NOTE: A common mistake here is to forget that you are still in Diameter when you need radius for the formula.

$$radius = \frac{1.5 \; ft.}{2} = 0.75$$

Now that we have the radius we can calculate the Surface area ft^2.

$$Area \; ft^2 = 3.14 \; x \; .75 \; x \; .75$$
$$\boldsymbol{Area = 1.8 \; ft^2}$$

2nd If the Velocity is not in ft/min convert until you get it there.
In this case the Velocity is already in ft/min so we just need to fill in the formula and calculate. **Velocity is 150 ft/min.**

$$Flow, ft^3/\min = Area, ft^2 \; x \; Velocity, ft/min$$
$$Flow, ft^3/\min = 1.8 \; Area, ft^2 \; x \; 150 \; Velocity, ft/min$$

$$\boldsymbol{Flow = 270 \; ft^3/min.}$$

Problems:

55. What is the flow in ft^3/min for a pipe that is 8 inches in diameter and the velocity is 100.8 ft/min?

A. 25 ft^3/min B 35 ft^3/min C. 45 ft^3/min

56. What is the flow in ft^3/min for a pipe that is 6 inches in diameter and the velocity is 225 ft/min?

A. 22 ft^3/min B 33 ft^3/min C. 44 ft^3/min

Conversions:

Convert MGD to ft^3/sec

To do this type of conversion you need convert the information given MGD to be in the format the answers are in. In this case ft^3/sec.

Example:

The water flow is 3.5 MGD. How many ft^3/sec is the water traveling?

1st Convert MGD to gpd to ft^3

3.5 MGD x 1,000,000 = 3,500,000 gpd ÷ 7.48 gal/ft^3 = 467,914 ft^3/day

2nd Convert day to seconds

467,914 ft^3/day ÷ 1440 min/day ÷ 60 sec/min = **5.4 ft^3/sec**

Problems:

57. Convert 5.1 MGD to cubic feet per second.

A. 7.48 ft^3/s B. 1440 ft^3/s C. 7.9 ft^3/s

58. Convert 2.1 MGD to cubic feet per second.

A. 5.48 ft^3/s B. 3.25 ft^3/s C. 6.97 ft^3/s

Convert ft^3/sec to gpm

Here we are just reversing the process

Example:

Convert 4.7 ft^3/sec to gpm

gpm = 4.7ft^3/sec x 7.48 gal/ft^3 x 60 sec/min

gpm = 2,109

Problems:

59. Convert 5.6 ft^3/s to gallons per minute.

A. 3,700 gpm B. 4,300 gpm C. 2,500 gpm

60. Convert 3.2 ft^3/s to million gallons per day.

A. 3.2 MGD B. 2.1 MGD C. 4.7 MGD

HYDRAULIC SURFACE LOADING RATE

When figuring hydraulic surface loading rate you need to remember that the average wastewater production per person per day is 70 to 100 gallons. It is better when figuring loading rates to use the higher per person per day production. (100 gallons).

Example:
A discharging lagoon measures 125 feet wide and 450 feet long, it is serving a population of 400 people. What is the hydraulic surface loading rate in gpd/ft^2?

$$\frac{(Number\ of\ people\ x\ 100\ gal\ per\ person\ per\ day)}{(length\ ft.\ x\ width\ ft.)} = Hydraulic\ surface\ loading\ rate\ in\ gpd/ft^2$$

$$\frac{(400\ people\ x\ 100\ gallons\ per\ person)}{(450\ ft.\ long\ x\ 125\ ft.\ wide)} = \text{gpd/ft}^2$$

$$\frac{40{,}000\ gallons}{56{,}250\ ft^2} = 0.71\ \text{gpd/ft}^2$$

Problems:

61. A discharging lagoon measures 100 feet wide and 250 feet long, it is serving a population of 250 people. What is the hydraulic surface loading rate in gpd/ft^2?

62. A discharging lagoon measures 145 feet wide and 375 feet long, it is serving a population of 375 people. What is the hydraulic surface loading rate in gpd/ft^2?

ORGANIC LOADING RATE CALCULATIONS

Organic loading rate calculations tell the operator the amount of food entering the plant. These calculations are used for wastewater treatment ponds, discharging lagoons, rotating biological contactors, or trickling filters.

Example:
There is a flow of 0.04 MGD going to a discharging lagoon that measures 125 feet wide and 450 feet long with a BOD concentration is 125 mg/L. What is the Organic loading rate lbs BOD/ft^2?

Formula as written in DEQ handout

$$\frac{BOD\ applied, lbs}{Surface\ Area, ft^2} = \text{Organic Loading, lbs. BOD/ft}^2$$

Above formula explained on the following page.

$$\frac{(Flow\ MGD\ x\ BOD\ mg/Lx\ 8.34 lbs/gal)}{(length\ ft.x\ width\ ft.)} = Organic\ loading, lbs.BOD/ft^2$$

$$\frac{(Flow\ 0.04\ MGD\ x\ BOD\ 125mg/Lx\ 8.34lbs/gal)}{(450ft.long\ x\ 125\ ft.wide)} = Organic\ loading, lbs.BOD/ft^2$$

$$\frac{41.7\ lbs\ BOD}{56,250\ ft^2} = Organic\ loading, 0.00074\ \ lbs.BOD/ft^2$$

Problems:

63. A flow of 0.1MGD with a BOD concentration of 108 mg/L is going to a discharge lagoon that measures 175 ft. wide and 500 ft. long. What is the Organic loading rate lbs BOD/ft^2?

64. A flow of 0.375 MGD with a BOD concentration of 112 mg/L is going to a discharge lagoon that measures 125 ft. wide and 355 ft. long. What is the Organic loading rate lbs BOD/ft^2?

Calculating lbs. of BOD/population

Example:

A population of 233 will contribute about how many pounds of BOD per day?

A. 40 lbs BOD B. 50 lbs BOD C. 60 lbs BOD

Approximately 0.17 lbs of BOD (0.17)(233 persons) = 39.61 lbs/BOD

Problems:

65. A population of 26,650 will contribute about how many pounds of BOD per day?

66. A population of 11,200 will contribute about how many pounds of BOD per day?

BOD loading lbs./day

Example

Calculate the BOD loading lbs/day on a stream if the secondary effluent flow is 2.5 MGD and BOD of secondary effluent is 20 mg/L:

A. 374 lbs/day B. 417 lbs/day C. 424 lbs/day

You can use the same pie or formula that is used when figuring Dosage for any 100% chemical (such as chlorine gas). Just change the wording.

$$Chemical\ Feed, lbs = (Dose, mg/L\ \ x\ Flow, Mlbs)$$

$$BOD, lbs/day = (Dose, mg/L\ \ x\ Flow, Mlbs)$$

Formula expanded:

$$BOD, lbs/day = (Dose, mg/L\ \ x\ 8.34\ lbs/gal\ x\ Flow, MGD)$$

$$BOD, lbs/day = (20\ \ mg/L\ \ x\ 8.34\ lbs/gal\ \ x\ 2.5\ MGD)$$

$$\boldsymbol{BOD, lbs/day = 417}$$

Problems:

67. Calculate the BOD loading lbs/day on a stream if the secondary effluent flow is 10 MGD and BOD of secondary effluent is 17 mg/L:

68. Calculate the BOD loading lbs/day on a stream if the secondary effluent flow is 21 MGD and BOD of secondary effluent is 20 mg/L:

ANSWER GUIDE

Question	Answer	Question	Answer
1	1,600.00 gpd	35	35.03 lbs/day
2	40,000 gpd	36	23.01 lbs/day
3	2,000 gpd	37	18.14 lbs/day
4	0.1 MGD	38	89.8 lbs/day
5	0.0053 MGD	39	2.9 lbs./day
6	0.000275 MGD	40	5.1 hrs.
7	800 ft^2	41	14.1 hrs.
8	75 ft^2	42	A
9	8,000 ft^3	43	C
10	600 ft^3	44	B
11	706.5 ft^2	45	A
12	4,415.6 ft^2	46	C
13	7,065 ft3	47	C
14	61,818.75 ft^3	48	B
15	3,702.6 gpd or 0.004 MGD	49	C
16	9,686.6 gpd or 0.0097 MGD	50	B
17	4,962 lbs. or 0.005 Mlbs	51	A
18	11,641 lbs. or 0.012 Mlbs	52	B
19	94.2 ft	53	11.5 ft/sec
20	235.5 ft	54	3.6 ft/sec
21	122.43 ft	55	B
22	288.75 ft	56	C
23	54.1 psi	57	C
24	23.8 psi	58	B
25	1.762	59	C
26	23,120	60	B
27	48.5 hrs. or 48 hrs. 30 min.	61	1 gpd/ft^2
28	17 hrs.	62	0.69 gpd/ft2
29	1.5 mg/L	63	0.001 lbs. BOD/ft^2
30	1.8 mg/L	64	0.008 lbs. BOD/ft^2
31	1.5 mg/L	65	4,530.5 lbs. BOD
32	1.3 mg/L	66	1,904 lbs. BOD
33	0.75 mg/L	67	1,418 BOD lbs/day
34	1.6 mg/L	68	3,503 BOD lbs./day

Appendix B
Certification Exam Formula Sheets

Listed in this appendix is the Class D & C exam formula sheet and the Class B & A exam
formula sheet. Examinees must be familiar enough with the formula to be able to recognize it and use it properly if it is needed while taking the exam.

NOTE: There are many mathematical calculations on the certification exams that do not
involve specific formulas listed here. Also, there may be several calculations needed to
convert the test question information into the form or units that the formulas require. Therefore, it is best to not limit your study of math to the use of these formulas only. To help prepare for other mathematical calculations that might be needed on an

Class D & C Wastewater Operations Certification Exam Formula Sheets

$$\text{Detention Time, hr} = \frac{(\text{Volume, gal x 24 hr/day})}{\text{Flow, gpd}}$$

$$\text{Dose, mg/L} = \frac{\text{Chemicals, lbs}}{\text{Flow, Mlbs}}$$

$$\text{Chemicals Feed, lbs} = (\text{Dose, mg/L x Flow, Mlbs})$$

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length}}$$

$$\text{Surface Loading, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$$

$$\text{Surface Loading, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$$

$$\text{Organic Loading, BOD/ft}^2 = \frac{\text{BOD applied, lbs}}{\text{Surface Area, ft}^2}$$

Class A/B Wastewater Operations Certification Exam Formula Sheets

$$\text{MLVSS, lbs} = \frac{(\text{BOD, mg/L x Flow, MGD x 8.34lbs/gal})}{\text{F/M Desired}}$$

$$\text{MLVSS, mg/L} = \frac{\text{MLVSS, lbs}}{(\text{Aerator Volum, MG x 8.34lbs/gal})}$$

$$\text{WAS, lbs/day} = \frac{\text{MLSS, lbs}}{\text{MCRT, days}} - \text{SS in Effluent, lgs/day}$$

$$WAS\ Rate, MGD = \frac{WAS, lbs/day}{(WAS\ SS, mg/L\ x\ 8.34 lbs/gal)}$$

$$\text{Change in WAS Rate, MGD} = \frac{(\text{Actual MLSS, lbs} - \text{Desired MLSS, lbs})}{(\text{WAS, mg/L x 8.34lbs/gal})}$$

$$\text{F/M} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$\text{Sludge Age, days} = \frac{\text{MLSS, lbs}}{\text{Aeration Influent SS, lbs/day}}$$

$$\text{Desired MLSS, lbs} = (\text{Sludge Age, days x Solids Added, lbs/day})$$

$$\text{MCRT, days} = \frac{\text{MLSS, lbs}}{(\text{SS WAS, lbs/day} + \text{SS Lost, lbs/day})}$$

$$\text{SVI} = \frac{(\text{Settleability, mL/L x 1000})}{\text{MLSS, mg/L}}$$

Class A/B Wastewater Operations Certification Exam Formula Sheets

$$\text{TF Organic Loading, (lbs BOD/day)/1000 ft}^3 = \frac{\text{BOD applied, lbs/day}}{\text{Media Volume, 1000 ft}^3}$$

NOTE: THE FOLLOWING FORMULA USE SHOULD NO LONGER BE NEEDED FOR TEST

$$RBC\ Orgainic\ Loading, lbs\ BOD/day 1000\ ft^2 = \frac{Soluble, BOD\ applied, lbs/day}{Media\ Area, 1000\ ft^2}$$

$$\text{Surface Loading, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$$

$$\text{Water HP} = \frac{(\text{Flow, gpm x TDH})}{3960}$$

$$\text{Motor HP} = \frac{(\text{Flow, gpm x Height or TDH, ft})}{(3960 \text{ x Ep x Em})}$$

$$\text{Brake HP} = \frac{(\text{Flow, gpm x Height or TDH, ft})}{(3960 \text{ x Ep})}$$

$$\text{Mixture Strength, \%} = \frac{[(\text{A, gal x A, \%}) + (\text{B, gal x B, \%})]}{(\text{A, gal + B, gal})}$$

$$H_2O\text{, gal} = \frac{[(\text{Chemical, gal x Chemical, \%}) - (\text{Chimical, gal x Desired, \%})]}{\text{Desired, \%}}$$

$$\text{Dose, mg/L} = \frac{\text{Chemical, lbs}}{\text{Flow, Mlbs}}$$

$$\text{Velocity, ft/ min} = \frac{\text{Distance, ft}}{\text{Time, min}}$$

$$\text{Chemical Feed, lbs} = (\text{Dose, mg/Lx flow, Mlbs})$$

$$\text{Dentention Time, hr} = \frac{(\text{Volume, gal x 24hr/day})}{\text{Flow, gpd}}$$

$$\text{Surface Loading, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$$

Appendix C

Introduction to Basic Chemistry

Basic Chemistry Terms	
Matter	All substance in the universe
Chemistry	The properties of matter and the changes in the composition of matter
Chemical Reactions	When the basic chemicals nature of the matter is changed
Element	A substance which cannot be separated into its constituents parts and still retain its chemical identity. For example sodium (Na) is an element
Atom	The smallest unit of an element; composed of protons, neutrons, and electrons.
Electron	An extremely small negatively-charged particle the part of an atome that deter mines its chemical properties
Compound	A substance composed of two or more elements whose composition is constant. For example, table salt (sodium chloride-NaCl) is a compound.
Molecule	The smallest division of a compound that still retains or exhibits all the properties of the substance.
Oxidizing Agent	Any substance, such as oxygen (O) or chloride (Cl) that will readily add (take on) electrons. The opposite is a reducing agent.
Reducing Agent	Any substance, such as base metal that will readily donate (give up) electrons. The opposite is an oxidizing agent.
Ion	An electrically charged atom or molecule formed by the loss or gain of one or more electrons. Positively-charged ions are often referred to as cations. Negatively-charged ions are often referred to as anions.
Anode	The positive pole or electrode of an electrolytic system, such as a battery. The anode attracts negatively-charged particles or ions (anions).
Cathode	The negative pole or electrode of an electrolytic systems. The cathode attracts positively-charged particles or ions (cations).
Valence	The combining capacity of an element in a compound. The number of atoms of hydrogens that are equivalent to one atom of the element.
Atomic Weights	The quantity that tells how the weight of an average atom of that element compares with the weight of all other element, with all other elements, with all relative weights based on the weight on the weight of Carbon ©, which has been set at 12.00.

Appendix C Table 1

Some Common Chemical Elements				
Element	Symbol	Atomic Weight	Normal	Valence
Calcium	Ca	40.08	2	
Carbon	Ca	12.00	4	
Chlorine	Cl	35.457		1
Hydrogen	H	1.008	1	
Nitrogen	N	14.008	5	
Oxygen	O	16.00		2
Phosphorous	Pa	31.02	5	
Potassium	K	39.096	1	
Sodium	Na	223997	1	
Sulfur	S	32.066	6	

Appendix C Table 2

Some Common Chemical Compounds		
Chemical	Common Name(s)	Chemical Symbol
Ammonia	ammonia	NH_3
Calcium carbonate	calcium carbonate	$CaCO_3$
Calcium oxide	lime	CaO
Calcium hydroxide	lime/ slaked lime/ hydrated lime	$Ca(OH)_2$
Calcium Hypochlorite	high-test hypochlorite/ HTH	$Ca(OCL)_2$
Carbon dioxide	carbon dioxide gas	CO_2
chlorine	chlorine	Cl_2
Copper sulfate	blue vitriol/ bluestone	$CuSO_4$ $5H_2O$
Hydrochloric Acid	muriatic acid	HCl
Hypochlorous Acid	hypochlorous acid	HOCl
Hydrogen sulfide	hydrogen sulfide gas	H_2S
Methane	methane gas	CH_4
Sulfuric Acid	sulfuric acid	H_4SO_4

Appendix C Table 3

Some Chlorination/ Dechlorination Reactions	
Chlorine and Water	$Cl_2 + H_2O \quad HOCL + HC$
Calcium Hypochlorite (HTH) and Water	$Ca(OCl)_2 + 2H_2O \quad 2HOCl + C(OH)_2$
Sulfur Dioxide and Chlorinated Water	$SO_2 + H_2O\ H_2SO_2 + HOCl\ \ H_2SO_4 + HCl$

Appendix C Table 4

Basic Abbreviations

ac	acre
ac-ft	acre feet
amp	ampere
˚C	degrees Celsius
cfm	cubic feet per minute
cfs	cubic feet per second
cm	centimeter
ft^3 or cu ft	cubic feet
in^3 or cu in	cubic inch
yd^3 or cu yd	cubic yard
˚F	degrees Fahrenheit
ft	feet
gal	gallon
g or gm	gram
gpd	gallon per day
gpm	gallon per minute
Hp	horsepower
hr	hour
in	inch
k	kilo
kg	kilogram
km	kilometer
kW	kilowatt
kWh	kilowatt-hour
L	liter
lb	pound
m	meter
M	million
mg	milligram
mg/L	milligram per liter
MGD	million gallons per day
ml or mL	milliliter
min	minute
psf	pounds per square foot
psi	pounds per square inch
ppb	parts per billion
ppm	parts per million
sec	second
ft^2 or sq ft	square feet
in^2 or sq in	square inch
W	watt

Basic Conversion Factors

Length		
12 in	1 ft	12 in/ft
3 ft	1 yd	3 ft/yd
5280 ft	I mile	5280 ft/mile
Area		
144 in^2	1 ft^2	144 in^2/ft^2
43,560 ft^2	1 acre	43,560 ft^2/acre
Volume		
7.48 gal	1 ft^3	7.48 gal/ft^3
1000 ml	1 liter	1000 ml/L
3.785 L	1 gal	3.785 L/gal
3,785 mL	1 gal	3,785 mL/gal
231 in^3	1 gal	231 in^3/gal
0.326 MG	1 ac-ft	0.326 MG/ac-ft
Weight		
1000 mg	1 g	1000 mg/g
1000 g	1kg	1000 g/kg
2.2 lbs	1kg	2.2 lbs/kg
Power		
0.746 kW	1Hp	0.746 kW/Hp
Density of Water		
8.34 lbs	1 gal	8.34 lbs/gal
62.4 lbs	1 ft^3	62.4 lbs/ft^3
Dosage		
1 mg/L	1 ppm	mg/L/ppm
17.1 mg/L	1 grain/gal	17.1 mg/L/grain/gal
Pressure		
2.31 ft water	1 psi	2.31 ft water/psi
0.433 psi	1 ft water	0.433 psi/ft water
Flow		
1,000,000 gpd	1 MGD	1,000,000 gpd/MGD
694 gpm	1 MGD	694 gpm/MGD
1.55 cfs	1 MGD	1.55 cfs/MGD
Time		
60 sec	1 min	60 sec/min
60 min	1 hr	60 min/hr
1,440 min	1 day	1,440 min/day
24 hr	1 day	24 hr/day

Answers to Sample Questions

CHAPTER 1

Class D	C
Class C	A
Class B	D
Class A	B

CHAPTER 2

Class D	B
Class C	A
Class B	B
Class A	B

CHAPTER 3

Class D	C
Class C	B
Class B	A
Class A	E

CHAPTER 4

Class D	C
Class C	B
Class B	B
Class A	B

CHAPTER 5

Class D	A
Class C	B
Class B	C
Class A	C

CHAPTER 6

Class D	C
Class C	B
Class B	C
Class A	D

CHAPTER 7

Class D	C
Class C	A
Class B	C
Class A	D

CHAPTER 8

Class D	C
Class C	B
Class B	A
Class A	C

CHAPTER 9

Class D	B
Class C	B
Class B	A
Class A	E

CHAPTER 10

Class D	A
Class C	B
Class B	D
Class A	A

CHAPTER 11

Class D	A
Class C	C
Class B	D
Class A	E

CHAPTER 12

Class D	A
Class C	A
Class B	D
Class A	B

GLOSSARY:

ACTIVATED SLUDGE - Are the solids that are formed when microorganisms are used to treat wastewater during the process referred to as activated sludge treatment. It includes organisms, accumulated food materials and waste products from the aerobic decomposition process.

ADVANCED WASTE TREATMENT - A treatment technology used to produce an extremely high-quality discharge.

AEROBIC - A condition in which atmospheric or dissolved molecular oxygen is present in the aquatic (water) environment.

AIR TEST - A method of inspecting a sewer pipe for leaks. Inflatable or similar plugs are placed in the line, and the space between these plugs is pressurized with air. A drop in pressure indicates the line or run being tested has leaks.

ANAEROBIC - A condition in which atmospheric or dissolved molecular oxygen is NOT present in the aquatic (water) environment.

ANAEROBIC DECOMPOSITION - The decay or breaking down of organic material in an environment containing no "free" or dissolved oxygen.

ANOXIC - Oxygen deficient or lacking sufficient oxygen.

ASPHYXIATION - An extreme condition often resulting in death due to a lack of oxygen and excess carbon dioxide in the blood from any cause.

AVERAGE MONTHLY DISCHARGE LIMITATION - The highest allowable discharge over a calendar month

AVERAGE WEEKLY DISCHARGE LIMITATION - The highest allowable discharge over a calendar week.

BOD - Biochemical Oxygen Demand. The rate at which organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation. BOD measurements are used as a measure of the organic strength of wastes in water.

BACKFILL - (1) Material used to full in a trench or excavation. (2) The act of filling a trench or excavation, usually after a pipe or some type of structure has been placed in the trench or excavation.

BACKFILL COMPACTION - (1) Tamping, rolling or otherwise mechanically compressing material used as backfill for a trench of excavation. Backfill is compressed to increase its density so that it will support the weight of machinery or other loads after the material is in place in the excavation. (2) Compaction of a backfill material can be expressed as a percentage of the maximum compatibility, density or load capacity of the material being used.

BACKFLUSHING - A procedure used to wash settled waste matter off upstream to prevent odors from developing after a main line stoppage has been cleared.

BACTERIA - Bacteria are living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BALLING - A method of hydraulically cleaning a sewer or storm drain by using the pressure of a water head to create a high cleansing velocity of water around the ball. In normal operation, the ball is restrained by a cable while water washes past the ball at high velocity. Special sewer cleaning balls have an outside tread that causes them to spin or rotate, resulting in a “scrubbing” action of the flowing water along the pipe wall.

BAR RACK - A screen composed of parallel bars, either vertical or inclined, placed in a sewer or other waterway to catch debris. The screenings may be raked from it.

BARREL - (1) The cylindrical part of a pipe that may have a bell on one end. (2) The cylindrical part of a manhole between the cone at the top and the shelf at the bottom.

BEDDING - The prepared base or bottom of a trench or excavation on which a pipe or other underground structure is supported.

BEDDING COMPACTION - (1) Tamping, rolling or otherwise mechanically compressing material used as bedding for a pipe or other underground structure to a density that will support expected loads. (2) Bedding compaction can be expressed as a percentage of the maximum load capacity of the bedding material. (3) Bedding compaction also can be expressed in load capacity or pounds per square foot.

BEDDING GRADE - (1) In a gravity-flow sewer system, pipe bedding is constructed and compacted to the design grade of the pipe. This is usually expressed in a percentage. A 0.5 percent grade would be a drop of one-half of foot per hundred feet of pipe. (2) Bedding grade for a gravity-flow sewer pipe can also be specified as elevation above mean sea level at specific points.

BELL - (1) In pipe fitting, the enlarged female end of a pipe into which the male end fits. (2) In plumbing, the expanded female end of a wiped joint.

BELL-AND-SPIGOT JOINT - A form of joint used on pipes which have an enlarged diameter or bell at one end, and a spigot at the other which fits into and is laid in the bell. The joint is then made tight by lead, cement, rubber O-ring, or other jointing compounds or materials.

BIOCHEMICAL OXYGEN DEMAND see (BOD)

BIOSOLIDS - Organic matter recovered from a sewage treatment process.

BIOSOLIDS CAKE - Solid discharge from a dewatering apparatus.

BIT - (1) Cutting blade used in rodding (pipe cleaning) operations. (2) Cutting teeth on the auger head of a sewer boring tool.

BLOCKAGE - (1) Partial or complete interruption of flow as a result of some obstruction in a sewer. (2) When a collection system becomes plugged and the flow backs up, "blockage."

BRANCH MANHOLE - A sewer or drain manhole which has more than one pipe feeding into it. A standard manhole will have one outlet and one inlet. A branch manhole will have one outlet and two or more inlets.

BRANCH SEWER - A sewer that receives wastewater from a relatively small area and discharges into a main sewer servicing more than one branch sewer area.

BUCKET - (1) A special device designed to be pulled along a sewer for the removal of debris from the sewer. The bucket has one end open with the opposite end having a set of jaws. When pulled from the jaw end, the jaws are automatically opened. When pulled from the other end, the jaws close. In operation, the bucket is pulled into the debris from the jaw end and to a point where some of the debris has been forced into the bucket. The bucket is then pulled out of the sewer from the other end, causing the jaws to close and retain the debris. Once removed from the manhole, the bucket is emptied and the process repeated. (2) A conventional pail or bucket used in BUCKETING OUT and also for lowering and raising tools and materials from manholes and excavations.

BUCKET BAIL - The pulling handle on a bucket machine.

BUCKET MACHINE -A powered winch machine designed for operation over a manhole. The machine controls the travel of buckets used to clean sewers.

BUCKETING OUT - An expression used to describe removal of debris from a manhole with a pail on a rope. In balling or high-velocity cleaning of sewers, debris is washed into the downstream manhole. Removal of this debris by scooping it into pails and hauling debris out is called "bucketing out."

BUFFER - A substance or solution that resists changes in pH.

BYPASS - A pipe, valve, gate, weir, trench or other device designed to permit all or part of a wastewater flow to be diverted from usual channels or flow. Sometimes refers to a special line which carries the flow around a facility or device that needs maintenance or repair.

BYPASSING - The act of causing all or part of a flow to be diverted from its usual channels. In a wastewater treatment plant, overload flows should be bypassed into a holding pond for future treatment.

CAKE SOLID DISCHARGE RATE – The dry solids cake discharge from a centrifuge, which is expressed as: dry cake solids discharge rate = (dry solids feed rate) x (solids recovery).

CATCH BASIN - A chamber or well used with storm or combined sewers as a means of removing grit which might otherwise enter and be deposited in sewers.

CHEMICAL GROUT - Two chemical solutions that form a solid when combined. Solidification time is controlled by the strength of the mixtures used and the temperature.

CHEMICAL OXYGEN DEMAND (COD) – The amount of chemically oxidizable material present in wastewater.

CLARIFIER- Is a structure designed to permit solids to settle or rise for the purpose of separation from the flow.

CLEANOUT - An opening (usually covered or capped) in a wastewater collection system used for inserting tools, rods or snakes while cleaning a pipeline or clearing a stoppage.

COLIFORM BACTERIA – Live in everyone's intestinal track. They are considered non-pathogenic.

COLLECTION SYSTEM - A network of pipes, manholes, cleanouts, traps, siphons, lift stations and other structures used to collect all wastewater and wastewater-carried wastes of an area and transport them to a treatment plant or disposal system. The collection system includes land, wastewater lines and appurtenances, pumping stations and general property.

COMMUNITY WASTEWATER SYSTEM – A public wastewater system which has at least 15 service connection or treats 5,000 gallons or more of wastewater per day. The term "community wastewater system" is used only to identify the public wastewater systems which must be operated by certified operators.

COMPOSITE SAMPLE – A combination of individual samples taken in proportion to flow.

COMPUTED PER CAPITA CONTRIBUTION
-The computed wastewater contribution from a domestic area, based on the population of the area. In the United States, the daily average wastewater contribution is considered to be 100 gallons per capita per day (100GPCD).

COMPUTED TOTAL CONTRIBUTION - The total anticipated load on a wastewater treatment plant or the total anticipated flow in any collection system area based on the combined computed contributions of all connections to the system.

CONCRETE CRADLE - A device made of concrete that is designed to support sewer pipe.

CONFINED SPACE
Confined space means a space that:

> **A**. Is large enough and so configured that an employee can bodily enter and perform assigned work; and
> **B**. Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry); and
> **C**. Is not designed for continuous employee occupancy. (Definition from the Code of Federal Regulations (CFR) Title 29 Part 1910.146).

CORROSION - The gradual decomposition or destruction of a material due to chemical action, often due to an electrochemical reaction. Corrosion starts at the surface of a material and moves inward, such as the chemical action upon manholes and sewer pipe materials.

COUPLING - (1) A threaded sleeve used to connect two pipes. (2) A device used to connect two adjacent parts, such as pipe coupling, hose coupling or drive coupling.

COUPON - A steel specimen inserted into wastewater to measure the corrosiveness of the wastewater. The rate of corrosion is measured as the loss of weight of the coupon or change in its physical characteristics. Measure the weight loss (in milligrams) per surface area (in square decimeters) exposed to the wastewater per day.

CROSS CONNECTION - A connection between a storm drain system and a sanitary collection system.

DAILY DISHARGE – The discharge of a pollutant measured during a calendar day or any 24 – hour period that reasonably represents a calendar day for the purposes of sampling.

DAILY MAXIUM DISCHARGE – The highest allowable value for a daily discharge.

DEQ - Department of Environmental Quality.

DEADEND MANHOLE - A manhole located at the upstream end of a sewer and having no inlet pipe.

DEBRIS - Any material in wastewater found floating, suspended, settled, or moving along the bottom of a sewer. This material may cause stoppages by getting hung up on roots or settling out in a sewer. Debris includes grit, paper, rubber, silt, and all materials except liquid.

DETENTION TIME – The theoretical time water remains in a tank at a given discharge.

DEWATER - To drain or remove water from an enclosure. A structure may be dewatered so that it can be inspected or repaired. Dewater also means draining or removing water from sludge to increase the solids concentration.

DIP - A point in the sewer pipe where a drain grade defect results in a puddle of standing water when there is no flow.

DICHARGE MONITORING REPORT (DMR) – The monthly report required by the treatment plant's NPDES / OPDES discharge permit.

DIGESTER – A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic or aerobic conditions.

DISINFECTION - The process designed to kill or inactivate most microorganisms in water, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being the most frequently used method in both water and wastewater systems.

DISSOLVED OXYGEN (DO) – Free or elemental oxygen that is dissolved in water.

DRAGLINE - A machine that drags a bucket down the intended line of a trench to dig or excavate the trench. Also used to dig holes and move soil or aggregate.

DROP MANHOLE - A main line or house service line lateral entering a manhole at a higher elevation than the main flow line or channel. If the higher elevation flow is routed to the main manhole channel outside of the manhole, it is called an "outside drop." If the flow is routed down through the manhole barrel, the pipe down to the manhole channel is called an "inside drop."

DRY WELL - A dry room or compartment in a lift station, near or below the water level, where the pumps are located.

EPA - United States Environmental Protection Agency.

EASEMENT - Legal right to use the property of others for a specific purpose. For example, a utility company may have a five-foot easement along the property line of a home. This gives the utility the legal right to install and maintain a sewer line within the easement.

EFFLUENT - Wastewater or other liquid—raw (untreated), partially, or completely treated—flowing FROM a reservoir, basin, treatment process, or treatment plant.

ELEVATION - The height to which something is elevated, such as the height above sea level.

EXFILTRATION - Liquid wastes and liquid-carried wastes which unintentionally leak out of a sewer pipe system and into the environment.

FACULTATIVE ORGANISMS - Organisms that can survive and function in the presence or absence of free, elemental oxygen. Basically organisms that can switch from aerobic or anaerobic depending on its environment.

FACULTATIVE POND (also known as a wastewater treatment pond or lagoon) – The most common type of treatment pond used for treating domestic wastewater. The upper portion is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen in the aerobic layer.

FAIR LEAD PULLEY - A pulley that is placed in a manhole to guide TV camera electric cables and the pull cable into the sewer when inspecting pipelines.

FECAL COLIFORM – A type of bacteria found in the bodily discharges of warm-blooded animals. Used as an indicator organism.

FLOAT LINE - A length of rope or heavy twine attached to a float, plastic jug or parachute to be carried by the flow in a sewer from one manhole to the next. This is called "stringing the line" and is used for pulling through winch cables, such as for a bucket machine work or closed-circuit television work.

FLOTATION - (1) The stress or forces on a pipeline or manhole structure below a water table which tend to lift or float the pipeline or manhole structure. (2) The process of raising suspended matter to the surface of the liquid in a tank where it forms a scum layer that can be removed by skimming. The suspended matter is raised by aeration, the evolution of gas, the use of chemicals, electrolysis, heat or bacterial decomposition.

FLOW - The continuous movement of a liquid from one place to another.

FLOW ISOLATION - A procedure used to measure inflow and infiltration (I/I). A section of sewer is blocked off or isolated and the flow from the section is measured.

FLUME – (1) An open conduit of wood, masonry, metal, or plastic constructed on a grade and sometimes elevated. (2) A flow rate measurement device.

FLUSHER BRANCH - A line built specifically to allow the introduction of large quantities of water to the collection system so the lines can be "flushed out" with water. Also installed to provide access for equipment to clear stoppages in a sewer.

FLUSHING - The removal of deposits of material which have lodged in sewers because of inadequate velocity of flows. Water is discharged into the sewers at such rates that the larger flow and higher velocities are sufficient to remove the material.

FOOD-TO-MASS RATIO (F/M) – An activated sludge process-control calculation based upon the amount of food (BOD_5 or COD) available per pound of mixed liquor volatile suspended solids.

FORCE MAIN - A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

FRICTION LOSS - The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.

GRAB SAMPLE – An individual sample collected at a randomly selected time.

GRADE - (1) The elevation of the invert (or bottom) of a pipeline, canal, culvert, sewer, or similar conduit. (2) The inclination of slope of a pipeline, conduit, stream channel, or natural ground surface; usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. A 0.5 percent grade would be a drop of one-half foot per hundred feet of pipe.

GRAVITY FLOW - Water or wastewater flowing from a higher elevation to a lower elevation due to the force of gravity. The water does not flow due to energy provided by a pump. Wherever possible, wastewater collection systems are designed to use the force of gravity to convey waste liquids and solids.

GREASE - In a collection system, grease is considered to be the residues of fats, detergents, waxes, free fatty acids,
calcium and magnesium soaps, mineral oils, and certain other non-fatty material which tend to separate from water and coagulate as floatables or scums.

GREASE BUILDUP - Any point in a collection system where coagulated and solidified greases accumulate and build up. Many varieties of grease have high adhesive characteristics and collect other solids, forming restrictions and stoppages in collection systems.

GREASE TRAP - A receptacle designed to collect and retain grease and fatty substances usually found in kitchens or from similar wastes. It is installed in the drainage system between the kitchen or other point of production of the waste and the building wastewater collection line. Commonly used to control grease from restaurants.

GRIT - The heavy mineral material present in wastewater such as sand, coffee grounds, eggshells, gravel and cinders. Grit tends to settle out at flow velocities below 2 ft. /sec,
and accumulates in the invert or bottoms of the pipelines.

GRIT CATCHER - A chamber usually placed at the upper end of a depressed collection line or at other points on combined or storm water collection lines where wear from grit is possible. The chamber is sized and shaped to reduce the velocity of flow through it and thus permit the settling out of grit.

GRIT TRAP - A permanent structure built into a manhole (or other convenient location in a collection system) for the accumulation and easy removal of grit.

INDUSTRIAL WASTEWATER – Wastes associated with industrial manufacturing processes.

INFILTRATION - The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections, or manhole walls.

INFILTRATION HEAD - The distance from a point of infiltration leaking into a collection system to the water table elevation. This is the pressure of the water being forced through the leak in the collection system.

INFILTRATION/INFLOW - The total quantity of water from both infiltration and inflow without distinguishing the source. Abbreviated I&I or I/I.

INFLATABLE PIPE STOPPER - An inflatable ball or bag used to form a plug to stop flows in a sewer pipe.

INFLOW - Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.

INFLUENT - Wastewater or other liquid—raw (untreated) or partially treated—flowing into a reservoir, basin, treatment process, or treatment plant.

INLET - (1) A surface connection to a drain pipe. (2) A chamber for collecting storm water with no well below the outlet pipe for collecting grit. Often connected to a CATCH BASIN or a “basin manhole” with a grit chamber.

INORGANIC - Material such as salts, metals, and all other substances of mineral origin.

INSERTION PULLER - A device used to pull long segments of flexible pipe material into a sewer line when sliplining to rehabilitate a deteriorated sewer.

INSITUFORM - A method of installing a new pipe within an old pipe without excavation. The process involves the use of a polyester-fiber felt tube, lined on one side with polyurethane and fully impregnated with a liquid thermal setting resin.

INSPECTION TELEVISION EQUIPMENT - Television equipment that is superior to standard commercial quality, providing 600 to 650 lines of resolution, and designed for industrial inspection applications.

INVERT - The lowest point of the channel inside a pipe or manhole.

INVERTED SIPHON - A pressure pipeline used to carry wastewater flowing in a gravity collection system under a depression such as a valley or roadway or under a structure such as a building.

KEY MANHOLE - In collection system evaluation, a key manhole is one from which reliable or specific data can be obtained.

KITE - A device for hydraulically cleaning sewer lines. Resembling an airport wind sock and constructed of canvas-type material, the kite increases the velocity of a flow at its outlet to wash debris ahead of it.

LAMPING - Using reflected sunlight or a powerful light beam to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole. If it can be seen from the next manhole, it indicates that the line is open and straight.

LATERAL - (See LATERAL SEWER)

LATERAL CLEANOUT - A capped opening in a building lateral, usually located on the property line, through which the pipelines can be cleaned.

LATERAL SEWER - A sewer that discharges into a branch or other sewer and has no other common sewer tributary to it. Sometimes called a “street sewer” because it collects wastewater from individual homes.

LIFT STATION - A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. Also, an installation of pumps that raise wastewater from areas too low to drain into available sewers. These stations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a PUMP STATION, but this term is usually reserved for a similar type of facility that is discharging into a long FORCE MAIN, while a lift station has a discharge line or force main only up to the downstream gravity sewer.

MAIN LINE - Branch or lateral sewers that collect wastewater from building sewers and service lines.

MAIN SEWER - A sewer line that receives wastewater from many tributary branches and sewer lines and serves as an outlet for a large territory or is used to feed an intercepting sewer.
MANDREL - (1) A special tool used to push bearings in or to pull sleeves out. (2) A gage used to measure for excessive deflection in a flexible conduit.

MANHOLE - An opening in a sewer provided for the purpose of permitting operators or equipment to enter or leave a sewer.

MANHOLE ELEVATION - The height (elevation) of the invert or lowest point in the bottom of a manhole above mean sea level.

MANHOLE FLOW - (1) The depth or amount of wastewater flow in a manhole as observed at any selected time. (2) The total or the average flow through a manhole in gallons on any selected time interval.

MANHOLE INFILTRATION – Groundwater that seeps or leaks into a manhole structure.

MANHOLE INFLOW - Surface waters flowing into a manhole, usually through the vent holes in the manhole lid.

MANHOLE INVERT - The lowest point in a trough or flow channel in the bottom of a manhole.

MANHOLE LID - The heavy cast-iron or forged-steel cover of a manhole. The lid may or may not have vent holes.

MANHOLE LID DUST PAN - A sheet metal or cast-iron pan located under a manhole lid. This pan serves to catch and hold pebbles and other debris falling through vent holes, preventing them from getting into the pipe system.

MANHOLE VENTS - One or a series of one-inch diameter holes through a manhole lid for purposes of venting dangerous gases found in sewers.

MEAN CELL RESIDENCE TIME (MCRT) – The average length of time a mixed liquor suspended solids particle remains in the activated sludge process. May also be known as sludge retention time.

MECHANICAL CLEANING - Clearing pipe by using equipment that scrapes, cuts, pulls or pushes the material out of the pipe. Mechanical cleaning devices or machines include bucket machines, power rodders and hand rods.

MECHANICAL PLUG - A pipe plug used in sewer systems that is mechanically expanded to create a seal.

MIXED LIQUOR – The combination of return activated sludge and wastewater in the aeration tank.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS) – The suspended solids concentration of the mixed liquor.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLSS) – The concentration of organic matter in the mixed liquor suspended solids.

MOISTURE CONTNET – The amount of water per unit weight of bio solids.

NONTRANSIENT NONCOMMUNITY (NTNC) WATER SYSTEM - Means a public water system that is not a community water system and that regularly serves at least 25 of the same persons over six months per year, including schools, day care centers, factories, restaurants and hospitals.

NPDES - National Pollutant Discharge Elimination System. NPDES permits are required by the Federal Water Pollution Control Act Amendments of 1972 with the intent of making the Nation's water suitable for swimming and for fish and wildlife. The permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal treatment plants, large agricultural feed lots and return irrigation flows.

NUTRIENTS – Substances required to support living organisms. Usually refers to nitrogen, phosphorus, iron and other trace metals.

OBSTRUCTION - Any solid object in or protruding into a wastewater flow in a collection line that prevents a smooth or even passage of the wastewater.

OFFSET - (1) A combination of elbows or bends which brings one section of a line of pipe out of line with, but into a line parallel with, another section. (2) A pipe fitting in the approximate form of a reverse curve, made to accomplish the same purpose. (3) A pipe joint that has lost its bedding support and one of the pipe sections has dropped or slipped, thus creating a condition where the pipes no longer line up properly.

ORGANIC - Material which comes from mainly animal or plant sources and contains carbon.

OPDES - Oklahoma Pollutant Discharge Elimination System – A permit program established in accordance with Section 402 of the CWA and authorized in 27A O.S. Environment and Natural Resources. This program regulates discharges into Oklahoma's waters from point sources, including municipal, industrial, commercial and certain agricultural sources.
OUTFALL - (1) The point, location or structure where wastewater or drainage discharges from a sewer, drain, or other conduit. (2) The conduit leading to the final disposal point or area.

OUTFALL SEWER - A sewer that receives wastewater from a collection system or from a wastewater treatment plant and carries it to a point of ultimate or final discharge in the environment.

OUTLET - Downstream opening or discharge end of a pipe, culvert, or canal.

OVERFLOW MANHOLE - A manhole which fills and allows raw wastewater to flow out onto the street or ground.

OVERFLOW RELIEF LINE - Where a system has overload conditions during peak flows, an outlet may be installed above the invert and leading to a less loaded manhole or part of the system. This is usually called an "overflow relief line."

PARACHUTE - A device used to catch wastewater flow to pull a float line between manholes.

PARSHALL FLUME - A specially constructed flume or channel used to measure flows in open channels.

PATHOGENIC ORGANISM – An organism that is capable of causing illness.

PEAKING FACTOR - Ratio of a maximum flow to the average flow, such as maximum hourly flow or maximum daily flow to the average daily flow.

PHOTOGRAPHIC INSPECTIONS - A method of obtaining photographs of a pipeline by pulling a time-lapse motion picture camera through the line.
By moving the camera a specific distance at timed intervals, a sequence of photographs covering the full length of the line is obtained.

PIG - Refers to a poly pig which is a bullet-shaped device made of hard rubber or similar material.

PIPE CAPACITY - In a gravity-flow sewer system, pipe capacity is the total amount in gallons a pipe is able to pass in a specific time period.

PIPE CLEANING - Removing grease, grit, roots and other debris from a pipe run by means of one of the hydraulic cleaning methods.

PIPE DIAMETER - The nominal or commercially designated inside diameter of a pipe, unless otherwise stated.

PIPE DISPLACEMENT - The cubic inches of soil or water displaced by one foot or one section of pipe.

PIPE GRADE - The angle of a sewer or a single section of a sewer as installed. Usually expressed in a percentage figure to indicate the drop in feet or tenths of a foot per hundred feet. For example, 0.5 percent grade means a drop of one-half foot per 100 feet of length.

PIPE JOINT - A place where two sections of pipe are coupled or joined together.

PIPE JOINT SEAL - (1) The tightness or lack of leakage at a pipe joint. (2) The method of sealing a pipe coupling.

PIPE LINER - A plastic liner pulled or pushed into a pipe to eliminate excessive infiltration or exfiltration. Other solutions to the problem of infiltration/exfiltration are the use of cement grouting or replacement of damaged pipe.

PIPE PLUG - (1) A temporary plug placed in a sewer pipe to stop a flow while repair work is being accomplished or other functions are performed. (2) In construction of a new sewer system, service saddles are sometimes installed before a building or a building lateral is in existence. Under such circumstances, a plug will be placed in the off-lead of the saddle of a "Y."

PIPE RODDING - A method of opening a plugged or blocked pipe by pushing a steel rod or snake, or pulling same, through the pipe with a tool attached to the end of the rod or snake. Rotating the rod or snake with a tool attached increases effectiveness.

PIPE RUN - (1) The length of sewer pipe reaching from one manhole to the next. (2) Any length of pipe, generally assumed to be in a straight line.

PIPE SECTION - A single length of pipe between two joints or couplers.

PLAN - A drawing showing the TOP view of sewers, manholes and streets. Also means approved contract drawings, town standards, working drawings, detail sheets or exact reproductions thereof, which show the location, character, dimensions and details of the work to be done.

PRELIMINARY TREATMENT – The removal of rocks, rags, sand, eggshells, and similar materials which may hinder the operation of a treatment plant. Preliminary treatment is accomplished by using equipment such as bar screens and grit removal systems.

PRIMARY TREATMENT (also known as sedimentation) – A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float o be separated from the water being treated.

PNEUMATIC EJECTOR - A device for raising wastewater, sludge or other liquid by compressed air. The liquid is alternately admitted through an inward-swinging check valve into the bottom of an airtight pot. When the pot is filled compressed air is applied to the top of the liquid. The compressed air forces the inlet valve closed and forces the liquid in the pot through an outward-swinging check valve, thus emptying the pot.

POPULATION EQUIVALENT (HYDRAULIC) - A flow of 100 gallons per day is the hydraulic or flow equivalent to the contribution or flow from one person. Population equivalent = 100 GPCD or gallons per capita per day.

PORCUPINE - A sewer cleaning tool the same diameter as the pipe being cleaned. The tool is a steel cylinder having solid ends with eyes cast in them to which a cable can be attached and pulled by a winch. Many short pieces of cable or bristles protrude from the cylinder to form a round brush.

POWER RODDER - A sewer cleaning machine fitted with auger rods which are inserted in a sewer line to dislodge and cut roots and debris.

PRECIPITATION - (1) The total measurable supply of water received directly from clouds as rain, snow, hail, or sleet; usually expressed as depth in a day, month, or year, and designated as daily, monthly, or annual precipitation. (2) The process by which atmospheric moisture is discharged onto a land or water surfaces. (3) The separation (of a substance) out in solid form from a solution, as by the use of a reagent.

PRE-CLEANING - Sewer line cleaning, commonly done by high-velocity cleaners, that is done prior to the TV inspection of a pipeline to remove grease, slime, and grit to allow for a clearer and more accurate identification of defects and problems.

PREVENTIVE MAINTENANCE - Crews assigned the task of cleaning sewers (for example, balling or high-velocity cleaning crews) to prevent stoppages and odor complaints. Preventive maintenance is performing the most effective cleaning procedure, in the area where it is most needed, at the proper time in order to prevent failures and emergency situations.

PRIMARY CONTAMINANTS - The contaminants identified by the EPA as harmful to human health. In order to protect public health, the primary contaminants must not exceed certain specified levels known as Maximum Contaminant Levels (MCL).

PROFILE - A drawing showing the SIDE view of sewers and manholes.

PUMP - A mechanical device for causing flow, for raising or lifting water or other fluid, or for applying pressure to fluids.

PUMP PIT - A dry well, chamber or room below ground level in which a pump is located.

PUMP STATION - Installation of pumps to lift wastewater to a higher elevation in places where flat land would require excessively deep sewer trenches. Also used to raise wastewater from areas too low to drain into available collection lines. These stations may be equipped with air-operated ejectors or centrifugal pumps.

PUBLIC SEWER - means a sewer in which all owners of abutting properties have equal rights and is controlled by acting as Sewer Commissioners, and maintained by the Public Works Superintendent.

REGULATOR - A device used in combined sewers to control or regulate the diversion of flow.

RETENTION - (1) That part of the precipitation falling on a drainage area which does not escape as surface stream flow during a given period. It is the difference between total precipitation and total runoff during the period, and represents evaporation, transpiration, subsurface leakage, infiltration, and when short periods are considered, temporary surface or underground storage on the area. (2) The delay or holding of the flow of water and water carried wastes in a pipe system. This can be due to a restriction in the pipe, a stoppage or a dip. Also, the time water is held or stored in a basin or wet well.

RETURN ACTIVATED SLUDGE SOLIDS (RASS) – The concentration of suspended solids in the sludge flow being returned from the settling tank to head of the aeration tank.

ROD GUIDE - A bent pipe inserted in a manhole to guide hand and power rods into collection lines so the rods can dislodge obstructions.

ROD (SEWER) - A light metal rod, three to five feet long with a coupling at each end. Rods are joined and pushed into a sewer to dislodge obstructions.

RODDING MACHINE - A machine designed to feed a rod into a pipe while rotating the rod.

RODDING TOOLS - Special tools attached to the end of a rod or snake to accomplish various results in pipe rodding.

ROOF LEADER - A downspout or pipe installed to drain a roof gutter to a storm drain or other means of disposal.

ROOT SEWER - Any part of a root system of a plant or tree that enters a collection system.

ROOT MOP - When roots from plant life enter a sewer system, the roots frequently branch to form a growth that resembles a string mop.

SADDLE - A fitting mounted on a pipe for attaching a new connection. This device makes a tight seal against the main pipe by use of a clamp, adhesive, or gasket and prevents the service pipe from protruding into the main.

SADDLE CONNECTION - A building service connection made to a sewer main with a device called a saddle.

SAND TRAP - A device which can be placed in the outlet of a manhole to cause a settling pond to develop in the manhole invert, thus trapping sand, rocks and similar debris heavier than water. Also may be installed in outlets from car wash areas.

SANITARY COLLECTION SYSTEM - The pipe system for collecting and carrying liquid and liquid-carried wastes from domestic sources to a wastewater treatment plant.

SANITARY SEWER - A pipe or conduit (sewer) intended to carry wastewater or waterborne wastes from homes, businesses, and industries to the POTW. Storm water runoff or unpolluted water should be collected and transported in a separate system of pipes or conduits (storm sewers) to natural water courses.

SCOOTER - A sewer cleaning tool whose cleansing action depends on the development of high water velocity around the outside edge of a circular shield. The metal shield is rimmed with a rubber coating and is attached to a framework on wheels (like a child's scooter). The angle of the shield is controlled by a chain-spring system which regulates the head of water behind the scooter and thus the cleansing velocity of the water flowing around the shield.

SCUM - (1) A layer or film of foreign matter (such as grease, oil) that has risen to the surface of water or wastewater. (2) A residue deposited on the ledge of a sewer, channel, or wet well at the water surface. (3) A mass of solid matter that floats on the surface.

SECONDARY CONTAMINANTS - Contaminants in drinking water that are not harmful to human health but are unpleasant. Secondary contaminants include substances that cause unpleasant tastes and odors or color the water. A Recommended Maximum Level (RCM) has been set for each of the secondary contaminants in order to make sure the water is pleasant to drink.

SEDIMENT - Solid material settled from suspension in a liquid.

SEDIMENTATION - The process of settling and depositing of suspended matter carried by wastewater. Sedimentation usually occurs by gravity when the velocity of the wastewater is reduced below the point at which it can transport the suspended material.

SELECT BACKFILL - Material used in backfilling of an excavation, selected for desirable compaction or other characteristics.

SELECT BEDDING - Material used to provide a bedding or foundation for pipes or other underground structures. This material is of specified quality for desirable bedding or other characteristics and is often imported from a different location.

SEPTIC – Wastewater that has no dissolved oxygen present it is generally characterized by black color and rotten egg (hydrogen sulfide) odors.

SETTLEABILITY – A process-control test used to evaluate the settling characteristics of activated sludge. Reading taken at 30 to 60 minutes are used to calculate the settled sludge volume (SSV) and the sludge volume index (SVI).

SETTLED SLUDGE VOLUME (SSV) – The volume in percent occupied by an activated sludge sample after 30 to 60 minutes of settling. Normally written as SSV with a subscript to indicate the time of the reading used for calculation (SSV_{60}) or (SSV_{30}).

SERVICE ROOT - A root entering the sewer system in a service line and growing down the pipe and into the sewer main.

SEWAGE - The used household water and water-carried solids that flow in sewers to a wastewater treatment plant.

SEWER - A pipe or conduit that carries wastewater or drainage water.

SEWER BALL - A spirally grooved, inflatable, semi-hard rubber ball designed for hydraulic cleaning of sewer pipes.

SEWER CLEANOUT - A capped opening in a sewer main that allows access to the pipes for rodding and cleaning. Usually such cleanouts are located at terminal pipe ends or beyond terminal manholes.

SEWER GAS - (1) Gas in collection lines (sewers) that results from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases. (2) Any gas present in the wastewater collection system, even though it is from such sources as gas mains, gasoline, and cleaning fluid.

SEWER USE DISCHARGE PERMIT - Permit required or issued jointly by the Authority and a Municipality for the discharge of industrial waste.

SEWERAGE SYSTEM - Any device, equipment or works used in the transportation, pumping, storage, treatment, recycling, and reclamation of Wastewater and Industrial Wastes.

SEWER JACK - A device placed in manholes which supports a yoke or pulley that keeps wires or cables from rubbing against the inlet or outlet of a sewer.

SEWER MAIN - A sewer pipe to which building laterals are connected.

SEWERAGE - System of piping with appurtenances for collecting, moving and treating wastewater from source to discharge.

SHORING - Material such as boards, planks or plates, and jacks used to hold back soil around trenches and to protect workers in a trench from cave-ins.

SILTING - Silting takes place when the pressure of infiltrating waters is great enough to carry silt, sand and other small particles from the soil into the sewer system. Where lower velocities are present in the sewer pipes, settling of these materials results in silting of the sewer system.

SLEEVE - A pipe fitting for joining two pipes of the same nominal diameter in a straight line.

SLIPLINING - A sewer rehabilitation technique accomplished by inserting flexible polyethylene pipe into an existing deteriorated sewer.

SLOPE - The slope or inclination of a sewer trench excavation is the ratio of the vertical distance to the horizontal distance or "rise over run." The inclination of a trench bottom or a trench sidewall, expressed as a ratio of vertical distance to the horizontal distance. For example, a 3:1 slope shall rise or fall 3' vertical feet in a distance of 1' horizontal foot.

SLUDGE – The mixture of settleable solids and water that is removed from the bottom of the settling tank.

SLUDGE LOADING RATE – The weight of wet bio-solids fed to the reactor per square foot of reactor bed area per hour (lb./ft^2/H).

SLUDGE VOLUME INDES (SVI) – A process-control calculation used to evaluate the settling quality of activated sludge. Requires SSV_{30} and mixed liquor suspended solids test results to calculate.

SMOKE TEST - A method of blowing smoke into a closed-off section of a sewer system to locate sources of surface inflow.

SNAKE - A stiff but flexible cable that is inserted into sewers to clear stoppages.

SOAP CAKE or SOAP BUILDUP - A combination of detergents and greases that accumulate in sewer systems, build up over a period of time, and may cause severe flow restrictions.

SOLIDS FEED RATE – The dry solids fed to a centrifuge.

SOLIDS LOADING (BELT FILTER PRESS) – The feed solids to the belt filter on a dry weight basis including chemicals per unit time.

SOLIDS LOADING RATE (DRYING BEDS) – The weight of solids on a dry weight basis applied annually per square foot of drying bed area.

SOLIDS RECOVERY (CENTRIFUGE) – The ratio of cake solids to feed solids for equal sampling times. It can be calculated with suspended solids and flow data or with only suspended solids data. The cenrate solids must be corrected if chemicals are fed to the centrifuge.

SOIL POLLUTION - The leakage (exfiltration) of raw wastewater into the soil or ground area around a sewer pipe.

SOUNDING ROD - A T-shaped tool or shaft that is pushed or driven down through the soil to locate underground pipes and utility conduits.

SPOIL - Excavated material such as soil from the trench of a sewer.

STATION - A point of reference or location in a pipeline is sometimes called a “station.” As an example, a building service is located 51 feet downstream from a manhole could be reported to be at “station 51.”

STILLING WELL - A well or chamber which is connected to the main flow channel by a small inlet. Waves and surges in the main flow stream will not appear in the well due to the small diameter inlet. The liquid surface in the well will be quiet, but will follow all of the steady fluctuations of the open channel. The liquid level in the well is measured to determine the flow in the main channel.

STOPPAGE - (1) Partial or complete interruption of flow as a result of some obstruction in a sewer. (2) When a sewer system becomes plugged and the flow backs up, it is said to have a “stoppage.”

STORM COLLECTION SYSTEM - A system of gutters, catch basins, yard drains, culverts and pipes for the purpose of conducting storm waters from an area, but intended to exclude domestic and industrial wastes.

STORM SEWER - A separate pipe, conduit or open channel (sewer) that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes. Storm sewers are often the recipients of hazardous or toxic substances due to the illegal dumping of hazardous wastes or spills created by accidents involving vehicles and trains transporting these substances.

STRETCH - Length of sewer from manhole to manhole.

SUCKER RODS - Rigid, coupled sewer rods of metal or wood used for clearing stoppages. Usually available in 3-ft, 39-in, 4-ft, 5-ft and 6-ft lengths.

SUCTION HEAD - The POSITIVE pressure (in feet or pounds per square inch (psi)) on the suction side of a pump. The pressure can be measured from the centerline of the pump UP TO the elevation of the hydraulic grade line on the suction side of the pump.

SUCTION LIFT - The NEGATIVE pressure (in feet or inches of mercury vacuum) on the suction side of the pump. The pressure can be measured from the centerline of the pump DOWN TO (lift) the elevation of the hydraulic grade line on the suction side of the pump.

SUPERNATANT – The amber-colored liquid above the sludge in a digester.

SURCHARGE - Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.

SURCHARGED MANHOLE - A manhole in which the rate of the water entering is greater than the capacity of the outlet under gravity flow conditions. When the water in the manhole rises above the top of the outlet pipe, the manhole is said to be "surcharged."

SUSPENDED SOLIDS - (1) Solids that either float on the surface or are suspended in water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, and referred to as Total Suspended Solids Dried at 103-105 ºC.

SWAB - A circular sewer cleaning tool almost the same diameter as the pipe being cleaned. As a final cleaning procedure after a sewer line has been cleaned with a porcupine, a swab is pulled through the sewer and the flushing action of water flowing around the tool cleans the line.

TAG LINE - A line, rope or cable that follows equipment through a sewer so that equipment can be pulled back out if it encounters an obstruction or becomes stuck. Equipment is pulled forward with a pull line.

TAP - A small hole in a sewer where a wastewater service line from a building is connected (tapped) into a lateral or branch sewer.

TELEVISION INSPECTION - An inspection of the inside of a sewer pipe made by pulling a closed-circuit television camera through the pipe.

TERMINAL "LAMPHOLES" CLEANOUT - When a manhole is not provided at the upstream end of a sewer main, a cleanout is usually provided. This is called a "terminal cleanout."

TERMINAL MANHOLE - A manhole located at the upstream end of a sewer and having no inlet pipe.

TOTAL CONTRIBUTION - All water and wastewater entering a sewer system from a specific facility, subsystem or area. This includes domestic and industrial wastewaters, inflow and infiltration reaching the main collection system.

TOTAL DYNAMIC HEAD (TDH) - When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TOTAL FLOW - The total flow passing a selected point of measurement in the collection system during a specified period of time.

TRAP - (1) In the wastewater collection system of a building, plumbing codes require every drain connection from an appliance or fixture to have a trap. The trap in this case is a gooseneck that holds water to prevent vapors or gases in a collection system from entering the building. (2) Various other types of special traps are used in collection systems such as a grit trap or sand trap.

TRUNK SEWER - A sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population.

TRUNK SYSTEM - A system of major sewers serving as transporting lines and not as local or lateral sewers.

TWO-WAY CLEANOUT - An opening in pipes or sewers designed for rodding or working a snake into the pipe in either direction. Two way cleanouts are most often found in building lateral pipes at or near a property line.

VAC-ALL - Equipment that removes solids from a manhole as they enter the manhole from a hydraulic cleaning operation. Most of the wastewater removed from the manhole by the operation is separated from the solids and returned to the sewer.

VELOCITY HEAD - The energy in flowing water as determined by a vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity (V2/2g).

VERTICAL OFFSET - A pipe joint in which one section is connected to another at a different elevation.

WASTELINE CLEANOUT - An opening or point of access in a building wastewater pipe system for rodding or snake operation.

WASTELINE VENT - Most plumbing codes require a vent pipe connection of adequate size and located downstream of a trap in a building wastewater system. This vent prevents the accumulation of gases or odors and is usually piped through the roof and out of doors.

WASTEWATER - A community's used water and water-carried solids that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WASTE ACTIVATED SLUDGE SOLIDS (WASS) – The concentration of suspended solids in sludge that is being removed from the activated sludge process.

WASTEWATER COLLECTION SYSTEM - The pipe system for collecting and carrying water and water-carried wastes from domestic and industrial sources to a wastewater treatment plant.

WASTEWATER FACILITIES - The pipes, conduits, structures, equipment, and processes required to collect, convey, and treat domestic and industrial wastes, and dispose of the effluent and sludge.

WASTEWATER TREATMENT PLANT - (1) An arrangement of pipes, equipment, devices, tanks and structures for treating wastewater and industrial wastes. (2) A water pollution control plant.

WATER POLLUTION - Any change in the natural state of water which interferes with its beneficial reuse or causes failure to meet water quality requirements.
The average **wastewater production per person per day** in most communities is between 70 and 100 gallons, depending upon a variety of factors including time of the year and water rates.

WAYNE BALL - A spirally grooved, inflatable, semi-hard rubber ball designed for hydraulic cleaning of sewer pipes.

WEIR - A device used to measure wastewater flow.

WET WELL - A compartment or tank in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

WETTED PERIMETER - The length of the wetted portion of a pipe covered by flowing wastewater.

ZOOGLEAL SLIME – The biological slime that forms on fixed film treatment devices. It contains a wide variety of organisms essential to the treatment process.

COMPLETED SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento – Operation of Wastewater Treatment Plants – Vol 1

Chapter 1	The Treatment Plant Operator
Chapter 2	Why Treat Wastes?
Chapter 3	Wastewater Treatment Facilities
Chapter 4	Racks, Screens, Comminutors, and Grit Removal
Chapter 5	Sedimentation and Flotation
Chapter 6	Trickling Filters
Chapter 7	Rotating Biological Contractors
Chapter 8	Activated Sludge (Package Plants and Oxidation Ditches)
Chapter 9	Waste Treatment Ponds
Chapter 10	Disinfection and Chlorination
Appendix	How to Solve Wastewater Treatment Plant Arithmetic Problems

California State University, Sacramento – Operation of Wastewater Treatment Plants – Vol. 2

Chapter 11	Activated Sludge (Conventional Activated Sludge Plants)
Chapter 12	Sludge Digestion and Solids Handling
Chapter 13	Effluent Disposal
Chapter 14	Plant Safety and Good Housekeeping
Chapter 15	Maintenance
Chapter 16	Laboratory Procedure and Chemistry
Chapter 17	Applications of Computers for Plant O & M
Chapter 18	Analysis and Presentation of Data
Chapter 19	Records and Report Writing

California State University, Sacramento – Advanced Waste Treatment

Chapter 2	Activated Sludge (Pure Oxygen Plants and Operational Control Optional)
Chapter 3	Solids Handling and Disposal
Chapter 4	Solids Removal from Effluents
Chapter 5	Phosphorous Removal
Chapter 6	Nitrogen Removal

California State University, Sacramento – O&M of Wastewater Collection Systems – Vol. 1

Chapter 1	The Wastewater Collecting System Operator
Chapter 2	Why Collection System Operation and Maintenance?
Chapter 3	Wastewater Collection Systems
Chapter 4	Safe Procedures
Chapter 5	Inspecting and Testing Collection Systems
Chapter 6	Pipeline Cleaning and Maintenance Methods
Chapter 7	Underground Repair

California State University, Sacramento – O&M of Wastewater Collection Systems – Vol. 2

Chapter 8	Lift Stations
Chapter 9	Equipment Maintenance
Chapter 10	Sewer Rehabilitation
Chapter 11	Safety Program for Collection System Operators
Chapter 12	Administration
Chapter 13	Organization for System Operator and Maintenance

General Water Quality (Chapter 611), Oklahoma Operator Certification rules (Chapter 710), Discharge – OPDEDS (Chapter 606), Non Industrial Impoundments and Land Application (Chapter 621), Rules for Oklahoma Hazard Communication Standard 40 CFR Part 503, Title 40 – Oklahoma Statutes for General Safety and Health
OSHA Confined Space Entry Rule Operations Manual, Stabilization Ponds, USEPA- 430/9-77-012
*Operations Manual – Anaerobic Sludge Digestion, USEPA 430/9-76-001
*Aerobic Biological Wastewater Treatment Facilities USEPA, MO-14
*Oklahoma Standards for Water Pollution Control Facilities (Chapter 656)
*AWWA Reference Handbook: Based Science Concepts and Applications – Hydraulic Section
*needed for certification purposes only by those person preparing for a Class A examination

REFERENCE SOURCES

(for all references listed in the Suggested References for Study and Other Study Suggestions)

CSUS Operation of Wastewater Treatment Plants, Volume 1
CSUS Operation of Wastewater Treatment Plants, Volume 2
CSUS Operations and Maintenance of Wastewater Collection Systems, Volume 1
CSUS Operations and Maintenance of Wastewater Collection Systems, Volume 2
CSUS Advanced Waste Treatment
Kenneth D. Kerri, Office of Water Programs, 6000 J Street, Sacramento, California 95819-6025
(916) 278-6142
Website: www.owp.csus.edu

Oklahoma Operator Certification Rules (Chapter 710)
Oklahoma Department of Environmental Quality
Customer Assistance
PO Box 1677
707 N. Robinson, Oklahoma City, Oklahoma 73101-1677
(405) 702-9100
Website: www.deq.state.ok.us

Discharge Standards (Chapter 606)
Non Industrial Impoundments and Land Application (Chapter 621)
Water Pollution Control Facility Construction (Chapter 656)
General Water Quality (Chapter 611)
Oklahoma Department of Environmental Quality
Customer Assistance
PO Box 1677
707 N. Robinson , Oklahoma City, Oklahoma 73101-1677
(405) 702-9100
Website: www.deq.state.ok.us

Operations Manual – Anaerobic Sludge Digestion, USEPA U-011
Aerobic Biological Wastewater Treatment Facilities, USEPA U-014
Operations Manual, Stabilization Ponds, USEPA U-015
Ohio State University
Educational Resources Information Center (ERIC)
(614) 292-6717
Website: www.ericse.org

AWWA WSO Basic Science Textbook & Workbook
American Water Works Association
6666 West Quincy Ave, Denver, Colorado 80235
1-800-926-7337
Website: www.awwa.org

Rules for Oklahoma Hazard Communication Standard
Title 40 – Oklahoma Statutes for General Safety and Health
OSHA confined Space Entry Rule
Oklahoma State Department of Labor/Division of Public Employees Safety and Health
4001 N. Lincoln Blvd.
Oklahoma City, Oklahoma 73105
(405) 528-1500 Extension 266
Website: www.state.ok.us/~okdol

Chlorine Manual (Chlorine Institute Pamphlet #1 Edition 5, 1986)
Chlorine Institute
2001 L St. N.W. Suite 506
Washington, D.C. 20036
(202) 775-2790

SOURCES OF ADDITIONAL STUDY MATERIAL

Manuals of Practice/Technical Publications and Materials	Water Environmental Federation 601 Wythe Street Alexandria, Virginia 22314-1994 1-800-666-0206, (catalog available) www.web.org
Operator Training Publications and Manuals	American Water Works Association 6666 West Quincy Ave. Denver, Colorado 80235 1-800-926-7337, (catalog available) www.awwa.org
Safety Publications and Materials	US. Department of Labor Occupational Sfy&Hth Adm(OSHA) 200 Constitution Ave., N.W. Washington, D.C., 20210 (202) 219-4667,(catalog available) www.osha.gov
Safety Publications and Materials	Oklahoma Safety Council 2725 E. Skelly Dr. Tulsa, Oklahoma 74105 1-800-324-6458, (catalog available) www.oksafety@ionet.net
Operator Math Manuals and Workbooks	Technomic Publishing Company 851 New Holland Ave, Box 3535 Lancaster, Pennsylvania 17604 1-800-233-9936, (catalog available) www.techpub.com
Environmental Protection Agency Technical Publications	Ohio State University Instructional Resource Center (614) 292-6717, (catalog available) www.ericse.org
Technical Publications and Materials (for systems <1 MGD)	National Small Flows Clearinghouse 1-800-624-8301 (catalog available)
Operator Training Material Information	National Environmental Training Ctr 1-800-624-8301

ADDITIONAL REFERENCE SOURCES

DEQ
DEQ State of Oklahoma Distribution/Collection Manual

DEQ Title 252 Chapter 656 Water Pollution Control Facility Construction

DEQ Title 252 Chapter 710 Waterworks and Wastewater Works Operator Certification

DEQ Title 252 Chapter 606 Oklahoma Pollutant Discharge Elimination System (OPDES) Standards

California State University, Sacramento
Operation and Maintenance of Wastewater Collection Systems (Volume I) - Fifth Edition California State University, Sacramento. 1998.

Operation and Maintenance of Wastewater Collection Systems (Volume II) - Fifth Edition California State University, Sacramento. 1998.

Collection Systems: Method for Evaluating and Improving Performance. California State University, Sacramento. 1998.

Collection Systems: Method for Evaluating and Improving Performance. California State University, Sacramento. 1998.

EPA
Collection Systems Technology Fact Sheet: Sewers, Lift Station. U.S. Environmental Protection Agency. September 2000. Available at: www.epa.gov/owm/mtb/mtbfact.htm

Collection Systems Technology Fact Sheet: Sewers, Conventional Gravity. U.S. Environmental Protection Agency. (undated). Available at: www.epa.gov/owm/mtb/mtbfact.htm

Collection Systems O&M Fact Sheet: Trenchless Sewer Rehabilitation. U.S. Environmental Protection Agency. September 1999. Available at: www.epa.gov/owm/mtb/mtbfact.htm

Wastewater Technology Fact Sheet: Sewers, Force Main. U.S. Environmental Protection Agency. EPA No. 832-F-00-071. September 1999. Available at:www.epa.gov/owm/mtb/mtbfact.htm

Decentralized Systems Technology Fact Sheet: Small Diameter Gravity Sewers. U.S. Environmental Protection Agency. EPA No. 832-F-00-038. September 2000. www.epa.gov/owm/mtb/mtbfact.htm

Manual: Alternative Wastewater Collection Systems. U.S. Environmental Protection Agency. EPA No. 625-1-91-024. October 1991. Available at: www.epa.gov/ORD/NRMRL/Pubs/1991/625191024front.pdf

Guide for Evaluating Capacity, Management, Operation, and Management Programs for Sanitary Sewer Collection Systems (DRAFT). U. S. Environmental Protection Agency. 2000. EPA No. 300-B-00-014.

Draft Notice of Proposed Rulemaking – NPDES Permit Requirements for Municipal Sanitary Sewer Collection Systems, Municipal Satellite Collection Systems, and Sanitary Sewer Overflows. U. S. Environmental Protection Agency. January 4, 2001.

Guide for Evaluating Capacity, Management, Operation, and Maintenance Programs for Sanitary Sewer Collection Systems (DRAFT). U. S. Environmental Protection Agency. 2000. EPA No. 300-B-00-014.

Asset Management for Sewer Collection Systems—Fact Sheet. U. S. Environmental Protection Agency. 2002.

Draft Notice of Proposed Rulemaking—NPDES Permit Requirements for Municipal Sanitary Sewer Collection Systems, (DRAFT). U. S. Environmental Protection Agency. 2000.
EPA No. 300-B-00-014.

Municipal Ordinance Considerations and Suggested Language to Help Control Sewer System Overflows (DRAFT). Parsons, Inc.2002. EPA Contract No. 68-C-00-116, Work Assignment No. 1-03.

Combined Sewer Overflow Technology Fact Sheet
Alternative Disinfection Methods EPA 832-F-99-033 September 1999

Wastewater Technology Fact Sheet
Ultraviolet Disinfection EPA 832-F-99-064 September 1999

Alternative Disinfection Methods Fact Sheet: Peracetic Acid
United States Environmental Protection Agency September 2012

Wastewater Technology Fact Sheet
Ozone Disinfection EPA 832-F-99-063 September 1999

40 CFR Parts 141 and 142 National Primary Drinking Water Regulations: Revisions to the Total Coliform Rule; Final Rule EPA

Revised Total Coliform Rule: A Quick Reference Guide EPA

Revised Total Coliform Rule Assessments and Corrective Actions Guidance Manual
Interim Final EPA 815-R-14-006 September 2014

OSHA
OSHA Technical Manual (OTM) Section V: Chapter 2

1910 Occupational Safety and Health Standards Subpart: J 1910.146 App D Sample Permits
Confined Space Pre-Entry Check List

1910 Occupational Safety and Health Standards Subpart: J 1910.146 App C
Examples of Permit-required Confined Space Programs

Entering and Working in Confined Spaces Reviewed January 2011
Developed in accordance with the OSHA Permit-Required Confined Space Standard, 29 CFR 1910.146

DOL
Small Business Handbook Occupational Safety and Health Administration
U.S. Department of Labor OSHA 2209-02R 2005

DOT
LEADER'S GUIDE 1716-LDG-E
SAFETY TRAINING FOR HANDLING AND TRANSPORTING HAZARDOUS MATERIALS
For the Department of Transportation's 49 CFR 172.700 Subpart H Training Requirements

The Hazardous Materials Regulations CFR 49 Parts 100 To 185 Department of Transportation's

Items for consideration for Self-Inspection 06/18/1999

Various
Wastewater Treatment Plant Operations Made Easy by Frank R. Spellman & Joanne Drinan

Water Distribution Operator Training Handbook 2nd edition by Harry Von Huben AWWA

Basic Science Concepts and Applications for Wastewater 1st edition AWWA

Communicating in a Crisis: Risk Communication Guidelines for Public Officials. U.S. Department of Health and Human Services. 2002.

Protecting Your Communities Assets: A Guide for Small Wastewater Systems. National Environmental Training Center. November 2002. Available at: www.nesc.wvu.edu/netcsc/

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The History of UV and Wastewater G. Elliott Whitby1,2 and O. Karl Scheible3

Evaluation of Disinfection Units for Onsite Wastewater Treatment Systems
Center for Environmental and Water Resources Engineering Prepared by Department of Civil and Environmental

Engineering Harold Leverenz University of California, Davis Jeannie Darby Davis, CA George Tchobanoglous
Report No. 2006-1 January 2006

WASTEWATER COLLECTION AND TREATMENT FACILITIES INTEGRATED MASTER PLAN
VOLUME 4: WASTEWATER TREATMENT SYSTEM
CHAPTER 9: DISINFECTION FINAL February 2008 City of Riverside

Wastewater Treatment Plant Operator Certification Training Module 5: Disinfection and Chlorination
This course includes content developed by the Pennsylvania Department of Environmental Protection

Wastewater Operator Certification Advanced Disinfection Study Guide Wisconsin Department of Natural Resources

Introduction to Disinfection Study Guide Wisconsin Department of Natural Resources, February 2010 Edition

Bleach Use in Wastewater Treatment Tom O'Donnell, Neptune Chemical Pump Company

Improving Pumping System Performance: A Sourcebook for Industry, Hydraulic Institute, January 1999. Available for download at: www.oit.doe.gov/bestpractices/pdfs/pump.pdf

Additional Information

Additional information on benchmarking is available from the following document:
Optimization of Collection System Maintenance Frequencies and System Performance. American Society of Civil Engineers. February 1999. Available at: www.epa.gov/npdes/pubs/optimizationfinalreport.pdf.

Model Emergency Response Plan for Municipal Sewage Discharges. Loureiro Engineering Associates. 2002.

The American Public Works Association (APWA) has developed a guidance document for preparing sewer overflow response plans titled Preparing Sewer Overflow Response Plans—A Guidebook for Local Governments, which is available (for a fee) from APWA. The APWA website is www.apwa.net and their telephone number is 1-816-472-6100.