WASTEWATER TREATMENT PLANT OPERATOR CERTIFICATION MANUAL

Kentucky Department of Environmental Protection

Division of Compliance Assistance

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Certification and Licensing Program

Mission

Promote responsible environmental stewardship.

Goal

Provide operators with the basic knowledge required to manage drinking water, wastewater and solid waste systems.

The Division of Compliance Assistance offers free compliance assistance. Our services are available to all individuals, communities and businesses regulated by the Kentucky Department for Environmental Protection. We want to help you succeed!

Hotline and Website for regulatory, technical or operational concerns
502-782-6189
dca.ky.gov

Other programs administered by the Division of Compliance Assistance:

Kentucky Excel Program
Kentucky Brownfield Program
Kentucky Environmental Compliance Assistance Program

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WASTEWATER TREATMENT PLANT OPERATOR CERTIFICATION MANUAL

Chapter 1: The Certified Plant Operator

Chapter 1 Objective

1. Identify the regulatory requirements relative to operator certification.

Why should I become a certified operator?

Wastewater and drinking water system operators are front-line environmental professionals who ensure the quality of Kentucky's water resources and protect the public's health. Only operators that are certified by the Kentucky Certification and Licensing Branch can be in responsible charge of a wastewater or drinking water system.

Working in the water and wastewater industry can be extremely rewarding as you will be providing a critical service to your community. It just might be one of the most important positions in the world since no one can live without water. It takes knowledgeable, conscientious people to deliver clean, potable water and to ensure that wastewater is treated and returned as clean water to the environment.

Certification Process

Certification is obtained by meeting minimum education and experience requirements, submitting the appropriate forms and fee and by passing the certification examination with at least a 70%. Regulations pertaining to the certification of drinking water and wastewater system operators are located in 401 KAR Chapter 11 (see appendix).

System Classifications

Class I	Wastewater treatment plant with a design capacity of ≤50,000 GPD
Class II	Wastewater treatment plant with a design capacity of 50,001 GPD to ≤ 2,000,000 GPD
Class III	Wastewater treatment plant with a design capacity of 2,000,001 to ≤ 7,500,000 GPD
Class IV	Wastewater treatment plant with a design capacity ≥ 7,500,001 GPD

Regulatory Education and Experience

Class I	High School Diploma or GED and One (1) year of acceptable operation of a wastewater treatment plant shall be required.
Class II	High School Diploma or GED and Two (2) years of acceptable operation of a wastewater treatment plant shall be required.
Class III	High School Diploma or GED and Three (3) years of acceptable operation of a wastewater treatment plant with one (1) year of that experience in a wastewater treatment plant with a design capacity greater than 50,000 gallons per day shall be required.
Class IV	Baccalaureate degree in engineering, science or equivalent is required and at least five (5) years of acceptable operation of a wastewater treatment plant shall be required. Three (3) years of the required experience shall be in a wastewater treatment plant with a design capacity greater than two (2) million gallons per day. At least two (2) years of primary responsibility in a wastewater treatment plant with a design capacity greater than two (2) million gallons per day shall be required.

Substitutions (401 KAR 11:030)

(4) Substitutions. The cabinet shall allow the following substitutions for the qualifications specified in subsections (1) and (2) of this section:

(a) Education in environmental engineering; environmental technology; and biological, physical, or chemical sciences shall be substituted if the substitution does not exceed fifty (50) percent of the required experience.

1. An associate degree may substitute for two (2) years of experience.
2. A baccalaureate degree may substitute for four (4) years of experience.
3. Education that did not result in a degree in a related field shall be substituted for the required experience as follows:

a. Ten (10) contact hours, one (1) Continuing Education Unit, or one (1) postsecondary education quarter hour with a passing grade shall substitute for 0.022 years of experience.

b. One (1) postsecondary education semester hour with a passing grade shall substitute for 0.033 years of experience.

4. Education applied to the experience requirements established in subsections (1) and (2) of this section shall not be applied to the education requirement.

(b) Experience shall be substituted for the educational requirement as follows:
1. One (1) year of operational experience at a treatment plant shall substitute for one (1) year of education.
2. One (1) year of collection system experience shall substitute for one (1) year of education.
3. The cabinet may allow partial substitution of the education requirement by experience in maintenance, laboratory analysis, or other work related to the collection, treatment or distribution of drinking water or wastewater. To establish how much experience shall be accepted, the cabinet shall determine the degree of technical knowledge needed to perform the work and the degree of responsibility the applicant had in the operation of the system.
4. Experience applied to the education requirement established in subsections (1) and (2) of this section shall not be applied to the experience requirement.

(c) Collection system and treatment experience may be substituted as follows:
1.a. Four (4) years of collection system experience shall be considered equivalent to one (1) year of treatment experience.
b. This substitution shall not account for more than fifty (50) percent of the experience required by subsection (1) of this section.
2. One (1) year of treatment experience shall be considered equivalent to one (1) year of collection system experience. (35 Ky.R. 476; Am. 1213; eff. 3-6-2009; 36 Ky.R. 454; 1052; 1456; eff. 2-5-2010; 36 Ky.R. 2105-A; 37 Ky.R. 51; eff. 8-5-2010.)

Operators in Training (OIT) Certifications

Operators in training certifications are available for each certification type. An individual can apply for an OIT license that is one level higher and of the same type as the certification that the individual currently holds. An individual may also apply for an entry level OIT certification. OITs must pass the appropriate operator certification exam and work under the responsible charge of a mentor. To apply for the exam, individuals must submit the following to the Certification and Licensing Branch:

- Education and Experience Documentation Form;
- Registration Form for Exams and Training;
- The appropriate fee; and

- A letter from the applicant's mentor. The letter from the mentor must include:
  - A commitment to oversee the applicant's work after the applicant becomes an OIT;
  - A commitment to mentor the applicant as long as the applicant is under the mentor's direct responsible charge;
  - Verification that the mentor is not currently mentoring any other OITs; and
  - Confirmation that the mentor holds a certification license that is equal to or greater than the certification level required to serve in primary responsibility of the facility where the mentor and prospective OIT works.

A Wastewater Treatment Class I-OIT who operates a wastewater treatment plant owned by the operator that serves only one residence may have primary responsibility for that plant. All other OITs may not be in responsible charge of a facility unless they hold an additional certification license that does not have an OIT designation.

Certification Renewal or Maintenance

Wastewater treatment and collection system certifications expire on **June 30 of odd-numbered years**. Certifications shall remain valid until the expiration date, unless suspended, revoked or replaced by a higher classification certificate before that date. Certificates issued between **Jan. 1** and **June 30** of a renewal year will be issued to include the next two-year renewal period. Failure to renew before July 1 of the renewal year will result in the expiration of certification and a late fee assessment. The certificate shall terminate if not renewed on or before **December 31** of the year the certification expired. Certified operators with expired certificates shall not be in responsible charge of a drinking water or wastewater facility.

Certified operators (excluding OIT certificates) may renew their license(s) electronically through the cabinet Web site using the E-Search link or by submitting the Application for Certification Renewal and the appropriate fee to the Division of Compliance Assistance, Certification and Licensing Branch, 300 Sower Blvd., Frankfort, KY 40601.

Certified operators who are designated an Operator in Training may renew a certification without examination if the operator has:

1. Satisfied the continuing education requirements;

2. Earned the required years of operational experience;
3. Submitted an Education and Experience Documentation form verifying his or her experience;
4. Submitted a letter of recommendation from a mentor; and
5. Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's Web site.

Wastewater treatment and collection certified operators training hours shall expire two years from the date earned. Certified operators holding both a treatment and a collection certificate shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for both certificates.

> ***Reminder*** *-- Continuing education hours earned prior to certification shall not count toward certificate renewal.*

Operator Ethics – Standards of Professional Conduct for Certified Operators

In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11. These standards state:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;

(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;

(c) If a certified operator's judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;

(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and

(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.

The full set of standards is located in 401 KAR 11:020.

Certified operators who violate the standards in 401 KAR 11:020 are subject to disciplinary actions which include but are not limited to:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;
(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;
(c) Revocation of the operator's certification;
(d) Civil or criminal penalties; or
(e) A combination of the disciplinary actions listed above.

Disciplinary actions are outlined in 401 KAR 11:050, Section 4 (see Appendix).

All regulations related to the certification of wastewater and drinking water operators are located in 401 KAR Chapter 11. A copy of the regulations is located in this manual and it is recommended that you become familiar with the regulations that govern your profession.

Key Definitions

<u>Operator</u> is defined as a person involved in the operation of a wastewater treatment plant or wastewater collection system.

<u>Ethics</u> are defined as a code of morality or a system of moral principles governing the appropriate conduct for a person or group.

<u>System Classifications</u> are used in determining regulatory standards and compliance requirements for each wastewater system.

<u>Discharge Monitoring Report</u> (DMR) means the report including any subsequent additions, revisions, or modifications, for the reporting of self-monitoring results by KPDES permittees.

KAR – Kentucky Administrative Regulations are the regulations set forth by the Commonwealth of Kentucky, some of which regulate public water systems (Chapters 5, 8, and 11).

KRS – Kentucky Revised Statutes are the laws that govern the Commonwealth of Kentucky.

AI # - Agency Interest Number is the number that the Kentucky Department for Environmental Protection uses to track all activities pertaining to an individual or group involving environmental or regulatory compliance activities.

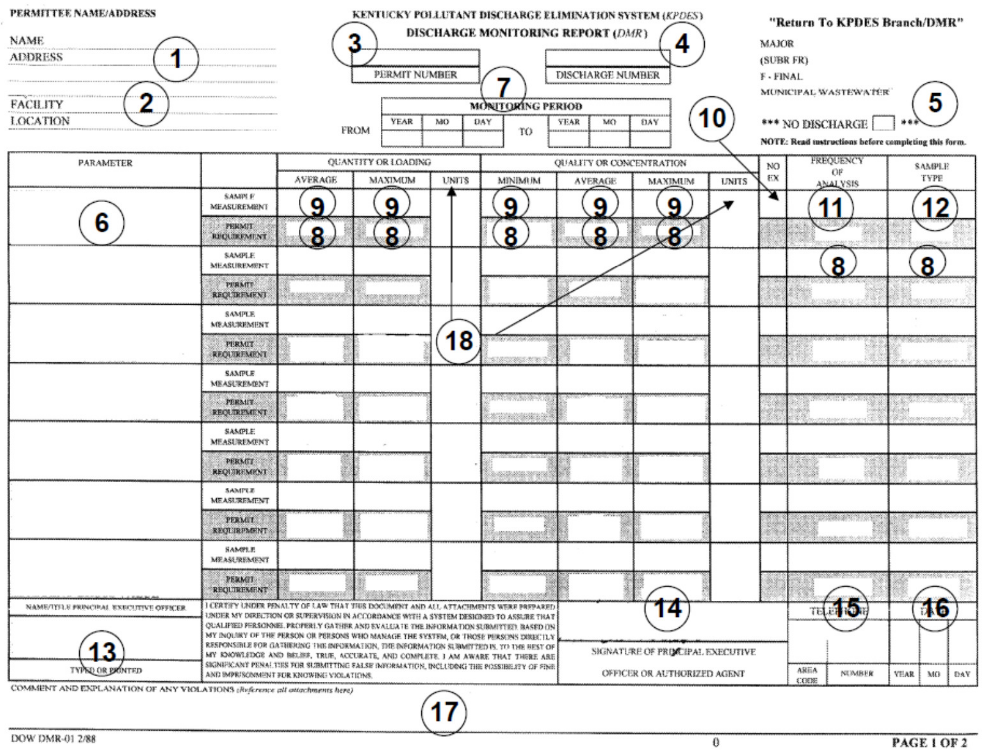
Chapter 1 Review

1. A class II operator may operate a plant ranging from _______ to _________ GPD.
2. A class III operator needs ______ hours of training to renew his/her certification.
3. Wastewater operators renew their certification in______ - numbered years.
4. Do criminal and civil penalties exist for operator misconduct?

Answers for Chapter 1 Review

1. 50,001 GPD – 2,000,000 GPD
2. 24 hours
3. odd
4. yes

Chapter 2: KPDES Permitting Program



Kentucky Department for Environmental Protection, 300 Fair Oaks Ln., Frankfort, KY 40601

Chapter 2 Objectives

1. Demonstrate knowledge of why there is a KPDES Permitting Program, what the permit contains and how to obtain a permit.
2. Demonstrate knowledge of sample types and collections procedures.

3. Define the permit parameters outlined in this section.
4. Demonstrate a working knowledge of the math associated with the Discharge Monitoring Reports.

Overview

This chapter defines the permit parameters related to permitted influent and effluent constituents and reviews the three major types of sampling (and how to conduct each). The first section identifies the procedures related to permitting and reporting. The second section describes the sampling and preservation procedures for permitted influent and effluent constituents.

The Importance of Clean Water

Prior to 1970, regulations did not exist to protect the waters of the United States. Due to public health and environmental concerns, public pressure on government officials resulted in an environmental movement that created the Environmental Protection Agency. As a result, the Federal Water Pollution Control Act was created, better known as the Clean Water Act (CWA). Improvements to water quality in this country are directly linked to implementation of programs to control the discharge of pollutants.

The Clean Water Act establishes federal guidelines by which states have the ability to draft laws and regulations and create programs to fulfill this mandate. In Kentucky, the regulations that govern pollutant discharges are found in Title 401 of the Kentucky Administrative Regulations Chapters 5, 10, and 11.

Why Do I Have a Permit?

The CWA made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit was obtained. As stated in Kentucky's laws on water quality, it is the policy of the Commonwealth:

1. to conserve the waters of the Commonwealth for public water supplies, for the propagation of fish and aquatic life, for fowl, animal wildlife and arborous growth, and for agricultural, industrial, recreational and other legitimate uses; to provide a comprehensive program in the public interest for the prevention, abatement and control of pollution; to provide effective means for the execution and enforcement of such program; and to provide for cooperation with agencies of other states or of the federal government in carrying out these objectives.

2. to safeguard from pollution the uncontaminated waters of the Commonwealth; to prevent the creation of any new pollution of the waters of the Commonwealth; and to abate any existing pollution.

EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls point source discharges. In Kentucky, point source discharges are regulated under the Kentucky Pollutant Discharge Elimination System (KPDES) program. This program was delegated to Kentucky's Division of Water in the mid 1980's. Industrial, municipal, and other facilities must obtain permits if their point source discharge flows to surface waters. Point sources are discrete conveyances such as pipes or man-made ditches. Examples include publicly owned treatment works (POTWs), industrial process wastewater discharges, runoff conveyed through a storm sewer system, and discharges from concentrated animal feeding operations (CAFOs.)

A KPDES permit is a license for a facility to discharge limited amounts of pollutants into receiving waters under certain conditions.

What is a Pollutant?

The term pollutant is defined in CWA section 502(6) and § 122.2. The statute defines pollutant very broadly and includes any type of industrial, municipal, or agricultural waste (including heat) discharged into water. In Kentucky, water pollution is defined as the alteration of the physical, thermal, chemical, biological, or radioactive properties of the waters of the Commonwealth in such a manner, condition, or quantity that will be detrimental to the public health or welfare, to animal or aquatic life or marine life, to the use of such waters as present or future sources of public water supply or to the use of such waters for recreational, commercial, industrial, agricultural, or other legitimate purposes.

For regulatory purposes, pollutants are grouped into three categories under the KPDES program: conventional, toxic, and nonconventional.

- Conventional pollutants are those defined in the CWA as BOD5, TSS, fecal coliform, pH, and oil and grease.
- Toxic pollutants are those defined in the CWA to include metals and manmade organic compounds.

- Nonconventional pollutants are those that do not fall under either of the above categories and include parameters such as chlorine, ammonia, nitrogen, phosphorus, and whole effluent toxicity (WET).

Obtaining a KPDES Permit

Any person who is required to have a KPDES permit must complete, sign, and submit an application to the Division of Water. An application for a new discharge must be received by the division at least one hundred and eighty (180) days before the proposed discharge is due to commence. Likewise, an application to reissue an expiring permit must be received one hundred and eighty (180) days before the expiration date. For details on applying for a KPDES permit, visit: http://dep.ky.gov/formslibrary/Documents/General_Instr.pdf.

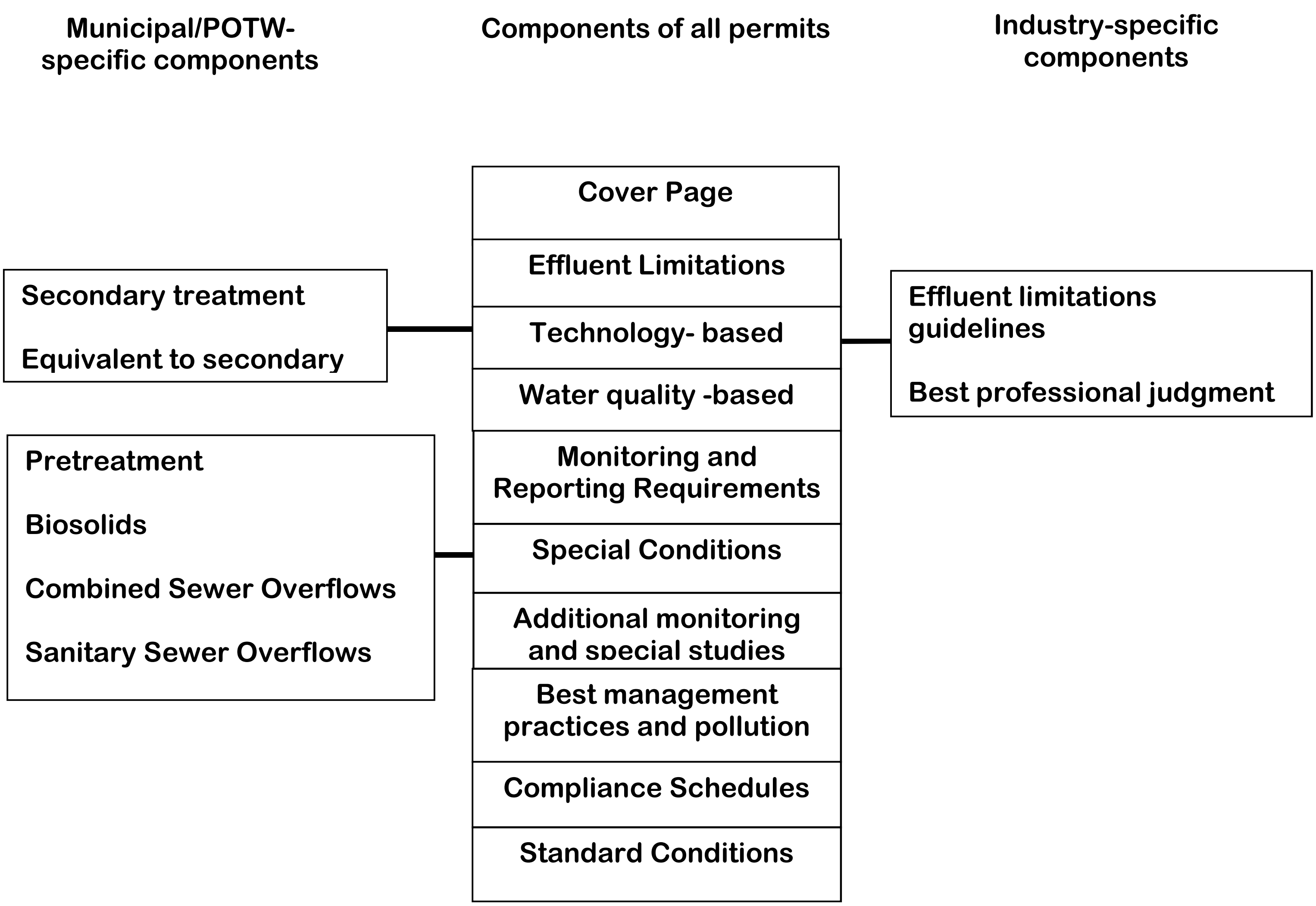
Once your application has been deemed administratively and technically complete, a draft permit will be issued. The draft permit is available for public comment and is your opportunity to review and provide feedback to the permitting authority.

Elements of a KPDES Permit

All KPDES permits may consist of:

- **Cover Page:** Contains the name and location of the permittee, a statement authorizing the discharge, and a listing of the specific locations for which a discharge is authorized.
- **Effluent Limitations:** The primary mechanism for controlling discharges of pollutants to receiving waters. A permit writer spends the majority of his or her time, when drafting a permit, deriving appropriate effluent limitations on the basis of applicable technology and water quality standards.
- **Monitoring and Reporting Requirements:** Used to characterize waste-streams and receiving waters, evaluate wastewater treatment efficiency, and determine compliance with permit conditions.
- **Special Conditions:** Conditions developed to supplement numeric effluent limitations. Examples include additional monitoring activities, special studies, best management practices (BMPs), and compliance schedules.
- **Standard Conditions:** Pre-established conditions that apply to all KPDES permits and delineate the legal, administrative, and procedural requirements of the KPDES permit.

In addition to the components of the permit, a fact sheet or statement of basis explaining the rationale for permit conditions makes up part of the documentation that supports a draft permit.


Municipal/POTW-specific components
Components of all permits
Industry-specific components
Cover Page
Effluent Limitations
Technology- based
Water quality -based
Monitoring and Reporting Requirements
Special Conditions
Additional monitoring and special studies
Best management practices and pollution
Compliance Schedules
Standard Conditions
Secondary treatment
Equivalent to secondary
Pretreatment
Biosolids
Combined Sewer Overflows
Sanitary Sewer Overflows
Effluent limitations guidelines
Best professional judgment

PART I A –

EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

During the period beginning on the effective date of this permit and lasting through the term of this permit, the permittee is authorized to discharge from Outfall serial number: 001 – Sanitary Wastewater (Design Flow = 0.010 MGD)
Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTICS	DISCHARGE LIMITATIONS (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS	
	Monthly Avg.	Daily Max.	Monthly Avg.	Daily Max.	Measurement Frequency	Sample Type
Flow (MGD)	Report	Report	N/A	N/A	1/Month	Instantaneous
BOD_5 (mg/l)	2.50	3.75	30	45	1/Month	24 Hr Composite
TSS (mg/l)	2.50	3.75	30	45	1/Month	24 Hr Composite
Ammonia Nitrogen (as mg/l N)	1.67	2.50	20	30	1/Month	24 Hr Composite
Escherichia Coli (N/100 ml)	N/A	N/A	130	240	1/Month	Grab
Dissolved Oxygen (mg/l) (minimum)	N/A	N/A	Not less than 2.0	1/Month	Grab	
pH (standard units)	N/A	N/A	6.0 (min)	9.0 (max)	1/Month	Grab
Total Residual Chlorine (mg/l)	N/A	N/A	0.011	0.019	1/Month	Grab
Total Phosphorus (mg/l)	N/A	N/A	1.0	2.0	1/Month	24 Hr Composite
Total Nitrogen (mg/l)	N/A	N/A	Report	Report	1/Month	24 Hr Composite

The abbreviation BOD_5 means Biochemical Oxygen Demand (5-day).
The abbreviation TSS means Total Suspended Solids.
The abbreviation N/A means Not Applicable.
The effluent limitations for BOD_5 and TSS are Monthly (30 day) and Weekly (7 day) Averages.
The effluent limitations for *Escherichia Coli* are thirty (30) day and seven (7) day Geometric Means.
Total Nitrogen is to be reported as the summation of the analytical results for Total Nitrates, Total Nitrites, and Total Kjeldahl Nitrogen.
There shall be no discharge of floating solids or visible foam or sheen in other than trace amounts.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location: nearest accessible point prior to discharge to or mixing with the receiving waters or waste streams from other outfalls.

EPA and KY DOW Oversight of KPDES Permits

Federal EPA along with the state of Kentucky is responsible for tracking and maintaining enforcement and compliance activities. EPA maintains national data systems to support program management and oversight of the NPDES\KPDES programs. The Kentucky Division of Water is responsible to the U.S Environmental Protection Agency (EPA) for assuring the DMR data is entered into the federal permit compliance system.

The Permit Compliance System (PCS), one of two national NPDES electronic databases, supports the management and oversight of the NPDES program. Due to changes in the NPDES\KPDES programs, the PCS system is being phased out and replaced by the Integrated Compliance Information System (ICIS) - https://icis.epa.gov/icis. ICIS provides an updated system that enables national program management and oversight activities such as:

- Permit tracking and management.
- Compliance monitoring.
- NPDES program management.
- Enforcement actions.

Due to state reporting requirements to EPA using ICIS, facilities with KPDES permits must submit Discharge Monitoring Reports to KY DOW. These reports are linked to ICIS.

Discharge Monitoring Reports (DMR)

The DMR is a tool used to characterize waste-streams and receiving waters, evaluate wastewater treatment efficiency, and determine compliance with permit conditions. The DMR should be representative of the pollutants discharged from the KPDES facility. Pollutants listed on the DMR come directly from the pollutants identified and regulated under your KPDES permit. Other parameters that are not pollutants on the DMR may include flow and percent removal efficiency.

Net*DMR Discharge Monitoring Report Submission Information*

*Net*DMR is a national tool for regulated Clean Water Act permittees to submit Discharge Monitoring Reports (DMRs) electronically via a secure Internet application to EPA through the Environmental Information Exchange Network. KY DOW requires all facilities to use NetDMR as of January 2014.

Benefits of NetDMR

- Reduces paperwork burden

- Assists with DMR data quality by automatically checking for certain violations prior to submission to the U.S. EPA database
- Improves timeliness and accessibility of DMR data
- Provides instant confirmation of submission
- Allows for fast revisions of DMR data that can be submitted electronically
- Allows the attachment of KY DOW approved supplemental documents

Information for NetDMR can be found at:
http://water.ky.gov/permitting/Pages/netDMRInformation.aspx.

PERMITTEE NAME/ADDRESS *(Include Facility Name/Location if Different)*
NAME
ADDRESS

FACILITY
LOCATION

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)*
DISCHARGE MONITORING REPORT *(DMR)*

Form Approved.
OMB No. 2040-0004

PERMIT NUMBER	DISCHARGE NUMBER

MONITORING PERIOD

	YEAR	MO	DAY		YEAR	MO	DAY
FROM	08	07	01	TO	08	07	31

MAJOR
(SUBR LV)
F - FINAL
MUNICIPAL WASTEWATER
EFFLUENT
*** NO DISCHARGE |__| ***
NOTE: Read instructions before completing this form.

PARAMETER		QUANTITY OR LOADING			QUALITY OR CONCENTRATION				NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
OXYGEN, DISSOLVED (DO)	SAMPLE MEASUREMENT	******	******		7.2	******	******	(19)	0	3/7	Grab
00300 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	********	7 INST MIN	******	******	MG/L		THREE/WEEK	GRAB
PH	SAMPLE MEASUREMENT	******	******		7.6	******	7.9	(12)	0	3/7	Grab
00400 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	********	6.0 MINIMUM	******	9.0 MAXIMUM	SU		THREE/WEEK	GRAB
SOLIDS, TOTAL SUSPENDED	SAMPLE MEASUREMENT	4853	5184	(26)	******	194	804	(19)	0	3/7	Comp
00530 G 0 0 RAW SEW/INFLUENT	PERMIT REQUIREMENT	REPORT MO AVG	REPORT MX WK AV	LBS/DY	******	REPORT MO AVG	REPORT MX WK AV	MG/L		THREE/WEEK	COMPOS
SOLIDS, TOTAL SUSPENDED	SAMPLE MEASUREMENT	58	77	(26)	******	2	3	(19)	0	3/7	Comp
00530 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	1501 MO AVG	2252 MX WK AV	LBS/DY	******	30 MO AVG	45 MX WK AV	MG/L		THREE/WEEK	COMPOS
NITROGEN, AMMONIA TOTAL (AS N)	SAMPLE MEASUREMENT	502	522	(26)	******	20.0	22.0	(19)	0	3/7	Comp
00610 G 0 0 RAW SEW/INFLUENT	PERMIT REQUIREMENT	REPORT MO AVG	REPORT MX WK AV	LBS/DY	******	REPORT MO AVG	REPORT MX WK AV	MG/L		THREE/WEEK	COMPOS
NITROGEN, AMMONIA TOTAL (AS N)	SAMPLE MEASUREMENT	3	6	(26)	******	0.14	0.26	(19)	0	3/7	Comp
00610 1 1 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	100 MO AVG	150 MX WK AV	LBS/DY	******	2 MO AVG	3 MX WK AV	MG/L		THREE/WEEK	COMPOS
PHOSPHORUS, TOTAL (AS P)	SAMPLE MEASUREMENT	******	******		******	0.16	0.248	(19)	0	1/7	Comp
00665 1 1 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	********	******	REPORT MO AVG	REPORT MX WK AV	MG/L		WEEKLY	COMPOS

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER

TYPED OR PRINTED

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT

TELEPHONE		DATE		
AREA CODE	NUMBER	YEAR	MO	DAY
		08	08	26

COMMENTS AND EXPLANATION OF ANY VIOLATIONS *(Reference all attachments here)*

USE MO AVG FOR BOD/TSS REMV: REPT IN MINIMUM COLUMN.

EPA Form 3320-1 (Rev. 3/99) Previous editions may be used.

01065/08 This is a 4 page form.

PAGE 1 OF

Sampling

The chart below details each of the **permit parameters for most domestic wastewater facilities.** It includes their typical preservation and holding times.

Figure 2.1

Parameter	Container	Preservative	Holding Time
E-Coli	P,G	Cool, < 6°C	6 hours
Hydrogen ion (pH)	P,G	None required	Analyze immediately
Ammonia Influent Range 25-50 mg/L 0.02 lbs per day	P,G	Cool, <6°C H^2SO^4 to pH < 2	28 days
Alkalinity	P,G	Cool, <6°C	14 days
Biochemical oxygen demand (BOD) Influent. Range 160- 280 mg/L 0.17 lbs per day	P,G	Cool, <6°C	48 hours
Biochemical oxygen demand, carbonaceous (CBOD)	P,G	Cool, <6°C	48 hours
Kjeldahl and organic nitrogen	P,G	Cool,< 6°C H_2SO_4 to pH < 2	28 days
Residue, non-filterable (TSS) Influent Range 180-300 mg/L 0.20 lbs per day	P,G	Cool, <6°C	7 days
Oxygen, dissolved probe (DO)	G	None required	Analyze immediately
Phosphorus, total Influent Range 5-20 mg/L 0.0048 lbs per day	P,G	Cool,< 6°C H_2SO_4 to pH < 2	28 days
Oil and grease	G	Cool, <6°C H_2SO_4 to pH < 2	28 days
Metals except CR VI and HG	G	Cool,< 6°C HNO_3 to pH < 2	6 months

Types of Sampling

The sampling of wastewater is one of the more important aspects of the wastewater operator's job. If the samples are not properly collected the sample results will not be representative of the plant conditions. There are two types of samples collected for analysis: grab samples and composite samples. There are two types of grab samples: instantaneous analysis and preserved samples. There are also two types of composite samples; flow proportionate and time-proportional.

Grab Samples

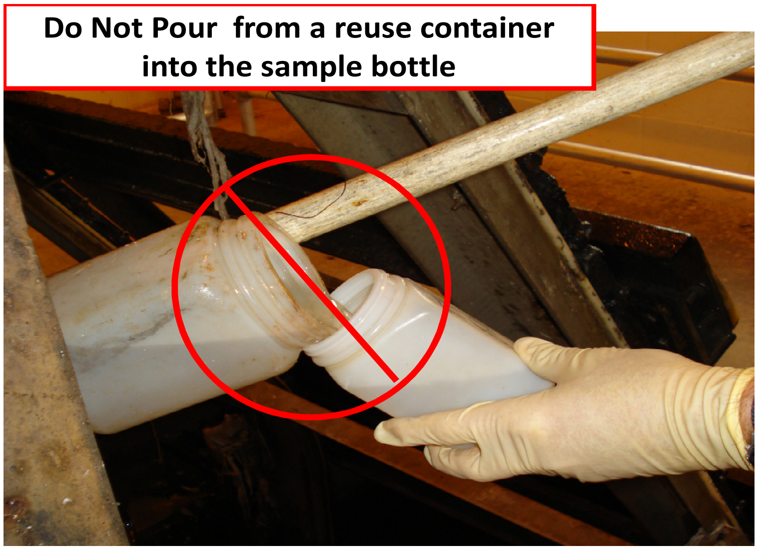
Grab samples are a "snapshot in time" type of sample. They only indicate what is in the water at the particular moment the sample is collected. Grab samples represent the conditions that exist at the moment the sample is collected and do not necessarily represent conditions at any other time.

1. ***Instantaneous Samples***
   An instantaneous sample is a grab sample that is analyzed on site immediately after collection. The most common are Dissolved Oxygen (DO), Total Residual Chlorine (TRC) and pH.

2. ***Preserved Samples***
   The distinction between instantaneous and preserved samples is that preserved samples require preservation and a holding time. The most common is e-Coli/Fecal Coliform.

Grab samples are a common type of sample for many KPDES permits. When taking a grab sample by hand, always wear gloves and hold the bottle well away from its mouth. If flow conditions at your plant are too low to sample effectively, or even zero flow, then do not take the sample and note the low flow conditions on your DMR.

Never artificially increase flow just to take a sample! However, if flow seems to be very low, double check that the flow measurement is accurate. Remember, if a sample can be taken, then it should be taken.



If the places where you need to take samples are difficult to reach, using an apparatus to help is acceptable. However the same considerations apply to it that you would apply to grab sampling by hand. You do not want to pour from a reused container into your sample bottle, so an apparatus that holds your bottle securely is a better choice. The apparatus must not hold the bottle too close to the mouth to prevent cross contamination from the apparatus which will be reused.

Composite Samples

A composite sample is a sample collected over time, formed either by continuous sampling or by mixing discrete samples. Composite samples reflect the average characteristics during the compositing period. They also eliminate the short-term effects of sampling, and are representative samples.

Composite samples are used when stipulated in a permit or when:

- The water or wastewater stream is continuous;
- Analytical capabilities are limited;
- Determining average pollutant concentration during the compositing period;
- Calculating mass/unit time loadings; or
- Associating average flow data to parameter concentrations

A 24-hour composite sample is composed of discrete equal volume aliquots (100 ml minimum) collected every 15 minutes over a 24-hour period and aggregated by an automated sampling device. The aggregate sample will reflect the average water quality of the compositing or sample period. The permit will specify which composite sample type to use, either time composites or flow proportional composites.

Time composite samples are based on a constant time interval between samples. A time composite sample should be collected manually or with an automatic sampler. This type of composite is composed of discrete sample aliquots collected in one container at constant time intervals. This method provides representative samples when the flow of the sampled wastewater stream is constant.

Flow proportional samples should be collected automatically with an automatic sampler and a compatible pacing flow measuring device, semi-automatically with a flow chart and an automatic sampler capable of collecting discrete samples, according to new composite sampling definition.

If you use an automatic sampling device, it is important that the manufacturer's instructions are followed precisely. This includes following all recommended maintenance and service guidelines. Be sure that your autosampler can take the samples required by your KPDES permit and that it is setup correctly to do so. Be sure to follow the manufacturer's instructions to successfully set up the correct type of sampling; either composite or grab.

Labelling of sample containers

Sample containers should be carefully labeled prior to use to ensure that samples do not become lost or mixed up. Sample containers may be labeled with permanent marker or a printed label. To ensure that a paper label remains attached, it is often useful to cover it with a large piece of clear postal, packing tape that wraps around the entire bottle. Be sure that your label contains all useful information such as:

- the KPDES number for the sampled effluent
- the name of the sample or a unique identification number
- what test this container is for (e.g. DO, pH, BOD, *E. coli*, *etc*.)
- the name of your treatment plant or company
- the date and time of collection, and the
- name of the person who collected the sample

When giving the time of collection, use military time exclusively to avoid possible confusion between AM and PM.

Example Label

KPDES Number: ____________________
Sample name or ID: ____________________
Analysis to be performed: ____________________
Entity requesting analysis: ____________________
____
Date: ____________________
Time: ____________________
Collected by: ____________________

Sampling Location:

Typically, samples are taken just after they exit the plant's final treatment step and before the treated water is released into the environment (effluent sampling). However, some permits require samples to be taken of the water entering the plant (influent sampling). If you need to do influent sampling, be sure to take the sample above the first form of water treatment, such as the bar screen. Your KPDES permit should indicate exactly where you should take your samples so refer to it when identifying your sampling location(s).

Total Suspended Solids (TSS)

Total suspended solids are solids that will not pass through a special glass filter with .45 micrometer pore size. Total solids make up approximately 0.1% of the total composition of domestic wastewater (700 – 1000 ppm). Figure 2.2 illustrates the typical composition of solids in raw wastewater

Total solids are composed of suspended and dissolved solids with colloidal solids making up a portion of both. Dissolved solids (400 – 700 ppm) consist of both organic and inorganic molecules and ions that are present in true solution in water (sulfates, chlorides, etc.). A certain level of these minerals in water is necessary for aquatic life.

TSS is normally a composite sample preserved with ice to < 6^{0}C for 7 days. Each individual in the system contributes **0.2 lbs of TSS per day.**

Effluent TSS have quantity and concentration limits. These concentration limitations are generally 30 milligrams per liter (mg/L) as an average and 45 mg/L as a maximum. Quantity limitations vary for each plant.

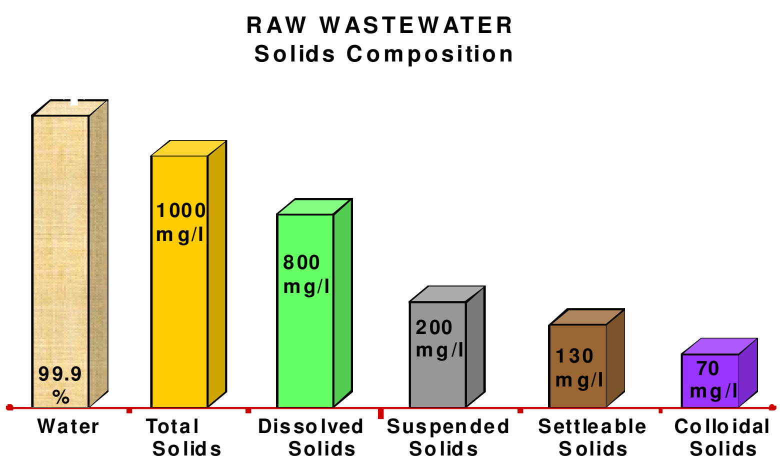


Figure 2.2 Typical composition of solids in raw wastewater

The range of total suspended solids in the influent is **180 – 300 mg/L** in domestic wastewater.

In order to calculate the pounds (of anything) in either the influent or effluent, the following equation is used**:**

Pounds = Flow (expressed in MGD) x 8.34 x sample result (expressed in mg/L)

Let's work a couple of problems to be certain you understand the concept.

Problem #1

The influent concentration of TSS to a 2 MGD oxidation ditch is 189 milligrams per liter (mg/L), the BOD influent concentration is 154 mg/L and the influent flow is 1.5 MGD. How many pounds of TSS enter this plant daily?

Problem #2

The flow to a 1MGD extended aeration plant is 725,000 GPD and the influent TSS concentration is 157 mg/L. How many pounds of TSS per day does this facility receive? To convert 725,000 GPD to MGD you can 1) move the decimal point 6 places to the left **or** 2) divide by 1,000,000.

A second parameter that we are required to sample influent and effluent for is biochemical oxygen demand (BOD).

Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand, (BOD_5), is a measure of the organic strength of wastewater. Each individual in the system contributes **0.17 lb of BOD per day**. The BOD test can be roughly defined as a measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter.

BOD is also a measure of the quantity of dissolved organic pollutants that can be removed in biological oxidation by bacteria. It is expressed in **mg/L of oxygen.** Some BOD_5 (organic material) that is degraded is used by the bacteria in the production of new bacteria cells.

The BOD_5 test only measures the BOD_5 (organic material) that is oxidized in bacterial respiration, it does not measure the carbon used for cell growth. Carbonaceous BOD (CBOD5) measures only the activity of carbonaceous organisms.

The range of BOD in domestic wastewater is ***160 – 280 mg/L***

Influent BOD_5\$CBOD_5$ typically do not have limitations and are report only values. Sample types are usually a composite sample as stated in your permit. Effluent BOD_5\$CBOD_5$ typically have quantity and concentration limits. These concentration and quantity limitations vary for each plant.

Sampling for BOD is normally a composite sample preserved with ice to < 6^0C for 48 hrs.

To calculate a BOD use the following equation:

$$\frac{\textbf{(Initial DO - Final DO) x BOD bottle volume}}{\textbf{Sample volume in Milliliters}}$$

Problem #3

The initial DO of a 15 /ML sample was 7.1 mg/L and the final DO after 5 days of incubation at 20^0C in a 300 /ML sample bottle was 4.1mg/L. What was the BOD in **mg/L**?

When calculating the **concentration** (of anything) in mg/L in the influent or effluent, use the following equation:

$$\frac{\textbf{Pounds}}{\textbf{(Flow in MGD X 8.34)}} = \textbf{mg/L}$$

Problem #4

The influent organic load to a 2.5 MGD wastewater treatment plant 3678.5 lbs with an influent flow of 1.9 MGD. What is the BOD concentration in the influent?

Be certain to pay attention to any necessary conversions (gallons per day vs. MGD).

Problem # 5

The influent flow to a 50,000 GPD package treatment plant is 41,000 GPD and from the discharge monitoring report you know that the average poundage in the influent is 51.6 lbs. What is the BOD **concentration** in mg/L?

Convert 41,000 GPD to MGD by moving the decimal 6 places to the left or divide by 1,000,000

In many KPDES permits a secondary standard of 85% removal is required for TSS and BOD. To calculate **percent removal,** use the following equation:

$$\frac{\textbf{Influent – Effluent}}{\textbf{Influent}} \textbf{ X 100}$$

Problem # 6

If the influent BOD concentration is 51.6 mg/L and the effluent BOD concentration is 3.12 mg/L. What is the **percent removal** of BOD?

Nutrient Parameters

Nutrients such as nitrogen and phosphorus are gaining increased attention due to hypoxia issues. States such as Kentucky are developing standards to address these pollutants. Limitations for these pollutants are currently being developed and implemented through Division of Water programs including KPDES.

Ammonia/Nitrogen

Another parameter required by the KPDES Permit is Ammonia as Nitrogen (NH3-N).

Total Kjeldahl Nitrogen is the sum of the organic nitrogen and ammonia-nitrogen. Normal ranges for domestic wastewater are Kjeldahl nitrogen (40 – 50 ppm), organic nitrogen (15-20 ppm), and ammonia-nitrogen (25 – 30 ppm).

Each customer contributes approximately 0.02 lbs of nitrogen to the facility per day.

Kentucky defines Total Nitrogen as the summation of the analytical results for Total Nitrates, Total Nitrites, and Total Kjeldahl Nitrogen. Concentrations values for Total Nitrogen are currently a report only. Effluent NH3-N has quantity and concentration limits. These concentration and quantity limitations vary for each plant. The concentration is reported as mg/L and the quantity is reported in pounds.

When sampling for ammonia nitrogen **the sample must be acidified with sulfuric acid (H_2SO_4) to a pH of less than 2 standard units and cooled to < 6^0C with a holding time of 28 days.**

Problem #7

The effluent ammonia as N from a .5 MGD contact stabilization plant with a flow of .25 MGD is 6 mg/L. How many **lbs of ammonia** as N are in the effluent?

Problem #8

The effluent ammonia as N poundage is 67.5 lbs with an effluent flow of 1.1 MGD. **What is the concentration** of ammonia as N in the effluent?

Phosphorus

Municipal wastewaters may contain from 5 to 20 mg/L of total phosphorous, of which 1-5 mg/L is organic and the rest in inorganic. The per capita phosphorous contribution per inhabitant per day **averages about 0.0048 lbs/person/day**.

Normally secondary treatment can only remove 1-2 mg/L, so a large excess of phosphorous is discharged in the final effluent, which can lead to eutrophication in surface waters. When sampling for total phosphorus the sample must be acidified **with sulfuric acid (H_2SO_4) to a pH of less than 2 standard units and cooled to < 6^0 C with a holding time of 28 days.**

Effluent Total Phosphorus is a measure of all the various forms of phosphorus that are found in a water sample. Phosphorus is an element that, in its different forms, stimulates the growth of aquatic plants and algae in water bodies. Currently, phosphorus concentration limitations are 1.0 mg/L as an average and 2.0 mg/L as a maximum. Sample types are usually a composite sample as stated in your permit.

The population equivalent for phosphorus is .0048 lbs per person per day.

Problem #9

If the flow to a 7 MGD wastewater treatment plant is 5.5 MGD and the population of this served community is 45,000 people, how many lbs of phosphorus will be in the influent daily?

Population X lbs per person/day

Metals

The 10 most prevalent metals in the influent are:

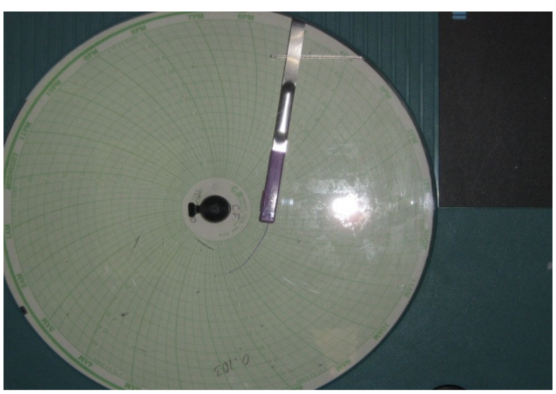
Pollutant	Symbol	Avg. Influent Concentration/mg/L
Cadmium	Cd	0.003
Chromium	Cr	0.05
Copper	Cu	0.061
Lead	Pb	0.049
Nickel	Ni	0.021
Zinc	Zn	0.175
Arsenic	As	0.003
Mercury	Hg	0.0003
Silver	Ag	0.005
Cyanide	CN	0.041

All metals, with the exception of mercury and chromium VI, are preserved with Nitric acid (HNO_3)to a pH of less than 2 and stored at < $6^{0}C$ for 28 days. Metals are considered **conservative pollutants**. These are pollutants that are not altered by the microorganisms and pass through the plant.

Flow

Flow is the volume of water moving through a location during a specific time period.

Results are normally expressed in million gallons per day (MGD).



Flow does **NOT** have a limitation and is report only.

A flow meter can be a requirement in your permit

The design flow through a wastewater treatment plant is determined by the number of residential customers and the estimated industrial flow. The design of a facility is determined by an average **flow of 100 gallons per person per day.** Flow measurement and recording is required by the permit issued to the facility. The flow meters need to be calibrated on a regular schedule.

The flow during a composite sampling period is what is used to determine the loading in pounds and mg/L. The flow measurement and recording must be accurate to +/- 10 %.

To calculate Flow in MGD, use the following equation:

Pounds ÷ (8.34 X concentration mg/L) = MGD

Problem #10

From the DMR you know the effluent BOD poundage is 871.2 lbs and the effluent BOD was 12 mg/L. What is the **flow in MGD**?

Problem #11

The influent TSS loading is 381.2 LBS and the influent TSS concentration is 176 mg/L. What is the flow in MGD?

Problem # 12

A city with a population of 8,000 people is building a new wastewater treatment plant. How many MGD should it be designed to treat?

Biological Samples/Fecal Coliform, E coli

Fecal coliform bacteria and Escherichia coli are microorganisms that grow at elevated temperatures and are associated with the fecal material of warm-blooded animals. The measurements of these organisms serve as an indicator of the level of effectiveness of disinfection. Results are reported as colony count per 100 milliliters of sample (N/100 ml).

Typical colony count limitations for fecal coliform bacteria are 200 for the monthly average and a maximum of 400. E coli colony count limitations typically are 130 for a monthly average and 240 for a maximum. Most permits require these results to be calculated by geometric averaging, not arithmetic averaging.

Sample collection and preservation is extremely important in obtaining accurate results from these types of samples. The samples must be collected with a sterile collection apparatus and then **preserved at a temperature of < 6^{0}C for no longer that 6 hours before analysis.**

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen in the water available for aquatic organisms. The dissolved oxygen level required in the effluent is set by the permit parameter. A typical D.O. limit normally is 7.0 mg/L, but other values are possible. For reporting purposes, D.O. is usually the lowest value (minimum) during the reporting period. It is a grab sample that is analyzed immediately. There is no preservation or holding time for DO samples.

Before sampling for either process control or effluent sampling can begin the meter that is to be used has to be calibrated. Follow the manufacturer's instructions for calibration. After calibration record the calibration in the calibration log book along with the date, time and your name.

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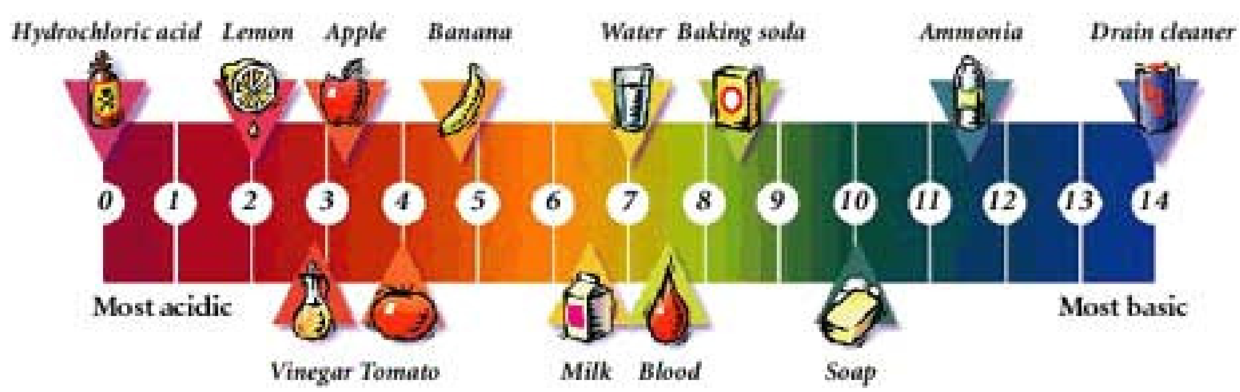
pH

pH is a measurement of the hydrogen ion (H+) concentration in a solution expressed as the negative log of the hydrogen ion concentration in standard units (SU). The pH scale measures the acidity or alkalinity of a solution. An acid is a chemical that releases hydrogen ions when dissolved in water, lowering pH**.** A base is a substance that produces hydroxide ions (OH^-) when dissolved in water, raising pH. At a pH of 7, the amount of (H+) ions is equal to the amount of (OH-) ions present, and the solution is said to be neutral.

Solutions with pH < 7 are increasingly acidic. Solutions with pH >7 are increasingly basic (alkaline).

Before sampling for either process control or effluent sampling, the meter that is to be used must be calibrated. For example, if the normal effluent flow pH is between 7 and 8 a 7 buffer and a 10 buffer should be used. Follow the manufacturer's instructions for calibration. After calibration record the calibration in the calibration log book along with the date, time and your name.

The pH Scale



pH results are expressed in standard units (S.U.). pH **limits usually fall between 6.0 – 9.0 standard units**. Sample results are NEVER averaged.

Chlorine

Chlorine is one of the methods that is used to disinfect wastewater effluents. The monthly average limitations are 0.011 mg/L and the daily maximum is 0.019 mg/L.

The meter used to determine the chlorine level must be calibrated daily. The calibration should be accomplished using the appropriate buffers.

Total residual chlorine is the amount of measurable chlorine remaining after treating water with chlorine i.e. amount of chlorine left in water after the chlorine demand has been satisfied.

Abbreviation or Acronym	Full Phrase	Definition
MGD	Million Gallons Per Day	A measure of flow
cfs	cubic feet per second	A measure of flow
SU	Standard Units	A measure of pH
mg/l	milligrams per liter	A measure of pollutant concentration (1000 milligrams = 1 gram)
µg/l	micrograms per liter	A measure of pollutant concentration (1000 micrograms = 1 milligram)
^{o}F	Degrees Fahrenheit	A measure of temperature
^{o}C	Degrees Centigrade or Celsius	A measure of temperature
N/A	Not Applicable	
lbs/day	pounds per day	A measure of pollutant loading

Chapter 2 Review Questions

1. Define a grab sample.
2. Explain composite sampling.
3. How many pounds (lbs) of BOD, TSS, and phosphorus are contributed by each person per day?
4. Design capacity of a treatment facility is determined by ___________ gallons per person per day?
5. What is the preservative for ammonia as nitrogen sample?
6. Define TSS?
7. Define dissolved oxygen?
8. Define BOD?
9. What acid is used to preserve most metals samples?

Answers for Chapter 2 Review

1. Grab samples represent the conditions that exist at the moment the sample is collected and do not necessarily represent conditions at any other time.
2. A 24-hour composite sample is composed of discrete equal volume aliquots (100 ml minimum) collected every 15 minutes over a 24-hour period and aggregated by an automated sampling device. The aggregate sample will reflect the average water quality of the compositing or sample period. The permit will specify which composite sample type to use, either time composites or flow proportional composites.
3. BOD = .17 lbs.; TSS = .2 lbs; phosphorous .0048 lbs.
4. 100 gallons
5. Sulfuric acid to pH of less than 2.
6. Total Suspended Solids (solids that will not pass through special glass filter)
7. The amount of oxygen available to aquatic organisms.
8. Biochemical Oxygen Demand (is food for the organisms and measure of the organic strength of wastewater).
9. Nitric acid

Answers for Chapter 2 Math

Problem #1

The influent concentration of TSS to a 2 MGD oxidation ditch is 189 mg/L, the BOD influent concentration is 154 mg/L and the influent flow is 1.5 MGD. How many pounds of TSS enter this plant daily?

1.5 MGD X 8.34 X 189 mg/L TSS = 2364.4 lbs/day

Problem #2

The flow to a 1MGD extended aeration plant is 725,000 GPD and the influent TSS concentration is 157 mg/L. How many pounds of TSS per day does this facility receive? To convert 725,000 GPD to MGD you can 1) move the decimal point 6 places to the left **or** 2) divide by 1,000,000

.725 MGD X 8.34 X 157mg/L TSS = 949.3 lbs. /day

Problem #3

The initial DO of a 15 /ML sample was 7.1 mg/L and the finial DO after 5 days of incubation at 20^{0}C in a 300 /ML sample bottle was 4.1Mg/L. What was the BOD in **mg/L**?

$$\frac{(7.1 \text{ mg/L} - 4.1 \text{ Mg/L}) \text{ X } 300 \text{ /ML}}{15 \text{ /ML}} = 60 \text{ mg/L}$$

Problem #4

The influent organic load to a 2.5 MGD wastewater treatment plant 3678.5 lbs with an influent flow of 1.9 MGD. What is the BOD concentration in the influent?

1.9 MGD X 8.34 = 15.84

$$\frac{3{,}678.5 \text{ LBS}}{15.84} = 232.2 \text{ mg/L}$$

Be certain to pay attention to any necessary conversions (gallons per day vs. MGD).

Problem # 5

The influent flow to a 50,000 GPD package treatment plant is 41,000 GPD and from the discharge monitoring report you know that the average poundage in the influent is 51.6 lbs. What is the BOD **concentration** in mg/L?

Convert 41,000 GPD to MGD by moving the decimal 6 places to the left or divide by 1,000,000

.041 MGD X 8.34 = 0.3419

$$\frac{51.6 \text{ lbs}}{.3419} = 150.92 \text{ mg/L}$$

Problem # 6

If the influent BOD concentration is 51.6 mg/L and the effluent BOD concentration is 3.12 mg/L . What is the **percent removal** of BOD?

$$\frac{51.6 \text{ mg/L} - 3.12 \text{ mg/L}}{51.6 \text{ mg/L}} \times 100 = 93.9\% \text{ removal}$$

Problem # 7

The effluent ammonia as N from a .5 MGD contact stabilization plant with a flow of .25 MGD is 6 mg/L. How many **lbs of ammonia** as N are in the effluent?

.25 MGD X 8.34 X 6 mg/L = 12.51 lbs

Problem #8

The effluent ammonia as N poundage is 67.5 lbs with an effluent flow of 1.1 MGD. **What is the concentration** of ammonia as N in the effluent?

1.1 MGD X 8.34 = 9.174

$$\frac{67.5 \text{ lbs}}{9.174} = 7.36 \text{ mg/L}$$

Problem #9

If the flow to a 7 MGD wastewater treatment plant is 5.5 MGD and the population of this served community is 45,000 people. How many lbs of phosphorus will be in the influent daily?

Population X lbs per person/day

45,000 X .0048 lbs. P = 216.0 lbs P

Problem #10

From the DMR you know the effluent BOD poundage is 871.2 lbs and the effluent BOD was 12 mg/L. What is the **flow in MGD**?

8.34 X 12mg/L BOD = 100.08

$$\frac{871.2 \text{ lbs BOD}}{100.08} = 8.71 \text{ MGD}$$

Problem #11

The influent TSS loading is 381.2 LBS and the influent TSS concentration is 176 Mg/L. What is the flow in MGD?

8.34 X 176 mg/L = 1467.84

$$\frac{381.2 \text{ lbs TSS}}{1,467.84} = .259 \text{ MGD}$$

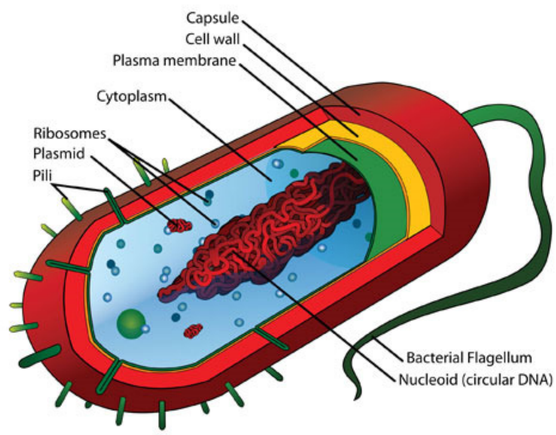
Problem # 12

A city with a population of 8,000 people is building a new Wastewater treatment plant. How many MGD should it be designed to treat?

Population X Flow /GPD per person = 8,000 X 100 GPD/Person = 800,000 GPD
Convert to MGD

MGD = .8 MGD

Chapter 3: Biology



Chapter 3 Objectives

1. Understand the basic structure and life functions of bacteria.
2. Demonstrate knowledge of population equivalents and its effect on nutrient ratios.
3. Describe the types of bacteria and identify the factors affecting bacteria.
4. Demonstrate an understanding of pH and its effects on the wastewater process.
5. Define and be able to calculate the food to microorganism ratio.
6. Understand the relationship between temperature and biological activity in the wastewater processes.
7. Demonstrate knowledge of shock loads, toxicity, and EPA mandated priority pollutants.
8. Demonstrate an understanding on the potentially detrimental effects of improper mixing procedures.
9. Demonstrate an understanding of the possible organic and hydraulic loadings added by industrial wastewater.

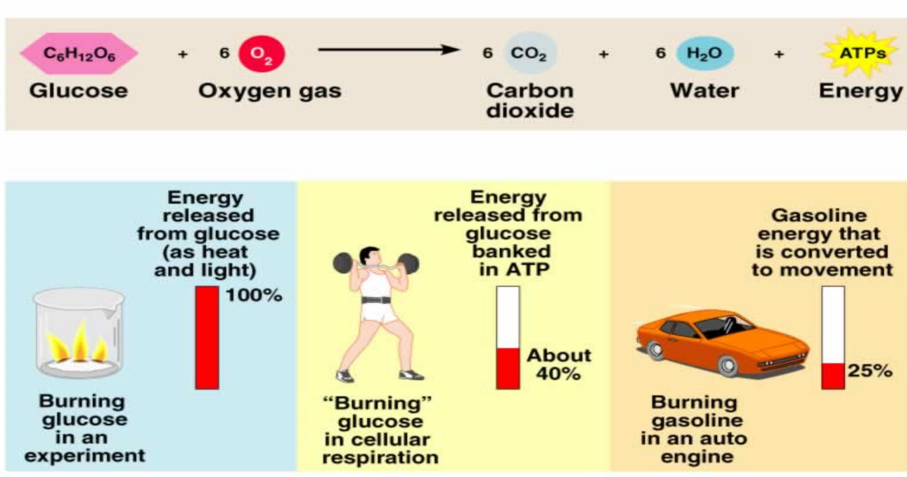
Biology as the Key to Successful Wastewater Treatment

The suspended growth/activated sludge process can be defined as "a mixture of microorganisms which contact and digest bio-degradable materials (food) from wastewater." In simple terms, activated sludge is microorganisms and the process is strictly biological.

To properly control the activated sludge process, the operator must properly control the growth of microorganisms. This involves controlling the items which may affect those microorganisms.

The activated sludge process is a biological method of wastewater treatment that is performed by a variable and mixed community of microorganisms in an aerobic aquatic environment.

These microorganisms derive energy from carbonaceous organic matter (BOD5) in aerated wastewater for the production of new cells in a process known as **synthesis**. Simultaneously these microorganisms are releasing energy through the conversion of this organic matter into compounds that contain lower energy, such as carbon dioxide (CO2) and water (H2O), in a process called **respiration**. The illustration below demonstrates the process of respiration.



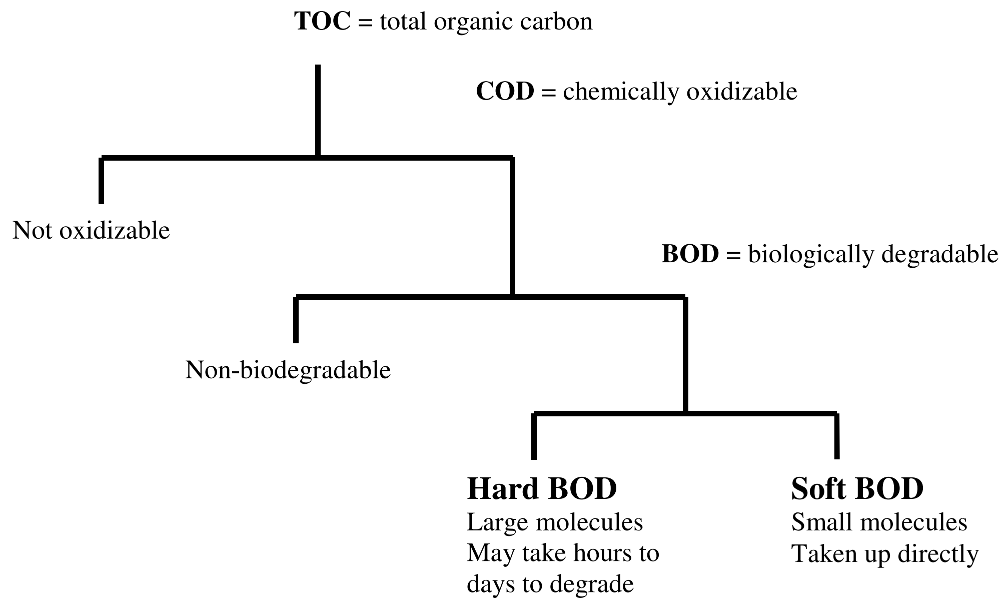
The overall goal of the activated sludge process is to remove substances that have a demand for oxygen from the system.

This removal is accomplished by the metabolic reactions (synthesis-respiration and nitrification) of the microorganisms, the separation and settling of the activated sludge solids to create an acceptable quality of secondary wastewater effluent, and the collection and recycling of microorganisms or returned activated sludge (RAS) back into the system or removal of excess microorganisms or waste activated sludge (WAS) from the system.

The influent flow (BOD_5) and RAS should be mixed as soon as is possible. The addition point of the RAS is important to the total treatment process. This point should be as close to the influent entry point as possible. This puts the bacteria in contact with the BOD_5 in the influent as soon as possible.

BOD Composition

Total organic carbon, or **TOC,** values include stable organic carbon that bacteria cannot degrade. The normal range in domestic wastewater is 200-250 mg/L. TOC is measured by burning a sample at high temperature (~550^{0} C) and measuring the carbon dioxide (CO_2) produced.



COD

Another measure of organic matter is the chemical oxygen demand, **COD**, which is normally in the range of 550 – 700 ppm. The COD analysis is a measure of the amount of oxygen necessary to oxidize all of the organic carbon in a sample completely to CO_2 and H_2O. COD values are expressed in **mg/L of oxygen.** Generally 1 gram of carbohydrate or protein is equivalent to 1 gram of COD.

The COD test is quicker to perform and results are more reproducible than with the BOD_5, test, but the **BOD_5 is the parameter required by the KPDES permit** and is a better indicator of biological toxicity. **COD** measures the quantity of organic matter that can be removed by chemical oxidation.

BOD

The BOD_5 concentration is always lower than the COD concentration due to the bacteria not being able to biodegrade all the carbon compounds that COD reports. Some of the biodegraded carbon is utilized by the bacteria for growth as new bacteria cells. BOD_5 only measures the carbon that is oxidized in respiration. It does not measure the carbon used for cell growth. A typical ratio of BOD_5/COD in the influent is about one pound of COD to 0.55 pound of BOD_5 with 0.2 pound of COD being biodegradable.

Most new KPDES permits now require measurement of $CBOD_5$ (carbonaceous biochemical oxygen demand) where a nitrification inhibitor is added to suppress the oxidation of ammonia to nitrite and nitrate by two groups of autotrophic bacteria (*Nitrosomonas & Nitrobacter*). This assures that only the oxygen demand for organic matter will be measured.

There are two types of BOD_5 in the influent, “soft” and “hard” BOD_5.

The soft BOD_5 is more readily degraded organic material. It is made up of smaller organic compounds and molecules that are attacked by the bacteria quickly and their removal may be accomplished in the first 1 to 2 hours of biological treatment.

The hard BOD_5 is made up of larger organic compounds that may take several hours or days to be removed.

The hard BOD_5 are first attacked by enzymes secreted by bacteria in the treatment process. These enzymes are released by the bacteria to begin the process of degrading the hard BOD_5 by breaking the larger organic compounds into smaller, less complex compounds and molecules that the bacteria can use for food for growth and reproduction.

These extracellular secretions also help to form and stabilize the floc particles. This enzymatic process may take several hours or days to accomplish, depending on the complexity of the compounds.

Some bacteria have the ability to secrete enzymes that are able to break down novel food sources, {benzene, toluene, etc.} to use for growth and energy. This process is known as acclimation or adaptation. The Biological Basis of Wastewater Treatment Peter Spencer Davies B sc. Ph. D, Strathkelvin Instruments Ltd.

These concentrated bacteria in the return sludge are the “activated” part of the activated sludge process.

These bacteria have been concentrated and deprived of both food (BOD_5) and oxygen in the secondary clarifier. When these organisms are mixed with the influent flow of BOD_5 there is a feeding frenzy as the organisms in the RAS have already acclimated or adapted to the normal BOD_5, TSS, DO and pH concentrations in the influent.

During this feeding frenzy the organisms take in enough energy to produce new cells in the process of synthesis.

Note that an individual bacterium has limited capacity for growth, only growing from the size of a new daughter cell produced at the time of division to the normal cell size. Growth rate of the bacteria is therefore measured as the increase in number of cells with time known as mixed liquor volatile suspended solids (MLVSS). The process these organisms use to reproduce is called binary fission.

If the optimum conditions are available the microorganisms have the capability to double their number every 20 minutes.

At this point in the treatment process, the food to microorganism (F/M) is high and the bacteria are reproducing as quickly as the environmental conditions will allow. This is called the log phase or the logarithmic growth phase of the growth curve.

As these organisms go through the process of degrading and stabilizing the wastewater, there are changes that take place to the organisms. These organisms mix with the influent and are dispersed throughout this section of the basin in small clumps and chains. The aeration used for mixing and DO addition keeps the bacteria dispersed. They have the ability to swim and feed on the soluble (soft) BOD_5 and secrete the enzyme-laden slime that breaks down the (hard) BOD_5. This ability to swim is provided by flagella, a whip like section of the organism.

The amount of BOD_5 removed by the dispersed bacteria is much less than that removed by the flocculated bacteria. The floc particles actually act like a sponge and pull the BOD5 to the floc particles.

As these bacteria move through the wastewater feeding they are also secreting the slime used to degrade the hard BOD_5 to soft. This slime is also instrumental in the formation of the floc particles that settle in the secondary clarifiers. Filamentous organisms (discussed later) may also be instrumental in floc formation.

When the bacteria take in the compounds they need for cell synthesis and respiration it is called **absorption**. When BOD_5, solids or other bacteria are caught up in the slime layer surrounding the bacteria it is called adsorption.

If there is a nutrient deficiency in the influent flow it may show up as a slime layer of microbial "fat" that does not allow the absorption of BOD_5 into the bacteria. The production of this bacteria "fat" has a detrimental effect on the percent removal of BOD_5. When the food to microorganism ratio (F/M) has decreased and the organisms have multiplied and degraded the BOD_5, in an attempt to save energy the bacteria lose their flagella and therefore they lose their ability to move.

Their movement is now dependent on the aeration process. The mechanical aeration process keeps the organisms mixed and in contact with the BOD_5, and DO by also adding oxygen.

There are as many bacteria as possible at this time in the treatment. This is called the stationary phase (see Figure 3.1) because the number of bacteria is stationary, some dying and some reproducing so the numbers stay basically the same.

The next phase of treatment would be the accelerated death phase (see Figure 3.1). This phase of treatment is when the bacteria are beginning to starve and die. The F/M is very low and most of the BOD_5 has been consumed.

As they move to the logarithmic death phase (see Figure 3.1) the bacteria are going into endogenous respiration. This is when there is little BOD_5 left in the water and they begin to ingest the bodies of the dead and dying bacteria around them. During this phase they also utilize stored carbohydrates from their energy storage areas.

The final phase is the survival phase. During this phase of treatment the bacteria are only staying alive by consuming their own cellular mass. No reproduction is occurring therefore there is no new cell sludge production.

The chart below shows the bacteria growth cycle in a suspended growth treatment process.

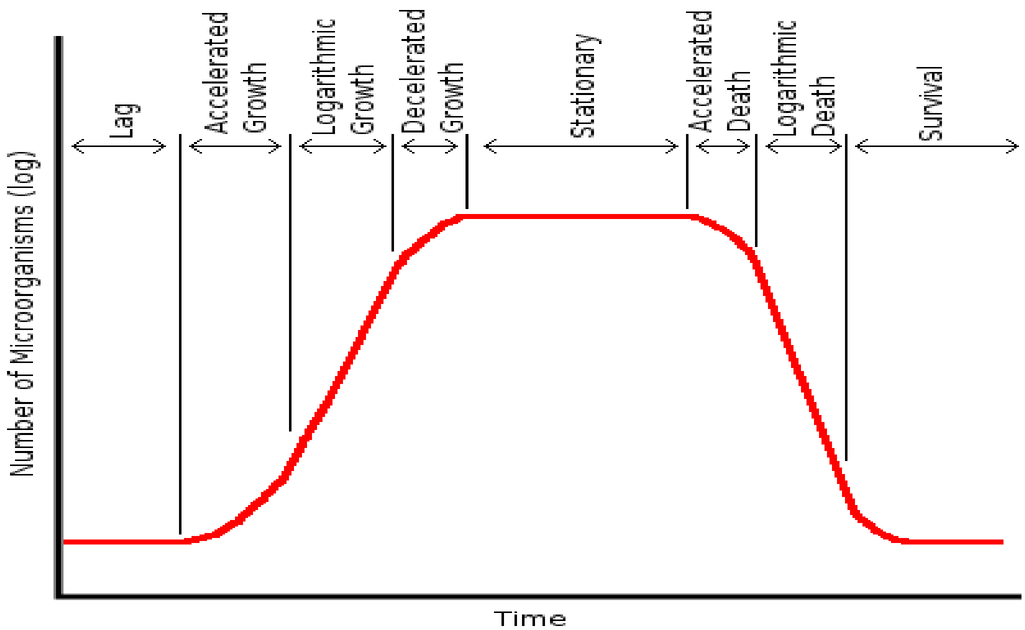


Figure 3.1

These phases are also used in the conventional activated sludge, contact stabilization and step-feed treatment designs as well as extended aeration and oxidation ditches. Each of these types of treatment may be operated as high or low growth rate system. This is accomplished by adjusting the F/M by raising or lowering the mixed liquor suspended solids (MLSS) concentration through adjustments made in sludge wasting.

When these types of treatments are operated in the low growth rate mode they have a lower F/M, a longer detention time in the plant and a more concentrated MLSS. This longer detention time/sludge age allows the bacteria to go into the endogenous respiration phase when the live bacteria feed on the dead and dying and use their stored carbohydrates/energy reserves.

Due to the longer detention time the amount of sludge produced is much less as the maximum growth rate was not achieved and most of the BOD_5 is used in the endogenous respiration phase of the treatment and converted to CO_2 and water (see Figure 3.2).

This change in treatment can be made by reducing the amount of sludge wasted until the concentration of MLSS is to a point where the F/M is at about 0.05. This level of F/M will put the bacteria into the required mode to produce more CO_2, H_2O and, other gaseous by-products than sludge, bacteria bodies (see Figure 3.2 and the section on Balanced Food Supply below for more information about how operators can control the F/M ratio).

When calculating the **food to microorganism ratio,** use the following equation:

F/M Ratio = pounds of incoming BOD ÷ pounds of MLVSS under aeration

Problem #1

The flow to a 1 MGD extended aeration plant is .8 MGD with a BOD concentration of 161 mg/L. The MLVSS in the aeration basin is 2,450 mg/L what is the food to microorganism ratio?

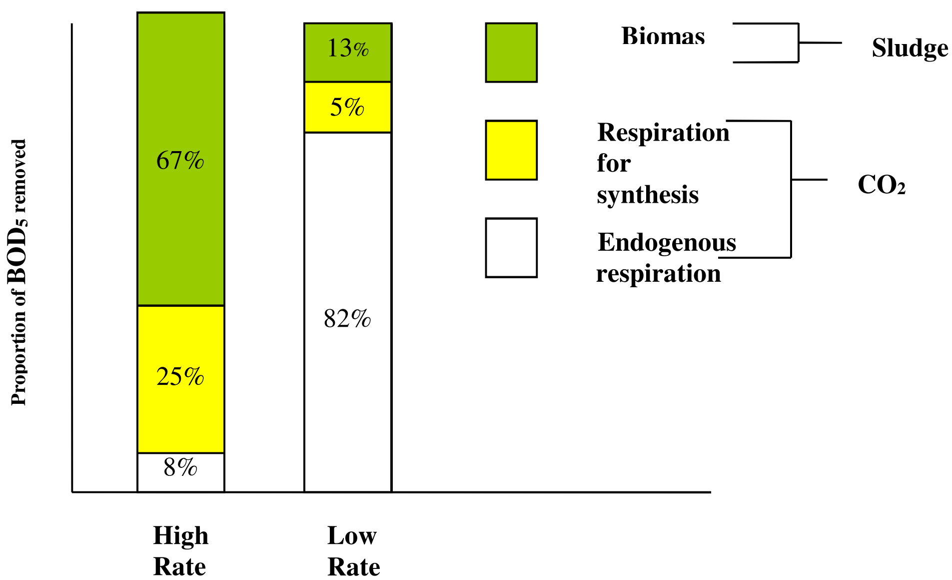
Problem #2

The flow to a 4.5 MGD oxidation ditch is 3.2 MGD with an influent BOD concentration of 188 mg/L. The MLSS of the oxidation ditch is 3,400 (65% of which is volatile). What is the F/M of this system?

As the bacteria use up to 70% of the available BOD for cell maintenance and produce CO_2 and H_2O in the process, they also produce heat. Most of this heat is lost to the environment through the outgassing of the gases produced. The outgassing of CO_2 also helps control the pH in the aeration basin

This low rate process will reduce the amount of sludge produced but it will also increase the amount of energy used for aeration. More concentrated MLSS means more air, more blowers, more mixing, more dollars for the electric bill but less money spent in sludge disposal. It is a trade off that is ultimately good for the environment, less sludge to the landfill.

Figure 3.2



These systems, when operated in a high growth rate mode, have a high F/M with a more concentrated MLSS which promotes high sludge production. This is due to most of the BOD_5 being used in the synthesis of new cells or biomass. The higher growth rate systems also use more energy due to the higher levels of aeration needed to keep the process going. The high growth rate systems normally have less detention time in-plant.

Biological Treatment – Design and Operational Considerations

Design and operational considerations are an important factor when discussing biological treatment. Some of the factors include the biological, chemical and physical aspect of the treatment process.

Population equivalents are estimates used to calculate hydraulic and organic loadings for domestic wastewater treatment if actual operating information is not available are as follows:

BOD5 = 0.17 lbs./capita/day
TSS = 0.20 lbs./capita/day
Phosphorus = 0.0048 lbs/capita/day
Nitrogen = 0.02lbs/capita/day
Flow = 100 gallons/capita/day

When calculating hydraulic loading or the surface loading rate use the following equation:

$$\textbf{Hydraulic Loading Rate (gal/ft}^2\textbf{/day)} = \frac{\textbf{Design Flow (gal/day)}}{\textbf{Area (ft}^2\textbf{)}}$$

Problem #3

What is the surface loading or hydraulic loading rate on a primary clarifier 75 feet in diameter, 10 feet deep, with an influent flow of 1.5 MGD?

When calculating the organic loading for an activated sludge plant use the following equation: **Lbs of BOD influent ÷ volume of the aeration basin in 1,000 ft^3**

Problem #4

The influent flow to a 2 MGD extended aeration plant is 1.3 MGD, the influent BOD is 169 mg/L. What is the organic loading on this facility in **lbs of BOD/1,000 ft^3**?

Problem #5

A community has a population 1900 people. They are served by a .25 MGD oxidation ditch what is the organic loading on this facility **in lbs of BOD per 1,000 ft^3**

Ideal nutrient requirements for biological stabilization of organic matter result in following ratio:

Carbon/Nitrogen/Phosphorus = C/N/P = 100/5/1

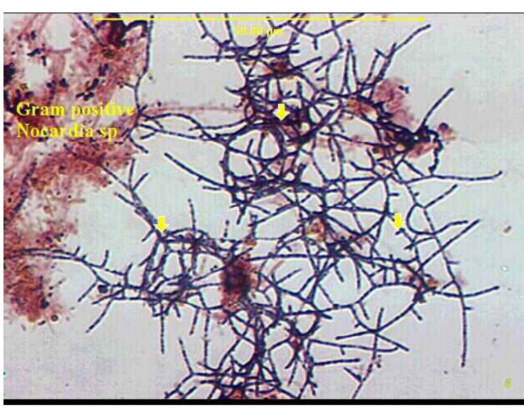
Another way of viewing this nutrient balance is to consider the BOD_5 as the carbon source so that for every 100 ppm of BOD_5 removed, there would have to be 5 ppm of nitrogen and 1 ppm of phosphorus available for cell synthesis. If the units of measure are the same it does not matter, it is the ratio that is important.

If a nutrient deficiency exists, the biological process could suffer from filamentous organism growth Problems. To obtain the necessary nutrients it may be necessary to add anhydrous ammonia for N, tri-sodium phosphate for P, or ferric chloride for Fe. Domestic wastewater flows usually have the proper nutrient ratio.

Excessive filamentous growth results in bulking sludge, which will not settle well in secondary clarifiers. A nutrient imbalance is normally caused by the addition of industrial wastewater to domestic flows.

Other causes of filamentous sludge bulking in activated sludge plants include:

- Low dissolved oxygen



- Low F/M = Food to Microorganism ratio
- Low pH
- Septic wastewater
- Toxicity
- Grease

Dissolved oxygen

The 2-5 mg/L of dissolved oxygen (DO) needed in an activated sludge plant is due to the oxygen requirements of the bacteria that degrade the BOD_5. The bacteria excrete an enzyme-laden slime that helps form stable floc particles.

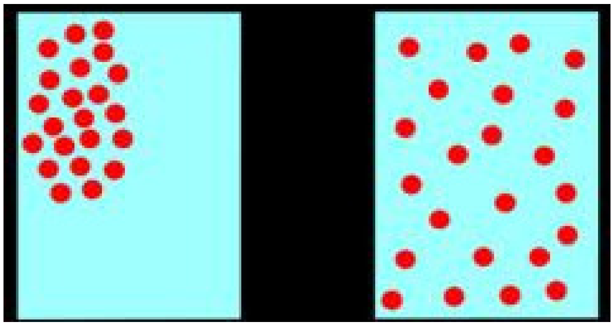
If less dissolved oxygen is supplied then the bacteria on the outer edges of the particle use the oxygen and the bacteria in the center of the floc particle die and the particle falls apart. This causes poor settling and normally a cloudy effluent due to elevated TSS.

The enzymes in the slime begin the process of breaking down the “hard” BOD_5 into its more basic components that the bacteria utilize for growth and reproduction.

Oxygen is constantly entering and leaving water, but there is a certain amount of oxygen in water at all times. This is because water has a natural attraction to oxygen.

When oxygen comes in contact with the surface of water, the oxygen tends to enter the water, becoming dissolved oxygen. The amount of attraction between oxygen and water depends on the amount of oxygen already in the water.

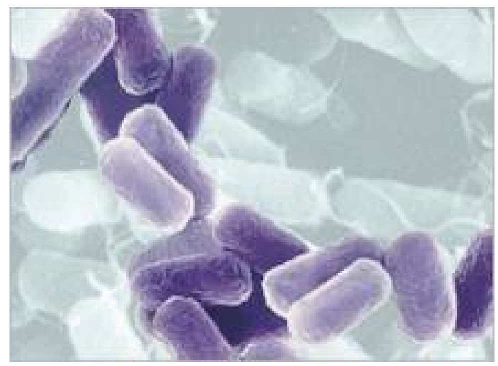
If there is very little oxygen in water, then the water is very attractive to oxygen. But when water has a high concentration of DO, then the water is **saturated**, meaning that the water contains as much oxygen as it can hold at that temperature.



The process of oxygen moving from an area with a high oxygen concentration to an area with a low oxygen concentration is known as **diffusion**.

Water temperature is very important in determining the amount of oxygen which will become dissolved in water. Cold water is able to hold more oxygen than warm water.

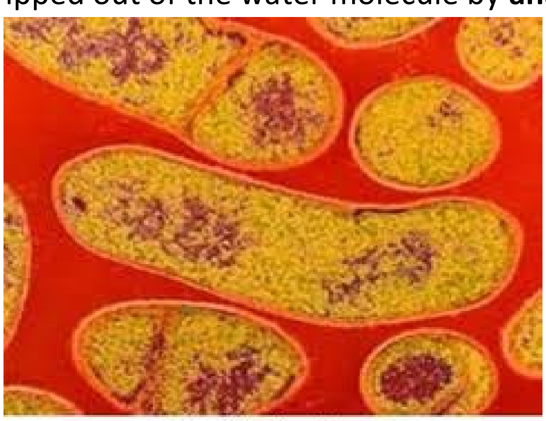
Aerobic Bacteria



Water, the home of most bacteria, contains oxygen in two forms. The first form, free oxygen, is the most readily available form. Free oxygen is basically the same as dissolved oxygen - oxygen from the atmosphere which has become dissolved in water. **Aerobic bacteria require free oxygen in order to survive.**

Anaerobic Bacteria

Oxygen can also be found in the water in another form. Food and even water itself contain oxygen, but this oxygen is tightly bound to the food and water. However the oxygen can be ripped out of the water molecule by **anaerobic bacteria**, but it takes much more energy to

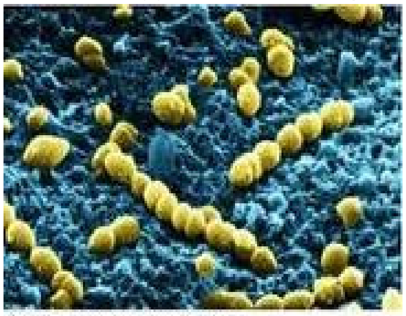


Clostridium botulinum

break apart food and water in search of oxygen than it does to simply use free oxygen. Since anaerobic bacteria use so much of their time and energy scrounging for oxygen, they take longer to digest organic matter in water.

Facultative Bacteria

The third type of microorganisms, those which are **facultative**, have properties of both aerobic and anaerobic organisms. They can live with or without free oxygen. When the oxygen content of water is high, facultative bacteria consume food very quickly using the free oxygen in the water. In low oxygen concentrations, facultative bacteria are still able to consume organic material, although they do so much more slowly.



Streptococcus pneumoniae
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In the activated sludge process, sludge age is a measure of the length of time a particle of suspended solids has been undergoing aeration, expressed in days. It is usually computed by dividing the weight of the MLSS in the aeration tank by the weight of influent TSS.

When calculating **sludge age,** use the following equation:

$$\frac{\textbf{Lbs of MLSS in the aeration basin}}{\textbf{Lbs of TSS in the influent}} = \textbf{SLUDGE AGE/DAYS}$$

Problem # 6

The influent flow to a 7.5 MGD facility is 6.4 MGD with an influent TSS concentration of 156 mg/L with a MLSS concentration of 3,375 mg/L. What is the sludge age of this facility in days?

Problem #7

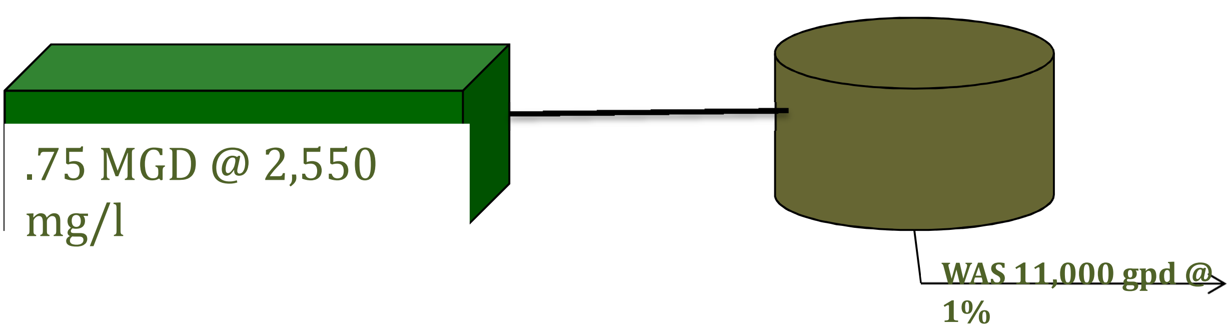
The sludge age that produces the least amount of sludge at a 3.5 MGD treatment facility is 19.5 days. The influent flow is 2.8 MGD with a TSS of 209 mg/L . How many lbs of solid are needed in the aeration basins to meet the 19.5 day old sludge?

Mean Cell Residence Time

The mean cell residence time or MCRT is the amount of time, in days, those solids or bacteria are maintained in the activated sludge process. Mean cell residence time is a key operating parameter because it directly controls nearly all other parameters when operating a biological treatment system. The unit of sludge age is “days,” and is termed the “specific growth rate of the sludge.” The daily wasting of activated sludge solids equals their daily growth. A portion of the daily solids production is lost in the effluent and this loss must be taken into account when calculating the sludge age. To determine the pounds of suspended solids leaving the activated sludge process, the pounds of suspended solids lost through wasting and discharged in the secondary effluent must be calculated. The pounds of suspended solids leaving the activated sludge process consists of pounds of activated sludge wasted per day and the pounds of activated sludge or secondary effluent solids discharged per day. The MCRT of an activated sludge process can be calculated by dividing the pounds of suspended solids or MLSS in the activated sludge process by the pounds of suspended solids leaving the activated sludge process.

Here is an example problem:

$$\text{MCRT, Days} = \frac{\text{Lbs, MLSS in Secondary System}}{\text{Lbs/day SS Wasted + lbs/day SS in effluent}}$$



Problem #8

What is the mean cell residence time for a .75 MGD extended aeration plant with a MLSS of 2,550 mg/l, an influent flow of .56 MGD an effluent TSS of 14 mg/l and a waste sludge flow of 11,000 gpd at 1 % concentration?

pH

The bacteria that are responsible for the degradation and stabilization of the wastewater activated sludge process work best in a **pH range of 6.8 to 7.2** but they have the ability to live and work in either depressed or elevated pH values. Less than optimal pH levels affect bacterial efficiency.

A change in pH can temporarily favor the growth of other microorganisms which may be less beneficial to the treatment process. For example, more acidic conditions promote the growth of fungi which do not settle very well and thus cause serious operational Problems at the plant. Finally, and perhaps most importantly, pH influences the ability of enzymes to function.

Balanced Food Supply

Food to microorganism (F/M) ratio is the pounds of BOD in the influent divided by the pounds of the mixed liquor volatile suspended solids in the aeration tanks. **This ratio is controlled by the operator to manipulate the biological treatment process.**

The operator controls the food to microorganism ratio (F/M) by the amount of sludge wasted from the system. To raise the F/M the operator would increase the amount of sludge wasted. This would reduce the number of microorganisms therefore raising the F/M. In order to lower the F/M, a decrease in sludge wasting would be indicated.

The F/M is used to help determine the amount of sludge to be wasted to maintain optimization of the treatment process and to maintain a F/M in the recommended design range of **0.05 to 0.15** for extended aeration systems with nitrification. This is accomplished by determining the pounds of BOD5 in the influent and the pounds of mixed liquor volatile suspended solids (MLVSS) in the aeration section of the treatment facility.

The F/M ratio also reveals something about growth and cell condition. If the F/M ratio is high, the microorganisms normally grow quite rapidly because there is a lot of "food" available in comparison to the amount of microorganism. If the F/M ratio is low, the microorganisms normally grow very slowly due to little food being available for growth.

The F/M ratio controls how well the process performs. The entire process produces roughly one half pound of solids each day per pound of BOD removed, which must be removed or wasted from the treatment system to keep the process in balance.

When optimizing the F/M ratio, operators must ensure a sufficient amount of microorganisms are present to digest the incoming BOD. In order to control the F/M ratio, **operators must know:**

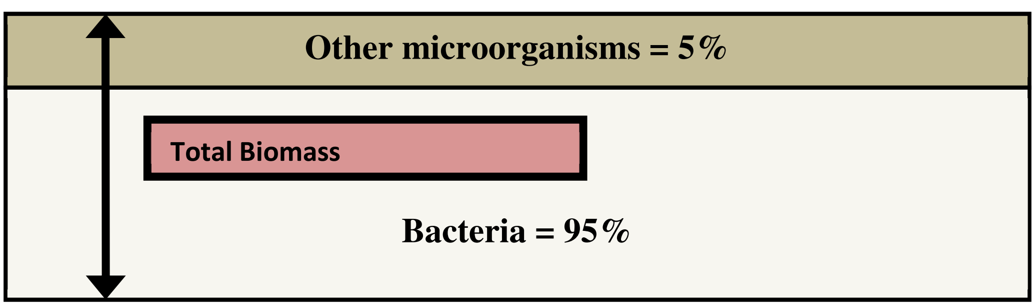
- RAS (Returned Activated Sludge) flow rates
- BOD loading
- Influent flow rate
- Solids percentage in the RAS

The "F" (food) portion of the ratio is determined by the BOD and flow measurements taken at the plant influent. The "M" (microorganism) portion of the equation is determined by monitoring both the **MLVSS (Mixed Liquor Volatile Suspended Solids)** concentration and the RAS flow rate.

Problem #9

The flow to a 1.5 MGD treatment facility is 1.1 MGD with an influent BOD of 216 mg/L, the F/M is .051. How many lbs of MLVSS should be maintained in the aeration section of this plant to continue the .051 F/M?

Active Living Biomass
(Measured as MLVSS)



LBs /BOD influent ÷ lbs MLVSS/ aeration basin = F/M

Temperature

Temperature controls the reaction rate. For example the metabolism reportedly drops by one half for a 10^o drop in temperature (25^o to 15^o C). Both high and low temperatures can be Problematic to microorganisms, due to each species having a temperature range in which growth is optimized.

Cold temperatures affect microorganisms by slowing down chemical reactions. **Most microorganisms will not be killed by low temperatures**, but their growth and reproduction will slow down or cease completely when temperatures drop below a certain point.

As mentioned above (see DO) **cold water holds more oxygen than warm water**. As the temperature of the wastewater increases the activity of the microorganisms increases but the amount of oxygen available decreases.

During elevated temperatures (**summer**) a lower concentration of microorganisms (MLSS) is needed to degrade and stabilize the BOD_5.

During depressed temperatures (**winter**) a higher concentration of microorganisms (MLSS) is needed to degrade and stabilize the same amount of BOD_5.

As with the other environmental variables, there is no single temperature at which all microorganisms thrive. Scientists place bacteria into three groups based on their tolerance for heat and cold (see Table 3.3)

Table 3.3 Bacterial Temperature Ranges

Bacteria	Temperature Range
Psychrophilic	Below 68°F (20°C)
Mesophilic	68°F - 113°F (20°C - 45°C)
Thermophilic	>113°F (45°C)

Free From Toxins

Toxin is any chemical that is harmful to an organism. The EPA has identified six pollutants which are potentially of concern to all wastewater treatment plants because of their widespread occurrence. They are referred to as "**priority pollutants**" and are as follows: **cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn).**
Four additional pollutants presumed to be of concern unless initial testing shows that they are <u>not</u> present are **arsenic (As), cyanide (CN), silver (Ag), and mercury (Hg).**

Other toxins such as herbicides, pesticides and waste oils have the capability to inhibit or kill off the bacteria needed to remove the BOD5.

Mixing
Processes are detention time-dependent for adequate treatment. Problems can be caused by:

1. short circuiting effects (object obstruction, un-level weirs, improper baffling, temperature gradients, etc.) / or

2. incomplete mixing (aerators on low speed, diffusers turned down too low or clogged, inadequate horsepower, improper design, mud or chemical sludge dragging solids to the bottom, floating aerators on deep basins with no draft tubes, etc.).

Another hydraulic influence is the effect of inflow and infiltration (I&I) on the treatment facility during and after wet weather events. Influent flows may increase appreciably during I & I events. These elevated flows shorten the detention time.

Ways to Mitigate I & I
1. use of flow equalization basins at the facility,
2. catch/detention basins in the collection system or
3. remove/rehabilitate I&I sources in the collection system.

Energy Efficiency
It should always be considered. Wasting energy goes against principles of conservation and work output.

Other Treatment Process Influences

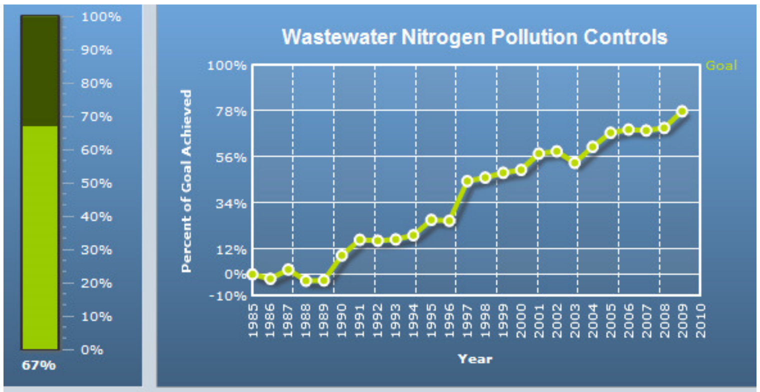
Other influences that can affect the biological treatment process include:

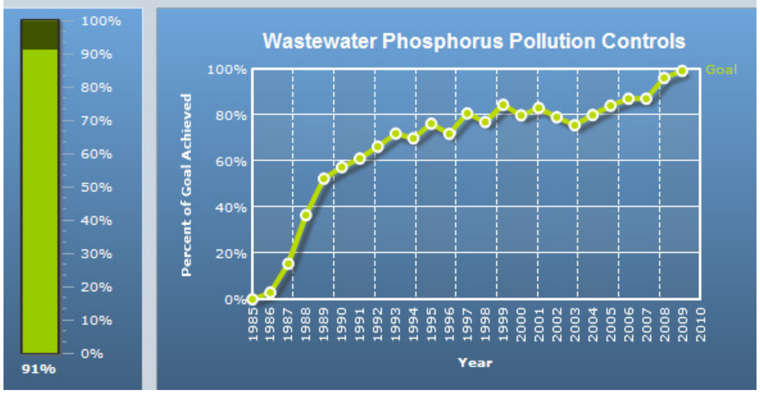
1. **Shock Loads** are increases in organic loading on the system. A shock load may upset the nutrient balance as well as overwhelm the biological population. For example, septic tank hauling typically has a **BOD5 of 2,000 to 6,000 mg/L and TSS concentration of 2-4% (20,000 – 40,000 mg/L).**

2. **Slug Loads** occur when treatment plants receive spills or dumps of unknown origin. These could be harmful to the treatment process and/or the operators. The key is to obtain as much information as possible to identify the chemical nature, concentration, and volume of the spill.

Maintain Accurate Log Information

Daily operations logs should also contain information on daily rainfall, temperature, and wastewater flows. This information may sometimes correlate to changes in the efficiency of the treatment process. Trend charts and /or bar graphs are the best methods for presenting lab data and process control parameters such as F/M, MCRT, and MLSS.





Industrial Wastewater

Industrial wastewater is potentially detrimental to the operation of your treatment facility. Below are the most frequently occurring industrial wastes in Kentucky:

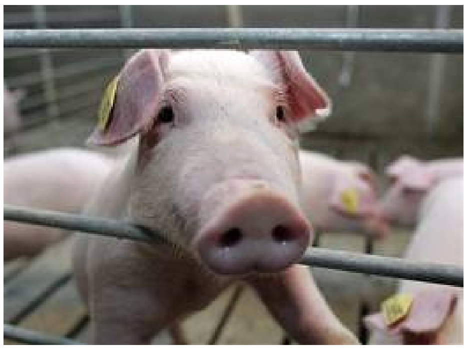
1. **Tannery Wastes** are wastes from the manufacture of leather from animal hides. Waste is high strength in salt, BOD5 (~1000 ppm), & TSS (~8000 ppm). Normal treatment is pre-screening followed by biological treatment.

2. **Dairy Wastes** are wastes from milk-product installations including bottling plants, cheese factories, and ice cream plants. Waste is high strength in BOD5 and TSS with BOD5 ranging from 1000 to 10,000 ppm.

Normal treatment is flow equalization, pretreatment by chemical precipitation, and biological treatment. Nutrient addition may be required for biological processes.

3. **Pulp and Paper Wastes** are wastes that are produced from the recovery of fiber from wood or other vegetable matter for subsequent processing into paper. BOD5 ranges from 200 to 1000 ppm. Normal treatment is primary settling followed by stabilization ponds, chemical precipitation or activated sludge. Nutrient addition may be required.

4. **Meat Packing Wastes** are wastes produced from stockyards, slaughter houses, and packing houses. Stockyard wastes (manure, straw, etc.) are suitable for land disposal. Slaughter and packing house waste is extremely high strength with BOD5 up to 400,000 ppm. Average water use is from 1000 to 5000 gallons per 1000 pounds of live weight killed.



Normal treatment includes pretreatment to include flow equalization, screening, and grease and solids separation by gravity and/or dissolved air flotation, and aerobic or anaerobic biological treatment.

5. **Fermentation Wastes** are wastes produced from the breaking down of sugars and starches into simpler compounds by yeasts (beer, wine, alcohol, and penicillin). Unfermented raw materials are recovered as insoluble solids and used as animal feed and the production of certain chemicals. Water use in the brewery industry is generally 10 to 15 gallons per gallon of beer produced. Strength of wastes varies from brewery BOD5 = 500 to 1000 ppm to antibiotic BOD5 = 20,000 ppm. Normal treatment is biological (trickling filters and anaerobic digesters). Nutrient addition may be required.

6. **Fruit and Vegetable Processing Wastes** are wastes from preliminary cleaning, blanching, canning, and juicing. Wastes can be highly variable in strength. Normal treatment includes screening, grit removal for root crops, sedimentation for potato, tomato, and carrot process wastewater. Biological treatment can be effective if nutrient deficiency and seasonal loading Problems can be overcome.

7. **Textile Wastes** are wastes produced from the manufacture of woven fabrics from either natural (wool, cotton, silk) or synthetic (rayon, acrylics, polyester) fibers. The primary wastes from natural fibers are dirt, grease, and waxes. The main synthetic wastes are the chemicals used in the processing. For every 1000 pounds of wool sheared, 400 pounds of finished wool is produced and the rest is waste.

Normal treatment includes flow equalization, pH adjustment, screening, chemical treatment for removal of metals or coagulation for removal of detergents, and subsequent biological treatment.

8. **Petroleum Wastes**: Wastes produced from the production or refining of oil. Brine is the main waste produced and is normally disposed by injection. It may also be treated by solar evaporation, dilution, or chemical coagulation. Normal treatment includes oil and water separation, chemical coagulation, sedimentation, and biological treatment.

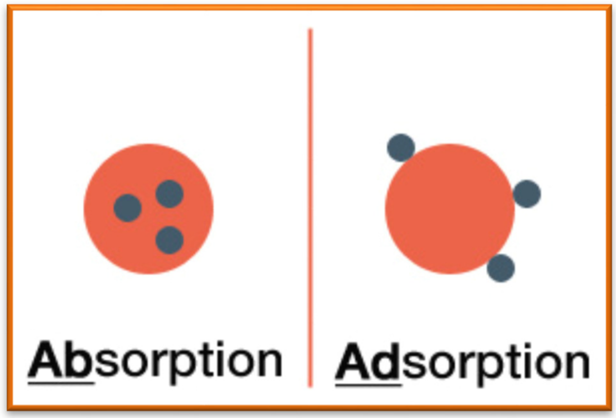
9. **Metal Finishing Wastes**: Wastes produced from the cleaning, hardening, softening, roughing, smoothing, coating, and plating of various metals. Metals most commonly plated are copper, cadmium, nickel, zinc, and chromium. Toxic materials produced are acids, chromium, zinc, copper, nickel, tin, and cyanide.

a. Normal treatment is by chemical addition due to high toxicity to biological treatment systems. The solubility of most metals of concern is directly affected by pH. By adjusting the pH to the point of least solubility for the metal, it can be precipitated out.

b. Cyanide wastes are normally treated using alkaline chlorination due to the release of highly toxic HCN gas at low pH values.

ACTIVATED CARBON

ABSORPTION – Taking in or soaking up of one substance into the body of another by molecular or chemical action (tree roots absorb dissolved nutrients in the soil).



ADSORPTION – The attraction and accumulation of a gas, liquid, or dissolved substance on the surface or interface zone of another substance (similar to a magnet).

1. Activated carbon adsorption is used to provide tertiary treatment to treatment plant effluents primarily to remove organics such as PCBs, phenols, and solvents.

2. Detention times are typically 15-35 minutes.

3. Removal efficiencies of organics are measured by COD & turbidity results on a routine basis.

4. Typical loading rates: Hydraulic = 2 to 10 gal/min/ft^2.
Organic = 0.5 lbs. COD/day/lb. of carbon

5. TSS concentrations of 20 mg/L or higher from secondary effluents will deposit on the carbon granules as a floc resulting in high pressure loss and blockage of flow. Similarly, variations in pH, temperature, and flow rate may adversely affect carbon adsorption.

Chapter 3 Review Questions

1. What type of Bacteria use dissolved oxygen to feed on BOD?
2. What is the proper nutrient ratio?
3. What effect does the Dissolved Oxygen level have on the bacteria?
4. List the three types of bacteria by their type of oxygen usage?
5. The process of producing a new cell is referred to as ______________.
6. What is the proper pH range for wastewater treatment?
7. List three other factors that affect the bacteria's ability to stabilize wastewater.
8. How does a low food to microorganism ratio (F/M) affect sludge production?
9. In what season does your MLSS need to be more concentrated?

Answers for Chapter 3 Review

1. Aerobic
2. 100 carbon / 5 nitrogen /1 phosphorus
3. At 2-4 mg/L, the optimum level, the bacteria have sufficient oxygen to stabilize the waste.
4. **Aerobic** (DO) **Facultative** (DO or Molecular Oxygen) **Anaerobic** (without DO)
5. Synthesis
6. 6.8 - 7.2
7. pH, temperature, DO, toxin-free, balanced food supply, nutrient requirements,
8. reduces sludge production
9. winter

Answers for Chapter 3 Math

Problem #1

The flow to a 1 MGD extended aeration plant is .8 MGD with a BOD concentration of 161 mg/L. The MLVSS in the aeration basin is 2,450 mg/L what is the food to microorganism ratio?

Lbs BOD in influent = .8 MGD X 8.34 X 161 mg/L = 1,074.2 lbs BOD influent

Lbs MLVSS in aeration basin = 1 MGD X 8.34 X 2,450 mg/L MLVSS = 20,433 lbs MLVSS

$$\frac{\text{1074.2 lbs BOD}}{\text{20,433 lbs MLVSS}} = .052$$

Problem #2

The flow to a 4.5 MGD oxidation ditch is 3.2 MGD with an influent BOD concentration of 188 mg/L. The MLSS of the oxidation ditch is 3,400 (65% of which is volatile). What is the F/M of this system?

Lbs of BOD influent = 3.2 MGD X 8.34 X 188 mg/L = 5,053.44 lbs BOD influent

4.5 MGD X 8.34 X 3,400 MG/L X .65 = 82,941.3 lbs

$$\frac{\text{5,053.44 lbs}}{\text{82,941.3 lbs}} = \text{.061 F/M}$$

Problem #3

What is the surface loading or hydraulic loading rate on a primary clarifier 75 feet in diameter, 10 feet deep, with an influent flow of 1.5 MGD?

$$0.785 \times 75^2 = \text{4,415.62 sq ft}$$

$$\frac{\text{1,500,000 GPD}}{\text{4,415.62 sq ft}} = \text{339.7 GPD/sq ft}$$

When calculating the organic loading for an activated sludge plant use the following equation: **Lbs of BOD influent ÷ volume of the aeration basin in 1,000 ft^3**

Problem #4
The influent flow to a 2 MGD extended aeration plant is 1.3 MGD, the influent BOD is 169 mg/L. What is the organic loading on this facility in **lbs of BOD/1,000 ft^3**?

Lbs of BOD influent = 1.3 MGD X 8.34 X 169 mg/L = 1,832.29 lbs BOD

Aeration tank Volume in ft^3 = 2,000,000 gal ÷ 7.48 gal/ft^3 ÷ 1,000 = 267.379 $_{1,000}$ ft^3

$$\frac{1{,}832.29 \text{ lbs BOD}}{267.379\ _{1,000}\text{ ft}^3} = 6.85 \text{ lbs BOD}/\ _{1,000}\text{ ft}^3$$

Problem #5
A community has a population 1900 people. They are served by a .25 MGD oxidation ditch what is the organic loading on this facility **in lbs of BOD per 1,000 ft^3**

Lbs BOD = 1,900 people X .17 lbs BOD person/day = 323 lbs BOD/day

250,000 gallons ÷ 7.48 gallons/ft^3 ÷ 1,000 = 33.422 $_{1,000}$ ft^3

$$\frac{323 \text{ lbs BOD}}{33.422\ _{1,000}\text{ ft}^3} = 9.66 \text{ lbs BOD}/\ _{1,000}\text{ ft}^3$$

Problem # 6
The influent flow to a 7.5 MGD facility is 6.4 MGD with an influent TSS concentration of 156 mg/L with a MLSS concentration of 3,375 mg/L. What is the sludge age of this facility in days?

7.5 MGD X 8.34 X 3,375 mg/L = 211,106 lbs MLSS in aeration basin
6.4 MGD X 8.34 X 156 mg/L = 8,326.65 lbs influent TSS

$$\frac{211{,}106 \text{ lbs in AB}}{8{,}326.65 \text{ lbs TSS inf}} = 25.35 \text{ days}$$

Problem #7
The sludge age that produces the least amount of sludge at a 3.5 MGD treatment facility is 19.5 days. The influent flow is 2.8 MGD with a TSS of 209 mg/L . How many lbs of solid are needed in the aeration basins to meet the 19.5 day old sludge?

Lbs Influent TSS = 2.8 MGD X 8.34 X 209 mg/L = 4,880.5 lbs TSS inf
Lbs TSS in Aeration Basin = 19.5 days X 4,880.5 lbs TSS inf = 95,171 lbs MLSS in AB

Problem #8

What is the mean cell residence time for a .75 MGD extended aeration plant with a MLSS of 2,550 mg/l, an influent flow of .56 MGD an effluent TSS of 14 mg/l and a waste sludge flow of 11,000 gpd at 1 % concentration?

First you calculate the number of lbs. in the mixed liquors suspended solids or Aeration Basin:

Lbs. MLSS in Aeration Basin
.75 MGD X 8.34 X 2,550 mg/l
15,950.25 lbs. MLS

Next calculate the number of lbs. wasted:

Lbs. TSS wasted
.011 MGD X 8.34 X 10,000 mg/l
917.4 lbs. TSS wasted

Next calculate the number of lbs. of TSS in the effluent:

Lbs. TSS effluent
.56 MGD X 8.34 X 14
65.38 lbs. TSS effluent

Last, place the values into the MCRT equation:

$$\textbf{MCRT} = \frac{\text{15,950.25 lbs MLSS in Aeration Basin}}{\text{917.4 lbs. TSS wasted + 65.38 lbs. TSS effluent}}$$

16.2 days

Problem #9

The flow to a 1.5 MGD treatment facility is 1.1 MGD with an influent BOD of 216 mg/L, the F/M is .051. How many lbs of MLVSS should be maintained in the aeration section of this plant to continue the .051 F/M?

LBs /BOD influent ÷ lbs MLVSS/ aeration basin = F/M

Lbs BOD influent = 1.1 MGD X 8.34 X 216 Mg/L= 1,981.5 lbs BOD inf

Lbs of MLVSS in AB = $\frac{\text{1,981.5 lbs BOD inf}}{.051}$ = 38,852.9 lbs MLVSS in AB

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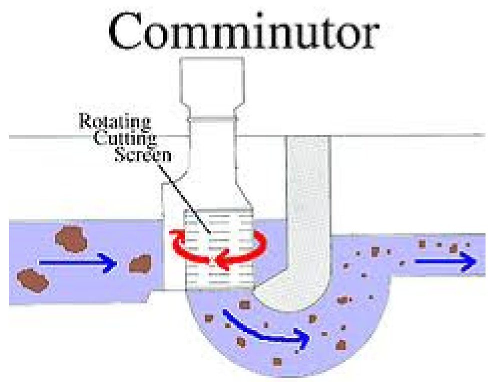
Chapter 4: Preliminary Treatment

BAR SCREEN



GRIT REMOVAL

EQUALIZATION BASINS

Chapter 4 Objective

1. Differentiate between the different preliminary treatment processes.

PRELIMINARY TREATMENT PROCESSES

Preliminary treatment is the removal of large untreatable and inorganic objects from the waste stream. Several preliminary treatment processes are listed below.

Screening

The first unit found at treatment plants is used to remove trash and coarse solids (wood, cloth, paper, plastics, garbage, etc.). Screening devices may consist of parallel bars, gratings, wire mesh, or perforated slots. The parallel bar or rod configuration is called a trash rack or bar screen and will have openings (space between bars) of ⅝" or more.

The 1990 edition of "Recommended Standards for Wastewater Facilities of the Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers" (commonly referred to as "Ten States' Standards") lists these as coarse screens. This publication recommends openings for manually cleaned bar racks be from 1" to 1¾" and placed on a slope of 30 to 45 degrees from the horizontal. It also recommends approach velocities be at least 1.25 fps to prevent settling and not more than 3.0 fps to prevent forcing material through the openings.

The term "screen" is used for screening devices consisting of perforated plates, wedge wire elements, and wire cloth and the openings will be less than ⅝". "Ten States' Standards" refers to screens with openings of approximately 1/16 inch as fine screens that can be used in lieu of primary sedimentation. Commonly used screens include the hydro-sieve, inclined fixed screen and the rotary drum screen.

A primary concern of screening devices is the potential head loss through them that increases with the degree of clogging. If they are not self cleaning; it is imperative that the operator clean them several times each day to prevent a damming effect that results in grit being deposited upstream from the unit. Where fine screens are used, consideration should be given to the prior removal of floatable oils and greases, which can clog the openings.

Grit Removal

These units are designed to remove grit or other heavy solid material that have subsiding velocities or specific gravities substantially greater than those of the organic putrescible solids in wastewater. In addition to grit consisting of sand, gravel, and cinders, other materials removed include eggshells, bone chips, seeds, coffee grounds, and large organic particles such as food wastes. Generally, grit removed is relatively dry and inert, but it can be highly variable with a volatile content up to 56%.

Removing the grit helps to prevent damage to downstream equipment such as pump impellers. Also, if the grit is allowed to settle in subsequent treatment units, space is taken up that reduces the treatment capacity of those units. Grit removal should be provided for all wastewater treatment plants, especially for those receiving wastewater from combined sewers.

There are three general types of grit chambers:

1. horizontal-flow channels,
2. aerated, and
3. vortex-type.

In the **horizontal channel**, velocities are reduced to 1-1.5 fps so that the grit will settle while the organics remain in suspension. The velocity is controlled by special influent distribution gates, dimensions of the unit, and special weir sections (proportional, sutro, etc.) at the effluent end.

The **aerated type** consists of a spiral-flow aeration tank where the spiral velocity is induced and controlled by the tank dimensions and quantity of air supplied to the unit. Aeration rates are adjustable in the range of 3-8 CFM (cubic feet per minute) per foot of tank length. Increasing the aeration rate helps to prevent the organic material from settling out. Detention times range from 3 to 5 minutes at design peak hourly flows.

The **vortex-type** unit consists of a cylindrical tank in which the flow enters tangentially creating a vortex-flow pattern; centrifugal and gravitational forces cause the grit to separate.

Grit always contains some organic matter that decomposes and creates odors. To facilitate economical disposal of grit without causing nuisance, the organic matter is sometimes washed from the grit and returned to the wastewater. Special equipment is available to wash grit.

Comminution

As an alternative to racks or coarse screens, comminutors are sometimes used to grind coarse solids without removing them from the flow stream. They are found mainly in smaller communities and should follow the grit removal process to prolong the life of the equipment and reduce the wear on the cutting surfaces.

If the comminutor precedes grit removal, the cutting teeth will require frequent sharpening or replacement. Units usually consist of a vertical stationary section and an oscillating or rotating section equipped with cutting teeth. The close tolerance between the shear bars and cutting teeth allow solids to be cut into smaller, more uniform size, which are taken out by subsequent treatment stages. If the cutting adjustment is improper, the solids will not be cut cleanly or shredded as desired.

Flow Equalization

Used to smooth out wide variations in flow so that a constant or nearly constant flow-rate can be achieved, flow equalization improves the performance of the downstream processes and reduces the size and cost of downstream treatment facilities.

They can be either in-line units where all the flow passes through the basin or off-line units where only the flow above some predetermined rate is diverted into the basin. The off-line basin is commonly used to capture the first flush from the combined sewers while the in-line basic must be used if equalization of the plant loadings is also desired.

Primary considerations in the operation include pump control systems, mixing, and aeration requirements. The mixing equipment has to be adequate to prevent deposition of solids in the basin. Aeration is needed to prevent the wastewater from becoming septic and odorous. [1] “Ten States’ Standards” recommends a minimum of 1.25 CFM per 1,000 gallons of storage capacity.

Chapter 4 Review Questions

1. Bar screens are used to remove ____.

2. Grit removal systems help to protect ____________________________.

3. What is commutation?

4. List two advantages of flow equalization.

Answers for Chapter 4 Review

1. Large untreatable objects from the waste stream.
2. Downstream pipe and pumping equipment.
3. Grinding.
4. Small downstream treatment units, may be used as an aeration basin for pretreatment.

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Chapter 5: Physical & Biological Treatment Processes

Chapter 5 Objectives

1. Describe the importance of primary clarifiers.
2. Demonstrate knowledge of detention time, surface loading, weir overflow and percent removal calculations.
3. Demonstrate knowledge of RBC and trickling filters operation; and knowledge of combined processes.
4. Identify and explain the seven suspended growth treatment processes listed in this chapter and the operational considerations thereof.
5. Explain the nitrification/denitrification process that includes: organic loading, solids retention time, alkalinity, pH, freedom from toxics, dissolved oxygen, temperature and chlorination.
6. Demonstrate an understanding of the biological processes involved in biological phosphorous removal.
7. Identify the three trivalent metals and explain their significance to the treatment process.
8. Identify and understand the four types of sedimentation.
9. Demonstrate mathematical competency relative to surface overflow and solids loading rates.
10. Differentiate between the types, applications, and classifications of waste treatment ponds.
11. Explain algal growths impact on dissolved oxygen and pH levels in waste treatment ponds.
12. Calculate waste loading rates.

13. Identify the principles of the operation and maintenance of stabilization ponds and aerated lagoons.
14. Demonstrate knowledge of short-circuiting alleviation.

Primary Treatment

The purpose of a **primary clarifier** is to create a relatively quiescent area where solids having a higher specific gravity than the liquid will tend to settle, and those with a lower specific gravity will tend to rise so that readily settleable solids and floating material such as grease can be removed and reduce the load on the subsequent biological treatment units.

Regular preventive maintenance on mechanical equipment is necessary to prevent breakdowns such as broken flights and locked speed reducer gears.

Sludge accumulating in the clarifier will normally concentrate to **4-8% before being transferred to the digester**. Small quantities of sludge should be pumped often

1. to prevent hydraulic & organic overloading of the digester, and
2. to keep sludge blankets down so that septic "floating" sludge will not result.

The best way to determine sludge blanket depth, to insure that sufficient quantities are being removed, is to measure it with a sludge judge, sludge core taker, or sludge blanket finder.

By knowing the concentration of sludge and the gallons pumped, pounds of sludge transferred to the thickener or digester can be calculated. If there is no flow-measuring device, the sludge pumping rate must be determined and the time in minutes that the pump operates to transfer sludge is then used to determine gallons pumped (see practice problem #1 on page 80).

The pounds wasted can also be compared with the pounds captured by the primary clarifier to see if waste sludge rates are sufficient (see practice Problem # 2 on page 80). "Ten States' Standards" recommends a minimum water depth for primary clarifiers of seven feet. Primary clarification normally precedes biological treatment using fixed film reactors or the conventional activated sludge process but is not used for the extended aeration process.

Conditions Affecting Settling Factors

- Concentration of Solids- The larger and heavier the suspended solids, the faster they will settle. The more particles there are (within design), the better the settling.
- Temperature- At higher temperatures, the water is less dense, therefore, the higher the temperature, the more rapid the settling.
- Detention Time- About 50% of a municipal type suspended solids will settle out in 30 minutes, about 60% after 1 hour, and about 70% after 2 hours.
- Usually, clarifier design allows for detention times ranging between 1.5 to 2 hours, however, it may be as long as 4 to 5 hours.
- If necessary use a settleometer to check how long solids can be in the clarifier without floating to the surface.

Surface Loading

- Condition of Wastewater- Wastewater strength, freshness, temperature, and the density, shapes and sizes of particles all impact the efficiency of the unit.
- Septic wastewater settles slower because of smaller particle size or gas bubbles on particles that can cause floating.

Monitoring and Control

The following should be routinely checked.

- Settleable solids in and out of clarifier,
- Sludge moisture,
- Sludge pumping cycle and sludge blanket depth,
- Weirs, skimmers, draw down tubes and rakes all need regular maintenance.

Causes of Low Solids Removal Efficiencies

- Hydraulic short circuiting can be caused by currents induced by inlets, effluent weir plates that are not level, a difference in influent and clarifier water temperature, or wind causing problems on large tanks.

Causes of Low Solids Removal Efficiencies- High Sludge Bed

- Sludge may be scoured & re-suspended by water forward velocity, there could be to low an underflow on sludge pumping rate or schedule, there could be high drive torque that may indicate a high bed.
- Light organic solids may not increase torque significantly with a high bed as compared to inorganic solids.

Causes of Low Solids Removal Efficiencies

- Increase in influent suspended solids can cause particles to settle as a mass rather than discretely.
- Increase in influent suspended solids can cause sudden increase in sludge bed height.
- If chemicals are used, a decrease in chemical/pound of solids is needed.

Causes of Low Solids Removal Efficiencies

If sludge is held too long:

- In clarifier it can create gasification by anaerobic decomposition.
- Gas bubbles can be seen breaking water surface.
- Re-suspension can occur of sludge solids.
- Floating black sludge can be seen.
- A strong hydrogen sulfide odor can be present in severe cases.

Operating Objectives

- Keep clarifier solids in balance.
- Maximize solids capture by influent flow control to minimize hydraulic surges.
- Control sludge bed depth by proper sludge pumping rate to minimize solids carry over.
- Maximum sludge concentration dependent on bed height and solids characteristics. Minimize sludge retention time.
- Improper sludge pumping rate is a common cause of clarifier failure.
- Check periodically
- Some primary clarifiers are covered.
- Open them up and check to see if there are solids floating on the top, and check for gassing.
- If present, make adjustments.
- Out of site, out of mind will not help with operation of the treatment plant.

$$\frac{\textbf{volume of sludge pumped in ft}^3 \textbf{ X 7.48 gal/ft}^3}{\textbf{Min. pump ran}} = \textbf{Gal per min}$$

Problem #1

Two 45 ft by 30 ft drying bed were filled with 1 ft of sludge from a digester in 2 hr 10 min. what is the gallon per minute pump rate?

Volume of sludge pumped in ft^3 X 7.48 gal/ft^3 X 8.34 lbs/gal X concentration/mg/L = lbs pumped

Problem #2

How many lbs of sludge will be loaded onto two 50 ft X 25 ft drying bed if 1.5 ft of sludge is added at a concentration of 22,500 mg/L?

Lbs of BOD_5 primary influent – lbs of BOD_5 primary effluent = lbs captured in primary

Problem #3

The influent flow to a 2 MGD fixed film reactor is 1.4 MGD with an influent TSS of 223 mg/L the effluent concentration from the primary clarifier is 102 mg/L. How many lbs of solids were captured in the primary clarifier?

Detention Time = 1.5 to 2.0 hours

When calculating for detention time in hours use the following formula.

$$\frac{\text{Tank volume in Ft}^3 \text{ X } 7.48 \text{ gal/Ft}^3 \text{ X } 24 \text{ hr}}{\text{Flow in GPD}}$$

Problem #4

The flow to a 75 feet diameter clarifier with a 10 feet water depth is 2 MGD. What is the detention time in hours?

Weir Overflow Rate = 5,000 to 15,000 gpd/ft

Formula for Weir overflow rate in GPD/ft = $\dfrac{\textbf{Flow in GPD}}{\textbf{Length of weir in ft}}$

Problem #5

The flow to a 100 ft clarifier is 2.1 MGD. What is the weir overflow rate?

Circumference = ∏ X diameter =

Surface Loading Rate = 600 to 800 gpd/ft²

Formula for surface loading rate in GPD/Ft² = $\dfrac{\text{Flow in GPD}}{\text{Surface area in Ft}^2}$

Problem #6

The flow to two 100 ft clarifiers is 8.9 MGD. What is the surface loading rate?

<u>Expected Removal Efficiency:</u> **BOD_5 = 25 – 40%**

TSS = 40 – 60%

Settleable Solids = 90 – 95%

Formula for removal efficiency or percent removal = $\frac{\text{Influent} - \text{Effluent}}{\text{Influent}} \times 100$

Fixed Film or Attached Growth Reactors

When using fixed film or attached growth reactors the wastewater is brought to bacteria that are attached to a substrate with oxygen being added without the use of mechanical aeration.

Trickling Filters: In use for more than 100 years, trickling filters consist of a bed of highly permeable medium to which microorganisms are attached and through which wastewater is percolated or "trickled".

Table 5.1

TYPICAL DESIGN INFORMATION FOR TRICKLING FILTERS*						
Item	**Low-Rate**	**Intermediate Rate**	**High-Rate**	**Super High-Rate**	**Roughing**	**Two-Stage**
Filter Medium	Rock, Slag	Rock, Slag	Rock	Plastic	Plastic, Redwood	Rock, Plastic
Hydraulic Loading, gpm/ft^2	0.02-0.06	0.06-0.16	0.16-0.64	0.2-1.2	0.8-3.2	0.16-0.64
BOD_5 loading lbs/1000 ft^3/day	5-25	15-30	30-60	30-100	100-500	60-120
Depth, feet	6-8	6-8	3-6	10-40	15-40	6-8
Recirculation Ratio	0	0-1	1-2	1-2	1-4	0.5-2
Filter Flies	Many	Some	Few	Few or None	Few or None	Few or None
Sloughing	Intermittent	Intermittent	Continuous	Continuous	Continuous	Continuous
BOD_5 Removal Efficiency, %	80-90	50-70	65-85	65-80	40-65	85-95
Effluent	Well nitrified	Partially nitrified	Little nitrification	Little nitrification	No nitrification	Well nitrified

* Adapted from Wastewater Engineering – Treatment, Disposal, Reuse by Metcalf & Eddy.

The efficiency of a trickling filter operation is most commonly measured by the **percent removal of BOD_5 and/or COD**. Recirculation, as indicated in Table 5.1, is sometimes used with trickling filters to:

(a) keep the distributor arm in motion and the media from drying out during low flow periods,
(b) dilute the organic strength of the influent,
(c) smooth out diurnal flow fluctuations,
(d) increase the contact time with the media and help to seed the lower portions of the filter with active microorganisms.

Formula for **percent removal** $= \dfrac{\textbf{Influent - Effluent}}{\textbf{Influent}}$ **X 100**

Problem #7

The influent BOD to a trickling filter plant is 179 mg/L and the effluent flow is 10 mg/L. What is the percent removal of BOD?

For filters using plastic media, "Ten States' Standards" limits the void area to no more than 30 ft^2 per cubic feet of volume for filters used for carbonaceous reduction and 45 ft^2 per cubic feet of volume for second stage ammonia reduction.

Use the following formula to calculate the organic loading on a trickling filter:

$$\frac{\textbf{Lbs of BOD}_5}{\textbf{volume of trickling filter in 1000 ft}^3}$$

Problem #8

The primary effluent flow is 1.2 MGD with a BOD_5 of 123 mg/L. This flow enters a 100 ft diameter trickling filter that is 5 ft deep with each ft^3 of area containing 30 ft^2 of filter material. What is the **organic loading in lbs of BOD_5 per 1000 ft^3**?

The underdrain system is important so that free passage of air is available. The size of the drains, channels, and pipe should be such that not more than 50% of their cross-sectional area will be submerged under the design peak instantaneous flow, including proposed or possible future re-circulated flows.

Trickling filters enable organic material in the wastewater to be absorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi, protozoa, and algae) attached to the medium as a biological film (biofilm) or slime layer.

This layer ranges from 0.1 to 0.2 mm thick. As the wastewater flows over the filter medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic material is then degraded by aerobic microorganisms in the outer part of the slime layer. As the slime layer thickens through microbial growth, oxygen cannot penetrate the medium face of the biofilm and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing.

The sloughed solids are picked up by the under-drain system and transported to a clarifier for removal from the wastewater. This type of biological growth, biofilms, is a normal part of the treatment of wastewater using all types of fixed film or attached growth treatment types.

Rotating Biological Contactors (RBCs): First used in West Germany in 1960 and later introduced in the U.S., the RBC process utilizes plastic disc filter media mounted on a long, horizontal, rotating shaft.

Shaft lengths are limited to 27 ft. with 25 ft. occupied by the media. Typical rotational speeds range from 1.5 to 1.6 rpm. With a media diameter of 12 ft., the peripheral speed is approximately 60 ft./minute.

The media is normally 40% submerged with tank depths averaging about 5 ft. The treatment process normally has two or more RBC units operating in series that are referred to as stages. A minimum of 2 to 3 stages are usually necessary to reliably achieve secondary BOD_5 limits, and 3 to 4 stages are required to achieve an effluent BOD_5 less than 20 mg/L.

Additional stages would need to be added to achieve nitrification. Standard density media containing 100,000 ft^2 of surface area per shaft is used on the first stages for BOD_5 removal. High-density media containing from 120,000 to 180,000 ft^2 of surface area per shaft is used on the later stages of nitrification.

When calculating organic loading on a Rotating Biological Contactor (RBC) use the following equation:

$$\frac{\textbf{Lbs of BOD}_5}{\textbf{Surface area of the media/ 1000 ft}^2}$$

Problem #9

The primary effluent flow to a 4 train RBC is .9 MGD with a BOD_5 concentration of 115 mg/L. What is the organic loading on each train of this RBC plant in Lbs of BOD_5 per 1,000ft^2?

Dissolved oxygen (DO) concentrations as a minimum should range from 0.5 to 1.0 mg/L at the end of the first stage and at least 2 to 3 mg/L at the end of the last stage. Plants designed for nitrification often operate to attain a 4 to 5 mg/L DO concentration coupled with excessive hydrogen sulfide concentrations can result in abnormal growth of filamentous organisms which will result in a white or gray biomass on the filter media.

A healthy first-stage biomass is **uniformly brown and distributed in a thin, even layer**. The biomass on the later stages tends to have a gold or reddish sheen. A heavy, shaggy biomass in the first stage indicates an organic overload. To improve DO concentrations and sloughing of the biomass, some of the earlier installations have been retrofitted with diffused aeration which can also eliminate solids accumulations in the basin's oxygen depleted or dead zones.

1. Hydraulic loadings should not exceed design loadings by more then 50% due to shortened detention times (0.12 gallons of tank volume per ft^2 of media), and the fact that this is a once through process without sludge recycle.

2. Recirculation of RBC-treated effluent does not significantly improve treatment efficiency and is not normally used. If it is used, recirculation through sludge holding or thickening tanks is to be avoided because the sludge could produce high sulfide concentrations in the recycle flow that would stimulate the growth of the aforementioned nuisance organisms.

3. Covers or enclosures are used with RBC's to (1) protect biological slimes from freezing, (2) prevent rain from washing off slime growths, (3) prevent exposure of media to sunlight resulting in algae growth, (4) avoid weakening the plastic media from ultraviolet rays, and (5) provide protection from the elements.

Operating parameters for RBCs are provided in Table 5.2.

TABLE 5.2

RBC OPERATING PARAMETERS		
PARAMETER	**UNITS**	**LOADING**
Organic Loading (1st stage)	lbs. Sol. BOD/1000 ft^2	2.5
Organic Loading (1st stage)	lbs. Total BOD/1000 ft2	4-6
Organic Loading (all stages)	lbs. Sol. BOD/1000 ft^2	0.5-1.5
Organic Loading (all stages)	lbs. Total BOD/1000 ft^2	1.5-3.0
Hydraulic Loading (BOD_5 removal)	gpd/ft^2/day	2-4
Hydraulic Loading (w/nitrification)	gpd/ft^2/day	0.75-2.0

Combined Processes: The principal reason for combining processes is that they provide the stability and resistance to shock loads of attached-growth processes and the high-quality effluent or increased nitrification of suspended-growth systems.

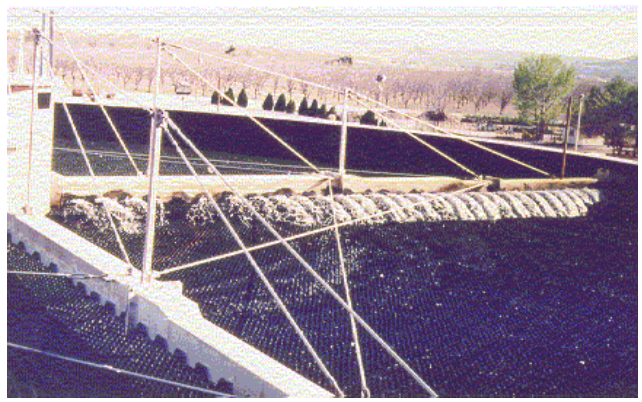
1. The **activated biofilter** (ABF) uses a redwood media on a lightly loaded trickling filter where biological or activated solids are recycled from the bottom of the secondary clarifier and returned to the filter. This process proved to be unable to consistently

achieve good effluent quality as organic loads approach 100 lbs. $BOD_5/1000\ ft^3/day$. Without short term aeration, it also performed poorly in cold climates. It was later modified to include a small aeration basin, referred to as the biofilter activated sludge (BF/AS) process.

2. The **trickling filter solids contact** (TF/SC) process uses a moderate to highly loaded trickling filter followed by a small contact channel only 8 to 17% of the size normally required for activated sludge alone. The filter size is generally reduced to 50% or less of that required with a trickling filter alone. From 60 to 85% of the BOD_5 is removed in the filter.

3. The **roughing filter** activated sludge (RF/AS) process is sometimes used to upgrade existing activated sludge plants by installing a roughing filter ahead. Similar to the TF/SC process, it operates at higher total organic loadings. Although it has the same flow schematic as the TF/SC, the RF/AS uses a much smaller trickling filter and depends more on the aeration basin to provide oxygen, remove BOD_5, and digest solids.

4. The **biofilter activated sludge** (BF/AS) process resembles the TF/SC or the RF/AS processes except that all the return activated sludge from the clarifier is recycled over the trickling filter in a similar fashion to that of the ABF process. In the TF/SC or RF/AS processes, the return sludge flow is routed to the underflow stream from the trickling filter where a portion is recycled across the filter and the remainder goes directly to the aeration basin.



5. The **series trickling filter activated sludge** (TF/AS) process differs from the others in that an intermediate clarifier is located between the trickling filter and the aeration basin. The intermediate clarifier removes sloughed solids from the trickling filter underflow before it enters the aeration basin so that solids can be separated from the second-stage treatment. This results in the second stage being dominated by nitrifying microorganisms. Reduced oxygen requirements or improved sludge settle ability, however, has not been demonstrated. Therefore, unless substantial nitrification is required, the RF/AS or BF/AS processes are normally used with high rate roughing filters to eliminate the cost of intermediate clarification.

Suspended Growth Process

Suspended growth processes are biological treatment processes that use mechanical aerators or diffused aeration to provide mixing action in the reactor basin to

1. keep solids in suspension,
2. help bring the food (BOD_5) and microorganisms (MLVSS) together, and
3. disperse oxygen throughout the basin.

The three principal suspended growth biological processes used for secondary treatment are:

1. the activated sludge process,
2. aerated lagoons, and
3. sequencing batch reactors (SBRs).

SBRs are essentially activated sludge processes that are operated in a fill-and-draw mode. Aeration and sedimentation are carried out simultaneously in separate tanks. Lagoons are discussed separately later in this supplement.
For the activated sludge process, the shape and number of aeration tanks can be modified to vary the flow pattern as complete-mix or plug flow.

The activated sludge process is the biological process by which non-settleable substances occurring in dissolved and colloidal forms are converted into settleable sludge which is removed from the liquid carrier (water). At a plant the activated sludge is settled out along with the suspended solids present in the wastewater. The activated sludge process provides one of the highest degrees of treatment obtainable within the limits of practical economy and present knowledge of the art and science of waste treatment.

The process depends upon groups of microorganisms, mainly bacteria, along with protozoan, fungi and rotifers, being maintained in contact with the organic matter in the waste in an aerobic (oxygen containing) environment. Many forms of organic matter carried in the wastewater serve as a food supply for these microorganisms. The mass of microorganisms present in the system is referred to as biological solids or **mixed liquor suspended solids** (MLSS).

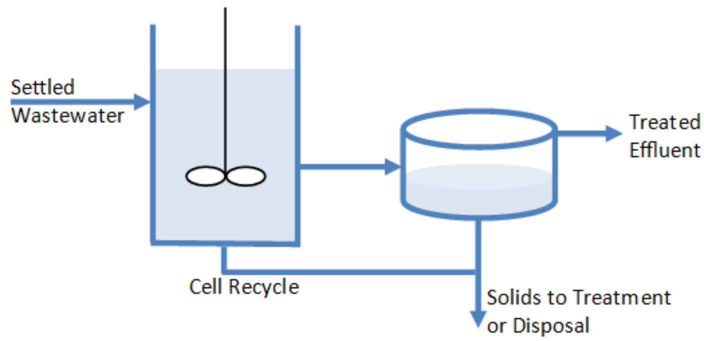
The basic purpose of the activated sludge system is to establish and maintain a viable population of microorganisms by supplying food (BOD_5) and the proper environment. In the proper environment the microorganisms convert the soluble and colloidal material present in the wastewater into new cells (activated sludge) and end products (CO_2 and water). During their life cycle, the microorganisms undergo a continuously changing cycle of growth and decline.

Influent Schemes

1. **Complete Mix**: In this process, the characteristics of the mixed liquor are similar throughout the aerations basin (small length to width ratio). Because the tank contents are similar, there is a very low level of food available at any time to a large mass of

microorganisms which is an advantage in handling surges in organic loadings without producing a change in effluent quality. A disadvantage is that it is more prone to filamentous bulking. Selectors, or small contact tanks preceding the main aeration tank, are sometimes used to provide initial conditioning to reduce bulking problems.

2. **Plug Flow:** This is the conventional activated sludge process where the aeration basin has a high length to width ratio.



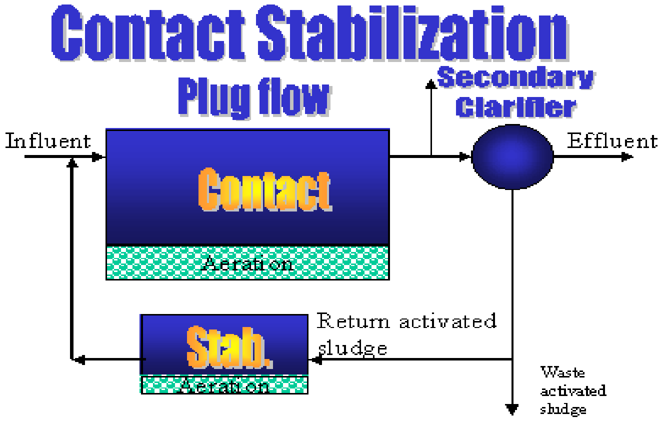
The MLSS in the initial part of the tank has a high organic load. The loading then decreases as the organic material in the raw wastewater is oxidized. In the latter half of the tank, depending on detention time, the oxygen consumption may primarily result from nitrification or endogenous respiration, the phenomenon whereby microorganisms metabolize their own cellular mass. Aeration is generally tapered or reduced toward the effluent end of the basin while a complete mix configuration must operate at a high DO for the entire tank.

4. **Step Feed:** A modification of the plug flow configuration, the influent is fed at two or more points along the length of the aeration basin to equalize the F/M ratio, thus lowering the peak oxygen demand. With this arrangement, oxygen uptake requirements are relatively even and the need for tapered aeration is eliminated.

Activated sludge treatment types

1. Contact Stabilization: This process has a short-term contact tank followed by a clarifier. The return sludge is routed to a sludge stabilization or re-aeration tank with about six times the detention time as the contact tank. Mixed liquor from the re-aeration basin is then routed to the head of the contact tank to mix with the influent. Tank size requirements are typically 50% less than required for conventional plug flow systems.

The contact stabilization activated sludge process is characterized by a two-step aeration system. Aeration of short duration (½ to 2 hours) is provided in the contact tank where raw or primary-settled wastewater is mixed with the activated sludge in the contact tank. The effluent from the contact tank is then settled in a final settling tank.

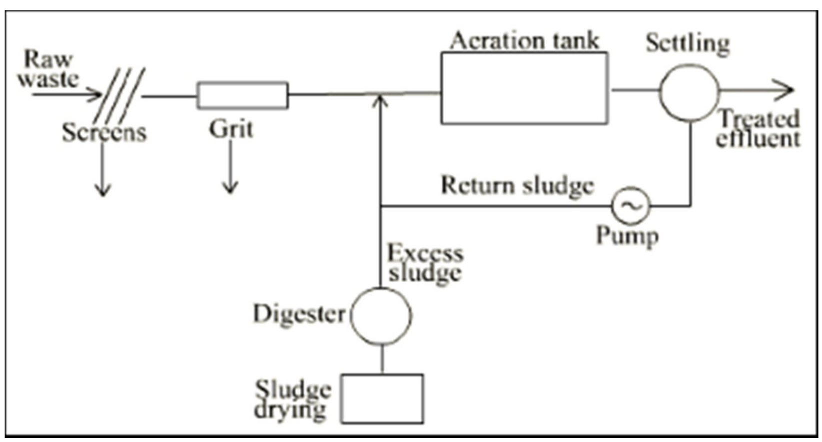


The settled activated sludge to be recycled from the final clarifier is drawn to a separate re-aeration in a stabilization basin for 3 to 8 hours of aeration time. It is then returned to the contact aeration basin for mixing with the incoming raw wastewater or primary settled effluent.

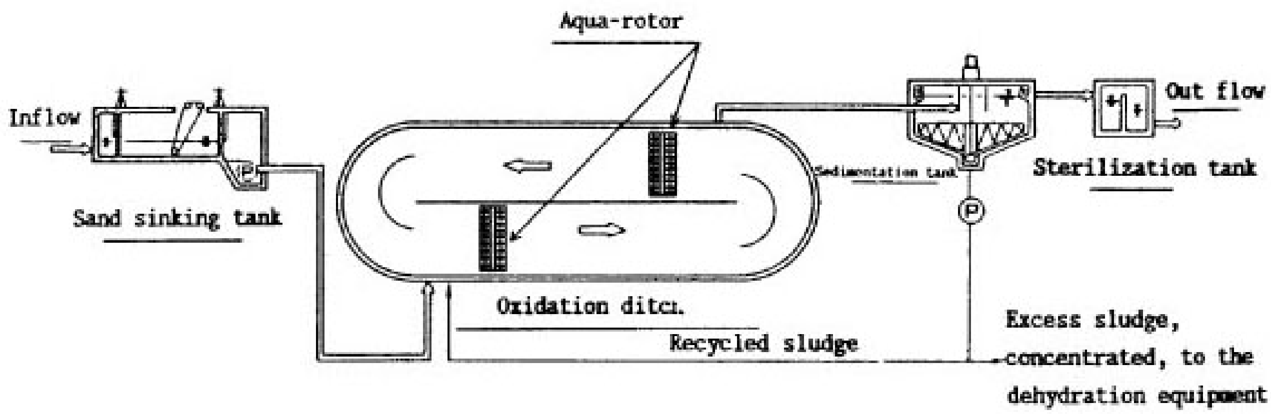
In addition to a shorter wastewater aeration time, the contact stabilization process has the advantage of being able to handle greater shock and toxic loadings than conventional systems because of the buffering capacity of the biomass in the stabilization tank. During these times of abnormal loadings, most of the activated sludge is isolated from the main stream of the plant flow.

2. **Extended Aeration:** The process uses the same flow pattern as conventional plug flow processes but operates in the endogenous respiration phase with long detention times of 18 hours or more with low organic loadings.

A disadvantage is the greater oxygen requirement versus the conventional activated sludge



process. However, the capital cost for primary clarification is eliminated that is a required component of the conventional activated sludge process.


Aqua-rotor
Inflow
Sand sinking tank
Sedimentation tank
Out flow
Sterilization tank
Oxidation ditch
Recycled sludge
Excess sludge, concentrated, to the dehydration equipment

3. **Oxidation Ditch:** A variation of the EA process, the wastewater typically flows along a circular or oval path. Mechanical aerators (horizontal axis type) provide oxygen and mixing action and move the MLSS along the pathway. Velocity is maintained between 0.8 and 1.2 ft./second in the channel to prevent solids settling. Solids will still settle in the ditch and have to be removed periodically.

4. **High Purity Oxygen:** Oxygen is used instead of air in the process in tanks that are covered. The amount of oxygen that is added is about 4 times greater than can be added with conventional aeration systems.

5. **Modified Aeration:** This process is similar to the conventional plug flow process except that shorter aeration times and higher F/M ratios are used. Removal efficiencies are also higher.

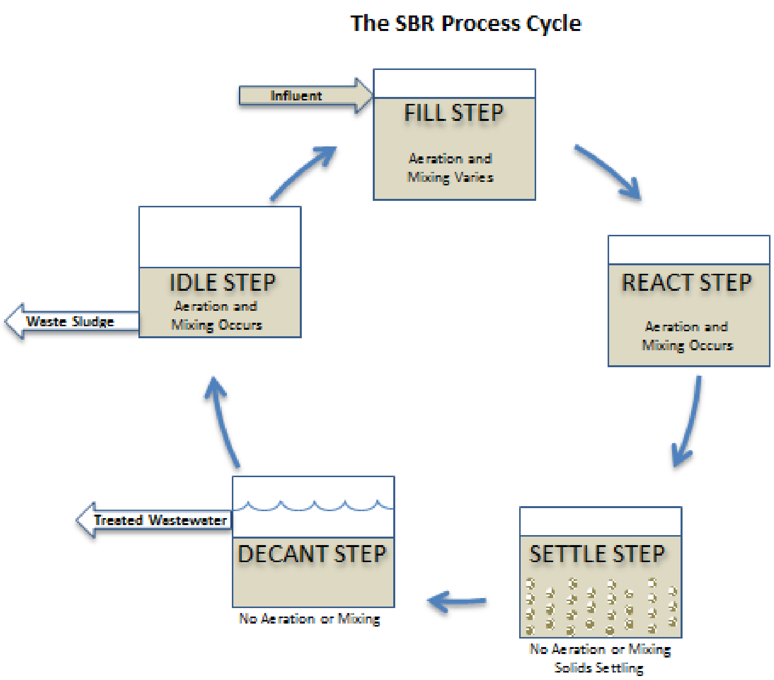
6. **Kraus Process:** A variation of the step aeration process used to treat wastewater with low nitrogen levels, digester supernatant is added as a nutrient source to a portion of the return sludge in a separate aeration tank designed to nitrify. The resulting mixed liquor is then added to the main plug flow aeration system.

7. **Sequential Batch Reactors:** The Sequencing Batch Reactor (SBR) process is a biological wastewater treatment process that is a time-oriented.

Each tank is filled for a distinct period of time and then operated as a batch reactor. Optimization of aeration and mixing strategies will lead to increased removal of carbon, nitrogen, phosphorus, and target organic compounds from industrial wastewaters. Since the SBR is a batch operation, it has significantly more flexibility than conventional systems allowing for more variances in the effluent levels. Given its structural simplicity, existing continuous-flow systems can be retrofitted to operate in batch.

Controls range from a simplified float and timer based system with a PLC, to a PC based SCADA system with color graphics using either flow proportional aeration or dissolved oxygen controlled aeration to reduce aeration to reduce energy consumption and enhance the selective pressures for BOD, nutrient removal, and control of filaments.

Sequencing batch reactors operate by a cycle of periods consisting of fill, react, settle, decant, and idle. The duration, oxygen concentration, and mixing in these periods could be altered according to the needs of the particular treatment plant. Appropriate aeration and decanting is essential for the correct operations of these plants. The aerator should make the oxygen readily available to the microorganisms. The decanter should avoid the intake of floating matter from the tank.



Because of the flexibility of working in time rather than space, the operating policy can be modified to meet new effluent limits, handle changes in wastewater characteristics, and accommodate the fluctuations in seasonal flow rate without increasing the sizes of the physical plant.

In its most basic form, the SBR system is a set of tanks that operate on a fill-and-draw basis. After desired treatment, the mixed liquor is allowed to settle and the clarified supernatant is then drawn from the tank. The cycle for each tank in a typical SBR is divided into five distinct time periods: **Fill, React, Settle, Decant, Idle**.

Operational Considerations

The total suspended solids in the aeration basin are controlled by the return sludge flow and the waste sludge flow. After determining the MLSS concentration by gravimetric balance, if the sample is burned in a muffle furnace at 550^0 centigrade, the volatile content can be determined. The solids that are burned off are called the mixed liquor volatile suspended solids (MLVSS) and considered to be the **active living biomass**.

By increasing the sludge wasted from an activated sludge plant, the following will be lowered while the F/M ratio is increased:

- MLSS
- MLVSS
- sludge age, and
- solids retention time or mean cell residence time (MCRT)

When calculating the MLSS gravimetrically use the following equation;

$$\underline{\mathbf{(W2)\text{-}(W1)}}\quad \mathbf{X\ 1{,}000\ X\ 1{,}000}$$

Sample volume/ml

W1 = weight of the dish (tare weight)
W2 = weight of the dish and the dry solids

Problem #10

The weight of the dish was 25.3334 gm and after drying the weight of the dish and the dry solids was 25.4329 gm, the sample size was 25 ml. What is the MLSS in mg/L?

To calculate the MLVSS gravimetrically use the following:

$$\frac{\underline{(W2) - (W3)}\ \mathbf{X\ 1{,}000\ X\ 1{,}000}}{\textbf{Sample volume/ml}}$$

W2 = weight of the dish and the dry solids
W3 = Weight of the dish and the ash

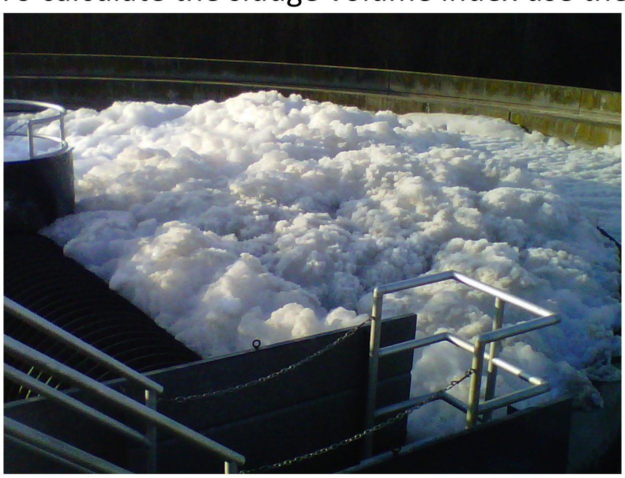
Problem #11

The weight of the dish and the ash was 25.3991 and the weight of the dish and the dry solids was 25.4329, the sample size was 25 ml. What is the MLVSS in mg/L?

Two process control tests commonly used to determine sludge wasting rates are the **centrifuge test** and the **settlometer test**.

The settlometer test is the most common because it demonstrates the sludge settling pattern, provides a means for judging filtering properties of floc particles, and provides information for calculating the SVI (sludge volume index).

To calculate the sludge volume index use the following formula:



<u>SSV 30 min/ml X 1,000 mg/g</u>
MLSS/mg/L

Problem #12

The thirty minute settled sludge volume (SSV_{30}) is 450 ml and the MLSS is 4,000 mg/L. What is the SVI?

As far as visual appearance, the aeration basin surface will contain a modest amount of crisp white foam if operated within recommended parameters. **Excessive white billowy foam is an indication of young sludge** (low MLSS, sludge age, SRT & high F/M).

An overabundance of dark, brown greasy looking foam is an indication of old sludge (high MLSS, sludge age, SRT & low F/M) or filamentous organisms.

Requirements generally depend on maximum design peak hourly BOD_5 loading, degree of treatment required, and level of MLSS to be maintained in the aeration basin. **DO concentrations of at least 2.0 mg/L should be maintained in the aeration basin**. An exception is in areas of oxidation ditches where it is desired to achieve denitrification to prevent denitrification from occurring in the clarifier.

According to "Ten States' Standards", the requirement for all activated sludge processes is **1.1 lbs. O_2 per lb. of BOD_5** applied with the exception of extended aeration processes where the requirement is **1.5 lbs. O_2 per lb. of BOD_5** applied to include endogenous respiration requirements. If ammonia removal is required, an additional oxygen requirement of **4.6 lbs. O_2 per lb. of Total Kjeldahl Nitrogen (TKN)** applied is required.

For diffused aeration systems, the air requirements can be determined using equations which take into account oxygen transfer efficiencies and oxygen saturation values at various temperatures and altitudes or assumed to be **1500 Ft^3. per lb. of BOD_5** applied for all but extended aeration processes where the value is **2050 Ft^3./lb. BOD_5**. To this amount will be added additional air requirements for digesters and air-lift pumps.

TABLE 5.3

TYPICAL DESIGN PARAMETERS FOR ACTIVATED SLUDGE PROCESSES						
PROCESS MODIFICATION	**SRT[a] (DAYS)**	**F/M lbs.BOD/ lb. MLVSS/day**	**ORGANIC LOADING (lbs.BOD/1000 ft^3.)**	**MLSS (mg/L)**	**DETENTION TIME (HOURS)**	**Return Flow to Plant Flow Ratio**

Conventional	5-15	0.2-0.5	20-40	1000-3000	4-8	0.25-0.75
Complete Mix	1-15	0.2-1.0	50-120	1000-6500	3-5	0.25-1.0
Step Feed	3-15	0.2-0.5	40-60	1500-3500	3-5	0.25-0.75
Modified Aeration	0.2-0.5	1.5-5.0	75-150	200-1000	1.5-3.0	0.05-0.25
Contact Stabilization	5-15	0.2-0.6	60-75	1000-3000 4000-9000	0.5-1.0[b] 3-6[c]	0.5-1.5
Extended Aeration	20-30	0.05-0.15	12.5-15	2000-6000	18-36	0.5-1.5
Oxidation Ditch	10-30	0.05-0.15	12.5-15	2000-6000	18-36	0.75-1.5
High Purity Oxygen	3-10	0.25-1.0	100-200	3000-8000	1-3	0.25-0.5
Kraus Process	5-15	0.3-0.8	40-100	2000-3000	4-8	0.5-1.0

[a] SRT based on aeration tank volume only.

[b] Contact Tank.

[c] Stabilization or Re-aeration Tank NITROGEN REMOVAL

When calculating the organic loading on a suspended growth system, use the following equation.

$$\frac{\text{Lbs of BOD}^5}{\text{Volume of AT in 1,000 ft}^3}$$

Problem #13

A community of 2,000 people has a .25 MGD extended aeration plant. How many lbs of BOD will be loaded per 1,000 ft^3 of aeration basin volume?

Nitrification/denitrification is the biological reduction of the ammonium ion to nitrogen gas. We wish to accomplish this in secondary treatment.

TABLE 5.4 - Biological Requirements for Nitrification

Organic loading	10 lbs. NH_3/1000 cu. ft. @ 2000 mg/l MLVSS @ 10^{o}C 25 lbs. NH_3/1000 cu. ft

	@2000 mg/l MLVSS @20^oC
Solids retention time	> 10 day sludge age needed for nitrification to begin
Alkalinity	7.2 ppm needed to convert 1.0 ppm ammonia to nitrate
pH	Optimal range of 7.8 to 9.0 but systems can acclimate to lower pH conditions
Freedom from toxics	Nitrifiers are more sensitive and slower to multiply
Dissolved Oxygen	Should be 2 - 3 mg/l
Temperature	Nitrification increases with higher temperatures. For example, when MLVSS = 2000 ppm. @ 10^oC---organic loading = 10 lbs. NH_3/1000 cu. ft. @ 25^oC---organic loading = 25 lbs. NH_3/1000 cu. ft
Chlorination	It takes approximately 9.0 ppm chlorine to oxidize 1.0 ppm ammonia assuming adequate pH, alkalinity, and temperature.

Denitrification is the biological conversion of nitrite (NO_2) and nitrate (NO_3) to nitrogen gas (N_2) or other reduced forms such as N_2O or NO by facultative heterotrophs which can utilize nitrate instead of free oxygen as their oxygen source. This process takes place under anoxic, or near anaerobic conditions, when dissolved oxygen concentrations are near zero.

In secondary clarifiers with high sludge blankets and long detention times, this process is sometimes observed by the presence of nitrogen gas bubbles floating to the surface and bringing the sludge blanket up with them.

To prevent this occurrence, DO concentrations in the aeration basin MLSS entering the clarifier should be at least 2.0 ppm and sludge blankets should be kept below 3 feet. Some oxidation ditches are now designed to achieve denitrification rather than allowing it to become a Problem in the clarifier. This is done by creating an area in the ditch upstream of the aerators where low DO concentrations are encouraged.

KPDES permits currently do not impose nitrate limits, so denitrification is not required on conventional treatment systems.

However, a treatment system designed for denitrification requires a carbon source, usually methanol (CH_3OH), for the reaction to proceed. As a cost saving measure, the influent BOD_5 can be used as the carbon source. Reaction rates are most rapid for methanol, then soluble BOD_5, slower for colloidal matter, and slowest for endogenous metabolism. During the nitrification process alkalinity is consumed, however, during the denitrification process alkalinity is actually produced.

For each **1 ppm of nitrate-nitrogen that is denitrified to nitrogen gas, 3.57 ppm of calcium carbonate alkalinity** is produced. Another benefit of the denitrification process is the reuse of the oxygen in the nitrate molecule. Theoretically, 67% of that oxygen can be used to oxidize organics. Therefore, dissolved oxygen used to convert ammonium-nitrogen into nitrate in the aerobic zone is recovered during subsequent denitrification.

Phosphorus

Municipal wastewaters may contain from 5 to 20 mg/L of total phosphorus, of which 1-5 mg/L is organic and the rest in inorganic. The per capita phosphorus contribution averages about **0.0048 lbs/person/day.**

Normally secondary treatment can only remove 1-2 mg/L, so a large excess of phosphorus is discharged in the final effluent, which can lead to eutrophication in surface waters. When sampling for **total Phosphorus the sample must be acidified with sulfuric acid to a pH of less than 2 standard units and cooled to < 6^0 C with a holding time of 28 days.**

Biological processes

Biological phosphorus removal is less expensive because of reduced chemical costs and less sludge production as compared to chemical precipitation.

In the biological removal of phosphorus, the phosphorus in the influent wastewater is incorporated into cell biomass, which is subsequently removed from the process as a result of sludge wasting. The reactor configuration provides the phosphorus accumulating organisms (PAO) with a competitive advantage over other bacteria. So PAO are encouraged to grow and consume phosphorus.

The reactor configuration is comprised of an anaerobic tank and an activated sludge activated tank (see Figure 5.5).

The retention time in the anaerobic tank is about 0.50 to 1.00 hours and its contents are mixed to provide contact with the return activated sludge and influent wastewater.

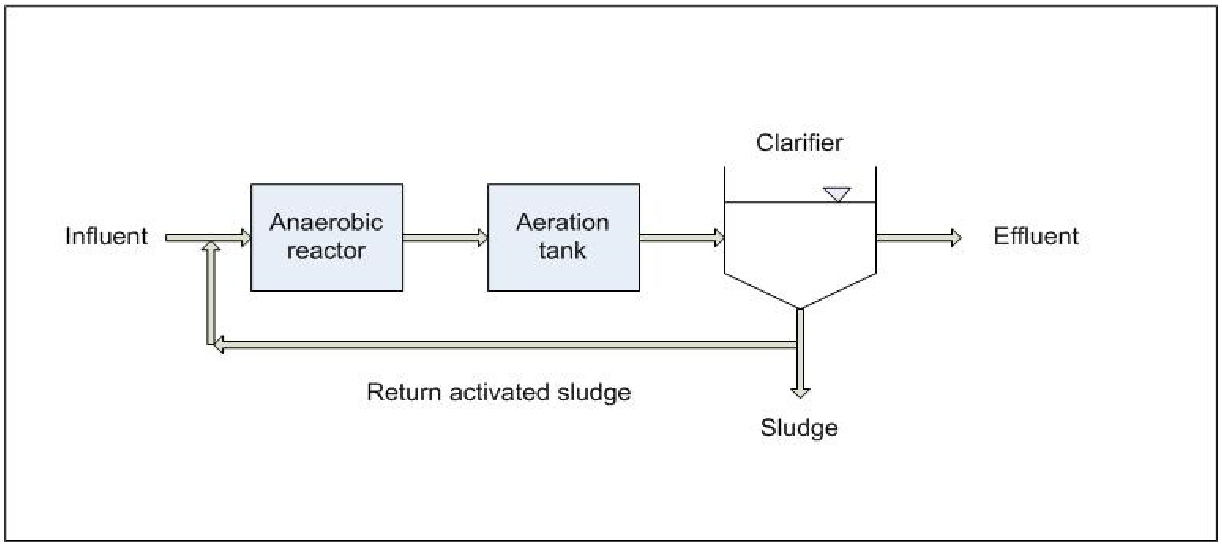
In the **anaerobic zone** (see Figure 5.5): Under anaerobic conditions, phosphorus accumulating organisms (PAO) assimilate fermentation products (i.e. volatile fatty acids) into storage products within the cells with the simultaneous release of phosphorus from stored polyphosphates.

Acetate is produced by fermentation of “soft” COD, which is dissolved degradable organic material that can be easily assimilated by the biomass. Using energy available from stored polyphosphates, the PAO assimilate acetate and produce intracellular polyhydroxybutyrate (PHB) storage products. Concurrent with the acetate uptake is the release of orthophosphates, as well as magnesium, potassium, calcium cations. The PHB content in the PAO increases as the polyphosphate decreases.

In the **aerobic zone** (see Figure 5.5): energy is produced by the oxidation of storage products and polyphosphate storage within the cell increases. Stored polyhydroxybutyrate (PHB) is metabolized, providing energy from oxidation and carbon for new cell growth. Some glycogen is produced from PHB metabolism. The energy released from PHB oxidation is used to form polyphosphate bonds in cell storage.

The soluble orthophosphate is removed from solution and incorporated into polyphosphates within the bacterial cell. PHB utilisation also enhances cell growth and this new biomass with high polyphosphate storage accounts for phosphorous removal. As a portion of the biomass is wasted, the stored phosphorous is removed from the bio treatment reactor for ultimate disposal with the waste sludge.

Figure 5.5



Chemical precipitation

Chemical precipitation is used to remove the inorganic forms of phosphate by the addition of a coagulant and a mixing of wastewater and coagulant. **The multivalent metal ions most commonly used are calcium, aluminium and iron.**

Calcium

It is usually added in the form of lime Ca $(OH)_2$. It reacts with the natural alkalinity in the wastewater to produce calcium carbonate, which is primarily responsible for enhancing SS removal. As the pH value of the wastewater increases beyond about 10, excess calcium ions will then react with the phosphate to precipitate in hydroxylapatite.

Because the reaction is between the lime and the alkalinity of the wastewater, the quantity required will be, in general, independent of the amount of phosphate present. It will depend primarily on the alkalinity of the wastewater. The lime dose required can be approximated at 1.5 times the alkalinity as $CaCO_3$. Neutralization may be required to reduce pH before subsequent treatment or disposal. Recarbonation with carbon dioxide (CO_2) is used to lower the pH value.

Aluminium

Alum or hydrated aluminium sulphate is widely used precipitating phosphates and aluminium phosphates. The dosage rate required is a function of the phosphorous removal required. The efficiency of coagulation falls as the concentration of phosphorous decreases. In practice, an 80-90% removal rate is achieved at coagulant dosage rates between 50 and 200 mg/L. Dosages are generally established on the basis of bench-scale tests and occasionally by full-scale tests, especially if polymers are used.

Aluminium coagulants can adversely affect the microbial population in activated sludge, especially protozoa and rotifers, at dosage rates higher than 150 mg/L. However this does not affect much either BOD or TSS removal, as the clarification function of protozoa and rotifers is largely compensated by the enhanced removal of SS by chemical precipitation.

Iron

Ferric chloride or sulphate and ferrous sulphate, are all widely used for phosphorous removal, although the actual reactions are not fully understood.

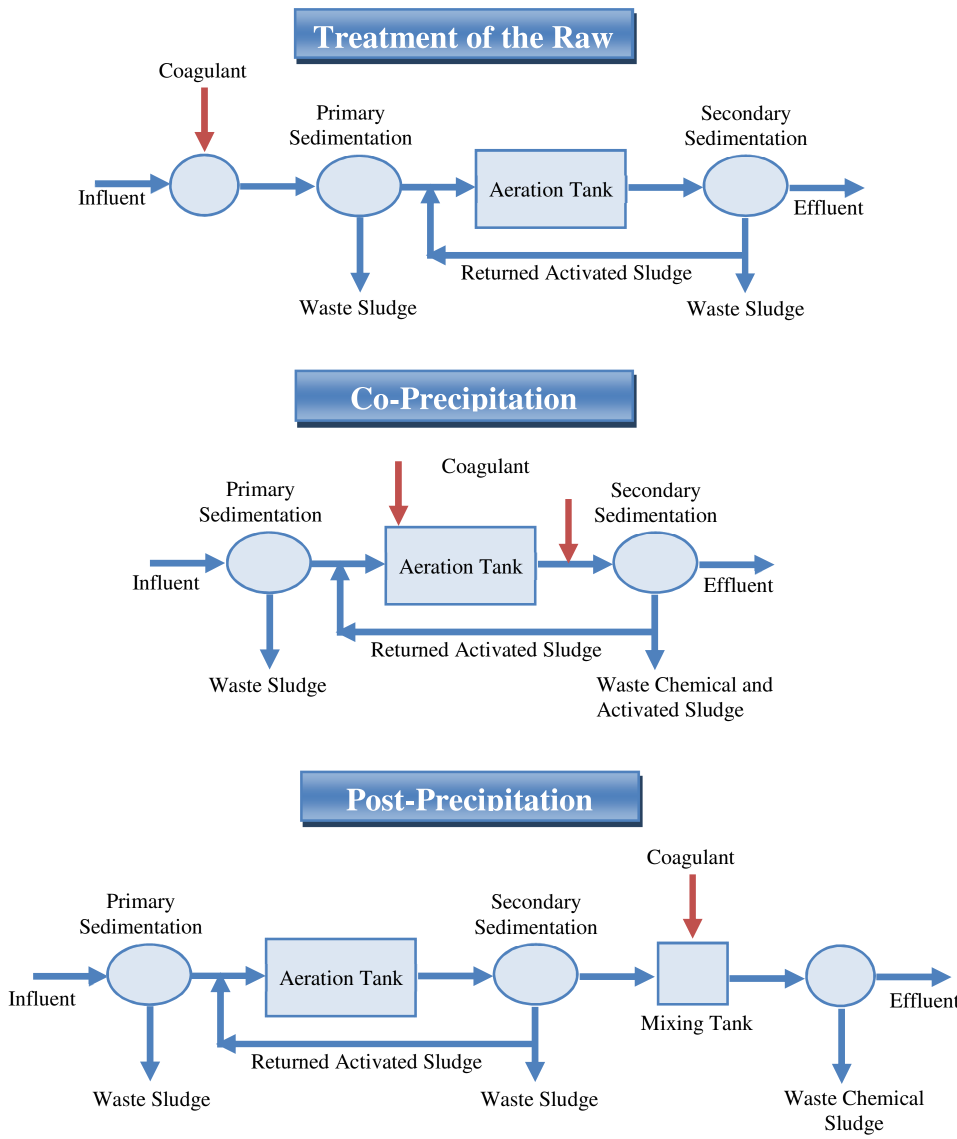
The main phosphate removal processes are, treatment of the raw wastewater, co-precipitation and post-precipitation (see Figure 5.6).

Treatment Schemes

The treatment of raw/primary wastewater is accomplished by the addition of a coagulant in the primary clarifier. The first process is included (see Figure 5.6) in the general category of chemical precipitation processes. Phosphorous is removed with 90% efficiency and the final P concentration is lower than 0.5 mg/L. The chemical dosage for P removal is the same as the dosage needed for BOD and SS removal, which uses the main part of these chemicals. Lime consumption is dependent on the alkalinity of the wastewater, only 10% of the lime fed is used in the phosphorous removal reaction.

Treatment contemporary to the secondary biologic reaction (co-precipitation) (see figure 5.6), is by the addition of the coagulant in the aeration section of the facility and before final clarification, the **co-precipitation process** is particularly suitable for active sludge plants, where the chemicals are fed directly in the aeration tank or before it. The continuous sludge recirculation, together with the coagulation-flocculation and adsorption process due to active sludge, allows a reduction in chemical consumption.

Figure 5.6



Moreover the costs for the plant are lower, since there is no need for big post-precipitation ponds. In this process the chemical added are only iron and aluminium, lime is added only for pH correction. Lower costs and more simplicity are contrasted by phosphorous removal efficiency lower than with post-precipitation (below 85%). The phosphorous concentration in the final effluent is about 1 mg/L. Another disadvantage is that biological and chemical sludge are mixed, so they cannot be used separately in next stages.

Treatment of final effluent of biological plants (**post-precipitation**) (see figure 5.6) by the addition of the coagulant to the secondary clarifier effluent in a mixing tank followed by further clarification. The post-precipitation is a standard treatment of a secondary effluent, usually using only metallic reagents. It is the process that gives the highest efficiency in phosphorous removal.

Efficiency can reach 95%, and phosphorous concentration in the effluent can be lower than 0.5 mg/L. Post-precipitation gives a good removal of the SS that escape the final sedimentation of the secondary process. Its advantage is also to guarantee purification efficiency at a certain extent even if the biological process is not efficient for some reason. The chemical action is stronger, since the previous biologic treatment transforms part of the organic phosphates in orthophosphates. Disadvantages are high costs for the treatment plant (big ponds and mixing devices) and sometimes a too diluted effluent.

Chemical precipitation of phosphorus is expensive due to the associated chemical cost and the increased cost due to the increase in sludge production. Sludge production and therefore disposal cost may increase from 40 to 60 %

For relatively soft water, **normally alkalinity is in the range of 100 – 125 ppm**. Alkalinity in wastewater results from the presence of the hydroxides (OH), carbonates (CO_3), and bicarbonates (HCO_3) of elements such as calcium, magnesium, sodium, and potassium. It is expressed in units of milligrams per liter (mg/L) of $CaCO_3$ (calcium carbonate).

Secondary Sedimentation

Sedimentation

The settling of suspended solids occurs because they are heavier than water. There are generally considered to be four types of settling (discrete particle, flocculent, hindered zone, and compression), and it is common to have more than one type occurring at the same time.

Operational Considerations

Multiple clarifiers capable of independent operation are recommended by "Ten States' Standards" for facilities where design average flows exceed 100,000 gallons/day.

Process control adjustments for facilities with multiple clarifiers that may help to eliminate or prevent long term solids washouts include:

- even distribution of flow to all clarifiers,
- reducing excessive return activated sludge (RAS) flow rates
- maintaining sludge blanket depths in all units at 1-3 feet

If abnormal conditions are observed in the clarifiers, the operator should look for problems:

- with sludge return pumps,
- sludge collection equipment (flights, scrapers, suction orifices), or
- inadequate control of sludge blanket depths.

Clarifier detention times should be at least 3-4 hours for suspended growth processes and 2-3 hours for fixed film (attached growth) processes.

Surface Overflow & Solids Loading Rates

Settling characteristics are affected by hydraulic influences, temperature, and relative abundance of nuisance filamentous organisms. Table 5.7 below (adapted from "Wastewater Engineering – Treatment, Disposal, and Reuse") lists typical design operating ranges for secondary clarifiers.

The solids loading units can be expressed as lbs./ft^2/hour as shown below or as lbs/ft^2/day. Table 5.7 recommends using the hourly rate because the loading should be evaluated at both peak and average flow conditions. If peaks are short duration, average 24-hour values may govern; if peaks are of long duration, peak values should be assumed to govern to prevent the solids from overflowing the tank.

When calculating solids loading rates use the following equation:

<u>Solids applied/lbs day</u>

Surface area / ft^2

Problem #14

The flow to a 4.5 MGD oxidation ditch is 3.1 MGD the MLSS concentration of the oxidation ditch is 3100 mg/L and the return sludge flow is 75 % of the influent flow. What is the solids loading rate on 2 clarifiers with a diameter of 100 feet each?

Activated sludge solids have a specific gravity so near to that of water that the increased density and viscosity of the wastewater under winter conditions adversely affect the settling properties of the sludge.

TABLE 5.7

TYPICAL DESIGN INFORMATION FOR SECONDARY CLARIFIERS					
TYPE OF TREATMENT	**OVERFLOW RATE (gal/ft^2./day)**		**SOLIDS LOADING (lbs./ft^2./hour)**		**DEPTH (feet)**
	Average	**Peak**	**Average**	**Peak**	
Following Air Activated Sludge	400-800	1000-1200	0.8-1.2	2.0	12-20
Following Oxygen Activated Sludge	400-800	1000-1200	1.0-1.4	2.0	12-20
Following Extended Aeration	200-400	600-800	0.2-1.0	1.4	12-20
Following Trickling Filtration	400-600	1000-1200	0.6-1.0	1.6	10-15
Following RBCs – Secondary Effluent	400-800	1000-1200	0.8-1.2	2.0	10-15
Following RBCs – Nitrified Effluent	400-600	800-1000	0.6-1.0	1.6	10-15

Weir Loading Rates

The flow divided by the length of the weir is a common control parameter for clarifiers although it is less critical than either the surface overflow or solids loading rates. If weirs are located at the tank perimeter or at end walls in rectangular tanks, a horizontal baffle should be provided to deflect the density currents toward the center of the tank and away from the effluent weir.

Circular clarifiers should be equipped with center diffusion wells with a minimum diameter of 25% of the overall tank diameter for the dissipation of the influent energy and the distribution of the incoming mixed liquor. Weir loading rates (WLR) should not exceed 30,000 GPD/ft at maximum flow for large tanks or 20,000 GPD/ft for small tanks. At average flows, the WLR should be 10,000 GPD/ft or less for small clarifiers. The upflow velocity in the immediate vicinity of the weir should be limited to 12-24 ft/hour.

When calculating the weir loading rate use the following equation:

$$\frac{\textbf{Flow in GPD}}{\textbf{Length of weir in feet}}$$

Problem #15

The flow to two 75 ft circular clarifiers is 5.25 MGD. What is the weir loading rate in gallons/ft?

Circumference = ∏ X diameter

Waste Treatment Ponds

Waste treatment ponds are any pond receiving raw or partially treated sewage or waste in which stabilization occurs through sunlight, air or microorganisms. This section will discuss the types, application, classification and detention times of ponds.

Types & Application

Stabilization ponds – Ponds designed to receive wastes with no prior treatment, also referred to as “raw wastewater (sewage) lagoons”.

Oxidation ponds – Ponds used in series following primary treatment to provide additional clarification, BOD removal, and disinfection.

Polishing ponds – Ponds used in series following secondary treatment (trickling filters), thus providing a form of “tertiary treatment.”

Pond Classifications

Aerobic ponds – Dissolved oxygen is distributed throughout the pond practically all of the time. Oxygen may be provided by algae during the daylight hours, mechanical surface aerators, or by diffused aeration provided by compressors.

Detention Times for Aerobic Ponds

- 3 days – Pond will perform similar to a sedimentation basin. Some growth of algae will occur, but it will not have a major effect on the treatment of the wastewater.

- 3 to 20 days – Prolific growth of algae with large amounts being carried over in the effluent. Organic material in the effluent may exceed organic content of the influent.

- 60 days – This is the amount of time necessary to establish a thriving biological population for waste reduction. Removals of 90 to 95% of coliform bacteria and 70 to 80% of BOD load can be achieved approximately 80% of the time.

- 180 days – Controlled discharge ponds. Removal efficiencies up to 85 to 95% for BOD_5 and TSS and 99% for fecal coliform can be achieved.

Anaerobic ponds – There is a lack of dissolved oxygen throughout the entire depth. Treatment depends upon fermentation of the sludge on the pond floor. They are used mainly for processing industrial wastes, but facultative domestic-waste ponds can become anaerobic if organically overloaded.

Facultative ponds – These are the most common type. They are usually 4 to 5 feet deep with the upper 2 feet being aerobic while the bottom 2 or 3 feet is anaerobic. Algae provide most of the oxygen for the upper portion of the pond.

Detention Times for Deep-cell Facultative Ponds

- 20 days for 85% BOD_5 removal. Aerated cells are required, with a polishing lagoon-tapered aeration is recommended.

- Existing ponds may be upgraded by deepening the pond and adding mechanical aeration. This upgrade will result in the pond being 12-18 ft. deep with the upper 4-6 ft being aerobic, 6-12 ft. facultative and the remaining area is anaerobic. These types of facilities are described as aerated deep cell facultative lagoon.

Algae Growth

Photosynthesis is necessary to create algae growth. Like land plants, they release oxygen and carbon dioxide as waste products. During photosynthesis in the daylight hours, dissolved oxygen levels and pH will increase. At night, both will drop since CO_2 is no longer being converted to free oxygen.

Each pound of algae in a healthy pond is capable of producing an average of 1.6 pounds of oxygen on a normal summer day by utilizing sunlight through photosynthesis. This is the process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material utilizing sunlight for energy.

The oxygen produced by the algae is then available for the aerobic bacteria to utilize in the breakdown of organic matter to carbon dioxide and ammonia that is then utilized by the algae in a continuous cycle.

During winter months when ponds are covered with ice and snow, sunlight is no longer available for the algae, and the system becomes septic. Odorous gases will then accumulate under the ice that is the result of anaerobic decomposition of the wastes.

Methods used to reduce odors in ponds have included:

(1) use of floating aerators,

(2) recirculation from aerobic units,

(3) use of odor masking chemicals,

(4) heavy chlorination. Chlorination is usually not recommended because it will interfere with the biological stabilization of the wastes.

Sodium Nitrate is one of the most common chemicals used as a source of oxygen for microorganisms in ponds to prevent or reduce odors.

Waste Loading Criteria for Ponds

Organic loading = pounds of BOD_5 per acre per day.

$$\text{Lb of } BOD_5\text{/day/acre} = \frac{(\text{Flow in MGD})(8.34)(BOD_5 \text{ mg/L})}{\text{Pond Surface area/ acres}}$$

Let's work a couple of practice problems.

Problem#16

The flow to two 500 ft wide by 600 ft long lagoons is .5 MGD with an influent concentration of 131 mg/L. What is the organic loading in lbs of BOD per acre?

Population loading = persons (or population served) per acre per day.

$$\text{Persons/acre} = \frac{\text{Population Served/Persons}}{\text{Pond Surface Area/Acre}}$$

Problem #17

The flow to two 700 ft long by 600 ft wide lagoons is .765 MGD. These lagoons serve a population of 4200 people. What is the loading in persons per acre?

Note - Hydraulic loading is another method of waste loading criteria for ponds. This method is not an operator practice for determining hydraulic loading. It is not taught in depth, this is more for you information. **Hydraulic loading = inches or feet of depth added per day.**

Operation & Maintenance of Stabilization Ponds

At least one foot of water should be in the pond before adding wastewater at start-up to reduce the potential of odors. It is also better to start ponds during the warmer months in order for the biological treatment process to become more quickly established.

The **pH of the pond should be kept above 7.5** as an aid to the digestion of sludge by the acid-producing anaerobic bacteria. Soda Ash (sodium carbonate) is sometimes added to the pond influent to increase the pH and alkalinity.

Scum should be kept under control on pond surfaces since it blocks sunlight to the algae and interferes with oxygen transfer from the atmosphere. Large amounts of brown or black scum usually indicate that the pond is overloaded.

If the first pond in a series operation is organically overloaded, they should be switched to parallel operation in order for the loading to be evenly distributed between the other units.

Pond depths of at least 3 feet are necessary to control the growth of weeds such as Tules.

Plants along the water's edge can cause problems by providing mosquito breeding grounds, and deep-rooted plants such as willows can cause problems with levees by providing water seepage paths that could possibly result in levee failure. Plants should be removed continuously from both sides of the levee as they appear and not be allowed to establish a deep root system.

Banks should be rip-rapped if not equipped with a liner to help control weed growth and to deter erosion caused by the water's wave action.

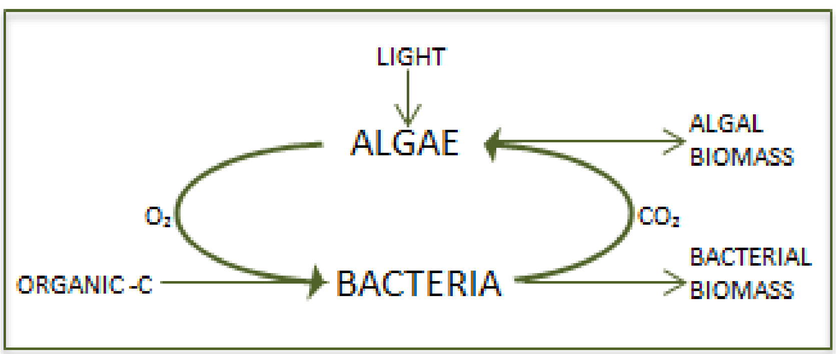
Use herbicides for vegetation control on levee banks only as a last resort.

Suspended and flowering plants such as duckweed will usually not flourish if exposed to enough wind action. If they are a problem, they should be pushed to one corner and physically removed.

Operation and Maintenance of Aerated Lagoons

Aerated lagoons will require the same daily inspections used for other facilities with special emphasis put on the aeration equipment.

- Maintain a minimum **DO of 2.0 mg/L and a pH above 7.5** throughout the cells.
- Mechanical surface aerators should provide good turbulence and a light amount of froth.
- Monitor and record the DO, pH, and flow daily.
- Monitor and record BOD_5 load, TSS, alkalinity, volatile acids and sludge depth on a regular basis.
- Check for "dead spots" where there appears to be no turbulence or mixing.
- Complete periodic inspection and maintenance on the aeration devices.



Facultative lagoons

Biodegradable organic carbon is introduced by the influent wastewater and converted by bacteria to biomass and carbon dioxide (CO_2). The latter (CO_2) is utilized photosythetically by algae to form algal biomass and oxygen. The oxygen (O_2) thus produced becomes available to the bacteria for the degradation of more organic carbon (C). Algal biomass, unlike bacterial biomass, resists gravity sedimentation. As a result, the effluent of a facultative lagoon generally consists of a high concentration of organic carbon in the form of algal biomass.

Facultative lagoons have three major disadvantages: **odors**, **variable effluent quality**, and **large footprint**. The sources of odors have been discussed above. Variable effluent quality is a characteristic of all facultative lagoons. The removal of BOD_5 will vary from 50 to 95 percent, depending on how much algae is in the lagoon at the time. Only with additional treatment such as intermittent sand filtration can facultative lagoons consistently achieve BOD_5 effluent limits now being imposed.

Furthermore significant concentrations of nitrogen and phosphorus are found in the effluents. As for land area requirements, a wastewater flow of 1 MGD will require about 30 acres of lagoon, if the latter is loaded at 50 lb BOD_5/acre-day.

Aerated Lagoons

The aerobic bacteria that occur are similar to those found in other treatment processes such as activated sludge. Four functional groups occur: freely dispersed, single bacteria; floc-forming bacteria; and filamentous bacteria. All function similarly to oxidize organic carbon (BOD) to produce CO_2 and new bacteria (new sludge).

An ample oxygen supply in a wastewater pond system is the key to rapid and effective wastewater treatment. Oxygen is needed by the bacteria to allow their respiration reactions to proceed rapidly. The oxygen is combined by the bacteria with carbon to form carbon dioxide. Without sufficient oxygen being present, bacteria are not able to quickly biodegrade the incoming organic matter.

Unlike conventional wastewater treatment plants that must remove excess sludges daily. A pond type system can go from ten to twenty years without ever needing cleaning. This is because, in the presence of sufficient oxygen, bacterial cells that settle to the ponds bottom are eventually biodegraded into carbon dioxide and inert materials.

If sufficient oxygen is not present in the ponds, the sludge layer will accumulate faster than it can be biodegraded. When this occurs, the sludges may build up to a point that it must be removed at a faster rate than would be expected for a pond. This effectively eliminates the main advantage of a lagoon system which is supposed to be an infrequent sludge removal need.

Adequate aeration is an important element in keeping the lagoons content mixed and in suspension. Even in a partially-mixed hydraulic regime, mixing is very important to the overall treatment process. With adequate mixing, incoming pollutants and wastewater are better distributed throughout the entire lagoon volume. This results in more uniform and efficient treatment

Biological activity in the ponds is optimized when a minimum dissolved oxygen saturation concentration of 2.0 ppm is maintained at all times. The aeration equipment should be sized for this basis.

Other Considerations

Short-circuiting occurs when no water movement is evident in a portion of the lagoon. It may be caused by poor design of the inlet and outlet arrangement or placement, unlevel bottoms, shape of the cells, wind patterns or by uncontrolled weed growth in the water. This may lead to dead spots, odors and sludge mats. These problems must be corrected as soon as possible.

Maintaining a minimum water level is necessary to prevent exposing the bottom of the lagoon to the atmosphere thus preventing odors and the drying out and cracking of the bottom.

Chapter 5 Review Questions

1. What is the designed detention time for a primary clarifier?
2. What should be routinely checked and monitored during settling?
3. The sludge from a primary clarifier is moved only one time a day? **True or False**
4. The sludge in a primary clarifier settles to a concentration of____ to ____% solids.
5. If the influent BOD to a primary clarifier is 167mg/L and the effluent is 104 mg/L. How efficient is the clarifier?
6. The efficiency of a trickling filter operation is most commonly measured by which parameter?
7. When using a fixed film/attached growth reactor for treatment, where do the bacteria grow?
8. When using a fixed film/attached growth reactor for treatment what may recirculation be used for?
9. List three reasons we use mechanical aeration in suspended growth systems.
10. The mass of microorganisms present in the system is referred to as biological solids or_______________.
11. Describe a step feed influent scheme.
12. What is the major disadvantage to the extended aeration treatment process?
13. List the cycles of a SBR.
14. The total suspended solids in the aeration basin are controlled by what?
15. How many parts per million of alkalinity does it take to convert 1 PPM of NH_3-N to NO_3?
16. Phosphorus is removed either ______________________ or through chemical addition or both.
17. If abnormal conditions are observed in the clarifiers, the operator should look for problems with what?
18. What are the three classifications of ponds?
19. In aerobic ponds, how may the oxygen be added?
20. In anaerobic ponds treatment depends on what?
21. During photosynthesis in the daylight hours, dissolved oxygen levels and pH will___________.
22. Why do you want to control scum on the surface of a lagoon?

23. Lagoons do/do not require the same daily inspections used for other types of facilities.
24. What DO level do you want to have in an aerobic lagoon to optimize the biological activity?
25. Why do you maintain a minimum water level in your lagoon?

Answers for Chapter 5 Review

1. 1.5 – 2 hours
2. Settleable solids in and out of clarifier, sludge moisture, sludge pumping cycle and sludge blanket depth, and weirs, skimmers, draw down tubes and rakes
3. False
4. 4-8 %
5. 37.7% Removal
6. BOD or COD
7. On the substrate
8. To equal out diurnal flows, reseed media substrate, or reduce organic strength.
9. Keep the food, microorganisms, and food in contact with each other.
10. MLSS Mixed Liquor Suspended Solids
11. Splitting the influent flow into multiple treatment trains/tanks.
12. Expensive/ high electrical costs.
13. Idle, Fill, React, Settle, Decant.
14. By the amount of sludge wasted.
15. 7.2
16. Biologically
17. The sludge handling equipment
18. Aerobic, anaerobic and facultative
19. Algae, mechanical aeration
20. Lack of dissolved oxygen
21. Increase
22. To allow sunlight and oxygen on the surface of the water to enhance treatment
23. Do.
24. 1-2 mg/L
25. To ensure proper operation

Answers for Chapter 5 Math

$$\frac{\text{volume of sludge pumped in ft}^3 \text{ X } 7.48 \text{ gal/ft}^3}{\text{Min. pump ran}} = \text{Gal per min}$$

Problem #1

Two 45 ft by 30 ft drying bed were filled with 1 ft of sludge from a digester in 2 hr 10 min. what is the gallon per minute pump rate?

2 drying beds X 45ft X 30ft X 1 ft = 2,700 ft^3 X 7.48 gal/ft^3 = $\frac{20{,}196 \text{ gal}}{130 \text{ min}}$ = 155.35 gpm

Volume of sludge pumped in ft^3 X 7.48 gal/ft^3 X 8.34 lbs/gal X concentration/mg/L = lbs pumped

Problem #2

How many lbs of sludge will be loaded onto two 50 ft X 25 ft drying bed if 1.5 ft of sludge is added at a concentration of 22,500 mg/L?

50 ft X 25 ft X 1.5 ft deep X 2 drying beds = 3,750 ft^3 X 7.48 gal/ft^3 =28,050 gal

.02805 X 8.34 X 22,500 mg/L = 5,263.58 lbs
or
28,050 gal X 8.34 X 2.25% solids = 5,263.58 lbs

Lbs of BOD_5 primary influent – lbs of BOD_5 primary effluent = lbs captured in primary

Problem #3

The influent flow to a 2 MGD fixed film reactor is 1.4 MGD with an influent TSS of 223 mg/L the effluent concentration from the primary clarifier is 102 mg/L. How many lbs of solids were captured in the primary clarifier?

1.4 MGD X 8.34 X 223 mg/L = 2,603.7 lbs TSS influent to primary clarifier

1.4 MGD X 8.34 X 102 mg/L = 1,190.9 lbs TSS effluent from primary clarifier

Pounds captured = 2,603.7 – 1,190.9 = 1,412.8 lbs captured

Detention Time = 1.5 to 2.0 hours

When calculating for detention time in hours use the following formula.

$$\frac{\textbf{Tank volume in Ft}^3 \textbf{ X 7.48 gal/Ft}^3 \textbf{ X 24 hr}}{\textbf{Flow in GPD}}$$

Problem #4

The flow to a 75 feet diameter clarifier with a 10 feet water depth is 2 MGD. What is the detention time in hours?

$$.785 \text{ X } 75 \text{ ft X } 75 \text{ ft X } 10 \text{ ft X } 7.48 = \frac{330{,}288.75 \text{ gal}}{2{,}000{,}000\text{GPD}} \text{ X } 24 \text{ hr} = 3.96 \text{ hrs}$$

Weir Overflow Rate = 5,000 to 15,000 gpd/ft

$$\text{Formula for Weir overflow rate in GPD/ft} = \frac{\textbf{Flow in GPD}}{\textbf{Length of weir in ft}}$$

Problem #5

The flow to a 100 ft clarifier is 2.1 MGD. What is the weir overflow rate?

Circumference = ∏ X diameter = 3.14 X 100 ft = 314 ft of weir

$$\frac{2{,}100{,}000}{314 \text{ ft}} = 6{,}684.5 \text{ gal/per ft of weir}$$

Surface Loading Rate = 600 to 800 gpd/ft^2

$$\text{Formula for surface loading rate in GPD/Ft}^2 = \frac{\text{Flow in GPD}}{\text{Surface area in Ft}^2}$$

Problem #6

The flow to two 100 ft clarifiers is 8.9 MGD. What is the surface loading rate?

.785 X 100ft X 100ft X 2= 15,700 sq ft

$$\frac{8{,}900{,}000 \text{ GPD}}{15{,}700 \text{ f}} = 566.9 \text{ gal/day/sq ft}$$

Problem #7

The influent BOD to a trickling filter plant is 179 mg/L and the effluent flow is 10 mg/L. What is the percent removal of BOD ?

$$\frac{179\ \text{mg/L} - 10\ \text{mg/L}}{179\ \text{mg/L}} \times 100 = 94.4\%$$

Problem #8

The primary effluent flow is 1.2 MGD with a BOD_5 of 123 mg/L. This flow enters a 100 ft diameter trickling filter that is 5 ft deep with each ft^3 of area containing 30 ft^2 of filter material. What is the **organic loading in lbs of BOD_5 per 1000 ft^3**?

LBS BOD_5 = 1.2 MGD X 8.34 X 123 mg/L BOD = 1230.9 lbs BOD_5

Volume of filter in ft^3 = .785 X 100 ft X 100 ft X 5 ft = 39,250 ft^3

Conversion to 1,000 ft^3 = 39,250ft^3 ÷ 1,000 = $39.25_{1,000}$ ft^3

$$\frac{1{,}230.9\ \text{lbs BOD}_5}{39.25\ _{1,000}\ \text{ft}^3} = 31.36\ \text{lbs BOD}_5\ /\ _{1,000}\ \text{ft}^2$$

Problem #9

The primary effluent flow to a 4 train RBC is .9 MGD with a BOD_5 concentration of 115 mg/L. What is the organic loading on each train of this RBC plant in Lbs of BOD_5 per 1,000ft^2?

Lbs BOD5 = .9MGD X 8.34 X 115 mg/L = 863.19 lbs BOD_5

Area of filter media in ft^2 = 100,000 ft^2 per train 4 trains = 400,000 ft^2

Conversion to 1000 ft^2 = 400,000 ft^2 ÷ 1,000 = 400 $_{1,000}$ ft^2

$$\frac{863.19\ \text{lbs BOD}^5}{400\ _{1,000}\ \text{ft}^2} = 2.15\ \text{lbs BOD}^5\ _{1,000}\ \text{ft}^2$$

Problem #10

The weight of the dish (tare weight) was 25.3334 gm and after drying the weight of the dish and the dry solids was 25.4329 gm, the sample size was 25 ml. What is the MLSS in mg/L?

$$25.4329\text{gm} - 25.3334 = .0995\text{gm} \times 1{,}000 \times 1{,}000 = \frac{99{,}500\text{gm}}{25 \text{ ml}} = 3{,}980 \text{ mg/L}$$

To calculate the MLVSS gravimetrically use the following:

$$\mathbf{\frac{(W2) - (W3) \times 1{,}000 \times 1{,}000}{Sample\ volume/\ ml}}$$

W2 = weight of the dish and the dry solids
W3 = Weight of the dish and the ash

Problem #11

The weight of the dish and the ash was 25.3991 and the weight of the dish and the dry solids was 25.4329, the sample size was 25 ml. What is the MLVSS in mg/L?

$$25.4329 \text{ gm} - 25.3991 \text{ gm} = .0338 \text{ gm} \times 1{,}000 \times 1{,}000 = \frac{33{,}800 \text{ gm}}{25 \text{ ml}} = 1{,}352 \text{ mg/L}$$

Problem #12

The thirty minute settled sludge volume (SSV_{30}) is 450 ml and the MLSS is 4,000 mg/L. What is the SVI?

$$\frac{450 \text{ ml} \times 1{,}000 \text{ mg/g}}{4{,}000 \text{ mg/}} = 112.5$$

Problem #13

A community of 2,000 people has a .25 MGD extended aeration plant. How many lbs of BOD will be loaded per 1,000 ft^3 of aeration basin volume?

Lbs BOD = population X .17 lbs BOD person/day = 2,000 X .17lbs BOD = 340 lbs BOD /day

Aeration tank volume in 1,000 ft^3 = 250,000 Gallons ÷ 7.48 gal/ft^3 ÷ 1,000 = 33.42 $_{1,000}$ ft^3

$$\frac{340 \text{ lbs BOD}}{33.42\ _{1,000}\ ft^3} = 10.17 \text{ lbs BOD}\ _{1,000}\ ft^3$$

Problem #14

The flow to a 4.5 MGD oxidation ditch is 3.1 MGD the MLSS concentration of the oxidation ditch is 3100 mg/L and the return sludge flow is 75 % of the influent flow. What is the solids loading rate on 2 clarifiers with a diameter of 100 feet each?

Solids applied = RAS flow + Influent flow X 8.34 X mg/L MLSS in OD

RAS flow = 3.1 X .75 = 2.325 MGD + 3.1 MGD = total flow to clarifiers = 5.425 MGD

5.425 X 8.34 X 3100 mg/L = 140,258 lbs solids applied

Clarifier area ft^2 =- .785 X 100 X 100 = 7850 ft^2 X 2 = 15,700 ft^2

$$\frac{140{,}258 \text{ lbs applied}}{15{,}700 \text{ ft}^2} = 8.93 \text{ lbs/ ft}^2$$

Problem #15

The flow to two 75 ft circular clarifiers is 5.25 MGD. What is the weir loading rate in gallons/ft?

Circumference = ∏ X diameter = 3.14 X 75 ft = 235.5 ft^2 X 2 = 471 ft

$$\frac{5{,}250{,}000 \text{ GPD}}{471 \text{ ft}} = 11{,}146.4 \text{ gal/day/ft}$$

Problem #16

The flow to Two 500 ft wide by 600 ft long lagoons is .5 MGD with an influent concentration of 131 mg/L. What is the organic loading in lbs of BOD per acre?

$$500 \text{ ft X } 600 \text{ ft X } 2 = \frac{600{,}000 \text{ ft}^2}{43{,}560 \text{ ft}^2 / \text{ac}} = 13.77 \text{ ac}$$

Lbs BOD = .5 MGD X 8.34 X 131 mg/L = 546.27 lbs BOD

$$\frac{546.27 \text{ lbs BOD}}{13.77 \text{ ac}} = 39.67 \text{ lbs BOD/ac}$$

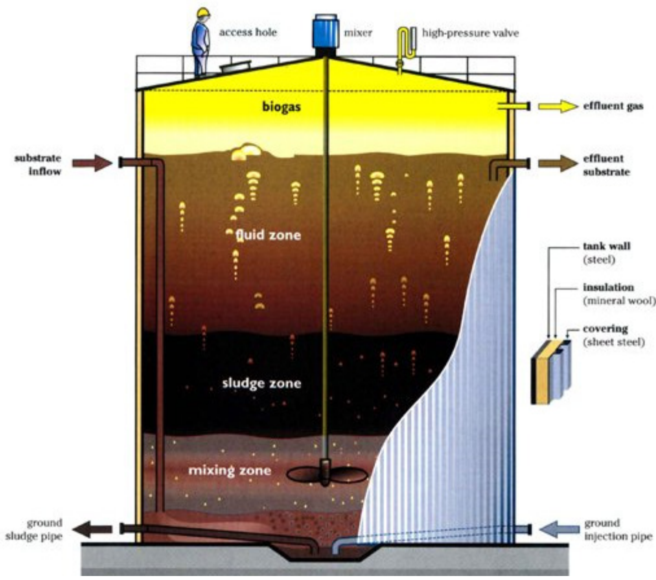
Problem #17

The flow to two 700 ft long by 600 ft wide lagoons is .765 MGD. These lagoons serve a population of 4200 people. What is the loading in persons per acre?

$$600 \text{ ft X } 700 \text{ ft X } 2 = \frac{840{,}000 \text{ ft}^2}{43{,}560 \text{ ft}^2/\text{ac}} = 19.28 \text{ ac}$$

$$\frac{4{,}200 \text{ people}}{19.28 \text{ ac}} = 217.84 \text{ people per ac}$$

Chapter 6: Digesters



Chapter 6 Objectives

1. Describe the aerobic digestion process and the affecting factors.
2. Calculate the specific oxygen uptake rate.
3. Understand the design criteria for aerobic digesters.
4. Demonstrate knowledge of the kinetics of anaerobic digesters, their chemistry, design parameters, and performance monitors.
5. Understand high-rate and standard digesters.
6. Demonstrate knowledge of the explosive gases that potentially emanate from anaerobic digesters.

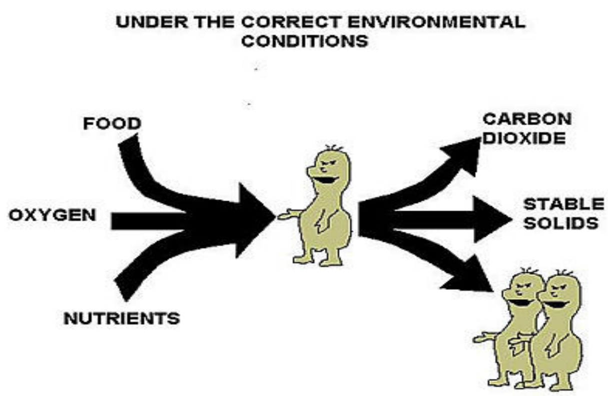
7. Identify and explain the various methods used for solids dewatering in the municipal wastewater treatment process.

Aerobic Digestion

Aerobic digestion is one of several methods used to treat the waste sludge solids before dewatering and disposal. It employs aeration to stabilize waste primary sludge, waste biological sludge, or a combination of these in an open or closed tank.

Digestion units can also serve as sludge storage to provide process flexibility ahead of dewatering units. Because drying beds cannot be used to dewater sludge during freezing weather, aerobic digesters serve as holding tanks in plants that employ drying beds.

Advantages claimed for **aerobic digestion over** anaerobic digestion include: (A) lower BOD concentrations in supernatant liquor; (B) production of an odorless, humus-like, biologically stable end product; (C) operation is relatively easy; and (D) lower capital cost.



Major **disadvantages** include high power costs associated with supplying the required oxygen and sludge is produced with poor mechanical dewatering characteristics.

Aerobic digestion is similar to the activated sludge process with one exception; the microorganisms are functioning in the "**endogenous respiration**" phase which means that as the available organic food supply (BOD) is depleted, the microorganisms begin to consume their own protoplasm to obtain energy for cell maintenance reactions.

About 75-80% of the cell tissue is oxidized aerobically to carbon dioxide, water, and ammonia. The remaining 20-25% is composed of inert components and organic compounds that are not biodegradable. The ammonia is subsequently oxidized to nitrate.
As in the activated sludge process, theoretically **7.2 per pounds of alkalinity** are utilized per pound of ammonia oxidized.

A pH drop can occur if the alkalinity of the wastewater is insufficient to buffer the solution. The process can be operated in a continuous or batch mode. Smaller plants use the batch system in which sludge is aerated and completely mixed for an extended period of time, followed by quiescent settling and decantation.
In continuous systems, usually a separate tank is used for decantation and concentration.

Factors that must be considered in the design and operation of aerobic digesters are as follows:

- Temperature;
- Dissolved oxygen requirements;
- Tank volume (Hydraulic Retention Time);
- Sludge characteristics (Percent Solids Reduction);
- Loading rate; and
- Energy requirements for mixing.

Similar to the respiration rate performed on activated sludge processes, the specific oxygen uptake rate (SOUR) is a process control test which measures the oxygen utilization by microorganisms in digesters and is used to determine the level of biological activity and the resulting solids destruction. The SOUR is expressed in terms of milligrams of oxygen per gram of volatile suspended solids per hour (mg/g VSS-hr) during active aerobic digestion; a common range is from 5 to 10 mg/g VSS-hr. A SOUR for well-digested sludge from the aerobic digestion process ranges from 0.5 to 5.0 mg/g VSS-hr.

Of these alternatives, the quickest and easiest to perform is the SOUR with the goal to achieve a value **less than or equal to 1.5 mg/g VSS-hr at 20^{o} C**. This test is performed by taking a well mixed sample of MLSS from the digester and supersaturating it with oxygen by shaking. Place the sample on a magnetic stirrer to maintain mixing conditions and measure the initial DO with a DO meter. Then take DO measurements every 30 seconds until the drop begins to taper off from previous readings (usually 6 or 7 minutes).

The calculation is as follows:

$$\text{SOUR} = \frac{\text{mg/L DO drop per minute} \times 60\ \text{min/hr} \times (1000\ \text{mg/g})}{\text{MLVSS in mg/L}}$$

Problem #1

The MLVSS is 2,550 mg/L and the initial DO was 7.9 mg/L and 6 minutes later the DO is 5.3 mg/L. What is the SOUR in MG/G VSS/hr?

The design criteria and operational parameters for aerobic digesters can be found in Table 6.1.

TABLE 6.1 Aerobic Digestion Design Criteria

PARAMETER	VALUE	REMARKS
Solids Retention Time, days	10-15[b]	Depends on temp, type of sludge
Solids Retention Time, days	15-20[c]	
Volume Allowance, ft^3/capita	3-4	
Volatile Suspended Solids loading, lb./ft^3/day	0.024-0.14	Depends on temp, sludge type, etc.
Air requirements-diffuser system, CFM/1000 ft^3	20-40[b]	Enough to keep solids in suspension & maintain 1-2 ppm DO.
Air requirements-diffuser system, CFM/1000 ft^3	60[c]	
Mechanical system, hp/1000 ft^3	1.0-1.25	Governed by mixing requirements
Minimum DO, mg/L	1.0-2.0	

Temperature, °F	59	If lower temp., additional detention time should be provided so that digestion will occur at lower biological reaction rates.
VSS reduction, %	35-50	
Power requirement, bhp/10,000 population	8-10	

[a] – Adapted from Operation of Municipal Wastewater Treatment Plants, MOP #11, Volume III, by Water Environment Federation.

[b] – Excess activated sludge alone.

[c] – Primary & excess activated sludge or primary sludge alone.

Anaerobic Digestion

Anaerobic digestion is a complex biological process involving several groups of anaerobic and facultative organisms simultaneously breaking down and assimilating organic matter in the absence of oxygen. For simplicity, it can be considered to be a three-stage process.

During the first stage, complex organic materials hydrolyze into simpler compounds. In the second stage, saprophytic organisms commonly referred to as "acid formers" convert these organic compounds into volatile organic acids. In the third stage, the "methane fermenters" convert the acids into methane and carbon dioxide.

Since the methane fermenters are not as abundant in raw wastewater as are the acid formers and are more easily stressed, care must be taken to operate an anaerobic digester so that the rate of acid formation and methane formation are approximately equal otherwise the reaction will get out of balance.

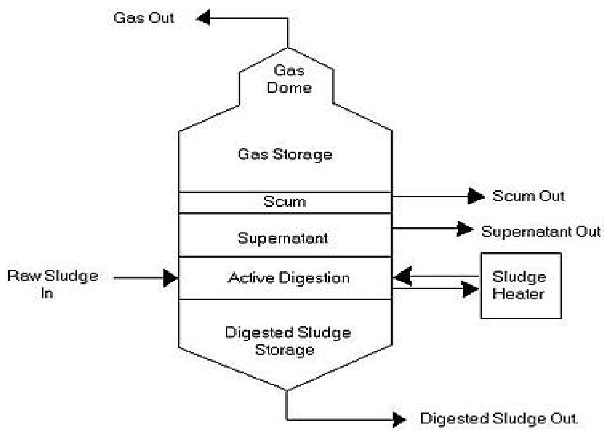
The entities that form methane function best at a pH range of 6.6 to 7.6 and will only reproduce in that range. Typical operating pH ranges are from 6.8 to 7.2. In most cases, the methane forming bacteria control the process. They are very sensitive to environmental factors and reproduce very slowly. Process design and operation, therefore, are tailored to satisfy the needs of the methane forming bacteria.

Factors affecting digester performance include

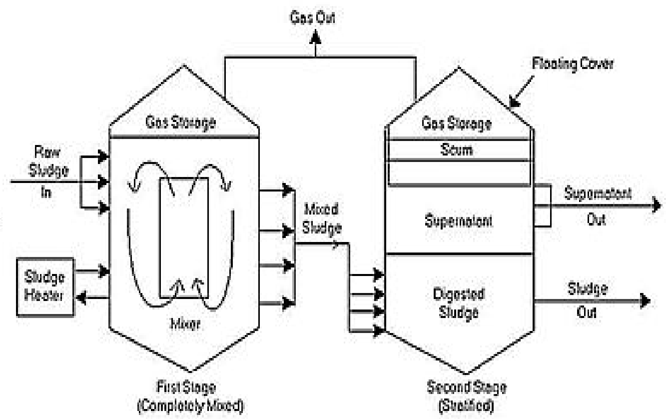
- detention time;
- temperature;
- solids concentration;
- degree of mixing;
- solids loading;
- pH, alkalinity;
- volatile acid content;
- nutrients; and
- toxic materials.

The two most common types of digesters are identified as **standard-rate** and **high-rate**. In the standard-rate digester, the contents are usually unheated and unmixed with detention times varying from 30 to 60 days. In the high-rate digestion process, the contents are heated and completely mixed with detention times typically 10-20 days. A combination of these two basic processes is known as the "**two-stage process**" where the primary function of the second stage is to separate the digested solids from the supernatant liquor, although additional digestion and gas production may occur.

Single Stage, Standard Rate Anaerobic Digester



Two Stage, High Rate Anaerobic Digester



Digesters are normally operated in one of three temperature ranges. The lowest range for unheated digesters is the psychrophilic zone. Organisms in this range tend to adjust to the outside temperature, however, below 50°F little or no bacterial activity occurs and the necessary reduction in sludge volatility will not occur. Few digesters today are designed to operate in this range, but there are still some in operation such as the Imhoff tank.

The second range and the one most commonly used is the mesophilic zone for temperatures ranging from 68°F to 113°F. Optimum ranges are from 85°F to 100°F with most being operated at 95°F. It is important to maintain a constant temperature and not let it vary more than one degree each day.

At temperatures above 113°F, digesters are operating in the thermophilic zone. Optimum temperature ranges are 120-135°F. Few digesters are operated in this range due to problems of maintaining temperature, sensitivity of the organisms to temperature change, and some reported problems of poor solids-liquid separation.

Digester covers may be of either the fixed type or floating type. With the fixed cover, care must be taken to prevent air from being drawn into the tank when sludge is withdrawn otherwise an explosive mixture can result. When starting up a digester, first check water, gas, and sludge lines for leaks; then fill the tank with water or wastewater to seal the cover. Bring the contents up to temperature and being mixing before ever adding raw sludge to lessen the possibility of an explosive mixture of gases being formed. The explosive range of the main product of anaerobic digestion, methane, is in the range of 5-15%.

If too much raw sludge is added to a digester, the acid fermenters will predominate, driving the pH down and creating an undesirable condition for the methane fermenters. The digester will go sour or acidic. When a digester recovers from a sour condition, the breakdown of the volatile acids and formation of methane and carbon dioxide is usually very rapid. The digester may then foam or froth, forcing sludge solids through water seals and gas lines and causing a fairly serious operational problem. A sour digester usually requires 30 to 60 days to recover.

The equation used to calculate the volatile solids loading on an anaerobic digester is as follows:

$$\frac{\textbf{Volatile Solids applied in pounds per day}}{\textbf{Digester volume in ft}^3}$$

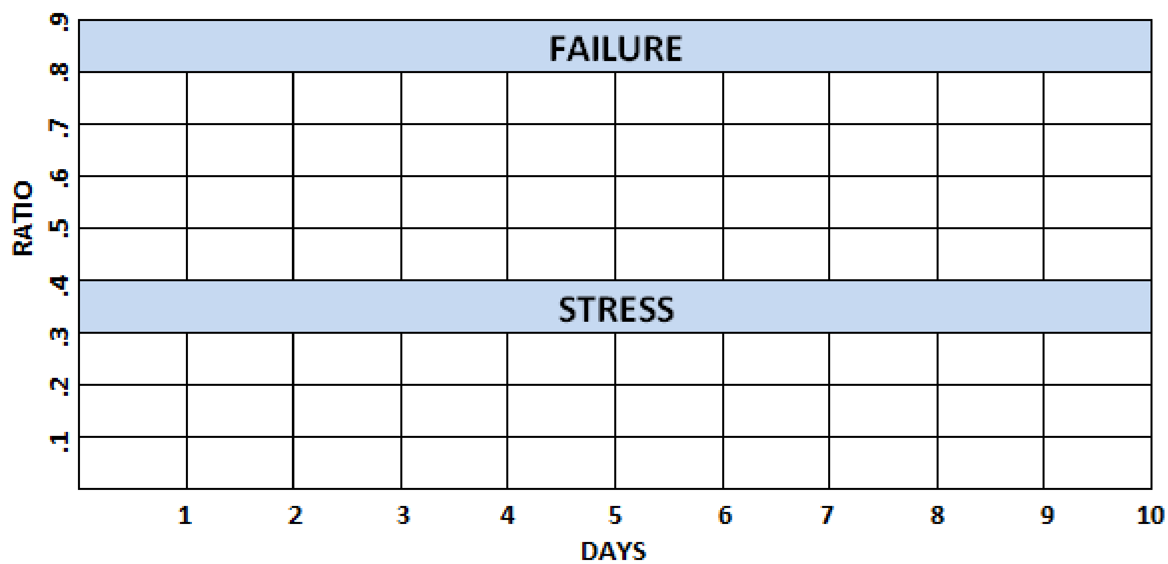
Problem #2

Calculate the volatile solids loading in **lbs VSS/ft³** on an anaerobic digester if the waste sludge flow is 8,500 GPD, the TSS is 3.5%, the VSS is 65% of the TSS and the digester volume is 50,000 gallons.

Gas produced from anaerobic digesters normally contains by volume 65-70% methane (CH_4), 25-30% carbon dioxide (CO_2), and small amounts of N_2, H_2, hydrogen sulfide (H_2S), water vapor, and other gases. Typical volumes of methane produced vary from 12 to 18 ft^3 per pound of volatile solids destroyed. The low heating value of the digester gas at 65%

methane is approximately 600 BTU/ft^3. By comparison, natural gas has a low heating value of approximately 1000 BTU/ft^3.

Monitoring this ratio is the key to successful digester performance. As long as the volatile acids remain low and the alkalinity stays high (example: 120 mg/L volatile acids/2400 mg/L alkalinity) anaerobic digestion will occur. When the ratio starts to increase, corrective action must be taken immediately to prevent the increase in CO_2 production with a resultant pH drop and eventual soured digester.



The ratio should be checked at least twice weekly and trend charts maintained. Possible causes for the ratio to get out of balance include sudden temperature drops, excessive feeding of raw sludge, excessive removal of digested sludge, or toxic overloads. Generally, the pounds of volatile solids in the feed sludge should not exceed 5% of the total pounds of volatile solids in the digester.

When digestion is proceeding satisfactorily, the alkalinity will normally range from 1000 to 5000 mg/L, and the volatile acids will be less than 250 mg/L. The volatile acid/alkalinity ratio must be maintained at less than 0.25. Generally, this ratio for a healthy digester will be 0.1 or less. Once the ratio reaches 0.3 – 0.4 the digester is being stressed and a definite problem is developing. Once the relationship reaches the vicinity of 0.5, serious decreases in the alkalinity usually occur and the concentration of CO_2 in digester gas will start increasing.

When the ratio reaches 0.8 or higher, the pH will begin to drop. However, since the pH depression does not occur until the alkalinity is depleted, digester failure has already occurred by the time the pH drop may have been detected.

Solids Dewatering & Disposal

It is usually more economical to dewater sludge prior to disposal rather than pumping or hauling liquid sludge to disposal sites. The primary objective of dewatering is to reduce sludge moisture and consequently sludge volume.

There are two types of **pressure filtration** systems used, (1) **plate and frame filter presses**, and (2) **belt filter press**.

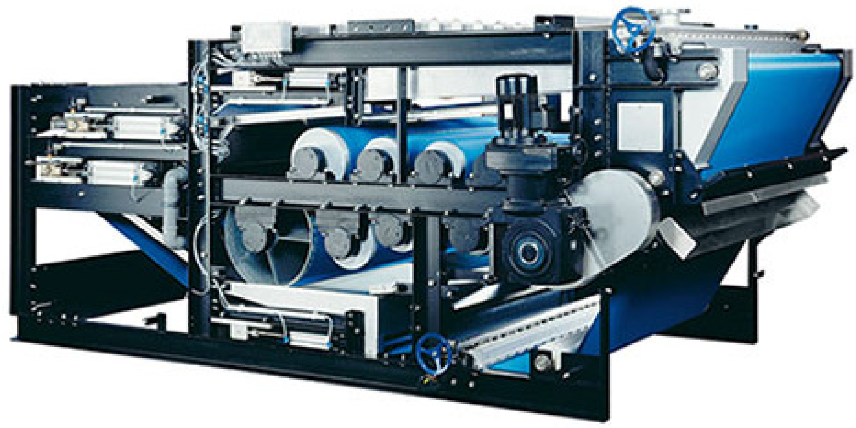
The **plate and frame filter press** operates in a batch manner and consists of vertical plates which are held rigidly in a frame and pressed together. Sludge is fed into the press through feed holes along the length of the press. As filtration proceeds, water filtrate passes through the fibers of the cloth mounted on the face of each plate and is collected in drainage ports provided at the bottom of each press chamber and then discharged.

As the cake builds up and the resistance increases, the volume of filtrate decreases. When the filtrate flow is near zero, the feed is shut off and the plates are disengaged, and the retained cakes fall by gravity into a hopper or conveyor. The solids removal efficiency is affected by sludge type, conditioning, filter pressure, filtration time, solids loading, filter cloth type, and pre-coat material used such as diatomaceous earth.

Materials used to condition sludge prior to filtration generally are lime or ferric chloride. Generally, the initial pressure is maintained at approximately **25 psi for 5 to 10 minutes** then increased at intervals approximating 5 psi/min until the terminal operating pressure is reached which can vary usually from **100 to 225 psi.**

Belt filter presses operate in a continuous manner and consist of two endless belts that travel over a series of rollers. Sludge is preconditioned usually with polymers and then applied to the free-water drainage zone of the filter belt.

The partially dewatered solids are carried to a point on the unit where they are trapped between two endless belts and further dewatered as they travel over a series of perforated and imperforated rollers.



This zone is known as the "press" or "dewatering zone." Water is forced from between the belts and collected in filtrate trays while the retained solids are scraped from the two belts when they separate at the discharge end of the press. The two endless belts then travel through respective washing chambers for the removal of fine solids to decrease the possibility of plugging.

Factors affecting belt pressure filtration include sludge type, conditioning, belt tension or pressure, belt speed, hydraulic loading, and belt type. With the addition of polymers, this blending has produced sludge cakes in the range of 24 to 26%. Belt speeds generally vary between 2 to 10 feet/minute with belt widths ranging from 1.5 to 7 feet. Loadings are from 10 to 25 gpm per foot of width.

Centrifugal sludge dewatering results from sedimentation and high centrifugal forces. Sludge is fed to a rotating bowl, and solids are separated from the liquid phase by the centrifugal forces and are forced to the bowl wall and compacted. Two basic designs include the batch operated basket centrifuge and continuous flow scroll centrifuges.

Sand drying beds are primarily used at smaller to medium sized treatment plants, drying beds usually contain 6 to 9 inches of sand placed over 12 to 20 inches of graded gravel or stone.

Sludge is placed on the beds normally to a depth of 8 to 12 inches that will result in dewatered sludge ready for removal in three to four weeks during the warm weather months. This process can be speeded up with the addition to polymers.

Factors affecting drying bed performance include **sludge type, conditioning, climatic conditions, sludge application rates and depths,** and **dewatered sludge removal techniques**. Fresh sludge should never be applied to a bed already containing partially dried sludge since unhindered filtrate drainage will be impaired.

Sludge should be digested to a volatile content of 45-60% for improved dewatering. Drying bed area is normally in the range of 2 ft^2 per capita. One problem with sludges containing polymers is that the water held by the polymer may be released during the transportation to the disposal site. Landfill disposed sludges must (1) pass the paint filter test, (2) pass the **Toxicity Characteristics Leaching Procedure** (TCLP) test, and (3) be adequately digested.

Chapter 6 Review Questions

1. List three advantages aerobic digesters have over anaerobic digesters.
2. In aerobic digestion the "endogenous respiration" phase means what?
3. List four factors that must be considered in the design and operation of aerobic digesters.
4. When primary clarifier sludge and secondary clarifier sludge are mixed in an aerobic digester the detention time is longer or shorter than that of secondary clarifier sludge alone.
5. How many stages is anaerobic digestion?
6. Organically overloading an anaerobic digester will cause the pH to __________.
7. Which type of digester has the longest detention time?
8. Digester covers may be of either the ________type or ________type.
9. At what volatile acid to alkalinity ratio does an anaerobic digester go into stress?
10. The most commonly used temperature range for anaerobic digestion is the __________ range with temperatures ranging from 68°F to 113°F.

Answers for Chapter 6 Review

1. Lower BOD concentrations in supernatant liquor; production of an odorless, humus-like, biologically stable end product; operation is relatively easy; lower capital cost.
2. Bacteria are feeding on themselves and on the dead and dying bacteria, reducing the sludge volume.
3. Solids retention time, loading rate, temperature, DO requirements/mixing, tank volume, percent solids reduction.
4. Longer
5. Three
6. Drop
7. Anaerobic
8. Floating or stationary
9. .3
10. Mesophilic

Answers for Chapter 6 Math

Problem #1

The MLVSS is 2,550 mg/L and the initial DO was 7.9 mg/L and 6 minutes later the DO is 5.3 mg/L. What is the SOUR in MG/G VSS/hr?

DO difference 7.9 mg/L – 5.3 mg/L = 2.6 mg/L DO Drop in 6 minutes

DO Drop per minute = $\frac{2.6 \text{ mg/L}}{6 \text{ minutes}}$ = .433 mg/L DO drop/min

$$\frac{.433 \text{ mg/L} \times 60 \text{ MIN} \times 1000 \text{ mg/g}}{2{,}550 \text{ mg/L MLVSS}} = 10.1 \text{ mg } O^2\text{/G/ VSS/hr}$$

Problem #2

Calculate the volatile solids loading in **lbs VSS/ft^3** on an anaerobic digester if the waste sludge flow is 8,500 GPD, the TSS is 3.5%, the VSS is 65% of the TSS and the digester volume is 50,000 gallons.

Convert 8500 GPD to .0085 MGD

.0085 MGD X 8.34 X 35,000 mg/L TSS X .65 VSS = 1612.74 lbs VSS

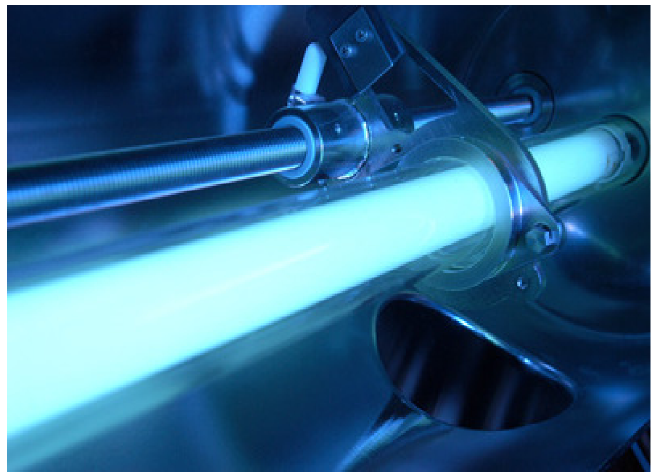
Or

8,500 GPD X 8.34 X .035 TSS X .65 VSS = 1,612.74 Lbs VSS

$$\frac{50{,}000 \text{ Gal}}{7.48 \text{ gal/ft}^3} = 6{,}684.5 \text{ ft}^3$$

$$\frac{1{,}612.74 \text{ Lbs VSS}}{6{,}684.5 \text{ ft}^3} = .24 \text{ lbs VSS/ ft}^3$$

Chapter 7: Disinfection

Chapter 7 Objectives

1. Delineate the three most commonly used disinfectants in Kentucky.
2. Explain the reactions of chlorine and water as well as sulfur dioxide and water.
3. Describe how ultra violet light and ozone accomplish disinfection.

Chlorine

The most common disinfectant used throughout the world is chlorine and its derivatives. Other methods used for disinfection to a lesser extent are ozone (O_3) and ultraviolet (UV) light. The most common compounds used in wastewater treatment plants are chlorine gas (Cl_2), calcium hypochlorite [$Ca(OCl)_2$], sodium hypochlorite (NaOCl), and chlorine dioxide (ClO_2). Calcium and sodium hypochlorite are most used in very small facilities where simplicity and safety are of more concern than cost. Since chlorine dioxide does not react with ammonia, it is favored at some facilities. Free chlorine combines with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl).

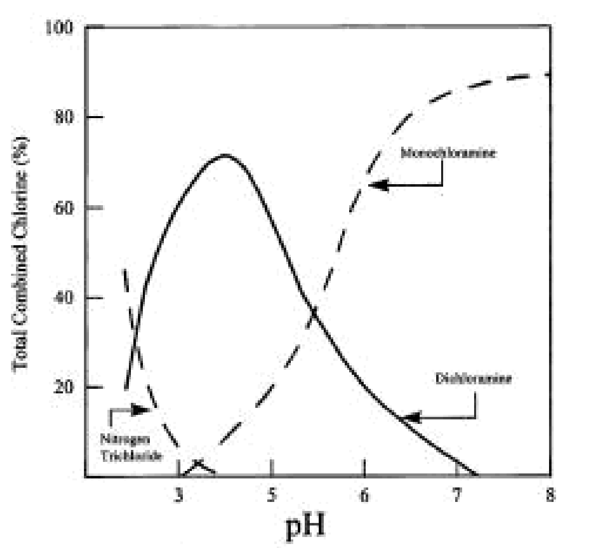
$$\mathbf{Cl_2 + H_2O <=> HOCl + HCl}$$

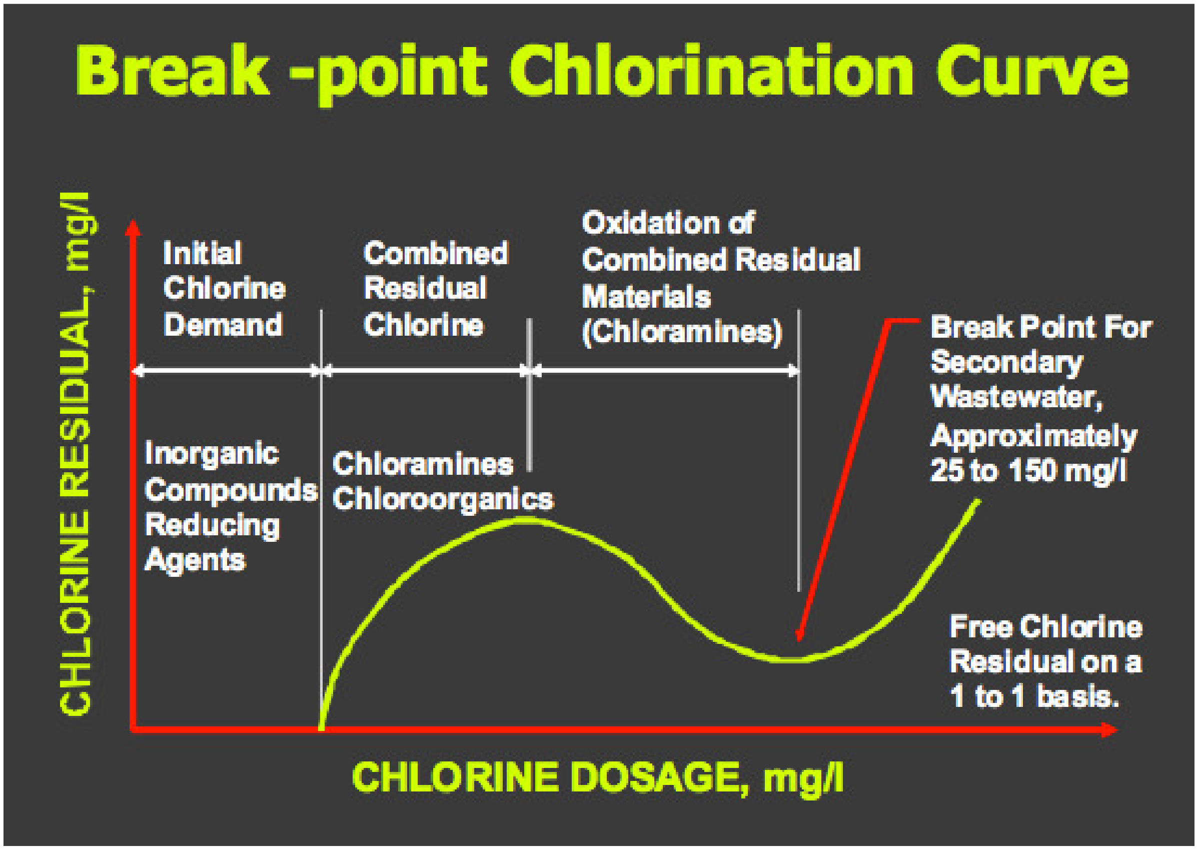
At pH > 4.0, the formation of HOCl is most complete. At higher pH ranges, the hypochlorous acid ionizes as follows:

$$\mathbf{HOCl <=> H^+ + OCl}$$

The hypochlorite ion (OCl) concentration increases as the pH increases and is roughly equal to the HOCl concentration at pH = 7.3. At higher pH values, the concentration of hypochlorite ion is greatest. Hypochlorous acid has a killing efficiency of 40-80 times that of the hypochlorite ion. Chlorine disinfection is more effective in the lower pH ranges.

Since chlorine is a very strong oxidizer, it will react with substances such as ferrous iron, hydrogen sulfide (H_2S), ammonia (NH_3-N), and phenols. The chlorine that is utilized in these side reactions is referred to as the chlorine demand. The remaining chlorine is available for disinfection to kill bacteria, viruses, and other pathogens (disease causing organisms). The reaction of chlorine with ammonia forms chloramines that have weak disinfection powers.





The total residual chlorine reported on DMR's is the **combined residual**.

The primary function is disinfection of the plant effluent so chlorine is added at the head of the chlorine contact chamber. The **minimum detention time recommended is 30 minutes**. To improve disinfection, it is recommended that the detention time be increased. Other points of application include:

- Collection system for corrosion and odor (H_2S) control.

- Prechlorination at the entrance to the treatment plant also for corrosion and odor control. It is also useful in reducing BOD_5 loading if the plant is slightly over-loaded and can be an aid to settling.

- In-plant chlorination can be used to control odors, corrosion, filamentous bulking in activated sludge plants, digester foaming, filter ponding, filter flies, and as an aid in sludge thickening. If used to control filamentous bulking, the normal application point is in the return sludge line.

Approved methods of chlorine residual measurement includes **amperometric titration, DPD colorimetric method using a spectrophotometer** with a wavelength of 515 nanometers and **iodometric electrode method** which uses an electrode and expanded scale pH/millivolt meter with 0.1 mV readability or a **direct-reading selective ion meter**.

The DPD color wheel and orthotolidine methods are not acceptable.

The lethal dose with a few breaths is 1000 ppm or 0.1% by weight. TRC limits for zero flow streams are set at 0.01 mg/L monthly average and 0.019 mg/L maximum because the fry of fish such as salmon and trout cannot tolerate more than trace amounts of chlorine (0.01 mg/L).

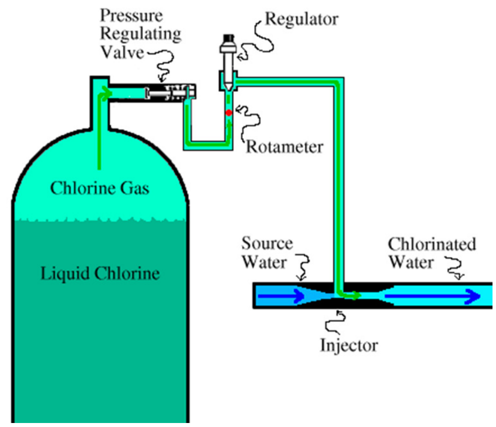
Chlorine gas is normally added using vacuum solution feed chlorinators because of safety. If a break occurs in the line, the chlorinator either stops the chlorine flow or allows air to enter the vacuum system that prevents the chlorine from escaping into the atmosphere.

EFFECTS OF EXPOSURE	CHLORINE GAS IN PARTS PER MILLION (ppm) OF AIR BY VOLUME
Slight symptoms after several hours of exposure.	1 ppm
Irritates throat.	10 -15 ppm
Causes coughing.	30 ppm
Dangerous in 30 minutes.	40 – 60 ppm
Fatal in a few breaths	*1000 ppm*

Some of the major components of a vacuum chlorination system include:

- the rotometer which indicates the rate of gas flow,
- the V-notch variable orifice which regulates the gas feed rate, and

- the heart of the chlorinator (or sulfonator) is considered to be the injector where a vacuum is created by the water flowing through the throat of the injector which allows chlorine gas to be pulled into the water flow stream to form a hypochlorous acid solution.



For effective chlorine disinfection both sufficient chlorine dosages as well as contact time are necessary along with proper pH and temperature.

Dechlorination

To reduce the toxic effects on aquatic organisms and long-term adverse effects caused by the reaction of chlorine with organic compounds to form toxic compounds, regulatory agencies now require that no measurable chlorine residual be allowed to enter the receiving stream from wastewater treatment plants.

Chemicals commonly used for dechlorination include:

- sulfur dioxide (SO_2),
- sodium sulfite (Na_2SO_3),
- sodium bisulfite ($NaHSO_3$),
- sodium metabisulfite ($Na_2S_2O_5$), and
- sodium thiosulfate ($Na_2S_2O_3$).

This discussion is limited to the most common chemical used, sulfur dioxide.

Chemical reaction

Sulfur dioxide is the dechlorinating chemical of choice because it reacts almost instantaneously with chlorine on a theoretical basis of one to one (1 ppm SO_2 to remove 1 ppm of Cl_2). In practice, wastewater treatment plants typically add 2 ppm SO_2 for every 1 ppm of chlorine. Because the reactions of sulfur dioxide with chlorine and chloramines are nearly instantaneous, contact time is not usually a factor and contact chambers are not used. However, rapid and positive mixing at the application point is necessary.

The reaction is as follows:

$$\mathbf{SO_2 + H_2O \rightarrow H_2SO_3 + HCOl \rightarrow H_2SO_4 + HCl}$$

Sulfur dioxide is a colorless gas with a sharp, biting odor. Dry gaseous sulfur dioxide is not corrosive, but in the presence of moisture it forms sulfuric acid (H_2SO_4).

When dissolved in water, it forms a weaker sulfurous acid solution (H_2SO_3). It is more soluble in water than chlorine, and like chlorine its solubility decreases as the temperature increases. Because of its similar density, the same type equipment can be used to feed sulfur dioxide as is used to feed chlorine. However, when using the chlorine rotometer, multiply the reading by 0.95 to obtain the pounds per day of sulfur dioxide fed.

Excessive dosages should be avoided not only because of the chemical wastage but also because of the oxygen demand exerted by the excessive sulfur dioxide.

The result is a reduction in the dissolved oxygen contained in the wastewater, a corresponding increase in the measured BOD_5 and COD, and a possible drop in the pH. All these effects can be eliminated by proper control of the dechlorination system.

SO_2 is extremely hazardous and must be handled with caution. Immediate dangerous concentrations are 400-500 ppm. Exposure to high concentrations can cause death due to lack of oxygen, chemical bronchopneumonia with severe bronchiolitis may be fatal several days later. Like chlorine, SO_2 is heavier than air and will settle in low areas.

Control of the sulfur dioxide dosage to remove chlorine depends on:

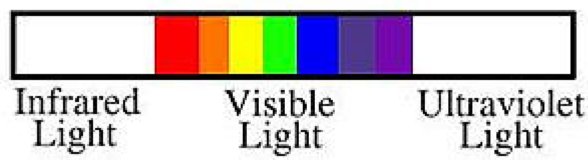
- Chlorine residual in mg/L.
- Plant flow rate in MGD.
- Amount of chlorine to remain in the effluent as allowed by the KPDES permit after the addition of sulfur dioxide.

EFFECTS OF EXPOSURE	SULFUR DIXOIDE GAS IN PARTS PER MILLION (ppm) OF AIR BY VOLUME
Lowest concentration detectable by odor	3 - 5 ppm
Lowest concentration immediately irritating to the throat	8 - 12 ppm
Lowest concentration immediately irritating to the eyes and causes coughing	20 ppm
Maximum allowable concentration for 8 hour exposure	10 ppm
Maximum allowable concentration for 1 hour exposure	50 - 100 ppm

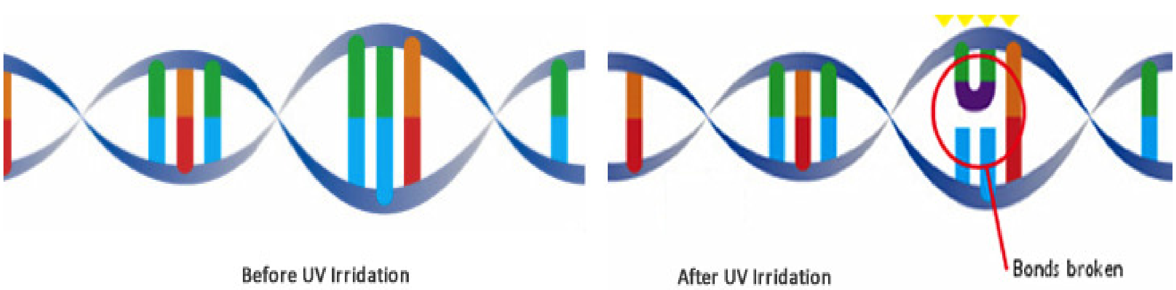
Tolerable for a brief period	150 ppm
Immediately dangerous concentration	400-500 ppm

Disinfection by Ultra Violet (UV) Light

Ultraviolet light is electromagnetic radiation with wavelengths shorter than visible light. UV can be separated into various ranges, with short range UV (UVC) considered "germicidal UV." At certain wavelengths UV is mutagenic to bacteria, viruses and other micro-organisms. At a wavelength 254 nm UV will render them unable to reproduce.



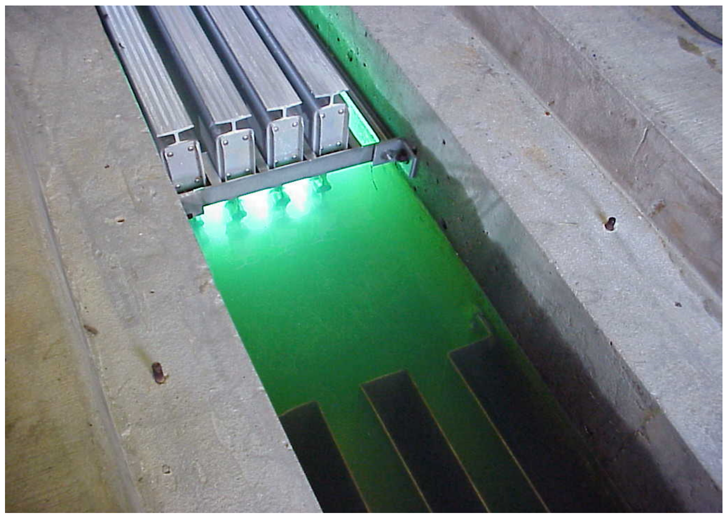
Some essentials of operation of ultra violet disinfection must be understood to appreciate its effectiveness. The UV radiation basically alters the DNA in the cells of microorganisms and thereby impedes their reproduction. The UV treatment merely inactivates the organisms and does not remove them from the water.



The effectiveness of UV disinfection process is directly related to:

- the lamp intensity
- the exposure time of the organisms to the radiation
- the general water quality parameters.

There is no residual disinfection in the water to inactivate bacteria that may survive or may be introduced after the water passes by the light source. If some material builds up on the glass sleeve and the intensity of the radiation reduces this adversely impinges on the effectiveness of the treatment.

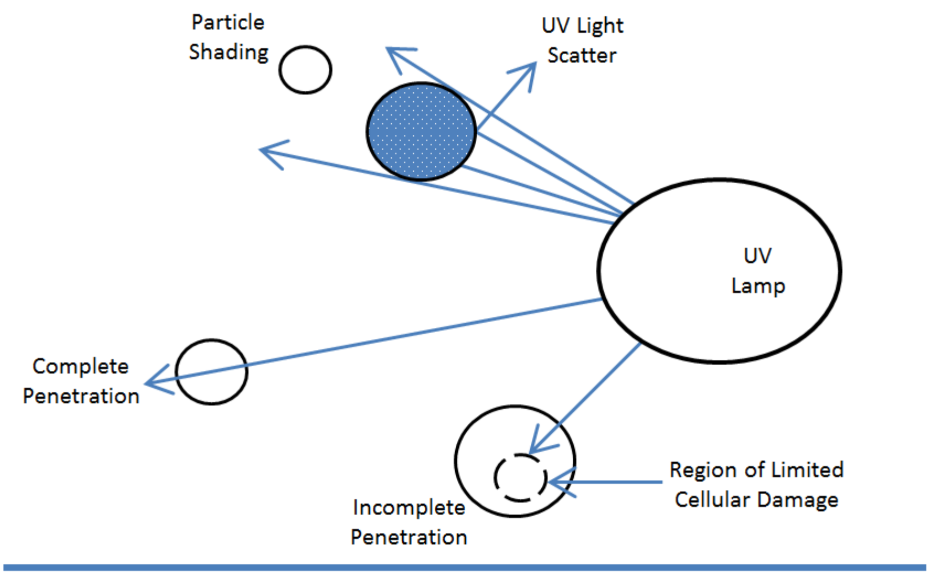


Cloudy water will be treated less successfully since solid matter can shield organisms, especially from ultraviolet light or if contact times are low. Generally, short contact times, low doses and high flows all mitigate against effective disinfection.

Ultra Violet Light Bulb Comparison

Low Pressure	Low Pressure High Output	Medium Pressure
Efficient in converting electrical energy to germicidal light	Has special features that produce higher intensity UV at lower pressure in the lamp	Higher intensity UV output, 8 to 16 times higher than low pressure lamps
UV Light from low pressure lamps is monochromic	Effective for most flow rates	Fewer lamps than low pressure or low pressure high output

Approximately 85% UV radiation is produced at 253.7 nm	Approximately 85% UV radiation is produced at 253.7 nm	UV radiation emitted is over a broad spectrum of germicidal wavelengths 200- 580 nm



The Effect of Particles of UV Intensity

Use of UV does not create a disinfectant residual for wastewater systems, which is considered a plus.

Advantages to UV Disinfection

- It is effective at inactivating most viruses, spores and cysts.
- UV is a physical rather than chemical process which eliminates the need to generate, handle, store or transport toxic or hazardous materials.
- There is no residual effect to harm the environment.
- UV is operator friendly, easy to use.
- Shorter contact timer than other disinfection processes.
- Smaller footprint for equipment.

Disadvantages to UV Disinfection

- Low dosage may not inactivate some organisms.
- Organisms can sometimes repair or reverse the destructive effect of UV through “repair mechanism” known as photo reactivation, or in the absence of light “dark repair”.
- A preventive maintenance program is necessary to control fouling of the tubes.

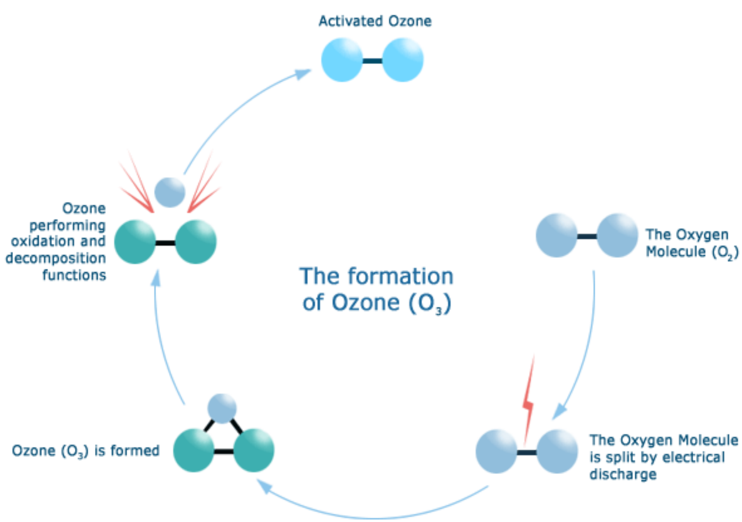
- Elevated TSS in the effluent can render UV ineffective. Bacteria live inside the TSS particle and are not affected by the UV.
- UV disinfection is not as effective at TSS concentration greater than 30 mg/L.

Ultraviolet light poses a special problem because it is invisible. Intense UV exposure can result in first temporary and eventually permanent damage to the eye, possibly leading to blindness. Should it be necessary to perform work inside the UV unit, be sure it is off and remains off during the maintenance procedure.

Ozone

Ozone is "active oxygen", nature's special molecule, an ozone molecule consisting of three oxygen atoms. It is created in nature by the combination of oxygen in the air and ultraviolet rays or by the electrical discharge during a lightning storm. Ozone is a natural purifier, meaning no harmful chemical by-products are created during purification. It has a clean, fresh scent noticed after a rainstorm.

Ozone, O_3 , is generated by passing oxygen O_2 through a high voltage potential resulting in a third oxygen atom becoming attached and forming O_3. It is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic microorganisms. Ozone is considered to be safer than chlorine because, unlike chlorine, which has to be stored on site, ozone is generated onsite as needed.



The mechanisms of disinfection using ozone include:

- Direct oxidation/destruction of the cell wall with leakage of cellular constituents outside of the cell.
- Damage to the constituents of the nucleic acids DNA (purines and pyrimidines).
- Breakage of carbon-nitrogen bonds leading to depolymerization.

When first introduced into wastewater, very little disinfection occurs. The ozone is rapidly consumed, satisfying the ozone demand of inorganic salts and organic matter dissolved in the wastewater. The disinfecting properties of the ozone come into play only after the ozone demand is satisfied. When the demand is satisfied, research studies indicate, ozone brings about disinfection **3100 times faster than chlorine**.

Typical ozone dosages needed to reach the disinfection stage vary with the quality of the effluent. Dosages between 5 to 15 mg/L are commonly cited for disinfection of secondary wastewater effluents. Ozone also exhibits excellent anti-viral properties at these dosages but with longer contact time of about 5 minutes needed. It has also been found that any residual ozone in the effluent of the contactor disappears in a matter of seconds outside the contactor.

Advantages of Ozone Disinfection

- More effective than chlorine in destroying viruses and bacteria.
- Utilizes a short contact time (approximately 10 to 30 minutes).
- No harmful residuals because ozone decomposes rapidly.
- After ozonation, there is no regrowth of microorganisms, except for those protected by the particulates in the wastewater stream.
- Ozone is generated onsite, and thus, there are fewer safety Problems associated with shipping and handling.
- Ozonation elevates the dissolved oxygen (DO) concentration of the effluent. The increase in DO can eliminate the need for reaeration and also raise the level of DO in the receiving stream.

Disadvantages of Ozone Disinfection

- Low dosage may not effectively inactivate some viruses, spores, and cysts.
- Ozonation is a more complex technology than is chlorine or UV disinfection, requiring complicated equipment and efficient contacting systems.
- Ozone is very reactive and corrosive, thus requiring corrosion-resistant material such as stainless steel.
- Ozonation is not economical for wastewater with high levels of suspended solids (SS), biochemical oxygen demand (BOD), chemical oxygen demand, or total organic carbon.
- Ozone is extremely irritating and possibly toxic, so off-gases from the contactor must be destroyed to prevent worker exposure.
- The cost of treatment can be relatively high in capital and in power intensiveness.

Disinfection Detention Times

Chlorine	30 minutes
Ultra Violet	5 minutes, depending on dosage
Ozone	10 to 30 minutes

Peracetic Acid Disinfection (PAA)

Peracetic acid has been studied for wastewater disinfection for quite some time. It has shown to be an effective disinfectant against many indicator microbes, including bacteria, viruses and protozoa. Peracetic acid has been used for wastewater disinfection in Europe for some time, and is gaining momentum as a replacement for chlorine disinfection. Peracetic Acid is a "greener" or more environmentally friendly alternative. PAA reduces and in some cases eliminates disinfection by products, sodium pollution, and total dissolved salts in treated water. The emergence of chlorine-resistant bacteria strains has caused some facilities to switch to PAA as a primary or sole disinfectant.

PAA is commercially available in 5-15% w/w hydrogen peroxide, acetic acid, and water. It is a clear colorless, organic liquid, has no toxic residualsor carcinogenic compounds post disinfection. Peracetic acid is more dependent on dosage as opposed to contact time. Some other effects water characteristics have on PAA disinfection are listed in the table below.

Effects of Wastewater Characteristics on the Disinfection Efficiency of Peracetic Acid

Wastewater Characteristic	Effect	Reference
Temperature	Disinfection efficiency increases with temperature. Active between 0 and 100˚C.	Baldryl et al. (1995) Stampi et al. (2001)
pH	More effective in acidic conditions. Above pH 9 the efficiency starts to decrease. The non-dissociated form (CH_3COOOH) is thought to be more active disinfectant than the dissociated form (CH_2C000).	Kitis (2004)
Suspended Solids, Turbidity	Slight decreases in the disinfection efficiency as suspended solids or turbidity increases. This can be seen in the required dose for difference effluents: primary > secondary > tertiary	Koivunen and Heinonen-Tanski (2005b) Lefevre et al. (1992)
Organic Matter	High organic load may increase the required dose, however it is less affected than other chemical disinfection methods. No significant formation of harmful by-products in reactions with organ matter.	Koivunen and Heinonen-Tanski (2005b)
Transition Metals	Catalytic decomposition and radical formation by PAA and hydrogen peroxide can be initialed by	Zhao et al. (2008) Rothbart et al. (2012)

	transition metals. In the case of the radical mechanisms, disinfection activity may intensify.	
Bicarbonate, Chloride	May cause abatement of radicals (e.g. OH) by radical scavenging effects.	Gultekin and Ince (2004) Liao et al. (2001)

Chemical dosages for successful PAA treatment have fallen in the range of 1.5-4 mg/L. Contact times of 10-15 minutes are sufficient for tertiary effluent bacteria removal and approximately 60 min (1 hour) to remove coliphage viruses. PAA is less effective for inactivation of spores, viruses, and protozoa, including Giardia and Cryptosporidium. Peracetic Acid reacts with organic matter in the wastewater. The less organics, the faster the disinfection reaction will occur. At high concentrations of organic matter, bacterial disinfection can occur after 30 provided that the PAA dosage is high enough to satisfy the demand and have some left as a residual. At peak flow rates contact time is significantly shorter than chlorine. Trace amounts of PAA and Hydrogen peroxide are present in the effluent, but is considered harmless to aquatic life and the environment. These trace amounts have been helpful in reducing biofilms in effluent discharge pipes. PAA has known to be effective in system trials with 250 MGD peak hour treatment. PAA has been successfully used in combination with UV disinfection, allowing reductions in lamp intensity and cleaning.

The Route to PAA Conversion

Capital costs of retrofitting existing chlorine facilities with Peracetic acid retrofit are very low. The most expensive item for most conversions is a flow-paced pump skid. PAA treatment is a single step process which can eliminate dechlorination tanks. In order to successfully use PAA as a wastewater disinfectant, the following things should be considered:

- **Storage Considerations for PAA**
    a. Containment required
    b. Never store on wooden pallets
    c. Do not store near reducing agents or combustibles

- **Bulk Storage for PAA**
    a. HDPE Linear (5yr max)
    b. Containment required (double wall acceptable)
    c. Product shelf life (C >15%)
        i. 1 year, T < 86 ˚F
        ii. 4 months, T < 100 ˚F
        iii. 1 month, T < 110 ˚F
    d. Free-lift emergency relief man
    e. Quick connect for fill line

- **Pump Skid**
    a. Peristaltic, Diaphragm or Solenoid acceptable
    b. Off-gas valve required at pump head for diaphragm and solenoid pumps
    c. Controller – Flow-paced or Compound loop
    d. Containment

- **Piping**
    a. Compatible wetted materials of construction (Teflon / 304SS)
    b. Vented ball valves
    c. Pressure relief valves to prevent PAA entrapment
    d. Flex Connections
        i. Tanks
        ii. Totes
        iii. Pumps

e. Gaskets
    i. GORE-TEX® •
    ii. Teflon
    iii. Garlock Gylon® Style 3504
f. Thread sealant
    i. White Teflon Tape (Do not use anti-galling tape)
    ii. Fluorolube®

Chapter 7 Review Questions

1. What are the four most common types of disinfection?
2. Gas chlorine disinfection is more effective at a_________ pH range?
3. The minimum detention time recommended for a chlorine contact basin is _________, minutes.
4. The fry of fish such as salmon and trout cannot tolerate more than how much chlorine?
5. What is considered the heart of the chlorinator or sulfonator?
6. Sulfur dioxide (SO_2) is considered immediately dangerous at what concentrations?
7. Over feeding SO_2 not only wastes chemical it also causes DO to ________.
8. UV light is what kind of radiation?
9. Is there a residual when using UV light for disinfection?
10. List 3 advantages and 3 disadvantages of UV light disinfection.
11. Can UV light harm the operator?
12. How?
13. Ozone is a nonreactive and very stable gas. True/ False
14. Ozone is a faster or slower disinfection than chlorine?

Answers for Chapter 7 Review

1. Chlorine, UV, Ozone, PAA
2. higher
3. 30 minutes
4. .01
5. injector
6. 400-500 ppm
7. increase
8. electromechanical
9. No
10. No chemicals onsite, no harmful byproducts, minimal contact time; high energy costs, not effective in turbid water, and bacteria have the ability to repair the UV damage
11. Yes
12. Has the ability to burn the retina.
13. False
14. Faster

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Chapter 8: Flow Measurement



Chapter 8 Objectives

1. Identify and explain the two types of flow measurement systems and the methods of measurement associated with each.
2. Demonstrate knowledge of the standard condition of weirs.

3. Describe the operational characteristics of flumes.

Types of Flow Measurement Systems

The two basic types of flow systems are **closed channel flow** and **open channel flow**. Common types of closed channel flow measuring devices are **venturi meters, ultrasonic meters** (both Doppler and transit time), **flow nozzles**, **orifice meters**, **magnetic flow meters**, and **Pitot tube flow meters**. This discussion is limited to open channel flow measurement.

The most commonly used technique of measuring the rate of flow in open channels is by inserting a hydraulic structure into the channel that changes the level of liquid in or near the structure. The flow rate through or over the restriction will be related to the liquid level, and the flow rate can be derived by measurement of the liquid level. These hydraulic structures are known as primary measuring devices and can be divided into two broad categories: **weirs** and **flumes**.

Secondary measuring devices (or open channel flow meter) are used in conjunction with primary measuring devices to measure the rate of flow in an open channel. This device basically has two functions:

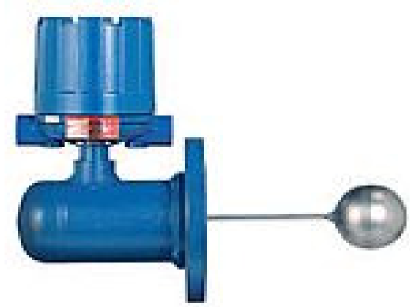
(1) measure the liquid level in the primary measuring device, and

(2) convert this liquid level into an appropriate flow rate according to the known liquid level-flow rate relationship of the primary device. This flow rate may then be integrated to obtain a totalized volume, transmitted to a recording device, and/or used to pace an automatic sampler.

Methods of Measurement

Float

These are used in conjunction with either a cable and pulley or a pivoting arm to convert the liquid level measured by the float to an angular position of a shaft. An indicator pointer attached to the shaft indicates the liquid level and/or flow rate shown on a permanently mounted scale. One problem often encountered is the build-up of trash and scum on floats which weighs them down and results in low flow measurements.



Electrical

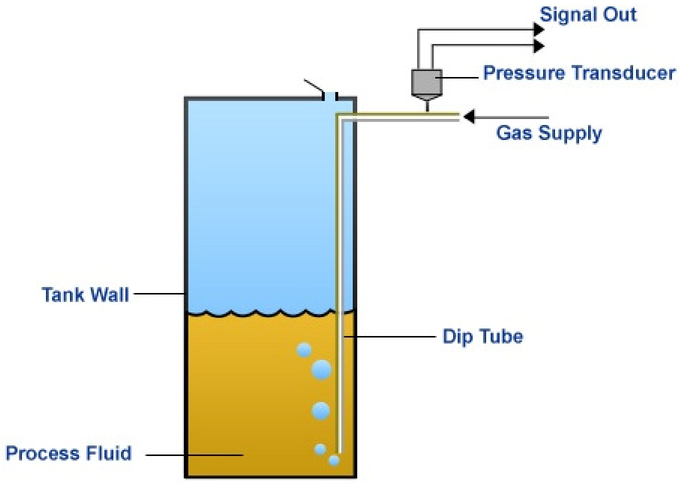
This type of level measurement system uses some sort of change in an electrical circuit caused by a changing level to indicate the liquid level. Most designs use a capacitive or reactance type probe.

Ultrasonic

The liquid level is measured by determining the time required for an acoustic pulse to travel from a transmitter to the liquid surface where it is reflected and returned to a receiver.

Bubbler

Using a bubbler tube anchored in the flow stream to a fixed depth, pressurized air bubbles are pumped through the tube at a constant rate. The pressure necessary to maintain a constant bubble rate is measured, and this pressure is directly proportional to the liquid level.



Bubbler Type Level Measurement Device

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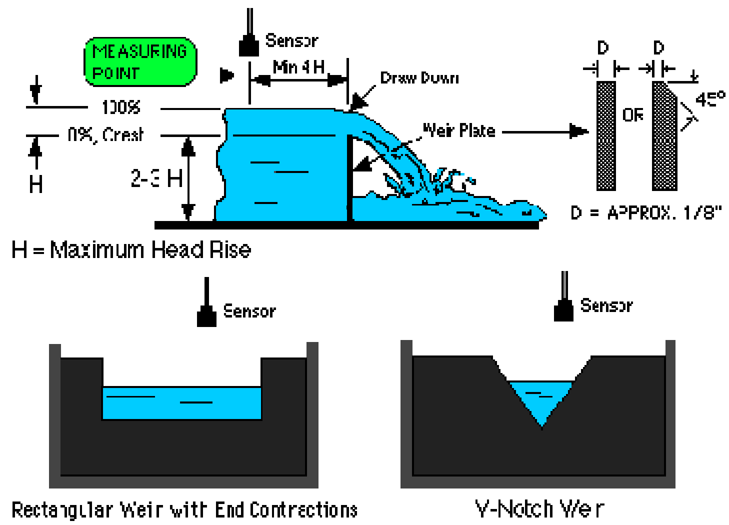
Submerged pressure transducer

A sealed pressure transducer is submerged directly in the flow stream, and the pressure measured by the transducer is proportional to the liquid level.



Sharp-Crested Rectangular and V-Notch Weirs

Weirs

These are the simplest and least expensive type of primary measuring device. Weirs should only be used at effluent or clear water locations due to the tendency of solids to accumulate upstream of the weir.

The most common weirs are:

- the contracted rectangular weirs (with end contractions)
- suppressed rectangular weirs (without end contractions),
- triangular (or V-notch) weirs, and
- trapezoidal (or Cipolletti) weirs.

The V-notch weir is an accurate flow measuring device particularly suited for small regular flows.

Standard Conditions for Sharp-Crested Weirs

- The weir should be installed so that it is perpendicular to the axis of flow. The weir plate should be level. The sides of rectangular contracted weirs should be truly vertical. V-notch weir angles must be cut precisely.
- The thickness of the weir crest should be less than 0.1 inch. The downstream edges of the crest or notch should be relieved by chamfering at a 45^o angle if the weir plate is thicker.
- The distance from the weir crest to the bottom of the approach channel should not be less than twice the maximum weir head and never less than one foot. The distance from the sides of the weir to the sides of the approach channel should be no less than twice the maximum head and never less than one foot (except for the suppressed rectangular weir).
- The nappe (overflow sheet of water) should touch only the upstream edges of the weir crest or notch.
- Air should circulate freely under, and on both sides of, the nappe.
- The measurement of head on the weir should be made at a point three to four times (3-4) the maximum head upstream from the weir crest.
- The cross-sectional area of the approach channel should be at least eight times that of the nappe at the weir crest for a distance of 15-20 times the maximum head upstream from the weir. The approach channel should be straight and uniform upstream from the weir for the same distance.
- If the criteria in items (C) and (G) are not met, the velocity of approach corrections will have to be made.
- Heads less than 0.2 feet (2.4”) should not be used under ordinary conditions, because the nappe may not spring free of the crest.
- All of the flow must pass through the weir and no leakage at the weir plate edges or bottom should be present.

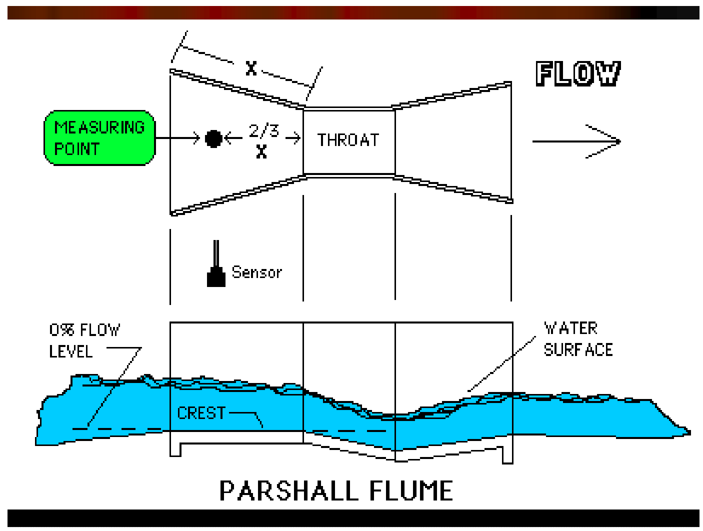
Flumes

Generally, flumes are used to measure flow in open channels where the use of weirs are not feasible. Although weirs are generally more accurate than flumes, flumes can measure flow over a wider range than weirs, and they operate with a much smaller loss of head, and advantage for many existing open channel applications where the available head is limited.

They are also better suited to handling flows containing solids (wastewater influent) because high velocity though the flume tends to increase solids because the high velocity through the flume tends to make it self-cleaning. The major disadvantage is that a flume installation is typically more expensive than a weir. The Parshall flume is the primary flume used in wastewater plant installations.

Standard conditions for Parshall flumes are as follows:

- Flow shall be evenly distributed across the channel, free of turbulence or waves and shall not be located after transition sections.
- Uniform channel width shall be maintained for a length of 15 to 20 times the channel width.
- The converging throat section of the flume should be level.
- Throat walls shall be vertical.
- The head (depth of water through the flume) measuring point shall be located at 2/3 the length of the converging sidewall.
- Longitudinal and lateral axes of the crest floor are level.
- Free flow conditions shall be maintained



Flow Measurement Considerations

Each wastewater treatment plant is required to have a flow measuring device capable of measuring the anticipated flow including variations within accuracy of ten percent (10%).

For treatment facilities of 50,000 gpd capacity or more, an indicating, recording and totalizing flow-measuring device is required.

Meters should be recalibrated:

- on a regularly scheduled basis;
- whenever accuracy is in question; and
- before implementing the addition of chemicals in proportion to flow.

Flow measurement is recommended throughout the plant (influent, effluent, WAS, RSF) in order to determine the hydraulic and organic loadings on the various treatment units.

When reporting flows, consistency must be used when reading charts and totalizers. In other words, to get a 24-hour flow **the meter should be read at the same time each day**. Staff gauge installations are recommended so that instantaneous head readings can be compared with flow meter results to see at any time if the flow meter is still accurate.

Flow conversions

To convert gallons per minute (GPM) to gallons per day(GPD) use the following:
GPM X 1440 minutes/day = GPD
To convert GPD to GPM use the following:

$$\frac{\text{GPD}}{1440 \text{ min/d}} = \text{GPM}$$

To convert from MGD to GPD move the decimal 6 places to the right or multiply by 1,000,000
To convert from GPD to MGD move the decimal point 6 places to the left or divide by 1,000,000

Problem # 1

The flow to a wastewater treatment plant is 435,000 GPD. How many MGD is this?

Problem #2

The waste sludge flow to a digester is 41 GPM. What is the flow in GPD?

Review Questions for Chapter 8

1. What are the two basic types of flow systems?
2. What two hydraulic structures are known as primary measuring devices?
3. List three of the five types of methods of measurements.
4. The V-notch weir is an accurate flow measuring device particularly suited for_______ __________ _________.
5. The weir should be installed so that it is_____________________to the axis of flow.
6. Generally, flumes are used to measure flow in ______ ___________.
7. Flow measurement devices must be +- ___.

Answers for Chapter 8 Review

1. Open channel and Closed Channel
2. Weirs and Flumes
3. Float, electrical, ultrasonic, bubbler, submerged pressure transducer.
4. Small, regular flows
5. Perpendicular
6. Open channels
7. 10%

Answers for Chapter 8 Math

Problem # 1

The flow to a wastewater treatment plant is 435,000 GPD. How many MGD is this?

$$\frac{435{,}000}{1{,}000{,}000} = .435 \text{ MGD}$$

Problem #2

The waste sludge flow to a digester is 41 GPM. What is the flow in GPD?

41 GPM X 1440 min/day = 59,040 GPD

Chapter 9: Pumps and Motors

Chapter 9 Behavioural Objectives

1. Identify and distinguish between the pump types and the correct applications.

2. Describe the troubleshooting techniques of pumps.

Pumps

A pump is a machine that imparts energy to a fluid causing it to flow, rise to a higher level, or both. It uses acceleration to transform mechanical (rotational) energy into hydraulic energy. This section will discuss the categories, types and operational & maintenance considerations.

Categories of pumps

Pumps may be classified by:

- the **character of the material handled** – raw wastewater, grit, effluent, activated sludge, raw sludge, or digested sludge.
- **pumping conditions** – high lift, low lift, recirculation, or high capacity.
- the **principle of operation** – centrifugal, propeller, reciprocating, incline screw, progressive cavity, or pneumatic ejector.

Types of Pumps

1. **Centrifugal pumps**

   Centrifugal pumps have an impeller (paddle-wheel type piece) rotating in a casing. The impeller is supported on a shaft that is then supported by bearings. Liquid enters the casing through the eye (at the center) of the impeller. It is then picked up by the curved impeller vanes and by the rotation of the impeller and is thrown out by the centrifugal force into the discharge. Impellers usually have large openings at their center to prevent clogging. Impellers may be in closed casings or they may be open if the pump is submersible and being used to pump wastewater from lift station wet wells. The motor or drive mechanism can be connected directly to the shaft or connected by a coupling flange depending upon the application.

   Shaft sleeves are used to cover the shaft that supports the impeller to protect the shaft from the corrosive and abrasive effects of the liquid going through the pump. The sleeves are mounted to the shaft on ball or roller bearings.

Wearing rings are used to plug the space between the impeller and the casing to prevent internal liquid leakage. These rings are either attached to the casing, the impeller, or both. Wearing rings should be inspected regularly and replaced when serious wear or leakage is observed. Since water is the lubricant between the rings and the impeller, a pump should never be allowed to run dry.

Stuffing boxes are used to prevent air from being sucked into the pump. Air affects the efficiency of the pump and could cause it to lose prime. It consists of a casing containing rings of packing and a gland or membrane at the outside end. Water is used in the stuffing box to block out the intake of air and to lubricate the packing.

The water is brought into a seal cage in the center of the stuffing box under pressure by connector piping to a point near the impeller rim *provided it is clean liquid.* If the liquid being pumped contains grit or other solids, it may be necessary to use potable water to provide the seal.

To prevent the possibility of a cross-connection, the connection with the potable water supply must include either an **air gap separation** or an **approved backflow preventer.**

The end gland or membrane is used to control liquid flow from the stuffing box. The gland should be tightened just enough such that a thin stream of water flows from the stuffing box. **Excessive leakage** is indicative of the need to replace the packing.

Lantern rings provide the water seal connection between the water supply line and the stuffing box. When packing is being replaced, the lantern ring should be completely filled with grease (if grease seals are used) before all the rings of packing are in place.

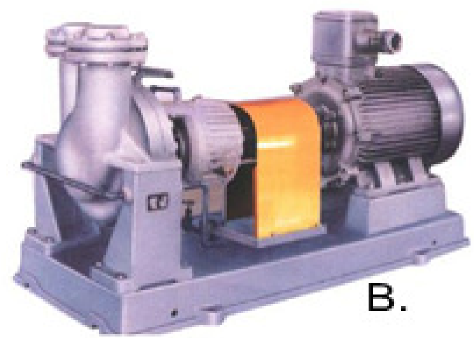
The **efficiency** of centrifugal non-clog pumps starts at zero at shut-off and increases rapidly until a peak is reached at approximately the mid-point of the overall capacity range of the pump. Therefore, for peak efficiency, best mechanical performance, and quietest operation; a pump should be selected so that the range of operation will be at the mid-point of the total pump curve. They should be operated near their rated heads (pressure). Otherwise, the pump is apt to operate under unsatisfactory and unstable conditions that reduce the efficiency and operating life of the unit.

2. Propeller pumps

Two basic types:

a. **Axial-flow pumps** have flow parallel to the axis of the impeller.

b. **Mixed-flow pumps** have flow that is both axial and radial (perpendicular to the shaft) to the impeller.

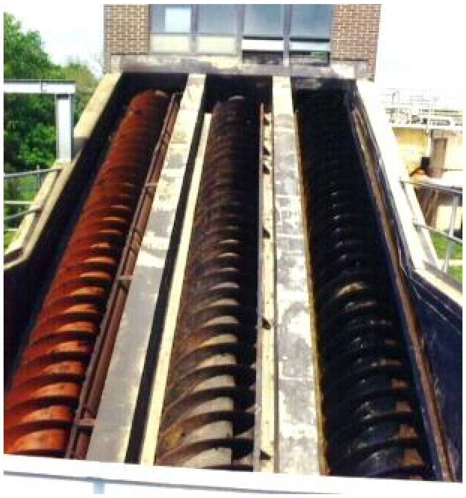


3. Reciprocating or Piston Pumps

Pumps used to move sludge by a piston that moves back and forth. Reciprocating pumps should **never** be allowed to pump against a closed discharge valve due to a buildup of pressure that could damage the pump and/or the piping.

4. **Incline Screw Pumps**

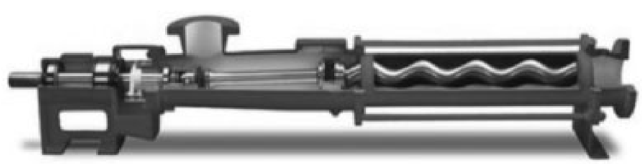
An auger type pump housed in a trough that is on an incline. The auger is supported



by bearings on both ends. The screw or auger operates at a constant speed moving the wastewater up the trough to a point of discharge. These are commonly used on influent and effluent waste streams where low lift, high capacity, non-clog pumping is required. They may range in size from 12 to 144 inches in diameter with rated capacities from 100 to 70,000 gpm. They are primarily suited for lifts up to 25 feet but are available for higher lifts.

5. **Progressive cavity pumps**

These are similar to incline screw pumps except that the screw shaped rotor is enclosed in a housing (stator). The spacing between the rotor and the inside casing walls form a series of cavities. As the rotor turns, the threads make contact with the walls and move the water along in auger fashion. The size of the cavities along the rotor determines the capacity of the pump. These pumps are recommended for liquids containing higher concentrations of solids. Like reciprocating pumps, they should never be operated dry nor against a closed discharge valve.



6. **Pneumatic ejectors (Air Lift)**

An air lift ejector consists of a receiving container, inlet and outlet check valve, air supply, and liquid level detector. When the wastewater reaches a preset level, air is forced into the container, ejecting the wastewater. Following the discharge cycle, the air supply is cut off and wastewater flows through the inlet into the receiver. With flow ranges from 30 to 150 gpm, they are mostly used for pumping raw wastewater. These pumps are capable of passing solids up to the size of the inlet and discharge valves since there is nothing on the inside of the ejector-receiver to restrict the flow. They are, however, a high maintenance problem. If a stick or other object gets stuck in either check valve, the ejector will not operate.

Maintenance of Pump Motors

Necessary maintenance elements of a pump motor assembly include:

1. Check the condition of the motor for
   - dirt
   - dust
   - moisture
   - air circulation obstructions
   - excessive leakage of grease from the bearings.
2. Observe any unusual conditions including:
   - noise,
   - excessive heat
   - vibration
   - intermittent to continuous sparking of brushes
   - sluggish operation

A stethoscope is sometimes used to check for bearing whines, gratings, or uneven noises.

3. Keep close watch on the amperage being pulled by the motors. A sudden increase could be indicative of a pumping restriction while a sudden decrease may be the result of a drop in pumping head caused by a break in the discharge line.

4. For motors wound for 3-phase current, periodically check to insure equal distribution across all three phases. If one phase cuts out while in operation the motor may overheat and become damaged unless it is stopped by a thermal control device.

Pump Operating Problems & Causes of Failure or Reduced Operating Efficiency

Common causes for pumps not starting are:

1. Blown fuses or circuit breakers due to:
   - Rating of fuses or circuit breakers not correct
   - Switch (breaker) contacts corroded or shorted
   - Terminal connections loose or broken somewhere in the circuit
   - Automatic control mechanism not functioning properly
   - Motor shorted or burned out
   - Wiring hookup or service not correct
   - Switches not set for operation
   - Contacts of the control relays dirty and arcing
   - Fuses or thermal units too warm
   - Wiring short-circuited
   - Shaft binding or sticking due to rubbing impeller, tight packing glands, or clogging of pump
2. Loose connection, fuse, or thermal unit.

Potential common causes for reduced pump discharge rates are:

- Pump not primed
- Mixture of air in the wastewater
- Speed of motor too low
- Improper wiring
- Defective motor
- Discharge head too high
- Suction lift higher than anticipated
- Impeller clogged
- Discharge line clogged
- Pump rotating in wrong direction
- Air leaks in suction line or packing box
- Inlet to suction too high, permitting air to enter
- Valves partially or entirely closed
- Check valves stuck or clogged
- Incorrect impeller adjustment

- Impeller damaged or worn
- Packing worn or defective
- Impeller turning on shaft because of broken key
- Flexible coupling broken
- Loss of suction during pumping may be caused by leaky suction line, ineffective water or grease seal.
- Belts slipping
- Worn wearing ring.

Potential common causes for high power requirements:

- Speed of rotation too high
- Operating heads lower than rating for which pump was designed, resulting in excess pumping rates
- Check valves open, draining long force-main back into wet-wall
- Specific gravity or viscosity of liquid pumped too high
- Clogged pump
- Sheaves on belt drive misaligned or maladjusted
- Pump shaft bent
- Rotating elements binding
- Packing too tight
- Wearing rings worn or binding
- Impeller rubbing.

Potential causes for noisy pump operation:

- Pump not completely primed
- Inlet clogged
- Inlet not submerged
- Pump not lubricated properly
- Worn impellers
- Strain on pumps caused by unsupported piping fastened to the pump
- Foundation insecure
- Mechanical defects in pump

- Misalignment of motor and pump where connected by flexible shaft
- Rags or sticks bound (wrapped) around impeller.

Chapter 9 Review Questions

1. What are the three ways we classify pumps?
2. Which type of pump has an impeller rotating in a casing?
3. What are used to plug the space between the impeller and the casing to prevent internal liquid leakage?
4. What provides the water seal connection between the water supply line and the stuffing box?
5. A pump should be selected so that the range of operation will be where in the total pump curve?
6. Name the two basic types of propeller pumps.
7. Which type of pump uses air to move the wastewater?
8. What can be used to listen to a pump during operation?
9. List three potential common causes for reduced pump discharge rates.
10. List three potential causes for noisy pump operation.

Answers for Chapter 9 Review

1. character of the material handled, pumping conditions, principle of operation
2. centrifugal
3. wearing rings
4. lantern rings
5. in the best efficiency point (BEP)
6. axial flow, mixed flow
7. air lift
8. stethoscope, screwdriver
9. loss of prime, sucking air, discharge head too high , motor speed too low, discharge line clogged
10. 1) Pump not completely primed (2) Inlet clogged (3) Inlet not submerged (4) Pump not lubricated properly (5) Worn impellers (6) Strain on pumps caused by unsupported piping fastened to the pump (7) Foundation insecure (8) Mechanical defects in pump (9) Misalignment of motor and pump where connected by flexible shaft (10) Rags or sticks bound (wrapped) around impeller.

Chapter 10: Hazards

Methane gas explosion at Coralville Wastewater Treatment Plant

Chapter 10 Objectives

1. Demonstrate knowledge of pathogenic organism's avenues of exposure.

2. Explain the potentially hazardous effects of depleted oxygen and dangerous gases.

Overview
Wastewater operators are exposed daily to numerous health risks. These risks include exposure to gases, chemicals, endotoxins, exotoxins, and pathogens.

In addition to these gases, chemicals such as vaporized, volatile organic compounds (VOCs) from wastewater also represent a health risk.

Dead and living bacterial cells release endotoxins and exotoxins, respectively. These toxins attack cells and tissues in the human body and cause gastrointestinal, respiratory tract, and nervous system diseases. Examples of several diseases caused by exotoxins include anthrax, food poisoning, and tetanus. Of all health risks associated with wastewater treatment facilities, perhaps disease transmission is of most concern to wastewater operators.

Pathogenic Organisms
Pathogens include **viruses**, **bacteria**, **fungi**, **protozoa**, and **helminths** (parasitic worms). Exposure to pathogens and the potential for disease transmission through contact with pathogen contaminated wastewater, aerosols, compost, foam, sludge, and work surfaces are considered to be risks for wastewater personnel

Pathogens enter wastewater treatment facilities from the bodily wastes of infected individuals, which may be human, domestic animals, or wild animals. Fecal waste and urine from cats and dogs enter wastewater treatment facilities through inflow and infiltration (I/I). Slaughterhouse waste from poultry, pork, and beef industries also contains many pathogens that are capable of infecting humans. Fecal waste and urine from rodents in the sanitary and combined sewers represent sources of pathogens. Travelers and military personnel, as well as migrant workers**,** represent an additional risk of the introduction of a new pathogen to the wastewater treatment facility.

Avenues of Exposure
In order for a wastewater worker to become infected with a pathogen, three steps in disease transmission must be satisfied. First, the pathogen must leave an infected individual within the community. Second, the pathogen must come in contact with a worker; and third, the pathogens must enter the worker.

There are three common routes of entrance or portals of entry for pathogens. These routes are ingestion (fecal-oral), inhalation, and invasion. The most common route of entrance is ingestion. For an infection to occur in a new individual, an adequate number of viable pathogens must enter the individual and overcome the individual's bodily defenses. Regardless of the risk assigned for disease transmission from any pathogen, that risk can be significantly decreased or eliminated through the use of proper hygiene measures, protective equipment, and common sense.

The use of proper hygiene measures, protective equipment, and common sense prevent contact with pathogens or block their portals of entry. These measures prevent infection.

Measures available to wastewater personnel to prevent infection include:

- the use of antimicrobial agents
- automation
- cleanliness
- consumption precautions and restrictions
- first aid
- proper sampling practices
- protective clothing
- records
- training
- ventilation.

Depleted oxygen environment

The required oxygen content is 19.5 % oxygen in a breathable atmosphere with 78% being made up of Nitrogen and the rest as trace gases.

A multi-meter should be used before entry for O_2 (oxygen), CO_2(Carbon Dioxide) H_2S (Hydrogen Sulfide) and UEL (Upper explosion limit)/LEL (Lower explosion limit). Use a meter through the inspection port or by partial lifting the lid on a manhole or liftstation before entry.

Hazardous Gases

Some asphyxiating, irritating and toxic gases produced by anaerobic digestion are

- Ammonia NH^3
- Carbon Dioxide CO_2
- Carbon Monoxide CO
- Hydrogen Sulfide H_2S
- Methane CH^4

Other gases the operator may be exposed to include chlorine and sulfur dioxide (discussed earlier in this manual).

H_2S is produced by the anaerobic biological reduction of sulfur containing materials in the waste water into H_2S. There is more production is the warmer month due to the increased bacterial activity in areas of long retention times, over 6 hrs,: i.e. , liftstations and forcemains, headworks building, gravity thickener, sludge processing areas and other areas. Hydrogen sulfide is an explosive gas at higher concentrations. The UEL is 46% and the LEL is 4.3%. There is odor recognition at 10 PPB and it is heavier than air. A single breath at 1000 ppm is fatal.

Methane gas is produced by the digestion of volatile organic material by anaerobic bacteria and has an explosive range of 5-15%. This gas may be produced in the collection system, anaerobic digesters or in other anaerobic areas in the treatment facility. The alarm set point on most meters is set at 10% of the LEL, which would be .5% for methane.

Chapter 10 Review Questions

1. List three pathogenic organisms found in wastewater.
2. What is the required oxygen content?
3. A _____________ should be used before entry into any possibly dangerous environment.
4. List three asphyxiating, irritating and toxic gases produced by anaerobic digestion.
5. What is the explosive range of methane?

Answers for Chapter 10 Review

1. Viruses, bacteria, fungi, protozoa and helminthes
2. 19.5%
3. multimeter
4. methane, hydrogen sulfide, carbon dioxide
5. 5% - 15 %

APPENDIX - Regulations

401 KAR 11:001. Definitions for 401 KAR Chapter 11.

RELATES TO: KRS 223.160-220, 224.01-010(9), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater operators. KRS 223.200 requires the cabinet to promulgate administrative regulations concerning the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes definitions applicable to the certification of wastewater and water operators.

Section 1. Definitions.
(1) "Applicant" means a person who has submitted an application to take an examination for certification.
(2) "Board" means:
(a) The Kentucky Board of Certification of Wastewater System Operators; or
(b) The Kentucky Board of Certification of Water Treatment and Distribution System Operators.
(3) "Cabinet" is defined by KRS 224.01-010(9).
(4) "Certificate" means a certificate of competency issued by the cabinet stating that the operator has met the requirements for the specified operator classification as established by 401 KAR Chapter 11.
(5) "Certified operator" means an individual that holds an active certified operator's certificate issued in accordance with 401 KAR 11:050.
(6) "Core content" means the information identified as essential by the board for purposes of certification examination and continuing education training.
(7) "Direct responsible charge" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the drinking water treatment plant or distribution system is operated in accordance with accepted practices and with KRS Chapters 223 and 224 and 401 KAR Chapters 8 and 11.

(8) "Operator" means a person involved in the operation of a wastewater treatment plant, wastewater collection system, drinking water treatment plant, or drinking water distribution system.
(9) "Primary responsibility" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the wastewater treatment plant or wastewater collection system is operated in accordance with accepted practices and with KRS Chapter 224 and 401 KAR Chapters 5 and 11. (35 Ky.R. 473; Am. 1210; eff. 3-6-2009; 36 Ky.R. 449; 1047; eff. 2-5-2010.)

401 KAR 11:010. Boards Of Certification.

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the board of certification of wastewater system operators and the certification of wastewater operators. KRS 223.160-220 authorizes the cabinet to promulgate administrative regulations concerning the board of certification for water treatment and distribution operators and the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes the duties of the Kentucky Board of Certification of Wastewater System Operators and the Kentucky Board of Certification of Water Treatment and Distribution System Operators.

Section 1. Duties of the Board. The board shall:
(1) Evaluate the qualifications of applicants and recommend qualified applicants to the cabinet for certification examination;
(2) Review and provide comments to the cabinet on proposed administrative regulations regarding operator certification;
(3) Review and make recommendations to the cabinet on core content for certification examinations and continuing education training for certification renewal;
(4) Review and make recommendations to the cabinet on training proposed to provide continuing education to certified operators. During the evaluation of training courses and seminars, the board shall consider:

(a) The consistency of training material with the core content;
(b) The ability of the training to provide information that supports effective water conveyance, treatment, and quality; and

(c) The ability of the instructor to properly present the training;
(5) Assist the cabinet in drafting examinations for the certification of operators;
(6) Review and provide comments to the cabinet on proposed fees for the training and certification of operators;
(7) Review applications for reciprocity and recommend to the cabinet the acceptance or denial of the application based on the criteria established in 401 KAR 11:050, Section 1(8); and
(8) Review evidence and advise the cabinet regarding disciplinary actions for certified operators who fail to comply with KRS Chapters 223 and 224 or 401 KAR Chapter 5, 8, or 11. (35 Ky.R. 474; Am. 1211; 1746; eff. 3-6-2009; 36 Ky.R. 450; 1049; eff. 2-5-2010.)

401 KAR 11:020. Standards Of Professional Conduct For Certified Operators.

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes standards for the performance of certified water and wastewater operator duties.

Section 1. Standards of Professional Conduct.

(1) In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, the following standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;

(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;

(c) If a certified operator’s judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;

(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and

(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.
(2) Proof of certification. While on duty, a certified operator shall carry the cabinet-issued wallet card showing the operator’s current certification status.
(3) Maintenance of records. If information related to the operator's employment or mailing address changes from that provided in the application for certification, the certified operator shall provide written notification to the cabinet within thirty (30) days. (35 Ky.R. 475; Am. 1212; 1747; eff. 3-6-2009; 36 Ky.R. 452; 1051; eff. 2-5-2010.)

401 KAR 11:030. Wastewater Treatment And Collection System Operators; Classification And Qualifications.

RELATES TO: KRS 224.73-110
STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater. This administrative regulation establishes classification of wastewater treatment and collection operator certifications and establishes the qualifications for certification.

Section 1. Classification of Wastewater Operator Certifications.

(1) Wastewater treatment certifications.

(a) Limited certification. As provided in KRS 224.73-110(5), an operator issued a limited certificate may have primary responsibility for a school wastewater treatment plant and collection system.

(b) Class I Treatment certification.

1. A Class I treatment operator may have primary responsibility for a wastewater treatment plant with a design capacity less than or equal to 50,000 gallons per day.

2. A Class I Treatment operator shall not have primary responsibility for a wastewater treatment plant with a larger design capacity.

(c) Class II Treatment certification.

1. A Class II Treatment operator may have primary responsibility for a wastewater treatment plant with a design capacity less than or equal to two (2) million gallons per day.

2. A Class II Treatment operator shall not have primary responsibility for a wastewater treatment plant with a larger design capacity.

(d) Class III Treatment certification.

1. A Class III Treatment operator may have primary responsibility for a wastewater treatment plant with a design capacity less than or equal to seven and one-half (7 1/2) million gallons per day.

2. A Class III Treatment operator shall not have primary responsibility for a wastewater treatment plant with a larger design capacity.

(e) Class IV Treatment certification. A Class IV Treatment operator may have primary responsibility for a wastewater treatment plant of any design capacity.

(2) Wastewater collection certifications.

(a) Class I Collection certification.

1. A Class I Collection operator may have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a design capacity of less than or equal to 50,000 gallons per day.

2. A Class I Collection operator shall not have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a larger design capacity.

(b) Class II Collection certification.

1. A Class II Collection operator may have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a design capacity of less than or equal to two (2) million gallons per day.

2. A Class II Collection operator shall not have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a larger design capacity.

(c) Class III Collection certification.

1. A Class III Collection operator may have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a design capacity of less than or equal to seven and one-half (71/2) million gallons per day.

2. A Class III Collection operator shall not have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a larger design capacity.

(d) Class IV Collection certification. A Class IV Collection operator may have primary responsibility for any wastewater collection system.

(3) Operator in Training designations.

(a) Except as provided in paragraphs (c) and (d) of this subsection, a certified operator with an Operator in Training designation shall not have primary responsibility of a wastewater treatment plant or wastewater collection system.

(b) A certified operator with an Operator in Training designation shall work under the direct supervision of a certified operator who works at the same facility and has obtained a certification level that is equal to or greater than the certification level required to serve in primary responsibility of the facility.

(c) A wastewater Class I Treatment operator with an Operator in Training designation who operates a wastewater treatment plant owned by the operator that serves only one (1) residence:

1. May have primary responsibility for that system; and

2. Shall be exempt from paragraph (b) of this subsection and 401 KAR 11:050, Section 1*(2)(b) and (9)(a)3.

(d) If a certified operator also has been issued a wastewater treatment or collection certification without an Operator in Training designation, the operator may have primary responsibility for a wastewater treatment plant or collection system as provided by this section for the certifications that do not have an Operator in Training designation.

Section 2. Wastewater Operator Qualifications: Experience, Education, and Equivalencies.

An individual desiring to become a certified operator shall meet the following minimum qualifications prior to the cabinet approving the individual to take a certification examination as provided in 401 KAR 11:050.

(1) The education and experience requirement for each class of wastewater treatment certifications shall be as follows:

(a) Limited certification.

1. Education. A minimum level of education shall not be required.

2. Experience. A minimum level of experience shall not be required.

(b) Class I Treatment certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a wastewater treatment plant shall be required.

(c) Class II Treatment certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a wastewater treatment plant shall be required.

(d) Class III Treatment certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a wastewater treatment plant with one (1) year of that experience in a wastewater treatment plant with a design capacity greater than 50,000 gallons per day shall be required.

(e) Class IV Treatment certification.

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. At least five (5) years of acceptable operation of a wastewater treatment plant shall be required.

a. Three (3) years of the required experience in a wastewater treatment plant with a design capacity greater than two (2) million gallons per day shall be required; and

b. At least two (2) years of primary responsibility in a wastewater treatment plant with a design capacity greater than two (2) million gallons per day shall be required.

(2) The educational and experience qualifications for wastewater collection certifications shall be as follows:

(a) Class I Collection certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a wastewater collection system shall be required.

(b) Class II Collection certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a wastewater collection system shall be required.

(c) Class III Collection certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a wastewater collection system with one (1) year of that experience in a wastewater collection system that transports wastewater to a treatment plant with a design capacity of greater than 50,000 gallons per day shall be required.

(d) Class IV Collection certification.

1. Education. A baccalaureate degree in engineering; environmental technology; biological, physical, or chemical sciences; or equivalent shall be required; and

2. Experience. At least five (5) years of acceptable operation of a wastewater collection system shall be required.

a. Three (3) years of the required experience in a wastewater collection system that transports wastewater to a treatment plant with a design capacity of greater than two (2) million gallons per day shall be required; and

b. At least two (2) years of primary responsibility in a wastewater collection system that transports wastewater to a treatment plant with a design capacity of greater than two (2) million gallons per day shall be required.

(3) The educational and experience qualifications for Operator in Training designations shall be as follows:

(a) Class I Treatment and Class I Collection certifications.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Experience shall not be required.

(b) All other applicants for the classifications identified in Section 1(1) and (2) of this administrative regulation:

1. Shall have successfully qualified for and passed the certification exam of the same type classification at one (1) level lower than the Operator in Training designation being pursued; and

2. Shall not have been subject to disciplinary action as provided by 401 KAR 11:050, Section 4.

(4) Substitutions. The cabinet shall allow the following substitutions for the qualifications specified in subsections (1) and (2) of this section:

(a) Education in environmental engineering; environmental technology; and biological, physical, or chemical sciences shall be substituted if the substitution does not exceed fifty (50) percent of the required experience.

1. An associate degree may substitute for two (2) years of experience.

2. A baccalaureate degree may substitute for four (4) years of experience.

3. Education that did not result in a degree in a related field shall be substituted for the required experience as follows:

a. Ten (10) contact hours, one (1) Continuing Education Unit, or one (1) postsecondary education quarter hour with a passing grade shall substitute for 0.022 years of experience.

b. One (1) postsecondary education semester hour with a passing grade shall substitute for 0.033 years of experience.

4. Education applied to the experience requirements established in subsections (1) and (2) of this section shall not be applied to the education requirement.

(b) Experience shall be substituted for the educational requirement as follows:

1. One (1) year of operational experience at a treatment plant shall substitute for one (1) year of education.

2. One (1) year of collection system experience shall substitute for one (1) year of education.

3. The cabinet may allow partial substitution of the education requirement by experience in maintenance, laboratory analysis, or other work related to the collection, treatment or distribution of drinking water or wastewater. To establish how much experience shall be accepted, the cabinet shall determine the degree of technical knowledge needed to perform the work and the degree of responsibility the applicant had in the operation of the system.

4. Experience applied to the education requirement established in subsections (1) and (2) of this section shall not be applied to the experience requirement.

(c) Collection system and treatment experience may be substituted as follows:

1.a. Four (4) years of collection system experience shall be considered equivalent to one (1) year of treatment experience.

b. This substitution shall not account for more than fifty (50) percent of the experience required by subsection (1) of this section.

2. One (1) year of treatment experience shall be considered equivalent to one (1) year of collection system experience. (35 Ky.R. 476; Am. 1213; eff. 3-6-2009; 36 Ky.R. 454; 1052; 1456; eff. 2-5-2010; 36 Ky.R. 2105-A; 37 Ky.R. 51; eff. 8-5-2010.)

401 KAR 11:050. Operator Certification.

RELATES TO: KRS 223.160-220, 224.10-420(2), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-220, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes application and examination procedures; provisions relating to certificate issuance, renewal, and termination; reciprocity; training; and disciplinary actions.

Section 1. Application and Examination for Certification.

(1) An individual desiring to become a certified operator shall first meet the qualifications established in 401 KAR 11:030 or 11:040 and then pass an examination administered by the cabinet.

(2) (a) An applicant for certification shall complete the Registration Form for Exams and Training and Education and Experience Documentation Form and shall submit them and the certification application fee to the cabinet.

(b) In addition to the requirements of paragraph (a) of this subsection, an applicant desiring to obtain an Operator in Training designation shall submit a signed letter for a certified operator located at the facility where the applicant will work. The letter shall include:

1. A statement from the certified operator indicating that the certified operator shall oversee the work of the applicant seeking an Operator in Training designation;

2. A commitment that the certified operator shall serve as a mentor to the applicant seeking an Operator in Training designation as long as the applicant is under the certified operator’s direct responsible charge;

3. Verification that the certified operator is not currently the mentor for any other individuals with an Operator in Training designation; and

4. Confirmation that the certified operator has obtained a certification level that is equal to or greater than the certification level required to serve in primary responsibility of the facility.

(c) An application shall not be submitted to the cabinet unless the applicant has met the qualifications for examination.

(3) (a) After receipt of the application items established in subsection (2) of this section, the cabinet, considering the recommendation of the board, shall determine if the applicant meets the qualifications established in 401 KAR 11:030 or 11:040.

(b) If the applicant meets the qualifications, the cabinet shall approve the application and notify the applicant of the scheduled exam date.

(4) (a) Upon the applicant’s completion of the examination, the cabinet shall notify the applicant of the applicant's examination score.

(b) A score of at least seventy (70) percent shall be required to pass the examination.

(5) (a) The cabinet shall issue a certificate and a wallet card to an applicant who successfully passes the certification examination.

(b) The certificate and wallet card shall designate the certification classification for which the operator has demonstrated competency.

(6) An applicant who fails to pass an examination may apply to take the examination again by resubmitting the Registration Form for Exams and Training and the application fee to the cabinet.

(7) (a) An examination shall not be returned to the applicant, but results may be reviewed by the applicant with a member of the cabinet.

(b) A request for a review shall be submitted to the cabinet in writing.

(8) A certificate shall be issued in a comparable classification, without examination, to a person who holds a valid certificate in a state, territory, or possession of the U.S. if:

(a) The requirements for certification under which the certificate was issued are not less stringent than the requirements for certification established in KRS 223.160-220, 224.73-110, and 401 KAR Chapter 11; and

(b) The applicant submits an Application for Reciprocity form and the reciprocity fee to the cabinet.

(9) (a) A certified operator who holds an Operator in Training designation may upgrade the certification by removing the Operator in Training Designation without examination if the operator:

1. Has satisfied the requirements of Section 3(1)(a) and (b) of this administrative regulation;

2. Has acquired the minimum experience required for the certification being pursued as required by 401 KAR 11:030 or 11:040; and

3. Submits a letter from the certified operator who has served as the applicant's mentor during the Operator in Training period that recommends the removal of the Operator in Training designation.

(b) A certified operator with an Operator in Training designation who is unable to comply with the requirements established in paragraph (a) of this subsection shall apply for and retake the certification exam to upgrade the operator's certification.

Section 2. Duration of Certification.

(1) (a) Wastewater certifications shall expire on June 30 of an odd-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Wastewater certifications issued on or after January 1 and on or before June 30 of an odd-numbered year shall expire on June 30 of the next odd-numbered year.

(2) (a) Water certifications shall expire on June 30 of an even-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Water certifications issued on or after January 1 and on or before June 30 of an even-numbered year shall expire on June 30 of the next even-numbered year.

(3) (a) An expired certification shall continue in force pending the administrative processing of a renewal if the certified operator has complied with the renewal requirements of Section 3 of this administrative regulation.

(b) A certification continued in accordance with this subsection shall remain fully effective and enforceable.

(4) A certification shall terminate if not renewed on or before December 31 of the year the certification expired.

Section 3. Continuing Education and Certification Renewal.

(1) A certified operator who is not designated an Operator in Training may renew a certification without examination if the operator has:

(a) Accumulated the training hours required in subsection (5) of this section; and

(b) Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet’s Web site.

(2) (a) A certified operator seeking to renew a certification with an Operator in Training designation shall apply for and retake the certification exam as provided in Section 1 of this administrative regulation.

(b) The cabinet shall not approve an operator to take an exam to renew a certification with Operator in Training designation unless the applicant has accumulated the training hours required in subsection (5) of this section.

(3) If the Application for Certification Renewal form and the renewal fee are not received by the cabinet or submitted electronically by June 30 of the year the certification expires, a late renewal fee as established in 401 KAR 8:050, Section 3 or 11:060, Section 1 shall be paid.

(4) (a) A terminated certification shall not be renewed.

(b) An operator whose certification is terminated and who wishes to become recertified shall reapply for and pass an examination in accordance with Section 1 of this administrative regulation.

(5) (a) Prior to applying for certification renewal, a certified operator shall complete the required number of cabinet-approved training hours.

(b) A certified operator holding multiple wastewater certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(c) A certified operator holding multiple water certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(d) Hours earned prior to initial certification shall not count toward certification renewal.

(e) Wastewater training hours shall expire two (2) years from the date earned.

(f) Water training hours shall be completed for each renewal during the two (2) year period immediately prior to the certificate expiration date.

1. Certified operators with a Bottled Water, Limited, Class I or II Treatment, Collection, or Distribution certification shall complete twelve (12) hours of approved training; or

2. Certified operators with a Class III or IV Treatment, Collection, or Distribution certification shall complete twenty-four (24) hours of approved training.

(6) (a) A training provider seeking approval of certified operator training shall submit to the cabinet a completed Application for Approval of Courses for Continuing Education Credit form.

(b) Upon completion of the approved training, the provider shall submit to the cabinet a completed Continuing Education Activity Report form.

(c) A certified operator who has attended training that has not been submitted to the cabinet for approval may apply for training approval as established in paragraph (a) of this subsection.

(d) A certified operator who provides approved training shall receive hour-for-hour credit for actual instruction time.

(7) (a) Cabinet approval of training shall expire two (2) years following the date of approval.

(b) The cabinet, in consultation with the board, shall extend the approval expiration date if:

1. The provider requests the extension in writing; and

2. The training has not changed from the previous approval.

Section 4. Disciplinary Action.

(1) A certified operator shall be subject to disciplinary action if the cabinet, in consultation with the board, determines that the certified operator has not satisfactorily performed the operator's duties in accordance with 401 KAR 11:020.

(2) (a) A written complaint received by the board or cabinet regarding a certified operator, unless duplicitous or frivolous, and violations of 401 KAR 11:020 that are identified by the cabinet shall be evaluated by the board.

(b) The certified operator shall appear before the board if requested by the board

(3) The board shall make a recommendation to the cabinet regarding disciplinary action. The board may recommend that disciplinary action not taken or recommend that a disciplinary action be taken if the board determines that the certified operator has not satisfactorily performed operator duties in compliance with 401 KAR 11:020.

(4) (a) Upon receiving a recommendation from the board, the cabinet shall review the available evidence.

(b) After completing the review, the cabinet shall initiate the recommended disciplinary action or notify the board as to why an alternative disciplinary action was taken.

(5) A disciplinary action shall be commensurate with the severity, duration, and number of the violations. Disciplinary actions may include:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;

(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;

(c) Revocation of the operator's certification;

(d) Civil or criminal penalties; or

(e) A combination of the disciplinary actions established in paragraphs (a) through (d) of this subsection.

(6) If disciplinary action is taken, the cabinet shall notify the certified operator and the operator's employer by certified mail of the action, the reasons outlined for the action, and the length of time for which the disciplinary action shall apply.

(7) (a) A certified operator whose certification has been suspended shall not have primary responsibility during the period that the suspension remains in effect.

(b) Experience gained during a suspension shall not be included toward meeting the requirements of 401 KAR 11:030 or 11:040.

(8) If a certification is revoked, the operator shall be ineligible for future certification.

(9) A certified operator who is aggrieved by a disciplinary action may file a petition for hearing with the cabinet pursuant to KRS 224.10-420(2).

Section 5. Incorporation by Reference.

(1) The following material is incorporated by reference:

(a) "Registration Form for Exams and Training", August 2009;

(b) "Education and Experience Documentation Form", July 2009;

(c) "Application for Certification Renewal", August 2009;

(d) "Application for Approval of Courses for Continuing Education Credit", August 2009;

(e) "Continuing Education Activity Report", August 2009; and

(f) "Application for Reciprocity", July 2009.

(2) This material may be inspected, copied, or obtained, subject to applicable copyright law, at the Division of Compliance Assistance, 300 Fair Oaks Lane, Frankfort, Kentucky 40601, Monday through Friday, 8 a.m. to 4:30 p.m. (35 Ky.R. 479; Am. 1216; eff. 3-6-2009; eff. 2-5-2010.)

401 KAR 11:060. Certification Fees.

RELATES TO: KRS 224.10-110, 224.73-110
STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater operators. This administrative regulation establishes a fee schedule for wastewater operator certification and for training of wastewater operators that is provided by the cabinet.

Section 1. Fees.

(1) Fees for certification of wastewater operators shall be:
(a) Certification application fee: $100.
(b) Renewal application fee:
1. Fifty (50) dollars if renewed through the cabinet Web site.
2. $100 if not renewed through the cabinet Web site.
(c) Renewal late fee: $250.
(d) Reciprocity fee: $500.
(2) Each year the cabinet, in consultation with the board, shall set fees for operator training conducted by the cabinet.
(3) (a) The fees in subsection (1) of this section of this administrative regulation are nonrefundable.
(b) Fifty (50) percent of the fees in subsection (2) of this section are refundable if registration is canceled at least two (2) business days prior to the beginning of the training event.
(c) The fees in subsection (2) of this section shall be fully refunded if the training event is cancelled by the cabinet. (35 Ky.R. 481; Am. 1219; eff. 3-6-09.)

GLOSSARY

ABSORPTION: Taking in or soaking up of one substance into the body of another by molecular or chemical action (tree roots absorb dissolved nutrients in the soil).

ACID:

1. A substance that dissolves in water with the formation of hydrogen ions.
2. A substance that is corrosive.
3. A substance that may lower pH.

ACIDITY: The capacity of water or wastewater to neutralize bases. Acidity is expressed in milligrams per liter of equivalent calcium carbonate.

ACTIVATED SLUDGE: Sludge particles produced in raw or settled wastewater (primarily effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term “activated” comes from the fact that the particles are teeming with bacteria, fungi, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.

ACTIVATED SLUDGE PROCESS: A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or refused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.

ADSORPTION: The attraction and accumulation of a gas, liquid, or dissolved substance on the surface or interface zone of another substance (similar to a magnet)

ADVANCED WASTE TREATMENT: Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. Typical processes include chemical treatment and pressure filtration. Also called tertiary treatment.

AERATION: The process of adding air to water. In wastewater treatment, air is added to freshen wastewater and to keep solids in suspension. With mixtures of wastewater and activated sludge, adding air provides mixing and oxygen for the microorganisms treating the wastewater.
AEROBES: Bacteria that must have molecular (dissolved) oxygen (DO) to survive.

AEROBIC BACTERIA: Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as water molecules (H2O), cannot be used for respiration by aerobic bacteria.

AIR LIFT: A type of pump. This device consists of a vertical riser pipe in the wastewater or sludge to be pumped. Compressed air is injected into a tall piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An air lift pump works like the center of a stand in a percolator coffee pot.

ALGAE: Microscopic plants, which contain chlorophyll and live floating or are suspended in water. They also may be attached to structures, rocks, or other similar substances. Algae produce oxygen during sunlight hours and use oxygen during night hours. Their biological activities appreciably affect the pH and dissolve oxygen of the water.

ALIQUOT: Portion of a sample. Often an equally divided portion of a sample.

ALKALINITY: the ability of water to buffer acids

ANAEROBIC: A condition in which atmospheric or dissolved molecular oxygen is *NOT* present in the aquatic (water) environment.

ANAEROBIC BACTERIA: Bacteria that live and reproduce in an environment containing no “free” or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO4 2-).

ANAEROBIC DIGESTION: Wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen.

ANOXIC: Oxygen deficient or lacking sufficient oxygen.

BACTERIA: Living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as the result of their life processes.

BAFFLE: A flat board or plate, deflector, guide or similar device constructed or placed in flowing water, wastewater, or slurry systems to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate liquids (water, chemical solutions, slurry).

BASE:

1. A substance which dissociates (separates) in aqueous solution to yield hydroxyl ions (OH^-).

2. A substance that may raise pH.

BIOMASS: A mass or clump of organic material consisting of living organisms feeding on the wastes in wastewater, dead organisms and other debris.

BIOSOLIDS: A primarily organic solid product, produced by wastewater treatment processes that can be beneficially recycled. The word biosolids is replacing the word sludge.

BIOCHEMICAL OXYGEN DEMAND: (BOD) The biochemical oxygen demand, (BOD_5), is a measure of the organic strength of wastewater. It is also a measure of the quantity of dissolved organic pollutants that can be removed in biological oxidation by bacteria. It is expressed in **mg/L of oxygen**. It is also the rate at which organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions.

BLANK: A bottle containing only dilution water or distilled water, but the sample being tested is not added. Tests are frequently run on a SAMPLE and a BLANK and the differences are compared.

BUFFER: A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BULKING: Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge does not settle properly. In the activated sludge process, bulking is usually caused by filamentous bacteria or bound water.

CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND: (CBOD): It is only the carbonaceous biochemical oxygen demand removal.

CAVITATION: The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.

CENTRIFUGE: A mechanical device that uses centrifugal or rotational forces to separate solids from liquids.

CHLORINATION: The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

CHLORINE DEMAND: Chlorine demand is the difference between the amount of chorine added to wastewater and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH or nature or amount of the impurities in the water.
Chlorine Demand, mg/L = Chlorine Applied, mg/L - Chlorine Residual, mg/L

CHLORINE REQUIREMENT: The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or oxidizing some substance in the water. In each case, a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CLARIFIER: Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time during which the heavier solids settle to the bottom and the lighter material will float to the water surface.

COAGULANTS: Chemicals that cause very fine particles to clump (floc) together into larger particles. This makes it easier to separate the solids from the water by settling, skimming, draining or filtering.

COAGULATION: The clumping together of very fine particles into large particles (floc) caused by the use of chemicals (coagulants).

COLIFORM: A type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air and the aquatic environment Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes various other environmental sources.

COLORIMETRIC MEASUREMENT: A means of measuring unknown chemical concentrations in water by *MEASURING A SAMPLE'S COLOR INTENSITY*. The specific color of the sample, developed by addition of chemical reagents, is measured with a photoelectric colorimeter or is compared with "color standards" using, or corresponding with, known concentrations of the chemical.

COMMINUTOR: A device used to reduce the size of the solid chunks in wastewater by shredding (comminuting). The shredding action is like many scissors cutting or chopping to shreds all the large influent solids material in the wastewater.

COMPOSITE: A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the rate of flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sample period.

CONFINED SPACE: Confined space means a space that:
(1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and
(2) Has limited or restricted means for entry or exit; and
(3) Is not designed for continuous employee occupancy.
(Definition from the Code of Federal Regulations (CFR) Title 29 Part 1910.146.)

CROSS CONNECTION: A connection between a drinking (potable) water system and an unapproved water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross connection, or mixing, between the two water systems can occur. This mixing may lead to contamination of the drinking water.

DECHLORINATION: The removal of chlorine from the effluent of a treatment plant.

DENITRIFICATION:
(1) The anoxic biological reduction of nitrate-nitrogen to nitrogen gas.
(2) The removal of some nitrogen from a system.
(3) An anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a result of this process.

DETENTION TIME: The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DETRITUS: The heavy, coarse mixture of grit and organic material carried by wastewater (also called grit).

DIFFUSED-AIR AERATION: A diffused air activated sludge plant takes air, compresses it, and then discharges the air below the water surface of the aerator through some type of air diffusion device.

DIFFUSER: A device used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DIGESTER: A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic (more common) or aerobic conditions.

DISINFECTION: The process designed to kill or inactivate most microorganisms in wastewater, including essentially all pathogenic (disease-casing) bacteria. There are several ways to disinfect, with chlorination being the most frequently used in water and wastewater treatment plants. Ozone and ultra violet light are also accepted methods.

DISSOLVED OXYGEN (DO): Molecular (atmospheric) oxygen dissolved in water or wastewater.

EFFLUENT: Wastewater or other liquid - raw (untreated), partially or completely treated - flowing *FROM* a reservoir, basin, treatment process or treatment plant.

EQUALIZING BASIN: A holding basin in which variations in flow and composition of a liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit. Also called a balancing reservoir.

EUTROPHICATION: The increase of nutrient levels (nitrogen and phosphorus) of a lake or other body of water; this usually causes an increase in the growth of aquatic animal and plant life.

FILAMENTOUS ORGANISMS: Organisms that grow in a thread or filamentous form. Common types are T*hiothrix* and *Actinomycetes*. A common cause of sludge bulking in the activated sludge process.

FLOC: Clumps of bacteria and particles or coagulants and impurities that have come together and formed a cluster. Found in aeration tanks, secondary clarifiers and chemical precipitation processes.

FLOCCULATION: The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing.

FORCE MAIN: A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

FREEBOARD: The vertical distance from the normal water surface to the top of the confining wall.

GRAB SAMPLE: A single sample of water collected at a particular time and place which represents the composition of the water only at that time and place.

GRIT: The heavy material present in wastewater, such as sand, coffee grounds, eggshells gravel and cinders.

GRIT REMOVAL: Grit removal is accomplished by providing an enlarged channel or chamber which causes the flow velocity to be reduced and allows the heavier grit to settle to the bottom of the channel where it can be removed.

HEADWORKS: The facilities where wastewater enters a wastewater treatment plant. The headworks may consist of bar screens, comminutors, and a wet well and pumps.

HYDROGEN SULFIDE GAS (H2S): A gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls the sense of smell so that it is unnoticeable after a prolonged period of time and because the odor is not noticeable in high concentrations. The gas is colorless, explosive, flammable, and poisonous to the respiratory system.

INFLOW: Water discharged into a sewer system and service connections from sources other than regular connections. This includes flow from yard drains, foundation drains and around manhole covers. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.

INFLUENT: Wastewater or other liquid - raw (untreated) or partially treated – flowing *INTO* a reservoir, basin, treatment process or treatment plant.

MASKING AGENTS: Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.

MECHANICAL AERATION: The use of machinery to mix air and water so that oxygen can be absorbed into the water.

MICROORGANISMS: Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesired matter.

MIXED LIQUOR: When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank. Mixed liquor may also refer to the contents of mixed aerobic or anaerobic digesters.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS): Suspended solids in the mixed liquor of an aeration tank.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS): The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.

NPDES PERMIT: National **P**ollutant **D**ischarge **E**limination **S**ystem permit is the regulatory agency document issued by either a federal or state agency which is designed to control all discharges of pollutants from all point sources and storm water runoff into U.S. waterways. A treatment plant that discharges to a surface water will have a NPDES permit.

NITRIFYING BACTERIA: Bacteria that change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).

OXIDATION: Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances.

PACKAGE TREATMENT PLANT: A small wastewater treatment plant often fabricated at the manufacturer's factory, hauled to the site, and installed as one facility. The package may be either a small primary or a secondary wastewater treatment plant.

PATHOGENIC ORGANISMS: Bacteria, viruses or cysts, which can cause disease (typhoid, cholera, dysentery) in a host such as a human. Also called Pathogens.

POLYMER: Used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water.

PONDING: A condition occurring on trickling filters when the hollow spaces (voids) become plugged to the extent that water passage through the filter is inadequate. Ponding may be the result of excessive slime growths, trash or media breakdown.
PRECIPITATE:
(1) An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.
(2) The separation from solution of an insoluble substance.

PRIMARY TREATMENT: A wastewater treatment process that takes the 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.

RAW WASTEWATER: Plant influent or wastewater *BEFORE* any treatment.

RECEIVING WATER: A stream, river, lake, ocean or other surface or groundwater into which treated or untreated wastewater is discharged.

RECIRCULATION: The return of part of the effluent from a treatment process to the incoming flow.

RETENTION TIME: The time water, sludge or solids are retained or held in a clarifier or sedimentation tank.

RISING SLUDGE: Rising sludge occurs in the secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.

SCREEN: A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.

SEPTIC: A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.

SEWAGE: The used water and water-carried solids from homes that flow in sewers to a wastewater treatment plant. The preferred term is WASTEWATER.

SHORT-CIRCUITING: A condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction or settling times in comparison with the theoretical (calculated) or presumed detention times.

SLUDGE:
(1) The settleable solids separated from liquids during processing.

SLUDGE DIGESTION: The process of changing organic matter in sludge into a gas or liquid or a more stable solid form. These changes take place as microorganisms feed on sludge in anaerobic (more common) or aerobic digesters.

SOLUBLE BOD: Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.

SOLUTION: A liquid mixture of dissolved substances. In a solution it is impossible to see all the separated parts.

STORM SEWER: A separate pipe, conduit or open channel (sewer) that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes.

SUPERNATANT: Liquid removed from settling sludge. Supernatant commonly refers to the liquid between the sludge on the bottom of an anaerobic digester and the scum on the surface. The liquid is usually returned to the influent wet well or to the primary clarifier.

SUSPENDED SOLID: Solids that either float on the surface or are suspended in water, wastewater or other liquids, and which are largely removable by laboratory filtering

TOTAL SUSPENDED SOLIDS (TSS) are solids that will not pass through a special glass filter with .45 micrometer pore size.

TOXIC: A substance which is poisonous to a living organism.

TOXICITY: The relative degree of being poisonous or toxic. A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

TURBID: Having a cloudy or muddy appearance.

VOLATILE SOLIDS: Those solids in water, wastewater or other liquids that are lost on ignition of the dry solids at 550ºC.

WASTEWATER: The used water and solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. The term “sewage” usually refers to household wastes, but this word is being replaced by the term “wastewater.”

WEIR:
(1) A wall or plate placed in an open channel and used to measure the flow of water. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used.
(2) A wall or obstruction used to control flow (from settling tanks and clarifiers) to assure a uniform flow rate and avoid short-circuiting.

WET OXIDATION: A method of treating or conditioning sludge before the water is removed. Compressed air is blown into the sludge; the air and sludge mixture is fed into a pressure vessel where the organic material is stabilized.

WET WELL: A compartment or tank in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

ZOOGLEAL MASS: Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes.

Wastewater Treatment Conversion Factors and Formulas

CONVERSION TABLE										
AREA				**TEMPERATURE**				**POWER**		
1 Acre	=	43,560 Sq Ft		°F	=	(°C x 1.8) + 32		1 hp		
1 Sq Ft	=	144 Sq Inches		°F	=	(°F – 32) ÷ 1.8				
								PRESSURE		
FLOW				**TIME**						
1 MGD	=	694 GPM		1 Minute	=	60 Seconds				
1 MGD	=	11.57 GPM		1 Hour	=	60 Minutes				
1 MGD	=	1.55 CFS		1 Day	=	24 Hours		**WEIGHT**		
				1 Day	=	1,440 Minutes				
LENGTH										
1 Foot	=	12 Inches		**VOLUME**						
1 Yard	=	3 Ft		1 Cu Ft	=	7.48 Gallons				
1 Mile	=	5,280 Ft		1 Cu Yd	=	27 Cu Ft				
1 Mile	=	1,760 Yds								

WASTEWATER TREATMENT CONVERSION FACTORS AND FORMULAS

CONVERSION TABLE

EA
3,560 Sq Ft
44 Sq Inches

OW
94 GPM
1.57 GPM
.55 CFS

GTH
2 Inches
Ft
,280 Ft
,760 Yds

VER
.746 Kilowatts

SURE
.31 Feet
.433 psi

TEMPERATURE
°F = (°C x 1.8) + 32
°C = (°F – 32) ÷ 1.8

TIME
1 Minute = 60 Seconds
1 Hour = 60 Minutes
1 Day = 24 Hours
1 Day = 1,440 Minutes

VOLUME
1 Cu Ft = 7.48 Gallons
1 Cu Yd = 27 Cu Ft

WEIGHT
1 ml Water = 1 Gram
1 Gal. Water = 8.34 Pounds
1 Cu Ft Water = 62.4 Pounds
1 Ton = 2,000 Pounds

SQ FT) VOLUME (CU FT)

Radius)^2 or 35)(Diameter)^2	n/a
	(Length)(Width)(Height)
	(π)(Radius)^2(Height) or (0.785)(Diameter)^2(Height)
gth)(Width)	(Length)(Width)(Height)
gth)(Width)	(Length)(Width)(Height)
π)(Diameter)	π = 3.14

ASIC FORMULAS (PONDS)

g, Person/Acre = $\frac{\text{Population Served, Persons}}{\text{Pond Surface Area, Acres}}$

c Loading, Lbs, BOD/Day/Acre = $\frac{\text{(Flow, MGD)(BOD, mg/l)(8.34)}}{\text{Area, Acres}}$

BASIC FORMULAS

Pounds of BOD or TSS = Flow, MGD x Concentration, mg/l x 8.34

BOD, mg/l = $\frac{\text{(Initial DO-Final DO) x BOD Bottle Vol, ml}}{\text{Sample, ml}}$

Population Equivalent = $\frac{\text{Flow, MGD x BOD, mg/l x 8.34}}{\text{0.17 Lbs, BOD/Person/Day}}$

Detention Time (Hours) = $\frac{\text{(Tank Volume, Cu Ft) (7.48 Gal/Cu Ft) 24 Hrs/Day}}{\text{Flow, Gal Per Day}}$

Detention Time (Days) = $\frac{\text{Volume, MG}}{\text{Flow, MGD}}$

FM Ratio = $\frac{\text{Flow, MGD x BOD, mg/l x 8.34}}{\text{Lbs MLVSS in Aeration Tank}}$

or = $\frac{\text{BOD, mg/l x Flow, MGD x 8.34}}{\text{MLVSS, mg/l x Vol in Aeration Tank, MG x 8.34}}$

Hydraulic Loading or Surface Loading, GPD/Sq Ft = $\frac{\text{Flow, GPD}}{\text{Surface Area, Sq Ft}}$

Aerator Loading, Lbs/BOD, Day = Flow, MGD x BOD, mg/l x 8.34

Organic Loading, Activated Sludge = $\frac{\text{Flow, MGD x BOD, mg/l x 8.34}}{\text{Volume in A.T., 1,000 Cu Ft}}$

Organic Loading, Tr. Filter = $\frac{\text{Flow, MGD x BOD, mg/l x 8.34}}{\text{Volume of Filter Media, 1,000 Cu Ft}}$

Organic Loading, RBC = $\frac{\text{Soluble BOD, Applied Lbs/Day}}{\text{Surface Area of Media, 1,000 Sq Ft}}$

M.C.R.T., Days = $\frac{\text{Lbs, MLSS in Secondary System}}{\text{Lbs/Day SS Wasted + Lbs/Day SS in Effluent}}$

Weir Overflow Rate, GPD/ft = $\frac{\text{Flow, GPD}}{\text{Length of Weir, Ft}}$

Oxygen Uptake Rate (OUR) Mg O_2/1/Hour = $\frac{\text{(DO1, mg/l – DO2, mg/l)}}{\text{(Time2, Min) – (Time1, Min)}}$ x 60 Min/Hour

Respiration Rate (RR) Mg O_2/Hour/Gm = $\frac{O_2\text{ Uptake, mg/l/Hour x 1000 mg/gm}}{\text{MLSS, mg/l}}$

BASIC FORMULAS (SLUDGE & SOLIDS)

Suspended Solids, mg/l = $\frac{\text{(W2) – (W1)}}{\text{ml Sample}}$ x 1000 x 1000

Volatile Suspended Solids, mg/l = $\frac{\text{(W2) – (W3)}}{\text{ml Sample}}$ x 1000 x 1000

Where W1 (Dish), W2 (Dish & Dry Solids), W3 (Dish & Ash)

Volatile Solids, Lbs = $\frac{\text{Dry Solids, Lbs x Raw Sludge, \% VS}}{\text{100\%}}$

Aerator Solids, Lbs = Tank Vol, MG x MLSS, mg/l x 8.34

Solids Applied, Lbs/Day = (Flow, MGD + RSF, MGD)(MLSS, mg/l x 8.34)

Solids Loading, Lbs/Day/Sq Ft = $\frac{\text{Solids Applied, Lbs/Day}}{\text{Surface Area, Sq Ft}}$

Sludge Volume Index (SVI), ml/gm = $\frac{SSV_{30}\text{, ml/l x 1000 mg/g}}{\text{MLSS, mg/l}}$

Sludge Age = $\frac{\text{Lbs TSS in Aeration Basin}}{\text{Lbs/Day TSS in Influent}}$

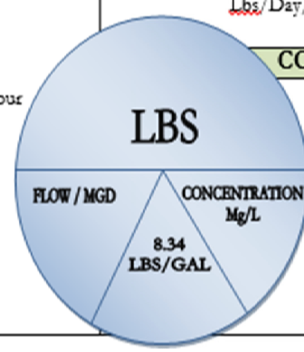
Reduction on Volatile Solids, % = $\frac{\text{In – Out}}{\text{In – (In x Out)}}$ x 100

Percent Removal = $\frac{\text{Inf – Eff}}{\text{Inf}}$ x 100

Dry Solids, Lbs = $\frac{\text{Raw Sludge, Gal x Raw Sludge, \% x 8.34}}{\text{100\%}}$

Return Sludge Rate, MGD = $\frac{\text{(Total Flow, MGD)(Settleable Solids, \%)}}{\text{100\%}}$

Digester Loading, Lbs/Day/Cu Ft = $\frac{\text{VS Added, Lbs/Day}}{\text{Digester Vol, Cu Ft}}$



CONCENTRATIONS & SOLUTIONS

1 mg/l = 1 ppm

Lbs, Chemical = $\frac{\text{Desired ppm x Flow, MGD x 8.34}}{\text{Purity of Chemical}}$

ppm = $\frac{\text{Lbs Chemical Fed}}{\text{MGD x 8.34}}$

1% Solution = 10,000 mg/l