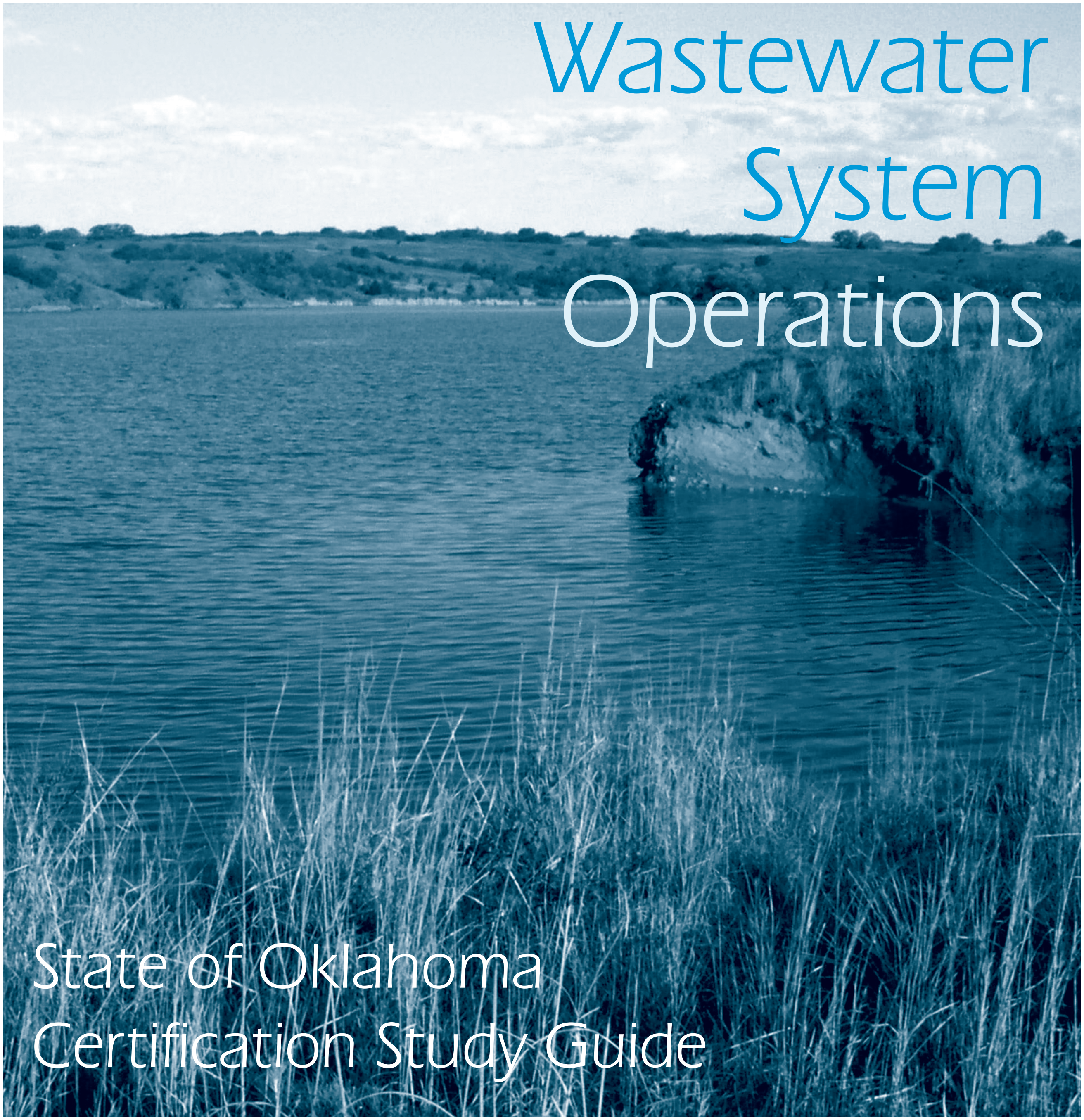
Wastewater System Operations



State of Oklahoma Certification Study Guide

DEQ

OKLAHOMA

DEPARTMENT OF ENVIRONMENTAL QUALITY

Department of Environmental Quality

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY
...for a clean, attractive, prosperous Oklahoma

NOTICE

NEW PROCEDURES FOR OBTAINING AGENCY ISSUED LICENSES/CERTIFICATIONS

Effective November 1, 2007

In order to comply with Oklahoma's new immigration law, 56 Okla. Stat. § 71, the Oklahoma Department of Environmental Quality has established the following new procedures for an individual to obtain an agency-issued license/certification.

A. **In order to obtain a license/certification or to renew an existing license/certification, the documentation requested in Sections C and E, including a signed Affidavit Regarding Citizenship, is required. In the absence of the required documentation, citizenship and immigration status cannot be determined and applicants may not be eligible for the license/certification for which they are applying.**

B. **The Department of Environmental Quality will have available notary public services for the Affidavit Regarding Citizenship at no cost to the applicant at the main office located at 707 N. Robinson, Oklahoma City, Oklahoma 73101 during regular business hours (8:00 a.m. – 4:30 p.m. Monday through Friday, except holidays).**

C. **The following documents must be provided to the agency with the relevant license/certification application in order to establish eligibility:**

ALL U.S. CITIZENS

1. A signed and notarized **Affidavit Regarding Citizenship (see attached affidavit)**

ALL NON-U.S. CITIZENS:

If you are not a U.S. Citizen, but are a qualified alien under the federal Immigration and Nationality Act and are lawfully present in the U.S. to work, please provide one of the documents listed in Section E, along with the Affidavit Regarding Citizenship.

D. **The Oklahoma Department of Environmental Quality participates in the Systematic Alien Verification for Entitlements (SAVE) Program, which is an intergovernmental information-sharing initiative designed to aid in determining a non-citizen applicant's immigration status (lawful presence), and thereby ensuring only eligible non-citizens receive government benefits, such as licenses/certifications.**

E. **The Oklahoma Department of Environmental Quality will only issue licenses/certifications to Qualified Aliens (non-U.S. citizens) who present valid documentary evidence of one (1) of the following:**

- ☐ Unexpired foreign passport, with I-551 stamp, or attached Form I-94 indicating unexpired employment authorization;
- ☐ Permanent Resident Card or Alien Registration Receipt Card with photograph (Form I-151, or I-551);
- ☐ Unexpired Temporary Resident Card (Form I-688);

- ☐ Unexpired Employment Authorization Card (Form I-688A)
- ☐ Unexpired Reentry Permit (Form I-327);
- ☐ Unexpired Refugee Travel Document (Form I-571);
- ☐ Unexpired Employment Authorization Document issued by Department of Homeland Security ("DHS") containing a photograph (Form I-688B);
- ☐ Valid unexpired immigrant or non-immigrant visa status for admission into the United States;
- ☐ Pending or approved application for asylum in the United States;
- ☐ Pending or approved application for temporary protected status in the United States;
- ☐ Approved deferred action status (Aliens whose deportation is being withheld under (1) § 243(h) of the Immigration and Nationality Act ("INA") as in effect prior to April 1, 1997 or (2) § 241(b)(3) of the INA;
- ☐ Pending application for adjustment of status to legal permanent resident or conditional resident status. (Aliens granted conditional entry under § 2039 (a)(7) of the INA before April 1, 1980). (Upon approval, the applicant may be issued a temporary license/certification for the period of time of the authorized stay in the U.S., or if there is no definite end to the period of authorized stay, then for period of one (1) year);
- ☐ Cuban and Haitian Entrants, as defined in § 501(e) of the Refugee Education Assistance Act of 1980;
- ☐ Aliens granted parole for at least one year under § 212(d)(5) of the INA;
- ☐ Battered aliens, who meet the conditions set forth in § 431(c) of Personal Responsibility and Work Opportunity Reconciliation Act ("PRWORA") as added by § 501 of the Illegal Immigration Reform and Immigrant Responsibility Act of 1996, P.L. 104-208 (IIRIRA), and amended by § 5571 of the Balanced Budget Act of 1997, P.L. 105-33 (BBA), and § 1508 of the Violence against Women Act of 2000, P.L. 106-386. Section 431(c) of PRWORA, as amended, is codified at 8 U.S.C. 1641(c);
- ☐ Victims of a severe form of trafficking, in accordance with § 107(b)(1) of the Trafficking Victims Protection Act of 2000, P.L. 106-386.

F. Complying with the above requirements does not guarantee issuance of a license/certification. Applicants must still satisfy all other required qualifications of the respective licenses/certifications for which they are applying.

G. <u>RENEWALS:</u>

Effective November 1, 2007, all applicants will be required to present the documentation listed in Sections C and E to establish eligibility. All licenses/certifications may be renewed upon expiration by, in addition to satisfying any other preconditions required by the particular license/certification, mailing a renewal application and any applicable renewal fee. For renewal applicants that have already demonstrated citizenship by satisfying the requirements set forth in Section C above in his/her original application or a prior renewal application, the applicant shall not be required to resubmit such documentation. For renewal applicants that identify themselves as a "qualified alien lawfully present" in the Affidavit Regarding Citizenship, the documents listed in

Section E must be resubmitted to the Oklahoma Department of Environmental Quality with the renewal application in order to demonstrate that the applicant's lawful status has not changed.

Department of Environmental Quality

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY
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AFFIDAVIT REGARDING CITIZENSHIP

I, ____ **(Print name)** swear under a penalty of perjury, that I am

(Check one) __________ a United States citizen; or

__________ a qualified alien lawfully present in the United States, and I authorize the United States Department of Homeland Security to release my citizenship and immigration Oklahoma Department of Environmental Quality in order to be eligible to receive the benefit/license/certification for which I am applying*

____

Signature License/certification Applicant

* Any person who knowingly and willfully makes a false, fictitious, or fraudulent statement or representation in this affidavit shall be subject to criminal penalties applicable in the State of Oklahoma for fraudulently obtaining a public assistance program benefit (a license/certification). If the affidavit constitutes a false claim of U.S. citizenship under 18 U.S.C. Section 911, a complaint will be filed by the Oklahoma Department of Environmental Quality with the United States Attorney for the applicable district based upon the venue in which the affidavit was executed.

ACKNOWLEDGEMENT

State of __________________________)
) ss:
County of ________________________)

Subscribed and sworn to before me this __________ day of __________, 20____.

____

Notary Public

My Commission expires:_______________________

The Oklahoma Department of Environmental Quality

INSTRUCTIONS for OPERATOR CERTIFICATION EXAM APPLICATION

1. If you are applying for certification as water, wastewater or laboratory operator by **RECIPROCITY** from another state. Please fill out this section along with the rest of the application.

2. List the **CITY** and **DATE** of the **EXAM** you wish to take. **Check** (X) the box indicating if this is an online exam or a written exam. Exam dates may be found in the current "MAIN EVENT" newsletter, or the Operator Certification website at www.deq.state.ok.us/WQDnew/opcert/index.html.

3. Print your **NAME**, **MAILING ADDRESS**, **CITY**, **STATE**, etc. Your **BIRTHDATE** and **SOCIAL SECURITY NUMBER** must be shown. The **MAILING ADDRESS** must be the **OPERATOR'S ADDRESS**!

4. List **YOUR JOB TITLE**: (Water Plant Supt, Wastewater Plant Supt, Water Plant Operator, etc).
   LICENSE NUMBER: If you are an Operator, Temporary operator or Helper in the State of Oklahoma, your **LICENSE NUMBER** may be found on the pocket card you are to carry with you at all times. If you are not certified, leave the space blank and a number will be assigned to you.
   DO YOU SUPERVISE OTHER EMPLOYEES? Answer yes or no. **IF YES**, list the number of employees you supervise. Please list the **NAME OF YOUR SUPERVISOR** and his/her **LICENSE NUMBER**.

5. List your **PLACE OF EMPLOYMENT'S** name, **ADDRESS**, **CITY**, **STATE**, etc.

6. **EMPLOYER'S WATER FACILITY / SEWER FACILITY ID NUMBERS**: The Water Facility Number is a seven-digit **NUMBER** and the Wastewater Facility **NUMBER** usually has 5 digits. These numbers identify the type of system. They can be obtained from your Supervisor or Employer.

7. **CHECK** (X) the box on the left of the exam you wish to take. Be sure to notice that there are separate boxes for water and wastewater.

8. List your **EXPERIENCE** in Water, Wastewater, Laboratory, or Distribution/Collection which will be used to qualify for this examination. Be sure to list **"TO"** and **"FROM"** dates as well as **DESCRIBE YOUR DUTIES**. Make sure to list the required amount of experience for the exam you wish to take. A chart of requirements for each exam is located at the bottom of the first page of the exam application.
   NOTE: It is important to update this information each time you apply. DO NOT rely on this office to maintain the information. The regulation states this is the responsibility of the Operator.

9. **TRAINING CREDIT** - Please read carefully and enter **TITLE, LOCATION, DATES, HOURS** and **CLASS NUMBERS** as requested. Be sure to list any training you will be taking prior to the exam. Make sure to list the required amount of training for the exam you wish to take. A chart of requirements for each exam is located at the bottom of the first page of the exam application. **<u>The training credit section cannot be left blank</u>.** Submit verification of required training, Academic Transcripts, Attendance Records, etc.
   NOTE: It is important to update this information each time you apply. DO NOT rely on this office to maintain the information. The regulation states this is the responsibility of the Operator.

10. Read the **"STATEMENT OF UNDERSTANDING", SIGN**, **DATE.** Must be the Applicant's Signature.

FEES: The application fee is a **non-refundable, nontransferable fee of $62 per exam.**
Please choose form of payment on the **PAYMENT FORM** located at the bottom of page 2 of the exam application.

Make your check or money order payable to: Dept of Environmental Quality and mail it with the exam application to:
DEPT OF ENVIRONMENTAL QUALITY
FINANCIAL & HUMAN RESOURCES **PO BOX 2036**
OKLAHOMA CITY, OK 73101-2036

As of September 10, 2009, faxed applications CAN be accepted. A purchase order, or credit card number MUST be included and the application must meet the 3 weeks prior deadline.

The application must be postmarked or faxed at least **THREE** weeks prior to the date on which you wish to take the exam.

√ Check your application to make sure that you have completed all blanks. If any information is not listed, your application is subject to being returned and not being approved.

√ If you need assistance contact the operator certification section at (405) 702-8150 or (405) 702-8100.

√ After you submit your exam application, you will receive a letter regarding approval/disapproval. If your application is returned to you with a disapproval letter, please make corrections and resubmit your application.

YOU ARE NOT APPROVED TO TAKE AN EXAM UNTIL YOU RECEIVE A LETTER OF APPROVAL FROM DEQ.

The Oklahoma Department of Environmental Quality
OPERATOR CERTIFICATION EXAM APPLICATION

Class______Water Exam – Score ______%
Class______Sewer Exam – Score ______%
Dist\Coll Operator Exam – Score ______%
Class______Water Lab Exam – Score ______%
Class______Sewer Lab Exam – Score ______%
Dist\Coll Technician Exam – Score ______%

Date Results Mailed______ ☐Internet exam **THIS BOX FOR DEQ OFFICE USE ONLY**

PLEASE RETURN THE APPLICATION AND APPLICATION FEE TO: Dept. of Environmental Quality
Financial & Human Resources
PO Box 2036
Oklahoma City, OK 73101-2036
Or: Fax # 405-702-8101

Must be postmarked or faxed 3 weeks prior to exam date.

PAYMENT INFORMATION

Payment must be included with this application. The **non-refundable** and **non-transferable** application fee is $62.00 per exam. Payment form is located at the bottom of page 2.

1. **Are you applying for this certification by reciprocity? _____From what state? _____What classification? _____**

Reciprocity may be granted when certification held in another state is current, in good standing and is comparable to Oklahoma Operator Certification rules.

2. **LOCATION & DATE OF EXAM APPLIED FOR: City ________________Date ________ Online☐ Written☐**

3. **Name - Last: ______________________ First: ________________________ MI: _______**

Mailing Address______________________City____________________State____Zip________

Social Security#_______/___/_______ Birthdate_____/_____/_____ Home Phone # ( ) ______________

Email Address: ___________________________

4. **Your Job Title__________________________________ Your License #__________________**

Do you supervise other operators or helpers? _______ If yes, how many? ______

Name of Immediate Supervisor_______________________ Supervisor's License #________________

5. **Employer______________________ Address_________________________City_________________**

State_____ Zip____________ Office Phone # ( ) ______________________

6. **Water Facility ID#_________________ Wastewater Facility ID#_________________**

7. **Please place an X in the box to the left of the exam(s) you are applying for.**

	WATER		WASTEWATER	REQUIRED AMOUNT OF TRAINING	REQUIRED EXPERIENCE
	D		D	16 hours	None
	C		C	36 hours	1 year
	B		B	100 hours	3 years
	A		A	200 hours	5 years
	C LAB		C LAB	32 hours of C lab training *	None
	B LAB		B LAB	32 hours of C lab training * & 32 hours of B level lab training	6 months
	A LAB		A LAB	32 hours of B lab training	5 years **
	DISTRIBUTION / COLLECTION				
	C OPERATOR			36 hours	1 year
	TECHNICIAN			8 hours	None

* An Associates Degree or greater in chemistry, biology, engineering, physical science, hydrology, geology, math, env. science, microbiology, toxicology, or civil, chemical, sanitary or env. engineering may be substituted for the 32 hours of DEQ approved C level training.

** Only 3 years of laboratory experience required with an Associates Degree in chemistry, microbiology, instrumental analysis or other field of science approved by the DEQ.

** **OR** 1 year of laboratory experience required with a Bachelor of Science degree in chemistry, microbiology, instrumental analysis or other field of science approved by the DEQ.

Exam Application Continued on Page 2

The Oklahoma Department of Environmental Quality
OPERATOR CERTIFICATION EXAM APPLICATION page 2

8. **Experience**: List your experience in water and/or wastewater system operations or maintenance. **YOU MUST LIST AT LEAST THE REQUIRED AMOUNT OF EXPERIENCE FOR THE LEVEL OF EXAM YOU WISH TO TAKE.** You can find the required amount of experience for each level in the chart at the bottom of the first page. List your present job first. Attach additional sheets if needed.

1. From______ To_______ Name of Employer_______________________________________

   Employer's Address___________________________City______________State___Zip______

   Describe your duties in detail: ____

   ____

2. From______ To_______ Name of Employer_______________________________________

   Employer's Address___________________________City______________State___Zip______

   Describe your duties in detail: ____

   ____

9. **Training Credit**: Please list all water and/or wastewater classes you have attended and/or will be attending prior to the exam. **YOU MUST LIST AT LEAST THE REQUIRED AMOUNT OF TRAINING FOR THE LEVEL OF EXAM YOU WISH TO TAKE.** You can find the required amount of training for each level in the chart at the bottom of the first page. Applicants requesting credit for technical school or college hours must attach an official transcript for credit to be granted.

! If you are planning to take an online exam you must complete the associated training class held immediately before the exam. You must list that training class below.

THIS SECTION CANNOT BE LEFT BLANK

Class Title and Location	Class Date(s)	Training Hours	Class Number

Total hours approved training ____________

Highest high school grade or college degree completed: __________________

10. **Statement of understanding**: I hereby certify under penalty of law that this application and any attachments contain no willful or negligent misrepresentation or falsification and that all information is true, accurate and complete. I understand that any misrepresentation or falsification may result in rejection of my application or in revocation of any certificate issued as a result of this application.

Signature of Applicant_________________________________**Date**__________________

Please Choose Form of Payment

___ Check Enclosed - Made Payable to DEQ
___ Money Order Enclosed - Made Payable to DEQ
___ Credit Card No: _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
(Must be Visa or MasterCard ONLY)

Exp. (mm/yy) _ _/_ _

Authorized Signature: ______________________________________

___ Purchase Order No.: _________________________ Rev. 5/2010

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:

Oklahoma Department of Environmental Quality
Operator Certification Section
P. O. Box 1677, 707 N. Robinson
Oklahoma City, OK 73101-1677

(405) 702-8100

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 answers 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 operation 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 or re-introduction to chemistry.

Oklahoma Certification Exam Qualifications

Water and Wastewater Works Operator Examination Applications are available from the DEQ Operator Certification Unit and 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 in *The Main Event* newsletter . *The Main Event* is mailed to all certified operators. To obtain a current copy, please call the Operator Certification Unit.

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 OPERATORS		
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 two years actual hands-on operating experience
[illegible]		
Technician	8 hrs of DEQ approved training	none
C Operator	36 hrs of DEQ approved training	1 year distribution collection operation

[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, an 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 certification 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**
Section I				
1. Basics 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. Operator 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

Usually within three weeks of exam completion, a report of your exam results will be mailed to your home. **Please do not call for exam results**. Your exam report will specify the number of questions which were included 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.

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WASTEWATER CERTIFICATION STUDY GUIDE CREDITS AND ACKNOWLEDGMENTS

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TABLE OF CONTENTS

Chapter 1
Basics of Wastewater Treatment

SUGGESTED STUDY GUIDELINES

All certification levels

Be prepared to answer questions concerning:

- The purposes of wastewater treatment
- The importance and role of the wastewater system operator
- The definitions of each of the following terms
  - aerobic
  - anaerobic
  - community wastewater system
  - digester
  - disinfection
  - effluent
  - facultative pond
  - influent
  - inorganic
  - National Pollutant Discharge Elimination System (NPDES)
  - organic
  - preliminary treatment
  - primary treatment
  - secondary treatment
  - sludge
  - stabilize
  - tertiary treatment
  - wastewater collection system
  - water pollution
- 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
- The most commonly used metric system units in wastewater systems and their values

ENTRY LEVEL DISCUSSION

The Federal Water Pollution Control Act Amendments of 1972 were passed by Congress to regulate and improve the quality of effluents discharged into the streams and rivers of this country. The goal of this legislation and of wastewater treatment is to have all public waters remain or become more suitable for wildlife and public use. To accomplish this aim, vast sums of money have been spent to upgrade existing facilities, construct new treatment plants, research more efficient treatment methods, develop better equipment, and train professionals to operate these systems.

As we move into the next century we are beginning to see greatly increased public awareness of the environment. As hazardous wastes, air quality issues, and oil spills dominate the news, the general public is increasingly emphasizing the preservation of the environment. It is now realized that as the quality of our environment declines, our society's quality of life also declines.

We are fortunate to live in a society that can voice concerns, and have government listen. Many major countries are decades behind the U.S. in environmental preservation. Some still have large epidemics of waterborne disease caused by inadequate or non-existent wastewater treatment systems. These diseases are spread by direct or indirect contact with untreated human wastes.

Our expectations about the way we want to live demands 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 their 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 definitions on the following pages should be helpful in gaining a better understanding of the fundamental purposes, processes, and functions of wastewater treatment. Subsequent chapters in this study guide and the suggested reference materials will address each of these subjects in more detail.

aerobic - A condition in which "free" or dissolved oxygen is present in water. Sometimes referred to as "fresh" conditions.

anaerobic - A condition in which "free" or dissolved oxygen is not present in water. Sometimes referred to as "septic" conditions.

bypass - The intentional or unintentional diversion of a waste stream from any portion of a wastewater system. All bypasses must be reported to DEQ.

community wastewater system - A public wastewater system which has at least 15 service connections or treats 5000 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.

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 wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect. Chlorine is the most frequently used method in both water and wastewater systems.

effluent - Wastewater or other liquid — raw or partially treated — flowing OUT of a reservoir, basin, treatment process or treatment plant.

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.

influent - Wastewater or other liquid — raw or partially treated — flowing INTO a reservoir, basin, treatment process or treatment plant.

inorganic waste - Waste material such as sand, salt, iron, calcium, and other chemical substances of mineral origin. It is generally not affected by the action of bacteria and other organisms.

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.

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.

organic waste - Waste material which comes mainly from animal or plant sources. Organic waste generally can be consumed by bacteria and other small organisms.

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 to be separated from the water being treated.

secondary treatment - A wastewater treatment process used to convert dissolved and suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated. Examples of secondary treatment processes include trickling filters, rotating biological contactors, and activated sludge processes.

sludge - The settleable solids separated from liquids during the processing of wastewater. Sludge is sometimes referred to as biosolids.

stabilize - To convert to a form that resists change. Organic material is stabilized by microorganisms which convert the material to gases and other substances. Stabilized organic material generally will not give off obnoxious odors.

tertiary treatment - Tertiary refers to the third treatment process or the process following a secondary treatment process. Some refer to tertiary treatment as advanced waste treatment, meaning processes that remove wastes not commonly removed by conventional (secondary) treatment processes.

wastewater collection system *(also known as a sanitary sewer)* - A network of pipes and equipment intended to carry wastewater from homes, businesses, and industries to a treatment facility. Storm water must be collected and transported in a completely separate system of pipes.

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.

Common conversion factors are needed by all operators working in this increasingly technical field. These include the conversions of cubic feet (ft^3) to gallons; from gallons to pounds; and from feet of head to pounds per square inch (psi). **Volume-time unit** conversions between **MGD** (million gallons per day), **gpd** (gallons per day), and **gpm** (gallons per minute) are other examples of basic math performed on a frequent basis at wastewater systems. The most commonly used **metric system units** and their values are also very important for operators to understand.

Other specific math skills needed by operators are identified by certification level in the suggested study guidelines of the other chapters in this study guide. Some assistance with common conversion factors and other basic math skills can be found in APPENDIX A in this study guide.

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 APPENDIX A of this study guide.

To help prepare for a Class C, B, or A exam, practice using the appropriate formula sheets found in APPENDIX B in this study guide.

SAMPLE QUESTIONS

Class D
Which of the following is the most accurate job title for certified wastewater system operators?

A. sewer workers
B. maintenance workers
C. public health professionals

Class C
To stabilize organic material means to

A. convert it to a stable form using microorganisms
B. convert it to a stable form using sedimentation and flotation units
C. remove all of the moisture in it

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 the necessary bonds to finance a new or improved wastewater treatment plant that you will operate. The consulting engineers have submitted their plans and specifications for the project. You 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 and comfortable with
E. participate in the ground floor planning and be present or available during the construction period but never offer advice to the consulting engineer, especially if it is an old plant being remodeled

Chapter 2
Characteristics of Wastewater

SUGGESTED STUDY GUIDELINES

Class D

Be prepared to answer questions concerning:

- The physical, chemical, and microbiological characteristics of wastewater
- The definitions of each of the following terms and their significance
  - pH
  - acid
  - base
  - neutral
  - total alkalinity
  - phenolphthalein alkalinity
  - total solids
  - total dissolved solids (TDS)
  - total suspended solids (TSS)
  - settleable solids
  - non-settleable solids
  - microbiology
  - bacteria
  - pathogenic
  - non-pathogenic
  - coliform
  - fecal coliform
  - dissolved oxygen (DO)
  - fresh wastewater
  - aerobic bacteria
  - septic wastewater
  - anaerobic bacteria
  - facultative bacteria
  - biochemical oxygen demand (BOD)
  - chemical oxygen demand (COD)
  - carbon dioxide
  - nutrients
  - nitrogen
  - phosphorus
- The proper units of measurement for each of the general characteristics of wastewater
- 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 questions 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 performed. The following discussion will address each of the primary characteristics, describing the fundamental concepts of each. Where appropriate, the basic method(s) used to analyze wastewater for these parameters is also briefly discussed for the benefit of entry level operators.

pH

The **pH** measurement is a way to determine how acidic or how basic the water is. The **pH scale** is from 0.0 to 14.0 ***(see Figure 2.1)***. A pH of less than 7.0 means the water is **acidic**. A pH of greater than 7.0 means the water is **basic**. A pH of exactly 7.0 is considered **neutral**.

To really understand the meaning of pH, it is necessary to discuss the basic chemistry that determines pH levels. 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^-).

*Note: An **ion** is any molecule with either a positive or a negative electrical charge.*

The hydrogen ion (H^+) is related to acidic conditions while the hydroxide ion (OH^-) is related to basic conditions.

Water is sometimes referred to as the **universal solvent**. Because of its tendency to dissolve most substances it comes in contact with, water usually contains many impurities. Even distilled or deionized water is not absolutely 100% pure. 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).

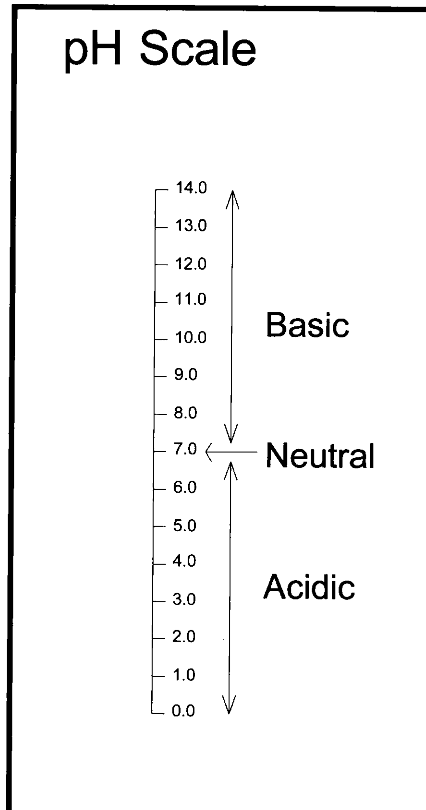


Figure 2.1

The most common method used for pH measurement is a pH meter using a hydrogen ion-sensitive electrode. The **pH scale** consists of 15 pH units (0.0 to 14.0). Each **pH unit** on the scale is very significant because it 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 are also never averaged together because it would result in an incorrect number being reported.

Alkalinity

Alkalinity can be defined as the ability to resist changes in pH in response to dilute acids or bases. In other words, the alkalinity in the water is caused by certain chemicals that act as a **buffer** against acids. Alkalinity reacts with acids that are added to the water and thereby reduces or eliminates any reduction in pH that would have been caused by the acid.

It should be noted that the presence of alkalinity does not necessarily indicate basic pH conditions (pH greater than 7.0). The chemicals producing alkalinity in water do tend to keep the water at a high pH, but it is possible to have acidic conditions (pH less than 7.0) and still have some alkalinity present or, on the other hand, to have basic conditions but not have a significant amount of alkalinity present.

The chemical ions that form alkalinity are **hydroxide** (OH^-), **carbonate** ($CO^{=}3$), and **bicarbonate** (HCO^-3) ions ***(see Figure 2.2)***. The pH of the water determines which of these three ions are present. The hydroxide, carbonate, and bicarbonate ions combine with calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^+) and potassium (K^+) ions to form the chemicals that contribute to alkalinity.

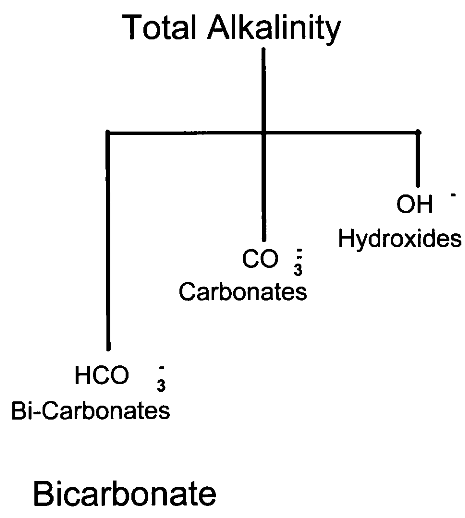


Figure 2.2

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**. Some operators may also refer to total alkalinity as M-alk. Total alkalinity only exists between pH 4.5 and pH 14.0. This means that if a water sample has a pH of less than 4.5, the alkalinity content is zero.

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. There is no p-alk in the sample if the pH is less than 8.3. The p-alk test is often performed to help determine the relative concentrations of hydroxide, carbonate and bicarbonate in the sample.

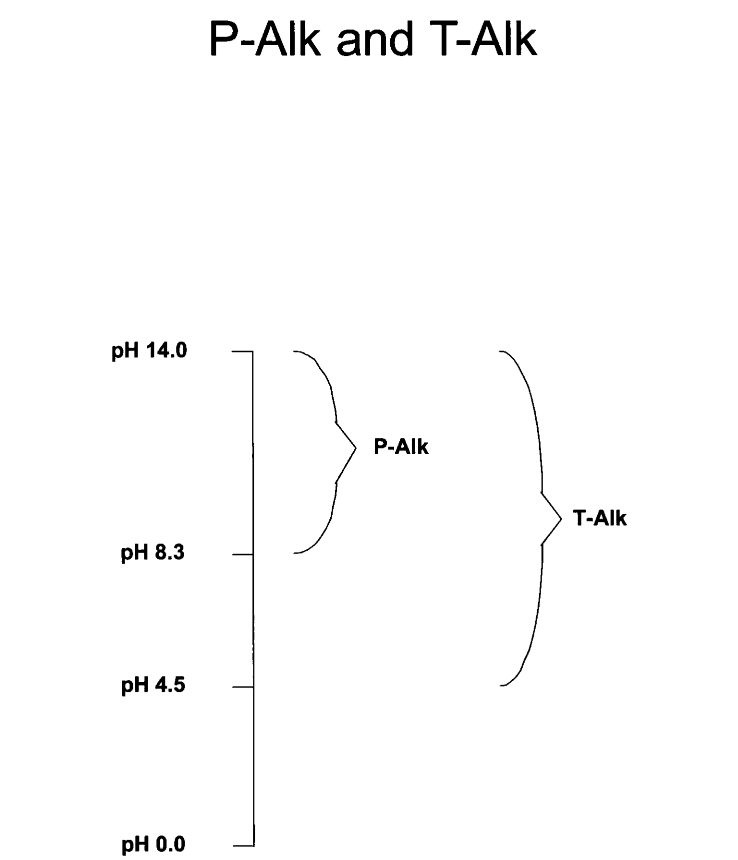


Figure 2.3

It should be remembered that p-alkalinity (if it is present) is only part of the total alkalinity, not an entirely separate measurement *(see **Figure 2.3**)*.

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 endpoint for T-alk is a pH of 4.5. The endpoint for p-alk is a pH of 8.3. 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).

Note: mg/L and ppm are just two different ways of saying the same thing.

Solids

Domestic wastewater will normally consist of 99.9 percent water with only 0.1 percent total solids, (equivalent to 1000 mg/L total solids content). The **total solids** in wastewater consist of both dissolved solids and suspended solids ***(see Figure 2.4)***.

The **total suspended solids** (TSS) is the portion of the total solids that can be removed by filtration. The suspended solids can be further categorized as either **settleable solids** or **nonsettleable solids**. Nonsettleable solids are also known as **colloids**. An important example of a settleable solid is grit. **Grit** is a heavy inorganic settleable suspended 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 filtration. About 80% of the solids in typical domestic wastewater are dissolved solids.

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 then are reported in mg/L (milligrams per liter) or ppm (parts per million).

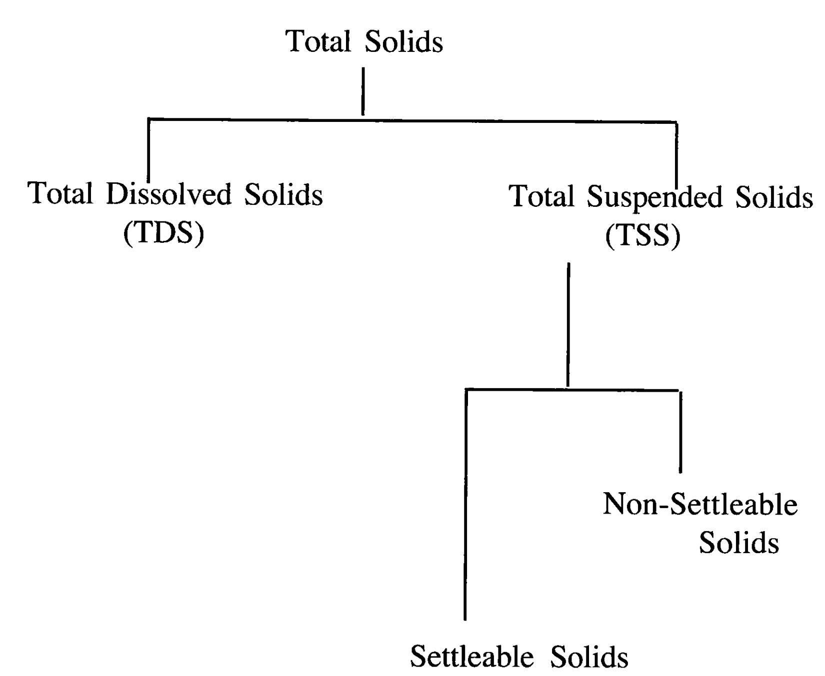


Figure 2.4

Microbiology

Microbiology is the study of very small forms of life. Microbiological organisms can only be seen with the aid of a microscope. These organisms include bacteria, virus, protozoa, rickettsia, fungi, algae, and other forms of microscopic life. The average-sized bacterial organism is so small that 20,000 could fit side-by-side in one inch. Viruses are much smaller.

Oxygen Requirements of Microbiological Organisms

Microbiological organisms can be classed by their oxygen requirements and are referred to as either aerobic, anaerobic, or facultative. **Aerobic** organisms require dissolved "free" oxygen (DO). Aerobic organisms use free oxygen (O_2) and produce carbon dioxide (CO_2). It is essential that the microorganisms present in most wastewater treatment processes be aerobic organisms.

Anaerobic organisms obtain oxygen from oxygen-containing compounds such as the sulfate molecule ($SO^{=}$). One of the many by-products of anaerobic organisms is hydrogen sulfide (H_2S). Hydrogen sulfide is a gas that has a sulfur-like "rotten egg" odor. Unfortunately, hydrogen sulfide not only has a$_4$bad odor, it is also very dangerous due to its toxicity to humans (see Chapter 6).

Facultative organisms can live with or without the presence of dissolved oxygen. If free oxygen is available in sufficient quantities, they will act like an aerobic organism. On the other hand, if there is not enough free oxygen they will actually convert and begin to use other sources of oxygen (act like an anaerobic organism). Actually, most bacteria are facultative and how they "act" is dependent upon the level of dissolved oxygen available to them.

Pathogenic or Non-Pathogenic

Organisms can also be classed as pathogenic or non-pathogenic. **Pathogenic** organisms are organisms that cause disease. **Non-pathogenic** organisms do not cause disease. Diseases caused by pathogens (pathogenic organisms) that can be transmitted by water are sometimes called **water-borne diseases**. The organisms causing waterborne disease are found in the intestinal tract of all persons that are infected with the disease. These diseases are transmitted when pathogenic waste material from infected persons enters drinking water supplies.

Historically, the five major waterborne diseases have been typhoid, cholera, dysentery, polio, and hepatitis (jaundice). These and other infectious diseases were at one time the leading causes of death. Now due to proper sanitation and regular monitoring practices (largely performed by operators of community water and wastewater systems), they are being managed. However this is an ongoing battle. Proper sanitation is just as important today as it was 75-100 years ago when many modern day sanitation practices were first implemented.

Coliform Bacteria

One group of non-pathogenic bacteria that plays a very important role in the monitoring of public waters and drinking supplies is known as Coliform group bacteria. **Coliform bacteria** live in everyone's intestinal tract. In fact, warm-blooded animals (including humans) can't live without them. Most types of these coliform bacteria also live in the environment. Coliform bacteria are considered non-pathogenic.

It would be very expensive, time consuming, and actually somewhat dangerous to monitor and test the water for all pathogenic organisms that may be present. What is done instead is to monitor all public water supplies for coliform bacteria. Although the coliform do not cause disease, they are excellent **indicators** of environmental and wastewater contamination. In wastewater treatment, an additional laboratory test is routinely performed on the treated wastewater to check how many of a particular coliform—known as **fecal coliform**—are present. Because the fecal coliform (also known as Escherichia Coli or E. Coli) are only found in fecal material, this test can be used as an indicator of how many other types of organisms, including pathogenic organisms, may still be present in treated wastewater.

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 (milliliters) of sample.

Another laboratory test sometimes used to check for coliform bacteria 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 a certain temperature for 48 hours. If a gas bubble is produced in one of the tubes, the sample is considered positive for coliform bacteria. A "most probable number" of coliform is then reported based on the number of tubes that tested positive.

Dissolved Oxygen (DO)

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 the **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 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^o Celsius (C) +or- 1^o C. Because it takes five days to get the results of this test it is sometimes written as BOD_5. BOD results are very important to operators because BOD is the primary guideline used to determine 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 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 the pH because carbonic acid (H_2CO_3) is produced when carbon dioxide reacts with water.

Nutrients

Nutrients in the form of nitrogen and phosphorus are present in wastewater. They are called nutrients because they are essential for plant and animal growth. **Nitrogen** is present in proteins and from urea. Urea (NH_2CONH_2) is found in urine and breaks down to form ammonia (NH_3). Ammonia produces an oxygen demand as it is biologically converted to nitrate ($NO^-{}_3$). The nitrate then stimulates excessive plant growth (also known as eutrophication) in receiving streams. Therefore nitrogen removal is sometimes required. **Phosphorus** can also stimulate excessive plant growth. Common sources of phosphorus in wastewater are feces, agricultural run-off, and some detergents.

General Procedures for Collecting Samples

Because there is a separate training and certification program for laboratory technicians in the State of Oklahoma, no detailed discussion concerning laboratory procedures for wastewater analyses is included within this study guide. However, collecting water samples is very often the direct responsibility of plant operators.

Sampling is a vital part of wastewater operations. A major source of error in the overall process of obtaining process control or effluent quality information often occurs during sampling. In any type of testing program where only small samples are 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 of samples 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).

SUGGESTED REFERENCES FOR STUDY

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

Chapter 2 Why Treat Wastes?

California State University, Sacramento - **Operation of Wastewater Treatment Plants - 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
Compounds likely to be produced in septic waters include

A. O_2, CO_2, and H_2CO_3
B. NH_4^+, CH_4, and H_2S
C. H_2S, NO_3^-, and HCl
D. NO_2^-, H_2S, and NH_4^+

Class A
Dissolved solids are also correctly called

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

Chapter 3
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 regulations. 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 of records
- 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
- What information is required to be reported on the MOR and DMR
- 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 calculations and analyze and present data using
  - charts and graphs
  - tables
  - 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 ten days of employment or appointment as an operator. An **operator** is any 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 a 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 Chapter 710-Waterworks and Wastewater Works Operator Certification. 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 must hold at least the same level of certification as the classification level of the system that he or she is responsible for. The **superintendent** is the operator in day-to-day direct responsible charge of an entire plant, distribution system or collection system. This is true even if other official titles are sometimes assigned by employers.

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 must be operated by a superintendent with at least a Class C certification regardless of population served. 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 decision regarding the daily operations activities of water/wastewater works.

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. The assistant superintendent shall be certified at no less than one certification level below that required for the superintendent. Employers may require their employees to hold a higher certification level than is required by state law.

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 hire 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.

Laboratory Technician Certification

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

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

Annual Renewal of Certificates

All certificates expire on June 30 of each year and must be renewed no later than July 30 to remain current. Operators are responsible for renewal of their certificates regardless of notification. Before renewing a certificate, the operator must have completed at least four hours of approved training within the last fiscal year (July 1-June 30). The renewal application should not be submitted until the training requirement has been met. Renewal applications/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) certificates may be reinstated for up to two years after the expiration date. After two years, the examination must be retaken to become certified.

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 a jail term.

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.

Oklahoma Pollutant Discharge Elimination System Standards (Chapters 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 discharges 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 and/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.

Reports

All community wastewater systems must keep a **Monthly Operational Report (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.

The MOR must be kept on file at the facility for at least three years. However, wastewater systems may not be required to submit the MOR (community water systems are required to submit the MOR).

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 OPDES (see Chapter 1 for definition).

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. A copy of the DMR must also be kept on file by the facility for at least three years. DMR forms are obtained through the Water Quality Division.

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 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 noncomplying 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 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 (see also Chapter 6). These records include—but are not limited to— **accident reports** and **safety checklists**, as well as **emergency guidelines and procedures**.

One of the most important sets of safety records required are 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.

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. 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 in trouble". Actually, they are making the situation 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 of 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, or a jail term or all three of these penalties combined. Federal penalties for falsification under the Clean Water Act may reach up to one year in prison and $25,000 per violation. Recent amendments to the Clean Water Act make enforcement procedures much more likely to be initiated by state and/or federal authorities.

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)***

sRules 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.

SAMPLE 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

BOD5 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?

	BOD5	*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.
BOD5 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 210, and the mode is 230
E. 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

Know the special safety considerations for collection system operators

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 requirements/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 advanced 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.

As discussed in Chapter 1, 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, higher cost of water in some communities may lower water usage.

In the early 1900's, 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.

This discussion will focus only on the operation and maintenance of wastewater collection systems.

Components of the Collection System

The different sections of the wastewater collection system each have specific roles to play ***(see Figure 4.1)***. 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** is used to "lift" the wastewater so it can continue along its way to the treatment plant.

Wastewater Collection System Lines

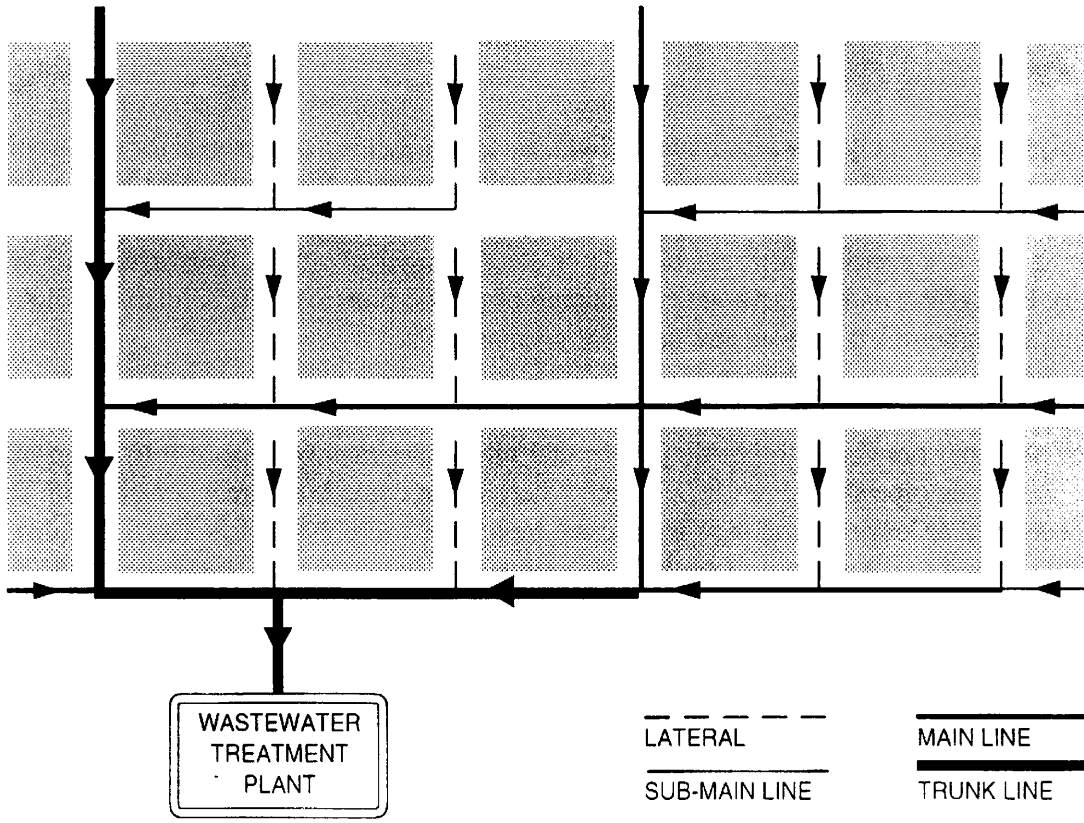


Figure 4.1

Piping Materials

Many different materials are used for collection system construction, including different types of piping used at different systems, and for different situations. All materials used to construct the collection system should have sufficient strength to resist hydraulic pressure, earth and traffic loads, and be resistant to corrosion and abrasion. Many different materials are used for collection systems including ductile iron, plastic, concrete and clay. The best type of material depends on individual situations within each system. Each type of piping has advantages and disadvantages and serious consideration should be given before making decisions involving material selection.

Ductile Iron Pipe (DIP)

Ductile iron pipe (DIP) is used mainly in submains and trunk lines where heavy loads or depths are encountered. This type of pipe often has a polyvinyl coating on the outside to protect it from corrosive ground soil. The inside is often coated with a bituminous (tar) material for protection from hydrogen sulfide gas. It is also used in lift station piping because of its wall strength.

DIP is very malleable (easily worked) yet it is strong. Because of its strength DIP is easily drilled and tapped for service lines. The disadvantage of DIP is that it is subject to corrosion from both inside and outside often requiring preventive measures. Flanged or mechanical joints are used to connect lengths of pipe.

Plastic Pipe

Plastic pipe is a relatively new pipe material but it is rapidly gaining acceptance for use in collection 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. Corrosive soils will also have very little effect on PVC. 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 a solvent weld for smaller sizes (up to six inch diameter) and the rubber ring push-on for larger sizes.

Reinforced Concrete Pipe (RCP)

Reinforced concrete pipe (RCP) has been widely used in the wastewater systems since the turn of the century. RCP can be classified into two general types: non-steel cylinder type and steel cylinder type.

NON-STEEL CYLINDER RCP. Non-steel cylinder RCP is constructed by forming up to three cages of reinforcing steel. These cages are then placed in a mold and are coated with concrete.

STEEL CYLINDER RCP. Steel cylinder RCP is constructed by taking a steel cylinder and lining it with cement mortar. Wire is then wrapped around the structure and a mortar coating is added over it.

Concrete pipe has a high compressive strength and can be installed under high backfill loads. Because of its strength, RCP is sometimes used in collection system submains and trunk lines. One disadvantage of concrete pipe is that hydrogen sulfide will damage and deteriorate it. Modern manufacturing techniques provide interior coatings which greatly reduce this problem. RCP is somewhat difficult to tap and may be hard to repair if damaged. Bell and spigot or push-on joints are used for connections.

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, submains, 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.

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 used. 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.

Lift Stations (see also Chapter 5)

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 two types of lift stations: drywell and wetwell installations.

Drywell stations have the pumps and controls housed in a separate dry compartment and the wastewater flows into a separate wetwell. 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 dry well 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.

Wetwells utilize one compartment with submersible pumps in the wetwell or suction lift pumps above the wetwell and enclosed in a housing or cover. Disadvantages of some wetwell 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 wetwells must also be especially designed for pumping raw wastewater. Wetwell 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 wetwell 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.

Lift Station Control Systems

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 wetwell. When the pressure reaches a pre-set point, the pump kicks on. When the pressure drops to a pre-set point, the pump shuts off. **Floats** are suspended in the wetwell. 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.

Preventing Stoppages

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 as 85% of these problems can be avoided by a good preventive maintenance program. Even when there is not a complete stoppage, poor construction or maintenance 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 pre-treatment 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.

Removing and Preventing Roots in Lines

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 the 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 preventive maintenance program and can control roots in a sewer for as long as two to 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 taps.

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 more 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.

A common method used to discover sources of I & I in collection systems is referred to as **smoke testing**. 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.

As discussed in Chapter 3, 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 (see Chapter 3 for reporting procedures).

State Construction Standards

According to Oklahoma standards, all wastewater collection 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 inch lines 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 (See also Chapter 6)

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 Applications *(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 collection 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. 1.0 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 pipe is large enough to walk it through manually
D. should always be pulled in the direction of flow unless the sewer lines have been cleaned prior to televising
E. 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, the procedures must be understood by all 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 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 proper maintenance for a piece of equipment
- The conditions under which centrifugal pumps should never be operated
- The conditions 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 procedures for proper alignment and maintenance of couplings and power drives
How to develop a comprehensive maintenance program for a wastewater treatment plant
How to develop and maintain a 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 couplings and power drives
- The basic descriptions and operating principles of the following controls
  - control panel (diagram of simple panel)
  - mercury floats
  - probes
  - bubbler

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

ENTRY LEVEL DISCUSSION

An important duty of an operator is plant and collection system maintenance. A successful maintenance program will cover everything from mechanical equipment to the care of plant grounds, buildings and structures.

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.

For a successful maintenance program, your supervisors must understand the need for and benefits from equipment that 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.

Preventive Maintenance Records

Preventive 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 preventive 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 preventive 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 Cards & Service Record Cards

An **equipment service card** or "master 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. See the *Suggested References for Study* in this chapter to find examples of how a service card can be set up to contain this information. 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 **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 master card. The *equipment service card* tells what should be done and when to do it, while the *service record card* is a record of what you did and when you did it.

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

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.

Buildings and Plant Grounds

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.

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 employer relations. Plant grounds that are well groomed and kept in neat condition will greatly add to the appearance of the overall plant area. This is also important to the operator in building good public relations with plant neighbors as well as the general public.

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. 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.

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.

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.

Electrical 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 INFORMATION.

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

Fundamentals of Electricity

In all water systems, there is a need for the operators to know something about electricity. However, very few operators, even those operators who specialize in maintenance, ever do the actual electrical repairs or troubleshooting because it is 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 the following 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 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, all motors above two horsepower are three-phase. Three-phase power usually is 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 and then some type of disconnecting switch such as a fuse or circuit breaker.

Fuse. 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."

Amps. 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.

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.

Mechanical Maintenance

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

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.

The type of material to be handled and the function or required performance of the pump vary so widely that 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 very commonly used types of pumps are centrifugal pumps and reciprocating pumps.

A **centrifugal pump** operates by the centrifugal force created when an impeller rotates inside its casing ***(see Figure 5.1)***. The impeller (a paddle wheel device) is supported on a shaft which is, in turn, supported by bearings. Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge. Centrifugal pumps cannot operate unless the impeller is submerged in water. Therefore they should NEVER be started until they are properly primed.

One type of centrifugal pump is the **volute centrifugal pump**. The term "volute" comes from the spiral-shaped interior of the casing. As the impeller spins the centrifugal force created throws the water outward into the volute. This creates a partial vacuum at the center of the impeller, which draws more water into the pump from the suction opening. Pressure will increase as more and more water is thrown into the volute, which forces water around the spiral and out of the discharge. The volute shape of the casing changes the high velocity and low pressure head of the water leaving the impeller to a lower velocity and higher pressure head at the discharge. The movement of water during pumping is radially outward, away from the shaft.

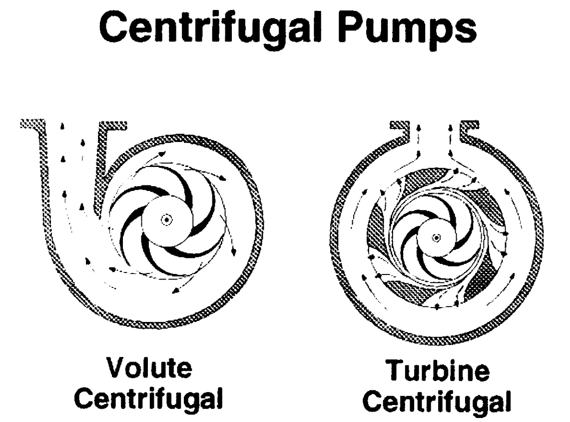


Figure 5.1

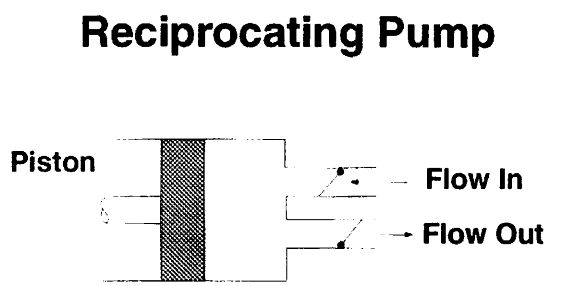


Figure 5.2

Another type of centrifugal pump is the **turbine centrifugal pump**. In this pump the impeller is mounted at the center of a circular casing. The pump has stationary diffuser vanes fixed to the inside of the casing which convert the velocity of the outwardly-thrown water to pressure head. Turbine pumps are generally considered to be more efficient than volute pumps. Because of their efficiency they are especially useful in high-head applications. However, the turbine pump has small clearances between the impeller and diffuser vanes and it can be easily fouled by dirt.

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 ***(see Figure 5.2)***. Two check valves alternately open and close as the piston cycles. Positive displacement pumps such as reciprocating pumps or piston pumps should NEVER be operated against a closed discharge valve.

Packing is used to keep air from being drawn into pumps. Packing should be replaced periodically depending upon conditions of operation. Use the packing recommended by the pump manufacturer. The stagger of packing joints can be determined by dividing 360° by the number of packing rings Many pumps being produced today use mechanical seals in place of packing. Mechanical seals serve the same purpose as packing; that is, they prevent leakage between the pump casing and the shaft. 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 5psi greater than the maximum pump suction pressure.

Bearings should usually last for years if serviced properly and used in their proper application. 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.

Unless **couplings** between the driving and driven elements of a pump or any other piece of equipment are kept in proper alignment, breaking and excessive wear in the pump and/or the motor can be the result. Burned out bearings, sprung or broken shafts, or ruined gears are some of the damages caused by misalignment. To prevent outages and the expense of installing replacement parts, regularly check the alignment of all equipment.

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.

Motors

Equipment used to operate pumps includes 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 which 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 under 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 recommendations 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 looses power; if the motor is running it will tend to overheat and damge 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 which 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, plug valves, and check valves are all commonly used in wastewater collection and treatment systems. **Gate valves** use discs or gates to provide a shut-off within the valve body ***(see Figure 5.3)***. Two types of gate valves are the Non-Rising Stem Valve and the Outside Screw & Yoke Valve.

Plug valves consist of a rotating plug within the valve body ***(see Figure 5.4)***. Many systems specify plug valves as opposed to gate valves as they are less susceptible to being fouled by debris. 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 properly and minimize chance of failure.

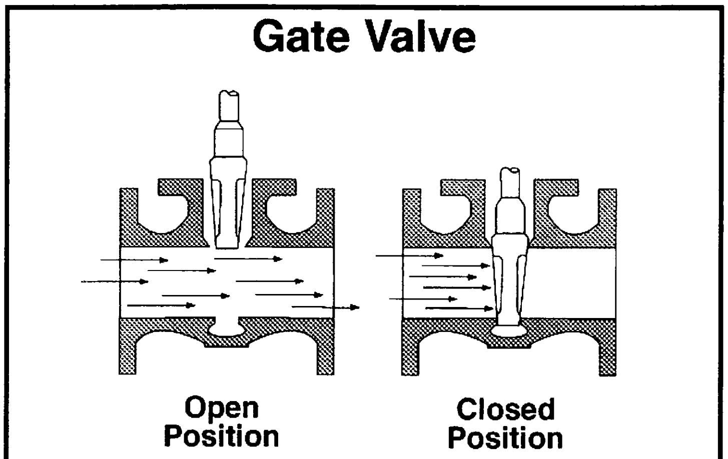


Figure 5.3

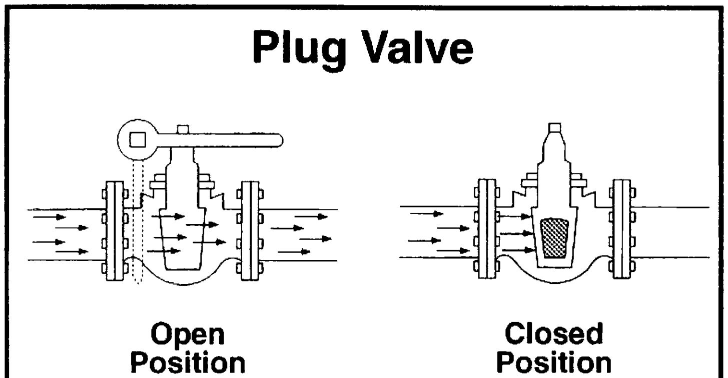


Figure 5.4

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.

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

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.

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. Step-by-step instructions for lockout-tagout can be found in Chapter 6 of this study guide.

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 10 — 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, 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.

Study troubleshooting charts for operation of pumps. Know how to correct cavitation, loss of prime, air lock.

Know what to look for in motor operation, such as overheating, vibration, and noise.

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.

SAMPLE 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 mechanical 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
E. propeller pumps

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 on this very important topic.

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
  - infectious materials
  - traffic
- The name of the service available in the case of an emergency involving hazardous chemicals
- The importance of and how to read 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 B and Class A

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

Why should safety be of such interest to wastewater 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 Title 29 (1926.650)

2. Confined Spaces -- OSHA Title 29 (1910.146)

3. Electrical and Mechanical Hazards -- OSHA Title 29 (1910.147)

4. Hazardous Chemicals -- Oklahoma Haz Com -- Title 380 chapter 45

5. Noise -- OSHA Title 29 (1910.95)

6. Physical Hazards -- OSHA Title 29 (1900-1926)

7. Fire Protection

8. Infectious Materials

9. Blood Borne Pathogens -- OSHA Title 29 (1910.151, 1910.1030)

10. Traffic

Ways operators deal with these day to day hazards may be detailed in a safety program. Aspects of a safety program 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 will be eliminated. Poor work habits, those short cuts you may take, or the messes that are left behind ultimately won't pay off. Eventually it will catch up with you or someone else and an injury will result. The trip to the doctor and days of lost time will more than make up for any time you may have thought you were saving.

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 a hardship to both the operator and his or her family.

The wastewater system suffers also. Injuries rob the system of needed operators. Others who may be less skilled may have to fill in. Even large crews may have to work shorthanded or overtime. This creates fatigue among the operators and results in an overtime expense to the system.

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** result from improper lifting, awkward positions, pushing, and slips and falls.
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.

Years of experience is a factor in who is most likely to be injured. As the experience level increases, the worker is more likely to have become more highly certified and educated about the hazards of the job. He or she may have moved up to a supervisory level where exposure to hazards is less, or may have learned about certain dangerous activities through his/her own experiences or experiences of others.

Operator Safety Training Programs

On-the-job training (OJT) is a very valuable tool to not only upgrade operational skills, but also to protect the worker's health. There is a great need for improved safety programs at wastewater facilities and in collection systems. 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 below.

1. Develop a written **Standard Operating Practice** (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 people 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 safe workers** with a certificate or some type of tangible recognition. Make safety and good work habits a part of annual evaluations and a factor in merit raises.

Trenching and Excavation Hazards

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 doesn't matter how short a time you might work in a trench, if there is not adequate cave-in protection provided you could easily be buried under tons of dirt. THERE IS USUALLY NO WARNING AND NO TIME TO ESCAPE. It is strongly recommended that some type of adequate cave-in protection be provided when the trench is four (4) or more feet deep. OSHA REQUIREMENTS STATE THAT ADEQUATE PROTECTION IS ABSOLUTELY REQUIRED IF THE TRENCH IS FIVE (5) FEET OR MORE IN DEPTH. In addition, A PERSON DESIGNATED AS QUALIFIED AND COMPETENT TO RECOGNIZE AND EVALUATE HAZARDS MUST BE PRESENT. Methods of adequate protection include shoring, shielding, and sloping.

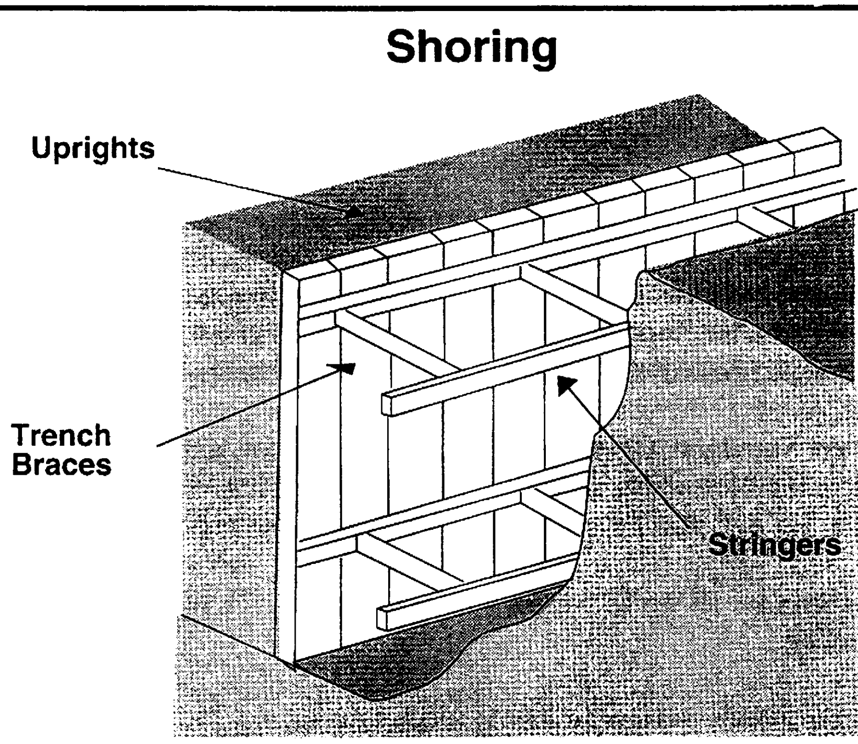


Figure 6.1

Shoring

Shoring is a complete framework of wood and/or metal that is designed to support the walls of the trench ***(see Figure 6.1)***. **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.

Shielding

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.

Sloping

Sloping is a practice that simply removes the trench wall itself. The amount of soil needed to be removed will vary, depending on the stability of the soil. A good rule of thumb is to always slope at least one foot back for every one foot of depth on BOTH sides of the excavation. For deep trenches, sloping will usually require more space than is available.

Other Trenching Requirements

Certain soil conditions can contribute to the chances of a cave-in. These conditions include low cohesion, high moisture content, freezing conditions, or a recent excavation at the same site. Other factors to be considered are the depth of the trench, the soil weight, the weight of nearby equipment, and vibration from equipment or traffic. It is worth repeating that regardless of the presence or absence of any or all of the above factors, the trench must still have proper cave-in protection if it is five or more feet deep. The **spoil** (dirt removed from the trench) must be placed at least two feet back from the trench and should be placed on one side of the trench only.

A LADDER IS REQUIRED FOR EACH WORKER IN THE TRENCH IF IT IS FOUR OR MORE FEET DEEP. THE LADDER MUST BE PLACED WITHIN 25 FEET OF THE WORKER AND MUST EXTEND AT LEAST THREE FEET ABOVE THE EXCAVATION WALL.

Confined Spaces

According to the Occupational Safety and Health Administration (OSHA) 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. Typical examples of confined spaces found in wastewater systems are pits, manholes, digesters, and tanks.

A **permit-required confined space** is defined as a confined space that presents or has the potential for hazards related to atmospheric conditions or any other serious hazard. The potential for build-up of toxic or explosive gas mixtures and/or oxygen deficiency exists in virtually all confined spaces found at wastewater systems. Employers must evaluate all workplaces and determine which confined spaces require an entry permit. One example of a confined space entry permit is shown on the following page ***(see Figure 6.2)***. 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, an **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

CONFINED SPACE ENTRY PERMIT

Date of Entry: ________ **Time:** ________ **Authorized Duration:** ____ hours (12 hours maximum)

Site Location & Description: ________________________________

Potential Hazards of Space: ___ Atmospheric ___ Engulfment ___ Entrapment ___ Other

Comments: ________________________________

Purpose of Entry: ________________________________

Entry Supervisor: __________________ (use separate roster to note replacement)

Authorized Attendant : __________________ (use separate roster to note replacement)

Authorized Entrant(s): __________________ __________________ __________________

(separate roster must be used to track all who are currently in the space)

Communication Procedures: ________________________________

All requirements to be completed and reviewed prior to entry. (Enter N/A for items that do not apply)

Requirements Completed:	**Date**	**Time**	**Requirements Completed:**	**Date**	**Time**
Lock-out/De-energize/Try-out	_____	_____	Full Body Harness w/ "D" Ring	_____	_____
Line(s) Broken-Capped-Blanked	_____	_____	Lifelines	_____	_____
Purge-Flush and Vent	_____	_____	Non-Entry Retrieval Equipment	_____	_____
Ventilation	_____	_____	Fire Extinguishers	_____	_____
Secure Area (Post and Flag)	_____	_____	Lighting	_____	_____
Warning Signs, Barricades	_____	_____	Protective Clothing	_____	_____
MSDS Review	_____	_____	Hearing Protection	_____	_____

Continuous Monitoring	**Permissible Entry Level**	**Record Monitoring Every Two Hours**				
Oxygen	19.5% to 23.5%	_____	_____	_____	_____	_____
Methane	Less than 0.5%	_____	_____	_____	_____	_____
Hydrogen Sulfide	Less than 10 ppm	_____	_____	_____	_____	_____
Carbon Dioxide	Less than 10,000 ppm	_____	_____	_____	_____	_____
__________________	______________	_____	_____	_____	_____	_____
Time Tests Were Performed		_____	_____	_____	_____	_____
Tester's Initials		_____	_____	_____	_____	_____

Testing Instrument ____________ Model/Serial# ____________ Date of Calibration ________

Rescue

All Emergencies (Fire, Rescue, Medical, Ambulance) - Call # ______________________

Safety Supervisor - Call # ____________________ Nearest Phone: ____________________

Rescue Personnel: __________________ __________________ __________________

Internal ____ Outside ____

Required Rescue Equipment: ________________________________

____

Authorizing Entry Supervisor: ____________________________ Date ______ Time ______

All required conditions satisfied? Yes ____ No ____ (Permit will remain at site until job completion)

Entry Supervisor Signature ____________________ Entry Concluded: Date ______ Time ______

Other Required Permits For Job: ________________________________

Figure 6.2

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)**		**Common Properties**	**Physical Effects**
			LEL	**UEL**		
Methane	CH_4	0.55	5.0%	15.0%	Colorless Tasteless Flammable Explosive	Asphyxiant Doesn't support life
Hydrogen Sulfide	H_2S	1.19	4.3%	46.0%	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	30 mg/l coughing 40-60 mg/l dangerous 1000 mg/l fatal in a few breaths

Table 6.3

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. Employers must provide any needed medical treatment or hospitalization.

Training to provide employees with the understanding, skills and knowledge to perform their jobs safely is required for all new employees and whenever duties change, the hazards in a space change or whenever an employee evaluation shows a need. Training records must include employee's name, signature or initials of trainer and date of training.

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 gases likely to be found 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. The oxygen concentration in normal breathing air is 20.9%. The atmosphere in the confined space must never fall below 19.5% oxygen.

THE SENSE OF SMELL IS ABSOLUTELY USELESS FOR EVALUATING THE PRESENCE OF GASES. Many dangerous gases have no odor at all. Furthermore, HYDROGEN SULFIDE PARALYZES THE SENSE OF SMELL. The higher the concentration, the faster the loss of smell. The **upper explosive limit (UEL)** and **lower explosive limit (LEL)** indicate the range of concentrations at which combustible/explosive gases will explode upon ignition ***(see Figure 6.3)***. No explosion occurs when the concentration is outside of these ranges. The **specific gravity** of a gas indicates its weight as compared to air. Air has a specific gravity of exactly 1.0. Several gases (including hydrogen sulfide and chlorine) have a tendency to collect in low places because they have a specific gravity of greater than 1.0. This means that these gases are heavier than air. Methane will rise out of low places because it has a specific gravity of less than 1.0 and is lighter than air.

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. Electrical energy of only 50 volts can be fatal if a good ground is made. Electricity is capable of paralyzing the nervous system and stopping the muscular action responsible for breathing and pumping blood.

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

1. Survey the scene and see if it is safe to enter.

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.

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 when working on electrical equipment.

1. Always lockout and tagout any electrical equipment being serviced. NEVER remove anyone 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.

5. OSHA requires that all systems have a ground fault circuit interrupter.

Basic Lock-out/Tag-out Procedures

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. Some of the most common forms of stored energy are electrical and hydraulic energy.

Whenever major replacement, repair, renovation, or modification of equipment is performed, the energy isolating devices (switch, valve, etc.) for the equipment must be designed to accept a lockout device. 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 shall know the type and magnitude of energy that the equipment utilizes and shall understand the hazard thereof.

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 in springs; elevated machine members; rotating flywheels; hydraulic systems; and air, gas, steam, or water pressure must be dissipated or restrained by methods such as repositioning, blocking, or bleeding down.

4. Lockout and/or tagout the energy isolating device with 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 employees are in the clear, remove all lockout or tagout devices. Operate the energy isolating devices to restore energy to the equipment.

Hazardous Chemicals

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. The treatment plant operators also may come in contact with a variety of chemicals used in the treatment process including various forms of chlorine (see also Chapter 12 for information specific to chlorine safety). 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) FOR EVERY CHEMICAL THAT IS PRESENT OR PRODUCED IN THE SYSTEM MUST BE READILY AVAILABLE TO ALL OPERATORS.

The MSDS is a 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 information on the MSDS through training provided by the employer and personal study.

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 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.

Noise

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, blower 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 source cannot be eliminated.

Physical Hazards

Physical hazards include falls and slips from stairs, ladders, rough ground, or slick surfaces. Other physical hazards are 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 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 the 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.

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 andaround the treatment plant. Fire classifications are important for determining the type of fire extinguisher needed to control the fire. Fires are classified as:

A -- Ordinary combustibles
B -- Flammable liquids
C -- Electrical equipment
D -- Combustible metals

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. Don't wear work clothes or shoes home if possible. Don't wash work clothes with other laundry.

4. Follow your doctor's recommendations for adult **immunizations and boosters**.

Bloodborne Pathogens

Regulations governing exposure to bloodborne pathogens are mandated by OSHA. It is the employer's responsibility to develop an exposer control plan and provide training to those workers potentially exposed 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.

Traffic

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

1. DON'T WORK 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.

4. PLACE A BARRIER BETWEEN THE WORKERS AND TRAFFIC such as a truck. The general rule is the bigger, the better.

Personal Responsibility for Safety

The final thing to remember about safety is that it is your life and health and that of your co-workers that is to be protected. THE FINAL RESPONSIBILITY LIES WITHIN YOU. The supervisor, manager, or mayor cannot be there at all times to make sure you do the safe thing. The safety gear provided should be used as it is intended to be used. Safety gear not already provided should be requested. DENIAL OF REQUESTS FOR LEGALLY REQUIRED SAFETY GEAR OR OTHER UNRESOLVED SAFETY VIOLATIONS SHOULD BE REPORTED TO THE:

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

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

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 and 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 addresses general issues
E. a safety officer that always has direct, unimpeded access to the top officials

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 preliminary treatment processes in the sequence of wastewater treatment
- What is removed from the flow stream as it goes through the 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 tests

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 will eventually end up coming into the wastewater treatment plant. Bottles, sticks, rocks, plastic lids, aluminum cans, rags, sand and silt, etc. Obviously, all of this junk entering the treatment plant must be removed in order to prevent damage to the mechanical systems of the plant. Therefore, it is apparent that an important part of a wastewater treatment plant is the equipment used to remove these rough materials before they have a chance to do damage to valuable machinery. The equipment that removes this rough material includes bar screens, comminutors, and grit removal devices and are commonly called **preliminary treatment** facilities.

Bar Screens

When the raw wastewater enters the treatment plant, the first treatment device that it will encounter is the **bar screen** ***(see Figure 7.1)***. The bar screen is a set of parallel bars placed in a channel in such a way that the wastewater will flow through the bars, but large pieces of debris and solids will be caught on the bars. Bar screens are used to screen the influent 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**. This equipment 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.

Comminution

A **Comminutor** is a mechanical device that acts as both a screen and a cutting device ***(see Figure 7.2)***. The purpose of the comminutor is to cut the solids that were small enough to pass through the bar screen into smaller pieces. Like the bar screen, comminutors are mounted in the channel of wastewater. The material is shredded by the cutters until it can 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 debrisis 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 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.

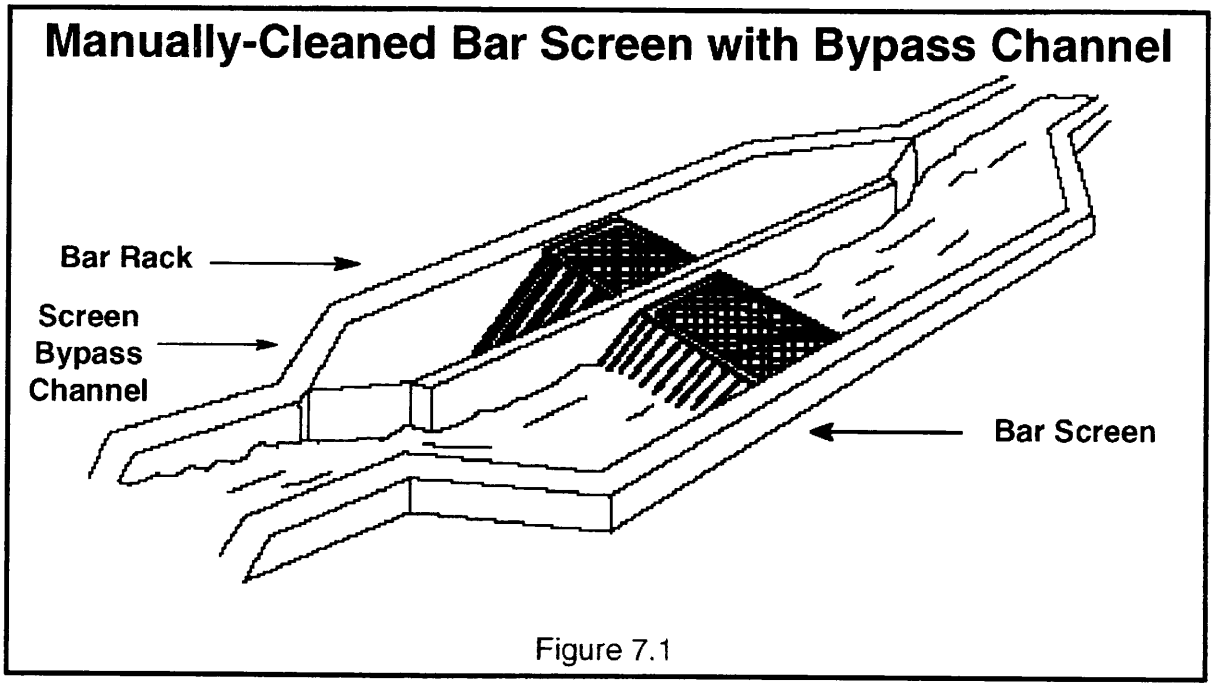


Figure 7.1

Grit Removal

Grit is heavy, mostly inorganic suspended solids that will readily settle out when the flow of the wastewater 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 it isn't removed, grit can cause excessive wear in pumps and damage other equipment in the treatment process.

The most common method of removing grit is to use channels or basins that reduce the velocity of the water to somewhere between 0.8 and 1.3 feet per second (fps). A velocity of one foot per second is sometimes 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 ***(see Figure 7.3)***. 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 that particles will settle through the water at a faster rate.

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 preaeration is needed to help freshen the wastewater. The older wastewater becomes, the more difficult it

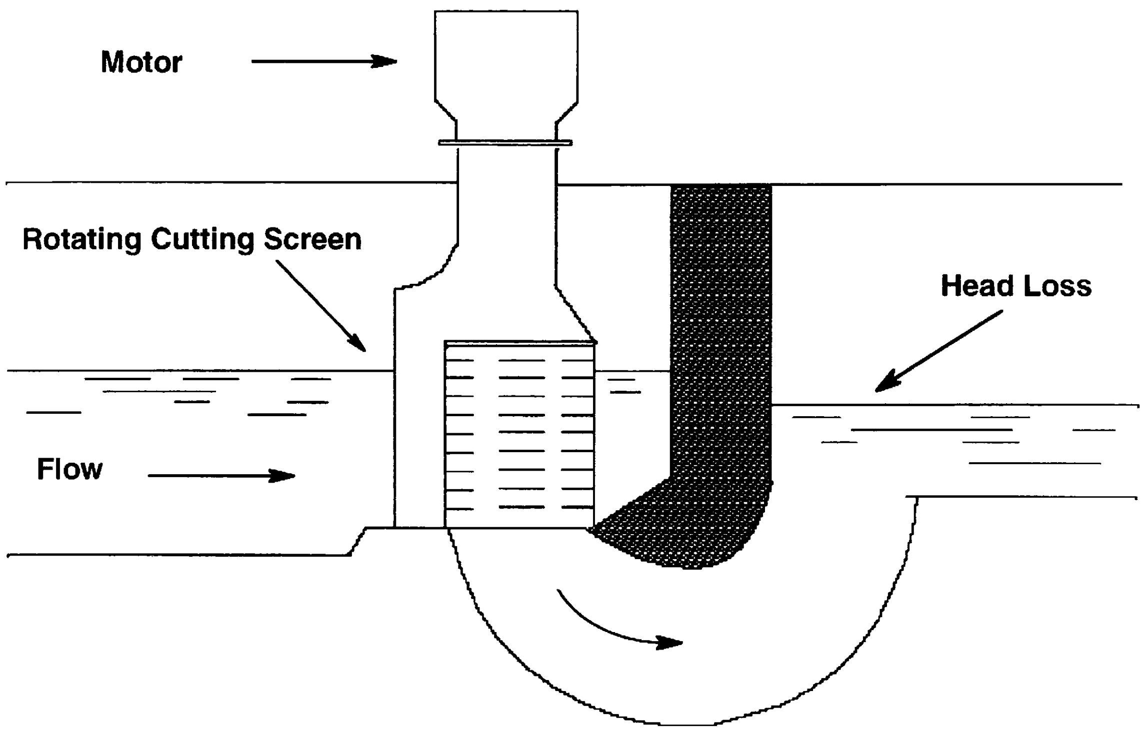


Figure 7.2

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.

Flow Measurement

Although flow measuring devices are not for treating wastes, 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. Most operators prefer to have a measuring device at the headworks of their treatment plant.

Probably the most common measuring device found at wastewater facilities is a Parshall flume *(see Figure 7.4)*. Basically, a **Parshall flume** is a narrow place in an open channel which allows the quantity of 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.

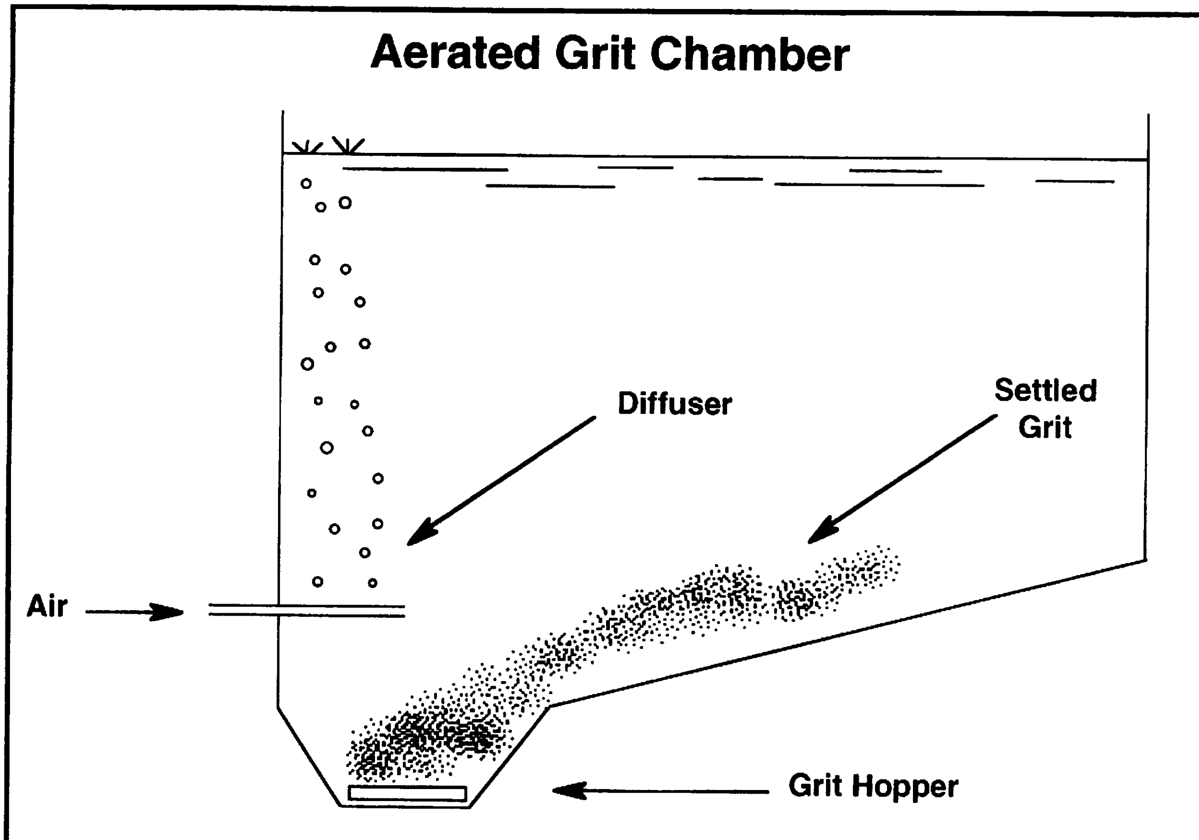


Figure 7.3

Another measuring device used in open channels is a weir *(see Figure 7.5)*. 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.

Another measuring device sometimes used for flows of treated or untreated wastewater is a **Venturi meter**. It measures flow in much the same way as a Parshall flume except that it utilizes a closed pipe instead of an open channel. The meter itself is an enclosed section of pipe shaped like an hourglass to create a throat and is equipped with pressure taps for manual or automatic sensing of pressure at two points. The rate of flow through a Venturi meter is determined by comparing the low pressure at the throat with the high pressure upstream of the throat. The difference in pressure can be converted to a flow rate in gpd. The flow conversion is usually done automatically using instruments that electronically convert the differential to a flow signal. The primary advantage of the Venturi meter is that it will perform reliably and little maintenance is required.

Other devices used at wastewater treatment plants to measure wastewater flow include magnetic flow meters and **rotameters**.

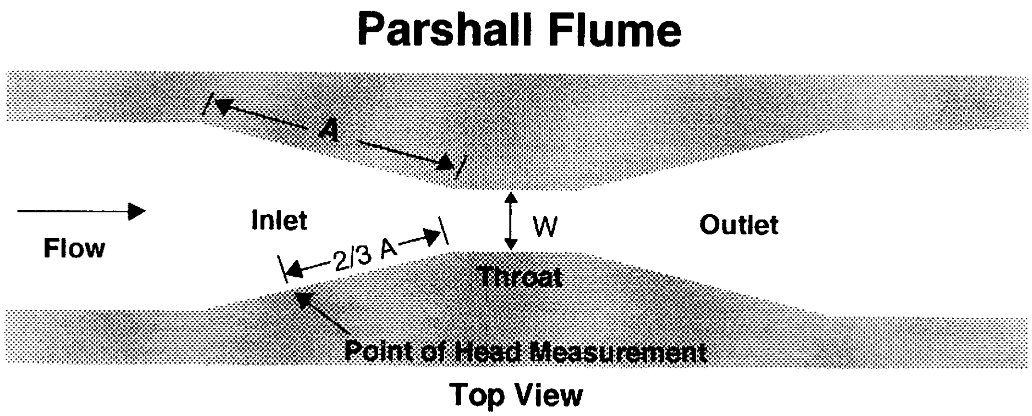


Figure 7.4

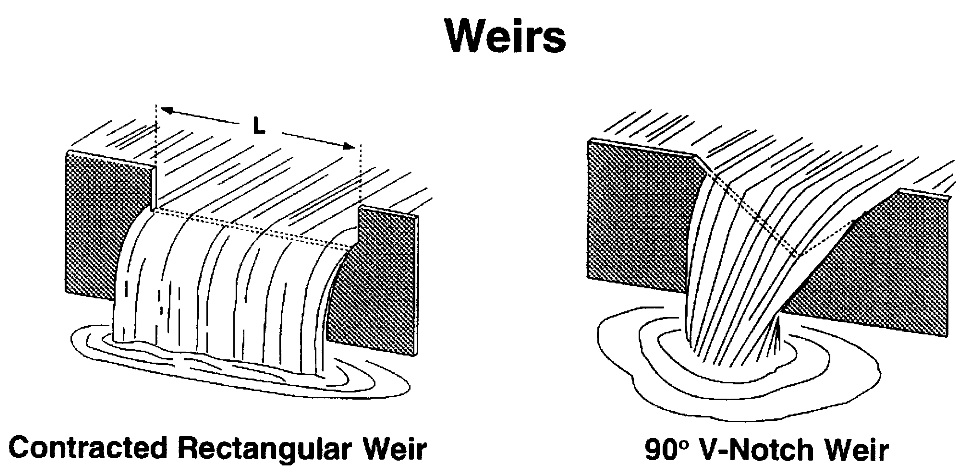


Figure 7.5

Sedimentation and Flotation

In most municipal wastewater plants, the phase that immediately follows preliminary treatment is the **sedimentation and flotation** unit, usually referred to as the **primary clarifier**. The primary clarifier is a settling basin that is designed to remove settleable solids from the wastewater ***(see Figure 7.6)***.

Typically, wastewater treatment plants will have clarifiers located at two different locations in the treatment system. The clarifier(s) that immediately follow preliminary treatment processes are called primary clarifiers. Clarifier(s) that follow the secondary treatment processes (see Chapter 8) are referred to as final clarifiers or **secondary clarifiers**.

Note: Much of the information in this discussion applies to both primary and 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 more dense and will have a higher solids content than sludge that settles 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.

Removal Efficiencies for Primary Sedimentation

By removing as much of the settleable suspended solids as possible, the primary clarifier will 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 has shown at many plants 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. A few of these are listed below:

Primary Clarifier

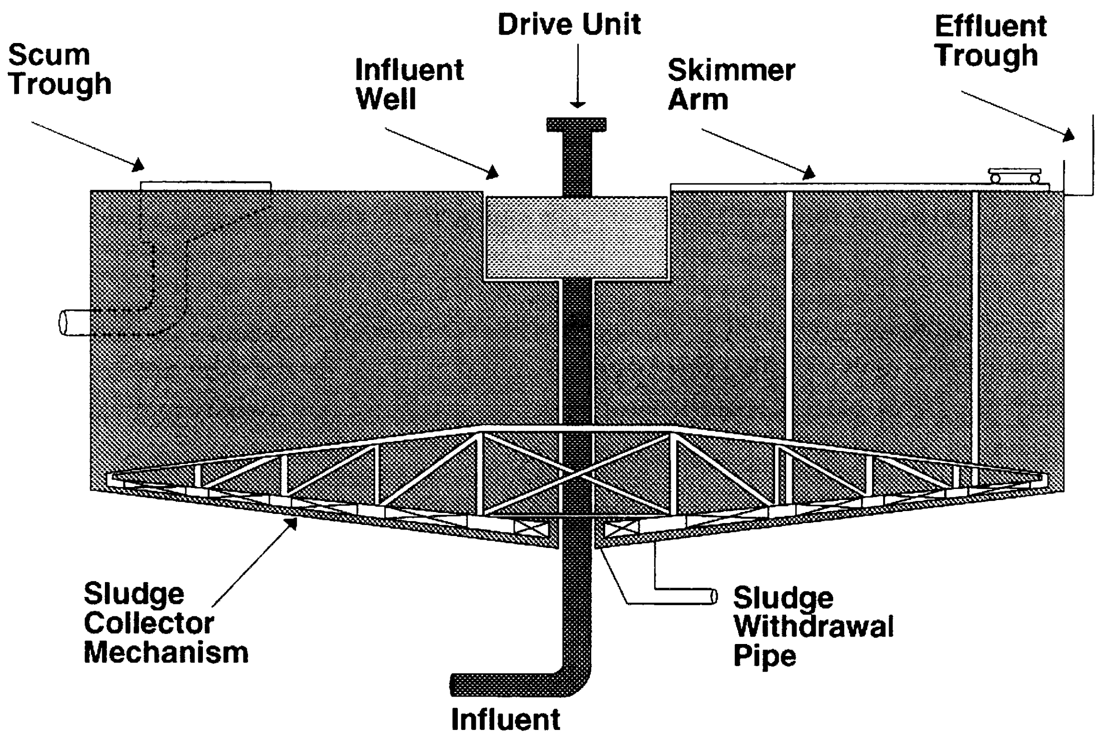


Figure 7.6

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, Comminutors, 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 comminutors.
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 comminutor 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 sedimentation 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 collodial 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
E. 15,000-25,000 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
  - rotating biological contactors (RBC's)
  - 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 mechanical components of a RBC
- The process controls of RBC's including rotational speed and flow distribution
- The typical hydraulic and organic loadings and removal efficiencies for RBC's
- How to determine the condition of RBC media by appearance and sloughing rate
- 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 filter and RBC's

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

How to remedy typical operational problems at RBC's including power outages and poor media conditions

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, MLVSS, 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 readings 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 non-settleable solids (colloids) or dissolved solids. In order to remove these solids, virtually all modern wastewater treatment facilities will include some form of **secondary treatment**. Secondary treatment facilities follow primary treatment processes and will 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 three most common types of secondary treatment processes in the state of Oklahoma today are trickling filters, rotating biological contactors, and various activated sludge processes. Trickling filters and rotating biological contactors 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 tricking filters are large diameter, shallow, cylindrical structures filled with stone and have an overhead rotary distributor *(see Figure 8.1)*. Trickling filters consist of these three basic parts.

1. The media and retaining structure.

2. The underdrain system.

3. The distribution system.

Trickling Filter

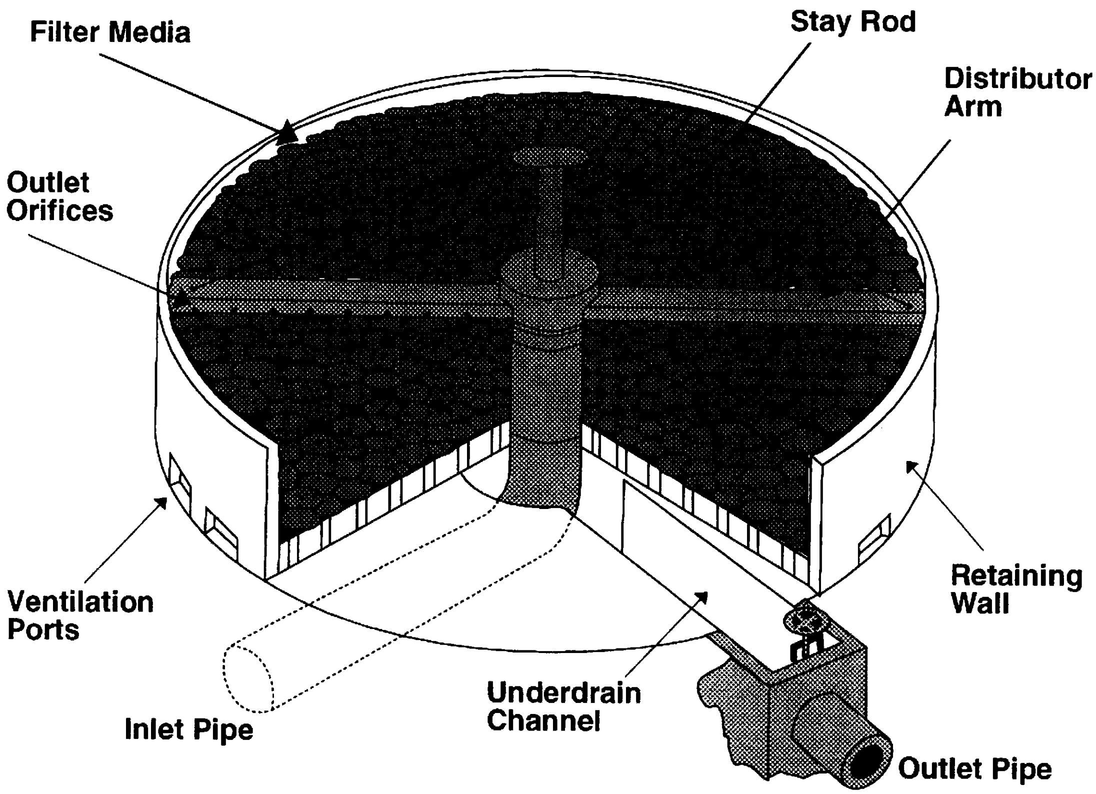


Figure 8.1

A typical trickling filter will consist of rock or plastic **media** with the individual stones being 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 a 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 as a food source. Because the organisms use this food to thrive and reproduce, the organic matter in the wastewater that passes through the trickling filter is constantly converted into more organisms.

The organisms found on trickling filters are mostly bacteria, algae, and, fungi. As these organisms grow, reproduce, and die, they will leave their dead remains behind. 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 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 filter effluent. The underdrain is sloped to allow the 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. Most rotary distributors will rotate 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 so that the entire surface of the media receives wastewater.

Common Problems with Trickling Filters

Ponding and Pooling

Ponding and pooling is 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 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. Proper maintenance, such as frequent cleaning of the distributor orifices, will help prevent ponding by maintaining a steady flow of water over the entire surface of the filter.

Ponding can usually be corrected by spraying with 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 the strategies sometimes used for correcting ponding conditions in order of preference depending on the severity of the condition. The last two solutions (#4 and #5) listed here are used only as last resorts 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. Dosing the filter with 5 mg/L of chlorine for several hours.

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

5. 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.

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 on trickling filters is a strategy called recirculation.

Recirculation

Recirculation is a process in which filter effluent is recycled back into the trickling filter unit ***(see Figure 8.2)***. This is a commonly used method for increasing the efficiency of trickling filter and helping to control some common problems.

Recycling some of the filter effluent increases the 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 a 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 "seed" the filter and keep the biological growth young.

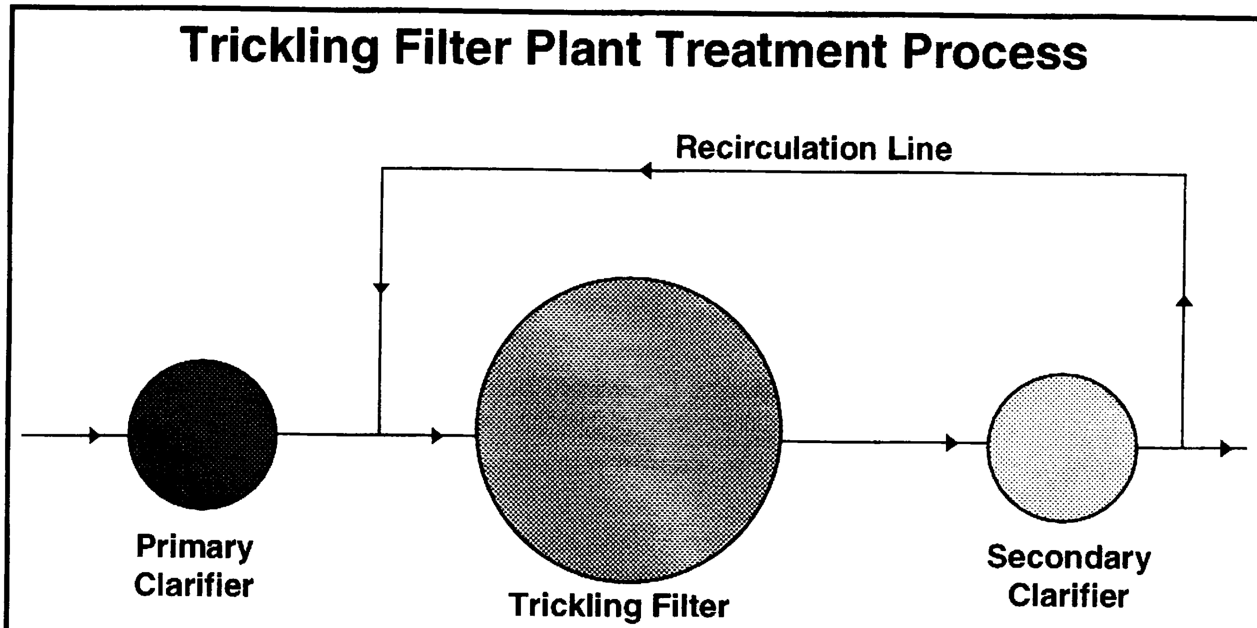


Figure 8.2

Sloughing of biological growths also improves ventilation through the filter and therefore helps to prevent ponding and pooling. An increase in hydraulic loading caused by recirculation may also help reduce 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.

Trickling Filter Loading Rates

Trickling filters can be put into three major categories depending on 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/1000 ft^3. The biological growth on the filter is usually heavy with many types of worms, snails, and insect larvae in addition to microorganisms found on all trickling filters.

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/1000 ft^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 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/1000 ft^3 of media is considered a roughing filter. Roughing filters and "biotowers" 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 as well as being 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.

Description of Rotating Biological Contactors

The **rotating biological contactor** (RBC) is one of the newer types of secondary biological treatment processes. Like the trickling filter the RBC is a fixed media system, meaning that the organisms that provide the biological treatment live on a solid or fixed surface media. RBCs have a rotating shaft surrounded by large plastic discs that provide the fixed surface media for the organisms ***(see Figure 8.3)***. The shaft and discs are often referred to as the **drum** or **biodisc**. The biological slime that grows on the surface of the discs is often referred to as **biomass**.

The RBC media on which the growth occurs is made of high-density plastic circular sheets usually 12 feet in diameter. The spacing between the sheets provides the voids for the distribution of wastewater and air. A concrete or coated steel tank is used to hold the wastewater being treated with about 40 percent of the RBC media being submerged in the wastewater. The drum or biodisc will usually rotate at around 1.5 rpm against the flow of the wastewater. As the drum rotates through the wastewater, the biological mass comes into contact with organic waste in the water which is used as a food source by the organisms, thus reducing the organic content of the wastewater.

Organic loading rates on RBCs are based on soluble BOD. Soluble BOD is the BOD of the water that has been filtered in the standard suspended solids test. Typically, the organic loading rate for and RBC will be from three to five pounds of soluble BOD per day per 1000 ft^2 of surface area.

As the drum rotates the biological growth through the wastewater, some of the growth is sloughed from the media as it rotates downward into the wastewater. The sloughed material will then be removed in the secondary clarifier. Most RBC plants do not utilize recycling of effluent sludge, which generally makes the process more simple to operate.

Rotating Biological Contactor

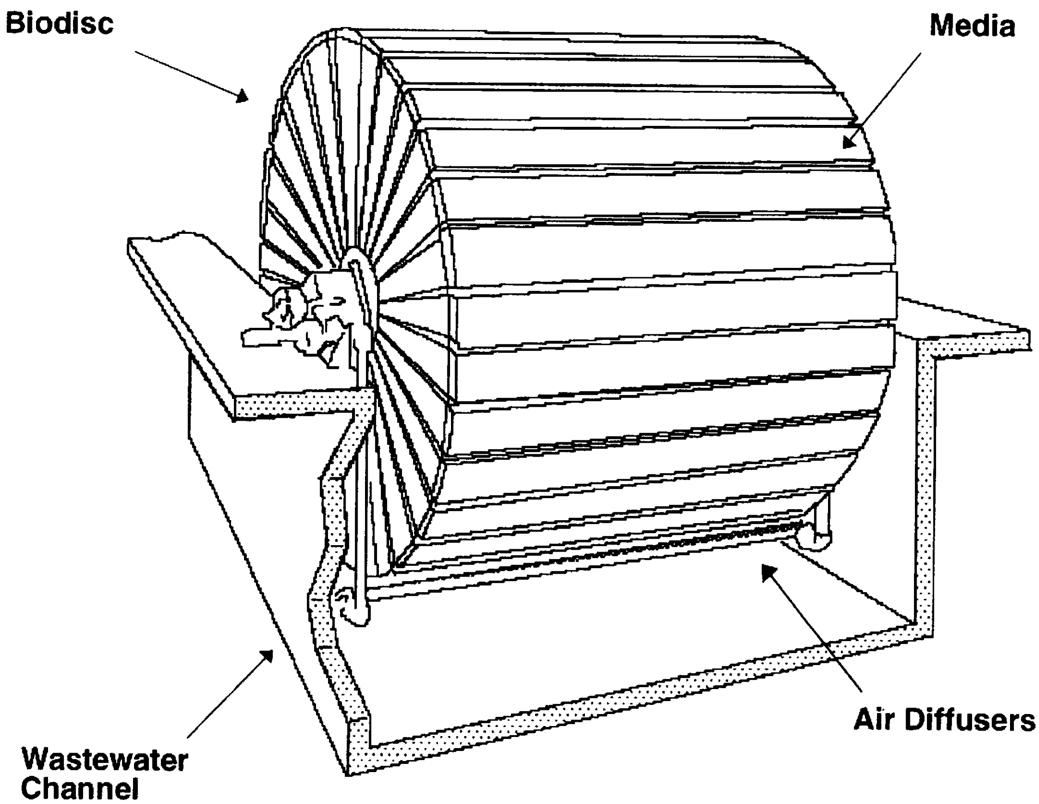


Figure 8.3

RBCs are much more sensitive to extreme temperatures than the trickling filter because there is more surface area of biological growth in contact with the open air. For this reason, RBC units are enclosed. The protective cover also prevents intense rains from washing away the biological growth and reduces exposure to sunlight, preventing the growth of unwanted algae.

Characteristics of Biological Growth on a RBC

The biomass on the drums that treat raw wastewater should have a grayish brown shaggy appearance. The media on these drums should be uniformly covered with very few bare spots. Later in the process train, the color of the drums may change to a dark or golden brown and more bare spots may appear. This indicates that the wastewater is being treated and there is less BOD for the organisms to consume. There should be no offensive odors anywhere in the RBC process since the treatment is based entirely on aerobic consumption.

If the biomass takes on a black appearance accompanied by hydrogen sulfide odors it could be an indication of solids or BOD overloading. These conditions would probably be accompanied by low DO in the plant effluent. A white appearance on the disc surface also might be present during high loading conditions as a result of "sulphur-loving" bacteria. This condition could indicate either inadequate raw sludge removal in primary clarifiers or the presence of industrial discharges which contain sulphur compounds.

If excessive sloughing suddenly occurs this could be an indication of toxic substances in the influent, probably resulting from industrial discharge. Another cause of excessive sloughing is an unusual variation in flow or organic loading.

Performance of RBC Systems

It is difficult at this time to fully assess the overall performance of the RBC treatment process simply because it is a comparatively new type of process. However, they are generally considered to be able to produce final effluents with a BOD reduction of 90 percent or more. RBC plants are usually less complicated to operate than activated sludge systems. In addition, the power requirements for RBC plants should be lower than for activated sludge. However, RBC plants are sometimes subject to problems caused by temperature and shock loads and are usually not considered as stable as a trickling filter system.

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 live 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, and protozoa microorganisms. The 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.

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 the MLVSS will make up approximately 70 percent of the MLSS.

WAS - Waste Activated Sludge. WAS refers to the removal of excess activated sludge from the system (WAS will be discussed in greater detail later in the chapter.)

RAS - Return Activated Sludge. RAS refers to the activated sludge that is returned to the aeration basin to provide a steady supply of organisms. RAS flows are maintained at a fairly constant rate by most activated sludge systems (RAS will be discussed in greater detail later in this chapter.)

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 (see APPENDIX B for the actual formula). A proper F/M ratio is very important to the successful operation of an activated sludge process.

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 detention time. Maintaining the proper sludge age is also very important to the activated 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 (see APPENDIX B for the actual formula).

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 (see APPENDIX B for the actual formula).

SVI - Sludge Volume Index. This is a calculation used to indicate the settling ability of activated sludge 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 settled solids (in ml) by the weight (in mg) of that sludge after it has been dried. The answer is multiplied by 1000 to obtain a whole number (see APPENDIX B for the actual formula). A sludge with an SVI of one hundred or greater will not settle as readily because it is as light or lighter than water.

Activated Sludge Process Description

Activated sludge secondary treatment processes remove BOD (organic material) in the form of dissolved and suspended materials. The aerobic organisms present in the process remove the

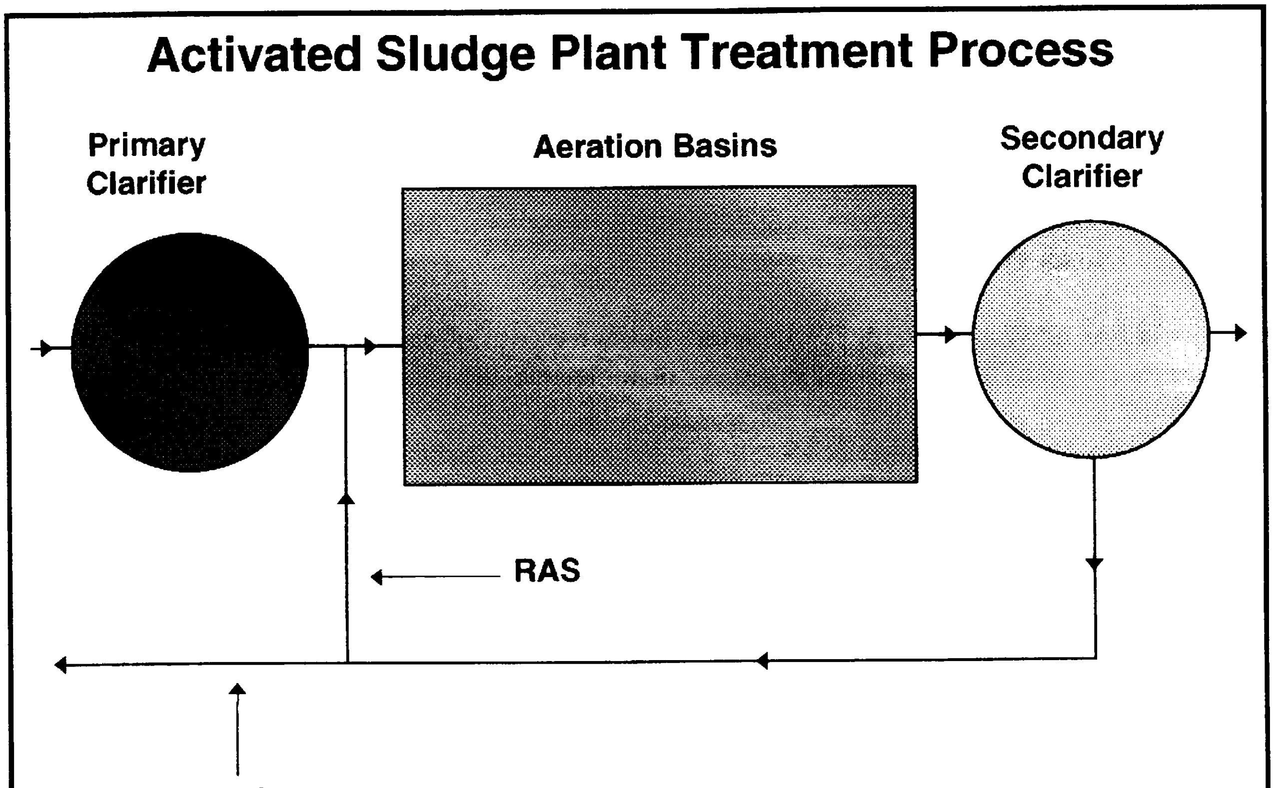


Figure 8.4

materials as the 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.

After aeration in the aeration basins, the wastewater is sent to the secondary clarifier to separate the sludge from the water. The sludge settles to the bottom of the clarifier resulting in a large reduction in the solids content of the final effluent. The sludge that settles consists mostly of living organisms and is quickly returned to the aeration basin as return activated sludge (RAS). At many 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 of the solids are not removed from the process, the solids build-up will continue to a point that the aeration basin will become overpopulated, reducing the efficiency of the process. 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 these excess solids from the system. The activated sludge process can be viewed as a loop, with the loop being formed by the constant RAS rate. When the solids concentration becomes too high, the WAS acts as an outlet for the activated sludge loop ***(see Figure 8.4)***. Never change the WAS rate more than 10 to 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 the conditions are right the operator will remove the excess organisms through the WAS to maintain the proper amount of organisms. In a healthy aeration tank, the MLSS will have a reddish brown to chocolate color.

Oxygen is required by the organisms for the oxidation of organic wastes to obtain energy for growth. If the oxygen supply is too low, the aerobic organisms will slow down and, eventually, anaerobic activity could start, producing odors and a reduction in treatment efficiency. An increase in the population of organisms in the aeration basin will require greater amounts of dissolved oxygen (DO). A higher BOD in the influent will promote the growth of more organisms resulting in an increase in the demand for dissolved oxygen. An excess of oxygen is 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 the DO level in the aeration basin is 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.

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 to 5000 mg/L. In the extended aeration plant the 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 ***(see Figure 8.5)***. The 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 velocity in the ditch 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.

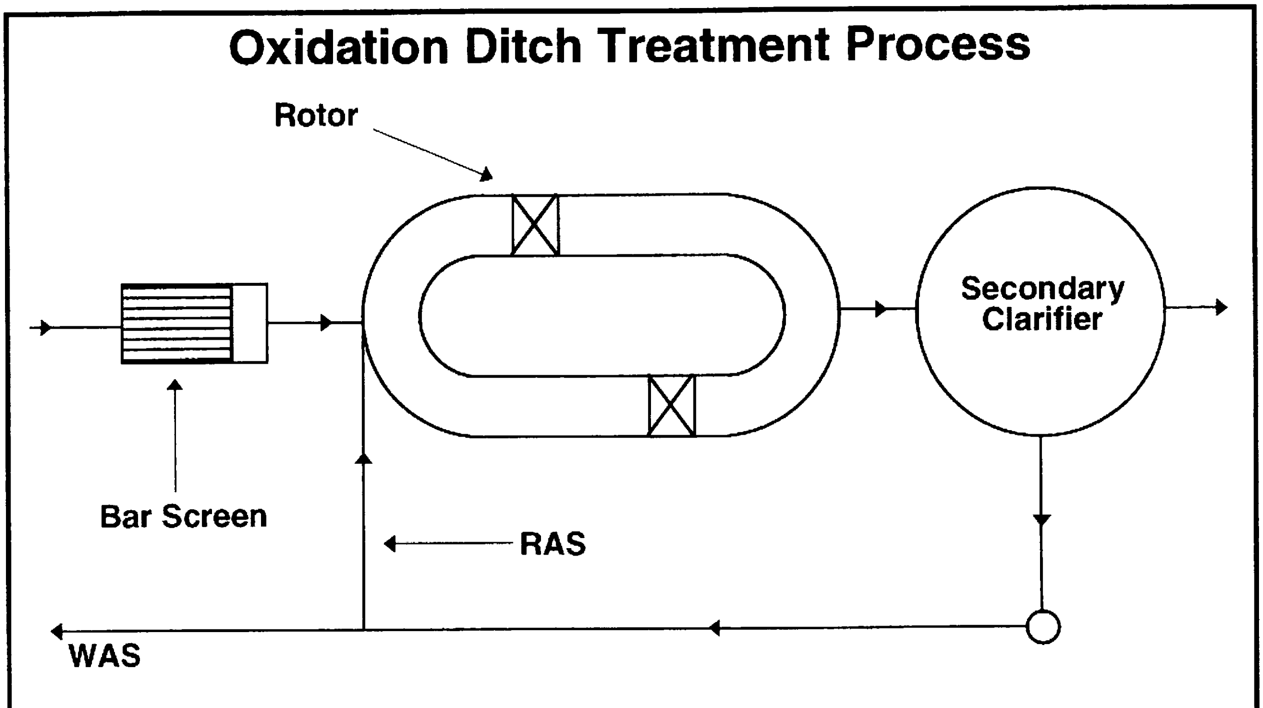


Figure 8.5

Sequential Batch Reactors

A relatively new development in the area of wastewater treatment is a treatment process referred to as a **sequential batch reactor** (SBR). Many plants utilizing this secondary treatment process have been built in recent years. An SBR could be described as an activated sludge process that treats wastewater in batches and provides all of the 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 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 aeration 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.

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 a 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 a 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 for an activated sludge plant. The primary advantage to the activated sludge process is the fact that BOD removal rates are usually significantly higher that in a trickling filter. BOD removal rates of 95 to 98 percent can be obtained in a well operated activated sludge system.

SUGGESTED REFERENCES FOR STUDY

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

Chapter 6	Trickling Filters
Chapter 7	Rotating Biological Contactors
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 - **Advanced Waste Treatment**

Chapter 2	Activated Sludge (Pure Oxygen Plants and Operational Control Options)
Chapter 6	Nitrogen Removal

Aerobic Biological Wastewater Treatment Facilities, *USEPA, 430/9-77-006 (process control manual)*

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. extended aeration
B. the Kraus method
C. step-feed
D. conventional

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
E. old sludge, low MCRT

Chapter 9
Advanced Treatment
(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. A fewer number of systems utilize advanced processes for solids removal from secondary effluents.

Nitrogen Removal

It is desirable to remove ammonia in the treatment plant rather than in the receiving stream. The conversion of ammonia to nitrate is an oxygen requiring process. 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, bacteria 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 that 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 (see also Chapter 12)

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 a 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 includes 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 of the DO, thus creating septic conditions. Some treatment plants are required to remove both nitrogen and phosphorus. Other plants may be designed to remove only the 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.

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 (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-).

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 PO_4
C. CaO and $KMnO_4$

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. a separate sludge post denitrification process
E. 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 the 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 are the use of 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 then 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**.

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 clarifiers (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 which do have these units should try to obtain maximum sludge thickening in the primary and secondary clarifiers (see Chapter 7) before sending the sludge 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 rising of the solids and also prevents the accumulation of solids floating on the surface of the thickener.

Anaerobic Digestion

The process of an**aerobic digestion** (see Figure 10.1) 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 produce methane and other by-products. The methane fermenters are not as numerous in raw wastewater as the 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; otherwise 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 cubical 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.

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.

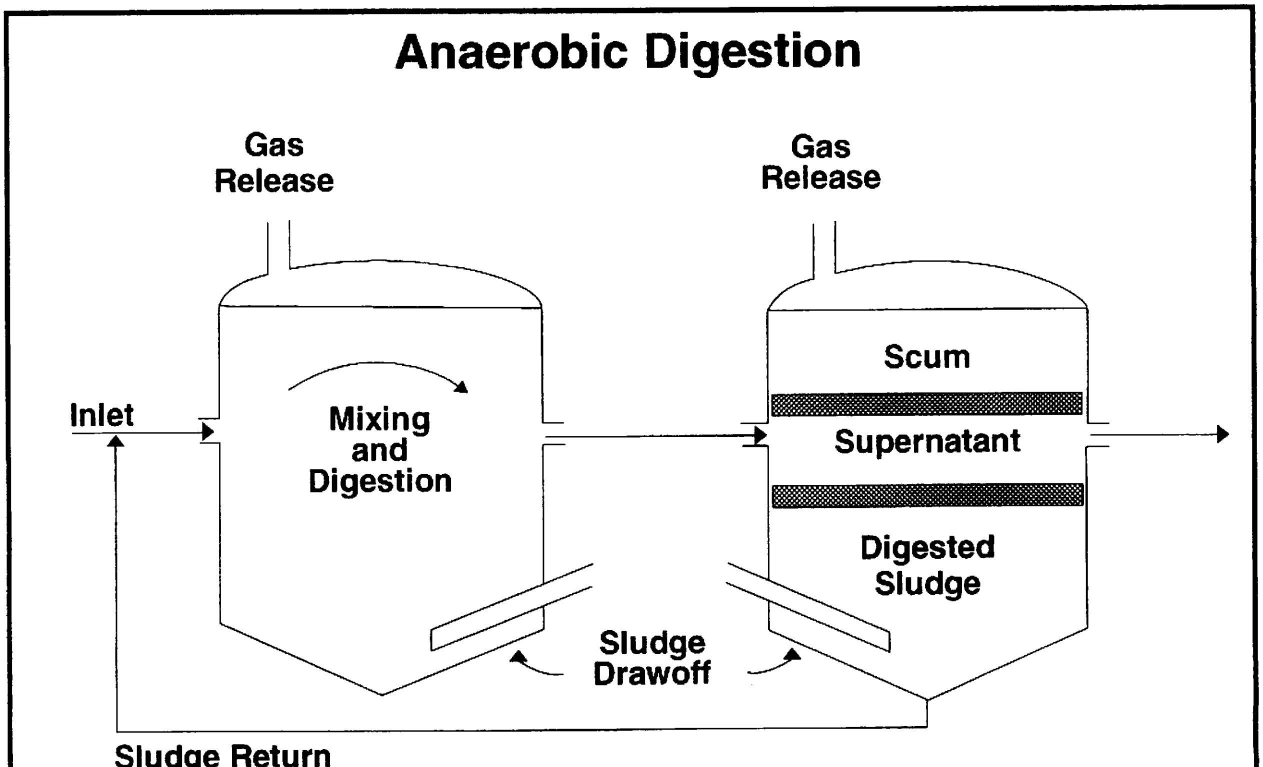


Figure 10.1

Operation and Process Control

The primary objective of good digester operation is maintaining the 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 relationship

4. Mixing of digester contents

Temperature

Anaerobic digesters could 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 range utilizes **psychrophilic bacteria** in unheated digesters. The temperature of the digester as well as the sludge, tends to fluctuate along with the 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. Very few digesters are operated in the psychrophilic range in the state of Oklahoma 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 (about the same temperature as the human digestive system). The digestion time needed in a mesophilic digester is about 5 to 50 days depending on 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. The mesophilic range is by far the most common temperature range utilized in Oklahoma 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 because 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 change the temperature more than one degree fahrenheit (F^{O}) 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. The pH of the digester contents will drop from about 7.0 to about 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 the methane fermenting bacteria to become active. The 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 temporary overloads on the digester and uses the space in the digester more efficiently. Several pumpings a day from the primary clarifier aids the digestion process, maintains better conditions in the clarifiers, and permits thicker sludge pumping. It is recommended that an operator pump as thick a sludge as possible to the digester. A 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 holding time of the sludge 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 condition can usually be remedied by adding alkalinity to buffer the excessive amounts of 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 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, the pH of the digester will begin to drop which can result in the problems described in the previous sections.

If the V/A ratio starts to increase, the operator may be able to avoid problems by using one or more of the following process controls.

1. Extending the mixing time of the digester contents.

2. Controlling heat more evenly.

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 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 principle 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 the sludge has passed 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 sludge can be disposed of is the level of conditioning that has been achieved in the treatment process. In addition to raw unconditioned sludge, there are two levels of sludge conditioning: Class A and B.

Class A Sludge

Class A sludge is raw primary sludge and secondary sludge that has not undergone any treatment for removal of pathogens. Obviously, Class A sludge is not yet ready for disposal.

Class B Sludge

Class B sludge conditioning is defined as processes designed to significantly reduce pathogens. Level II sludge may be disposed of in landfills approved for accepting municipal sludge or applied to agricultural land in accordance with an approved sludge management plan.

The most common methods of obtaining Class B conditioning are **anaerobic digestion** or **aerobic digestion**, each discussed earlier in this chapter. Another method of reaching Class B conditioning that is less commonly used in Oklahoma is **lime stabilization**. Lime stabilization is achieved by adding enough lime to raise the pH to 12.0 and maintain this pH for a contact time of two hours. This method of stabilization is very effective for raw sludges. 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°C (176°F) 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 soil nutrients. However, because of the energy requirements necessary, this process is very rarely utilized in the State of Oklahoma.

SUGGESTED REFERENCES 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 - **Advanced 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, V/A 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 dewatering process as appropriate.

Identity 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
E. 1444 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 the purposes for which they are used. 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**. When ponds follow a secondary treatment process they 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 (land application of treated wastewater will be discussed later in this chapter).

Ponds that discharge an effluent into a receiving stream are called **discharging ponds**. According to Oklahoma standards, the detention time for a discharging pond 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 (see Chapter 3).

Series and Parallel Operation

Systems with multiple ponds are operated either in series or in parallel ***(see Figure 11.1)***. **Series operation** refers to the use of several consecutive ponds, with the raw wastewater flowing first to

Series and Parallel Operation

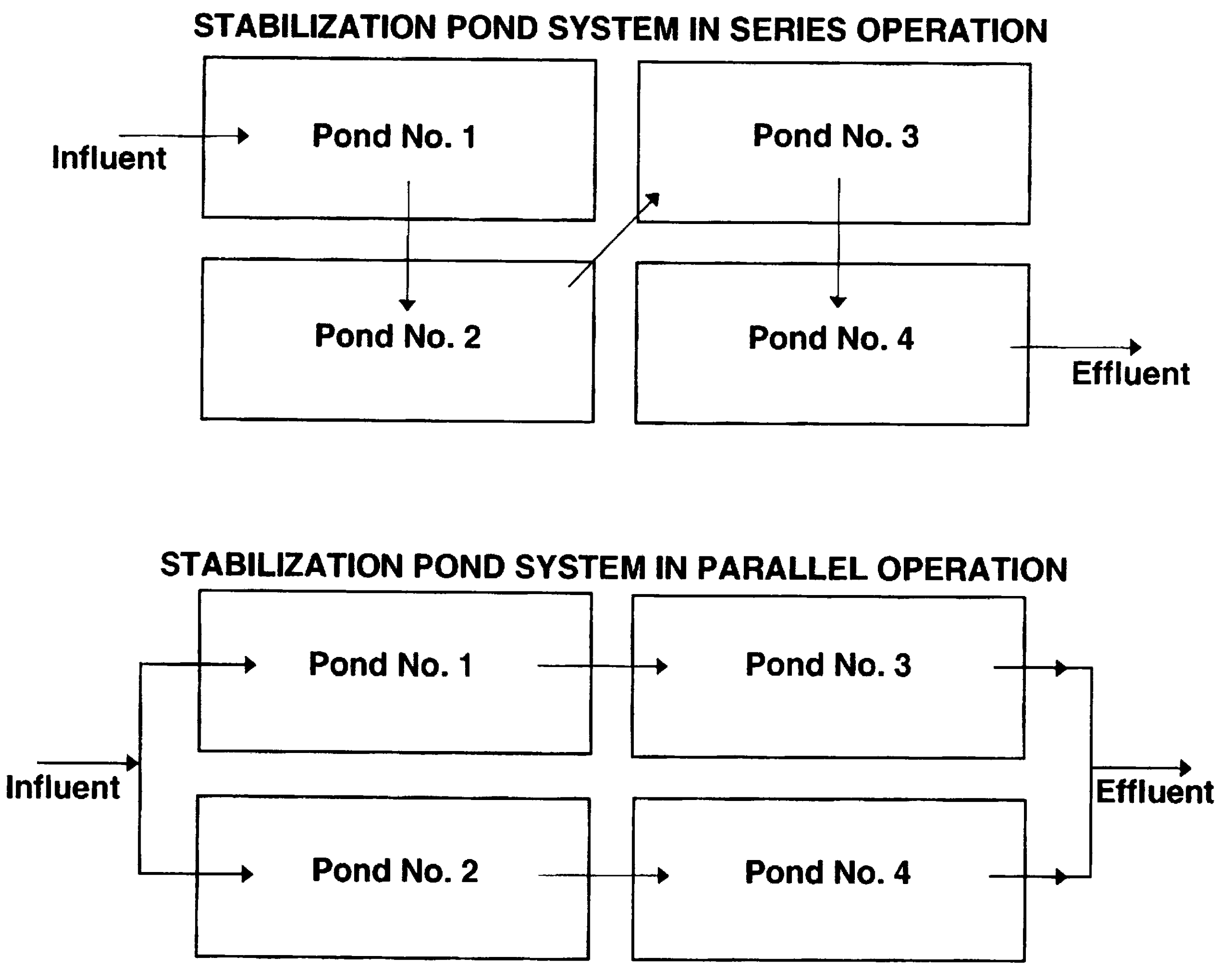


Figure 11.1

a **primary pond** before being routed to the **secondary pond(s)**. 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.

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 the access of vehicles used by operators in daily inspections and routine maintenance. The inside and outside slopes of the dike should not be steeper than 1 foot vertical rise for every 3 feet horizontal distance. Sometimes in older pond systems, erosion has washed away some of the inside slope, 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 100 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 numbers 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 ***(see Figure 11.2)***. 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 through photosynthesis, the green algae uses the carbon in the carbon dioxide to release free oxygen, making it available to the aerobic bacteria in the pond. The aerobic bacteria then produce carbon dioxide which the algae needs for respiration. Thus, the algae and bacteria have a mutually beneficial relationship. If the pond is operated properly, 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 or near the saturation point (the point at which no more oxygen could be dissolved in the water).

Treatment Processes in the Anaerobic Layer

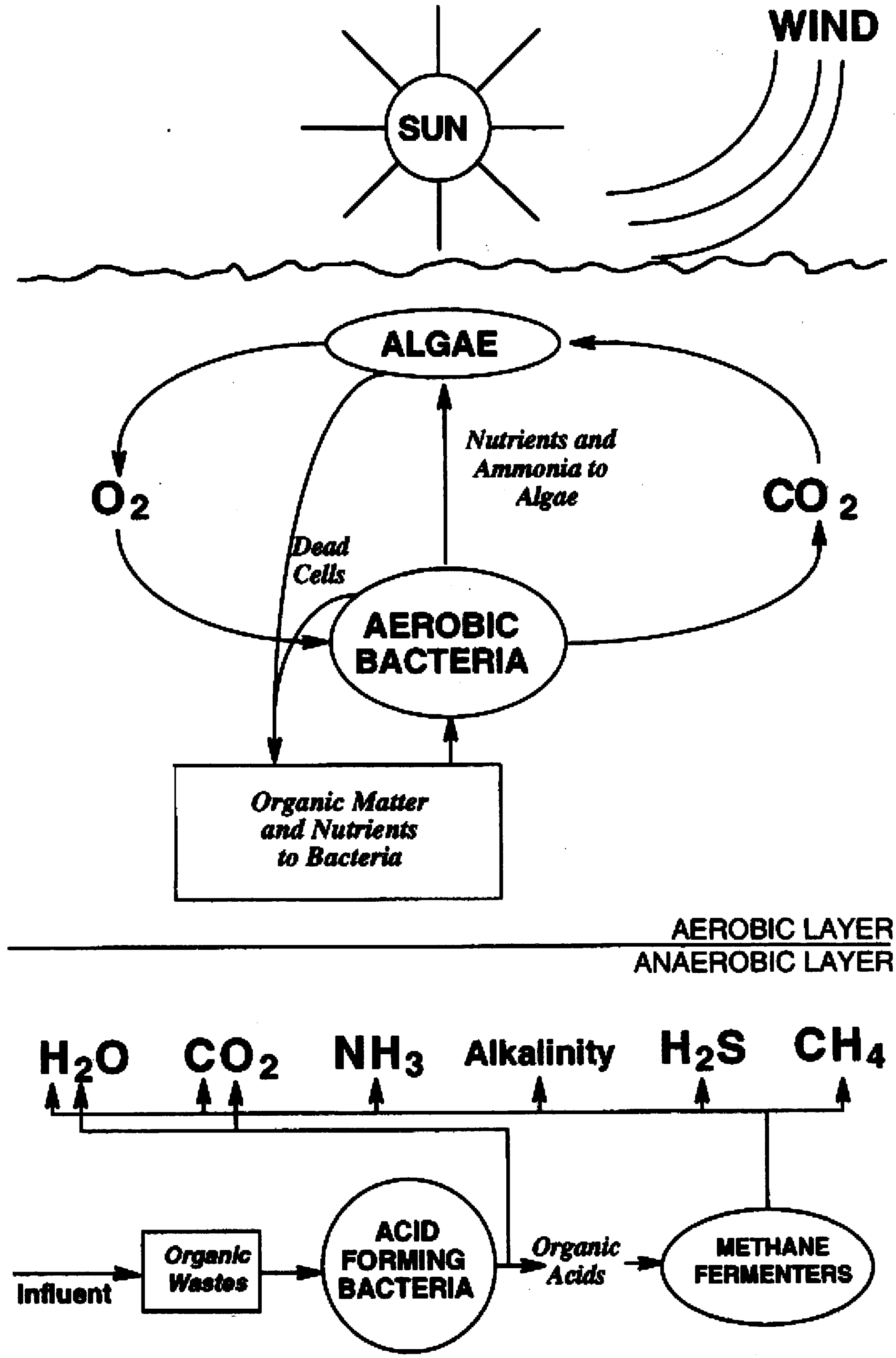
In the **anaerobic layer** (bottom layer) of a facultative pond, the organic waste entering the system at the bottom of the primary pond(s) will be first converted into carbon dioxide, nitrogen, and organic acids by a type of anaerobic bacteria called **acid formers**. Next, a group of bacteria called **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.

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 are 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, bullrushes 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 algae doesn't 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 mosquitos 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 shows 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 a cover grass that will outcompete undesirable growth. Because emergent weed growth will occur only when sunlight is able to reach the pond bottom, the single best preventive 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 well 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 stream, if discharging.

Blue-Green Algae (Cyanobacteria)

Another common problem for pond operators which sometimes prevents sunlight from reaching the pond is blue-green algae, also known as cyanobacteria. **Cyanobacteria** is a 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). Although copper sulfate is sometimes applied to kill cyanobacteria in surface water reservoirs, it is NOT recommended at pond systems because it could also kill the desirable green algae.

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 (see Chapter 3). 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.

An 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 equipment used are pumps feeding water cannon or rain-bird type sprayers.

Special Safety Considerations at Pond Systems (see also Chapter 6)

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 (disease-causing) 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 (such as those sometimes used to mow along highways). 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. conductivity, BOD, and fecal coliform
E. pH, conductivity, and SAR

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 definitions of dose, chlorine demand and chlorine residual
- 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 general safety considerations for working with chlorine and chlorinating 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
- One of 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 hypochlorination 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
- How to perform a variety of dosage calculations involving chlorine gas and HTH

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 related reactions of wastewater chlorination including reducing compounds and ammonia

The products of the chemical reaction between sulfur dioxide and chlorine
The characteristics and hazards of sulfur dioxide
How to troubleshoot problems with hypochlorinators, gas chlorine ejectors, and regulators used for chlorine and sulfur dioxide gas

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

ENTRY LEVEL DISCUSSION

Among the suspended materials in wastewater are microscopic organisms, many of which have the potential to produce disease in humans. Disease causing organisms are known as **pathogenic organisms**. Disinfection of wastewater is needed to reduce the amount of pathogenic organisms released to the environment. The effectiveness of disinfection is tested by monitoring the **fecal coliform** bacteria level in the effluent (see Chapter 2). The presence of fecal coliform indicates the possible presence of pathogenic organisms.

Chlorination processes normally take place in a **chlorine contact basin** which is located at the very end of the wastewater treatment process. The chlorine is usually added only after all other plant processes have been accomplished and the treated wastewater is about to be discharged.

It is important to distinguish between disinfection and sterilization. **Sterilization** is the complete destruction of all organisms present in the water. Sterilization of the effluent 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 ultraviolet light will offered here.

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 usually comes in 150 pound or one ton cylinders. Calcium hypochlorite $Ca(OCl)_2$, also known as **High Test Hypochlorite** or **HTH** will be about 65 percent available chlorine and is usually purchased in powder forms. 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 will be about 5.25 percent available chlorine. However, most wastewater (or water) systems that use bleach will use a 10, 12 or 15 percent concentration.

Of these three major forms of chlorine, chlorine gas is by far the most common type used and will be the main focus of this discussion on chlorine.

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^{o}F (28^{o}C), the volume of the chlorine gas in the cylinder would increase by 84-89 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 not completely understood but there are a couple of theories that have been put forth. One hypothesis contends that chlorine exerts a direct action on the organism itself, thus destroying it. Another hypothesis holds that the toxic nature of chlorine inactivates the enzymes that enable living microorganisms to use their food supply. In other words the organisms will 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.

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 is added is then available for disinfection purposes and is referred to as **chlorine residual**. The total chlorine residual is the total of all the compounds with disinfection properties plus any remaining free chlorine. 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 Dose = Chlorine Demand + Total Chlorine Residual

Combined Residual and Free 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 a disinfecting residual often referred to as the **combined residual**, because they are a combination of both chlorine and ammonia. Combined residuals 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 residual.

Total Chlorine Residual = Combined Residual + Free 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.

Chlorine Gas Safety

Chlorine (Cl_2) reacts with water (H_2O) to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). **Hypochlorous acid** is a weak acid that gives chlorine its disinfectant properties. **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. When chlorine gas is inhaled it may cause severe **lung damage** and can cause **blindness** if it comes into contact with the eyes.

IT IS EXTREMELY IMPORTANT FOR ALL FACILITIES THAT USE CHLORINE GAS OR ANY OTHER FORM OF CHLORINE TO FOLLOW ALL SAFETY PRECAUTIONS.

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 or washer when replacing a chlorine cylinder, even if they appear to be in good condition. Reusing gaskets or washers on chlorine cylinders is probably the most common source of chlorine leaks.

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. 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 falls below $60^{o}F$. Chlorine should therefore be stored away from heat or direct sunlight and should be used only under climate controlled conditions at essentially room temperature. Also, Cylinders should not be connected together to a common manifold unless special precautions are taken to prevent one cylinder from backfeeding to another.

Also mentioned earlier is the fact that chlorine gas is about 2.5 times heavier than air. This means it will have a tendency to collect in low places. For this reason, exhaust ducts for chlorine rooms are placed near the floor. Mechanical ventilation equipment 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 30 minute minimum air supply and be compatable 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. The units should be compatible with those that are used by the local fire department.

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**. This system simply never allows a person to be left alone when performing dangerous work. Another person trained in emergency techniques and procedures is always 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 entering the room.

Dechlorination

Many facilities that use chlorine are now required to dechlorinate the effluent to ensure that no chlorine damage occurs to aquatic life in the receiving stream. Sulphur dioxide gas (SO_2) is the most commonly used dechlorinating agent. It is fed into the effluent after the chlorine contact basin. Sulfur dioxide has hazardous properties much the same as chlorine gas. Other dechlorinating agents include hydrogen peroxide and sodium meta-bisulfite. Hydrogen peroxide is a very strong liquid oxidizing agent that 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.

Disinfection using Ultraviolet Light

Ultraviolet (UV) light disinfects by altering the genetic material of bacteria. UV has been used for disinfection of water for many years in Europe. The effluent water comes in close contact (3/4 inch or less) with mercury lamps which give off radiation. Some of the advantages and disadvantages of UV light are listed below.

1. UV light systems are relatively expensive.

2. UV light produces no residual compounds.

3. Only small flows can be channeled in such a way to come in close contact with the lamps.

4. The UV lamps loose power with use.

5. Any slime growth, solids, or color in the effluent will absorb UV light and minimize disinfection.

6. UV radiation is not visible but is VERY HARMFUL to the human eye. Special goggles must be worn when the lamps are operating.

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 the 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% HTH are needed per day to achieve a chlorine residual of 0.5 mg/L if the chlorine 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_2 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 mg/L of chlorine residual
C. 1 mg/L SO_2 is needed for every 2 mg/L of chlorine residual
D. 1 mg/L SO_2 is needed for every 5 mg/L of chlorine residual
E. 1 mg/L SO_2 is needed for every 8 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 find 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 your 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.
4. Review before taking your 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."

VOLUME-TIME UNITS

Volume-time units measure the volume of flow over a specific period of time. There are many other volume-time units that are used for many different purposes. Two very commonly used volume-time units are MGD and gpd.

MGD (Million Gallons per day)
gpd (gallons per day)

It is important that all operators know how to convert between these two units. The real key to converting between MGD and gpd is to know how to move the decimal place exactly six places. This method of conversion works because the only difference between MGD and gpd is one million. One million is equal to six decimal places. If it's a little difficult at first, a little practice is all that's needed.

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
cu ft or ft^3	cubic feet
cu in or in^3	cubic inch
cu yd or yd^3	cubic yard
°F	degrees Fahrenheit
ft	feet or foot
gal	gallon
gm	gram
gpd	gallons per day
gpm	gallons 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	milliliter
min	minute
psf	pounds per square foot
psi	pounds per square inch
ppb	parts per billion
ppm	parts per million
sec	second
sq ft or ft^2	square feet
sq in or in^2	square inches
W	watt

Basic Conversion Factors

Length		
12 in	1 ft	12 in / ft
3 ft	1 yd	3 ft / yd
5280 ft	1 mi	5280 ft / mi
Area		
144 sq in	1 sq ft	144 sq in / sq ft
43,560 sq ft	1 acre	43,560 sq ft / acre
Volume		
7.48 gal	1 cu ft	7.48 gal / cu ft
1000 ml	1 liter	1000 ml / liter
3.785 L	1 gal	3.785 L / gal
231 cu in	1 gal	231 cu in / gal
0.326 MG	1 ac-ft	0.326 MG / ac-ft
Weight		
1000 mg	1 gm	1000 mg / gm
1000 gm	1 kg	1000 gm / kg
454 gm	1 lb	454 gm / lb
2.2 lbs	1 kg	2.2 lbs / kg
Power		
.746 kW	1 HP	.746 kW / HP
Density of Water		
8.34 lbs	1 gal	8.34 lbs / gal
62.4 lbs	1 cu ft	62.4 lbs / cu ft
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 secs	1 min	60 secs / min
60 min	1 hr	60 min / hr
1440 min	1 day	1440 min / day
24 hr	1 day	24 hr / day

PROBLEM

You have a flow of 17,000 gpd. What is the flow in MGD?

SOLUTION

First, start by writing down what you know. You know you have a flow of 17,000 gpd and you want to know what the flow is in MGD.

17,000 gpd = ? MGD

The decimal place is now just to the right of the last zero, at the end of the whole numbers.

17,000**.** gpd = ? MGD

Next, move the decimal place exactly six places to the left. You will see as you count out the six places to the left that you must add one zero to make room for the last decimal place. After this is done you can "drop off" the three zeroes that are "left over" on the right.

17,000. gpd = **.017 MGD**

PROBLEM

You have a flow of 2.3 MGD. What is the flow in gpd?

SOLUTION

Once again, start by writing down what you know. You know you have a flow of 2.3 MGD and you want to know what the flow is in gpd.

2.3 MGD = ? gpd

Next, move the decimal place exactly six places to the right. You will see as you do this that you must add five zeros on the right.

2.3 MGD = **2,300,000 gpd**

VOLUME/TIME PRACTICE PROBLEMS

1. The flow is 100,000 gpd. What is the flow in MGD? ____________
2. The flow is 1,200,000 gpd. What is the flow in MGD? ____________
3. The flow is 120,000 gpd. What is the flow in MGD? ____________
4. The flow is 56,000 gpd. What is the flow in MGD? ____________
5. The flow is 8,200,000 gpd. What is the flow in MGD? ____________
6. The flow is 5,300 gpd. What is the flow in MGD? ____________
7. The flow is 11,000 gpd. What is the flow in MGD? ____________
8. The flow is 4,336,000 gpd. What is the flow in MGD? ____________
9. The flow is 1.60 MGD. What is the flow in gpd? ____________

10. The flow is 2.36 MGD. What is the flow in gpd? ____________
11. The flow is .08 MGD. What is the flow in gpd? ____________
12. The flow is .004 MGD. What is the flow in gpd? ____________
13. The flow is .876 MGD. What is the flow in gpd? ____________
14. The flow is .054 MGD. What is the flow in gpd? ____________
15. The flow is 1.76 MGD. What is the flow in gpd? ____________

AREA AND VOLUME

Area and Volume of Squares and Rectangles

The formula for calculating the **surface area** of a square or rectangle is:

A = L X W

A = Area
L = Length
W = Width

The formula for calculating the **volume** of a square or rectangle is:

V = L X W X H

V = Volume
L = Length
W = Width
H = Height or depth

Notice that the formula for area is the same as for the formula for volume except that one more "dimension" has been added (the height or depth).

PROBLEM

What is the surface area of a basin that is 40 feet long and 20 feet wide?

SOLUTION

The first thing to do when working with any math problem that requires the use of a formula is to write down the formula.

A = L X W

Now place the numbers into the formula and multiply.

$$A = 40 \text{ ft} \times 20 \text{ ft}$$

And you are left with:

$$A = 800 \text{ ft} \times \text{ft}$$

A better way of saying "ft x ft" is "ft^2" which is read as "square feet."

$$A = 800 \text{ ft}^2$$

PROBLEM
What is the volume of a basin that is 40 feet long, 20 feet wide, and 10 feet deep?

SOLUTION
First, write down the formula you are going to use.

$$V = L \times W \times H$$

Place the numbers into the formula and multiply.

$$V = 40 \text{ ft} \times 20 \text{ ft} \times 10 \text{ ft}$$

And you are left with:

$$V = 8000 \text{ ft} \times \text{ft} \times \text{ft}$$

A better way of saying "ft x ft x ft " is "ft^3" which is read as "cubic feet."

$$V = 8000 \text{ ft}^3$$

Area and Volume of Cylinders

The formula for calculating the **surface area** of a round or cylindrical container is

$$\mathbf{A = \pi \times R^2}$$

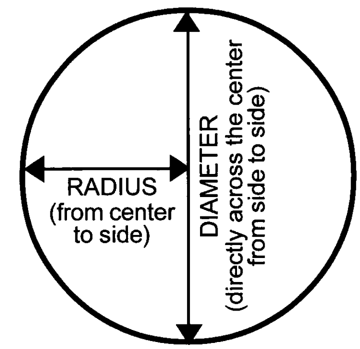
$\pi = 3.1416$
$R^2 = R \times R$ = radius x radius

The formula for calculating the **volume** of a round or cylindrical container is

$V = \pi \times R^2 \times H$

$\pi = 3.1416$
$R^2 = R \times R =$ radius X radius
$H =$ height or depth

The symbol "π" is the Greek letter pi (pronounced pie). π is a symbol used to represent the relationship of the diameter of a cylinder to its circumference. The circumference of a cylinder is always 3.1416 times greater than the diameter.



The letter "R" stands for radius.
The radius of a cylinder is exactly one-half of the diameter.

PROBLEM
What is the surface area of a basin that has a diameter of 60 ft?

SOLUTION
First, write the formula

$$A = \pi \times R^2$$

As you work the formula from left to right, the first thing to do is replace π with the number 3.1416.

$$A = 3.1416 \times R^2$$

R^2 means "R squared" or "R x R."

$$A = 3.1416 \times R \times R$$

Remember that the R stands for ***radius****. If the diameter is 60 feet, the radius is 30 feet because the radius is always exactly one-half of the diameter.*

$$A = 3.1416 \times 30 \text{ ft} \times 30 \text{ ft}$$

Now use your calculator to solve the problem.

$$A = 3.1416 \times 30 \text{ ft} \times 30 \text{ ft}$$

And you are left with

$$A = 2{,}827 \text{ ft} \times \text{ft}$$

$$A = 2{,}827 \text{ ft}^2$$

PROBLEM

What is the volume of a basin that is 60 ft in diameter and 15 feet deep?

SOLUTION

First, write the formula.

$$V = \pi X R^2 X H$$

As you work the formula from left to right, the first thing to do is replace the symbol π with the number 3.1416.

$$V = 3.1416 X R^2 X H$$

Another way of saying R^2 is "R x R."

$$V=3.1416 X R X R X H$$

If the diameter is 60 feet, the radius is 30 feet.

$$V = 3.1416 X 30 ft X 30 ft X H$$

The H stands for the height or depth which is 15 feet.

$$V = 3.1416 X 30 ft X 30 ft X 15 ft$$

Now use your calculator to solve the problem.

$$V = 3.1416 X 30 ft X 30 ft X 15 ft$$

$$V = 42{,}412 ft X ft X ft$$

$$V = 42{,}412 ft^3$$

PROBLEM

What is the volume in **gallons** of a basin 60 feet in diameter and 15 feet deep?

SOLUTION

This is the same as the last problem except that the answer needs to be given in gallons instead of in cubic feet. Therefore, this problem will be worked exactly the same as the last problem except that one more step must be taken to convert from cubic feet to gallons.

There are 7.48 gallons in each cubic foot of water (see the Common Conversion Factors listed in this Appendix). In order to find out how many gallons are in the basin this conversion factor must be used.

$$V, gal = 42{,}412\ ft^3 \times \frac{7.48\ gal}{ft^3}$$

And the correct answer is

$$V, gal = 317{,}242\ gal$$

PROBLEM

What is the volume in **pounds** of a basin 60 feet in diameter and 15 feet deep?

SOLUTION

Now the question is how many pounds of water are in the basin. This is the same as the last problem except that the answer needs to be reported in pounds instead of in gallons. This type of information might be necessary in order to determine dosage rates, because dosages are often calculated in pounds of chemical added for every million pounds of water being treated.

A gallon of water weighs or has a "mass" of 8.34 lbs (see the Common Conversion Factors listed in this Appendix). In order to find out how many pounds of water are in the basin, this conversion factor must be used.

$$Mass, lbs = 317{,}242\ gal \times \frac{8.34\ lbs}{gal}$$

And the correct answer is

Mass, lbs = 2,645,796 lbs

If the answer was "rounded off" and the decimal place was moved six places, it could also be correctly written as

Mass, lbs = 2.65 Mlbs

AREA AND VOLUME PRACTICE PROBLEMS

1. A basin is 60 feet long and 30 feet wide. What is the surface area? ____________
2. A basin is 35 feet long and 20 feet wide. What is the surface area? ____________
3. A basin is 40 feet in diameter. What is the surface area? ____________
4. A basin is 82 feet in diameter. What is the surface area? ____________
5. A basin is 12 feet in diameter. What is the surface area? ____________
6. What is the volume of a basin 20 feet long, 10 feet wide, and 5 feet deep?____________
7. What is the volume in gallons of the basin in question #6? ____________
8. How many pounds of water are in the basin in question #6? ____________
9. What is the volume of a basin 40 feet long, 15 feet wide, and 10 feet deep?____________
10. What is the volume in gallons of the basin in question #9? ____________
11. How many pounds of water are in the basin in question #9? ____________

12. What is the volume of a basin 30 feet in diameter and 10 feet deep? ____________
13. What is the volume in gallons of the basin in question #12? ____________
14. How many pounds of water are in the basin in question #12? ____________
15. What is the volume of a basin 50 feet in diameter and 8 feet deep? ____________
16. What is the volume in gallons of the basin in question #15? ____________
17. How many pounds of water are in the basin in question #15? ____________
18. What is the volume of a basin 45 feet in diameter and 15 feet deep? ____________
19. What is the volume in gallons of the basin in question #18? ____________
20. How many pounds of water are in the basin in question #18? ____________

DETENTION TIME

The detention time is the amount of time the water or wastewater is retained in a tank or basin.

A formula used for measuring the detention time in days is

$$\text{Detention Time, days} = \frac{\text{Volume, gal}}{\text{Flow, gpd}}$$

A formula used for measuring the detention time in hours is

$$\text{Detention Time, days} = \frac{(\text{Volume, gal})\ (24\ \text{hrs/day})}{\text{Flow, gpd}}$$

PROBLEM

A basin has a volume of 317,242 gallons and a flow of 2.3 MGD. What is the detention time in hours?

SOLUTION

First, write down the formula.

$$\text{Dentenion Time, hrs} = \frac{(\text{Volume, gallons})(24\ \text{hrs/day})}{\text{Flow, gpd}}$$

Next, place the needed numbers that are called for in the formula.

$$\text{Detention Time, hrs} = \frac{(317{,}242\ \text{gal})\ (24\ \text{hrs/day})}{2{,}300{,}000\ \text{gpd}}$$

It was necessary to convert MGD to gpd because the formula required the flow to be entered as gpd. Now use "cancellation" to eliminate some of the units of measurement

$$\text{Detention Time, hours} = \frac{317{,}242\ \cancel{\text{gallons}}\ (24\ \text{hrs}/\cancel{\text{day}})}{2{,}300{,}000\ \cancel{\text{gpd}}}$$

Next, solve the multiplication problem on the top

$$\text{Detention time} = \frac{7{,}613{,}808 \text{ hrs}}{2{,}300{,}000}$$

And the answer is

Detention Time, hours = 3.3 hrs

PROBLEM

A basin is 70 ft in diameter and 15 ft in depth and has a flow of 4 MGD. What is the detention time in hours?

SOLUTION

First, write down the formula.

$$\text{Detention Time, days} = \frac{(\text{Volume, gal})\ (24 \text{ hrs/day})}{\text{Flow, gpd}}$$

In this problem, the volume in gallons is not provided. All that is given are the dimensions of the basin and the flow. Before you can use the formula you must first find the volume of the basin in gallons. It will also be necessary to convert MGD to gpd before using the formula.

To find the volume of the clarifier use the formula for the volume of a cylinder.

$$V = \pi\ X\ R^2\ X\ H$$

Using the same steps used in the earlier example for this formula, the volume of this basin is

$$V = 57{,}727 \text{ ft}^3$$

Now it is necessary to convert the ft^3 of water into gallons of water. This is done by multiplying the ft^3 of water by 7.48 because each ft^3 of water is equal to 7.48 gallons of water. (See the conversion factors listed at the beginning of this Appendix)

$$V = 57{,}727 \text{ ft}^3 \text{ X } \frac{7.48 \text{ gal}}{\text{ft}^3} = 431{,}798 \text{ gal}$$

After you convert the MGD to gpd, you will have all of the numbers necessary to proceed with the detention time formula.

$$\text{Dentention time, hrs} = \frac{(431{,}798 \text{ gal})\ (24 \text{ hrs/ day})}{4{,}000{,}000 \text{ gpd}}$$

And the answer is

Detention time, hours = 2.6 hrs

DETENTION TIME PRACTICE PROBLEMS

1. A basin holds 100,000 gallons. The flow is 600,000 gpd. What is the detention time in hours?

   ____

2. A basin holds 220,000 gallons. The flow is 1.3 MGD. What is the detention time in hours?

   ____

3. A basin is 40 ft long, 15 ft wide, and 6 ft deep and has a flow of .08 MGD. What is the detention time in hours?

   ____

4. A basin is 50 ft in diameter and 15 ft deep and has a flow of 1.5 MGD. What is the detention time in hours?

   ____

5. A pond holds 83 MG. The flow is 0.65 MGD. What is the detention time in days?

   ____

BASIC DOSAGE CALCULATIONS

A common way of expressing dosage levels in both water and wastewater treatment is in parts milligrams per liter, (mg/L)

A milligram per liter is **one one-thousandth of a gram for every liter of water**.

A mg/L is a unit of measurement often used for expressing a dosage of a substance in water or wastewater. **A mg/L is the same thing as a ppm.**

The ppm *or* mg/L are the pounds of the substance for every million pounds of water being treated. For example, 1 pound of chlorine in 1 million pounds of water would be 1 mg/L.

Concentrations will always be expressed as mg/L.

There are two basic formulas that are used for dosage calculations. Which of the two formulas you use depends upon what you need to know.

If you need to know what the mg/L is, this formula can be used.

If you need to know how many pounds of chemical you need to use for the dosage level you want, this formula can be used.

$$\text{Chemical, lbs} = (\text{Dose, mg/L})\ (H_2O\text{, Mlbs})$$

PROBLEM

You have a flow of 2.3 MG that is being treated with 115 lbs of chlorine gas. What is the dosage in mg/L?

SOLUTION

First, choose the formula that will give you what you need to know and write it down

$$\text{Dose, mg/L} = \frac{\text{Chemicals, lbs}}{H_2O\text{, Mlbs}}$$

This is the correct dosage calculation formula to use because mg/L is what you are looking for.

Next, make sure that you have all the information needed to work the problem. The formula needs the pounds of chemical being added each day and the million pounds of water being treated each day. You already know how many pounds of chemical are being used (115 lbs). However, the flow is listed in million gallons instead of in million pounds.

Therefore, you must convert the MG to Mlbs before you can work the dosage problem. This is done by multiplying the MG of water by 8.34 because each gallon of water weighs 8.34 lbs. (See the Common Conversion Factors listed in this Appendix)

$$2.3\ MG\ X\ \frac{8.34\text{ lbs}}{\text{gal}} = 19.2\ Mlbs$$

Now you know have all of the information needed for the formula in the proper units and you are ready to proceed.

Place the numbers in the proper places in the formula and finish the problem using division.

$$\text{Dose, mg/L} = \frac{115\text{ lbs}}{19.2\text{ Mlbs}}$$

$$\text{Dose} = 6\text{ mg/L}$$

PROBLEM

Your plant has a flow of 3.8 MG and requires a chlorine dose of 8 mg/L. How many pounds of chlorine gas is needed to achieve this dosage?

SOLUTION

First, choose the formula that will give you what you need to know and write it down.

$$\text{Chemical, lbs} = (\text{Dose, mg/L})\ (H_2O\text{, Mlbs})$$

This is the correct dosage calculation formula to use because pounds is what you need to know. Once again, you must make sure that you have all the information needed to work the problem. And once again you need to convert the MG to Mlbs before you can use the formula.

$$3.8 \text{ MG} \times \frac{8.34 \text{ lbs}}{\text{gal}} = 31.7 \text{ Mlb}$$

Now you are ready to proceed with the formula. Place the numbers into the formula and multiply.

Chemical, lbs = (Dose, mg/L) (H_20,Mlbs)

Chemical, lbs = (8 mg/L) (31.7 Mlbs)

And the answer is

lbs = 254 lbs

PROBLEM

Your plant has a flow of 3.8 MG and requires a chlorine dose of 8 mg/L. How many pounds of 65% HTH would be needed to achieve this dosage?

SOLUTION

This is the same as the previous problem except that 65% HTH is to be used instead of 100% chlorine gas. Probably the easiest way for most people to work this problem is to start by finding out how much chlorine gas would be needed, and then convert it to HTH.

First, work the problem in the same way it was done in the last problem.

lbs = 254 lbs

Because 65% HTH is being used, it will take more pounds than would be needed for chlorine gas. To get the correct answer, divide the number of pounds of chlorine gas that would be needed by 0.65 to find out how many pounds of 65% HTH would be needed.

$$\text{Chemical, lbs} = \frac{254 \text{ lbs}}{.65}$$

lbs = 391 lbs

BASIC DOSAGE PRACTICE PROBLEMS

1. The flow is 2.4 MGD and the chlorine gas feed rate is 40 lbs/day. What is the dose in mg/L?

   ____

2. The flow is 1.2 MGD and the chlorine gas feed rate is 50 lbs/day. What is the dose in mg/L?

   ____

3. The flow is 0.60 MGD and the chlorine gas feed rate is 15 lbs/day. What is the dose in mg/L? ___________
4. The flow is 0.30 MGD and the chlorine gas feed rate is 18 lbs/day. What is the dose in mg/L? ___________
5. The flow is 2.4 MGD and a chlorine dose of 4 mg/L is required. How many pounds of chlorine gas must be used?

   ____

6. The flow is 1.8 MGD and a chlorine dose of 2 mg/L is required. How many pounds of chlorine gas must be used?

   ____

7. The flow is 3.0 MGD and a chlorine dose of 6 mg/L is required. How many pounds of chlorine gas must be used?

   ____

8. The flow is 0.3 MGD and a chlorine dose of 3 mg/L is required. How many pounds of chlorine gas must be used?

   ____

9. The flow is 0.5 MGD and a chlorine dose of 5 mg/L is required. How many pounds of 65% HTH must be used?

   ____

10. The flow is 0.018 MGD and a chlorine dose of 6 mg/L is required. How many pounds of 65% HTH must be used?

    ____

THE METRIC SYSTEM

The metric system is the main method of measurement in almost all of the industrialized countries in the world. Although many persons in the United States think that the metric system is confusing, it is probably even easier than the "english" system once you learn how to use it. Generally speaking, there are only three types of measurement; length, weight, and volume.

In the english system, length is measured in inches, feet, yards, miles, etc. In the metric system, length is measured in **meters**. In the english system, weight is measured in ounces, pounds, tons, etc. In the metric system, weight is measured in **grams**. In the english system, volume is measured in fluid ounces, pints, quarts, gallons, etc. In the metric system volume is measured in **liters**. The metric system is actually simpler than the english system because there is only one basic unit for length, one basic unit for weight, and one basic unit for volume.

Unit	Symbol	Measurement
Meter	m	Length
Gram	g or gm	Weight (or mass)
Liter	l or L	Volume

But how many or what part of a meter, gram, or liter? In the metric system, a prefix is used to tell you this. A prefix is something that is put in front of a word to modify it. In the metric system, a prefix is often used in front of one of the three basic units of measurement.

Prefix	Symbol	Meaning	
Mega	M	one million	(1,000,000)
Kilo	k	one thousand	(1000)
Hecto	h	one hundred	(100)
Deka	da	ten	(10)
Deci	d	one tenth	(0.1)
Centi	c	one one-hundredth	(0.01)
Milli	m	one one-thousandth	(0.001)
Micro	µ	one one-millionth	(0.000001)

QUESTION
What is a ml?

ANSWER
The m is the prefix (it comes first). The prefix m is the symbol for milli which means one one-thousandth (1/1000). The l is a symbol for liter. A liter is the basic unit for measuring volume in the metric system.

ml is a symbol for **milliliter** which is **one one-thousandth of a liter**.

QUESTION
What is a mg?

ANSWER
The m is the prefix (it comes first). The prefix m is the symbol for milli which means one one-thousandth (1/1000). The g is a symbol for gram. A gram is the basic unit for measuring weight in the metric system.

mg is a symbol for **milligram** which is **one one-thousandth of a gram**.

QUESTION
What is a mg/L?

ANSWER
A mg is a milligram which is one one-thousandth of a gram. L is the symbol for liter . The slash / means "per" or "in every".

A mg/L is a symbol for a **milligram per liter.**

A milligram per liter is **one one-thousandth of a gram for every liter of water**.

Note: A mg/L is a unit of measurement often used for expressing a dosage of a substance in water or wastewater. A mg/L is the same thing as a ppm.

ANSWERS TO APPENDIX A PRACTICE PROBLEMS

Volume/Time Units Practice Problems

1. 0.10 MGD
2. 1.2 MGD
3. 0.12 MGD
4. 0.056 MGD
5. 8.2 MGD
6. 0.0053 MGD
7. 0.011 MGD
8. 4.34 MGD
9. 1,600,000 gpd
10. 2,360,000 gpd
11. 80,000 gpd
12. 4000 gpd
13. 876,000 gpd
14. 54,000 gpd
15. 1,760,000 gpd

Area and Volume Practice Problems

1. 1800 ft^2
2. 700 ft^2
3. 1257 ft^2
4. 5281 ft^2
5. 113 ft^2
6. 1000 ft^3
7. 7480 gals
8. 62,383 lbs *or* 0.06 Mlbs
9. 6000 ft^3
10. 44,880 gals
11. 374,299 lbs *or* 0.37 Mlbs
12. 7069 ft^3
13. 52,873 gals
14. 440,962 lbs *or* 0.44 Mlbs
15. 15,708 ft^3
16. 117,496 gals
17. 979,915 lbs *or* 0.98 Mlbs
18. 23,857 ft^3
19. 178,447 gals
20. 1,488,246 lbs *or* 1.49 Mlbs

Detention Time Practice Problems

1. 4.0 hrs
2. 4.1 hrs
3. 8.1 hrs
4. 3.5 hrs
5. 128 days

Dosage Calculations Practice Problems

1. 2.0 mg/L
2. 5.0 mg/L
3. 3.0 mg/L
4. 7.2 mg/L
5. 80 lbs
6. 30 lbs
7. 150 lbs
8. 7.5 lbs
9. 32 lbs
10. 1.4 lbs

Appendix B
Certification Exam Formula Sheets

Listed in this appendix is the Class C exam formula sheet and the Class B and A exam formula sheet. Examinees must be familiar enough with the formula to be able to recognize it an 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 exam, operators are encouraged to follow the *Other Study Suggestions* related to math as well as practice the math problems found in the *Suggested References for Study* for each chapter.

Class C Wastewater Operations Certification Exam Formula Sheet

$$\text{Detention Time, hr} = \frac{\text{(Volume, gal) (24 hr/day)}}{\text{Flow, gpd}}$$

$$\text{Dose, mg/L} = \frac{\text{Chemical, lbs}}{\text{Flow, Mlbs}}$$

$$\text{Chemical Feed, lbs} = \text{(Dose, mg/L (Flow,Mlbs)}$$

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Lenth, ft}}$$

$$\text{Surface Loading, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$$

$$\text{Organic Loading, lbs BOD/ft}^2 = \frac{\text{BOD applied, lbs}}{\text{Surface Area, ft}^2}$$

Class A/B Wastewater Operations Certification Exam Formula Sheet

$$\text{MLVSS, lbs} = \frac{\text{(BOD, mg/L) (Flow, MGD) (8.34 lbs/gal)}}{\text{F/M Desired}}$$

$$\text{MLVSS, mg/L} = \frac{\text{MLVSS, lbs}}{\text{(Aerator Volume, MG) (8.34 lbs/gal)}}$$

$$\text{WAS, lbs/day} = \frac{\text{MLSS, lbs}}{\text{MCRT, days}} - \text{SS in Effluent, lbs/day}$$

$$\text{WAS Rate, MGD} = \frac{\text{WAS, lbs/day}}{\text{(WAS SS, mg/L) (8.34 lbs/gal)}}$$

$$\text{Change in WAS Rate, MGD} = \frac{\text{Actual MLSS, lbs - Desired MLSS, lbs}}{\text{(WAS, mg/L) (8.34 lbs/gal)}}$$

$$\text{F/M} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$\text{Sludge Age, days} = \frac{\text{MLSS, lbs}}{\text{Aeration Influent SS, lbs/day}}$$

$$\text{Desired MLSS, lbs} = \text{(Sludge Age, days) (Solids Added, lbs/day)}$$

$$\text{MCRT, days} = \frac{\text{MLSS, lbs}}{\text{SS WAS, lbs/day + SS Lost, lbs/day}}$$

$$\text{SVI} = \frac{\text{(Settleability, mL/L) (1000)}}{\text{MLSS, mg/L}}$$

Class A/B Wastewater Operations Certification Exam Formula Sheet

$$\text{TF Organic Loading, lbs BOD/day/1000 ft}^3 = \frac{\text{BOD applied, lbs/day}}{\text{Media Volume, 1000ft}^3}$$

$$\text{RBC Organic Loading, lbs BOD/day 1000 ft}^2 = \frac{\text{Soluble BOD applied, lbs/day}}{\text{Media Area, 1000 ft}^2}$$

$$\text{Surface Loading, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Surfac Area, ft}^2}$$

$$\text{Water HP} = \frac{\text{(Flow,gpm) (TDH)}}{\text{33,000 ft/lb/min/HP}}$$

$$\text{Motor HP} = \frac{\text{(Flow, gpm) (Height, ft)}}{(3960)\ (E_p)\ (E_m)}$$

$$\text{Brace HP} = \frac{\text{(Flow, gpm) (Height, ft)}}{(3960)\ (E_p)}$$

$$\text{Detention Time, hr} = \frac{\text{(Volume, gal) (24 hr/day)}}{\text{Flow, gpd}}$$

$$\text{Dose, mg/L} = \frac{\text{Chemical, lbs}}{\text{Flow, Mlbs}}$$

Chemical Feed, lbs = (Dose, mg/L) (Flow, Mlbs)

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$$

Appendix C
Introduction to Basic Chemistry

Basic Chemistry Terms	
Matter	All substances in the universe.
Chemistry	The properties of matter and the changes in the composition of matter.
Chemical Reaction	When the basic chemical nature of the matter is changed.
Element	A substance which cannot be separated into its constituent 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_2) or chloride (Cl^-) that will readily add (take on) electrons. The opposite is a reducing agent.
Reducing Agent	Any substance, such as a 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 electode of an electrolytice system. The cathode attracts positively-charged particles or ions (cations).
Valence	The combining capacity of an element in a compound. The number of atoms of hydrogen that are equivalent to one atom of the element.
Atomic Weight	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 realtive weights based on the weight of Carbon (C), which has been set at 12.00.

Appendix C Table 1

Some Common Chemical Elements

Element	Symbol	Atomic Weight	Normal Valence +	Normal Valence -
Calcium	Ca	40.08	2	
Carbon	C	12.00	4	
Chlorine	Cl	35.457		1
Hydrogen	H	1.008	1	
Nitrogen	N	14.008	5	
Oxygen	O	16.00		2
Phosphorous	P	31.02	5	
Potassium	K	39.096	1	
Sodium	Na	22.997	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	$CuSO_4 \cdot 5H_2O$
Hydrichloric 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_2SO_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	$SO_2 + H_2O \quad H_2SO_3 + HOCl \quad H_2SO_4 + HCl$

Appendix C Table 4

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

COMPLETE 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 Contactors
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 Procedures 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 Options)
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 Collection 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 Operation and Maintenance

Gerneral Water Quality (Chapte 611)
Oklahoma Operator Certification Rules (Chapter 710)
Discharge - OPDES (Chapter 606)
Non Industrial Impundments 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: Basic Science Concepts and Applications - Hydraulics Section***
**** needed for certification purposes only by those persons 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 Operation and Maintenance of Wastewater Collection Systems, Volume 1
CSUS Operation 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
Okla. City, OK 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 Facilitly Construction (Chapter 656)
General Water Quality (Chapter 611)
Oklahoma Department of Environmental Quality
Customer Assiatance
PO Box 1677
707 N. Robinson
Okla. City, OK 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.
Okla. City, OK 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 Environment Federation 601 Wythe Street Alexandria, Virginia 22314-1994 1-800-666-0206 (catalog available) www.wef.org
Operator Training Publications and Materials	American Water Works Association 6666 West Quincy Ave. Denver, Colorado 80235 1-800-926-7337 (catalog available) www.awwa.org
Safety Publications and Materials	U.S. Dept. of Labor Occupational Sfty. & Hlth. Adm.(OSHA) 200 Constitution Ave, NW Washington D.C., 20210 (202) 219-4667 (catalog available) www.osha.gov
Safety Publications and Materials	Oklahoma Safety Council 2725 E. Skelly Dr. Tulsa, OK 74105 1-800-324-6458 (catalog available) www.oksafety@ionet.net
Operator Math Manuals and Workbooks	Technomic Publishing Company 851 New Holland Avenue, 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 Center 1-800-624-8301

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