Drinking Water B,C & D Level Certification Review

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How to Improve Your Score on the Operator Certification Exam

Test Preparation Strategies for Success on the WTP Exam

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1st – Prepare for the Test You are Taking

You won't panic… if you have a plan and are prepared

- Target those areas of study on your test
- Set priorities
  - What are the subjects where I am weak?
  - Study most important subjects first !
  - Know the Math presented by FRWA !!
- Improve Study Habits!
  - Set up a Schedule that aligns with your test date
  - Use the Taylor Tutorial !!!
  - Stick to a Study Schedule !

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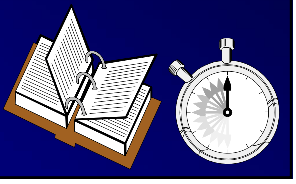
2nd – Set a Reasonable Study Schedule

- **Set a Test Date close to the FRWA training**
- Then set a Schedule that is realistic for ***YOU!***
- Study early that aligns with your test date
- Study in short spread-out sessions according to a plan that includes FRWA handouts
- Begin each session with quick review of previous material
  - Use the Study materials provided by FRWA !
  - Something in this Course will help you answer every question !



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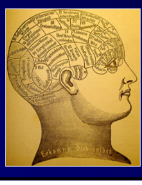
3rd – Build your Memory

- Long-term memory is a powerful tool
- It is Formed by the process of creating connections, reinforcing the same connections and expanding strength by forming meaningful associations or secondary connections
- In other words,
  - ✓ if a pathways are **FORMED**,
  - ✓ and you **USE them**, and
  - ✓ you **REPEAT them**,
  - ✓ You'll **REMEMBER the information** !



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Prepare Physically & Mentally for Exam Day

My To Do List:

1. Get Ready for Test
2. Get Ready for Test
3. Get Ready for Test
4. Repeat #'s 1 - 3

Focus = **Mental Preparedness** + **Physical Preparedness**

6

Be Comfortable

- Breakfast is mandatory and includes protein:
  - eggs, bacon, peanut butter, cheese, (Brain Food !)
- Drink plenty of fluids
- Wear comfortable clothes & shoes
- Test Calculator operation
- ***Get Some new Pencils***
- ***Be Early !!!!***

7

Have a Positive Mental Attitude

- Confidence and positive attitude are very important in test taking as in anything we do that is challenging .
- **Confidence is something that can be built by reinforcing fundamentals.**

"Ninety Percent of this game is half mental."
Yogi Berra

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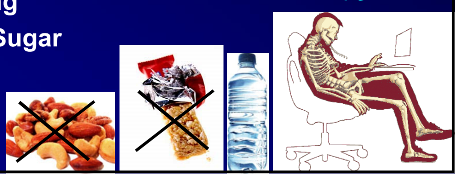
During the Exam

- **Stay Comfortable and Focused**
- **Stretch during test**
- **Take Deep Breathes**
- **Stop Occasionally to rest**
- **Don't drink lots of coffee if you didn't do so when you were studying**
- **Avoid Sugar**



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Approaching Tests Systematically

End

Start

1. Nail What you know.
2. Do the ones where you can eliminate
3. Record the ones you were not so sure on

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Beginning the Test

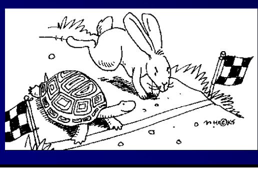
The test is not a race!

You have plenty of time to finish!

No need to Rush !

Use Effective Strategies!

Do not Rush



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Before Starting the Test

- ✓ Read ALL directions
- ✓ Scan the questions
  - Get a sense of the nature of questions
  - Think of the questions as several *small* jobs, not one big, overwhelming test
- ✓ Map out your time (3-hrs)
  - How much time per question?
  - Keep schedule flexible
- ✓ Use your Scratch Pad
  - Keep track of thoughts and questions
  - Take notes & jot things down

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Plan of Attack

1

FIRST SWEEP

- Read each question in order, answering the ones that you know easily in your first reading,
- Save harder questions for later,
- When you get to the end of the test, pause, relax, stretch, close your eyes and clear your mind for a minute or two; then begin again.

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Read the Questions !

- Read Questions Methodically and Carefully
- Most frequent problem -- question not completely read, misread or misunderstood
- "NOT" is the most commonly misread word.
- Reread the question several times to make sure you are answering the right question

RTQ x2

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Plan of Attack

2

SECOND SWEEP

- Begin your "second sweep"
  - work on the questions that you can answer with a little thought,
- Save the really tough ones for last,
- Reread the questions that you were not able to answer the first time.
- NEVER GUESS ! Answer all questions using something that you know or think you may know about it !

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Plan of Attack

3

THIRD SWEEP

- Answer hardest questions last,
- After you have answered all questions, if you have time, you can skim all the questions and answers one last time.
- Don't change an answer unless you have found additional clues or misread the question the first time
  - Most changed answers are not as good as the original ones

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Plan of Attack

4

FOURTH and FINAL SWEEP

- Re-read Each question and answer!
- After you have answered all questions, use your time to re-read all the questions and answers to identify a few obvious mistakes: 1.) keyed in the wrong letter, 2.) missed a "not" or read a "maximum" as a "minimum", 3.) did not bother to read all the answers given and there was a better answer and, 4.) found a math error!

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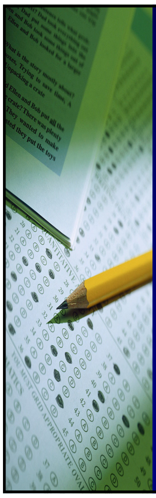

Strategies for Conquering Multiple Choice Questions

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Multiple Choice Mastery is in the Numbers

- Never Leave Blank !!!
- State the answer then;
  - Find the best match !
- If you can't match then Eliminate Distracters i.e., Cross out the Wrong answers
- Use the question clues to find the best answer
- Always favor the one that you remember about subject matter

1 of 4 = 25%
1 of 3 = 33%
1 of 2 > 50%

?

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Study by Stating the Answer, i.e., as if, it's not Multiple Choice

- Read the question only,
  - covering up the answer choices,
  - see if you already KNOW the answer.
- Always predict the answer first
- Then, read ALL of the answer choices
- Find the best match of the choices

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Using Prediction with Multiple Choice

- If your prediction isn't one of the choices, reread the question
  - you may have misunderstood the question
  - You may have misread the question
- Double check your answer by going back to the question again for clues

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Eliminating Multiple Answers increases your Odds

- ALWAYS ! Cross out those answers that are obviously wrong to get it down to two.
- If more than one choice seems true, then one of them doesn't answer the specific question or is not as complete
- Reread the question to see which answer is best

When you eliminate wrong answers, your chances for success increase dramatically!!

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Opposite Answers Increase Your Odds

- If two answers are opposites, one is often the correct answer
- Some answers are partially true
  - If any part of the answer is false, eliminate it
- Rephrase the question: "In other words, what I'm looking for is..."

Tests are a perfect time to talk to yourself, but not too loudly.

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Beware of Negatives

- If a negative such as "**NONE**", "**NOT**", "**NEVER**", or "**NEITHER**" occurs in the question then you're looking for a "catch".
- Read these carefully and be positive you understand the question.
- There will be an answer that matches even if your thinking is backwards.

NO

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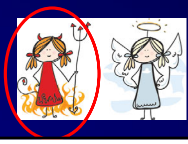
Recognize Absolutes

- Words such as "**EVERY**", "**ALL**", "**NONE**", "**ALWAYS**", and "**ONLY**" are superlatives that usually indicate a bad choice.

"If the world were perfect, I wouldn't be here" Yogi Berra



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Recognize Qualifiers

- "**USUALLY**", "**OFTEN**", "**GENERALLY**", "**MAY**", and "**SELDOM**" are qualifiers that usually indicate a true statement

or a good answer.

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Rely on Initial Logic

- Research shows that initial logic is often the best but:
  - ✓ Did you properly read the question?
    And then:
  - ✓ Is the revision **based on new clues?**
- If you cannot figure out the answer by rereading the question and using these strategies within a few minutes
  - ✓ go with the ***initial logic used***

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Solution to Two Possible Answers

- Ask how the two answers differ (just the answers, ignore the question), then look at the question again and ask yourself "How is this difference important for this question?"
- If you really think there's absolutely no difference between the two answers, then look again at the answers you've eliminated, maybe one of them is actually a better answer.

House Wins 28

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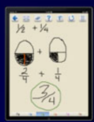
Scratch Paper is your Friend



- Helps you focus and ignore distractions
- Helps to Simplify Difficult concepts
- Helps you remember the questions that were difficult to answer and records their location (#) for your "second sweep".
- Helps to record information that you are sure you will need but might forget in other parts of the test.

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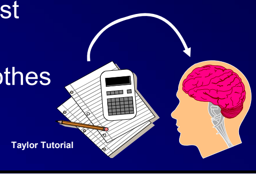
SUMMARY

How to Do Well on Exams

- Devise a plan
- Set a study schedule for FRWA materials
- Build long-term memory using repetition
- Be physically well as you can be
- Avoid stress and outside distractions
- Prepare the night before the test
- Have a good breakfast
- Drink plenty of fluids
- Wear comfortable clothes & shoes
- *SHOW UP EARLY*



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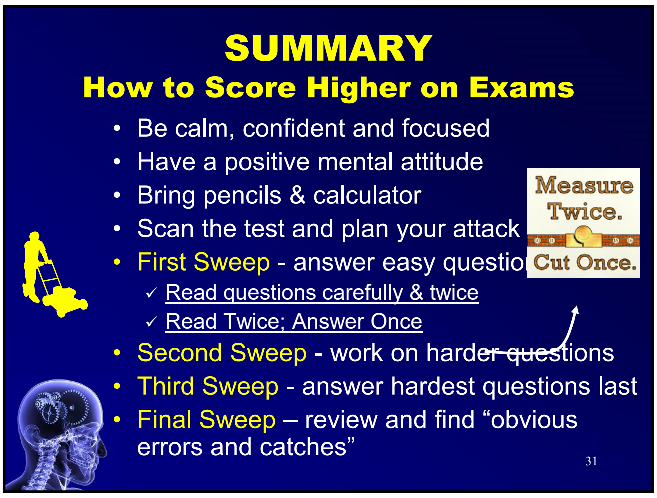
SUMMARY
How to Score Higher on Exams
Be calm, confident and focused
Have a positive mental attitude
Bring pencils & calculator
Scan the test and plan your attack
First Sweep - answer easy questio
Read questions carefully & twice
Read Twice; Answer Once
Second Sweep - work on harder questions
Third Sweep - answer hardest questions last
Final Sweep – review and find "obvious errors and catches"
Measure Twice.
Cut Once.
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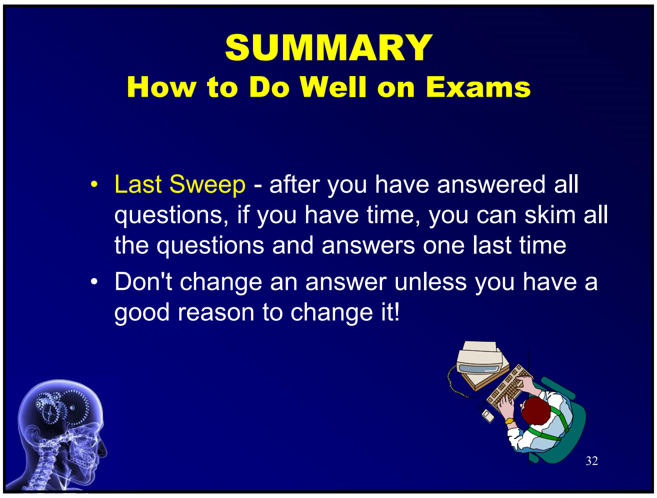
SUMMARY
How to Do Well on Exams
Last Sweep - after you have answered all questions, if you have time, you can skim all the questions and answers one last time
Don't change an answer unless you have a good reason to change it!
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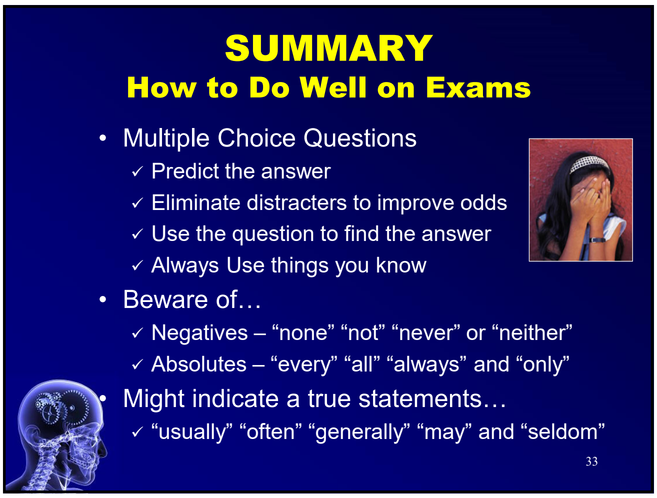
SUMMARY
How to Do Well on Exams
Multiple Choice Questions
Predict the answer
Eliminate distracters to improve odds
Use the question to find the answer
Always Use things you know
Beware of…
Negatives – "none" "not" "never" or "neither"
Absolutes – "every" "all" "always" and "only"
Might indicate a true statements…
"usually" "often" "generally" "may" and "seldom"
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Computer Based Examinations

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Overview

Drinking Water and domestic Wastewater Treatment Plant Operator Examinations

- Composed of four levels – Class A, B, C, and D
- Class A, B, and C
  - Time allocated is three hours
  - 100 multiple choice questions
- Class D
  - Time allocated is two hours
  - 50 multiple choice questions

Water Distribution System Operator Examinations

- Composed of four levels – Class 1, 2, 3, and 4
  - Time allocated is two hours
  - 50 multiple choice questions

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Examination Process

- Submit application to DEP for review and approval
- Notified of approval in writing and given testing location
- Go to the following web site for an examination request form and the location/dates where exams are given:

http://online.goamp.com/

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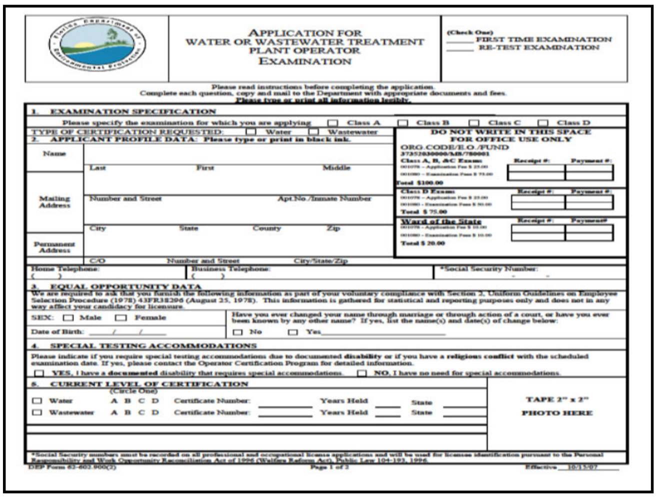

APPLICATION FOR
WATER OR WASTEWATER TREATMENT
PLANT OPERATOR
EXAMINATION

(Check One)
_____ FIRST TIME EXAMINATION
_____ RE-TEST EXAMINATION

Please read instructions before completing the application.
Complete each question, copy and mail to the Department with appropriate documents and fees.
Please type or print all information legibly.

1. EXAMINATION SPECIFICATION

Please specify the examination for which you are applying ☐ Class A ☐ Class B ☐ Class C ☐ Class D

TYPE OF CERTIFICATION REQUESTED: ☐ Water ☐ Wastewater

2. APPLICANT PROFILE DATA: Please type or print in black ink.

Name: Last / First / Middle

Mailing Address: Number and Street / Apt.No./Inmate Number / City / State / County / Zip

Permanent Address: C/O / Number and Street / City/State/Zip

Home Telephone: ( ) | Business Telephone: ( ) | *Social Security Number: - -

DO NOT WRITE IN THIS SPACE
FOR OFFICE USE ONLY
ORG.CODE/E.O./FUND
37352030000/MB/780001
Class A, B, &C Exam: Receipt #: Payment #:
Total $100.00
Class D Exam: Receipt #: Payment #:
Total $ 75.00
Ward of the State Receipt #: Payment#
Total $ 20.00

3. EQUAL OPPORTUNITY DATA

We are required to ask that you furnish the following information as part of your voluntary compliance with Section 2, Uniform Guidelines on Employee Selection Procedure (1978) 43FR38296 (August 25, 1978). This information is gathered for statistical and reporting purposes only and does not in any way affect your candidacy for licensure.

SEX: ☐ Male ☐ Female

Date of Birth: ___/___/___

Have you ever changed your name through marriage or through action of a court, or have you ever been known by any other name? If yes, list the name(s) and date(s) of change below:
☐ No ☐ Yes_____

4. SPECIAL TESTING ACCOMMODATIONS

Please indicate if you require special testing accommodations due to documented **disability** or if you have a **religious conflict** with the scheduled examination date. If yes, please contact the Operator Certification Program for detailed information.

☐ YES, I have a **documented** disability that requires special accommodations. ☐ NO, I have no need for special accommodations.

5. CURRENT LEVEL OF CERTIFICATION

(Circle One)
☐ Water A B C D Certificate Number: _____ Years Held ___ State _____
☐ Wastewater A B C D Certificate Number: _____ Years Held ___ State _____

TAPE 2" x 2"
PHOTO HERE

*Social Security numbers must be recorded on all professional and occupational license applications and will be used for licensee identification pursuant to the Personal Responsibility and Work Opportunity Reconciliation Act of 1996 (Welfare Reform Act), Public Law 104-193, 1996.

DEP Form 62-602.900(2) Page 1 of 2 Effective 10/15/07

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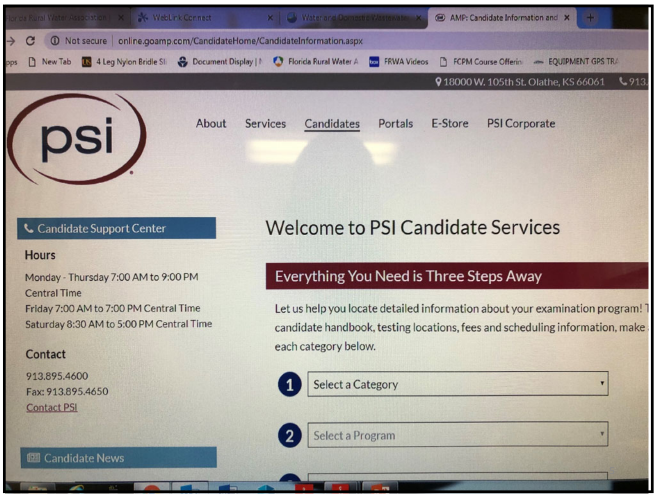

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What to Bring and what not to Bring to the Examination Site

- What to Bring
  - Two forms of identification
  - Only keys and wallets are allowed
  - Only calculators that are silent, hand-held, non-printing, non-programmable, no RAM, and no alphabetical key pads are allowed.
- What not to Bring
  - Cameras, recorders or cell phones
  - No personal items
  - No pencils or scratch paper (to be provided)

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Examination Scores

- Candidates will receive an on-site score report
- Minimum passing score is 70%
- Candidates that fail to achieve a passing score must wait at least 60 calendar days before they will be permitted to retake their exam

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WTP Class C

	Content Area 2014 - 2015	#		
1	Aeration	2		
2	Characteristics of Source Water	1		
3	Coagulation/Flocculation	9		
4	Laboratory Sampling, Analysis, and Interpretation	7		
5	Corrosion Control	5		
6	Disinfection	9		
7	Distribution	3		
8	Evaluate Equipment	1		
9	Filtration	7		
10	Iron and Manganese Control	2		
11	Clarification/Sedimentation	3		
12	Facility Operation and Maintenance	5		
13	Taste and Odor Control	2		
14	Operate Equipment	3		
15	Regulations	5		
16	Reservoir and Well Field Management	2		
17	Perform Safety and Security Procedures	7		
18	Softening	10		
19	Disinfection and Disinfectant Byproducts	3		
20	Waste Handling and Disposal	3		
21	Water Process	3		
22	Maintain Equipment	2		
23	Math	6		
24	Demineralization			

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WTP Class D

	Content Area	#
1	Maintain equipment	4
2	Chemical treatment and analysis	4
3	Plant Operation	30
4	Regulations	8
5	Reporting Requirements	2
6	Perform Safety and Security Requirements	2

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Good Luck!

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Introduction to Water Treatment
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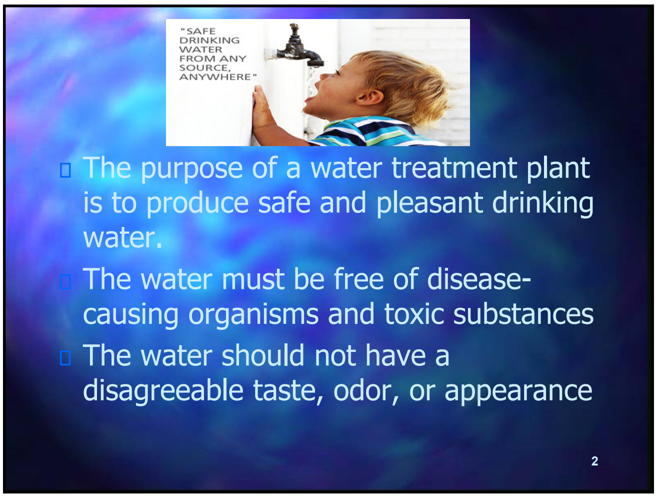
"SAFE DRINKING WATER FROM ANY SOURCE, ANYWHERE"
The purpose of a water treatment plant is to produce safe and pleasant drinking water.
The water must be free of disease-causing organisms and toxic substances
The water should not have a disagreeable taste, odor, or appearance
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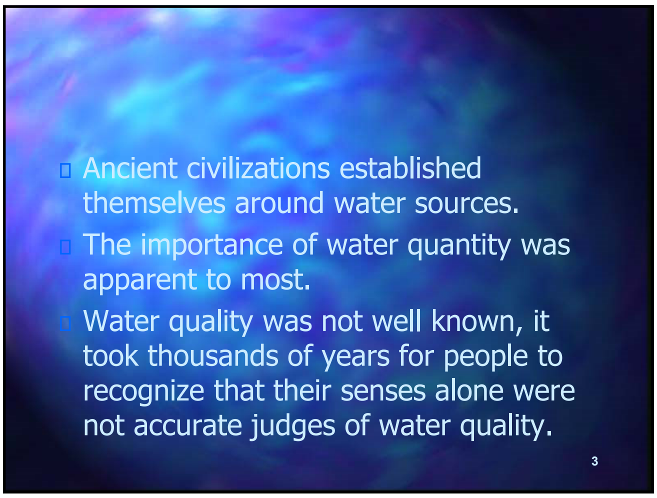
Ancient civilizations established themselves around water sources.
The importance of water quantity was apparent to most.
Water quality was not well known, it took thousands of years for people to recognize that their senses alone were not accurate judges of water quality.
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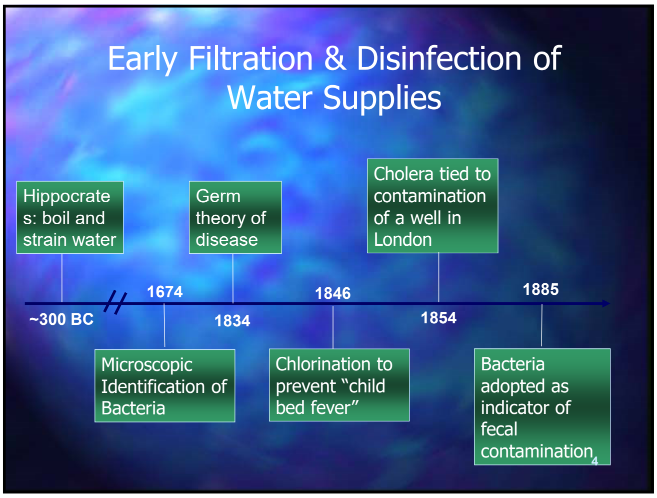

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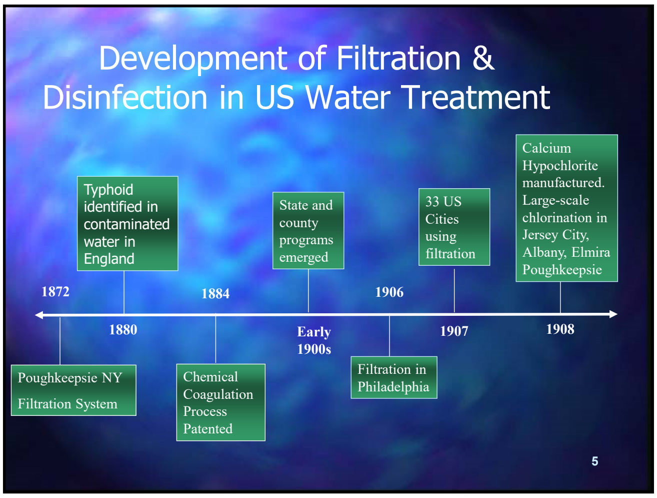

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Early US Treatment Techniques for Bacterial Inactivation

- Slow Sand Filtration (no backwash)
  - Large filter beds with relatively slow filtration rates that strain out particles
  - Particles are removed by sieving and organic action
- Disinfection
  - Chlorine added to drinking water in very small concentrations
  - Introduction of Chlorine in 1908
  - By late 1920's eliminated Cholera and Typhoid

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- 1846 – Dr. Ignaz Semmelweis instituted a requirement for physicians at a Vienna Hospital to wash their hands with soap and chlorine water to reduce infections and child bed fever in patients.
- 1854 – Dr. John Snow used chlorine in an attempt to disinfect the Broad Street Pump water supply in London, which he had identified as a cause of a cholera outbreak due to sewage contamination.
- 1879 – William Soper of England used chlorinated lime to treat the feces of typhoid patients before disposal into the sewer.
- 1893 – Chlorine was used on a plant scale basis for drinking water disinfection in Hamburg, Germany.
- 1897 – Sims Woodhead temporarily sterilized the potable water distribution mains at Maidstone, Kent, in England, using a bleach solution.

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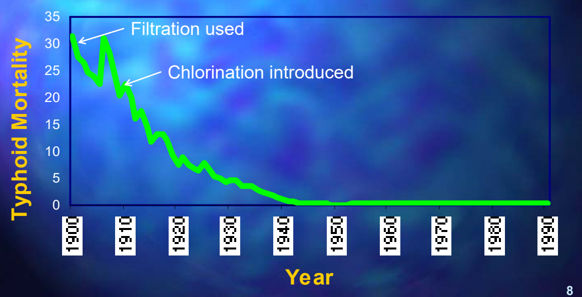
Early Success in Drinking Water Protection with Typhoid

Typhoid Deaths Per 100,000 People – Albany NY



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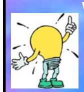

Water Borne Illnesses of Concern

- Cholera
- Dysentery
- Gastroenteritis
- Giardiasis
- Hepatitis
- Typhoid

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Symptoms of Waterborne Illnesses:

- Abdominal cramping
- Fever
- Vomiting
- Diarrhea, possibly leading to:
  - Severe dehydration
  - Malnutrition
  - Death

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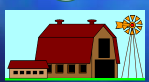
Drinking Water Health Concerns Resulting from Cultural Changes in US



- Urbanization
  - Discharge from septic tanks, storm and sanitary sewers
- Industrialization
  - Discharges of metals and chemicals
  - Production of nuclear material
- Intensive Farming and Agriculture
  - Pesticide and fertilizer use
  - Feedlots and meat production

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Types of Contaminants, Some Examples and Sources

Contaminant	Examples	Source
Microbial Contaminants	*Cryptosporidium*, *E. coli*, Norovirus	Sewage treatment plants, septic systems, agricultural livestock operations, and wildlife
Inorganic Chemical Contaminants	Arsenic, Copper, Fluoride, Lead	Naturally occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, soil and gas production and mining or farming
Disinfectants	Chlorine, Chloramine	Water additive for inactivating microbial contaminants
Disinfection Byproducts	Trihalomethane, Haloacetic acid	Byproduct of drinking water chlorination
Organic Chemical Contaminants	Pesticides and Herbicides, Benzene, Toluene	Agriculture, stormwater runoff, byproducts of industrial processes and petroleum production, gas stations, urban stormwater runoff, and septic systems
Radioactive Contaminants	Radium, Uranium	Naturally occurring or result from oil and gas production and mining activities

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Modern Water Treatment

Filtration

- Surface Water contains organisms
- Turbidity is representative of quality
- Graded sand provides effective removal

Chlorination

- Cl is a very strong Oxidant that destroys integrity of Bacterial Cell Wall
- Highly effective for low turbidity water
- Residual provides evidence for continued effectiveness

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Multiple Barrier Approach

Risk Prevention: Source Selection and Protection

Risk Management: Treatment Methods and Efficiencies

Monitoring and Compliance: Detecting and Fixing Problems

Individual Action: Consumer Awareness and Participation

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Your Role as an Operator

- Responsible for the operation of the water system
- First priority is to ensure water is free from harmful bacteria and toxic materials
- Correction of any problems that make the water unsafe
- Monitoring the water for contamination
- Adherence to state and federal rules and regulations that apply to the water treatment aspect of providing water to the public

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The Safe Drinking Water Act

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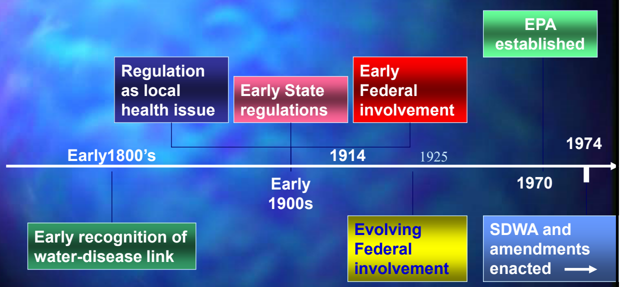
Government Regulation of Drinking Water in US



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Safe Drinking Water Act 1974

- Impetus for passage
  - Increased concern and awareness (driving force behind passage)
  - Because of Inconsistent State Requirements
- Development of Standards
  - Scientifically Based on Health Impacts
  - National Enforceable Standards
  - Required Water Systems to Monitor to Ensure Compliance
- SDWA enacted – December 16, 1974

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Safe Drinking Water Act Contents

- EPA established National Primary (Enforceable) and Secondary Drinking Water Standards (Recommended)
- Regulations use a multi-barrier approach.
- Establishes a public water system supervision program (PWSS), based on the level of risk posed to the public.
- Provide for State implementation and enforcement
- Requires Licensed Operators

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Safe Drinking Water Act

- Gave EPA authority to set drinking water standards in Three Ways:
  - Maximum Contaminant Level Goal (MCLG) (**Secondary Standards**) Note: all are MCLs in Florida!
  - If a Secondary Standard exceeds an MCL, it must be reported.
  - Maximum Contaminant Level (MCL) or numeric standards (**Primary Standards**)
  - Provided for Treatment Techniques (TT) for Surface Water Plants (most effective way to remove contaminants)

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- ***Maximum Contaminant Level Goal*** (MCLG) is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effects would occur.
- MCLGs are not enforceable at the federal level; however, some states such as Florida have adopted some MCLG's and set MCL's**.**

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- ***Maximum Contaminant Level*** (MCL) is enforceable. It is the maximum permissible level of a contaminant in water that can be delivered to any user of a public water system.
- For some contaminants, there is not a reliable method that is economically and technologically feasible to measure the contaminant, particularly at low concentrations. In these cases, EPA establishes a ***treatment technique***.

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- **Treatment Technique Is** A required process intended to reduce the level of a contaminant in drinking water.

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- ***treatment technique***. A treatment technique is an enforceable procedure or level of technological performance that public water systems must follow to ensure control of a contaminant.
- Treatment techniques are very important in ensuring viral and pathogen removal because of the difficulty and expense in identification.

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SDWA Contaminant Monitoring

- Chemicals (Inorganic)
- Pesticides (Organic)
- Bacteria and Viruses (Micro-organisms)
- Radioactivity
- Turbidity
- Trihalomethanes (Disinfection By-products)

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1986 SDWA Additions

- PWS system revised; Created the NTNC category of water system
- Organic Chemical Monitoring and Detection Added (led to detection of previously unidentified microbial problems)
- Tightened Requirements for Surface Water Treatment
  - provided for Higher Filtered Water Standards (lower NTU requirements) (NTU – Nephelometric Turbidity Unit)
  - Disinfectant CT (contact time) calculations for Giardia (Birds) and Viral Inactivation

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State and Federal Regulations

- Multiple Barriers Regulated:
- Plans and Specifications for Water Systems after 350 customers.
- New water systems or major alterations to exixting systems need to be approved prior to construction.
  - Plans and Specs
  - Facility Locations
  - EMP (Environmental Monitoring Plan).
  - Backup Generation
- Sanitary Surveys Required
- Training for Operators Required

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Effects of 1986 Amendments
(continued)

- Ground water under the direct influence (GWUDI) must meet Surface Water Standards (Microscopic Particle Analysis)
- More stringent coliform monitoring requirements added for all PWS
- Lead/Copper and Corrosion Monitoring
- Public Notification for CWS (Tier 1, 2 & 3)
  - Tier 1: violations, exceedances, and failures posing an acute health risk; Public notice NLT 24 hours after learning of problem
  - Tier 2: violations of a non-acute MCL or TT; Public notice NLT 30 days after learning of problem
  - Tier 3: other violations, variances or exemptions; Public notice within 3 months after learning of problem

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Public Water System (PWS) Designations

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Public Water System (PWS)

A public water system (PWS) is defined by the Safe Drinking Water Act (SDWA) as "a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections, or regularly serves at least twenty-five individuals at least 60 days out of the year."

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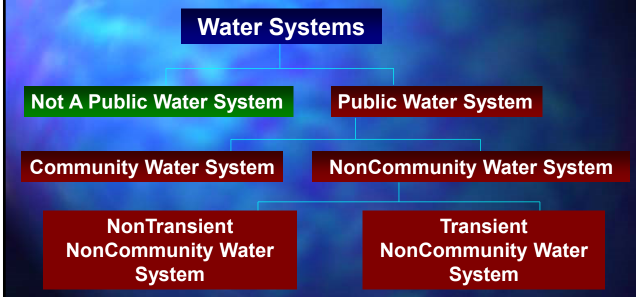
Regulatory Distinctions Between Water Systems



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Community Water System (CWS)

- A public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.
- Serves people where they live.
- Exposure to contaminants could be lifetime.

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Noncommunity Water System (NCWS)

- A public water system that is not a community water system.
- There are two types of non-community systems (based on the length of exposure of the consumers to the water): transient and non-transient.

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Non-transient Non-Community Water System (NTNCWS)

- A public water system that is not a community water system but that regularly serves at least 25 of the same persons over 6 months of the year.
- e.g., schools or businesses with their own water system
- Exposure to contaminants could be similar to that for community water systems.

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Transient Non-Community Water System (TNCWS)

- A noncommunity water system that does not regularly serve at least 25 of the same individuals at least 6 months per year.
- e.g., rest areas, campgrounds, truck stops, visitor centers with their own water system
- Individual exposure to the water is very short-term.

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Specific Rules and Regulations of the Safe Drinking Water Act

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Current SDWA Regulations

- Total Trihalomethanes (TTHMs and HAA5s)
- Chemical Rules (Phases I, II, IIb, and V)
- Surface Water Treatment Rule (Turbidity Control)
- Total Coliform Rule (Monitoring Based on Population)
- Lead and Copper Rule (Action Levels Established)
- Stage 1 D/DBP Rule (DBP Monitoring)
- Interim Enhanced SWTR (CT and Disinfection Profiles)
- Radionuclides
- Consumer Confidence Report Rule
- Arsenic
- Filter Backwash Recycling Rule
- Long Term 1 Enhanced Surface Water Treatment Rule

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Total Trihalomethanes (TTHM) and Haloacetic Acids (HAA5s)

- Disinfection By-Products are Trihalomethanes and Haloacetic Acids. They are the by-products of disinfectants that combine with organic materials in the water
- Standard applies to CWS' and NTNCS' that use a disinfectant
- TTHM < 80 PPB or .08 mg/l and HAA5 < 60 PPB or .06mg/l based on RAA (Rolling Annual Average)

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Chemical Contaminants

- Regulations cover 72 drinking water contaminants, most of which are carcinogens
- Applies to CWSs and NTNCWSs
- Contaminants cover three types:
  - Inorganic chemicals (metals)
  - Volatile organic chemicals (Solvents)
  - Synthetic organic chemicals (Chlorinated Hydrocarbons such as herbicides and pesticides)

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Inorganic Contaminants

Chemical	Probable Source	Health Effect
Aluminum	Coagulation	Dialysis Dementia
Arsenic	Dissolution of Rock	Gastrointestinal, Cardiac
Asbestos	Dissolution of Rock and As pipeline	Gastric, kidney, pancreatic cancer
Barium	Industrial Release	Hypertension
Cadmium	Industrial Release	Testicular, prostrate tumors
Chromium	Industrial Release	Liver and kidney damage

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Inorganic Contaminants (cont.)

Chemical	Probable Source	Health Effect
Molybdenum	Industrial Discharge	Bone loss, infertility
Nickel	Industrial Discharge	Possible carcinogen
Nitrate/Nitrite	Agriculture and Urban septic tanks	Methemoglobin, possible carcinogen
Selenium	Industrial Discharge	Liver, fatigue, diarrhea
Sodium	Water Softeners	Hypertension
Sulfate	Natural Waters	Laxative Effects
Zinc	Corrosion	Muscular weakness, pain, nausea

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Volatile (evaporative) Organic Compounds

#	Contaminant	Constituents	Probable Source
1.	Petroleum or Petroleum additives	Benzene, Toluene and Xylenes	Leaky fuel tanks (also MBTE)
2.	Halogenated VOCs	Dichlorobenzene, Dichloroethane, Dichloroethelyne, Tetrachloroethylene (PCE), Trichloroethylene (TCE)	Degreaser and solvent disposal, former use as Septic Tank cleaners (low odor thresholds)
3.	Chlorinated Disinfection by-products	Trihalomethanes	Industrial discharge

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Synthetic Organic (Pesticides) Contaminants

#	Contaminant	Constituents	Probable Source
1.	Insecticides	DDT, DDE, DDE. Carbamates, i.e. Aldicarb, Carbofuran, Oxamyl, Dieldrin. Organophosphates, i.e. Diazinon	Agricultural
2.	Herbicides	Alachlor, Atrazine, Cyanazine, Dachal, Dicamba, 2,4,D, Picloram, Microprop	Agriculture, Picloram is used in ROWs; Mecoprop is used on lawns
3.	Fungicides	1,2-Dichloropropane, Ethylene Thiourea (ETU)	Agriculture

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Surface Water Treatment Rule

- Applies to systems that use surface water (including GWUDI)
- Sets MCLGs for Legionella, Giardia, and Viruses at zero due to there health risk
  - Establishes treatment techniques for these contaminants because identification is not feasible
- Requires Disinfection and Filtration (adequacy of filtration is measured by turbidity)
- Establishes monitoring requirements for turbidity and disinfectant residuals

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Lead and Copper Rule Basic Requirements

- Provide optimal corrosion treatment
- Determine tap water lead and copper levels
- Rule out Source Water as the problem
- When levels are exceeded notify the public of the dangers and perform corrective actions
- The rule was promulgated in 1991, and revised in 2007.

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Stage 1 D/DBP Rule

- Limits TTHMs and HAA5s in drinking water
- Establishes treatment performance standards for filtration, enhanced coagulation and softening
- Applies to all NTNCWS and CWS's
- Requires systems to sample for Disinfectant Residuals and Disinfection By-Products
- Number of Samples based on source and system size

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Stage 2 D/DBP Rule

- Requires Monitoring Plan when Stage 1 > 60 PPM TTHM and/or > 40 PPM HAA5
- Must Submit Monitoring Plan or Apply for exemption
- Multiple locations depending on source and size different than Stage 1 D/DBP Sites

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Interim and Long Term Enhanced Surface Water Treatment Rule (IESWTR) and (LTESWTR)

- Optimize existing conventional treatment systems for pathogen removal
- Requires disinfection profiling and benchmarking
- Requires filter profiles, filter self-assessments and comprehensive performance evaluations
- Applies to all surface water and GWUDI source waters according to size

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Radiological Contaminants

Types of Radiation	Description
Alpha Radiation (massive ingestion can damage cells)	Large positively charged particles made up of two protons and two neutrons
Beta Radiation (smaller size with less damage to organs)	Electrons or positrons.
Gamma Radiation (min. effect at small levels)	Electromagnetic or wave energy such as X-rays

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Consumer Confidence Reports

Consumer Confidence Report PDF

- Required Annually all CWS
- Easy-to-understand explanations of drinking water standards and health effects
- Information on the quality of the water system's source and monitoring results
- Health effects information on any contaminant in violation of an EPA health standard

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Filter Backwash Recycling Rule

- Applies to all public water systems that:
  - Use surface water or GWUDI plants
  - Utilize direct or conventional filtration
  - Recycle backwash water
- To control microbiological contaminants in plant recycling streams; reduce risk to public
- Requires increased monitoring
  - filter backwash frequency
  - loading rates

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Operator Certification Requirement
EPA Role
Publish operator certification and recertification guidelines
– Specify minimum standards for State programs
– Apply to CWSs and NTNCWSs
State Role
Determine appropriate experience, education and training requirements
Certify operators
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State of Florida Drinking Water Rules

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Florida Drinking Water Rules are found in Florida Administrative Code (FAC)

- "*Florida Drinking Water Rules*" Updated each Year by DEP
- DEP also updates Forms each Year
- Can be obtained from DEP or at FRWA, annual Focus on Change presentation hosted around the state beginning in January each year.

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Florida Administrative Code and adoption of CFR 40 Federal Regulations Rule Coverage and Requirements

Which F.A.C. regulates recordkeeping?
62-550.720

Florida Administrative Code – Only in FL

- 62-550 FAC
- Drinking Water Standards, Monitoring and Reporting

- 40 CFR 141, Subpart H, 7/1/03,
- Filtration and Disinfection

SDWA

- 40 CFR 141, Subpart I, 7/1/02,
- Control of Lead and Copper in Drinking Water

- 40 CFR 141, Subpart L,1/16/01
- Disinfection Residuals, Byproducts and Precursors

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Florida Administrative Code and Adoption of CFR 40 Federal Regulations Rule Coverage and Requirements

- 40 CFR 141, Subpart O, 12/09/02
  Consumer Confidence Reports
- 40 CFR 141, Subpart P, 7/1/03,
  Enhanced Filtration and Disinfection serving 10,000 people or more
- 40 CFR 141, Subpart T, 7/1/03,
  Enhanced Filtration and Disinfection serving less than 10,000 people
- 62-555 FAC
  Permitting, Construction, Operation and Maintenance of Public Water Systems

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Florida Administrative Code and adoption of CFR 40 Federal Regulations Rule Coverage and Requirements

- 62-560 FAC
- Requirements of Public Water systems that are out of Compliance
- 62-699 FAC
- Treatment Plant Classification and Staffing
- 62-602 FAC
- Drinking Water and Domestic Wastewater Treatment Plant Operators
- 62-532 FAC
- Well Permitting and Construction Requirements

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When do secondary standards need to be included in the CCR?

When they exceed the MCL

Monitoring and Reporting Excerpts from 62-550 FAC

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Purpose of Monitoring

- Detect potential problems
- Inform the public of dangerous conditions
- Verify compliance
- Collect data on emerging contaminants of concern
- Determine program effectiveness

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Monitoring Points

- Beginning of Process (Ambient monitoring)
- Within treatment processes
- End of treatment processes and distribution system

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Parameters Monitored

- Chemical
  - Mostly numeric standards for contaminants or other parameters
- Physical
  - Numeric (flow, temperature, turbidity or narrative (objectionable color, taste)
- Biological
  - Presence (total coliform, fecal coliform)
- Radiological
  - Presence (gross alpha monitoring)

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Florida Primary and Secondary Drinking Water Standards and Other Regulated Parameters

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Florida Regulated Contaminants

Florida Rule CH 62-550	Coverage Area
Table 1	MCLs for Inorganic Compounds
Table 2	Maximum Residual Disinfectant Levels
Table 4	MCLs for Volatile Organic Contaminants
Table 5	MCLs for Synthetic Organic Contaminants
Table 6	Secondary Drinking Water Standards
Table 7	Monitoring Frequencies and Locations
Table 8	Initial and Routine Monitoring Schedule

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SDWA Current Number of Regulated Contaminants by Category

Inorganic (IOC's)	17
Volatile Organic Contaminants (VOC's)	21
Synthetic Organic Contaminants (SOC's)	30
Radionuclides (RAD's)	4

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Some Common Inorganic Contaminants and their Maximum Contaminant Levels (MCLs)

Contaminant	MCL (mg/l)
Arsenic	0.010
Asbestos	7 (MFL)
Fluoride	~~4.0~~ 2.0 in FL
Mercury	0.002
Nickel	0.1
Nitrate	10
Nitrite	1
Total Nitrate+Nitrite	10
Sodium	160

Million fibers per liter

Discovered by Dr Black at UF

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Fluoride

A major cause of overexposure to fluoride while working at a treatment plant is inhaling fluoride dust.

The percent purity (available fluoride) of fluoride compounds is important in calculating dosages.

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Some Regulated Volatile and Synthetic Compounds

Select Volatile	MCL	Select Synthetic	MCL
Trichloroethylene (TCE)	.003	Alachlor	.002
Vinyl Chloride	.001	Diquat	.002
Trichloroethane	.2	EDB	.00002
Benzene	.001	Heptachlor	.0004

Removed by aeration

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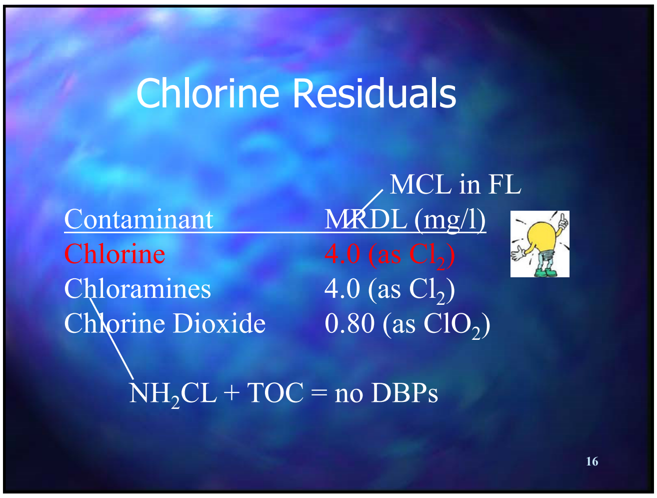
Chlorine Residuals
MCL in FL
Contaminant
MRDL (mg/l)
Chlorine
4.0 (as Cl_2)
Chloramines
4.0 (as Cl_2)
Chlorine Dioxide
0.80 (as ClO_2)
NH_2CL + TOC = no DBPs
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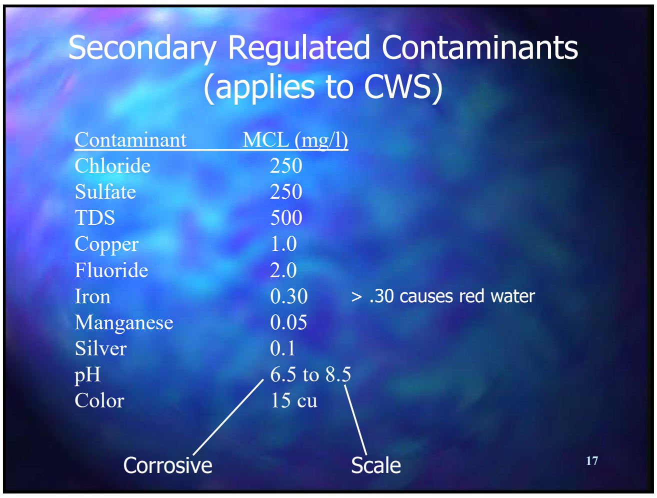
Secondary Regulated Contaminants (applies to CWS)
Contaminant MCL (mg/l)
Chloride 250
Sulfate 250
TDS 500
Copper 1.0
Fluoride 2.0
Iron 0.30
> .30 causes red water
Manganese 0.05
Silver 0.1
pH 6.5 to 8.5
Color 15 cu
Corrosive
Scale
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Maximum Contaminant Levels for Disinfection Byproducts
Contaminant MCL (mg/l)
Total Trihalomethanes 0.08
Haloacetic Acids (Five) 0.06
Bromate 0.010
Chlorite 1.0
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Monitoring and Reporting

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Initial and Routine Monitoring for CWS & NTNCWS

Parameter	Frequency/Application
Asbestos	Every 9 Yrs
Nitrate/Nitrite	GW: Yearly
	Subpart H: Quarterly
Microbiological	Monthly Multiple Locations
CL and NH_2Cl	Monthly at Coliform Location
THMs and HAA5s	GW: QTR ≥10K; Yrly <10K (Month w/warmest water temp)
	Subpart H: QTR ≥ 500; Yrly <500 (month w/warmest water temp)

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Initial and Routine Monitoring for CWS & NTNCWS

Parameter	Frequency/Application
Inorganic	Every 3 Years GW
	Yearly Subpart H
Volatile Org.	Every 3 Yrs, 4 Quarterly
Synthetic Org.	Every 3 Yrs, 4 Quarterly
Secondary	Every 3 Years
Radiological	Every 3 Years

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Compliance Cycles

- Nine year cycle - Three year compliance periods
- Large systems 3,300 population and above sample first year of compliance period.
- Population <3,300 sample in second year of compliance period.
- Non-Transient Non-Community sample in third year of compliance period.

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Specific State Requirements that Water Treatment Plant Operators Must Know

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Specific Rules and Regulations that Water Plant Operators Must Know

- Chapter 62-550
  Standards, Monitoring, and Reporting
- Chapter 62-555
  Permitting, Construction and Operation and Maintenance of Public Water Systems
- Chapter 62-560
  Requirements of Public Water Systems that are out of Compliance
- Chapter 62-602
  Operator Certification Rule
- Chapter 62-699
  Plant Classification and Staffing Requirements

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Bacteriological Monitoring
Four Principle DEP Requirements

1. All PWS Systems must test for coliform bacteria to determine compliance.
2. All PWS Systems must provide raw sample from each source or each well.
3. The number of distribution samples is dependent on the population served.
4. Provide bacteriological and chemical analysis results to FDEP postmarked by the 10th of following month.

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Bacteriological Monitoring Failure to Meet Standards

- For systems collecting more than 40 samples per month, MCL is violated when more than 5% are total coliform-positive.
- For systems collecting fewer than 40 samples per month, MCL is violated when more than one sample is total coliform-positive.
- Repeat samples must be taken upon failure in the same month.
- Repeat samples must be taken at site of failure and at location within 5 service connections upstream and downstream within 24 hours of being notified of the result.
- Systems collecting fewer than five samples a month that has one or more total coliform-positive samples shall collect at least five routine samples the next month.
- If fecal coliform is detected DEP must be notified by the end of the day that the system is notified of the test result.
- The MCL for coliform bacteria is based upon the presence or absence of the bacteria.

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- According to Chapter 62-560-410 FAC, Public Notice must be made for violations of the MCL of contaminants that pose an ACUTE risk to human health as soon as possible but no later than 24 hours after the system learns of the violation.

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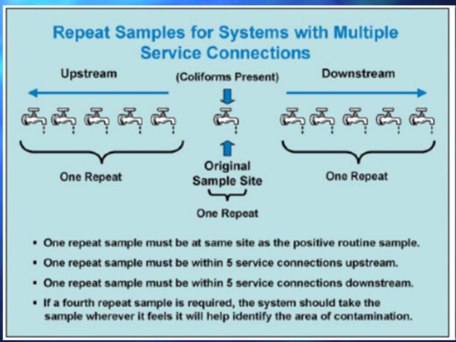
Requirements for Repeat Samples



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Chemical Constituents Nitrate/Nitrite Testing

- Transient Non-Community Water Systems (TNCWS) must test for Nitrate/Nitrite yearly, along with quarterly bacteriological samples.
- All PWS's must test for Nitrate/Nitrite yearly, with Community (CWS) and Non-Transient Non-Community (NTNCWS) monitoring for bacteriological samples monthly.
- Nitrate MCL - 10 mg/l
- Nitrite MCL - 1 mg/l
- Combination – 10 mg/l

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Chemical Constituents Lead and Copper Action Levels

Chemical Constituent	Action Level	MCL (mg/l)
Lead (Pri DW Std)	>0.015 mg/l	0.015
Copper (Sec DW Std)	>1.3 mg/l	1.0

- All CWS and NTNCWS are covered
- Compliance is based on the 90th percentile
- Action levels are exceeded if the "90th percentile" is greater than the above action levels or more than 10% are exceeded.
- Samples are based on population served

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Lead Toxicity

- Interference with Red Blood Cell Chemistry
- Delays in Physical and Mental Development
- Learning Disabilities
- Kidney Disease, Stroke and Cancer

Lead Problems originate from Corrosion of fittings and solder in Dist. System especially when copper fittings were installed before 1982.

Florida Rural Water Association 31

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Chemical Constituents Secondary Contaminants

- Non-Transient Non-Community Systems must test for chemical analyses excluding secondary contaminates in their three year compliance cycle.
- Community Systems must test for chemical analyses and secondary contaminates in their three year compliance cycle.
- Secondary physical contaminates are non-health related (pH, color, odor)

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Naturally Occurring Radionuclides (MCLs)

Contaminant	MCL
Radium 238 and 228	5 pCi/L
Gross Alpha incl. Radium 226 not Radon or Urnanium	15 pCi/L
Uranium	30 ug/L

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Manmade Radionuclides (MCLs)

Contaminant	Detection Limit
Gross Alpha	3 pCi/L
Radium 226 or 228	1 pCi/L
Uranium or Iodine 131	1 pCi/L
Tritium	1,000 pCi/L
Strontium 89 or Cesnium 134	10 pCi/L
Gross Beta	4 pCi/L

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Minimum Reporting Requirements for CWS

- MORs postmarked by the 10th of the month following the reporting period;
- Submit chemical analysis results for Pesticides & PCBs, Volatile Organics, Radionuclides, Primary Inorganics, TTHMs, Asbestos, Nitrate and Nitrite, Secondary Contaminants.

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Water System Record Keeping Requirements 62-550.720

- Copies of written reports, cross connection control programs, sanitary surveys, shall be kept at least 10 years.
- Chemical analyses shall be kept for 10 years.
- Records of action to correct a violation shall be kept for 3 years.
- Water plant operation reports (MORS) shall be kept for not less than 10 years.
- Records concerning a variance or exemption granted shall be kept for at least 5 years.
- Records of bacteriological analyses shall be kept for not less than 5 years.

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Water Treatment Plant Operating Requirements

- Must provide the required DEP certified water plant operator.
- Plant shall be maintained in good condition
- A hard bound Operation and Maintenance logbook shall be on site and available for inspection; all maintenance and daily testing records shall be recorded.
- Can not modify treatment or source without DEP approval
- Monthly Operating Reports (MOR's) are to be kept and submitted to DEP each month by the 10th.
- Can not operate plant greater than capacity without DEP approval

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Water Treatment Plant Category Designations for C and D WTPs

Category	Description
I	Chemical Preparation
II	Demineralization
III	Filtration w/ Primary Treatment or Ion Exchange
IV	Primary Treatment, Aeration and Stabilization
V	Disinfection Only

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DEP WTP License Requirements

- Lead Operator Must have License shown
- Your job as an operator will depend to a large degree on the capacity and type of water treatment plant

Water Treatment Process	Class A	Class B	Class C	Class D
Category 1: Chemical preparation with filtration including lime softening, coagulation, direct filtration.	5.0 MGD and above	1.0 MGD up to 5.0 MGD	up to 1.0 MGD	None at this level
Category II: Demineralization including reverse osmosis desalinization, electrodialysis, and ultra filtration.	6.5 MGD and above	1.0 MGD up to 6.5 MGD	up to 1.0 MGD	None at this level
Category III: Filtration (other than category II) including primary treatment or ion exchange.	8.0 MGD and above	2.0 MGD up to 8.0 MGD	up to 2.0 MGD	None at this level
Category IV: Primary Treatment (includes aeration, stabilization, and disinfection).	None at this level	10 MGD and above	0.1 MGD up to 10 MGD	Up to 0.1 MGD
Category V: Disinfection only	None at this level	None at this level	.25 MGD and above	Up to .25 MGD

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Class C Staffing Requirements

Category	1	II	III	IV	V
5 visits/week and 1 visit/ weekend		Below 0.1 MGD	Below 0.25 MGD	0.1 to 1.0 MGD	0.25 to 3.0 MGD
Total hours/ week		2.4	1.8	1.2	0.6
1 hr. ea. Day and weekend	Less than 0.1 MGD	0.1 to 0.25 MGD	0.25 to 0.5 MGD	1.0 to 3.0 MGD	3.0 to 5.0 MGD
3 hr. ea. Day and weekend	0.1 to 0.3 MGD	0.25 to 0.5 MGD	0.5 to 1.0 MGD	3.0 to 5.0 MGD	
6 hr. ea. Day and weekend	0.3 to 1.0 MGD	0.5 to 1.0 MGD	1.0 to 2.0 MGD	5.0 to 10 MGD	5.0 & Above

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Class D Staffing Requirements

Category	IV	V
3 visits/week on nonconsecutive days for total of 0.6 hours/week	Less than o.1 MGD	
3 visits/week on nonconsecutive days for total of 0.3 hours/week		0.05 to 0.25 MGD
2 visits/week on nonconsecutive days for total of 0.2 hours/week with no more than 5 days between visits		Less than 0.05 MGD

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Water System Capacity Requirements

- For new community water systems (CWS), or for CWS and NTNCWS that grew to CWS status through facility expansion.
- Construction Permit from FDEP and demonstrate financial, managerial and technical capacity.
- Have required operator license
- Have capability to conduct monitoring and reporting

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Water Distribution System Requirements

- Maintain 20 psi in distribution system at service connection except for break or extraordinary conditions.
- Document program for exercising all system valves
- Must have quarterly dead-end system flushing program and as necessary from complaints
- > 350 people or 150 connections
  - must map locations of valves, fire hydrants and facilities
  - must have Emergency Preparedness Plan for system,
  - and have minimum of two wells and backup generator

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DOH GUIDELINES FOR THE ISSUANCE OF PRECAUTIONARY BOIL WATER NOTICES

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Types of Problems Resulting in PBWN

- Microbiological
- Zero or Negative Pressure
- Low Water Pressure (maintain pressure during repair, maintain > 0.2 Cl residual and limit affected area.)
- Water Main Breaks or Interruptions
- Flooding of Wells

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Confirmed Microbiological Problems

- The Presumptive test is that Total Coliform has been detected.
- The Confirmation test is the confirmed presence of fecal indicator such as E coli or other fecal bacteria such as coliphage;
- Boil water notices must be issued ASAP but no later than 24 hours after results;
- DEP must be contacted by end of day;
- To lift notice repeat samples must be clear of TC, FC and EC and residual >0.20 mg/l Cl.

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Main Break Clearance Samples

- Require two satisfactory days of sample results (PBWN may be lifted after first set contingent on second set)
- Two consecutive sets of repeat if second set is positive;
- Main clearance samples should be clearly marked and submitted with MORs.

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Water Pipeline Additions to Distribution Systems

- Must have DEP permit
- Must provide a horizontal separation of 6′ from sanitary sewer pipe
- Must maintain 6″ above or at least 12″ below gravity, vacuum sewer, or storm sewer and 12″ above/below for pressure type sewers or reclaimed pipelines.
- Must maintain 1 full length centered of water pipe to ensure joints are farthest away from intrusion points.

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Minimum Disinfection Requirements

- Maintain a free chlorine residual of 0.2 or combined chlorine residual of 0.6 mg/l throughout the distribution system.
- Provide an approved DPD "free chlorine" test kit and daily checks 5 days per week Chlorination facilities with a daily demand of 10 lbs./day or more must provide gas chlorination with automatic switchover.

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Water Treatment System Facility Maintenance Requirements

- Must inspect storage tanks with access every 5 years
- Must rehabilitate tanks as needed using approved coatings
- Must clean sludge accumulations yearly
- Must exercise isolation valves at water storage tanks and in-plant facility

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Sanitary Surveys Requirements

- Currently cover Subpart H Systems and are performed every 3 years for CWS and 5 years for NCWS by DEP
- On-site evaluation
  - Source
  - Treatment
  - Distribution system
  - Finished water storage
  - Pumps, pump facilities, and controls
  - Monitoring and reporting and data verification
  - System management and operation
  - Operator compliance with State requirements

51

Basic Chemistry for Water Plant Operators

1

1

Matter

What is Matter?

(It is anything that has weight and occupies space)

- Physical States of Matter
  - Solids – have a definite shape with the particles closely packed together; A solid doesn't change its shape to fit into a container
  - Liquids – maintain a constant volume but will change shape to fit their container.
  - Gases – have no fixed shape and their volume can be expanded or compressed to fit different sizes of containers.
- Matter can change in two different ways; physical and chemical changes

2

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Elements

- All matter is made up of pure basic substances or combinations of these basic substances, known as ELEMENTS.
- 118 known elements
- The atom is the smallest unit of an element

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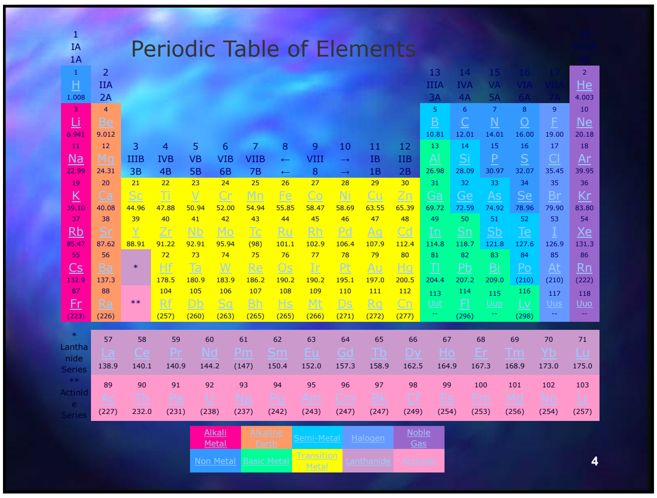
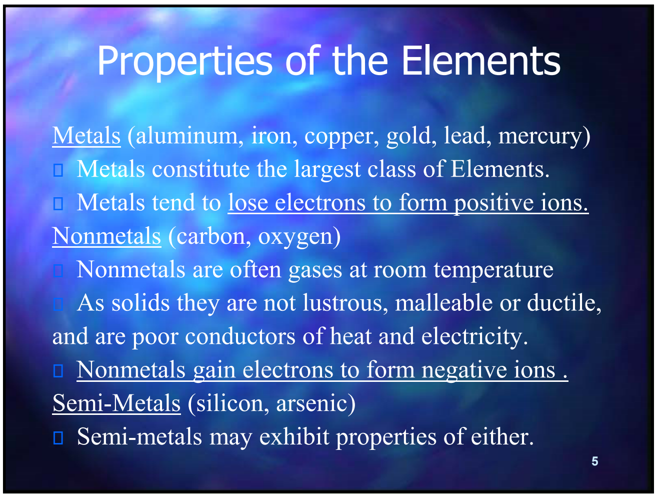

Periodic Table of Elements
4

4


Properties of the Elements
Metals (aluminum, iron, copper, gold, lead, mercury)
Metals constitute the largest class of Elements.
Metals tend to lose electrons to form positive ions.
Nonmetals (carbon, oxygen)
Nonmetals are often gases at room temperature
As solids they are not lustrous, malleable or ductile, and are poor conductors of heat and electricity.
Nonmetals gain electrons to form negative ions .
Semi-Metals (silicon, arsenic)
Semi-metals may exhibit properties of either.
5

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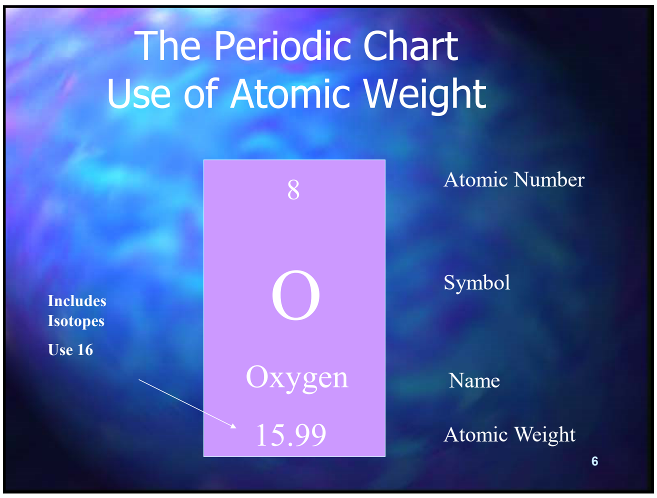
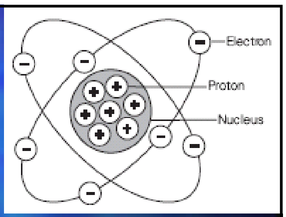

The Periodic Chart
Use of Atomic Weight
8
O
Oxygen
15.99
Atomic Number
Symbol
Name
Atomic Weight
Includes Isotopes
Use 16
6

6

Atoms are classified by the # of Protons in the Nucleus called the Atomic Number



- Atoms are made up of protons, electrons and neutrons.
- Atoms are classified by the number of protons in the nucleus and is its atomic number.
- Nucleus is made up of protons and neutrons which give the atom it's atomic mass. Mass of each is 1. Electrons do not have mass.
- Electrons orbit the nucleus and have a negative charge. Protons have a positive charge and neutrons have no charge.
- Atoms have the same number of electrons as protons unless acted upon by an external force.

7

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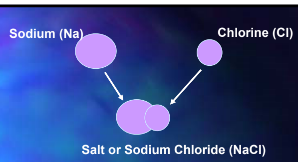
Compounds



- Substances composed of two or more elements are called compounds
- If you sub-divide a compound into its smallest particle you have a molecule
- Chemical compounds are represented by chemical formulas like salt (NaCl)
- The majority of compounds that contain carbon are termed "organic"

8

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Calculating Molecular Weight of a Compound

The Molecular Weight of a Compound is the sum of the Atomic Weights of all of the atoms in a compound. For example take sodium silicofluoride (Na_2SiF_6). What is it's molecular weight?

Symbol	No. of Atoms	Atomic Weight	Molecular Weight
Na (Sodium)	2	22.99	45.98
Si (Silica)	1	28.09	28.09
F (Fluoride)	6	19.00	114.00
	Molecular Weight of Chemical		188.07

Based on this information what is the Fluoride ion purity, % in the compound?

Fluoride ion purity, % = $\frac{\text{molecular wt. of F in compound}}{\text{molecular wt. of the compound}} = \frac{114}{188}$ = .606 or 60.6%

9

9

What is a molecule and how do you calculate molecular weight?

- A molecule is the smallest unit of a compound (a combination of two or more atoms).
- A molecule may contain two atoms of the same element or consist of two or more different atoms (such as O_2 and H_2O).
- The molecular weight of a molecule is calculated by adding the atomic weights (in atomic mass units or amu) of the atoms in the molecule.
- Given a molecule of calcium hydroxide (lime - $Ca(OH)_2$) how many atoms are there of each element and what is its molecular weight?

Element		Atoms	Atomic Wt
Ca	=	1 ;	40
Oxygen	=	2 ;	16
Hydrogen	=	2 ;	1

Molecular Weight = (1x40)+(2x16)+(2x1) = 74

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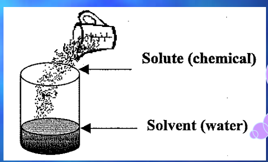
Concentration

- The concentration of a solution is a measure of the amount of solute dissolved in a given amount of solvent.
- A solution consists of two parts: a solvent and a solute.
- When working in water treatment, the solvent is usually water.



How would you concentrate a solution?

Add more solute or reduce the amount of solvent

- Commonly expressed as mg/l (same as ppm) but can be expressed as percent strength and grains per gallon GPG.
- A concentration at which no further solute will dissolve in a solution is said to be saturated.

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Percent Strength

- Percent strength of a solution can be expressed as percent-by-weight or percent-by-volume.
- To calculate percent strength by weight , the following formulas are used:
- Percent strength = $\frac{\text{Weight of Solute}}{\text{Weight of Solution}}$ x 100 or
- Percent strength = $\frac{\text{Weight (dry)}}{\text{Weight (prod)}}$ x 100 or
- Percent strength = $\frac{\text{part}}{\text{whole}}$ x 100

Weight of solution equals the weight of solute plus the weight of solvent

12

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If 10lbs of chemical are added to 100 lbs of water, what is the percent strength (by weight) of the solution?

- Percent strength = $\frac{\text{Weight of Solute x 100}}{\text{Weight of Solution}}$
- Weight of Solute = 10lbs
- Weight of Solution = 110lbs
- Percent strength = $\frac{10}{110}$x 100 =1000 =9%

13

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Solutions and Standards

Aqueous Solution	Mixture completely dissolved in water
Standard Solution	A solution in which the exact concentration (molecular weight is known)
Standardize	Determining the exact strength of solution by comparison with standard of known strength
Titration	Process of adding chemical of known strength to determine concentration of unknown compounds

14

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Alkalinity

- Alkalinity is the measurement of the water's capacity to neutralize an acid.
- There are three types of alkalinity: bicarbonate (HCO_3^-), Carbonate (CO_3^{-2}), and hydroxide (OH^-).
- Many of the chemicals used in water treatment, such as alum, chlorine, or lime, cause changes in alkalinity.
- Alkalinity of water is needed to:
  - Calculate the chemical dosages in coagulation and water softening
  - Calculate corrosivity
  - Estimate carbonate hardness of water
- Type of alkalinity and quantities determined from acid titrations.

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Alkalinity/Acidity

Alkali	Soluble Salts that neutralize Acids
Alkaline	Sufficient amount of alkali to raise pH above 7
Alkalinity	Capacity of Water to neutralize acids
	Does not exist below pH 4.5
Acidic	Condition of Water to lower pH below 7

16

16

Acids

- An acid is any substance that releases hydrogen ions when mixed with water.
- For example: Hydrochloric acid (HCl) dissociates or breaks apart in water, forming H^+ and Cl^- ions.
- In general, acids contain an "H" in the chemical formula.
  - Sulfuric acid: H_2SO_4; Nitric acid: HNO_3; Carbonic acid: H_2CO_3

17

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Bases

- A base is any substance that produces hydroxyl ions (OH^-) when dissociated in water.
- For example, caustic soda (NaOH) releases sodium (Na^+) ion and a hydroxyl ion (OH^-) in water.
- Examples of bases: Calcium Oxide (Quicklime) – CaO; Caustic soda - NaOH; Hydrated Lime – $Ca(OH)_2$; Potassium hydroxide – KOH; Ammonia – NH_3

18

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Acids and Bases
Hydrogen Ions (moles/liter)

pH	Compound	Hydrogen Ions
0	Hydrochloric Acid	10^{0}
1	Stomach Acid	10^{-1}
2	Lemon Juice	10^{-2}
3	Vinegar	10^{-3}
4	Root Beer	10^{-4}
5	Rainwater	10^{-5}
7	Pure Water	10^{-7}
9	Baking Soda	10^{-9}
10	Ammonia	10^{-10}
12	Drain Cleaner	10^{-12}
13	Sodium Hydroxide	10^{-13}

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Salts

- Salts are compounds resulting from an acid-base mixture.
- These compounds do not contain either a hydrogen or hydroxide ion.
- Mixing hydrochloric acid and caustic soda forms basic table salt (sodium chloride)

  HCL + NaOH ⟶ NaCl + H_2O
- Mixing hydrated lime and carbonic acid form calcium carbonate.

  $Ca(OH)_2 + H_2CO_3 \longrightarrow CaCO_3 + 2H_2O$

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pH

- pH is most important parameter in our drinking water.
- pH of a solution is a measurement of how acidic or basic a solution is.
- pH is measured on a scale of 0 to 14.
- Pure water is considered neutral and has a pH of 7.0.
- Solutions that contain a greater number of hydrogen ions than hydroxide ions are considered acidic and has a pH below 7.0.
- Solutions that contain a greater number of hydroxide ions compared to hydrogen ions is considered basic and has a pH above 7.0.

21

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pH (continued)

- pH is a major constituent in corrosion control.
  - Increasing pH above 7.0 in the distribution system reduces lead and copper.
  - In most cases, pH levels above 9.0 can induce scaling or precipitation of calcium carbonate.
- pH is also a major factor in floc formation for filtration.
  - Alum works best at pH's at or below 7.0.
  - Ferric products work best at pH's above 8.0.
- pH has an effect on chlorine disinfection and formations of trihalomethanes (THM's).
- A high pH may reduce the Chlorine level.

22

22

Ions in Water Treatment

- All acids, bases and salts disassociate or ionize in water. These are known as electrolytes.
- Electrolytes normally have the same number of protons as electrons that neutralize one another. When dissolved in water they split into their respective elements or compounds and lose or gain electrons. This results in the elements or compounds becoming positively or negatively charged.
- Sodium and Calcium give up electrons and become positively charged. Positively charged ions are called "cations."
- Chlorine is negatively charged because it gains electrons. Negatively charged ions are called "anions."

23

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- Cations are ions with a net positive charge.
- Cation Examples: Calcium (Ca2+) Magnesium (Mg2+) Iron (Fe 2+)
- Anions are ions with a net negative charge.
- Anion Examples: Chloride (Cl-) Nitrate (NO3) Hydrogen Carbonate (HCO3-)
- Because they have opposite electrical charges, cations and anions are attracted to each other. Cations repel other cations, while anions repel other anions.

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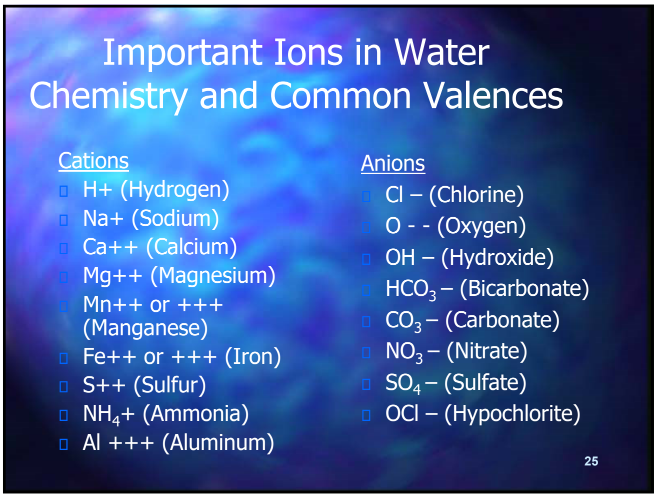
Important Ions in Water Chemistry and Common Valences
Cations
H+ (Hydrogen)
Na+ (Sodium)
Ca++ (Calcium)
Mg++ (Magnesium)
Mn++ or +++ (Manganese)
Fe++ or +++ (Iron)
S++ (Sulfur)
NH_4+ (Ammonia)
Al +++ (Aluminum)
Anions
Cl – (Chlorine)
O - - (Oxygen)
OH – (Hydroxide)
HCO_3 – (Bicarbonate)
CO_3 – (Carbonate)
NO_3 – (Nitrate)
SO_4 – (Sulfate)
OCl – (Hypochlorite)
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Water Sources for Drinking Water Supplies

1

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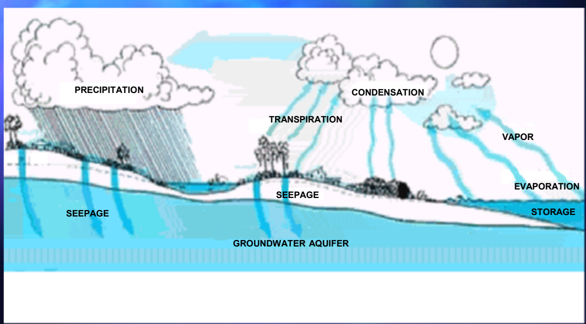
Hydrologic Cycle

Infiltration and percolation are both terms for:

The flow of water into and through the pores of the soil



2

Percentage of Water

- Water covers 71% of the earth's surface.
- 96.5% is in oceans
- 1.7% is in glaciers and ice caps
- 0.001% in vapor and clouds
- 1.7% in groundwater
- Only 2.5% of the earth's water is freshwater and 98.8% of that water is in ice and groundwater.

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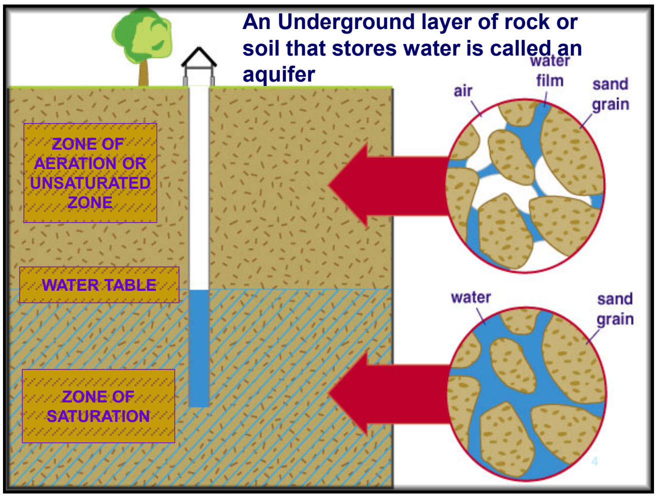
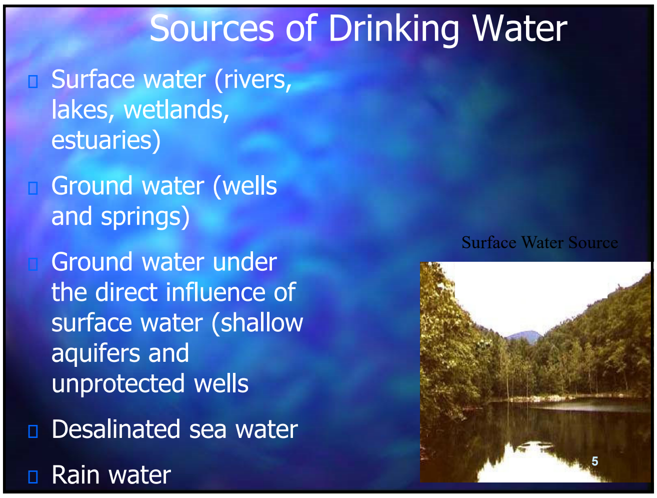

An Underground layer of rock or soil that stores water is called an aquifer
ZONE OF AERATION OR UNSATURATED ZONE
WATER TABLE
ZONE OF SATURATION
air
water film
sand grain
water
sand grain

4


Sources of Drinking Water
Surface water (rivers, lakes, wetlands, estuaries)
Ground water (wells and springs)
Ground water under the direct influence of surface water (shallow aquifers and unprotected wells
Desalinated sea water
Rain water
Surface Water Source
5

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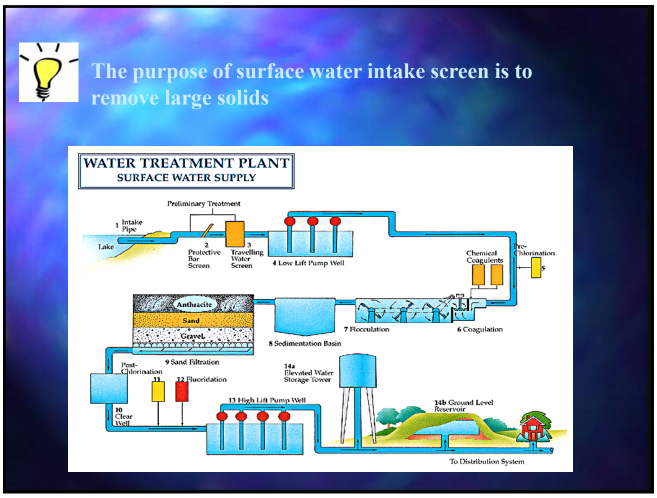
The purpose of surface water intake screen is to remove large solids
WATER TREATMENT PLANT
SURFACE WATER SUPPLY
Preliminary Treatment
1 Intake Pipe
Lake
2 Protective Bar Screen
3 Travelling Water Screen
4 Low Lift Pump Well
Chemical Coagulents
Pre-Chlorination
5
6 Coagulation
7 Flocculation
8 Sedimentation Basin
Anthracite
Sand
Gravel
9 Sand Filtration
Post-Chlorination
10 Clear Well
11
12 Fluoridation
13 High Lift Pump Well
14a Elevated Water Storage Tower
14b Ground Level Reservoir
To Distribution System

6

Rights to the Use of Water

- There are three basic types of water rights.
- Riparian – rights which are acquired with title to the land bordering a source of surface water.
- Appropriative – rights which are acquired for the beneficial use of water by following a specific legal procedure.
- Prescriptive – rights which are acquired by diverting water to which other parties may or may not have prior claims and putting it to use for a period of time specified by statute.

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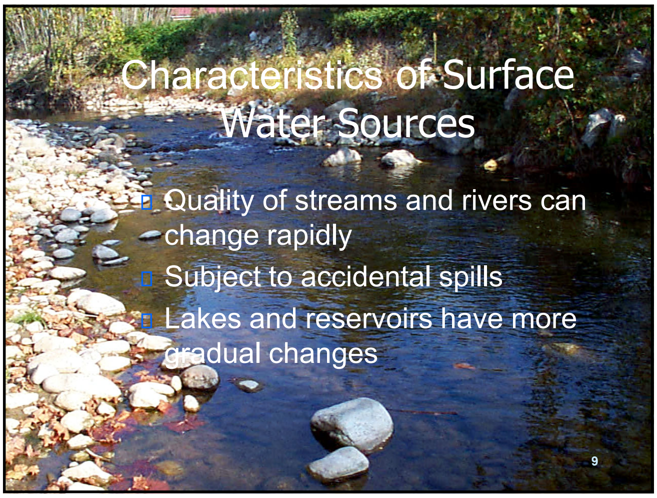

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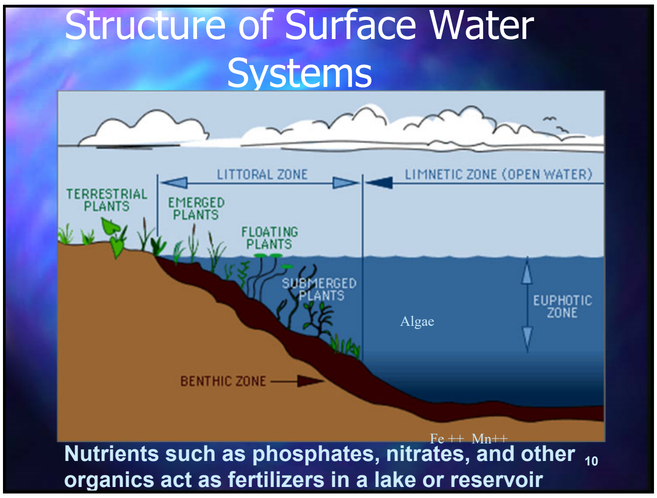
Structure of Surface Water Systems
TERRESTRIAL PLANTS
LITTORAL ZONE
LIMNETIC ZONE (OPEN WATER)
EMERGED PLANTS
FLOATING PLANTS
SUBMERGED PLANTS
Algae
EUPHOTIC ZONE
BENTHIC ZONE
Fe ++ Mn++
Nutrients such as phosphates, nitrates, and other organics act as fertilizers in a lake or reservoir
10

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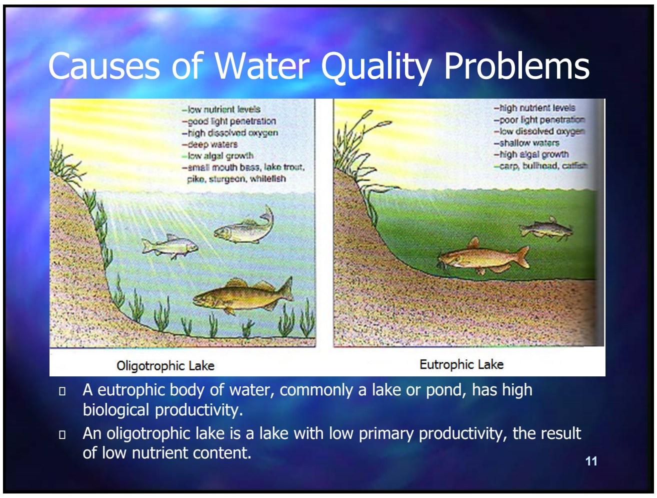
Causes of Water Quality Problems
–low nutrient levels
–good light penetration
–high dissolved oxygen
–deep waters
–low algal growth
–small mouth bass, lake trout, pike, sturgeon, whitefish
–high nutrient levels
–poor light penetration
–low dissolved oxygen
–shallow waters
–high algal growth
–carp, bullhead, catfish
Oligotrophic Lake
Eutrophic Lake
A eutrophic body of water, commonly a lake or pond, has high biological productivity.
An oligotrophic lake is a lake with low primary productivity, the result of low nutrient content.
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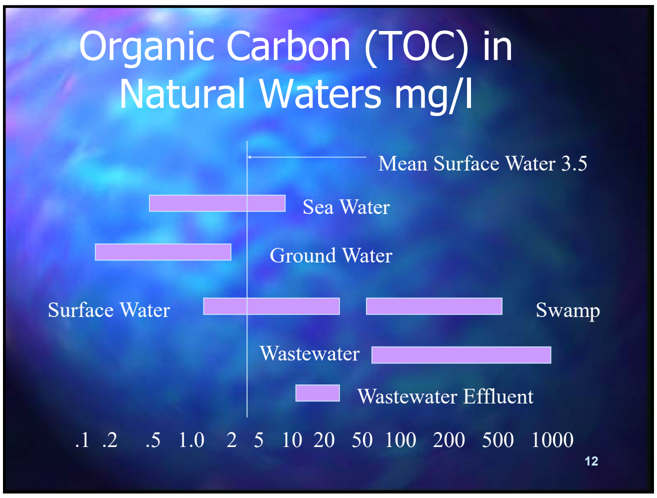
Organic Carbon (TOC) in Natural Waters mg/l
Mean Surface Water 3.5
Sea Water
Ground Water
Surface Water
Swamp
Wastewater
Wastewater Effluent
.1 .2 .5 1.0 2 5 10 20 50 100 200 500 1000
12

12

Algae Considerations

Lakes and reservoirs are susceptible to algal blooms when there is sufficient nutrients and the temperature is right.

- Taste and Odor
  - Most common problem . Algae blooms in warm weather contribute to taste and odor.
  - Produce fishy, aromatic, grassy, septic, musty, and earthy tastes and odors.
- Shortened Filter Runs
  - Tends to clog filters reducing filtration rate and duration of filter runs.
- Increased pH
  - Algae blooms increase pH during daylight hours (decrease CO2 content).
  - At night, algae blooms lower pH.
- Dissolved Oxygen Depletion
  - Water becomes supersaturated with oxygen as algal blooms progress.
  - As algal cells die, oxygen is used up. May be reduced to point that fish kills occur.
- Organic Loading
  - Increased color; increased Cl demand.
  - Associated with high THMs

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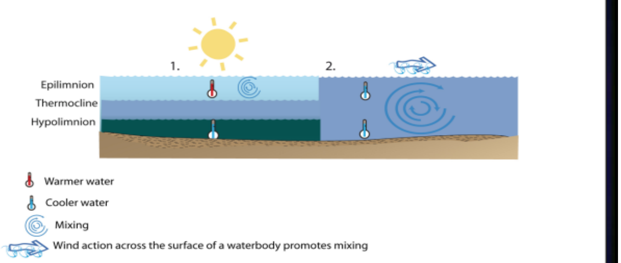
When the surface of a lake or reservoir cools to the same temperature as the lower layers, the lake or reservoir de-stratifies and turnover occurs.

Lake Stratification with Temperature



14

Reaeration-Destratification

Purpose – to eliminate, control, or minimize the negative effects on domestic water quality that occur during periods of thermal stratification and dissolved oxygen depletion.

- Reaeration
  - Introduces air through forced air diffusers into the lower layers of the water body, replenishing the dissolved oxygen.
  - Also, rising bubbles cause lower waters to rise to surface where oxygen is transferred to the water (surface reaeration).
- Destratification
  - Vertical mixing with the water body to eliminate separate layers of temperature, plant or animal life.
  - Mixing is through mechanical (pumps) or through forced air diffusers.

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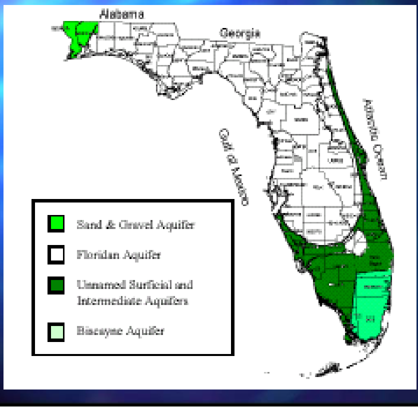
Florida Groundwater Sources



16

Characteristics of Ground Water Sources

- Seasonal quality is relatively constant
- Quality may vary greatly from well to well
- Usually superior to surface water in:
  - Bacteriological content
  - Turbidity
  - Total organic concentrations
- Mineral content may be inferior to surface water

Increased turbidity levels occurring from major runoff and/or reservoir turnovers is a serious concern because waters with increased turbidity have a ….
Higher chlorine demand

Well being drilled

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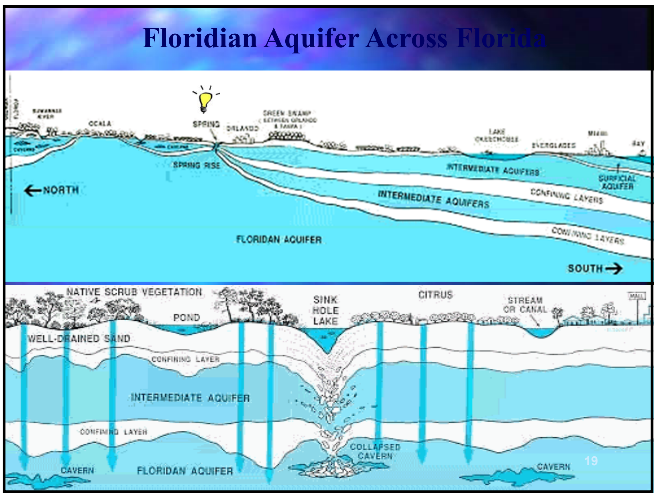
Ground Water Sources Must Provide Quantity and Quality

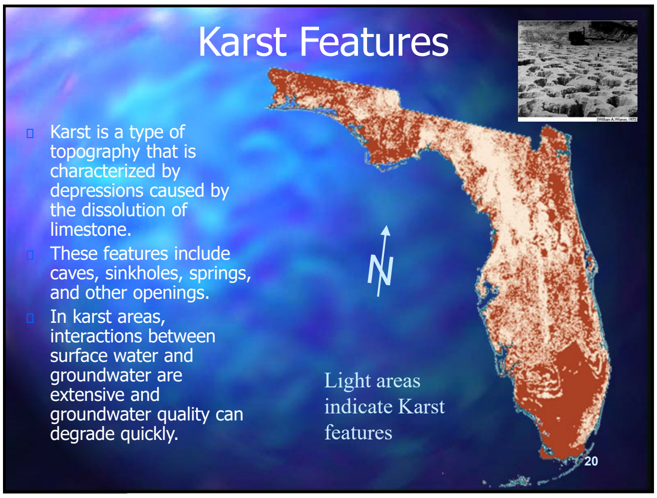
- **Quantity**
  - Equal or exceed design maximum and average day demands with largest producing well out of service
  - Minimum of two sources
  - Standby power supply
- **Quality**
  - Every new, modified or reconditioned ground water source must sample to demonstrate quality
  - Adequate separation between well and potential sources of contamination and ground water development

Artesian well

18


Floridian Aquifer Across Florida
SPRING
SPRING RISE
←NORTH
INTERMEDIATE AQUIFERS
INTERMEDIATE AQUIFERS
CONFINING LAYERS
FLORIDAN AQUIFER
SOUTH→
NATIVE SCRUB VEGETATION
POND
SINK HOLE LAKE
CITRUS
STREAM OR CANAL
WELL-DRAINED SAND
CONFINING LAYER
INTERMEDIATE AQUIFER
CONFINING LAYER
COLLAPSED CAVERN
CAVERN
FLORIDAN AQUIFER
CAVERN
19

19


Karst Features
Karst is a type of topography that is characterized by depressions caused by the dissolution of limestone.
These features include caves, sinkholes, springs, and other openings.
In karst areas, interactions between surface water and groundwater are extensive and groundwater quality can degrade quickly.
N
Light areas indicate Karst features
20

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Karst Features and Solution Cavities
Karst Limestone Feature
Limestone is easily dissolved by Carbon Dioxide.
Carbon Dioxide is dissolved from the air and from decomposing matter.
Subsurface cavities, caves, drainage basins, sinkholes and other geologic features characterize Florida's karst conditions.
21

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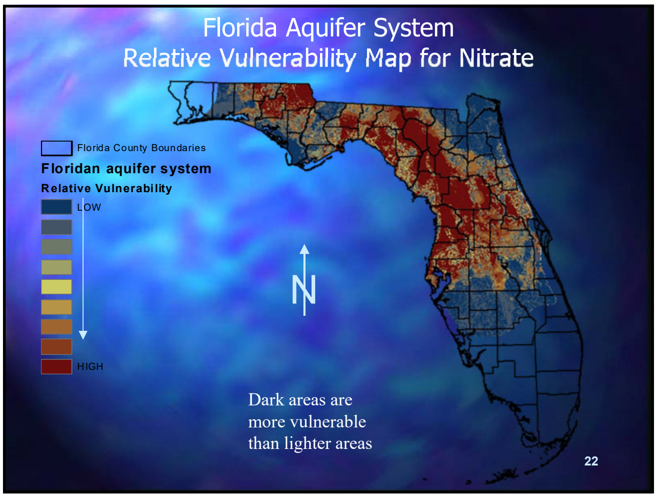
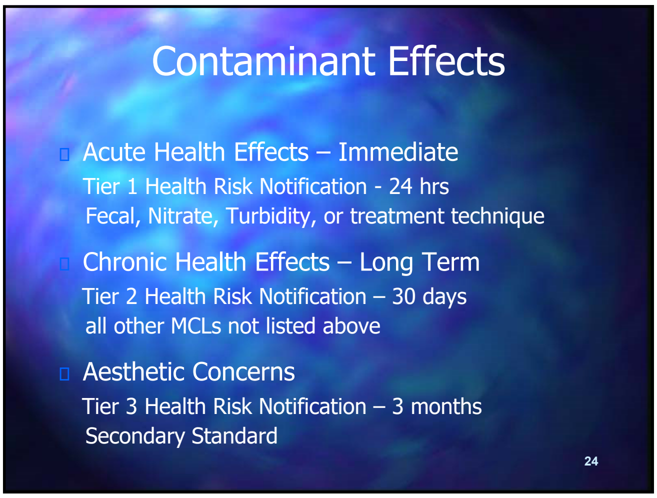

Florida Aquifer System
Relative Vulnerability Map for Nitrate
Florida County Boundaries
Floridan aquifer system
Relative Vulnerability
LOW
HIGH
N
Dark areas are
more vulnerable
than lighter areas
22

22


Threats to
Drinking Water
23

23


Contaminant Effects
Acute Health Effects – Immediate
Tier 1 Health Risk Notification - 24 hrs
Fecal, Nitrate, Turbidity, or treatment technique
Chronic Health Effects – Long Term
Tier 2 Health Risk Notification – 30 days
all other MCLs not listed above
Aesthetic Concerns
Tier 3 Health Risk Notification – 3 months
Secondary Standard
24

24

Four Categories of Contaminants

- Physical
- Chemical
- Biological
- Radiological

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Pathogens Causing Acute Health Affects

- Bacteria (e.g., *Shigella, Legionella, Salmonella, E.coli*)
- Viruses (e.g., Hepatitis A & E, Norwalk Virus, Enteroviruses, Adenoviruses, Rotaviruses)
- Parasites, protozoa and cysts (e.g., *Giardia lamblia, Cryptosporidium*)

26

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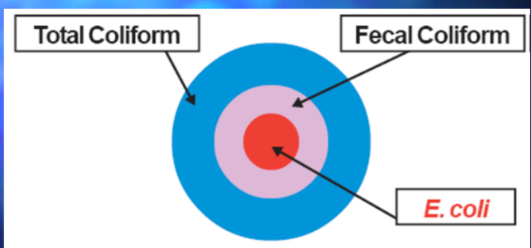
Indicator Organisms and Pathogenic Contaminants



Fecal and E. coli are very specific indicators of contamination and are not easily isolated and identified

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Some Facts About Bacteria

- Bacteria are widely distributed on earth
- They have been found 4 miles above earth and 3 miles below sea sediments.
- One gram of fertile soil contains up to 100,000,000 bacteria.
- Bacteria are inconceivably small and measured in microns. One micron is equal to 1/1,000,000 of a meter.
- During the rapid growth phase bacteria undergo fission (cell division) about every 20 to 30 minutes.
- One bacterial cell after 36 hrs of uncontrolled growth, could fill approximately 200 dump trucks.

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Gastroenteritis (Most Common Illness) from Fecal Contamination of Water

- Symptoms are nausea, vomiting and diarrhea; typically not reported
- Can be caused by viral or bacterial contamination
- Over 100 types of human enteric viruses have been identified in wastewater; some not yet identified may be virulent
- Viruses can survive outside host organism
- Viruses survive longer than indicator organisms in the presence of disinfectant

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Viruses (Require Host)

Size	0.02 to 0.30 um
Structure	Particles, Protein Coat and Nucleic Core
Enteric	Excreted in Feces
Number	>100 known

Photo: Rotavirus, ASM Digital Collection

30

Enteric Viruses (Human Feces)

Poliovirus	Poliomyelitis
Coxsackievirus	Upper Respiratory
Echovirus	Upper Respiratory
Rotavirus	Gastroenteritis
Norwalk Virus	Gastroenteritis
Hepatitis A & E	Infectious (A) Hepatitis
Astrovirus	Upper Respiratory
Adenovirus	Upper Respiratory

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At Highest Risk for Disease

- Very Young
- Elderly
- Immunocompromised
  - HIV infected
  - Chemotherapy (cancer, organ transplant)
- Pregnant women
- Persons with chronic diseases

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Regulated Protozoa

Giardia

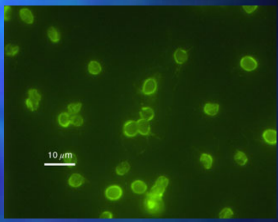
Cryptosporidium

33

33

Cryptosporidium Oocysts and Giardia Ocysts

- Extremely Small
- Electron Microscope required
- Form protective layer
- Bunch in clusters
- Turbidity will protect from Cl and UV



Oocysts showing protective layer

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Attributes of the Three Waterborne Pathogens of Concern in Water Treatment

Organism	Size (µm)	Mobility	Points of Origin	Resistance to Disinfection	Removal by Sedimentation, Coagulation, and Filtration
Bacteria	0.1-10	Motile, Nonmotile	Humans and animals, water, and contaminated food	Type specific – bacterial spores typically have the highest resistance whereas vegetative bacteria have the lowest resistance	Good, 2 to 3-log removal
Viruses	0.01-0.1	Nonmotile		Generally more resistant than vegetative bacteria	Poor, 1 to 3-log removal
Protozoa	1-20	Motile, Nonmotile		More resistant than viruses or vegetative bacteria	Good, 2 to 3-log removal

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Contamination Sources

- Septic Tanks, storm and sanitary sewers
- Waste disposal activities
- Horticulture and animal pasturing
- Chemically treated lawns
- Subsurface liquid disposal
- Runoff from storm events
- Characteristics of soil above rock
- Decomposition of organic matter

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Types of Contaminants Causing Chronic Health Effects

- Volatile organic chemicals (VOCs)
- Inorganic chemicals (IOCs)
- Synthetic organic chemicals (SOCs)
- Radionuclides

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Sampling

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Types of Samples

Compliance Routine Samples	
	Annual, Monthly, or Quarterly samples, collected from representative locations throughout your water system in 100mL or 125mL containers and submitted to a lab within 30 hours.
- Repeat Samples	collected within 24 hours after you receive notification of a positive coliform result.
Non-Compliance Samples	
- Additional	samples required by DEP in order to help identify extent of the contamination or provide better info.
- Replacement	compliance sample that is collected but does not get analyzed, i.e., expired, broken, insufficient vol.
- Special Samples	collected due to repairs, complaints, or maintenance to ensure that coliform has not entered the water distribution system.

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Sample Collection Procedures

- Accidental Contamination – Remove Obstruction (aerators, hoses, etc. that harbor bacteria
- Sample Containers – Use Appropriate Type of Container (Sample Bottles or Whirl-Pac)
- Preservation- Use Specified Method; if refrigeration required use $\leq$ 4° C
- Label – Sample Container and Time
- Chain of Custody – Tracing and Handling

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Source Water Protection

- Security and Safety
  - Secure from unwanted intruders
  - Safe from contamination (natural or man-made)
- Contamination Prevention Programs

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Security and Safety of the Water Sources

- Secure surface water sources
- Properly seal wellheads
- Screen and securely attach well vents and caps
- Properly secure observation, test and abandoned wells

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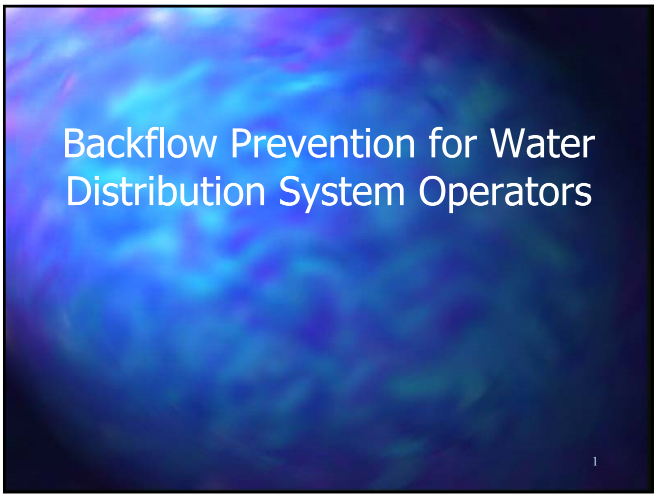
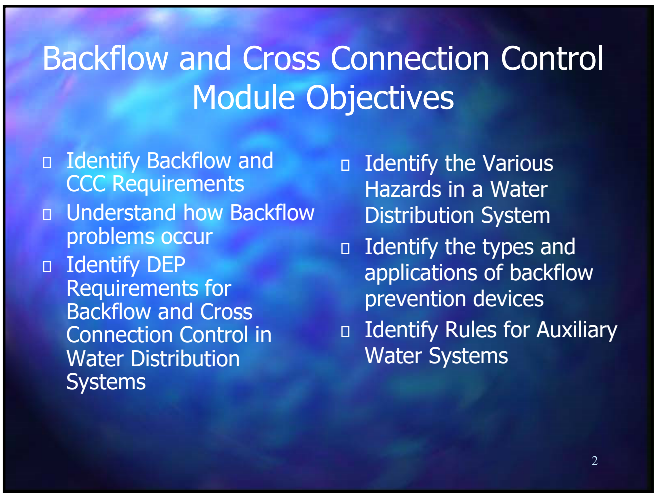
Long-Term Groundwater or Wellhead Protection
Protection of ground water sources
Subdivision growth controls
Zoning
Land purchase
Acquisition of development rights
Land use restrictions
WELL HEAD PROTECTION AREA
43

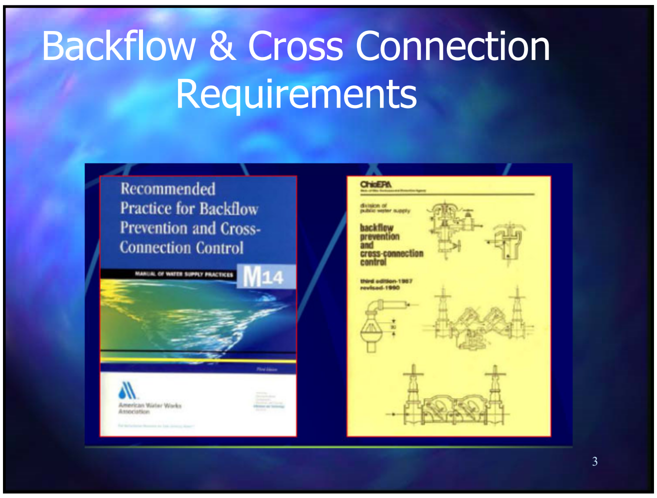
43


Backflow Prevention for Water Distribution System Operators
1

1


Backflow and Cross Connection Control Module Objectives
Identify Backflow and CCC Requirements
Understand how Backflow problems occur
Identify DEP Requirements for Backflow and Cross Connection Control in Water Distribution Systems
Identify the Various Hazards in a Water Distribution System
Identify the types and applications of backflow prevention devices
Identify Rules for Auxiliary Water Systems
2

2


Backflow & Cross Connection Requirements
Recommended Practice for Backflow Prevention and Cross-Connection Control
M14
backflow prevention and cross-connection control
3

3

Cross-Connections

"CROSS-CONNECTION" means any physical arrangement whereby a public water supply is connected, directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture, or other device which contains or may contain contaminated water, sewage or other waste, or liquid of unknown or unsafe quality which may be capable of imparting contamination to the public water supply as the result of backflow.

- By-pass arrangements, jumper connections, removable sections, swivel or changeable devices, and other temporary or permanent devices through which or because of which backflow could occur are considered to be cross-connections.
- A cross connection is a improper connection between a contaminated water source and the public water system.
- A connection between an approved and an unapproved water supply.

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Reducing the Probability for Cross-Connections

- Education is essential even for those experienced in piping installations
- The biggest hazard in a backflow problem is the failure to recognize the cross-connections and its potential dangers
- Control of plumbing cross-connections is possible through thorough knowledge and vigilance

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Examples of connections hazards

Common examples of cross connection hazards (source of contamination) that need to be protected with a backflow preventer include:

Residential
- Fire sprinkler system
- Lawn irrigation systems
- Auxiliary water supply (wells)
- Hot tubs/spas
- Swimming pools
- Hose bibs/garden hose
- Boiler
- Pumps installed in water lines

Commercial
- Boiler
- Carbonation equipment
- Film processors
- Fire systems
- X-ray machines
- Dental equipment
- Etching tanks

Note: Toilets and sinks have an air gap for backflow protection

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Most Frequent Causes of Cross Connections

According to the CDC, what causes more waterborne disease outbreaks than any other factor?

Cross Connections

- Plumbing cross-connections are a dynamic problem because piping systems are continually being installed, altered or extended.
- Plumbing is frequently installed by persons unaware of the inherent dangers of cross connections.
- Connections are made a matter of convenience without regard to the dangerous situation that might occur
- Connections are made with reliance on inadequate protection such as a single valve or other mechanical device that does not provide the needed protection from backflow

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Methods of Contamination through Cross-Connections

Cross-connections are the links through which it is possible for contaminating materials to enter a potable water supply.

- Backflow is directly related to system pressure. Contaminants enter the potable water system when the pressure of the polluted source exceeds the pressure of the potable source.
- The likelihood of backpressure increases when the distribution system pressure drops to below normal operating pressure due to changes in valve setting, pipeline breaks, air valve slams, loose-fitting service meter connections, surge or feed tank draining, or a sudden change in demand.
- Backpressure can occur with pressurized residential, industrial, institutional, or commercial systems which use pumps, including chemical feed pumps or booster pumps, or pressurized auxiliary water systems for irrigation, fire protection, car washes, and cooling systems.

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Most Frequent Types of Cross-Connection Problems Encountered in the Field

- A sprinkler system using nonpotable water is connected to a potable water supply.
- Hose connected to the house is left in a swimming pool.
- A hose connected to the house is used to flush a car radiator.
- A hose connected to the house is used to apply chemical fertilizers or pesticides.

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State Mandated Cross - Connection Program

- Each community water system (CWS) shall establish and implement a cross-connection control program utilizing backflow protection at or for service connections from the CWS.
- Program shall include a written plan that is developed using AWWA Manual M14. Minimum components for the plan are listed in DEP rule 62-555.360.
- Each CWS serving more than 10,000 persons shall prepare and submit cross-connection control program annual reports. **First reports due in 2016.**

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Backflow

- The term *backflow* means any unwanted flow of used or non-potable water or substance from any domestic, industrial, or commercial or institutional piping system into the potable water distribution system.
- Backflow is a reverse flow condition, created by a difference in water pressures. Results from either:
  - back pressure
  - backsiphonage

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Back Pressure

- Reversed flow due to backpressure other than siphon action
- Any interconnected fluid systems in which the pressure of one exceeds the pressure of the other may have flow from one to the other as a result of the pressure differential
- Flow occurs from the zone of higher pressure to the zone of lower pressure

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Backsiphonage

- A form of backflow caused by a negative or below atmospheric pressure within a water system
- Higher elevations in the system cause the water to reverse gradient and flow into areas of lower gradients
- Water flows from the zone of higher pressure to the zone of lower pressure
- This is why DEP requires 20 psi at the service connection

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Degree of Hazard (def.)

- The *"Degree of* Hazard" is a determination on whether the substance in the non-potable system is toxic (health hazard) or non-toxic (non-health hazard).
- Sewage and radioactive materials are considered lethal hazards due to the epidemic possibilities

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Health Hazard Facilities

Type of Facility	Potential Hazard
Hospitals, clinics, laboratories, mortuaries	Bacterial cultures, laboratory solutions, blood & tissue, toxic materials
Sewage & industrial wastewater treatment fac.	Sewage industrial wastewater, contaminated water, toxic chemicals
Paper manufacturing, dye plants, petroleum processing, tanneries	Toxic chemicals, water conditioning compounds (acids, solvents, mercury, chromium
Canneries, breweries, food processing, meat packers	Process wastewater, steam, detergents, acids, caustics
Commercial greenhouses, spraying & irrigation systems using herbicides and pesticides	Toxic chemicals (phosphates, arsenite, lindane, malathion
Metal-plating, photo processing, car washes, dry cleaning	Toxic chemicals, concentrated cleaning agents, solvents (cyanides, copper, chromium, caustic & acid solutions

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Types of Backflow Prevention Devices

- Air Gap
- Reduced-Pressure Principle Detector Assembly (RPDA) or a Reduced-Pressure Principle Assembly (RP)
- Pressure Vacuum Breaker Assembly (PVB)
- Double Check Valve Assembly (DC) or Double Check Detector Assembly (DCDA)
- Dual Check Device (DuC)

The most suitable type of device depends on the degree of hazard

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Air Gap

- Provides Maximum Protection
- Physical Separation
- Gap must be 2x Diameter but not less than 1" vertically above the overflow rim
- Protects against backpressure and backsiphonage
- An Air Gap shall be maintained between any public water system and a wastewater system or reclaimed water system

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Reduced-Pressure Principle Detector Assembly (RPDA)

- Prevents the reverse flow of fire protection system substances from being pumped or siphoned into the potable water supply.
- Some incorporate a meter to detect ground leaks and unauthorized illegal taps.
- Protects against back-pressure and backsiphonage

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Reduced Pressure Principle Assembly

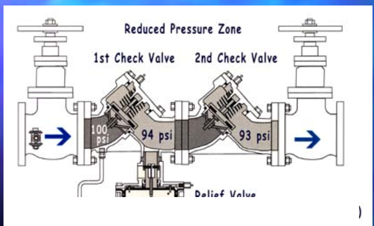

FIGURE 2 - Reduced Pressure Principle Backflow Preventer

- Prevents both Back-Siphonage and Backpressure
- Independent operated dual check valves and automatically operated pressure differential relief valve that will open and release water
- Must be installed above grade

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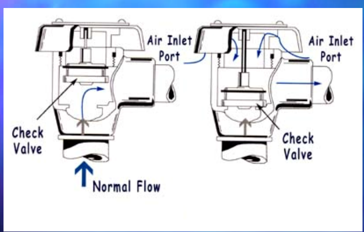
Pressure Vacuum Breaker



- Used in both health and non-health applications
- Prevents backsiphonage only not backpressure.
- Air vent opens system to atmospheric pressure when flow stops.
- Minimum of 12” above highest outlet
- May have two valves and two test cocks

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Double Check Detector Assembly

- Double check valve assembly with a specific bypass meter and meter-sized double check valve assembly.
- Registers accurately for vey low flows to detect unauthorized use.
- Will isolate backflow and backsiphonage but used only in non-health hazards.
- Normally these assemblies are reserved for use on fire sprinkler lines.

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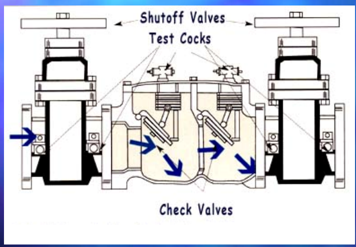
Double Check Valve Assembly



Check Valves May Be Tested In-Place

- Two single operating check valves and four test cocks located between two tightly closing shutoff valves.
- Will isolate backflow and backsiphonage but used only in non-health hazards
- Place valve 12" or more above high water level of surrounding ground.

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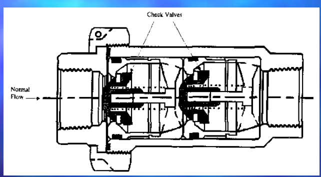
Dual Check Device



- Protects against both backsiphonage and backpressure in low hazard situations
- May be used under continuous pressure
- Low initial installation cost
- May be used in areas served by reclaimed water
- No external indication of failure

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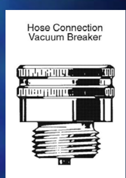
Example of a Cross Connection with Possible Backflow



Device to prevent backflow from hose.

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Responsibility for Cross-Connections

- Purveyor, supplier, or the water utility;
  - Under the provisions of the SDWA of 1974 and subsequent Amendments, the water purveyor is held responsible for providing water that meets all applicable National Primary DW Stds
  - Upon discovery of a cross-connection the public water system shall eliminate the cross-connection, shall ensure the appropriate backflow protection is installed to prevent backflow, or shall discontinue water service.
- Water users
- Plumbing officials
- Health agencies

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Acceptable DEP Cross Connection and Backflow Program

Must be developed using AWWA Manual 14

1. Establishment of authority and policy
2. Establishment policy requirements and appropriate use of BFP devices for health hazards encountered.
3. Establish installation and service standards
4. Establish policy for testing and maintenance
5. Establish procedures for new and existing service connections
6. Establish procedures to correct prohibited or inappropriately protected cross-connections
7. Establish procedures for maintaining CCC records
8. Establish standards for customer notification and education

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Identification of Backflow Problems

If customers complain of odor, discoloration and taste problems what may be the cause?

- Watermain breaks where pressure <20 psi
- Rapid Drops in Disinfection Residual
- Meters Running in Reverse
- Persistent Bacterial contamination

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Color Identification for Reclaimed Water Pipe
WARNING
THIS ESTABLISHMENT IS IRRIGATED WITH RECLAIMED WATER DO NOT DRINK WATER FROM IRRIGATION SYSTEM
ADVERTENCIA
ESTE ESTABLECIMIENTO ES REGADO CON AGUA RECUPERADA NO BEBA AGUA DEL SISTEMA DE RIEGO
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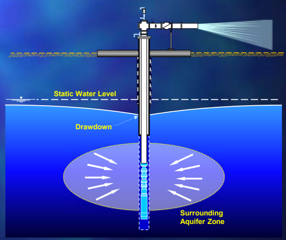
Well Requirements for Public Water Systems



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Suitability of Well Construction

Bored
- ~100′
- 2-30″ dia.
- Soils or Small Boulders, Fractured Formations

Driven
- ~50′
- 1.25 -2″
- Soils, no Boulders & only very thin Rock Formations

Jetted
- ~100′
- 2-12″ dia.
- Soil Formations Only

Drilled
- ~1000′
- 4-24″
- All Geological Formations

2

2

Well Location Considerations

- Geologic/hydrologic Characteristics
- Slope of Ground Surface
- Nature of Soil and Homogeneousness
- Slope of Water Table (field determined)
- Size of Drainage Area
- Nature and Distance to Pollution Sources
- Methods in-place to Protect Well

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Source Water Parameters

Quality and Quantity Dictates Depth of Well

- TDS — Requires RO plant
- Total Hardness
- Total Fe and Mn
- Chlorides & Sulfates
- Total Alkalinity
- Nitrate — 10mg/l Blue baby
- pH
- Corrosivity
- CO_2
- H_2S — Has to be removed. Will eat pipes.
- Fluoride
- TOC — High TOC produces DBPs

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Well Yield

- Depends on Characteristics of Aquifer and Drawdown (Porosity, Permeability and Thickness of Aquifer)
- Rule of Thumb is that Doubling Diameter increases Production by 10%
- Increasing Well Capacity requires Deepening
- Difficult to Predict Yield without pumping
- Based on estimating from Nearby Wells
- Driven Wells produce ~30 gpm and Jetted and Drilled Wells > 300 gpm.

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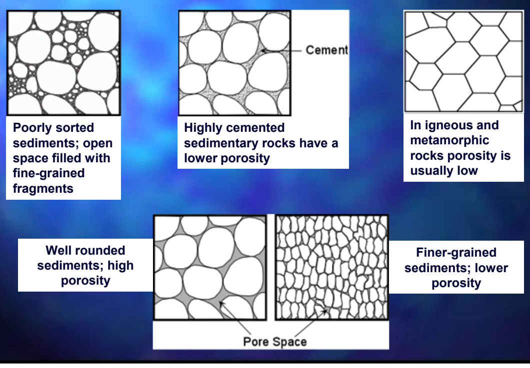
Porosity: the percentage of the volume of the rock that is open space (pore space).



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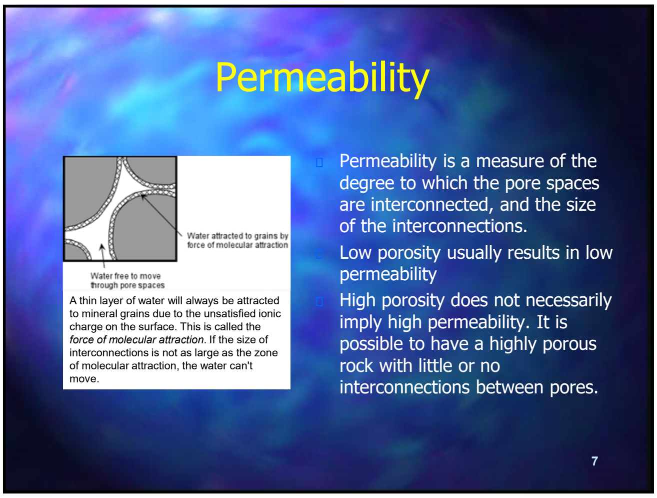

Permeability
Water attracted to grains by force of molecular attraction
Water free to move through pore spaces
A thin layer of water will always be attracted to mineral grains due to the unsatisfied ionic charge on the surface. This is called the *force of molecular attraction*. If the size of interconnections is not as large as the zone of molecular attraction, the water can't move.
Permeability is a measure of the degree to which the pore spaces are interconnected, and the size of the interconnections.
Low porosity usually results in low permeability
High porosity does not necessarily imply high permeability. It is possible to have a highly porous rock with little or no interconnections between pores.
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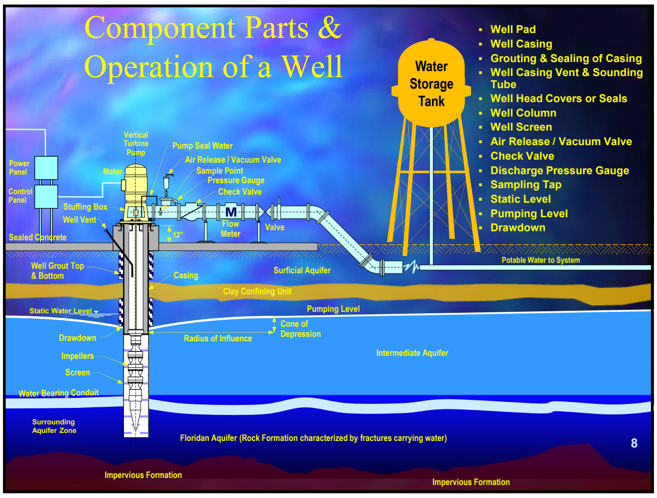
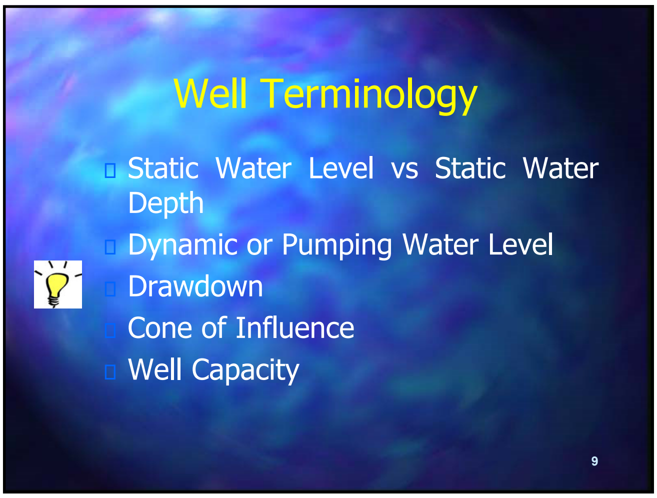


Component Parts & Operation of a Well
Water Storage Tank
Well Pad
Well Casing
Grouting & Sealing of Casing
Well Casing Vent & Sounding Tube
Well Head Covers or Seals
Well Column
Well Screen
Air Release / Vacuum Valve
Check Valve
Discharge Pressure Gauge
Sampling Tap
Static Level
Pumping Level
Drawdown
Vertical Turbine Pump
Pump Seal Water
Air Release / Vacuum Valve
Sample Point
Pressure Gauge
Check Valve
Power Panel
Control Panel
Motor
Stuffing Box
Well Vent
Sealed Concrete
Flow Meter
Valve
12"
Potable Water to System
Well Grout Top & Bottom
Casing
Surficial Aquifer
Clay Confining Unit
Static Water Level
Pumping Level
Cone of Depression
Drawdown
Radius of Influence
Intermediate Aquifer
Impellers
Screen
Water Bearing Conduit
Surrounding Aquifer Zone
Floridan Aquifer (Rock Formation characterized by fractures carrying water)
8
Impervious Formation
Impervious Formation

8



Well Terminology
Static Water Level vs Static Water Depth
Dynamic or Pumping Water Level
Drawdown
Cone of Influence
Well Capacity
9

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Systems for Sensing Water Level

There are several ways to measure the static water level

- an electric sounder or electric depth gauge
- wetted tape
- air line.

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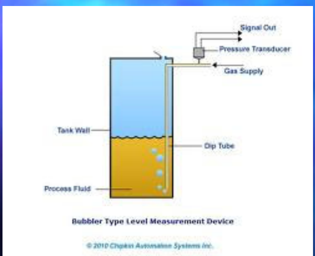
Air Bubbler System



- Air bubbler systems contain no moving parts.
- Uses a tube with an opening below the surface of the liquid level. A fixed flow of air is passed through the tube. Pressure in the tube is proportional to the depth (and density) of the liquid over the outlet of the tube.

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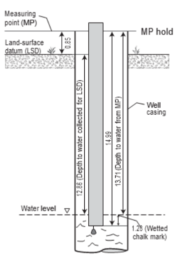
Wetted Tape



- Accurate for measuring water levels to depths up to about 90 feet.
- To use this method, you must know the approximate depth to water in your well.
- In this method, a lead weight is attached to the end of a 100 foot steel measuring tape. Eight to ten feet of tape end is dried and coated with carpenter's chalk before each measurement. The tape is lowered into the well until a part of the chalked section is below the water. The contractor will align and note an even foot mark on the tape exactly at the top of the casing or some other measuring point. Then, the tape is pulled up to read the mark where the line is wet. He can determine the actual depth from the top of the casing to water level by subtracting the wetted mark from the mark he held at the top of the casing.

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Question: Which of the following methods is best for determining the depth of water in a clearwell?

A. A bubbler
B. A load cell
C. A rotameter
D. A venturi

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Importance of Well Grouting

Pressure Testing of Grout Seal @ ~10 psi for 1 hr. Should be Performed.

- Prevent movement of water between aquifer formations
- Preserve quality of producing zones
- Preserve Yield
- Prevent water intrusion from surface
- Protect Casing against Corrosion!

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Well Disinfection is Critical in Obtaining DEP Approval

- Must Remove all Foreign Matter prior to Disinfection; grease, oil, and soil harbor bacteria, surfactant agents sometimes used should not contain phosphorus!
- Contact times of 8 hrs. for chlorine solutions of 50, 150 or 200 ppm (based on pH are effective)
- If well is not in use, chlorination should be continuous (~10 ppm Residual) to prevent bacterial growth

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Methods for Disinfecting Wells

- Protect all parts and swab with 50 mg/l solution before installation
- Inject Chlorine through the column pipe not only the vent pipe!
- 50 mg/l is needed for 24 hours
- Pump well until no chlorine residual is observed
- Test for Coliform (mo-mug or Colilert has more false positives for fecal!)

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Air Considerations

- Air lock - an accumulation of air in the pump housing that prevents the flow of water.
  - An air-relief valve used to prevent this condition.
  - Submersible pumps have footer valves.

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Well Maintenance

- Well Yield Declines Over Time
- Failure or Wear of Pump (check pump curves!)
- Decline of Aquifer Water Levels
- Plugged or Corroded Screens
- Accumulations of Sand or Silt in the Well
- Build up of calcium carbonate in solution cavities

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Acidization

- Can improve productivity and lower pumping (electricity) costs of older wells
- Injection of 18/20 Baum HCL into borehole
- Acid diversion is important, otherwise only the first interval will be affected; accomplished by packers or plugs
- Can increase specific capacitance (= pump rate/drawdown) by several hundred percent

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Over Pumping Wells or Overdraft

- Can Permanently Damage Storage and Transmission Properties of the Aquifer
- Can Cause Subsidence and Compaction of the Aquifer
- Reduces Yield of the Well Field
- Can Result in Cascading of Water and Failure of the Well

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Safe Yield vs Sustainable Yield

- Excessive pumping can have serious social and economic consequences.
  - Reduced discharge of groundwater to surface water features
  - Reduction in ecological base flows
  - Overlapping of drawdown cones
  - Depletion of reserves
  - Land subsidence due to pore pressure reduction
- Attempts to limit based on concept of "safe yield"
  - Balance between the annual amount of ground water withdrawn by pumping and the annual amount of recharge.
- New emphasis is on "sustainable yield"
  - Reserves a fraction of safe yield for benefit of surface waters
  - No set percentage (there are social, economic and legal issues

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Determining Well Yield with Well Pump Test

- Well is Pumped for at least 4 hours
- Determine how much water is pumped per min or hour (GPM)
- Determine the depth to pumping level (maximum drawdown) over time at one or more constant pumping rates
- If well does not recover in 24 hrs. to original level, Aquifer is not dependable
- Determine the recovery of water level
- Determine the length of time the well is pumped at each test

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Well Pump Considerations

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Types of Pumps and Uses

Turbine Pumps

- Single Stage limited to 28' lift; multi-Stage 50 – 300' lift
- Submersible low head and low flow conditions (typically <100' and 100 GPM)
- Vertical Turbine high head and high flow

Positive Displacement

- Shallow ~25' Deep ~600'
- Limited to ~25 GPM
- High Maintenance Cost

Jet Pumps

- Shallow ~20' Deep 50 - 200'
- Generally limited to small capacities < 50 GPM

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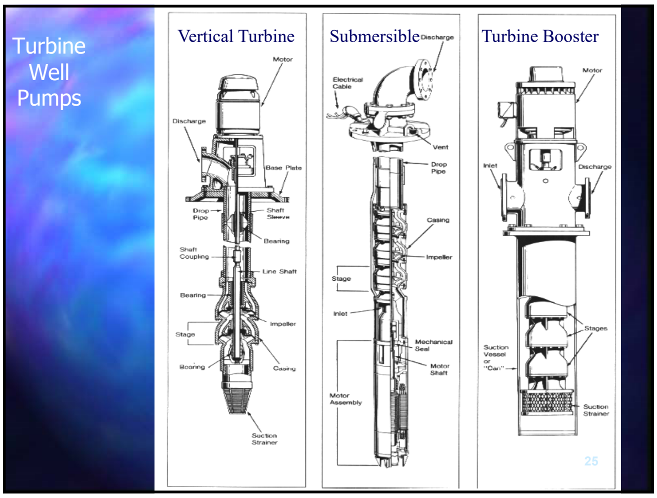
Turbine
Well
Pumps
Vertical Turbine
Submersible
Turbine Booster
Motor
Discharge
Base Plate
Drop Pipe
Shaft Sleeve
Bearing
Shaft Coupling
Line Shaft
Impeller
Stage
Casing
Suction Strainer
Electrical Cable
Vent
Inlet
Mechanical Seal
Motor Shaft
Motor Assembly
Stages
Suction Vessel or "Can"

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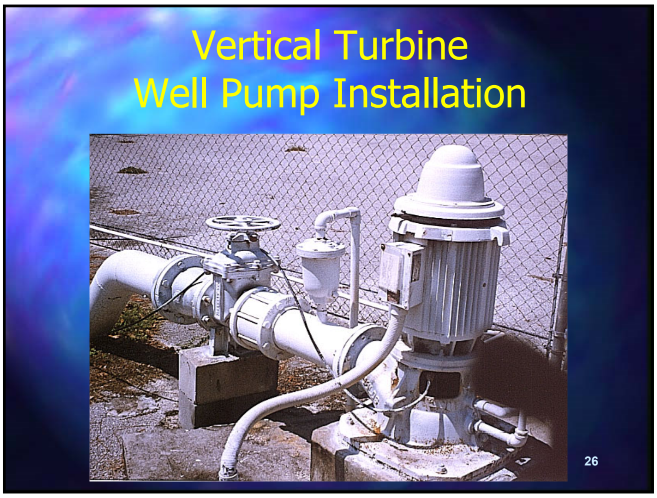
Vertical Turbine
Well Pump Installation
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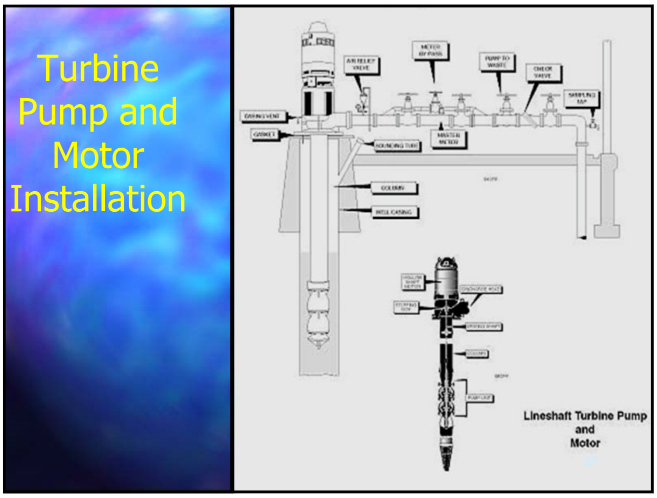
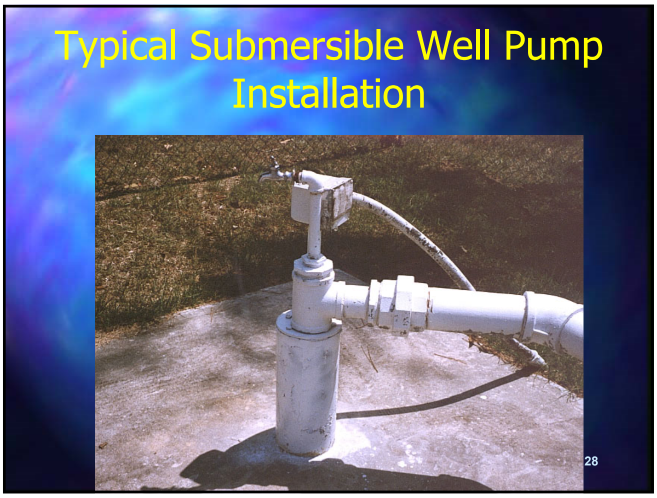
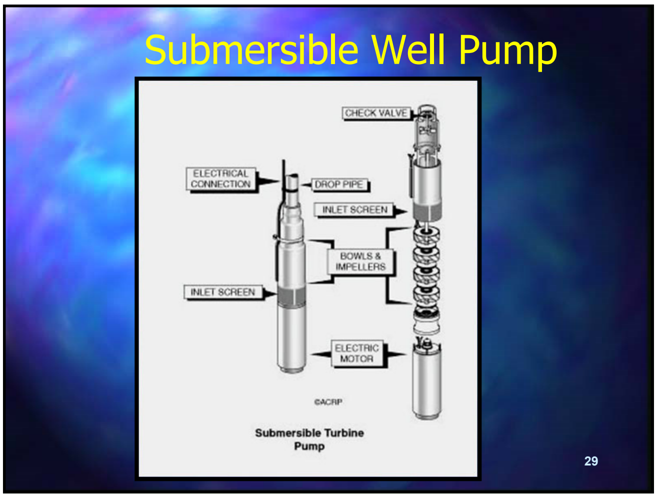

Turbine
Pump and
Motor
Installation
Lineshaft Turbine Pump
and
Motor

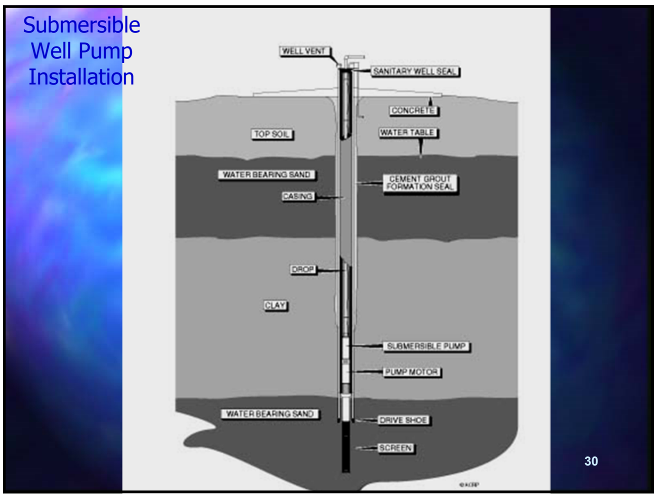
27


Typical Submersible Well Pump Installation
28

28


Submersible Well Pump
CHECK VALVE
ELECTRICAL CONNECTION
DROP PIPE
INLET SCREEN
BOWLS & IMPELLERS
INLET SCREEN
ELECTRIC MOTOR
©ACRP
Submersible Turbine Pump
29

29


Submersible Well Pump Installation
WELL VENT
SANITARY WELL SEAL
CONCRETE
TOP SOIL
WATER TABLE
WATER BEARING SAND
CEMENT GROUT FORMATION SEAL
CASING
DROP
CLAY
SUBMERSIBLE PUMP
PUMP MOTOR
WATER BEARING SAND
DRIVE SHOE
SCREEN
30

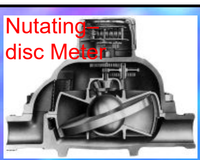
30

Metering

- A metered water system is one in which a meter is installed at all strategic points:
  - Main supply lines
  - Pumping stations
  - Reservoir outlets
  - Connections to other utilities
  - Customer service lines
- Benefits
  - Customer can be billed for exact amount
  - Amount of water produced can be determined
  - Losses of water can be detected
  - Capacities of pipelines can be determined

31

31



Meters:

the primary function is to measure and display the amount of water passing through it.

- Small-flow (displacement type): can measure wide variations in flow rate, in sizes up to 2 inches; accurate for low flows
  - Nutating-disc: most commonly used meter on small-diameter domestic services; when water flows, the tilted disc rotates
  - Piston: have greater head loss than nutating-disc meters
- High-flow (velocity type): measure the velocity of flow past a cross section of known area
  - Types include: turbine, propeller, venturi, electronic (include magnetic and sonic types), and insertion
- Combination meters (compound type): combination of the displacement and velocity-type meters; best suited for locations with widely varying flows; accurate and rugged but have higher head loss from friction than large-flow meters

32

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Meter Types (cont.)

- Large-flow (velocity type – sometimes called current meters)
  - Turbine: high flows and low friction loss
  - Propeller: high flows and low friction loss
  - VENTURI: DOES NOT INTERFERE WITH FLOW IF METER FAILS; ACCURATE AND CAUSE LITTLE FRICTION LOSS
  - Electronic: adversely affected by velocity interruptions; if used leave at lease a distance of ten pipe diameters between an upstream obstruction or fitting and the flowmeter
  - Insertion: more severe pressure losses and are somewhat less reliable.

33

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Well Field Management Preventing Contamination at the Wellhead

34

34

Preventing Contamination at the Well Head

#	Observation	Likely Pathway
1	Septic tanks, broken storm or san. pipes, ponds	Through Surface Strata
2	Drainage up-hill	Surface water runoff
3	Well subject to flooding	Surface water transport of contaminants
4	Casing termination	Must be 1' and above 100 yr flood plane
5	Area around well is wet	Corroded Casing Pipe
6	Possible Abandoned wells in area	Surface water intrusion from contaminated source
7	Sanitary condition unacceptable	Contaminated water intrusion

35

Preventing Contamination at the Well Head (continued)

#	Observation	Likely Pathway
8	Cracking in Well Slab	Contaminated water intrusion
9	Evidence of Algae or Mold on Slab	Birds and insects attracted by moist conditions
10	Poor Drainage	Surface water intrusion from contaminated source
11	Seal water draining into well head	Contaminated water entering borehole
12	Well Seal damaged	Contaminated water intrusion
13	Fittings pointing upward	Contaminated Water intrusion into casing
14	Well vent not properly installed	Contaminated Water intrusion into casing

36

Preventing Contamination at the Well Head

#	Observation	Likely Pathway
15	Check Valve absent or not working	Contaminated water back-flowing into casing
16	Cavitation or water hammer	Ck. Valve damage & water back-flowing into casing
17	Well Site Security Compromised	Contaminated Water from undesirable activities
18	Livestock or wild animals close by	Animal source of Contamination
19	Surface water evidence ID	Indicator organisms, color, temp and TOC contributing

37

37

Preventing Contamination at the Well Head

#	Observation	Likely Pathway
20	Several wells available	One well is more likely to contribute than others
21	Intermittent Well Operation	Contaminated occurring from long-term biological activity
22	Wet or extreme weather events	Contamination from run-off or from higher pumping levels.

38

38

DEP Well Setback Requirements

Minimum Setbacks

- 200 feet from septic tank if over 2000 gpd (commercial)
- 100 feet from septic tank if under 2000 gpd (residential)
- 100/50 feet from a sanitary hazard (high vs moderate risk)
- 500 feet from domestic wastewater residuals land application areas
- 500 feet from land application areas for reclaimed water

39

39


Water System
Well Capacity Requirements
For GWPWS serving > 350 people or 150 service connections
– Minimum of two wells
– Wells must meet design average daily demand with largest well out of service.
For all GW Public Water Systems well(s) must provide capacity to meet maximum-day demand.
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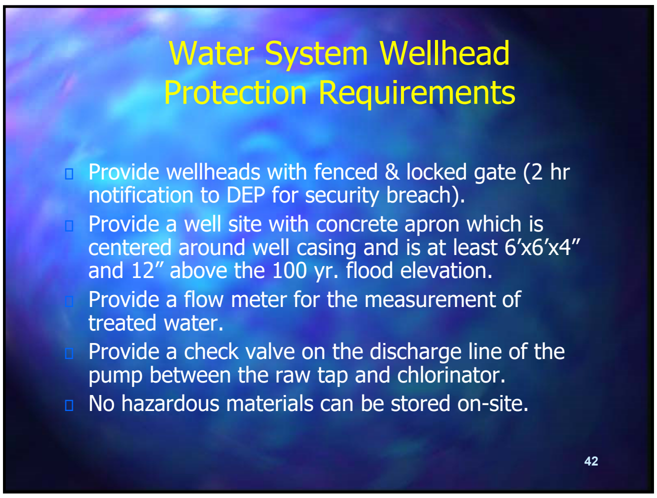
Water System Auxiliary Power Requirements
Community systems over 350 or more people, or 150 connections shall provide a minimum of 2 wells and auxiliary power for the operation of the systems source, treatment and pumping facilities at a rate of equal to average daily demand for the system.
Auxiliary power shall be equipped with automatic startup unless 24 hr., 7 days per week supervision is provided.
Auxiliary power shall be operated at least 1 per month for 4 hours under load.
41

41

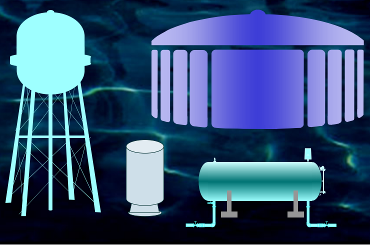

Water System Wellhead Protection Requirements
Provide wellheads with fenced & locked gate (2 hr notification to DEP for security breach).
Provide a well site with concrete apron which is centered around well casing and is at least 6′x6′x4″ and 12″ above the 100 yr. flood elevation.
Provide a flow meter for the measurement of treated water.
Provide a check valve on the discharge line of the pump between the raw tap and chlorinator.
No hazardous materials can be stored on-site.
42

42


Wellhead Protection
Obtain Community Involvement
Collect existing data, i.e. geology, hydrology, locations of underground storage tanks, septic tanks,
Collect additional data and conduct surveys of the well head area
Determine what land uses present a threat to groundwater quality
Analyze the data and hydrogeology
Test for contaminants
Set well head protection zones from certain activities
Obtain public support and implement new well head protection regulations
43

43

Water Storage Systems



1

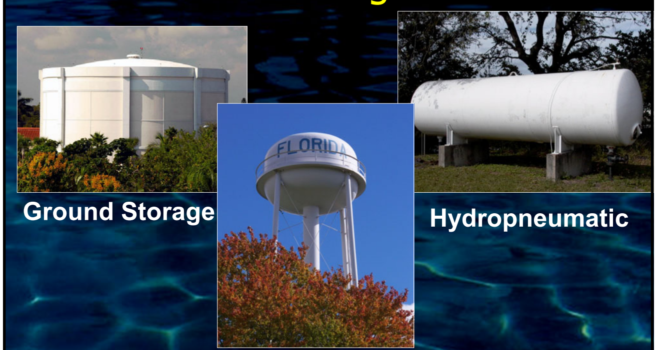
Water Storage Tanks

Types:

- Gravity or Elevated
- Ground Storage
- Hydropneumatic

2

Water Storage Tanks

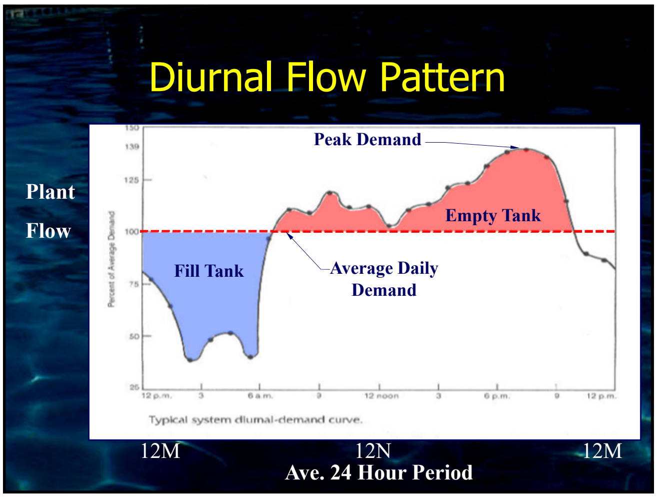


Ground Storage

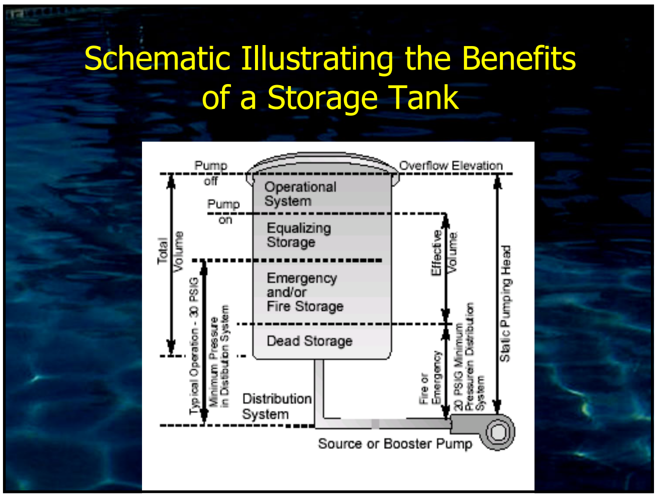
Hydropneumatic

Elevated Storage

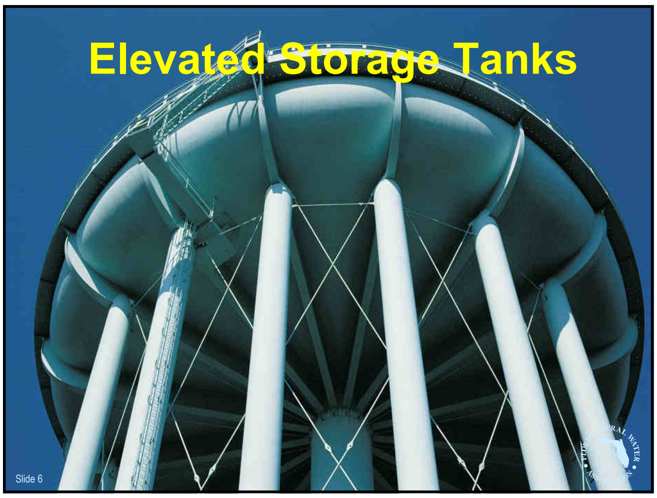
3


Diurnal Flow Pattern
Plant
Flow
Peak Demand
Empty Tank
Fill Tank
Average Daily
Demand
Typical system diurnal-demand curve.
12M
12N
12M
Ave. 24 Hour Period

4

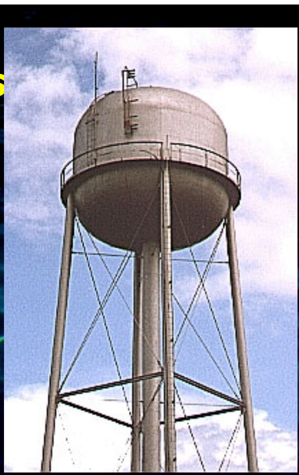

Schematic Illustrating the Benefits
of a Storage Tank
Pump
off
Pump
on
Overflow Elevation
Operational
System
Equalizing
Storage
Emergency
and/or
Fire Storage
Dead Storage
Total
Volume
Effective
Volume
Static Pumping Head
Typical Operation - 30 PSIG
Minimum Pressure
in Distribution System
Fire or
Emergency
20 PSIG Minimum
Pressure in Distribution
System
Distribution
System
Source or Booster Pump

5


Elevated Storage Tanks
Slide 6

6

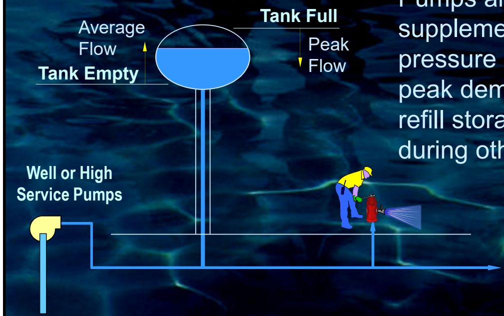
Elevated Tanks



- Stabilize distribution system pressures
- Provide water to meet peak demands
- Keeps pumps from cycling and operating in efficient ranges

7

Fluctuating Levels in an Elevated Storage Tank



Pumps are used to supplement system pressure during peak demands & refill storage tank during other times.

8

Advantages Offered by Elevated Tanks

- Less variation in pressure
- Available water for fire fighting
- Storage to meet peak demands
- Allows use of lower capacity wells
- Cycling of well pumps is reduced
- Wells can be better matched to average water demand
- High service pumps and the treatment plant can operate more efficiently

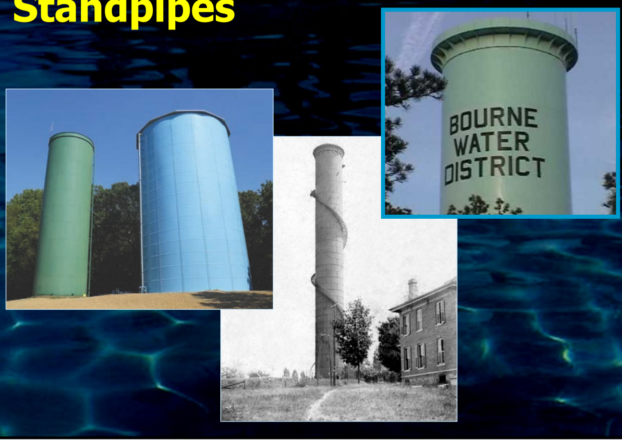
9

Maintenance Considerations for Elevated Water Storage Tanks

- Check for Intrusion of Water
- Secure Tank Site from unauthorized access
- Clean Tank yearly recommended (DEP 5-yr. required!)
- Ensure that overflow structures are working, secure and properly drained
- Inspect Structures for Stability, Blockages and Surface and Internal Corrosion.

10

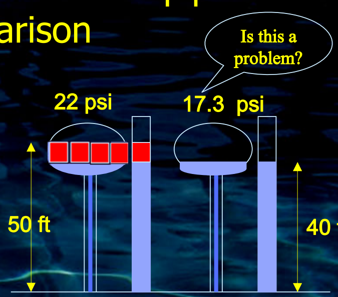
Standpipes



11

Elevated Tank and Standpipe Comparison

- Used to provide pressure head to the distribution system.
- Large storage capacity
- Shallow tanks with large diameter are preferred over deep one with small diameters.
- Less pressure drop in elevated tanks.



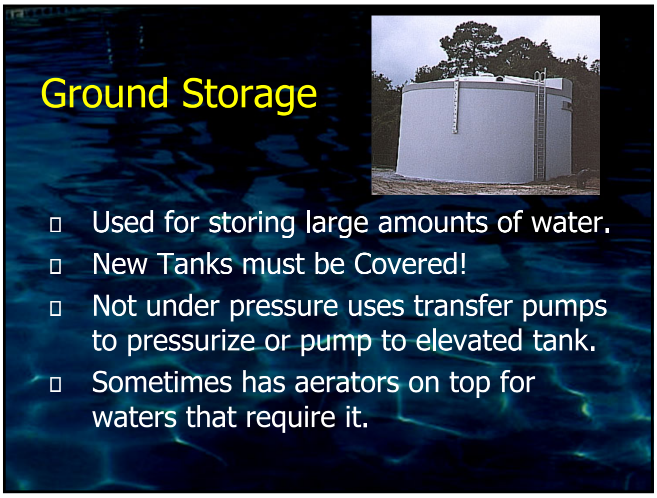
Pressure = Water Elevation (ft) * Water Density (lb/ft) * (1 ft2/ 144 in2)

Where: Water Density = 62.4 lb/ft^3

12


Ground Storage Tanks
Slide 13

13


Ground Storage
Used for storing large amounts of water.
New Tanks must be Covered!
Not under pressure uses transfer pumps to pressurize or pump to elevated tank.
Sometimes has aerators on top for waters that require it.

14

15

16


Hydropneumatic Tanks
Must be built to ASME standards

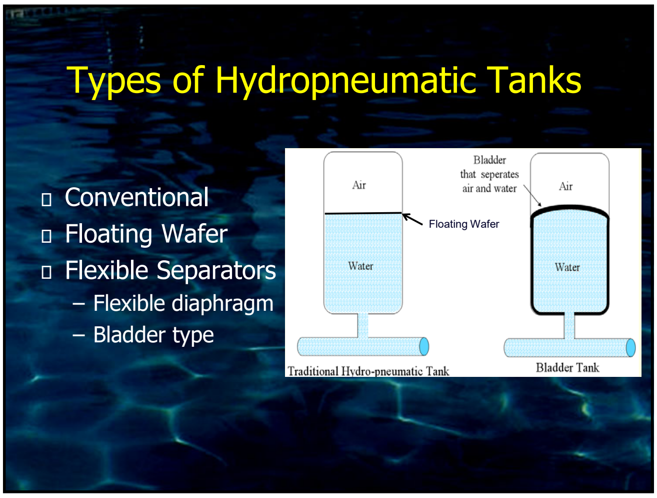
17


Hydropneumatic Tanks
Under 120 gallon PST 2000 tanks allowed by FDEP

18


Hydropneumatic Tanks
Combination of compressed air pressure to force water into the distribution system when pump is off
Slide 19

19


Types of Hydropneumatic Tanks
Conventional
Floating Wafer
Flexible Separators
– Flexible diaphragm
– Bladder type
Air
Water
Floating Wafer
Traditional Hydro-pneumatic Tank
Bladder that seperates air and water
Air
Water
Bladder Tank

20


Operating Considerations for Conventional Hydropneumatic Tanks
Must have air to operate correctly
Must have a pressure relief valve
Need a sight glass to observe level in tank
Must have By-pass piping for repairs
Valve for flushing
Air volume control
Scheduled maintenance program

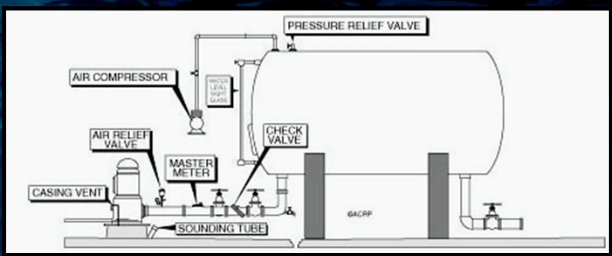
21

Components of Conventional Hydropneumatic System

Components	Function
Air Volume Control -	Control amount of air in tank
Relief Valve -	Prevent excessive high pressure
Pressure Gauge -	Monitor water/air pressure
Motor Controls -	Control cut-in and cut out
Level Controls -	Regulate high/low water levels
Compressor -	Replenishes Air

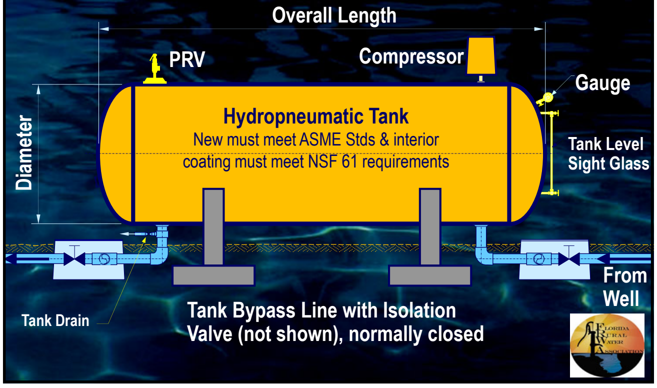
22

Conventional Hydropneumatic Tank Schematic



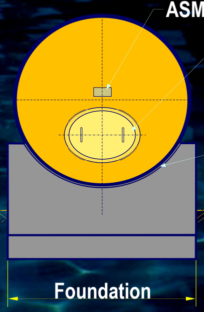
23

Hydropneumatic Tank Side View



24

Hydropneumatic Tank End View



New Hydropneumatic Tanks as required by FDEP Rule 62-555.320(20), FAC and *Recommended Standards for Water Works* (a.k.a. Ten States Standards.)

25

Sizing Considerations for a Conventional Hydropneumatic Tank

- Capacity of the wells and pumps should be at least ten times the average daily consumption.
- Gross volume of the tank, in gallons should be at least ten times the capacity of the largest pump, rated in gpm.
- Sizing must consider the need for disinfectant contact time.
- Operating pressure is generally sized to operate between 40 and 60 psi
- The pressure pump should not cycle more than 6 to 8 times per hour

26

Air Compressor Maintenance Considerations

- Regularly scheduled maintenance:
- Clean or replace filters
- Drain condensate frequently
- NSF approved lubrication

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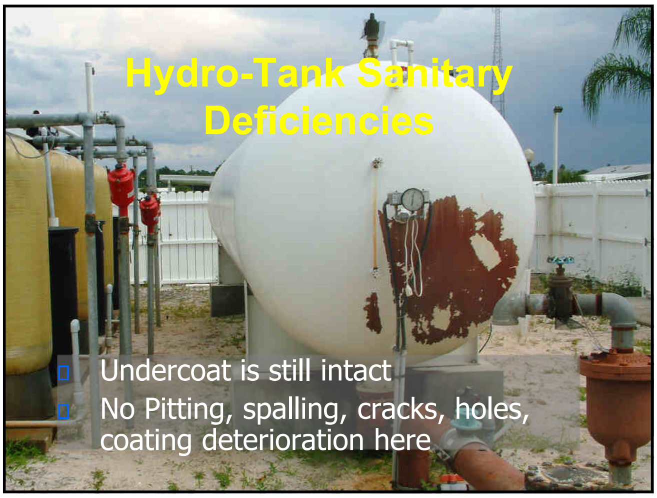
Hydro-Tank Sanitary Deficiencies
Exterior staining does NOT always mean corrosion or possible contamination

28


Hydro-Tank Sanitary Deficiencies
Pitting, spalling, cracks, holes, coating deterioration

29


Hydro-Tank Sanitary Deficiencies
Undercoat is still intact
No Pitting, spalling, cracks, holes, coating deterioration here

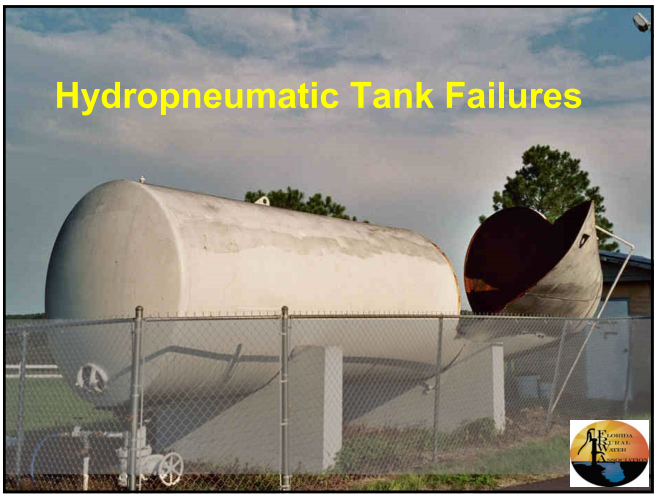
30


Hydropneumatic Tank Failures
Metal skin under continual tension
Crack rips at hundreds to thousands of miles / hour
You will hear it AFTER failure occurs!
You will most likely not have a chance to react

31


Hydropneumatic Tank Failures
This water system called about their hydropneumatic tank
They had just welded a plate over a pinhole leak
Luckily 2-weeks later when the tank blew out, no one was in the immediate area and no extensive damage was done to other structures.
This type of repair significantly compromises the tank & shorten its life
Instead of strengthening the tank, the welds increased metal stresses

32


Hydropneumatic Tank Failures

33

Chlorination and Disinfection

1

1

Disinfection and Sterilization

- Disinfection – inactivates pathogenic organisms
- Sterilization - destroys all organisms

"To all Citizens: boil and strain the water before drinking to prevent hoarseness."

Hippocrates, 350 B.C.

2

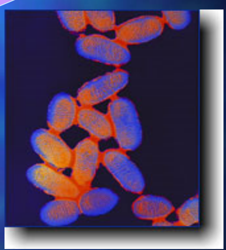
2

Purpose of Disinfection

- Destroy harmful organisms
- Protect the public from disease-causing pathogens by **inactivating** pathogens to ensure that they are reduced to non-harmful levels
- The measure used to determine the effectiveness of disinfection is the coliform group; means pathogenic bacteria may be present.

Disease producing organisms are commonly called:

Pathogens



3

3

Coliform Group of Bacteria

Includes all the aerobic and facultative anaerobic gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose (a sugar) within 48 hours at 35 °C (human body temperature).

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4

Considerations for Choosing a Disinfectant

- Effective for the Conditions Encountered
- Economical
- Operationally practical
- Reliable
- Safe for public consumption with no unintended consequences

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Disinfection Agents

- Heat energy (Boiling)
- Radiant energy – UV (Ultraviolet Radiation)
- Chemical Agents (Cl2, ozone, Chlorine dioxide)
- Three types of disinfection agents used in water treatment.

6

6

Disinfection by Heat

- Expensive to operate on large scale
- Used for emergency situations in distribution systems
- Precautionary Boil Water Notices are issued when the distribution system is compromised
- Clearance requires two consecutive days of negative coliform samples

7

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Disinfection by Radiant Energy (Ultraviolet Radiation)

- Ultraviolet Radiation (UV) used selectively in surface water treatment plant applications
- No residual activity so chlorine is used as secondary disinfectant
- Inactivation of cycts (Giardia) and oocyts (Crypto) difficult to measure
- Very Susceptible to turbidity (acts as a shield)

8

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Disinfection by Chemical Agents in the U.S.

- Chlorine and Monochloramine 93%
- Potassium Permanganate 5%
  (Used as alternate oxidant w/ Cl_2 secondary)
- Ozone (O_3) 1%
  (requires secondary disinfectant)
- Chlorine Dioxide 1%
  (requires secondary disinfectant)
- Hydrogen Peroxide < 1%
  (requires secondary disinfectant)

9

9

Reasons for the Selection of Chlorine as a Disinfectant

- Readily available and economical
- Low cost compared to other substances
- Proven effectiveness in relatively low dosages
- Simple feed and control procedures
- Requires safe storage and handling

10

10

Disadvantages in the Use of Chlorine

- Highly toxic
- Regulatory agencies placing tightening restrictions on storage and use
- Must have Emergency Response Plan
- Produces Disinfection Byproducts

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Other Uses of Chlorine at a Water Treatment Plant

- Control Aquatic Life
- Oxidize Iron, Manganese and Sulfides
- Remove Tastes and Odors
- Maintain a Microbial Residual in Water Distribution System
- Prevent Algal Growth in Basins and Plant Process Facilities. (Pre-Chlorination)
- Improve Coagulation and Filtration

When taking a bac-t sample you should neutralize the chlorine with sodium thiosulfate

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Use of Chlorine for Removing Taste and Odors

- Most widely used chemical for color removal
- Effective for use for organic odors such as fishy, grassy or flowery
- Very effective for removing (oxidizing) inorganics such as iron or hydrogen sulfide
- Will intensify phenolic (solvent) odors
- Will increase THM's and HAA5's
- Alternatives include Potassium Permanganate, Ozone and Chlorine Dioxide

13

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Use of Potassium or Sodium Permanganate as Disinfectant

- Powerful Oxidizing Agent
- Used to Remove Fe/Mn and TOC
- Does not produce DBPs
- Shipped as a Solid (KMnO4) or Liquid (NaMnO4)
- Two to three times as expensive as Cl
- Corrosive, stains purple and can color water pink (removed with chlorine).
- Requires Secondary Disinfectant

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Use of Ozone (O_3) as a Disinfectant

- Effective in taste in odor removal. Does not produce TTHMs or DBP
- Bromate, MCL must be controlled
- No residual, so secondary disinfectant required
- Requires on-site generation
- Unstable - not stored
- Utilizes sensitive equipment which requires careful monitoring

15

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On-site Ozone Generation

Ozone is always generated on-site. Dosing is accomplished in chamber, any residual Ozone is purged and secondary disinfectant is added.

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Chlorine Dioxide

- Long been used for taste and odor and for iron and manganese control.
- Will not produce THMs and HAA5s.
- Can produce chlorite and chlorate residuals in drinking water. Chlorate has an established MCL.
- Must be prepared on-site and uses gas chlorination system to produce feed product.
- It is hazardous and can cause suffocation due to lack of oxygen.
- It is odorless, colorless, and will accumulate at lowest level because it is heavier than air.

17

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Chloramines

- Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia
- Used as an alternative disinfectant but is less effective as a disinfectant than free chlorine residual
- Its use dependent on raw water quality
- Effective in accomplishing these objectives:
  - Reducing formation of THMs and DBPs
  - Maintaining residual in distribution system
  - Penetrating the biofilm and reducing the potential for coliform regrowth.
  - Killing or inactivating HETEROTROPHIC plate count bacteria
  - Reducing taste and odor problems

18

18

Methods of Producing Chloramines

- Preammoniation followed by later chlorination (produces less THMs with no phenolic tastes and odor)
- Concurrent addition of chlorine and ammonia (produces the lowest amount of THMs)
- Prechlorination/Postammoniation (will result in formation of more THMs)

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Use of Chlorine

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Chlorine Ionization Reactions with Water

- When Chlorine is added to water it disassociates (ionizes)
- This reaction produces hypochlorous acid (HOCl) and the hypochlorite ion (OCl-)
- Their relative concentrations are dependent on the pH
- They provide the disinfection ability of chlorine

21

Forms of Chlorine

- Gas Chlorine (Cl_2) - 100% available as chlorine
- Liquid Chlorine or Bleach (NaOCL) - Sodium hypochlorite (5% - 15% active chlorine) is a pale yellow liquid
- Solid Chlorine [$Ca(OCL)_2$] - Calcium hypochlorite comes in a granular, powdered or tablet form. It is a white solid that contains 65% to 75% available chlorine.

22

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Gas Chlorine

- Lowers the pH of the water
- Produced from liquid chlorine shipped in pressurized cylinders
- 100% available as chlorine
- Moisture in a chlorination system will combine with the chlorine gas and cause corrosion

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Liquid Chlorine
(Sodium Hypochlorite)

- Liquid chlorine raises the pH of the water
- Arrives in a plastic container
- 5 -15% chlorine by weight
- More expensive than converting chlorine in liquid form to gas
- Safe and easy to handle and dose
- Very corrosive
- Toxic - apply in vented area
- Weakens over time

24

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Solid Chlorine
(Calcium hypochlorite)

- Solid chlorine raises the pH of the water
- 65% to 75% available chlorine
- Easily dissolves in water
- Easy to store; longer shelf life than liquid
- Very corrosive
- Highly reactive
- Toxic - apply in vented area
- Undissolved solids can foul check valves and plug injection fittings (calcium carbonate build up).

25

25

Factors Affecting Chlorination Effectiveness

- Chlorine concentration (higher increases effectiveness)
- Form (gas lowers pH, more effective)
- Effluent pH (lower increases effectiveness)
- Effluent temperature (higher increases effectiveness)
- Contact time (generally, longer increases effectiveness)
- Effluent suspended solids (turbidity reduces effectiveness)

26

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Chlorine Residual Requirements in Distribution System

A chlorine residual of 0.20 mg/l means that the amount of chlorine in the water is

0.20 pounds of chlorine per 1 million pounds of water

A free chlorine residual of 0.20 mg/l or a combined chlorine residual of 0.60 mg/l or an equivalent chlorine dioxide residual, must be maintained in the water distribution system at all times.

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Breakpoint Chlorination

Breakpoint chlorination is the process of adding chlorine to water until the chlorine demand has been satisfied.

- Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint
- Public water supplies are normally chlorinated PAST THE BREAKPOINT.

28

28

Reactions of Chlorine with Water Constituents

Order of Reaction

1. Reducing agents (inorganics)
   (hydrogen sulfide (H_2S), ferrous ion (Fe^{2+}), manganous ion (Mn^{2+}), and nitrite ion (NO_2^-)
2. Reducing agents (organics and ammonia)
   Chloramines and chlororganics will form, highly turbid waters will reduce the effectiveness of chlorine.
3. Chlororganics and chloramines partly destroyed
4. Breakpoint - Free available residual formed (some chlororganics remain)
5. Process is called "Breakpoint Chlorination"

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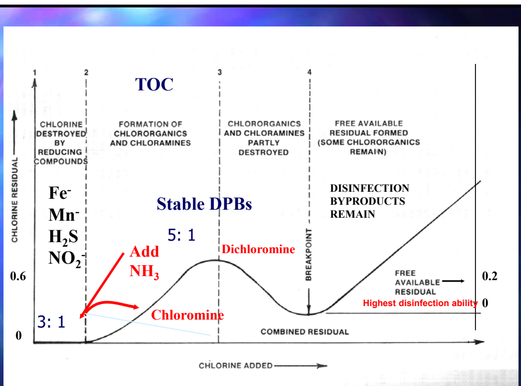

Breakpoint Chlorination Curve

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Process Calculations

- Two process calculations
  - Chlorine dosage, mg/l
  - Chlorine demand, mg/l
- To calculate dose use feed rate formula or use Davidson's Pie

$$\text{Chemical feed, lbs/day} = \frac{(\text{Chlorine Dose, mg/l})(\text{Flow, MGD})(8.34\ \text{lbs/gal})}{(\text{Purity, decimal})}$$

$$\text{Chlorine Dose, mg/l} = \frac{(\text{Chemical feed, lbs/day})(\text{Purity, decimal})}{(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

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Example: A chlorinator is set to feed 15 pounds of chlorine in 12 hours to a flow of 0.95 MGD. Find the chlorine dose in mg/l.

$$\text{Chlorine Dose, mg/l} = \frac{(\text{Chemical feed, lbs/day})(\text{Purity, decimal})}{(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

$$\text{Chlorine Dose, mg/l} = \frac{30\ \text{lbs Cl/day}}{(0.95\ \text{MGD})(8.34\ \text{lbs/gal})}$$

Chlorine Dose, mg/l = 3.8 lbs Cl/million lbs of water

or = 3.8 ppm or 3.8 mg/l

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Chlorine Relationships

CL Dose = Chlorine Residual + CL Demand

Chlorine Residual = CL Dose - CL Demand

CL Demand = CL Dose - Chlorine Residual

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Determine the chlorine demand in mg/l for our previous example if the chlorine residual after 30 minutes of contact time is 1.0 mg/l.

Chlorine Demand = CL Dose - CL Residual

Chlorine Demand = 3.8 mg/l – 1.0 mg/l

Chlorine Demand = 2.8 mg/l

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Inactivation of Bacteria and Virus with Chlorine

- Inactivation of Pathogens is accomplished by meeting CT limits (Time that Pathogen is in contact with concentration of residual chlorine)

- 3-Log Giardia Inactivation for SW — 99.9%
- 4-Log Virus Inactivation for GW — 99.99%
- Tables of acceptable Inactivation (mg-min/l) are published by DEP

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Chlorine Residual

- Free Chlorine - aqueous chlorine, hypochlorite ion and hypochlorous acid
- Combined Chlorine Residual - compounds formed by reactions of hypochlorous acid and ammonia (chloramines)
- Total Chlorine Residual - sum of free and combined chlorine

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Minimum Chlorine Residual

- DEP requirements are 0.20 PPM Free Chlorine Residual or 0.60 PPM Chloramine Residual at all points in Distribution System

The most probable cause of the coliform count failing to meet regulatory standards is?

A low chlorine residual

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Considerations for Hypochlorination Systems

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Difference between Gas and Hypochlorination

- Gas chlorine lowers the pH (increases the hydrogen concentration) favoring the formation of Hypochlorous acid (more effective)
- Hypochlorination (both Sodium and Calcium) raises the pH favoring the formation of the Hypochlorite ion. (less effective)

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Parts of a Hypochlorinator

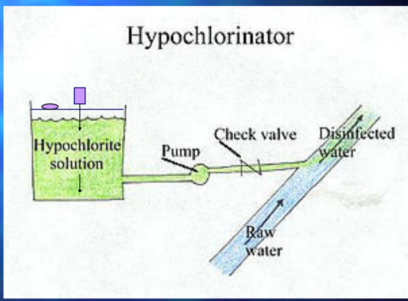
Parts:

Mixing Tank

Metering Pump

Check Valve

Well Pump



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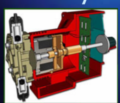
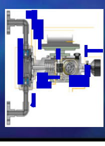
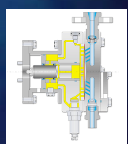
Chemical Feed Pumps

2 Basic Types

- Peristaltic (tube or hose)
- Diaphragm (solenoid, Motor or Hydraulic)

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Parameter	Peristaltic Pump	Diaphragm Pump
Fluid		
Chemical resistance	- Fewer components to be attacked. Few pump tube material options.	- Many components to be attacked. Many component material options.
Un-dissolved solids	- Excellent: no valves to clog.	- Poor: valves can clog causing failures.
Outgassing	- Excellent: automatically primes	- Poor: difficult to prime
Shear stress	- Excellent: will not damage fluid	- Poor: can damage delicate fluid
Temperature	- Limited range: pump tubing is affected by high and low temperatures.	- Extended range: effect of temperature on the diaphragm is minimal.
Pressure		
Injection Pressure	- Limited discharge range - <125psi typical. No change in output due to changes in system pressures.	- Extended discharge range - >125psi typical. Large change in output due to changes in system pressure.
Control		
Remote Adjustment	- Excellent: steady dispersion of chemical at very low output with speed adjustment.	- Good: intermittent dispersion of chemical at low outputs.
External communications	- Excellent	- Excellent
Diagnostics	- Excellent: tube failure and flow verification alarm systems available.	- Excellent: diaphragm failure and flow verification alarm systems available.
Maintenance		
Service interval	- Service required at regular intervals.	- Service recommended at regular intervals.
Life expectancy	- Excellent	- Excellent

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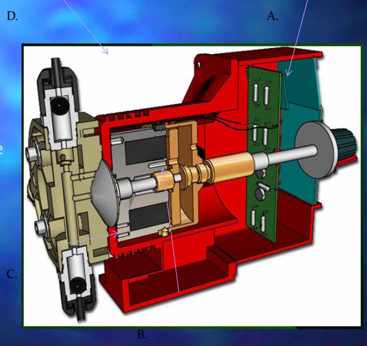
Diaphragm Metering Pump

Change stroke length only when running

A. The coil is energized via electrical charge on the board
B. The solenoid shaft pushes the diaphragm into the pump head cavity
C. The suction ball valve seats (via gravity)
D. Liquid in the pump head is forced out through the discharge valve as the ball is forced to raise in the guide



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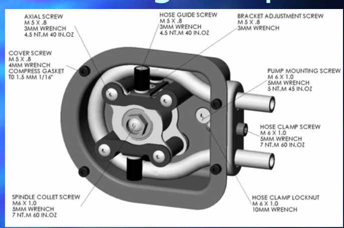
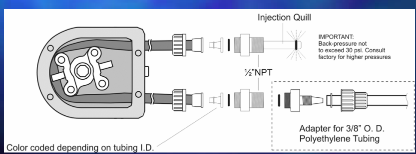
Peristaltic Metering Pump

- A motor drives a shaft that is connected to rollers
- The rollers push the tubing flat against the collet which drives the liquid through the tube





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Hypochlorination System Maintenance Considerations

Cl lines are what color? YELLOW

- Scale has a tendency to form in pumps, feed lines, and injection points
- Regularly inspect and clean pumps, poppet valves, and injector points. If this is not done, scale will prevent the pump from moving solution into the water to be disinfected. Monitoring chlorine residuals may point to needed pump maintenance.
- Clean by pumping a mild acid (HCL) solution through system.
- Pump should be properly lubricated and free of corrosion
- Adjust feed rate only when running
- Do not store chemical for long periods

@ Date of Manf. 12.5% after 30 days 11.5%

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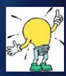
Considerations for Hypochlorite Storage

- Protect skin, eyes, and respiratory tract
- Wear protective gloves Hypochlorite will burn skin
- Cover all containers
- Keep chemical dry, covered and stored away from direct sunlight.
- Add water to container before the hypochlorite is added to avoid splashing of acid.
- Flush all spills with large amounts of water
- Keep the chlorine room well ventilated.
- Store Calcium hypochlorite away from contact with organic matter to prevent fire.



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Considerations for Gas Chlorination Systems

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Physical and Chemical Properties of Chlorine as a Gas

- Pressurized liquid expands 450 times in atmosphere
- Under normal atmospheric pressure at room temperature, chlorine is a yellow-green gas
- 2.5 times heavier than air

Exhaust fans should be located where?
Floor level.

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Maximum Draw-Off Rates

150 lb cylinders - approximately 40 lbs/day
1-ton containers - approximately 400 lbs/day
Computed as 8 pounds / F° drop

- Temperature of remaining chlorine decreases as the rate of withdrawal increases
- When temperature of chlorine is low enough it will not evaporate

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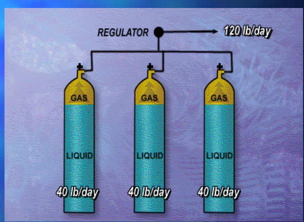
Preventing Chlorine Icing

- When attempting to feed more than the allowable amount from any container, manifolding is required



Computed as 8 pounds / F° drop

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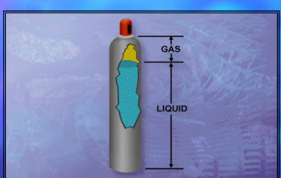
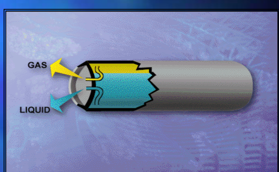
Dosing Configurations of Chlorine Cylinders



150 lbs Cl - 92 lbs Tare
Total Weight ~ 242 lbs



2000 lbs Cl – 1550 lbs Tare
Total Weight ~ 3,600 lbs

When exposed to heat gas inside tank will expand and could easily rupture a cylinder. For this reason cylinders are not filled to more than 85% of their volume.

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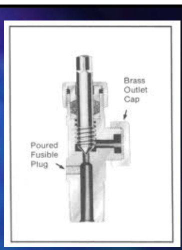
Storage of Chlorine Cylinders



- Keep away from heat or direct sunlight.
- Provide separate room with ventilation.
- Maintain temperature above 50°F to prevent icing.
- Protect from Fire
- Never store near turpentine, ether, anhydrous ammonia, hydrocarbons or other materials that will react violently with chlorine.
- Chlorine tanks are provided with fusible plugs that melt between 158 to 165 degrees F.
- Ton cylinders will have 6 to 8 of these plugs, 3 or 4 on each end; 150 lb, one below the valve seat.

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Safe Handling of 1-Ton Cylinder

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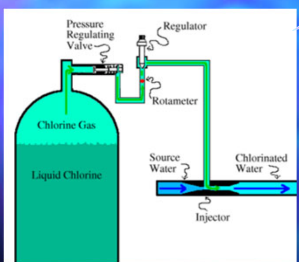
Principles of Gas Chlorination

Feed pump is not pumping what is the problem?

Vacuum leak



Primary advantage of vacuum operation is safety. If there is a break in vacuum the chlorinator stops the flow of chlorine.

- Pressure Regulating Valve - maintains proper operating pressure
- Rotameter – indicates the rate of flow
- Regulator – used to adjust the CL feed rate
- Injector – injects gas into flow stream
- Chlorine gas pressure at a gas chlorinator should be between 20 and 30 PSI

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Disinfection Troubleshooting

Symptom	Cause
Increase in coliform level	Low chlorine residual
Drop in chlorine level	Increase in chlorine demand
	Drop in chlorine feed rate

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- Question: A plant uses 647 chlorine containers in a year. The average withdrawal from each is 138 pounds. What is the total number of pounds used for the year?

a. 89,286 lb
b. 28,487 lb
c. 89,875 lb
d. 69,876 lb

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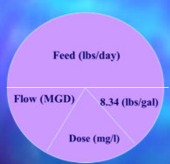
Find the Chlorine Dose



A chlorinator is set to feed 20lbs of chlorine in 12 hrs to a flow of 0.85 MGD. Find the chlorine dose in mg/l.

Dose = Feed/(flow x 8.34)

Check units

$$\text{Feed} = \frac{20\text{lbs}}{12\text{hrs}} \times \frac{24\text{hrs}}{1\text{ day}} = \frac{40\text{lbs}}{\text{day}}$$

$$\text{Dose} = \frac{40\text{lbs}}{\text{day}} \times \frac{\text{day}}{0.85\text{ MGal}} \times \frac{\text{gal}}{8.34\text{lbs}}$$

Dose = 5.6 ppm or 5.6 mg/l

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Chlorine Safety

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All Forms of Chlorine are Hazardous

- Chlorine gas/liquid - extremely hazardous substance
- Calcium hypochlorite and sodium hypochlorite - hazardous substance
- Disinfection agents kill living organisms and tissue

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Chlorinator Start Up

- Use Self Contained Breathing Apparatus, Protective Clothing and work in pairs
- Inspect cylinder before connecting
- Check fittings
- Use new lead gasket 
- Connect yoke with ¾ turn
- Open cylinder valve one turn
- Check for leaks with ammonia (rag preferable)
- Have emergency repair equipment on-hand (A-kit 150, B-kit 2000, C-kit tank car)

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Chlorine Leaks

- Inspect for leaks by placing an ammonia - soaked rag near each valve and joint.
- A polyethylene "squeeze bottle" filled with ammonia water to dispense ammonia vapor may also be used.
- Avoid spraying ammonia water on any leak or touching the soaked cloth to any metal (will form acid).
- The formation of a white cloud of vapor will indicate a chlorine leak .

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Emergency Eyewash Shower at Small Plant

Required for Gas Chlorine

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Effects of Chlorine on Humans

If a victim of chlorine gas contact has throat irritation, what liquid will help to reduce the irritation? **MILK**

Chlorine Conc	Physiological Response
0.3-3.5 mg/L	detectable by smell & devices
5 mg/L	noxiousness
15 mg/L	throat irritation
30 mg/L	causes coughing
40-60 mg/L	damage to tissue
1000 mg/L	death after a few breaths

- Permissible Exposure Level (PEL) is 0.5 ppm (8-hour weighted average)
- Immediately Dangerous to Life or Health (IDLH) concentration is 10 ppm

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Contents of a Chlorine Emergency Preparedness Program

- Chlorine Safety Program
- Written Rules and Safety Procedures
- Periodic hand-on training
- Establishment of Emergency Procedures
- Establishment of Maintenance and Calibration Program
- Fire, Police, Emergency Agency Coordination and (Chemtrec 800-424-9300.)

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Fluoridation

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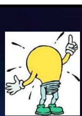
Fluoridation Considerations



- Added as Supplement to Natural Occurring Concentrations
- Typically 1 to 1.2 mg/l as Fluoride
- Regulated MCL at 4 mg/l SDA and 2 mg/l DEP
- Halogen and as Oxidant very Active!
- Overdosing causes mottling of teeth and bone deterioration
- When working with fluoridation systems using sodium fluoride, a hardness greater than 75 mg/l will cause severe scaling in the equipment.

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Fluoride Compounds

Compound Name	Formula	Purity	pH
Sodium Fluoride	NaF	97%	7.6
Sodium Fluorosilicate	Na_2SiF_6	98%	3.6
Hydrofluoro-silicic Acid *	H_2SiF_6	23%	1.2

* Because hydrofluosilicic acid is a liquid it is the easiest to feed and requires the least maintenance

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Symptoms of Fluoride Poisoning

When swallowed
- Vomiting
- Stomach cramps
- Diarrhea

When inhaled
- Sharp biting pain in the nose
- Runny nose
- Nosebleed

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Disinfection and Disinfection Byproducts (DBP)

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Regulatory Requirements for Disinfection By-Product Management & Disinfection By-Product Monitoring for Water Treatment Plants

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Disinfection By-Product (DBP) Formation

- Disinfection Byproducts (DBP) are produced by the reaction of free chlorine with organic substances found in natural waters (formed from decomposition of vegetation).
- The amount of organic materials in a natural water called NOM can be approximated by the amount of Total Organic Carbon (TOC) present in the water source.
- NOM consists of various chemical compounds containing carbon, originating from decayed natural vegetative matter found in water.

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Raw Water Considerations

- Generally surface waters or ground waters under the direct influence of surface water will have higher levels of organic materials (TOC.)
- Surface waters have higher organic content than Ground Water
- If surface water mixes with ground water, each well may experience different levels of TOCs.
- Type of organic content will influence how the water is treated.
  - Specific type of TOC can be determined by conducting a Specific Ultraviolet Absorption (SUVA) test.
  - Used to determine if enhanced coagulation is appropriate.

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Typical Values of TOC for Various Waters

Type of Water	Range in mg C/l
Sea Water	0.5 – 5.0
Most Ground Water	0.1 – 2.0
Surface Water	1.0 – 20
Swamp Water	75 – 300
Effluents Biotreatment	8.0 – 20
Wastewater	50 – 1000

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DBP Health Impacts

- Can be carcinogenic (cancer causing)
- Can cause reproduction problems
- Can damage blood or kidneys
- For these reasons, EPA has set DBP limits in the drinking water

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Production of Trihalomethanes

- Trihalomethanes (THMS) are produced by the reaction of chlorine with organic constituents found in natural waters.
- The 4 compounds of concern are:
  - Chloroform (typically 70%)
  - Bromoform
  - Bromodichloromethane
  - Dibromochloromethane
- The sum of the concentrations of these four compounds are Total Trihalomethanes (TTHMs)

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Production of Haloacetic Acids

- Haloacetic Acids (HAA5) are produced by the addition of chlorine with organic constituent found in natural waters
- The 5 compounds of concern are:
  - Monochloroacetic Acid
  - Dichloroacetic Acid
  - Trichloroacetic Acid
  - Monobromoacetic Acid
  - Dibromoacetic Acid
- The total concentrations of these five compounds are known as HAA5s

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Disinfection Byproducts (DBP) and Chlorination Considerations

- DBP's are produced by the reaction of free chlorine with organic material called "precursors"
- Precursors" are best reduced prior to chlorination for minimizing DBP production

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Factors Affecting Disinfection By-Product Production

- Turbidity and the type of NOM present
- Concentration of Chlorine added
- pH of water
- Bromide Ion Concentration
- Temperature
- Contact Time

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Simultaneous Compliance Balancing Disinfection Protection with DBP Formation

- To disinfect and inactivate pathogens, WTPs generally add free chlorine to the water and if NOM is present DBPs will form.
- Pathogen inactivation is proportional to concentration of chlorine and contact time (C x T).
- Increasing free chlorine (C) or contact time (T) will increase pathogen inactivation potential and also increase DBP formation potential.

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Which will have a Higher DBP Formation Potential?

- A softening plant or a plant using conventional coagulation?
  - Softening
- A surface water treatment plant or a ground water treatment plant in the summer?
  - Surface Water Treatment Plant

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Locating TTHM Areas

- High Water Age
- Storage Tanks do not fluctuate
- No / Few Customer Areas
- Stagnant Areas
- Dead Ends
- Bad Pipe
- Regrowth Areas

Pipe Tuberculation with Bacterial Growth producing Organic Precursors

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Locating HAA5 Areas

- Low Demand Areas
- Toward Middle System Areas w/ Stagnant / High Water Age
- Areas with No / Little Regrowth
  - Eliminate Biodegradation Locations
  - Free Chlorine Residuals < 0.2 mg/L
  - HPC Data (Heterotrophic Plate Count)
- No Dead Ends

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Treatment Techniques for Controlling DBPs

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Which of the following will increase the production of THMs?

1. Using chloramines as a disinfectant
2. Using chlorine dioxide
3. Using PAC or GAC to reduce precursors
4. Using prechlorination in the treatment process

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Strategies for Reducing DBPs in Order of Cost Effectiveness

- Precursor Removal
- Disinfection By-Product Management using System Flushing and Storage Tank Management
- Use of Alternative Disinfection Strategies
- Disinfection By-Product Removal

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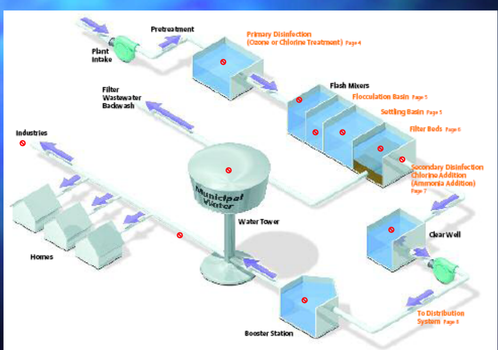
Formation of DBP in a Water System



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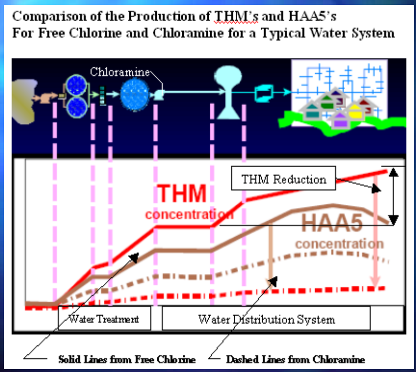
Disinfectant and DBP Production in a Typical Water System



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DBP Precursor Reduction Strategies

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Methods for Reducing Precursors

- Disinfection By-Product Management
  i.e. Nutrient control in source and finished water.
- Solids removal systems including:
  pre-sedimentation, infiltration galleries, filtration, coagulation and membrane filtration.
- Addition of powdered or granular activated carbon to remove organics.

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DBP Management in a Water Distribution System

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DBP Reduction Techniques in a Water Distribution System

- Reducing detention time in storage tanks
- Ensuring turnover in distribution system
- Flushing dead-end lines.

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Typical Distribution System Water Age (Days)

Population	Miles of WM	Water Age
> 750,000	> 1,000	1 – 7 days
< 100,000	< 400	> 16 days
< 25,000	< 100	12 – 24 days

AWWA: Water Age for Ave and Dead End Conditions

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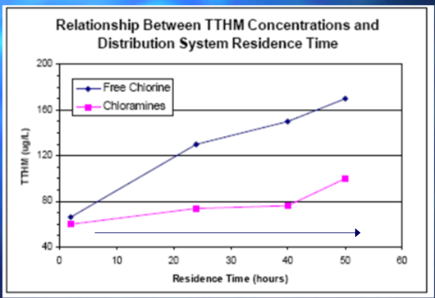
Effects of Water Age on DBP Production



Franchi and Hill, 2002

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Problems with Water Turnover and Sediments in Storage Tanks

- Sediments contain significant concentrations of organic nutrients
- Sediments exert a disinfectant demand
- Sediments provide protective layers for biofilms which allow pathogens to repair
- Sediments encourage the growth of slow growing nitrifying bacteria that lower residual
- Can contribute toward the formation of DBPs
- Can cause turbidity, taste and odor problems

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DBP Reduction by Establishment of a Flushing Program

Flushing Program	Suggested Actions/DEP Rule	Benefits to Treatment System
Written Flushing Procedures	Submit a Written Water Main Flushing Program. DEP Rule 62-555.350	Sampling is during normal operating conditions, and is not valid if you ONLY flush the day you are collecting samples
Treatment Components in Contact With Water	Clean & remove biogrowths, calcium or iron / manganese deposits, & sludge DEP Rule 62-555.350(2)	Improves water quality, reduces chlorine demand & regrowth in the water system.
Reservoirs and Storage Tanks	Clean & remove biogrowths, Ca or Fe / Mn deposits, & sludge from storage tanks. DEP Rule 62-555.350(2) FAC	Improves water quality, reduces chlorine demand & biological regrowth in the water system.
Water Distribution Mains	Begin systematic flushing of water system from treatment plant to system extremities.	Improves water quality, reduces chlorine demand & biological regrowth in the water system.
Dead-End Water Mains	Flushing (every other day) or Automatic Flushing. DEP Rule 62-555.350(2)	Improves water quality,& reduces biological regrowth.

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In-Plant DBP Management
Disinfectant Strategies

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Use of Disinfectant Strategies

- Reduce Dosing Concentration of Disinfectant
- Change Points of Application
- Change forms of Disinfectant
- Use of Multiple Disinfectants
- Change Disinfectant

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Effective Chlorination System Modification Strategies

Disinfection Location	Action	Benefit
Chlorine Feed	Reduce chlorine feed rates while maintaining proper chlorine residuals	Fewer DBPs formed in the water system. No / little cost for this option.
Chlorine Injection Point	Change point of chlorine injection to reduce the age of chlorinated water	Fewer DBPs formed in the water system. Small cost for this option.
Chlorine Injection Boosters	Add chlorine injection point(s) to boost Chlorine residuals in the distribution system instead of at the plant	Lower total chlorine added at the plant site. Fewer DBPs formed in the distribution system.
Alternate Disinfection / Application	Use of chloramines in distribution systems with long detention times with ozone or chlorine dioxide as a primary disinfectant	Fewer DBPs formed in the water system. Costs for this option could be significant.

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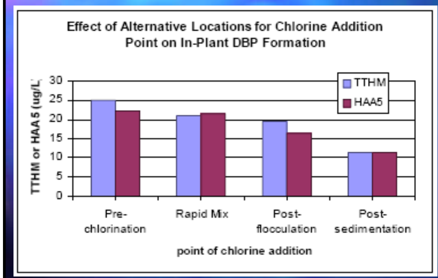
Effects of Moving the Point of Disinfection



- Pre-chlorination is used to oxidize taste and odor problems but causes DBPs.
- Moving the point of disinfection is effective because TOC is being removed at each step in the treatment process

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Changing the Disinfectant to the Use of Chloramines

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Chloramines are Formed by adding Ammonia to Chlorine

- Ammonia Gas (anhydrous ammonia): fed like chlorine gas.
- Aqueous Ammonia: anhydrous ammonia dissolved into deionized or softened water. Feed is similar to other chemical feed systems
- Chlorine and ammonia reactions

$NH_3 + HOCl = NH_2Cl + H_2O$ (Monochloramine)

$NH_2Cl + HOCl = NHCl_2 + H_2O$ (Dichloramine)

$NHCl_2 + HOCl = NCl_3 + H_2O$ (Nitrogen Trichloride)

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Chloramine Advantages

- Chloramines Not As Reactive With Organic Compounds
- Chloramine Residual are More Stable & Longer Lasting
- Chloramines Provides Better Protection Against Bacterial Regrowth in Systems with Large Storage Tanks & Dead End Water Mains when Residuals are Maintained
- Since Chloramines Do Not React With Organic Compounds; Less Taste & Odor Complaints
- Chloramines Are Inexpensive
- Chloramines Easy to Make

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Chloramine Disadvantages

- Not as strong as other disinfectants
  Eg. Chlorine, ozone, & chlorine dioxide
- Cannot oxidize iron, manganese, & sulfides.
- Necessary to periodically convert to free chlorine for biofilm control in the water distribution system
- Chloramine less effective at high pH than low pH
- Forms of chloramine such as dichloramine cause treatment & operating problems
- Excess ammonia leads to nitrification
- Problems in maintaining residual in dead ends & other locations

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Nitrification Concerns in Water Storage Tanks with the Use of Chloramine

- Nitrification is the conversion of ammonia to nitrate (can cause serious health effects)
- During conversion a small amount of nitrite is produced and will rapidly consume free chlorine and chloramine disinfectants.
- Nitrification can cause a loss of total chlorine and ammonia residuals and an increase in heterotrophic plate count (HPC) bacteria concentration.
- Occurs in dark areas, at pH > 7, at warm temperatures and long detention times
- Must ensure that disinfectant residual levels are adequate (> 1.5 ppm chloramine with 2.5 mg/l recommended)

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Nitrification Monitoring Indicators

- Depressed Disinfectant Levels
- Elevated DBPs
- Elevated Bacterial Counts (HPC)*
- Elevated Nitrate/Nitrite Levels for Chloramination Systems
- High Corrosion Potential
- Note: Direct Monitoring ineffective

* HPC use organic carbon as food, include total coliform; Not to exceed 500/ml in 95% of samples

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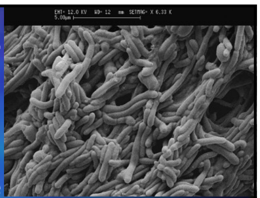
Biofilms in Drinking Water Distribution Systems



- Found anywhere in a distribution system where water contacts a surface
- Formed when microbial cells (large particles, including microorganisms) attach to pipe surfaces and form a slime layer
- Microorganisms convert dissolved organic material into biomass
- Water flowing past cells provide nutrients for survival and growth
- Bacteria comprise largest portion of biofilm
- Cause esthetic problems with water quality, including taste, odor, and color problems
- Pathogens can exist even in the presence of high levels of free chlorine

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How do microorganisms get in the system?

Microorganisms enter through two main categories:

- Surviving the treatment process
  - effectively treated water contains some bacteria
  - potable water is not sterile
- Recontamination
  - cross connections
  - back flow
  - leaking pipes, joints, and valves

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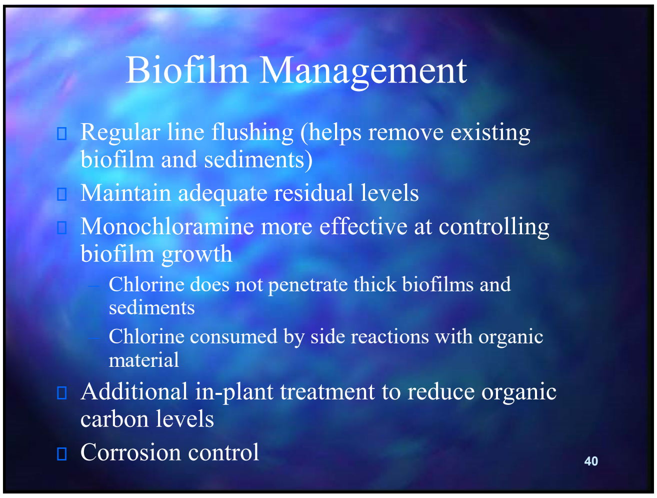
Biofilm Management
Regular line flushing (helps remove existing biofilm and sediments)
Maintain adequate residual levels
Monochloramine more effective at controlling biofilm growth
– Chlorine does not penetrate thick biofilms and sediments
– Chlorine consumed by side reactions with organic material
Additional in-plant treatment to reduce organic carbon levels
Corrosion control
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Direct Removal of DBP
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Disinfection By-Product Removal Systems
Oxidation: Ozone, Chlorine Dioxide, and UV.
Aeration: Open Storage, Diffused Air and Packed Towers.
Adsorption: Powdered Activated Carbon and Synthetic Resins
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DEP Water Quality and Treatment Process Requirements for D - DBP

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Safe Drinking Water Act
MCL's for TTHM, HAA5, Chlorite and Bromate

- TTHM .080 mg/l
- HAA5 .060 mg/l
- Chlorite 1.0 mg/l*
- Bromate 0.010 mg/l **

* associated with the use of Chlorine Dioxide
** naturally occurring precursor in systems near saltwater, associated with use of Ozone

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Also Maximum Residual Disinfectant Limit

Chlorine	4 mg/l
Chloramine	4 mg/l
Chlorine Dioxide	0.8 mg/l

These concentrations have been found to have adverse health effects

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Inactivation Reductions for Pathogens required for Surface Water/UDI Systems

- Giardia lamblia 99.9% or 3 log
- Viruses 99.99% or 4 log
- Cryptosporidium 99% or 2 log *

Water Systems are assumed to be in compliance if they use conventional or direct filtration and meet turbidity requirements

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Simultaneous Compliance Balancing Disinfection Protection with DBP Removal

- Deactivation is proportional to concentration of chlorine and contact time (C x T).
- Reducing free chlorine (C) will reduce disinfection inactivation potential but reduce DBP formation potential.
- Reducing contact time (T) will reduce disinfection potential and reduce DBP formation potential.

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General Guidelines for Surface Water Treatment

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Turbidity Standards

Alternative filtration technology in combination with disinfection consistently achieves removal and/or inactivation of:

- 99.9% of Giardia lamblia cysts (filtration + disinfection)
- 99.99% of viruses (filtration + disinfection)
- 99% of Cryptosporidium (filtration alone) (Interim Enhanced SWTR 12/16/98)

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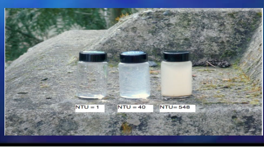
Turbidity Reductions for Subpart H Treatment Plants Using Conventional or Direct Filtration

- 95% of samples taken each month must be less than 0.3 NTUs
- no one sample can exceed 1 NTU

Plants meeting these criteria are assumed to meet the 2 log removal for Cryptosporidium



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Subpart H System requirements for Conventional Filtration

- Must use enhanced coagulation or enhanced softening
- may be exempted if source water are consistently below 2.0 mg/l TOC and 2.0 L/mg-m SUVA
- can achieve .040 mg/l TTHM and .030 mg/l HAA5

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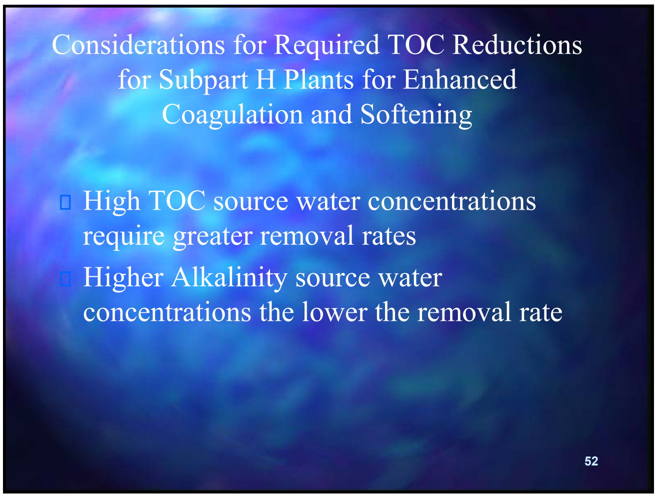
Considerations for Required TOC Reductions for Subpart H Plants for Enhanced Coagulation and Softening
High TOC source water concentrations require greater removal rates
Higher Alkalinity source water concentrations the lower the removal rate
52

52

Water Treatment Plant Safety

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- A SAFETY PROGRAM HAS ONE OBJECTIVE:
- TO PREVENT ACCIDENTS

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Safety Program

Most accidents in a water plant are caused by what?
Negligence and carelessness

- Everyone is responsible for safety
- Management is responsible for the safety of the agency's personnel and the public exposed to the water utility's operations. They also have the responsibility to establish the safety policy and appoint a safety officer.
- Supervisors control the operators' general environment and work habits and influences whether or not the operators comply with safety regulations.
- Operators share in the responsibility for an effective safety program. The development of safe working habits is an employee responsibility.

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STEPS TO AVOID ACCIDENTS

- Ask about the safety program established and actively participate in safety training and tailgate safety meetings.
- Routinely use the safety equipment, i.e. lockout/tag out, SCBA, PPE, hard hats, safety goggles, gloves, etc.
- Follow safety procedures at ALL times.

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Confined Space Definition

(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 (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry.); and

(3) Is not designed for continuous employee occupancy

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Employer's Confined Space Entry Program

- Required for all Employees working in a Confined Space
- Procedures include Permitting System for entering, attendant, testing devises and monitors and personal protective equipments
- Training for all Employees

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Hazardous Atmospheres and Confined Spaces

- Workers may not enter spaces with < 19.5% or > 23.5% Oxygen
- Workers may not enter spaces with a combustible gas concentration of 20% of the Lower Flammable Limit
- Workers may not enter spaces with Threshold Limit Values of Airborne Contaminants established by American Conference of Governmental Industrial Hygienists

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Testing of Atmospheric in Confined Space

- Testing must be conducted before employees enter a trench
- Oxygen must be not less than 19.5%
- Frequency of testing must be increased if equipment is operated in the confined Space
- Testing Frequency must be increased if welding, cutting or burning is occurring

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Confined Space Requirements

- Fitted Respirators must be used in Hazardous Atmospheres
- Employees must be trained in their use and a program established
- Attended (at all times) lifelines must be provided when employees enter bell-bottom pier holes, deep confined spaces, or other similar hazards.
- Employees who enter confined spaces must be trained.

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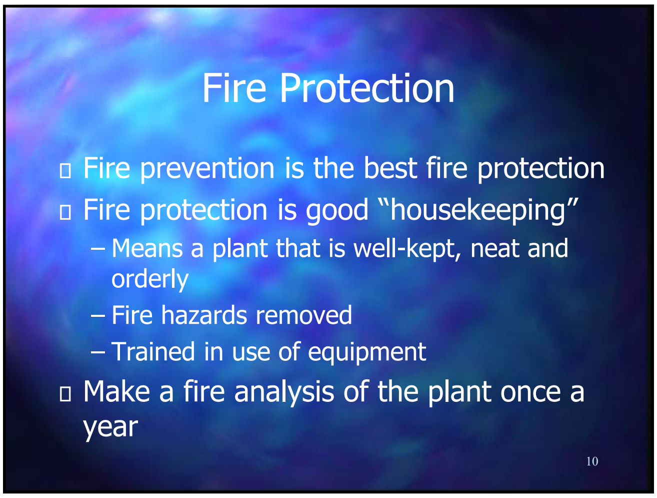
Fire Protection
Fire prevention is the best fire protection
Fire protection is good "housekeeping"
– Means a plant that is well-kept, neat and orderly
– Fire hazards removed
– Trained in use of equipment
Make a fire analysis of the plant once a year
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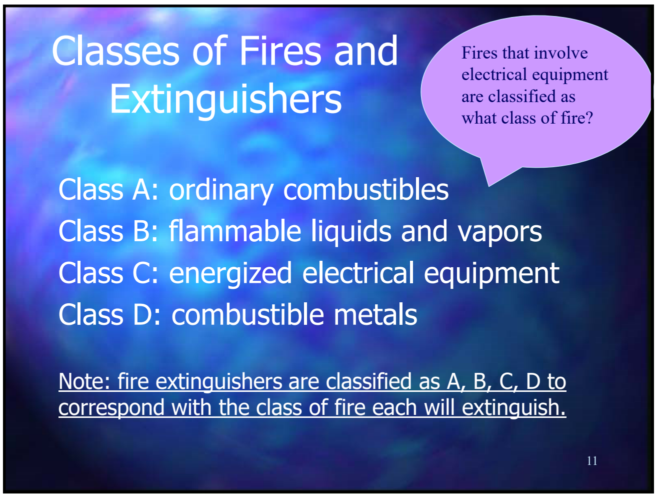
Classes of Fires and Extinguishers
Fires that involve electrical equipment are classified as what class of fire?
Class A: ordinary combustibles
Class B: flammable liquids and vapors
Class C: energized electrical equipment
Class D: combustible metals
Note: fire extinguishers are classified as A, B, C, D to correspond with the class of fire each will extinguish.
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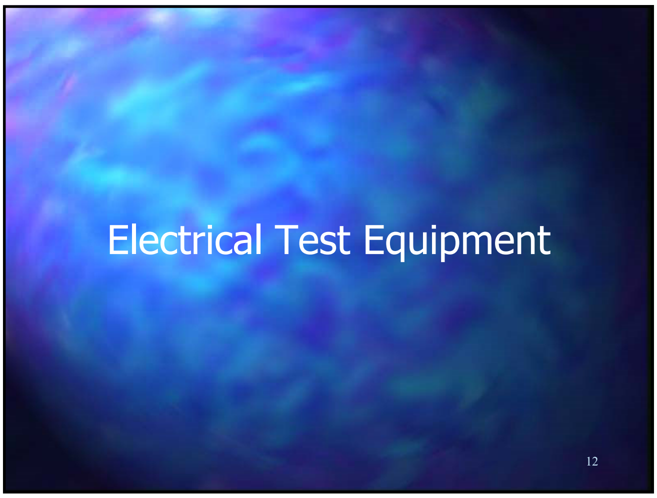
Electrical Test Equipment
12

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Basic Electrical Measurement Devices

NEVER USE A METER UNLESS QUALIFIED AND AUTHORIZED 13

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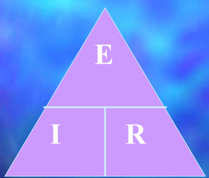
Electrical Relationships



- Voltage (E) is the electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed. Voltage is also called Electromotive Force (E.M.F.)
- Amperage (I) is the strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.
- Ohm (R) is the unit of electrical resistance. The resistance of a conductor in which one volt produces a current of one ampere.

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Voltage Testing (E.M.F.)

- To check voltage use a multimeter
- Used on energized circuits so use caution
- Used to check:
  - to determine if circuit is live
  - voltage (electrical pressure) at each leg
  - electrical components for activation
  - continuity of a circuit or a device such as a fuse

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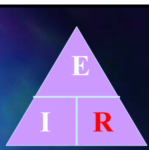
Ohmmeters



- Used to measure the resistance (ohms) in a circuit
- Use only on de-energized circuits
- Often used to:
  - Test the control circuit components of coils, fuses, relays, resistors, and switches
  - Check for continuity

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Some Uses of an Infrared Thermometer

- Check tightness of conduit connections
- Check for high heat that varies from equipment signature

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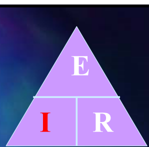
Ammeter: records the current or amps flowing in a circuit



Uses of an ammeter in Testing Pumps and Motors	
Problem	Indication
Pump clogged with rags or other obstructions	Amp Readings that exceed FLA or normal signature
Pump shaft broke or impellor loose	Amp Readings that are significantly under FLA or normal signature
Problem with motor or electrical feed	Motor legs have amp imbalance

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Megger Tester

- Used for checking the insulation resistance on motors, feeders, bus bar systems, grounds and branch circuit wiring.
- Use only on de-energized circuits or motors.
- Results indicate if the insulation is deteriorating or cut
- Motors and wirings should be megged at least once a year.
- Record and plot readings to determine if insulation is breaking down; downward trends may indicate a problem

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Chemical Safety

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Chemical Handling

- Acids are used extensively in water treatment
- Some acids react violently with water such as sulfuric acid
- Always pour acid into water and wear eye protection
- The antidote to all acids is neutralization
- Hydrochloric acid: often used for cleaning; highly reactive to metals and will produce hydrogen gas
- Hydrofluosilicic acid is hazardous to handle under any conditions; use protective equipment

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The antidote to all acids is:

a. Flushing
b. Oxidation
c. Neutralization
d. Chelation

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If an operator comes in contact with chlorine gas and has a throat irritation, what liquid would help reduce the irritation?

a. Water
b. Coke
c. Milk
d. Cough syrup

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Chemical Labeling

- All chemical containers must be labeled, tagged or marked with the identity of hazardous chemical and must show hazard warnings appropriate for employee protection
- The hazard warning can be any type of message, words, pictures or symbols that provides information regarding the hazards of the chemical in the container, generally ANSI standards will be used
- Labels must be legible, in English and all other necessary languages appropriate to the facility
- Exemption to requirement would be for
  - Portable containers in which hazardous chemicals are transferred from labeled containers and that are intended only for the immediate use of the employee who makes the transfer

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Detection and Protection for Hazardous Chemicals

Detection Training

- During training provide samples of hazardous chemicals to observe for odor, color and viscosity
- Prior to observation, review each SDS for hazardous chemical and review
- Go over exposure and symptoms
- Review the standard precaution of any unmarked, unidentifiable chemical. Dispose of as a hazardous chemical.

Protective Measures

- For all hazardous chemicals in your facility you must include in your training employee’s PPE. It is important to provide this training at the same time as SDS training

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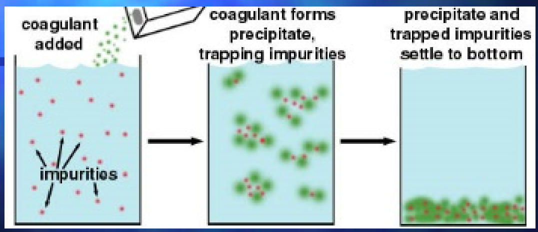
Coagulation and Flocculation



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Coagulation and Flocculation

- Coagulation is a physical and chemical reaction occurring between the "ALKALINITY" of the water and the coagulant added to the water which results in the formation of insoluble flocs (floc that will not dissolve).
- The reaction is very complex and is effected by a variety of factors including :
  - Temperature
  - pH
  - Alkalinity
  - Specific conductance
- Changes in factors may have an impact on the clumping together of floc during the coagulation-flocculation process

What is specific conductance? it is the ability of a water to conduct an electrical current; provides an estimate of the amount of dissolved solids

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Purpose of Coagulation and Flocculation

Remove particulate impurities (turbidity) from the water

- Turbidity is the cloudy appearance of water caused by small suspended particles
- Commonly referred to as non-settleable or colloidal solids

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Particles in Water

- Chemicals in solution (have been completely dissolved in the water).
- Colloidal solids, also known as nonsettleable solids (do not dissolve in water although they are electrically charged).
- Suspended, or settleable solids (will settle out of water over time).

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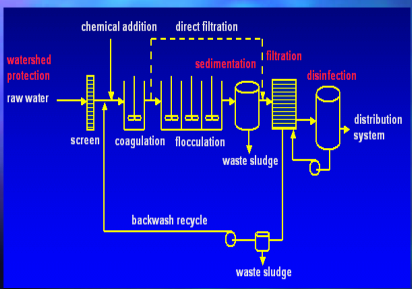
Conventional Coagulation/Flocculation Process



- Pretreatment
- Chemical Feed
- Flash Mixing
- Coagulation & Flocculation (require detention times up to 30 minutes)
- Sedimentation
- Filtration
- Disinfection

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Pretreatment Considerations in the Coagulation/Flocculation Process

Factors that May Dictate Pretreatment
- Leaves, plant material and silt
- Seasonal raw water quality changes caused by drought, high water or temperature changes
- Potential upstream pollution
- Wind conditions
- Algae blooms
- Bacterial problems

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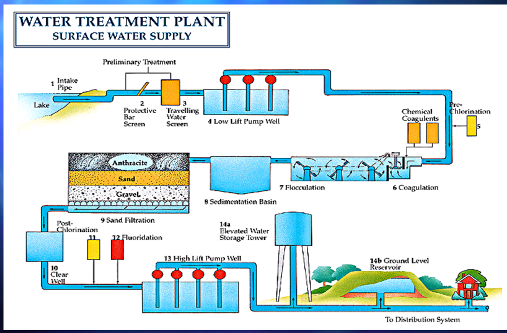
The purpose of surface water intake screen is to remove large solids



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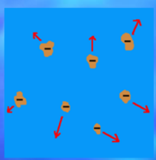
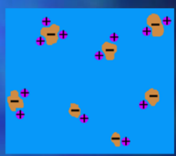
Particle Removal by Coagulation



Negatively charged particles repel each other due to electricity.



Positively charged coagulants attract to negatively charged particles due to electricity.

- Coagulants neutralize negative charged particles
- Allows particles to come closer and form larger clumps
- Provides "agglomeration sites" for larger floc

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Factors Affecting the Effectiveness of the Coagulation Process

- Best pH (pH Range: Al, 5 – 7 ; Fe, 5 – 8)
- Alkalinity of water (> 30 PPM residual)
- Concentration of Salts (affect efficiency)
- Turbidity (constituents and concentration)
- Type of Coagulant used (Al and Fe salts)
- Temperature (colder requires more mixing)
- Adequacy of mixing (dispersion of chemical)

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Chemical Coagulants Used in Water Treatment

Chemical Name	Chemical Formula	Primary Coagulant	Coagulant Aid
Aluminum Sulfate	$Al_2(SO_4)_3$	X	
Ferrous Sulfate	$FeSO_4$	X	
Ferric Sulfate	$Fe_2(SO_4)_3$	X	
Ferric Chloride	$FeCl_3$	X	
Cationic Polymer (+)	Various	X	X
Calcium Hydroxide	$Ca(OH)_2$	X[a]	X
Calcium Oxide	CaO	X[a]	X
Sodium Aluminate	$Na_2Al_2O_4$	X[a]	X
Bentonite	Clay		X
Calcium Carbonate	$CaCO_3$		X
Sodium Silicate	$NaSiO_3$		X
Anionic Polymer (-)	Various		X
Nonionic Polymer	Various		X

[a] - Used as primary coagulant in water softening processes.
Alum is the most commonly used coagulant

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Primary Coagulants

- Primary coagulants are always used in the coagulation/flocculation process. Alum and ferric sulfate are most commonly used.
- Different sources of water need different coagulants to react over a wider pH range.
- Primary coagulants have multivalent charges (+2, +3, +4) which allow them to react with the negatively charged colloidal materials in the water.
- All of the coagulant chemicals will remove alkalinity from the water.
- It may be possible to reduce the coagulant dose by increasing the detention time.

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Coagulant Aids

- Add density to slow-settling floc and add toughness to the flocs so that they will not break up during mixing and settling processes.
- Not always required and are generally used to reduce flocculation time.
- Effective at extending pH ranges for primary coagulant performance.
- Most are expensive.

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Raw Water Parameter	Chemical Consideration
Alkalinity *Alkalinity is a measure of the ability to neutralize acid. Alkalinity levels are typically expressed as calcium carbonate ($CaCO_3$) in mg/L.*	Alkalinity influences how chemicals react with raw water. Too little alkalinity will result in poor floc formation, so the system may want to consider adding a supplemental source of alkalinity (such as lime, soda ash, or caustic soda). **Beware that these supplemental sources of alkalinity may raise the pH of the water, and further pH adjustment may be needed to obtain proper floc formation.** Systems should discuss this issue with a technical assistance provider or a chemical supplier. One rule of thumb is that alum consumes half as much alkalinity as ferric chloride.[1]
Alkalinity < 50 mg/L	This concentration of alkalinity is considered low, and acidic metallic salts, such as ferric chloride or alum, may not provide proper floc formation. Systems may want to consider a high basicity polymer, such as polyaluminum hydroxychloride (PACl), or an alum/polymer blend.[1]
Increase in total organic carbon	More coagulant is typically needed. Remember, organics influence the formation of disinfection byproducts and systems will need to comply with the Stage 1 Disinfection Byproduct Rule. A good resource is the EPA guidance manual *Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual* (May 1999).
pH between 5.5 and 7.5	Optimum pH range for alum.[2]
pH between 5.0 and 8.5	Optimum pH range for ferric salts.[2]
pH > 8.5	Ferric salts might work or other high acidic coagulants[3].
Temperature < 5•C	Alum and ferric salts may not provide proper floc formation. May want to consider using PACl[1] or non-sulphated polyhydroxy aluminum chloride.[3]

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Use of Alum as a Coagulant

- Earliest and most widely used coagulant
- Effective range pH 5.0 to 7.0; (6.5 optimal)
- Effective range for color is ~ 5.5
- Reacts with alkalinity to form floc - results in drop in pH
- For every 2 mg/l Alum; 1 mg/l Lime is added to replace alkalinity; Caustic soda can also be used.

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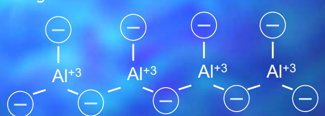
Floc Formation

- The positively charged aluminum ions (Al^{+3}) attract the negatively charged particles that cause color and turbidity, thus forming microfloc.



- The positive charged microfloc particles begin to attract and hold more negatively charged particles in the water.
- The microfloc grows into large settable floc due to adsorption and collison of other floc particles

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Use of Ferrous Sulfate (Copperas) and Lime for Coagulation

- Combination produces Ferric Hydroxide
- pH 8.4 range to 9.0
- Oxygen must added by aeration or chemically such as chlorine
- Very Effective for turbid water
- Care must be taken because color not removed at high pH

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Use of Ferric Chloride as a Coagulant

- Has wider pH range than Ferrous Sulfate
- Typically used where color removal is also desirable.
- Does not require oxygen supplement

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Use of Ferric Sulfate as a Coagulant

- Does not require oxygen supplement
- Effective over wider pH ranges
- Effective within all temperature ranges
- Eliminates odors from existing Hydrogen Sulfide
- Lower doses required than Ferrous Sulfate

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Use of Coagulant Aids

- Lime (Increases the Alkalinity)
- Weighting Agents (Provides binding and forms floc particles large enough to settle out the finer particles).
- Polymers
  - Cationic +
  - Anionic -
  - Nonionic

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Coagulant Mixing and Flash Mixers

Purpose of the flash mix process is to rapidly mix and equally distribute the coagulant chemical throughout the water.

- Coagulant must make contact with all of the suspended particles.
- Process occurs in seconds.
- First results are formation of very small particles.
- Detention time and the speed of the mixer should be sufficient to thoroughly mix all the chemical with no breakup of floc particles.
- If the majority of floc settles within one or two minutes after mixing then too much coagulant was added

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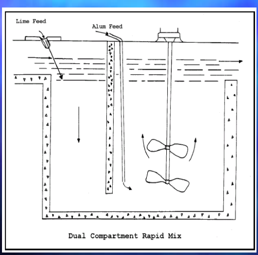
Mixing Coagulants and Coagulant Aids



- Rapid/Flash Mix typically occurs in a tank
- Mixing Devices
  - Mechanical (paddles, turbines, and propellers) are versatile and reliable but use highest amount of energy
  - Diffusers are sensitive to flow changes
  - Pumped blenders – no significant head loss and energy use much less than mechanical
  - Hydraulic uses flow energy in the system
- Mixing velocity 5 – 7 fps
- Coagulant and coagulant aids added in first chamber

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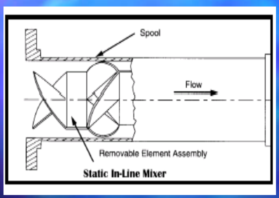
Static Mixer for Polymers



- Used prior to Coagulation
- Addition of oxidizing agents, GAC and polymers
- Used as far as possible upstream to maximize contact time

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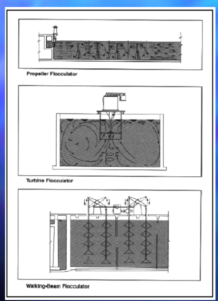
Flocculation Process



- Flocculation is a slow stirring process that causes the gathering together of small, coagulated particles into larger, settleable particles.
- The best flocculation is usually achieved in a compartmentalized basin. Most often three BASINS separated by baffles to prevent SHORT-CIRCUITING.
- Flocculation is controlled by the mixing rate.
- Mixer speed reduced in subsequent tanks to reduce turbulence. This is called tapered-energy mixing.
- Changes in temperature can necessitate longer detention times.

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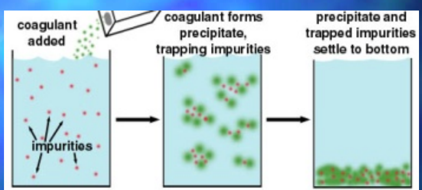
Flocculation Followed by Sedimentation



- Instantaneous mix of coagulants
- Neutralizes the negative charges on colloids
- During the gentle mixing of flocculation, allows particles to agglomerate into larger particles
- Heavier particles are removed by settling

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Importance of Flocculator Speed

- If the speed of the stirring process is to great then the floc particles will be "sheared" or broken apart causing an increase in turbidity.
- If flocculator speed is to slow then "short-circuiting" may occur.
- The Velocity should be about 1ft/sec
- Purpose is to create a floc of good size (0.1 to 3mm), density, and toughness for later removal in the sedimentation and filtration processes.

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FLOCCULATION BASINS

- The actual shape of flocculation basins is determined partially by the flocculator selected.
- The best flocculation is usually achieved in a compartmentalized basin.
- The compartments (most often three) are separated by baffles to prevent short circuiting of the water being treated.

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What is Short-Circuiting?

"A condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water."

May result in shorter contact, reaction, or settling times.

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Desirable Floc Quality

- A popcorn flake is a desirable floc appearance.
- Smooth circular particles tend to settle quicker while irregular shaped particles settle slower.
- Tiny alum floc may be an indication that the chemical dosage is too low.
- If the water has a milky appearance or a bluish tint, the alum dose is probably too high.
- Should be increasing in size as it moves through the basins
- Can be described as discrete and fairly dense in appearance

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Performance Monitoring

What adjustment should be made in the speed of flocculators when the water temperature drops?

Increase Speed

- Mixing needs to be adequate
- Monitor pH for optimum conditions
- Flow measurement is important to accurately establish chemical feed rates, wash water rates, and unit loadings
- Chemical feed systems need dosage control
- Jar Test at the Start of Every Shift or more!

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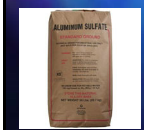
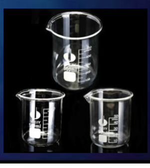
PROCESS CONTROL

- The most important consideration in coagulation-flocculation process control is selection of the proper type and amount of coagulant chemicals to be added to the water being treated.





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Performance Measurement Using the Jar Test

- A jar test is a lab procedure where varying dosages of coagulant are tested in a series of glass or plastic jars under identical conditions to determine the optimum dosage.
- The jars are injected with coagulant dosages and gently paddled or flocculated to match field conditions as closely as possible.
- After a set of time to simulate field conditions the jars are observed to determine which dosage produces the largest, strongest floc or which dosage produces the floc that settles the fastest.
- Other tests sometimes include a jar test to determine the optimal pH or to determine the turbidity of the settled water and its filterability.
- In a conventional treatment plant, when the results of a jar test indicate that 80% of the floc has settled in less than 2 minutes, the floc is too heavy.

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Jar Test Apparatus and Procedures

Flash Mix: 1 Minute at 80 RPM

Flocculation: 30 Minutes at 20 RPM

Settling: 30 Minutes

- Six paddles
- One container is control
- RPM gauge allows for mixing speed to match plant conditions

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Evaluation of Jar Test Results

- Rate of Floc Formation (15 min.)
- Type of Floc Particles (circular or popcorn)
- Clarity of the Water between the Floc
- Size of the Floc (.1 to 3 mm)
- Amount of Floc (too little may need agent)
- Clarity of Water above Settled Floc (clear)
- Volume of Floc

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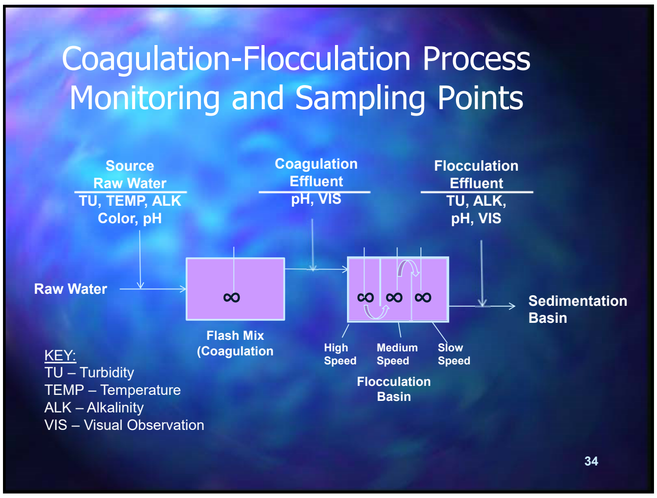
Coagulation-Flocculation Process
Monitoring and Sampling Points
Source
Raw Water
TU, TEMP, ALK
Color, pH
Coagulation
Effluent
pH, VIS
Flocculation
Effluent
TU, ALK,
pH, VIS
Raw Water
Sedimentation
Basin
Flash Mix
(Coagulation
High
Speed
Medium
Speed
Slow
Speed
Flocculation
Basin
KEY:
TU – Turbidity
TEMP – Temperature
ALK – Alkalinity
VIS – Visual Observation
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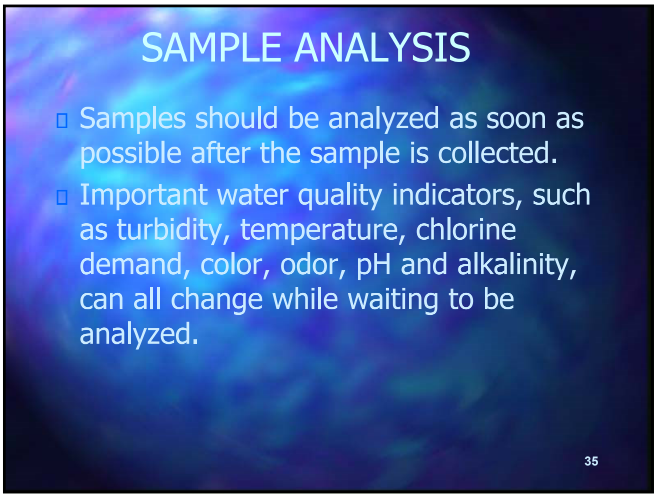
SAMPLE ANALYSIS
Samples should be analyzed as soon as possible after the sample is collected.
Important water quality indicators, such as turbidity, temperature, chlorine demand, color, odor, pH and alkalinity, can all change while waiting to be analyzed.
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Sedimentation

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Theory of Sedimentation

- Decreasing the velocity of water to allow heavier particles to settle out by the effect of gravity.
- Two to four hours detention is usually provided
- Velocity through the basin should be from 1 to 3 feet per minute.

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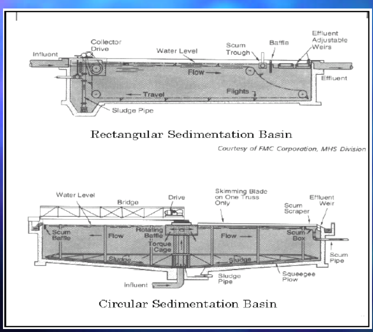
Types of Basins



Rectangular
- Achieve Higher Solids Removal
- Less Sensitive to Short Circuiting

Circular
- More Compact per Unit Space

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Some of the important control and operational guidelines for sedimentation basins are:

- Coagulant Dosage
- Flow Velocity
- Detention Time

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Factors That Affect Particle Settling

1. Particle size and distribution
2. Shape of the particles
3. Density of particles
4. Temperature (viscosity and density of water) when the temperature decreases the settling velocity decreases.
5. Electrical charge on particles
6. Dissolved substances in the water
7. Flocculation characteristics of particles
8. Wind
9. Inlet and outlet conditions and shape of basin

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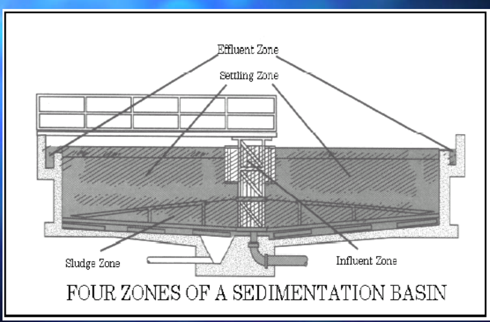
Schematic of a Sedimentation Tank



FOUR ZONES OF A SEDIMENTATION BASIN

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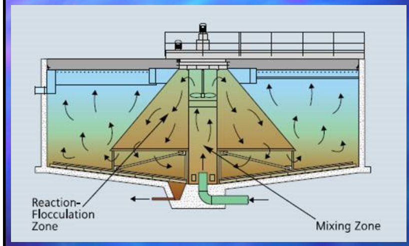
Solids-Contact Units



For most solids contact units, the chemical dosages that produce floc which gives the lowest turbidity within a 5 minute settling period after mixing stops, should be selected as the unit's dosage

- Referred to as an "upflow solids-contact unit" or "upflow sludge-blanket clarification"
- Combine three processes in a single basin. Coagulation, Flocculation, and Sedimentation.
- Sludge is recycled through the process to act as a coagulant aid
- When treating water with poor settling floc it may be necessary to augment the chemical process with polymers

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Influent Sedimentation Zone

- Inlet to the sedimentation basin
- End point in a rectangular tank and middle in a round tank
- Baffles direct flow ensuring lateral flow and prevent short circuiting and carryover.
- Inlet should be designed to minimize high flow velocities near the bottom which could scour settled particles causing them to become resuspended.

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Settling Sedimentation Zone

- Largest Portion of the Tank
- Velocity reduced to 1 to 3 ft/min
- Detention times ranges from 2 to 4 hours
- Overload Loading rates of ~ 800 gpd/ft^2
- Tube and plate settlers can greatly improve settling rates

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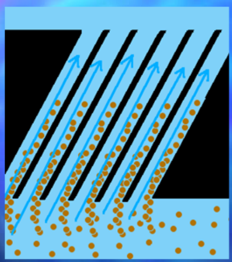
High Rate Settling



Tube settlers and lamella plates - Water flows up through slanted tubes or along slanted plates. Floc settles out in the tubes or plates and drifts back down into the lower portions of the sedimentation basin. Clarified water passes through the tubes or between the plates and then flows out of the basin.

- Tube and plate settlers increase the area to allow more settling
- Use much smaller footprint
- Increase capacity of existing basins. Loading rates 5 to 10 X conventional for plates and 2 to 5 X for tubes
- Placed at 60° angles to allow solids to be removed by gravity
- Currents and wind are dampened by tubes

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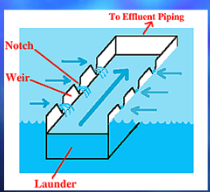
Effluent Sedimentation Zone



- Effluent Lander collects effluent flow
- Weirs along the edge skim water evenly
- Typically weirs have V notches every foot
- Weirs must be kept clean and level to ensure even flow and sludge blanket
- Baffle plate used to retain floating solids
- Weir Loading rates of 10,000 to 14,000 gpd/ft are used

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A rectangular basin has a total flow of 1,000,000 gal/day. There are 6 double sided effluent launders that are six-feet long. What is the weir overflow rate in gal/day/ft?

$$\text{Weir Overflow rate, gal/day/ft} = \frac{\text{total flow, gal/day}}{\text{length of weir, ft}}$$

Total flow is 1,000,000 gal/day
Total Length of Weir is (6, weirs x 2, sides x 6, ft long)
Total Length of Weir is 72 ft

$$\text{Weir Overflow Rate} = \frac{1{,}000{,}000\text{ gal/day}}{72\text{ ft}} = 13{,}889\text{ gpd/ft}$$

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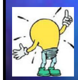
Sludge Sedimentation Zone

- Collection zone at bottom of tank
- Sludge must be removed at min. once per day to prevent septicity and bulking.
  - Useable volume of the tank will decrease, reducing efficiency.
  - Sludge built up on the bottom of the tank may become septic, meaning that it has begun to decay anaerobically.
  - Septic sludge may result in taste and odor problems and may float to the top of the water and become scum.
  - To prevent interference with the settling process (such as resuspension of solids due to scouring).
- Turbine or rake equipped with torque indicator: high torque will break shear pin (too much sludge); fluctuating torque (uneven sludge distribution)



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Performance Monitoring for Sedimentation Processes

Filter effluent turbidity is a good indicator of overall process performance. However you must still monitor performance of each process

- The sedimentation tank is measured by a comparison of the turbidity entering and leaving the basin; measured several times per shift or when quality changes
- Observe clarity of settled water noting size and appearance of any suspended floc
- Ensure clean weirs at influent and effluent
- Observe sludge blanket depth; high blanket depths favor particles passing over weirs at higher flows.
- Remove sludge at min. daily
- Do not exceed loading rates

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Record to be Maintained for Sedimentation Basin Performance

1. Influent and effluent turbidity and influent temperature
2. Process Water Production
3. Process Equipment Performance
4. Solids Removed from Basin

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Short Circuiting in Sedimentation Tanks
Short-circuiting occurs when the path of the flow passes directly through potions of the sedimentation tank; these can usually be observed as floc over the ends of basins.
These high velocities occur under high flow conditions.
Short-circuiting causes particulate matter to be held in suspension and be transported through the tank.
Baffling can help break up the flow paths and can help control short-circuiting.
Sedimentation tanks should not be loaded above tank design overflow rates.
When dealing with chemical floc loading rates must be reduced
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Sludge Treatment and Disposal
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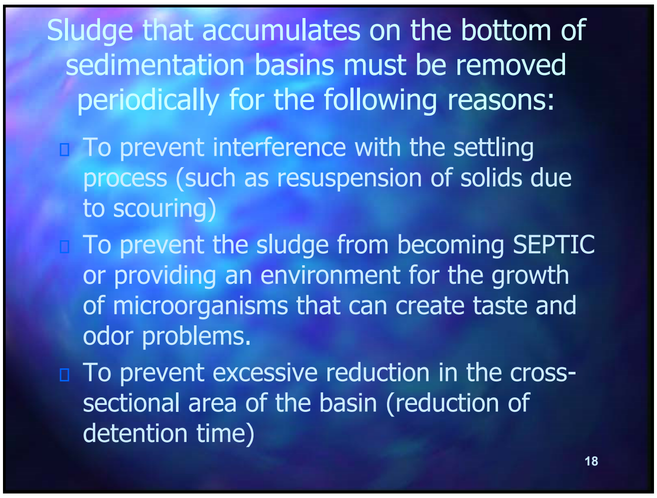
Sludge that accumulates on the bottom of sedimentation basins must be removed periodically for the following reasons:
To prevent interference with the settling process (such as resuspension of solids due to scouring)
To prevent the sludge from becoming SEPTIC or providing an environment for the growth of microorganisms that can create taste and odor problems.
To prevent excessive reduction in the cross-sectional area of the basin (reduction of detention time)
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Volumes of Waste Sludge Produced

Amount of residuals produced is a function of:

- Raw Water Quality
- Facility Design
- Flow
- Treatment Process Employed
  - Lime plants generate 3 pounds of solids for every pound of hardness removed
  - Small alum plants with flows of 0.5 to 1 MGD can generate several 100,000 gallons of alum wastes per year

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Raw Water Constituents that may Limit Disposal Options

- Excessively high or low pH;
- High total suspended solids (TSS);
- High total dissolved solids (TDS);
- High concentrations of heavy metals, including arsenic, lead, and aluminum;
- High concentrations of competing ions, including fluoride, sodium, sulfate, chloride, and other salts concentrations; and,
- High concentrations of radionuclides and daughter products

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DISPOSAL ALTERNATIVES

- Disposal options will be limited by regulation, type of waste (liquid or solid, hazardous or non-hazardous) and the concentrations of contaminants in the waste
- Public law 92-500 restricts or prohibits the discharge of process wastes from water treatment plants. These wastes are considered <u>industrial waste</u> and under the National Pollutant Discharge Elimination System (NPDES) requires a permit to discharge to:
  - Land Disposal and Landfilling
  - Deep Well Injection
  - Discharge to POTW
  - Surface Water Disposal
  - Beneficial Reuse

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Off-site Disposal of Waste Sludge

- Regulations require monitoring of liquid wastes prior to off-site disposal for water quality indicators such as pH, turbidity, TDS, settleable solids and other harmful materials.
- Treatment of liquid waste streams prior to off-site discharge often include:
  - Flow Equalization
  - Brine Recycling
  - pH Neutralization
  - Settling and Gravity Thickening
  - Evaporation
  - Chemical Precipitation

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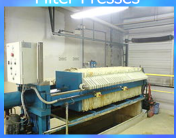
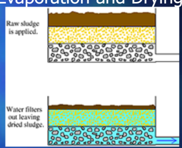
Processing of Liquid Sludge

Filter Presses

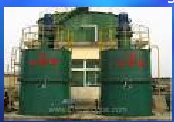


Evaporation and Drying



Drying Bed

Mechanical Dewatering



Centrifuge filter press

Thermal Processing

There are a variety of options for thickening sludge. All reduce the volume of sludge and the cost of handling.

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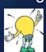
Effects of Concentrating Chemical Sludge

Concentration (% solids)	Volume Total (gallons)	Water Removed (gallons)
2%	10,000	0
4%	5,000	5,000
8%	2,500	7,500
16%	1,250	8,750
32%	625	9,375
64%	312	9,688

FIGURE 1 The goal of any sludge handling system is maximum dewatering at minimum cost.

The liquid from settled sludge is called “Supernatant”



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Filtration

(The final and most important step in the solids removal process)

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Filtration

- The process of passing water through material such as a bed of sand, coal, or other granular substance to remove floc and particulate impurities. Impurities include:
  - Suspended particles (fine silts and clays)
  - COLLOIDS (Turbidity)
  - Biological forms (bacteria and plankton)
  - Floc

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Filtering Mechanisms

Mechanism	Process
Sedimentation	Sedimentation on media
Adsorption	Gathering of particles on the surface of the media or interfaces
Biological Action	Breakdown of organic material by bacteria that cause a mat to develop that stains particles
Absorption	Soaking particles into the body of the media by molecular or chemical action
Straining	Capturing particles in media pore spaces

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Filtration Types

1. Gravity Filtration
   - Sand
   - Dual Media (sand and anthracite coal)
   - Multi or Mixed Media (sand, anthracite coal, and GARNET)
2. Pressure Filtration
   - Mixed Media
3. Diatomaceous Earth Filtration
   - Precoat Filtration
4. Slow Sand

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Solids Removal by Gravity and Pressure Filtration:

- Particulate Matter
- Flocs formed by Coagulation
- Calcium Carbonate and Magnesium Hydroxide Flocs formed in Lime Treatment
- Precipitates such as Iron and Manganese
- Some Microorganisms (effective removal depends upon effective chemical disinfection)

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Gravity and Pressure Filtration Processes

Conventional Filtration

- Filtration is preceded by coagulation, flocculation and sedimentation
- Conventional Filtration plants require flocculation detention times up to 30 minutes.

Direct Filtration

- Same as conventional filtration without sedimentation

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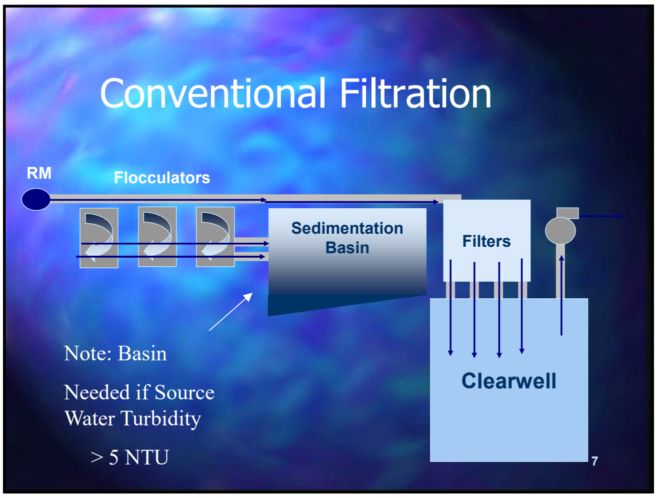
Conventional Filtration
RM
Flocculators
Sedimentation Basin
Filters
Clearwell
Note: Basin
Needed if Source Water Turbidity
> 5 NTU
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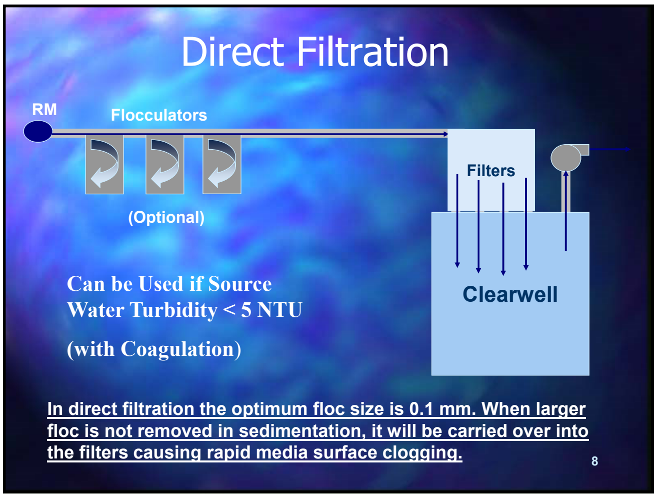
Direct Filtration
RM
Flocculators
(Optional)
Filters
Clearwell
Can be Used if Source Water Turbidity < 5 NTU
(with Coagulation)
In direct filtration the optimum floc size is 0.1 mm. When larger floc is not removed in sedimentation, it will be carried over into the filters causing rapid media surface clogging.
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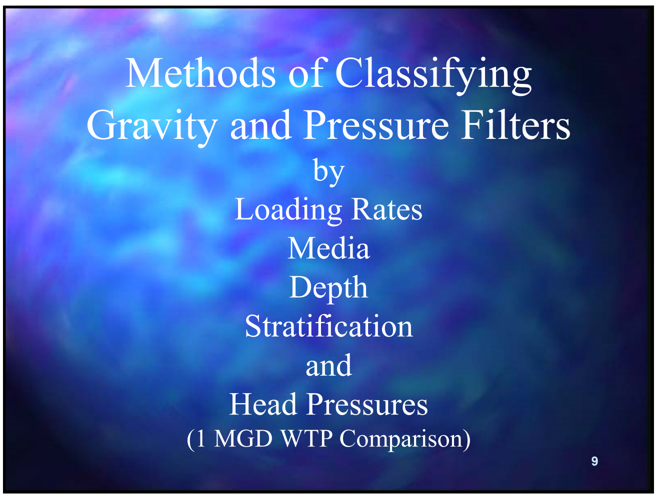
Methods of Classifying Gravity and Pressure Filters
by
Loading Rates
Media
Depth
Stratification
and
Head Pressures
(1 MGD WTP Comparison)
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General Properties Filtration Media

- Coarse enough to retain large quantities of floc
- Sufficiently fine to prevent passage of suspended solids
- Deep enough to allow relatively long filter runs
- Graded to permit backwash cleaning

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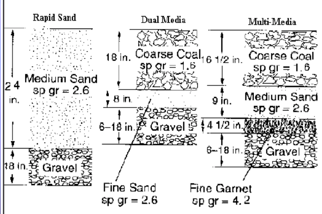
Media Configurations for Gravity Filters



Filter Media Configurations

- Single media (sand)
- Dual Media (sand and anthracite)
- Mixed or multi-media (sand, anthracite and garnet)

How does the uniformity of the media in a gravity filter affect the head loss? The more uniform the media, the slower the head loss build up.

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Filter Media Characteristics

Filter	Media	Size (mm)	Spec Grav	Depth (in)	Flow Type	Flow gpm/sf
Slow Sand	Fine Sand	0.2	2.6	36 – 48	Gravity	.05 - .03
Rapid Sand	Course Sand	0.35 – 1.0	2.6	24 – 36	Gravity	2 – 4
Dual Media	Anthracite Sand	0.9 – 1.2 0,4 – 0,55	1.4 – 1.6 2.6	18 – 24 6 – 10	Gravity	4 – 5
Mixed Media	Anthracite Sand Garnet	0.9 – 1.2 0,4 – 0,55 0.2	1.4 – 1.6 2.6 4.2	16.5 9 4.5	Gravity	5
Diatom. Earth	Diatomaceous	0.005 to 0,125		1/16 to 1/8	Pressure or Vacuum	0.5 – 5
Pressure	All Media	Application			Pressure	2 – 4

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Characteristic	Rapid Sand	Slow Sand	Diatomaceous Earth or Pressure Filter
Filtration Rate	2 gpm/sft.	.06 gpm/sft.	1 gpm/sf
Filtration Area	350 sft.	11,000 sft.	700 sft.
Depth of Media	18" gravel 30" sand Permanent	12" gravel 42" sand to 12" after ultimate use	1/16 to 1/8" surface Recoating Required
Size of Sand (Uniformity Coef .)	.35 to .80 mm U.C<1.7.	.20 to .40 mm U.C.<2.5	.01 to .20 mm
Media Distribution	Stratified	Unstratified	Unstratified
Loss of Head	< 1 ft. initial 9 ft. final	0.2 ft. initial 4 ft. final	2 psi (5 ft.) initial 30 psi (70 ft.) final
Cycle Time	To 200 hrs.	60 days	To 40 hrs
Penetration of Matter	Deep Vertical	Shallow	Surface
Cleaning Method	Backwash/expansion	Surface Scraping of Schmutzdecke	Air Bump/Backwash
Wash Water Used	> 1%	< 0.6 %	< 1%
Pretreatment	Coagulation Flocculation Sedimentation	None Sometimes Aeration And/or Presettling	None, sometimes Aeration, Presettling or micro screening
Chlorination	Always	Always	Always
Raw Water Quality	High Turbidity High Color Moderate Algae	Moderate Turbidity Low Color Moderate Algae	Low Turbidity Low Color Low Algae
Hydraulic Type	Gravity Flow	Gravity Flow	Vacuum or Pressure

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Media Type, Backwashing Frequency and Maximum Loading Rate

Dual and Multimedia Filters allow more time between Backwashing and can handle higher flow rates through the filter with the same removal efficiency.

- Sand Only 2 GPM/sf.
- Dual or Multi-Media 4 GPM/sf.
- Deep Bed (depth > 60") 6 GPM/sf.

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Filter Components

- Inlet chamber
- Filter media
- Underdrain
- Washwater trough/ Backwash trough
- Effluent Chamber
- Scouring Mechanism

Water or other liquids flowing into a reservoir, basin, or treatment process is called?
Influent

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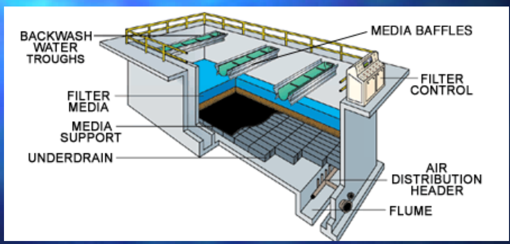
Standard Filter Configuration



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Purpose and Types of Underdrains

- Support the filter media
- Collect the filtered water
- Distribute the water for backwashing and air scouring
- Common types of underdrains include:
  - High-density polyethylene underdrain block
  - Plastic nozzle underdrain systems

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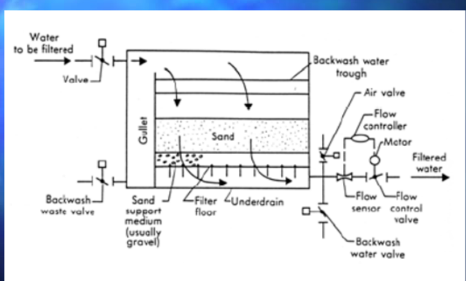
Filter Operation



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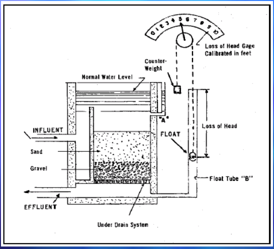
Head Loss Control



- Head loss/Clogging through a filter is due to friction losses caused by material building up on the surface or in the top part of the filter
- Loss of head gauge indicates when a filter should be backwashed
- Generally 8 ft head max. allowable loss
- Some Systems also use Turbidity Meter

Measurement of head loss in a filter gives a good indication of when backwashing is required.

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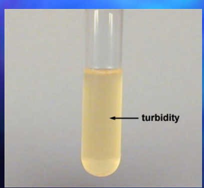
FILTER CLOGGING



- Clogging of the filter leads to Breakthrough, a condition in which solids are no longer removed by the already overloaded filter, causing an increase in turbidity

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Gravity Filter Backwashing

- All filters clean in backwash. In order to achieve a proper bed expansion for cleaning, choosing your media is, in many cases, dependent on the well pump flow rate.
- If the chosen filter requires a backwash flow rate of 10 gpm and the pump only produces 7 gpm, the bed will not clean completely and though it may take a few months to a year, the bed will foul prematurely.

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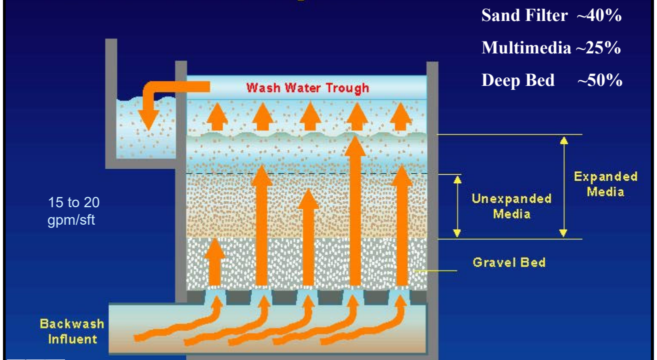
Filter Bed Expansion



Backwash rate must be high enough to cause the media grains to agitate violently and rub against each other.

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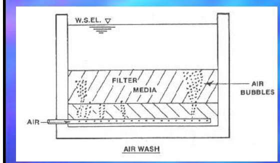
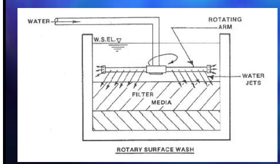
Filter Scouring Considerations



Air Scour

- Generally run before or during initial backwash
- Stops before bed is fully expanded to prevent media loss
- Stop and run Backwash 2 min to restratify bed



Surface Water Scour

- Fixed or Rotating Arm
- Break up Surface Mats
- Also used during backwash to clean media

23

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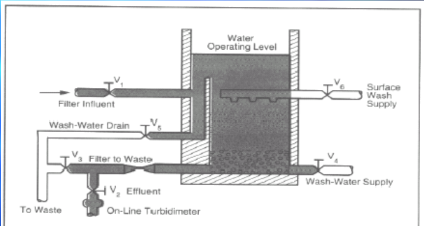
Filter Backwashing Procedures



Valve Position During Filtration

Valve	*Filtering*	*Backwashing*	*Filtering to Waste*
V_1 — Influent	Open	Closed	Open
V_2 — Effluent	Open	Closed	Closed
V_3 — Filter to Waste	Closed	Closed	Open
V_4 — Wash-Water Supply	Closed	Open	Closed
V_5 — Wash-Water Drain	Closed	Open	Closed
V_6 — Surface Wash Supply	Closed	Open	Closed

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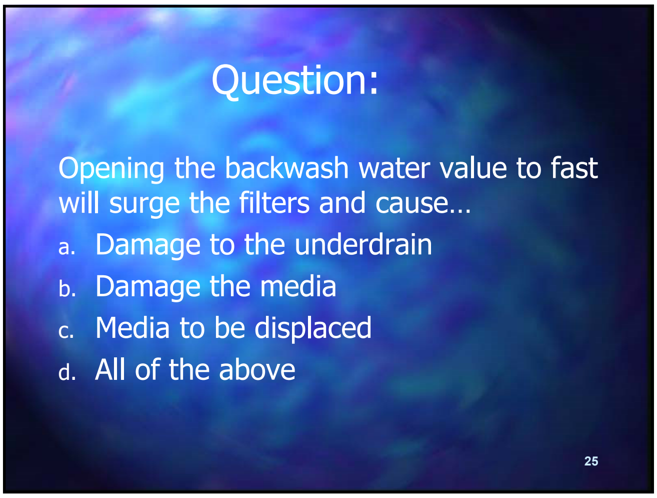
Question:
Opening the backwash water value to fast will surge the filters and cause…
a. Damage to the underdrain
b. Damage the media
c. Media to be displaced
d. All of the above
25

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Recognizing and Correcting Filter Problems
26

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Filter Performance Troubleshooting
Filter Problems: operational, mechanical equipment failure, media failure
Turbidity Errors: calibration, air bubbles, debris
Chemical Feed Failures: coagulant, coagulant aid, filter aid
Poor Water Quality: increased turbidity, algae
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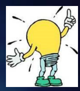
Problems Caused By Improper Backwashing Techniques



- Mudballs
- Surface Cracking
- Media Boils
- Air Binding

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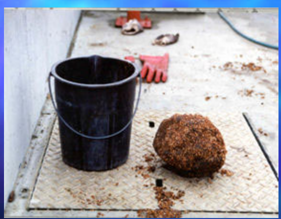
Large Mudball
Typical Size ¼" to 2+" dia.



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Troubleshooting Mudballs

Problem
Mud ball formation in the filter bed.

Cause/Check
- Over Dosing
- Poor coagulation
- Poor Sedimentation
- Improper Backwashing

The best way to prevent mudball formation is to employ?

Proper Backwashing

Result
- Shortened filter runs
- Loss of filter capacity

Solution
- Correct coagulation and sedimentation problems
- Adjust backwash cycle
- Manually remove mudballs (hoses or rakes)
- Generally, proper surface washing will prevent formation

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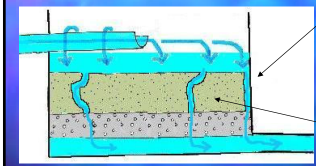
Surface Cracking in a Filter



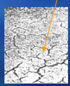
Retraction:

Filter Media Separation along wall.

Filter Cracking:

Cracks on the Filter Surface.

- 12 inches long **or**
- ¼-inch wide **or**
- ½-inch deep.



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Troubleshooting Surface Cracking

Problem

Surface Cracking

Cause/Check

- Caused by compressible matter around media at surface
- Excessive filtration rate
- Filter runs too long

Result

- Breakthrough of untreated water
- Sudden increase in effluent turbidity

Solution

- Adjust backwash cycle

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Media Boils in a Filtration System

Gravel Movement in Media Bed

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Troubleshooting Media Boils

Problem

Media boils

Cause/Check

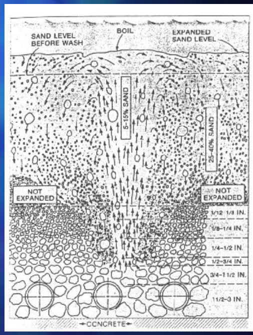
- Backwash valve opened too quickly, surging gravel
- Plugged filter underdrain causing uneven distribution

Result

- Filter media washed into underdrain and lost

Solution

- Remove filter media and rebuild



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Air Binding

Problem

Shortened filter runs because of air-bound filters.

Cause/Check

- Low pressure/decrease in the pressure of the water during filtration (negative head)
- Release of dissolved gases from the water into the filter or underdrain
- Air prevents water from passing through the filter.
- Filtering of very cold, supersaturated water
- When a filter is operated to a head loss that exceeds the head of water over the media, air will be released

Result

- Prevent the passage of water during the filtration process causing shorter filter runs
- Can cause loss of filter media during the backwash process

Solution

- Adjust backwash cycle (more frequent)

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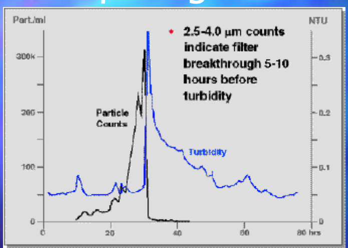
Anticipating Filter Breakthrough



If the filter loss of head gauge is broken the Best test to determine the time to backwash is: The Turbidity of the water and elapsed time.

Filter Process Control

- Head Pressure
- The pressure loss through a filter caused by clogging of the media is head loss
- Increase in Turbidity

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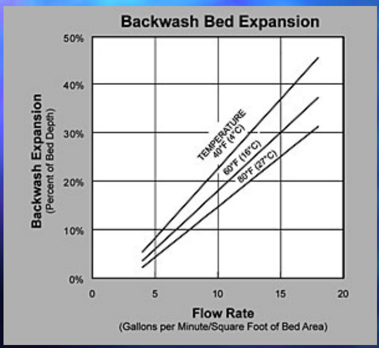
Effects of Temperature on Backwashing



- Colder water will expand the media more than warmer water
- Comparing 40°F to water at 80°F the media will expand by an additional 50%
- If the manufacturer recommends a backwash rate of 10 to 12 gpm per square foot, use the low range on cold water and the high range on warmer water

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Special Application Filters

Greensand for Iron Removal
Activated Carbon for Organic Removal

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Greensand Media for Iron and Manganese Removal

- Greensand added to filter media
- Greensand is a Natural Resin specific to Iron and Manganese
- Oxidize iron and manganese to their insoluble oxides
- Regenerated by adding potassium permanganate until pink color is achieved
- For the process of a greensand filter to be effective the chemical of potassium permanganate is necessary

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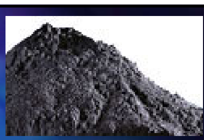
Powdered Activated Carbon Filtration for Taste and Odor Removal



- Added at flash mixer in coagulation process or ahead of conventional filter using a dry or wet slurry
- Dry Feeders used for batches and Slurry feeders used for continuous feeds.
- Effective at doses from 1 to 15 mg/l for taste and odors but > 100 mg/l for THM or precursor removal
- PAC is removed from the water before it reaches the consumer by filtration.

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Granular Activated Carbon Filter for Taste and Odor

- Used as a separate media layer or as a "contactor" following filtration
- Requires 10 minutes of contact time with filter media
- High adsorptive capacity enables it to remove taste and odor-causing compounds.

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Slow Sand Filtration

- Straining
  - Particles are big and trapped on surface
  - Increase effectiveness by coagulation/flocculation
- Adsorption
  - Particles stick to the media
- Biological Action
  - A dense layer of microorganisms develops on the surface. These organisms feed on and break down organic material that get trapped on the mat (called a "schmutzdecke" (sh-moots-Deck-ee)

42

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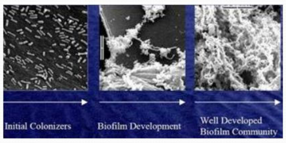
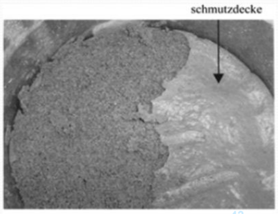
Biological Layer: The Schmutzdecke

- Due to the organic and biological matter in the water to be filtered, a bio-layer grows on top of the sand layer
- The bio-layer contributes to water treatment by consuming organic contaminants including bacteria and viruses
- A four week period of saturation before drinking is suggested so the layer fully develops
- The majority of biological activity occurs in the top 20 cm of the filter



Biofilm Development



Layer of Schmutzdecke

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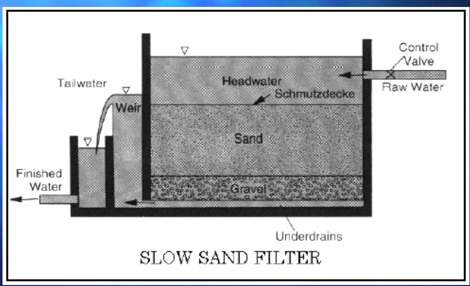
Slow Sand Filter Configuration



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Benefits of Slow Sand Filtration

- Effective in reducing disinfection by-product precursors
- Effective at removing Giardia lamblia cysts, Cryptosporidia, coliforms, and other microorganisms
- Require very little operator attention
- Very Reliable

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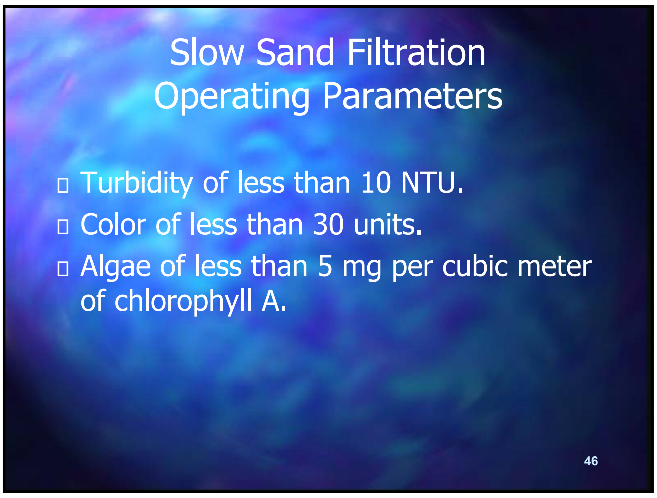
Slow Sand Filtration
Operating Parameters
Turbidity of less than 10 NTU.
Color of less than 30 units.
Algae of less than 5 mg per cubic meter of chlorophyll A.
46

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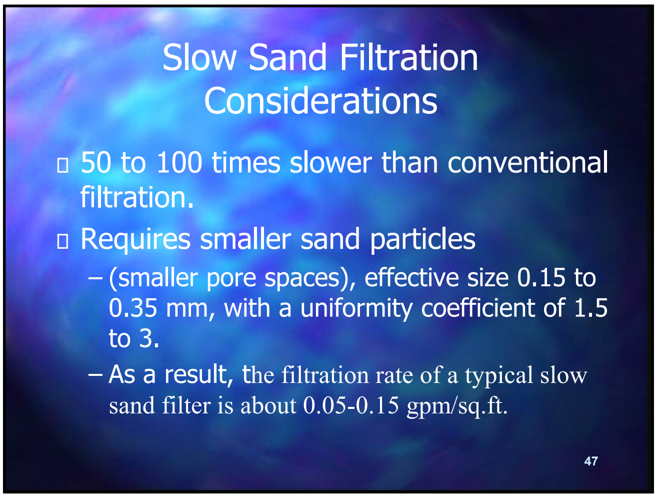
Slow Sand Filtration
Considerations
50 to 100 times slower than conventional filtration.
Requires smaller sand particles
– (smaller pore spaces), effective size 0.15 to 0.35 mm, with a uniformity coefficient of 1.5 to 3.
– As a result, the filtration rate of a typical slow sand filter is about 0.05-0.15 gpm/sq.ft.
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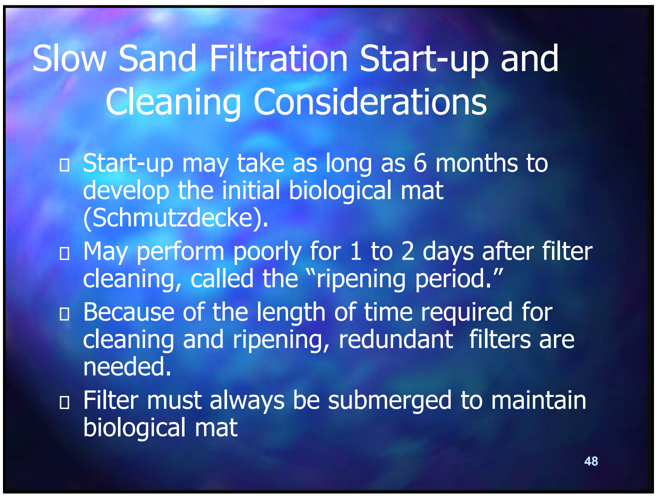
Slow Sand Filtration Start-up and
Cleaning Considerations
Start-up may take as long as 6 months to develop the initial biological mat (Schmutzdecke).
May perform poorly for 1 to 2 days after filter cleaning, called the "ripening period."
Because of the length of time required for cleaning and ripening, redundant filters are needed.
Filter must always be submerged to maintain biological mat
48

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Cleaning Slow Sand Filters
Filter cleaning
The normal length of time between cleanings is 20 to 90 days.
Cleaning involves scraping manually 1 to 2 inches and discarding the sand.
New sand should be added when sand depth approaches 24 inches, approximately every 10 years.
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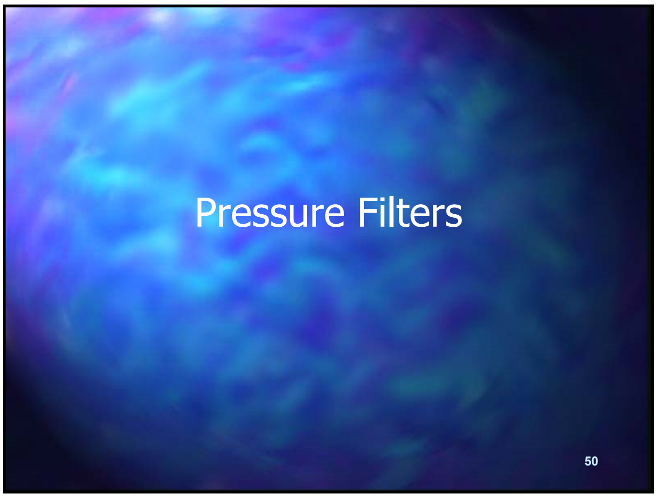
Pressure Filters
50

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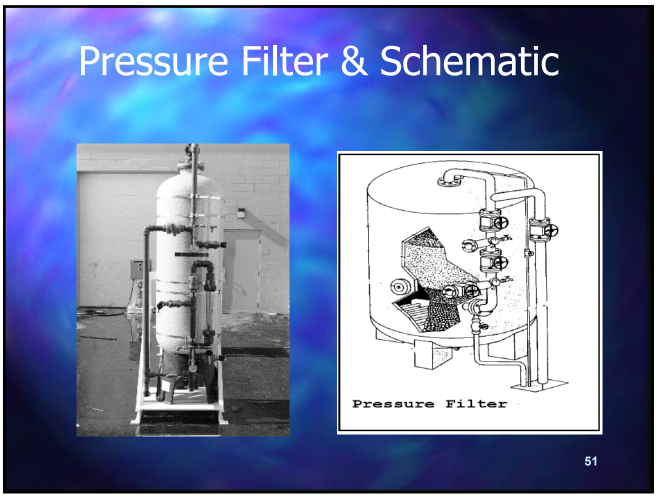
Pressure Filter & Schematic
Pressure Filter
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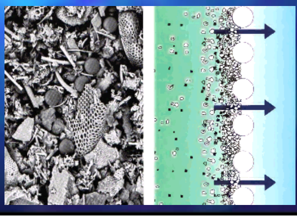
Diatomaceous Earth Filtration

- Filter is composed of siliceous skeletons of microscopic plants called diatoms or diatomaceous Earth.
- Skeletons are irregular in shape therefore particles interlace and overlay in a random strawpile pattern which makes it very effective for Giardia and crypto removal.



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Diatomaceous Earth Filtration Precoat Considerations

- Difficulty in maintaining a perfect film of DE of at least 0.3 cm (1/8 in) thick has discouraged widespread use except in waters with low turbidity and low bacteria counts.
- The minimum amount of filter precoat should be 0.2 lb/sft and the minimum thickness of precoat should be 0.5 to enhance cyst removal.

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Bag and Cartridge Filter Technologies

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Bag and Cartridge Filter Loading Rates

- Used generally for polishing flow into RO unit
- Filter can accommodate flows up to 50 gpm.
- As the turbidity increases the life of the filters decreases; bags will last only a few hours with turbidity > 1 NTU.
- Operate by physically straining the water
- Can operate down to ~ 1.0 micron

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Application of Bag and Cartridge Filters as Finishing Filters

- For a conventional or direct filtration plant that is on the borderline of compliance installing bag/cart filtration takes the pressure off by increasing the turbidity level to 1 NTU
- Increases public health protection by applying two physical removal technologies in series

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Operator Functions Related to Filtration

- Monitor process performance
- Evaluate water quality conditions (turbidity, head loss, color) and make appropriate changes
- Check and adjust process equipment (change chemical feed rates)
- Backwash filters
- Evaluate filter media condition (media loss, mudballs, cracking, boils)
- Visually inspect facilities

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Demineralization
(RO, NF, UF, MF, ED, IE)

"The purpose of demineralization is to separate minerals from water"

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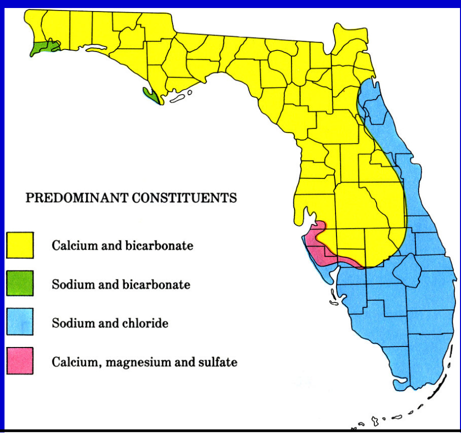
Predominant Constituents of Dissolved Solids



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Water Supply Classification

- Fresh Water, less than 1,000 mg/l TDS
- Brackish Water, 1,000 – 10,000 mg/l TDS
- Seawater, 35,000 mg/l TDS

3

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Types of Demineralization Processes

Phase Change

- Freezing
- Distillation

(Seawater)

Non-Phase Change

- Reverse Osmosis (Membrane Filtration)
- Electro Dialysis
- Ion Exchange

(Fresh to Brackish)

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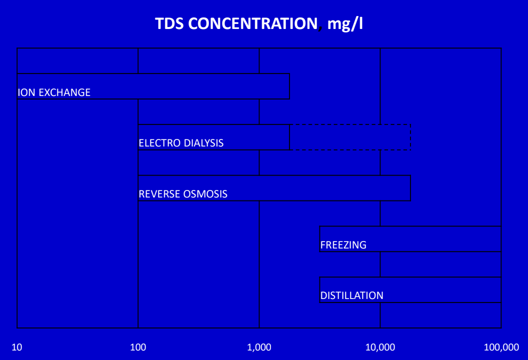

Note: The dashed lines indicate a feasible range of operation, but not typical range.

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Selection of Demineralization Process

- Mineral Concentration in Source Water (The lower the minerals the easier to produce potable water)
- Product Water Quality Required (Compliance with Primary Drinking Water Standards)
- Brine Disposal Alternatives (Problematic) deep well injection is expensive.
- Pretreatment Required (particle removal)
- Other Particle Removal Considerations
- Cost Effectiveness

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Selective Membrane Treatment Comparison

Membrane Process	Reverse Osmosis	Nano-Filtration	Ultra-Filtration	Micro-Filtration	No Membrane Particle Filtration
Retained	Most Everything	Higher Charged Ions	Larger Molecules	Larger Particles	Gross Particles
Passed	Very Small Uncharged molecules	Monovalent ions and Small molecules	Small molecules and ions	Dissolved Salts and small particles	Colliods, TDS and minerals

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Membrane Filtration

"The ability of the membrane to reject minerals is called the mineral rejection."

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Pressure Filtration Membrane Treatment Systems

(water flux is dependent on the applied pressure)

Higher Pressures (150 to 1200 PSI)

1200

- Desalination Reverse Osmosis
- Conventional Reverse Osmosis (250)
- Nanofiltration Reverse Osmosis

150

Lower Pressure (20 to 70 PSI)

150

- Electrodialysis
- Ultrafiltration
- Microfiltration
- (Conventional)

0

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REVERSE OSMOSIS (includes RO, NF, UF, MF)

- Osmosis can be defined as the passage of a liquid from a weak solution to a more concentrated solution across a semi-permeable membrane.
- The membrane allows the passage of the water (solvent) but not the dissolved solids (solutes).
- The water flux is the flow of water in grams per second through a membrane area of one square centimeter or in gallons per day per square foot.
- From the previous slide we see that: the water flux is dependent on the applied pressure, while the mineral flux is not dependent on pressure.
- The water that has passed through the membrane in the RO process is called permeate.

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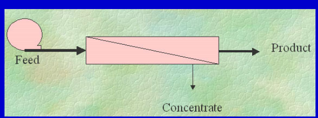
Reverse Osmosis

- Reverse Osmosis (RO) systems are used for inorganic mineral removal and for saline water including desalination of sea water.
- RO excludes atoms and molecules < 0.001 microns; the ionic or mineral size range.



RO Treatment Element

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Reverse Osmosis Treatment

- Two types of selective membranes are used for demineralization: Cellulose Acetate and Thin Film Composite
- Operated at 200 to 400 psi, @ 5.5 pH
- Salt Rejection above 95%*
- Quality and Quantity of Permeate increase with higher Pressure
- Flow (Flux) Rate depends on Mineral Concentration
- Subject to Fouling from biological contaminants

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Components of a Reverse Osmosis System

- Pressure Vessel Housing
- *Concentrate Control Valve
- Sample Valves
- Flush Connection
- Cleaning Connections
- Permeate Rinse Valve
- Permeate Drawback Tank
- Membranes
- Pumps
- Piping

* Never leave the Concentrate Control Valve Closed as it can damage the membrane

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Reverse Osmosis Treatment Operating Considerations

- Used for mineral removal only
- Turbidity <1 NTU; high turbidity causes deposition of particulate matter on membrane resulting in fouling
- Flux Range 15 – 20 GFD (gallons Flux per day per sq. ft. membrane surface)

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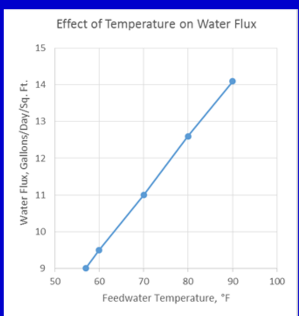
Reverse Osmosis Treatment Operating Considerations

Temperature

- As temperature of feedwater increases the flux increases
- Flux is usually reported at a std temperature



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Types of Semipermeable Membranes

As the membrane hydrolyzes, both the amount of water and the amount of solute which permeate the membrane increase and the quality of the product water deteriorates. T or F **True**

Cellulose Acetate
- First commercially available membrane
- Operating pressure: 400 psi
- Operating pH: 4.0 – 6.0
- Flux rate: 25 GFD (gallons of flux per square foot per day)
- Subject to biological attack and hydrolysis (lessons mineral rejection capability over time)

Thin Film Composites
- Operating pressure: 200 psi
- Operating pH: 3.0 – 10.0
- More expensive than cellulose acetate membrane
- Higher rejection (98%) and flux rates (25 – 30 GFD)
- Not subject to biological attack, hydrolysis, or compaction but is sensitive to oxidants in feedwater

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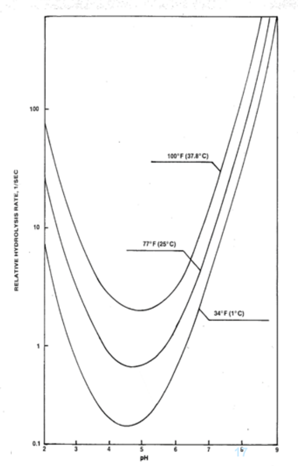
Effect of Temperature and pH on Hydrolysis Rate for Cellulose Acetate Membranes In order to slow hydrolysis an acid is added as pretreatment BEFORE Demineralization



Effect of temperature and pH on hydrolysis rate for cellulose acetate membrane

17

- Hydrolysis - Hydrolysis refers to the chemical breakdown of a reverse osmosis membrane from exposure to low or high pH, bio-activity and temperature. Normally associated with cellulose acetate membranes where the acetyl groups are replaced by hydroxyl groups. Hydrolysis in increased salt leakage (i.e. greater conductivity of the permeate) and a lower feed pressure requirement.

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Membrane Configurations

- Spiral Wound
- Hollow Fine Fiber
- Tubular

(Which membrane used would depend on the type of treatment.)

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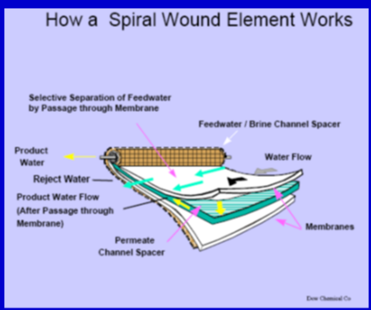
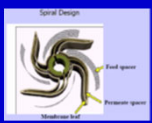
Spiral Wound Membrane Element Configuration





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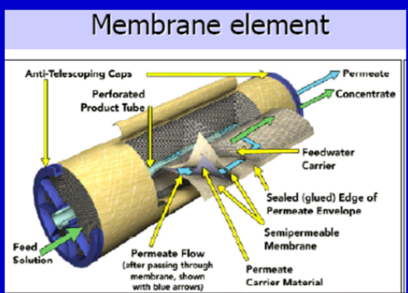
Membrane Element Configuration



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Spiral Wound Membrane

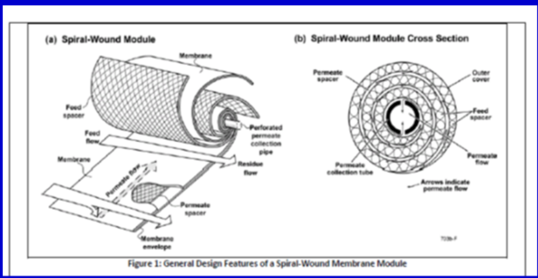

Figure 1: General Design Features of a Spiral-Wound Membrane Module

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Hollow Fine Fiber Membrane Element Configuration

- Fibers are placed in a pressure vessel
- Membranes are about the size of a human hair
- Brackish water is under pressure on outside of fibers
- Product water flows inside of the fiber to the open end

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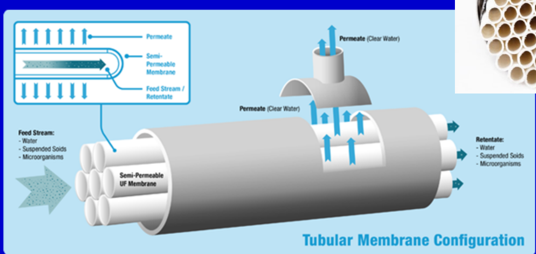
Tubular Membrane Element Configuration



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Constituents Affecting the Reverse Osmosis Process

- pH – slows hydrolysis and extends life of cellulose acetate membranes
- Temperature – as the temperature of the feedwater increases, flux increases (max temp is 104 degrees)
- Suspended Solids & Turbidity (susceptible to fouling)
- Mineral Content (salts)
- Microbes

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pH Adjustment with Reverse Osmosis

- pH is lowered with acid prior to treatment to prevent minerals from coming out of solution and clogging membranes
- A pH of 5.5 is standard for most feedwater
- If pH and temp. are allowed to increase, Hydrolysis (breakdown of the acetate membranes) will occur and mineral rejection will decrease

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Pretreatment Requirements for Reverse Osmosis Systems

What is the most frequently used scale inhibitor?

Hexametaphosphate

Constituent	Problem	Treatment
Gross suspended particulates	Blockage	Media Filtration
Colloidal materials	Fouling	Coagulation/Filtration
Microbiological Matter	Fouling	Add oxidizing agent
Oxidizing agents (Cl)	Failure	GAC or Dechlorination
Carbonates (CO_3, HCO_3)	Scaling	pH adjust or softening
Sulfate (SO_4)	Scaling	Inhibitor or Cation Rem.
Silica	Scaling	Lime Softening
Iron (Ferric, +3)	Scale/Foul	Greensand (no aeration)
Hydrogen Sulfide (H_2S)	Scale/Foul	Degasification

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Removal of Microbial Contaminants with Reverse Osmosis

- The bacterial film covering the entire filtration area of a membrane is known as confluent growth.
- Organisms removed to keep them from fouling or plugging membranes.
- Organisms can be removed by pre-chlorination and maintaining 1 to 2 mg/l chlorine residual through the RO process. Too much chlorine can impair membrane efficiency.
- If oxidant-intolerant (composite polyamide-type) membranes are used then chlorination must be followed by de-chlorination

Why is chlorine added to the feedwater of an RO unit?

Prevent Biological Fouling

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Polarization in Reverse Osmosis Systems

- Polarization is the buildup of mineral deposits along the edges of the membrane.
- Polarization reduces both flux and reject
- Polarization is reduced by increasing flow velocity causing deposits to breakaway from the membrane walls.
- Brine flow rates can be kept high as product water is removed by staging.
- The most common and serious problem resulting from concentration polarization is the increasing tendency for precipitation of sparingly soluble salts and the deposition of particulate matter on the membrane surface.

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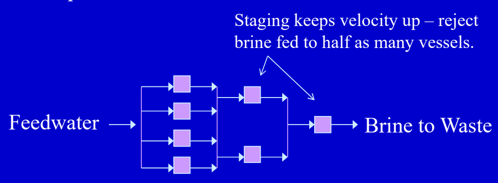
Staging

Vessels in a 4-2-1 configuration yields an 85% recovery of feedwater as product water.



Product Water not Shown

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NF and RO Comparison

Softening (Nanofiltration)
- Applied pressure: 150 psi
- Min Salt Rejection: 75-80%
- Hardness Rejection >95%
- Flux Range: 25 – 30 GFD
- Used for softening or special applications

Reverse Osmosis
- Applied Pressure: 225 psi
- Min Salt Rejection: 97-98%
- Hardness Rejection >99%
- Flux Range: 25-30 GFD
- Used for mineral removal

GFD – gallons of flux per sq. ft. per day

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When Should RO Elements be Cleaned?

- Element cleaning should be performed at regular intervals to keep pressure as low as possible.
  - When pressure to maintain rated capacity increases by 15%.
  - When product water flow decreases by 15% at constant pressure.
  - When a rise of 15% in the system differential pressure has been observed.
- Symptoms of membrane fouling
  - Lower product water flow rate
  - Lower salt rejection

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How to Clean RO Membranes

- To remove inorganic precipitates, use an acid flush of citric acid.
- For biological or organic fouling, use various solutions of detergents, sequestrants, chelating agents, bactericides, or enzymes.
- Clean at low pressure not to exceed 60 psi.
- Membranes are typically cleaned for approximately 45 minutes.

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Ultrafiltration Membrane Systems

- Generally used for Pretreatment
- Can replace several treatment processes (Coagulation, Flocculation, Sedimentation)
- Extremely flexible for changed feed water conditions
- Operates at 50 psi

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Ultrafiltration Operation

- Units are operated in parallel with some product recirculated to maintain high flow velocity
- Increase recirculation rates for higher TDS removal
- Units are backwashed to remove fouling with product water

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Microfiltration Membrane Filtration Treatment Process

- Microfiltration is used for removal of particles, suspended solids, bacteria and cysts in source water.
- Organics are not removed.
- Operates at 20 to 35 PSI.
- Typically used for Pretreatment in front of RO Systems

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Advantages of Microfiltration

- Highly automated with little operator attention
- Water quality achieved regardless of source water changes
- Chlorine Demand Reduced
- Replaces conventional treatment processes
- Wide flow ranges (.6 to 22 MGD)

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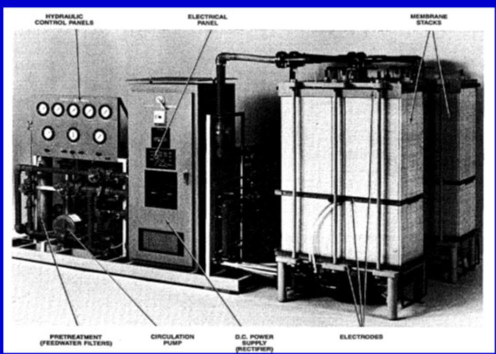
Electrodialysis



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Electrodialysis Applications

- Selective membrane process for removing Minerals Only!
- Uses membrane filtration in combination with electricity.
- Electrodialysis can be less expensive to operate for low TDS waters or when a 50% mineral removal is adequate.
- Positive ions are attracted to a negatively charged cathode and negatively charged ions are attracted to a positively charged anode.

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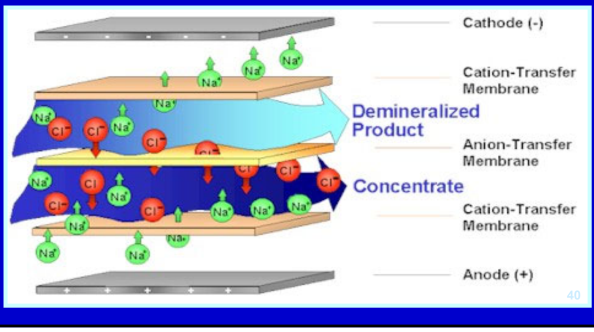
Electrodialysis

- Uses electrical power to draw ions from product water to the concentrate stream.



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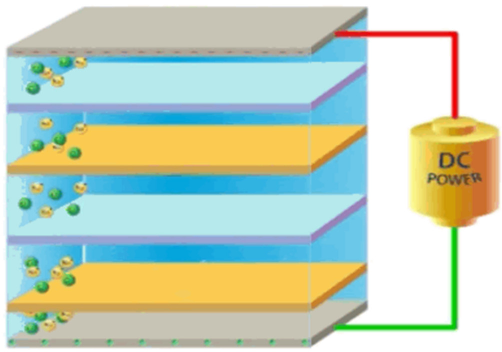

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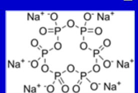
Operating and Maintenance Considerations for ED Systems

- Fouling and Plugging of Membranes
- Water Temperature
- Alkaline Precipitation
- Pretreatment for Solids Removal
- Undesirable Minerals (Fe, Mn, H_2S & Cl)
- Hexametaphosphate 

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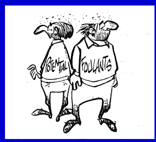
Do Not Operate if Feedwater has any of the following:



- Chlorine residual of any concentration
- Hydrogen sulfide of any concentration
- Calgon or other hexametaphosphates in excess of 10 mg/l
- Manganese in excess of 0.1 mg/l
- Iron in excess of 0.3 mg/l

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Which of the following items is/are acceptable in the feedwater to an electrodialysis unit?

1. Chlorine residual
2. Hydrogen sulfide
3. Iron
4. Manganese
5. Sodium

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Ion Exchange

Ion exchange can be defined as exchanging hardness causing ions (calcium Ca and magnesium Mg) for the sodium ions Na that are attached to the ion exchange resins to create a soft water. The term "ion exchange" is the same as the term "Zeolite".

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ION EXCHANGE

- The removing of non-desirable ions by replacing them with more desirable ions.
- Generally, the process is used for softening but can be used with any positively charged ion including Tannins.
- Can also be used with negative charged particles.

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Ion Exchange Unit Types

- Upflow (water flows from the bottom to the top.)
- Gravity Sand Filter Type Unit (water flows down and out the bottom)
- Pressure Downflow (most common: can be either horizontal or vertical units. The vertical are preferred because they tend to prevent short circuiting.

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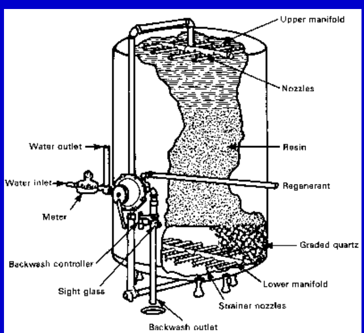
Parts of an Ion Exchanger



- Vessel
- Distributor
- Backwash Space
- Resin
- Resin Support
- Underdrain
- Piping & Valves

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Ion Exchange Resins

- Natural zeolites (crystalline aluminosilcates) no longer used
- These have been replaced by synthetic resins.
- Resins made of cross-linked polymer matrixes that attached to functional groups with covalent bonds
- Resins are manufactured as beads and typically screened to 0.3 to 1.3 mm dia.
- A typical resin used for softening is poystyrene attached to 6 to 8% divinylbenzene (DVB).
- Service life can be as much as 10 years with 3 to 5 typical. Generally resin replaced when capacity is reduced by 25%.

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Flow Considerations for Ion Exchange Softening

- Limited by pressure loss and physical characteristics of the Cation resin
- Flows above 20 gpm/sf will break beads
- Pressure losses above 50 psi across bed will also break beads
- Pressure losses across beds < 20 psi
- Generally a flow rate of 10 gpm/sf and a bed depth of 3 feet is typical.
- Ion Exchange Design is based on empty bed contact time (EBCT), 1.5 - 7.5 min or its reciprocal service flow rate (SFR) 1 - 5 gpm/cf

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Operating Considerations Ion Exchange Softening

- Iron: Ferrous captured deep inside resin bead or Ferric (precipitation) causes beads to become clogged and can not be removed.
- If Iron in the ferric form is found in the water, the unit will act as a filter.
- Corrosiveness of Brine Solution on metallic parts
- Oxidation of polymer from high chlorine level
- Strainer blockage
- Fouling of Resin from oil, grease or organic matter (Resin cleaning takes about 8 hours)
- Normal chlorine dosages will not present a problem, but high residuals could damage the resin and reduce its life span.

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Optimal Water Characteristics for Ion Exchange

pH	6.5 – 9.0
$NO_{3(nitrates)}$	< 5 mg/l
$SO_{4(sulfates)}$	< 50 mg/l
TDS	< 500 mg/l
Turbidity	< 0.3 NTU
Total Hardness	<350 mg/l

Selectivity Considerations

$S04^{-2} > NO3^{-2} > CO3^{-2} > NO2^{-2} > CL^{-1}$

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Stages of Ion Exchange

Stage 1. Service Stage

Stage 2. Backwash Stage

Stage 3. Brine or Regeneration Stage

Stage 4. Rinse Stage

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Ion Exchange Service Stage 1

- Normal operating stage where actual softening takes place.
- Length of service is mainly dependent on source water hardness.
- High source water sodium and or TDS can hinder process.
- TDS, unit size, and removal capacity affect length of time between regeneration.
- Beware of iron and manganese. Insoluble particles will plug the filter media. Monitor source water on a routine basis.

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Ion Exchange Backwash Stage 2

- A reverse flow through the softening unit is used to expand and clean resin particles.
- Ideal bed expansion during backwash is 75 - 100 %
- Some resin could be lost during backwash. Should be monitored to minimize loss.
- Too much loss of resin may be caused by an improper freeboard on the tank or wash troughs.
- Backwash durations widely vary based on the manufacture, type and size of resin used and the water temperature.

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Ion Exchange Regeneration Stage 3

- Sodium ion content is recharged by pumping concentrated brine solution onto the resin.
- Optimum brine solution is between 10 -14% sodium chloride solution.
- A 26% brine solution (fully concentrated or saturated) can cause resin to break up.
- The salt dosage used to prepare brine solution is one of the most important factors affecting ion exchange capacity. Ranges from 5 to 15 lbs/ft^3.
- The lower the concentration, the longer will be the regeneration time.

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Ion Exchange Rinse Stage 4

- Clean water is washed through the system to rinse the resin and to washout the excess brine solution.
- If rinse is not sufficient for removal of concentrate a salty taste will be noticed in the effluent. If a salty taste is noticed then rinse rate and time should be increased.

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Corrosion Concerns in Ion Softening

- Ion Exchange produces a water with zero hardness.
- Water with zero hardness is very corrosive creating red water problems.
- "Ideal" water hardness for drinking water ranges between approximately 50 to 100 mg/L.
  - Above this level, hardness can contribute to scaling of water heaters and boilers.
  - Water with hardness below this level tends to be more aggressive and can cause deterioration of the inner surface of pipes, eventually leading to pinholes or leaks.
- Water is adjusted by blending to achieve 86 mg/l or 5 gpg Hardness

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Concentrate Disposal

- Combine with reclaimed water and release to surface water. (CWA & NPDES)
- POTW (Publicly Owned Treatment Works) (TBLL; Effluent & Biosolids)
- Deep Well injection – (UIC)
- Evaporation/Crystallization - Capacity limited (RCRA)
- Landfill (PELT (paint test), TCLP (leaching)

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Taste and Odor Control, Aeration, Iron Removal and Basic Stabilization

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Taste and Odor Control Problems

- Taste and odors in drinking water is a common problem faced by the operator
- Consumer evaluates water on three senses: sight, smell, and taste
- Effects of taste and odor problems
  - Complaints by customers
  - Consumer may switch to unsafe water
  - Loss of confidence in utility to produce a safe water
- Secret to successful taste and odor control is to PREVENT TASTES AND ODORS FROM EVER DEVELOPING

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Causes of Tastes and Odors

Can be the result of natural or manmade conditions that exist within the total water supply system

- Raw water sources
- Conveyance facilities
- Treatment plants
- Chlorination stations
- Finished storage facilities
- Distribution systems
- Consumer plumbing

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Types of Pollutant Sources

- Municipal wastewaters
- Domestic wastes
- Industrial discharges (requires NPDES permit)
- Chemical spills (primary concern is health related effects)
- Urban runoff
- Agricultural wastes
- Irrigation runoff
- Distribution system maintenance
- Consumer plumbing

Note: If taste and odor problems and organic loadings are controlled, the need for activated carbon treatment at the plant may be reduced or eliminated.

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What is the first step in determining the cause of taste and odor problems in a water system?

a. Flush the system
b. Change the coagulant dosage
c. Do a taste test
d. Locate where in the system the problem is originating

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Environmental Conditions

- Organisms (bacteria, algae, diatoms, or fungi) that grow in water or in the sediments of lakes, reservoirs, and rivers are significant contributors to tastes and odors.
- If organic matter decays when there is no oxygen present (anaerobic conditions) undesirable tastes and odors are produced.
- When sulfate is reduced to sulfide in the anaerobic bottom sediments of a lake or reservoir the result can be a strong odor of rotten eggs.
- The diurnal variation in dissolved oxygen concentrations may have significant effect on taste and odor.

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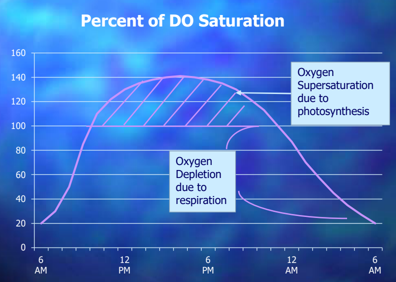
Diurnal Variation in Dissolved Oxygen Concentrations



- Large populations of algae can produce oxygen faster than it can escape to the atmosphere
- Oxygen depletion during the night may result in fish kills and die-off of aquatic organisms and vegetation which will produce foul tastes and odors

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Importance of Diurnal Oxygen Fluctuations

- Significantly different conditions can and do exist from day to night
- Oxygen depletion at night may result in fish kills and die-off of aquatic organisms and vegetation which will produce foul tastes and odors
- During darkness anaerobic organisms may become established and contribute to the aesthetic qualities of the water

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Operations Impact

- Significant dissolved oxygen fluctuations caused by algae in raw water will also be accompanied by changes in the pH.
  - During daylight hours when algae produces oxygen, carbon dioxide (CO^2) is removed and the pH will increase
  - At night during the respiration process, algae will consume oxygen and release carbon dioxide which will lower the pH
  - These changes will influence the chemical doses required to effectively treat the water.
  - Tastes and Odors that are fishy, grassy, septic, musty, and earthy are often caused by Algal Blooms.
- Tastes and odors caused by algae are best removed through improved coagulation and sedimentation.
  - Allows longer filter runs
  - If chlorine is used upstream of filtration it will reduce the reaction of chlorine on algae cells that would be release cellular materials into the water.

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Taste and Odor Control by Aeration

- Effective in removing gases and organic compounds which are relatively volatile, this is known as DEGASIFICATION
- Can also destroy some compounds by OXIDATION, such as ferrous iron and manganous manganese.
- Aeration may also reduce the chemical dosage needed by removing the gases and organic compounds.

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Taste and Odor Control Through Adsorption

- Adsorption is the process of removing materials from water by adding a material to the water to which taste-and-odor-producing compounds will attach themselves
  - Addition of powdered activated carbon; usually at the influent
  - Use of granular activated carbon as a filter medium

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Iron and Manganese Problems

- Dissolved ferrous iron (Fe^{+2}) gives water a disagreeable taste and will encourage the growth of iron bacteria in the water distribution system .
- Iron combined with tea, coffee and other beverages, produces an inky, black appearance and a harsh, unacceptable taste.
- Vegetables cooked in water containing excessive iron turn dark and look unappealing.
- Concentrations of iron as low as 0.3 mg/l will leave reddish brown stains on fixtures, tableware and laundry that are very hard to remove.
- Precipitates will form in the distribution system
- When these deposits break loose from water piping, rusty water will flow through the faucet.

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Forms of Iron Found in Water Treatment

- Soluble Iron or Clear Water Iron (Fe^{+2})
- Precipitant Iron or Red Water Iron (Rust, Fe^{+3}, settles out)
- Organically Bound Iron Soluble Iron
- Iron Bacteria (Slime or biogrowth)

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Iron and Manganese Facts

Regulated SMCL	Problem Types
Iron < 0.30 mg/l	Red Water
Manganese < 0.05 mg/l	Black Particles

- Weathering processes release the elements into waters.
- Iron dissolved by reaction with CO_2. Reduces insoluble iron (Fe^{+3}) & Manganese (Mn^{+3}) to soluble Fe^{+2} & Mn^{+2} only under anaerobic conditions.
- Ground waters that contain Iron and Manganese are devoid of Oxygen otherwise they would settle out.
- When exposed to O_2 precipitants forms insoluble hydroxides in water.
- Visible as red and brown color. Will stain fixtures and clothes. Imparts taste and odor to water.

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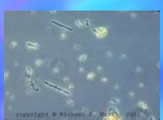
Iron Bacteria in Water Supply System


Iron Bacteria Cells


Bacterial Growth


Iron Problem

- Iron and manganese are most frequently found in water systems supplied by wells and springs.
- Iron and manganese react with oxygen to promote the growth of iron bacteria.
- These bacteria form thick slime growths on the walls of the piping system and on well screens.
- The growth can be controlled by chlorination

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Iron and Manganese Control

- Alternate source
- Ion exchange
- Oxidation
- Phosphate treatment
- Lime softening

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Soluble Iron (Fe^{+2})and Manganese (Mn^{+2}) Can be Removed by Aeration

- Water with Fe + Mn > 0.3 PPM will have disagreeable taste and odor.
- Removal of Fe/Mn by aeration is dependent on pH, contact time, temperature and presence of organic material.
- By maintaining pH above 7, contact time can be significantly reduced.
- pH can be adjusted by adding lime (increases pH and speeds oxidation).
- It will be necessary to periodically chlorinate the aeration system to control slime growths.

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Treatment Methods to Remove Iron and Manganese

Comparison of Oxidants Required to Oxidize 1mg/l of Ferrous Iron or Manganous Manganese

Oxidant	Iron	Manganese
Oxygen	0.14	0.29
Chlorine	0.62	1.30
Chlorine Dioxide	1.21	2.45
Ozone	0.86	0.87
Potassium Permanganate	0.91	1.92

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Aeration Processes

- Aeration works in two different ways to remove the undesirable compounds from the water, oxidation and volatilization (degasification.)
- Volatilization removes undesirable gases such as Hydrogen Sulfide or Carbon Dioxide by forcing them to escape into the air. A substance that easily changes to a vapor at relatively low temperatures is considered volatile.
- Removal of iron and manganese is accomplished by chemical oxidation. Once oxidized, these new compounds can be removed by sedimentation or filtration.
- Aeration also facilitates the oxidation reaction by removing CO2 which raises pH.

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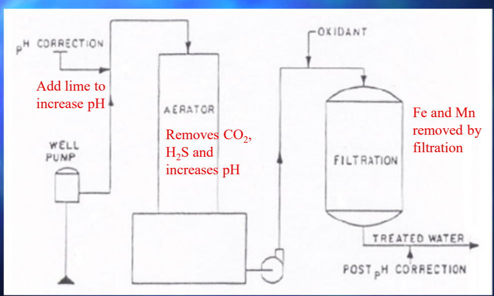
Schematic of Typical Fe Removal Aeration System



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Results of Aeration

- Taste and odors caused by Fe, Mn, H_2S, and any volatile compounds are removed.
- An increase in pH may accelerate the oxidation of Fe, by aeration.
- Reduces corrosive constituents, i.e. CO_2 (to 5 ppm) and H_2S.
- Supersaturated water is corrosive and stability must be adjusted.
- Aeration will not remove tastes and odors caused by organic sources such as algae.

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Types of Aeration Systems

- Water into Air. This method produces small drops of water that fall through the air.
- Air into Water This method creates small bubbles of air that rise through the water being aerated. (less common in small systems).

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Cascade Tray Aerator

- Termed to be a waterfall device; passes water through the air
- Even distribution of water over top tray
- Loading Rates of 1 to 5 GPM for each sqft. of tray area.
- Trays ½" openings perforated bottoms
- Protect from insects with 24 mesh screen
- May encourage biological growths which may cause taste and odor problems
- Evaporation losses are a disadvantage

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Forced Draft Aeration System (Air Stripping)

- Combines elements of both air blowers and waterfall devices
- Includes weatherproof blower in housing
- Counter air through aerator column
- Includes 24 mesh screened downturned inlet/outlet
- Discharges over 5 or more trays
- Increased aeration in air stripping towers is achieved by packing and counter current air flow.

Blower

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Aeration Process Control Parameters

- DO
- pH
- Air and Water Temp
- Air to Water Ratio
- Height of Packing or Tower
- Water Loading Rate
- Chemistry of Constituents Removed

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Protection of Aerations Systems from Insect, Vermin and Slime

- Growth of Insects
- Contamination from Bird Droppings
- Contamination from Animals
- Growth of Slime

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Chemical Oxidation of Fe and Mn Using Chlorine

- The main advantage of chlorine over aeration is the requirement for much shorter reaction times
- Chlorine is frequently used instead of aeration when iron concentrations exceed 5 PPM
- When levels of iron and manganese exceed 5 PPM, sedimentation may also be necessary prior to filtration
- The higher the amount of chlorine fed, the more rapid the reaction
- After filtration, water may need to be dechlorinated by addition of sodium bisulfide or sulfur dioxide to prevent TTHMs
- Chlorine residual concentration after a contact tank should never be allowed to drop below 0.5 PPM
- The Chlorine concentration that is most effective is determined by the use of a jar test

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Determining if Dissolved Iron is Present

- Draw a sample from the well and allow it to stand for 30 minutes
- Water should be clear and colorless turning to a slight yellow haze color after contact with air
- If allowed to stand it will finally form a yellowish brown color
- If aerated and allowed to stand it will form reddish brown deposits in bottom of container

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Clarification Requirements for Iron and Manganese

- Oxidized particles must be removed
- Anthracite filters are frequently employed
- With high Fe/Mn concentrations in source water (> 6 PPM) a clarifier may be necessary

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Use of Potassium Permanganate

- Oxidizes iron and manganese to insoluble oxides
- Sulfides and color are also removed
- Potassium permanganate is added upstream of filters
- Permanganate is a reactive, fast-acting oxidizer
- Dose must be exact
  - Too little will not oxidize the manganese in the water
  - Too large a dose will allow permanganate to enter the system and may produce a pink color in the water
  - Bench scale tests required to determine the proper dosage
- It is a poor disinfectant

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Filter Considerations Using Permanganate

- Filtration is used as the final step in Fe and Mn treatment
- Gravity and pressure filters are typically used
- The normally-used filter media will work if the combined concentration is below 1 ppm.
- Higher concentrations require different type of filter materials and different methods of operation
  - Use of manganese greensand filter
  - Charged with potassium permanganate after the backwashing process
  - This method allows the oxidation process to be completed in the filter

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Stabilization of Iron and Manganese using Phosphates

- Phosphates are used keep Fe and Mn in a dissolved state. The effect is called sequestration.
- Reduces the layer of scale that forms on the pipe.
- Very small quantity are required to inhibit precipitation in water distribution lines.
- Sequestering agents bind with the mineral (Fe, Mn, Ca, Mg) to keep them in suspension. This prohibits (delays) them from falling out and causing buildup, stains, discoloration, etc.
- At high mineral levels, the agents are not very effective. With long detention times in your storage, they are also not very effective.
- Testing should be performed to determine if they work.

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Some Benefits Attributed to Phosphate Addition

- Control of Iron and Manganese Color and Staining
- Scale Reduction
- Corrosion Inhibition
- Hydrogen Sulfide Oxidation
- Chlorine Demand Reduction
- Bacterial (MPN) Reduction
- Disinfectant By-Product Reduction
- Increased Life of Iron Pipelines
- Increased Life of Water Heating Elements
- Improved Taste of Water
- Water Color Enhancement

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Considerations in the Use of Polyphosphates for Sequestering

- Polyphosphates are effective for low concentrations of iron and manganese
- Polyphosphate sequestering agents can start to degrade to orthophosphate after about 2 days
- Polyphosphate sequestering does not work under stagnant conditions (slow moving water or dead end conditions)
- Over feeding Polyphosphate can contribute phosphorus as a nutrient that favors the growth of slime bacteria

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Considerations in the Use of Polyphosphates for Sequestering (cont.)

- The Polyphosphate, Hexametaphosphate is commonly used for Sequestering Soluble Iron and Manganese
- Large doses (>5 mg/l) will soften rust deposits in pipelines which are transported into homes
- Proper dose is to keep soluble iron and/or manganese tied up for 4 days so deposits won't build up on the pipe walls
- Chlorine usually must be fed along with the polyphosphate to prevent the growth of iron bacteria

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Use of Orthophosphates for Sequestering

- Orthophosphate is used to sequester iron ions at pipe surfaces
- The sequestering forms a protective coating that prevents further iron migration
- Ortho/Poly Blends provide both sequestering of soluble iron and manganese movement from pipelines under corrosive conditions

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DEP Limitations in Sequestering Iron and Manganese

- Sequestering with polyphosphates may be used when the combination of ($Fe + Mn$) < 1 mg/l
- Polyphosphate may not exceed 10 mg/l
- Sequestering with sodium silicates may be used when combination of ($Fe + Mn$) < 2 mg/l
- Sodium Silicate can not exceed 20 mg/l
- Sodium Silicate is applicable prior to air contact only!

Polyphosphate Dosing System 37

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Taste and Odor from Hydrogen Sulfide

- Not uncommon in Florida well waters, Smells like rotten eggs.
- Typical concentrations not a health risk but do affect the taste of water; Detected in concentrations as low as 0.05 mg/l
- Presence of sulfate-reducing bacteria causes rotten egg odor of hydrogen sulfide.
- Free hydrogen sulfide (H_2S) can react with water forming sulfuric acid (H_2SO_4) which is extremely corrosive to metals.
- Removed by aeration, greensand/ potassium permanganate, and chlorination
- It takes 2.08 mg/l to oxidize 1 mg/l of H_2S

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Hydrogen Sulfide Removal Techniques (DEP)

Sulfide (mg/l)	Recommended Treatment Process	Achievable Range of Removal
<0.3	Direct Chlorination	100%
>0.3	Direct Chlorination (requires filtration)	100%
0.3 to 0.6	Conventional Aeration	50%
0.6 to 3.0	Forced Draft Aeration	90%
>3.0	Packed Tower Aeration	>90%

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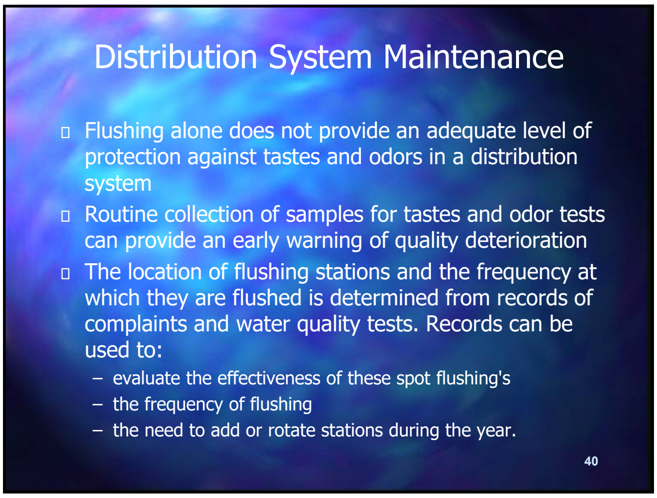
Distribution System Maintenance
Flushing alone does not provide an adequate level of protection against tastes and odors in a distribution system
Routine collection of samples for tastes and odor tests can provide an early warning of quality deterioration
The location of flushing stations and the frequency at which they are flushed is determined from records of complaints and water quality tests. Records can be used to:
– evaluate the effectiveness of these spot flushing's
– the frequency of flushing
– the need to add or rotate stations during the year.
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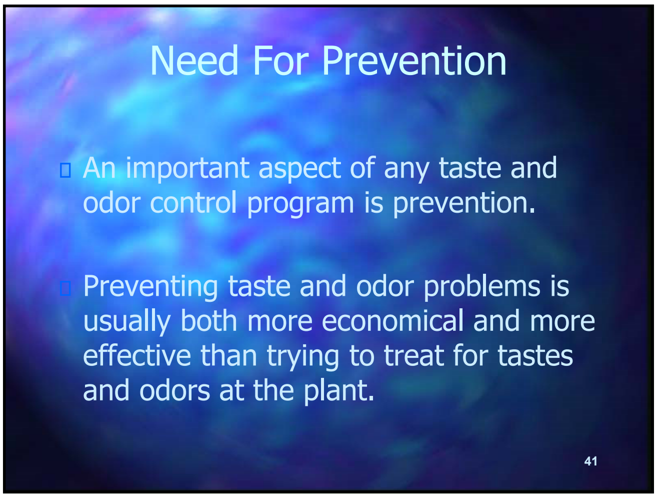
Need For Prevention
An important aspect of any taste and odor control program is prevention.
Preventing taste and odor problems is usually both more economical and more effective than trying to treat for tastes and odors at the plant.
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Corrosion and Corrosion Control

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What is Corrosion?

- Corrosion is the gradual decomposition or destruction of a material (such as metal or cement lining) as it reacts with water or the environment.
- Severity and type of corrosion depends on the chemical and physical characteristics of the water and the material.
- Corrosion starts at the surface of a material and moves inward.

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How to Determine if Corrosion Problems Exist

- Examine materials removed from your distribution system for signs of corrosion
- Chemical tests
- Increasing number of leaks
- Consumers complaining about dirty or red water

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Corrosive Water

- Weakens pipes and equipment, including residential plumbing.
- Dissolves toxic metals such as lead and copper from the distribution system or house plumbing into the drinking water.
- Causes color, taste, and odor problems when metals such as iron and copper are dissolved into the water. (stained laundry, greenish blue stains and bitter metallic taste)
- Causes TUBERCULATION which can reduce capacity of system, increase pump energy costs, and reduce system pressures.

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Types of Electrochemical Corrosion

Metallic corrosion

Metallic Corrosion can be defined as the destructive attack of a metal through interaction with its environment.

Rust

Galvanic Corrosion

Galvanic corrosion of aluminium. A 67-cm-thick Al alloy plate is physically (and hence, electrically) connected to a 10-mm-thick mild steel structural support. Galvanic corrosion occurred on the Al plate along the joint with the steel. Perforation of Al plate occurred within 2 years.

Joining of dissimilar metals

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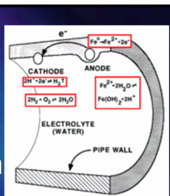
Conditions for Corrosion to Occur



Corrosion is a chemical reaction and requires three things:

1. Anode – Point from which metal is lost and electric current begins.
2. Cathode – Point where electric current leaves the metal and flows to the anode through the electrolyte.
3. Electrolyte – Conducting solution (usually water with dissolved salts

Corrosion where a positive metal (Anode) flows to a negative ion (Cathode)

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- The formation of a rust coating on the pipe has an important effect on the rate of corrosion.
- As the rust film forms, it begins to cover and protect the anode, slowing the rate of corrosion.
- If the rust film is flushed away, the corrosion reaction accelerates again.

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Galvanic Series

A Galvanic Cell is an electro Chemical Corrosion Cell found in water systems and plumbing.

ANODE (Most Active)

Magnesium
Zinc
Aluminum (2S)
Cadmium
Aluminum (175T)
Steel or Iron
Cast Iron
Lead – Tin Solder
Lead
Nickel
Brasses
Copper
Bronzes
Stainless Steel (304)
Monel Metal
Stainless Steel (316)
Silver
Graphite
Gold

CATHODE (Least Active)

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Physical Factors Influencing Corrosion

- Type and arrangement of materials
- System pressure – increases maximum concentration of corrosive gases, like oxygen and carbon dioxide
- Soil moisture - the moisture functions as the electrolyte, the same as water inside the pipe.
- Presence of stray electric currents – grounding of electric circuits can lead to corrosion of pipes
- Temperature - of increases the corrosion rate
- Water flow velocity - high or low flow rates increase the rate of corrosion. Low flows water is stagnant. High flows water becomes highly oxygenated and increases the contact of oxygen with the pipe surface

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Chemical Factors Influencing Corrosion

- pH - the hydrogen ion is extremely active (corrosive) at pH values below 4
- Alkalinity - the simplest form of corrosion control is to simply add more alkalinity in the form of lime, soda ash or caustic soda, or directly as calcium carbonate in the form of crushed limestone to form protective film on the inside of pipes
- Chlorine residual - neither chlorine nor hydrogen ions are usually present in sufficient concentrations in potable water to have a significant effect on corrosion
- Dissolved solids and gases in the water – the higher the dissolved solids, salt, the higher the potential for corrosion due to increased conductivity
- Types and concentrations of minerals present - phosphate and silicate in the water have a tendency to form protective films in water systems. Trace metals when present at high levels usually indicate corrosion of the pipes and fittings

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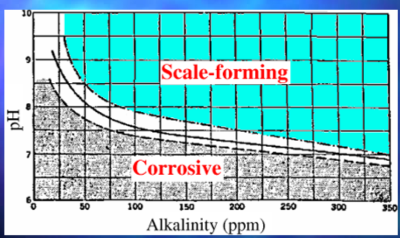
Relationships between Alkalinity, pH



This graph is known as the Baylis Curve. It shows the relationship between pH, alkalinity, and water stability. Water above the lines is scale-forming while water below the lines is corrosive. Stable water is found in the white area between the lines.

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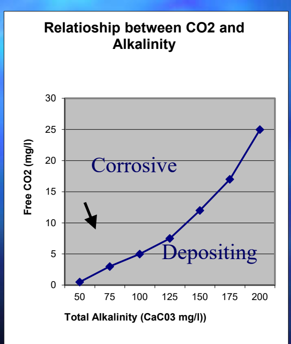
Carbon Dioxide Content in Water Greatly Affects it's Corrosivity



- Without proper buffering or alkalinity high Concentration of CO_2 will be very Corrosive.
- CO_2 is often removed to it's ambient air concentration of 3.5 – 4 PPM by Aeration.

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Types of Chemical Corrosion in a Water System

Type	Cause
Galvanic	Dissimilar metals in contact in water. Frequently occurs in service lines.
Pitting	Caused by scratches or imperfections in metal pipe. Can result in holes in pipe.
Tuberculation	Caused by metal ion transfer and development of electrolytic cell formation inside pipe. Can result in large deposits.
Crevice	Occurs at joints where there is little water movement.
Biological	Bacterial wastes contacting pipe materials. Cause of most taste and odor problems.
Dealloying	Preferential removal of one alloy from a metal. Can result in pipe failure.

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Cathodic Protection by Direct Protection or Electrical Polarization

- Cathodic protection means protection against corrosion
- Linings are provided that shield metal surfaces from contact with water
- Selecting dissimilar metals that result in flooding or Polarizing the cathode with electrons. Sacrificial (magnesium) anodes decay in the water slowly, providing protection
- Electronic cathodic protection system polarizes by supplying a continuous flow of electrons from the anode (metal surface) through the water carrier to the cathode

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Other Chemical Corrosion Protection Mechanisms

- Removing Corrosive Agents - Treating the water that removes contaminants such as CO_2, or dissolved solids thus reducing rate of corrosion in the water.
- Chemical Addition - Adding chemicals that slow the chemical corrosion reaction rates by raising the pH and Alkalinity of the water
- Sequestering – Adding phosphates that tie up a particular metal in solution or at the metal surface.

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Corrosion Control by Adjusting pH or Alkalinity

- Adjustment of water chemistry to raise:
  - pH
  - Alkalinity
- Phosphates
- Thin Coating of calcium carbonate to protect water mains and plumbing inhibits corrosion

To reduce pipe corrosion, calcium carbonate saturation is achieved by increasing the lime or soda ash dose.

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Chemical Stabilization Recap

- Stabilization of water is best accomplished through chemical means by controlling the pH and alkalinity of unstable water
  - For high pH waters, lower the pH by adding sulfuric acid or carbon dioxide
  - For low pH waters, lime, soda ash, sodium bicarbonate, or caustic soda can be added to raise pH
- Sequestering agents or silicates can be added that chemically tie up the scale forming ions

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Concepts of Alkalinity and Chemical Adjustment

- Alkalinity increases when an alkali is added to a water
- Carbon dioxide is produced in a water when alkalinity is consumed
- Carbon dioxide is destroyed when an alkali is added to a water.
- The pH of a water will decrease when carbon dioxide is formed and will increase when CO_2 is destroyed.
- Knowing the changes that various chemicals make to alkalinity and carbon dioxide levels allows prediction of the pH of the water as a result of different treatment regimes

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Chemicals Used in Water Treatment that change Alkalinity and pH

Lower
- Gas Chlorine
- Sulfuric Acid (Muriatic)
- Carbon dioxide
- Alum
- Ferric Chloride
- Hydrofluosilicic Acid

Raise
- Sodium Hydroxide (Caustic Soda)
- Calcium Hydroxide (Lime)
- Sodium bicarbonate (Soda)
- Sodium Carbonate (Soda Ash)
- Calcium Hypochlorite

The pH of a finished water is consistently between 6.5 and 6.8. One way to reduce the corrosive nature of this water is to add Calcium Hydroxide to raise the pH.

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A water is considered stable when it is just saturated with calcium carbonate.

In this condition the water will neither dissolve or deposit calcium carbonate.

In this state the calcium carbonate is in equilibrium, if you raise the pH the water will become scale forming, if the pH is lowered the water will become corrosive

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Use of the Langelier Index for Determining Water Stability

- The Langelier Index is used to measure the corrosivity parameter in water.
- Every water has a particular pH value where the water will neither deposit scale nor cause corrosion.
- A stable condition is termed saturation.
- Saturation (pH_s), varies depending on calcium hardness, alkalinity, TDS, and temperature.
- The Langelier Index = pH – pH_s

  Corrosive 0 > LI > 0 Scale Forming

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Langelier Index

- Water quality indicators that are used to calculate the Langelier Index are:
- Temperature, pH, calcium, total alkalinity.
- A NEGATIVE value for the Langelier Index means the water tends to be Corrosive
- A POSITIVE value for the Langelier Index means the water tends to be Scale Forming.

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Recommended Treatment for Corrosive and Scaling Water based on LI

Saturation Index	Description	General Recommendation
- 5	Severe Corrosion	Treatment Recommended
- 4	Severe Corrosion	Treatment Recommended
- 3	Moderate Corrosion	Treatment Recommended
- 2	Moderate Corrosion	Treatment May Be Needed
-1	Mild Corrosion	Treatment May Be Needed
-0.5	None- Mild Corrosion	Probably No Treatment
0	Near Balanced	No Treatment
0.5	Some Faint Coating	Probably No Treatment
1	Mild Scale Coating	Treatment May Be Needed
2	Mild to Moderate Coatings	Treatment May Be Needed
3	Moderate Scale Forming	Treatment Advisable
4	Severe Scale Forming	Treatment Advisable

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Corrosion Control Summary

Chemical Characteristic	Effect
pH	Low pH may increase the corrosion rate; high pH may protect pipes and decrease corrosion rates.
Alkalinity	May help form a protective $CaCO_3$ coating, helps control pH changes, and reduces corrosion.
Dissolved oxygen (DO)	Increases the rate of many corrosion reactions.
Chlorine residual	Increases metallic corrosion
Total dissolved solids (TDS)	High TDS increases conductivity and corrosion rate.
Hardness (Ca and Mg)	Ca may precipitate as $CaCO_3$ and thus provide protection and reduce corrosion rates.
Chloride, sulfate	High levels increase corrosion of iron, copper, and galvanized steel.
Hydrogen sulfide (H_2S)	Increases corrosion rates.
Silicate, phosphates	May form protective films.
Natural color, organic matter	May decrease corrosion.
Iron, zinc, or manganese	May react with compounds on the interior of A-C pipe to form a protective coating.

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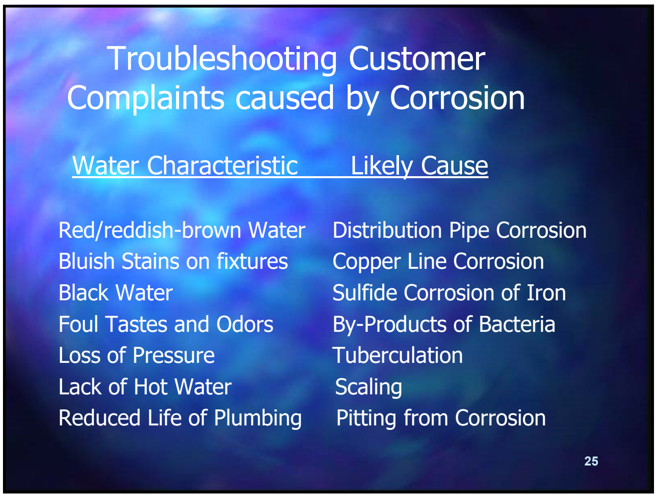
Troubleshooting Customer Complaints caused by Corrosion
Water Characteristic
Likely Cause
Red/reddish-brown Water
Distribution Pipe Corrosion
Bluish Stains on fixtures
Copper Line Corrosion
Black Water
Sulfide Corrosion of Iron
Foul Tastes and Odors
By-Products of Bacteria
Loss of Pressure
Tuberculation
Lack of Hot Water
Scaling
Reduced Life of Plumbing
Pitting from Corrosion
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Water Softening for Hardness Removal

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Hardness in Water

- High concentration of calcium (Ca2+) and magnesium (Mg2+) ions in water cause hardness
- Generally, water containing more than 100 mg/l of hardness expressed as calcium carbonate (CaCO3) is considered to be hard
- Excessive hardness is undesirable because it causes the formation of soap curds, increased use of soap, deposition of scale in boilers, pipelines and home appliances, damage in industrial processes and can cause objectionable tastes.

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Methods of Removing Hardness

Treatment Method	Hardness Levels Retained
Lime Softening (Chemical Precipitation)	Solubility Level of about 35 mg/l ($CaCO_3$)
RO (Nanofiltration) (Membrane Filtration)	85 – 90% removal
Ion Exchange (Chemical Exchange)	Basically Zero Water must be blended

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Hardness Descriptions

Description	Hardness (mg/l of $CaCO_3$)
Extremely soft to soft	0 – 45
Soft to moderately hard	46-90
Moderately hard to hard	91-130
Hard to very hard	131-170
Very hard to excessively hard	171-250
Too hard for ordinary domestic use	Over 250

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Important Definitions in Lime Softening Treatment

- HARDNESS is caused mainly by the salts of calcium and magnesium, such as bicarbonate, carbonate, sulfate, chloride, and nitrate
  - CALCIUM HARDNESS is caused by calcium ions (Ca^{2+})
  - MAGNESIUM HARDNESS is caused by magnesium ions (Mg^{2+})
- TOTAL HARDNESS is commonly measured by titration and is described in two ways:
  - The sum of the hardness caused by both calcium and magnesium ions, expressed as $CaCO_3$
  - The sum of the carbonate (temporary) and noncarbonate (permanent) hardness
- CALCIUM CARBONATE (CaCO3) EQUIVALENT is an expression of the concentration of a chemical in terms of their equivalent value to calcium carbonate.
- CARBONATE HARDNESS is caused by alkalinity present in the water up to the total hardness. It is the total measure of the waters alkalinity.
- NONCARBONATE HARDNESS is that portion of the total hardness in excess of the alkalinity. Requires use of both lime and soda ash to remove.
- ALKALINITY is the capacity of water to neutralize acids. Alkalinity is a measure of how much acid must be added to a liquid to lower the pH to 4.5. This capacity is caused by the water's content of bicarbonate, carbonate, hydroxide, and occasionally borate, silicate, and phosphate.

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Benefits of Lime Softening

- Removal of Ca and Mg hardness
- Removal of iron, manganese, arsenic and uranium.
- Reduction of solids, turbidity and TOC
- Removal and inactivation of bacteria and viruses due to high pH.
- Raises pH and prevents Corrosion
- Removal of excess fluoride.

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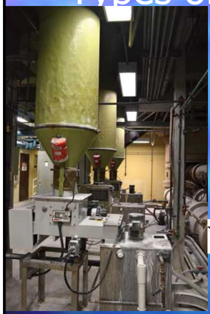
Types of Lime Used in WTP



Volumetric Multiscrew Feeder

You should never use the same conveyor or container for quicklime and alum because it could explode under certain conditions.

- Quick Lime (CaO) (molecular wt. 56)
  - 75 % - 99% purity (typically 85%)
  - Dry powder and must be slaked for 15 - 30 minutes at cold temperature
  - Slaking (agitating with water) produces $CaOH_2$ (Calcium Hydroxide)
  - Used at large WTP because lower cost
- Hydrated Lime $Ca(OH)_2$ (molecular wt. 74)
  - Made when Quick Lime is slaked
  - $CaO + H_2O \longrightarrow Ca(OH)2 + HEAT$
  - Very stable
  - Small WTPs use directly due to convenience
  - Hydrated Lime shipped 80% - 99% purity (typically 95%)

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Chemical Precipitation

- Hardness causing ions are converted from soluble to insoluble forms (Ca and Mg) at high pH
- Addition of lime:
  - increases the hydroxide concentrations, increasing the pH
  - Converts alkalinity from the bicarbonate form to the carbonate form which causes the calcium to precipitate out as $CaCO_3$
  - If more lime is added the phenolphthalein (P) alkalinity increases to a level where hydroxide becomes present (excess causticity) allowing magnesium to precipitate as magnesium hydroxide.

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SUPERSATURATED

- Following the softening process the
  - pH is high
  - Water is Supersaturated with excess caustic alkalinity in either the hydroxide or carbonate form
  - Carbon dioxide can be used to decrease the causticity and scale-forming tendencies of the water prior to filtration

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Types of Alkalinity that can be Present at pH Values

Addition of lime to water increases the hydroxide concentrations, thus increasing the pH. It is important to control pH in the finished water in a lime softening plant to prevent scaling or corrosion.

- Below 4.5 only CO_2 present, no Alkalinity
- Between 4.5 to 8.3, CO_2 and Bicarbonate present
- Above 8.3 alkalinity may consist of Bicarbonate, Carbonate, and Hydroxide (no CO_2 present)
- When pH is greater than 8.3, the amount of titrant used to reach pH 8.3 is the phenolphalein alkalinity
- Between 10.2 to 11.3 Carbonate & Hydroxide
- At 9.4 Calcium Carbonate becomes insoluble and precipitates
- At 10.6 Magnesium Hydroxide becomes insoluble and precipitates

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Chemical Titration with Methyl Orange (T) and Phenolphthalein (P)

- Methyl Orange is used to determine the combination of alkalinity provided by carbonate, bicarbonate and hydroxide or Total Alkalinity.
- A sample of the water is titrated by adding the Methyl Orange color indicator and adding measured amount of acid until the color is absent.
- The Total Alkalinity (T) is then computed.
- Phenolphthalein is used to determine the carbonate and hydroxide alkalinity present.
- A sample of the water is titrated by adding the Phenolphthalein color indicator and adding measured amount of acid until the color is absent.
- The Hydroxide and Carbonate Alkalinity (P) is then computed

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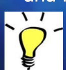
Hardness Relationship to Alkalinity

- TH = CH + NCH (each expressed as mg/l as $CaCO_3$)
- The amount of carbonate and noncarbonate hardness depends on the alkalinity of the water
  - Alkalinity > Total Hardness (all hardness is in carbonate form)

    TH = CH
  - Alkalinity < Total Hardness (both Carbonate Hardness and Noncarbonate Hardness are present)



CH = Alkalinity

NCH = TH - CH = TH - Alkalinity

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Lime Softening Process Limitations

- Unable to remove all carbonate (~ 30 mg/l) and no Non-Carbonate hardness.
- High degree of operator control.
- Color removal for highly colored waters may be hindered due to high pH.
- Important to maintain proper pH to prevent scaling or corrosion.
- Sludge handling and disposal are costly (~ 2.5 mg/l per mg/l lime added)

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Primary Coagulants Sometimes Used in Lime Softening

- Acidic compounds: aluminum sulfate (alum) $Al_2(SO_4)_3$, ferrous sulfate, ferric sulfate, and ferric chloride.
  - Increase lime demand
  - Highly colored waters are best treated at low pH values
  - Alum Sludge has a tendency to harden the soil
- Basic compounds: sodium aluminate
  - Lime required will be less
  - High pH values will tend to set color
- Cationic polymers
  - Not very pH sensitive and often used in softening

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Secondary Coagulant Aids Sometimes Used in Lime Softening

- Coagulant aids often added to help stimulate the production of floc.
- They include sodium aluminate, bentonite or clay, sodium silicate and various synthetic cationic and non-ionic polymers.
- Bentonite is often used in waters with high color and low turbidity to bind with small floc

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Types of Lime Treatment

- Excess Lime Treatment
  - Removes Ca & Mg
  - Produces an excessive amount of sludge
- Partial Lime Softening
  - Used for low Mg FL waters
  - Only enough lime to remove calcium is added
  - Sludge amounts reduced
- Split Treatment
  - Split Treatment is sometimes used when non-carbonate hardness is low and Mg concentration are high
  - CO_2 requirements can be reduced or eliminated by blending the softened water with an unsoftened flow stream
  - Generally 80% treated and 20% raw
- Non-carbonate Hardness removal using Lime-Soda
  - When the water contains non-carbonate hardness (calcium sulfate) it requires the addition of soda ash (sodium carbonate, Na_2CO_3)
  - An alternative to the lime-soda ash process is the use of caustic soda (sodium hydroxide, NaOH)

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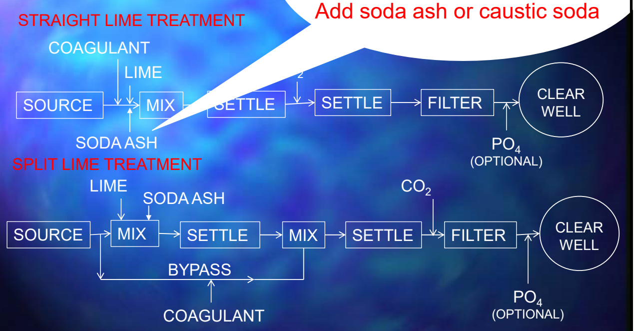
Types of Treatment

When water cannot be softened to the desired level, what action do you take?

Add soda ash or caustic soda



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Recarbonation in Lime Softening

- Lime softened water is supersaturated
- If not recarbonated, Ca and Mg carbonate will form on the filters and distribution piping
- Unused lime (calcium hydroxide and magnesium hydroxide) in solution at high pH (11), must be converted to a stable forms.
- First, CO_2 is added to reduce $Ca(OH)_2$ to $CaCO_3$ which precipitates at about pH 10
- Additional CO_2 is added to convert $Mg(OH)_2$ to soluble $Mg(HCO_3)_2$ which occurs at a pH of 8.4.
- Reaction must be completed before filtration so that calcium carbonate will not precipitate in the filters or carry into distribution system.

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Water Treatment Plant Maintenance Considerations

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Operation and Maintenance

- Purpose of O&M
  - maintain design functionality (capacity)
  - restore the system components to their original condition and thus functionality.
- Effective O&M programs are based on:
  - knowing what components make up the system
  - where they are located
  - condition of the components.

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Types of Maintenance

- Corrective
  - Reactive
  - Includes emergency maintenance
- Preventive
  - Proactive
  - Improved system performance
- Predictive
  - Proactive
  - Planned and scheduled basis

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Corrective Maintenance

- Reactive – operate equipment until it fails
- Little or no scheduled maintenance
- Results in poor system performance
- Approach characterized by:
  - Inability to plan and schedule work
  - Inability to budget adequately
  - Poor use of resources
  - High incidence of equipment and system failures

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Preventive Maintenance

- Proactive - performed on regular schedule
- Programmed, systematic approach
- Based on equipment operating time or number of days in operation
- Major elements of a good program:
  - Planning and scheduling
  - Records Management
  - Spare parts management
  - Cost and budget control
  - Emergency repair procedures
  - Training program

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Predictive Maintenance

- Proactive
- Establishes a baseline using performance criteria
  - Vibration Monitoring
  - Infrared Heat Monitoring
  - Electrical Monitoring (Volts and Amps)
  - Flows & Pressure Monitoring - Laser Alignment
  - Wear/Corrosion Monitoring - Ultrasonic Testing

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Development of an Effective Work Management Monitoring System

- Work is categorized
- Work standards that include time and quality are developed
- Work is assigned based on standards to individuals or crews
- Work is completed, data recorded (and inspected)
- Work data is compared to acceptable standards
- Deviations of acceptable performance is identified
- Problems that inhibit performance are eliminated
- Maintenance equipment histories are often an outcome of a successful work management program

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Pumps

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Pumps Used in Water Treatment

Application	Function
Low service (transfer pump)	To lift water from the source to treatment processes or from storage to filter backwashing system.
High service	To discharge water under pressure to distribution system
Booster	To increase pressure in the distribution system or to supply elevated storage tanks
Well	To lift water from shallow or deep wells and discharge it to the treatment plant, storage facility, or distribution system
Chemical feed	To add chemical solutions at desired dosages for treatment processes
Sampling	To pump water from sampling points to the laboratory
Sludge	To pump sludge from sedimentation facilities to further treatment or disposal

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Pump Classifications

Material Handled
- Raw water
- Filtered water

Condition of Pumping
- High lift
- Low lift
- High capacity


High Service Pumps

Principal of Operation
- Centrifugal (variable heads and flow) or turbine pumps
- Piston or Reciprocating (fixed head and flow)
- Rotary
- Progressive Cavity (sludge)

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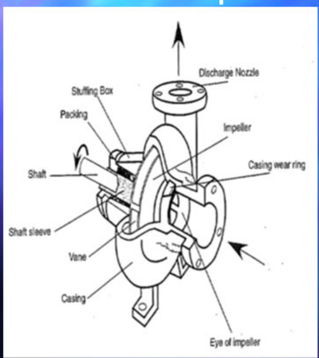
Centrifugal Pump



Three main components:
- Impeller: device that creates a vacuum by spinning and impelling liquid outward between the blades by centrifugal force.
- Casing (volute): The volute is the casing that receives the fluid being pumped by the impeller
- Shaft: part of the pump that turns the impeller.

Other components:
- Wear rings act as the seal between the casing and the impeller. Prevents excessive internal water circulation between the suction and discharge sides of a pump and prevents wear of the impeller and inside case.
- Bearings allow smooth rotation of the pump shaft.
- Stuffing boxes are used to keep air leakage out of a pump.

Note: never start a centrifugal pump until it is properly primed

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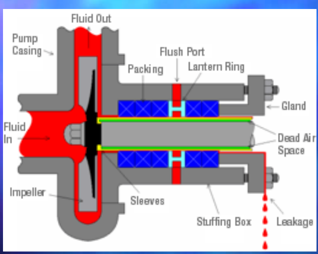
The Stuffing Box



Note:If there is excessive leakage around the packing gland you should first try to tighten the packing gland.

- Stuffing boxes are used to keep air leakage out of a pump. It consists of a casing, rings of packing (or mechanical seal) and a gland at the outside end.
- Packing: The function of packing is to control leakage and not to eliminate it completely. The packing must be lubricated, and a flow from 40 to 60 drops per minute out of the stuffing box must be maintained for proper lubrication; Packing ring notches should be staggered 90 degrees.
- Lantern ring: distributes liquid uniformly around the shaft to provide lubrication and cooling; also prevents or limits air from entering the flow stream.

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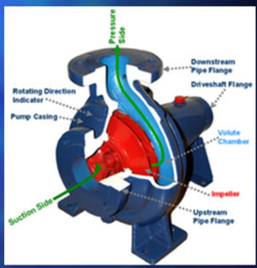
Centrifugal Pump

- Centrifugal pumps raise the water by a centrifugal force
- Never allow a pump to run dry (either through lack of proper priming when starting or through loss of suction when operating). Water is a lubricant between rings and impeller.



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Pump Maintenance: Common Problems with Centrifugal Pumps

- Packing should be replaced periodically. Packing gland should have small amount of water leakage for lubrication (1 drop/sec) to keep packing cool and in good condition.
- Replace wearing rings when necessary to plug internal leakage
- Pump should be checked for excessive vibration
- Minimize friction in bearings and stuffing boxes by proper lubrication
- Misalignment
  - Alignment should be performed using a laser
  - Foundation deterioration or settlement
  - Piping can change position and bolts can loosen
- Foreign materials
- Mechanical defects

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Centrifugal Pump Operation

- Every pump has certain characteristics under which it will operate efficiently.
- These conditions can be illustrated with characteristic curves.
- Operating a pump outside these ranges will cause damage to the pump

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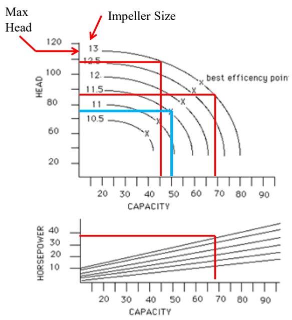
Pump Curve Basics

- Different size impellers have different capacities and head
- Shutoff head is maximum head of pump
- Best efficiency point is 80-85% of the shutoff head
- Capacity expressed in gallons per minute, liters per minute, or cubic meters per hour
- Head of a pump is read in feet or meters
- Power consumption expressed in horsepower or kilowatts



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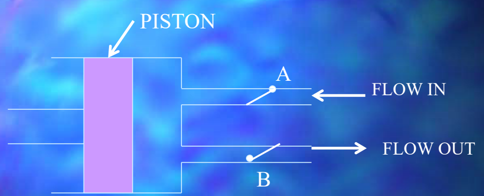
Question: Two pumps, having equal output, pump 6.5 MGD of water into a plant. What is the rating of each pump in gallons per minute?

- Two pumps have an output of 6.5 MGD
- One pump would have output of 3.25 MGD
- We are looking for gal, not MG, so we change 3.25 MG to 3,250,000 gal.
- We also need to change from days to minutes so we use the conversion of 1 day is equal to 1440 minutes

$$\frac{3{,}250{,}000 \text{ gal}}{\text{day}} \times \frac{1 \text{ day}}{1440 \text{ min}} = 2257 \text{ gpm}$$

17

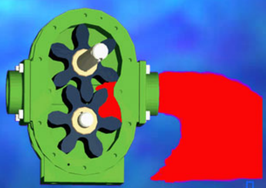
Piston or Reciprocating Pump



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

18

Rotary Pump



- The rotary pump uses cogs or gears, rigid vanes and flexible vanes to move the water
- As the gears rotate they separate on the intake side of the pump, creating a void and suction which is filled by fluid. The fluid is carried by the gears to the discharge side of the pump, where the meshing of the gears displaces the fluid.
- Rotary pumps are usually used for booster purposes and are generally used in conjunction with another pump.

19

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Progressive Cavity Pump

The shape of the cavities between the rotor and the stator is shown in blue

- A progressive cavity pump is a positive displacement pump.
- It transfers fluid by means of the progress, through the pump, of a sequence of small, fixed shape, discrete cavities, as its rotor is turned.
- Commonly used to pump sludge.
- Never operate dry and never run against a closed discharge valve.

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Lubrication Considerations

- Too much grease in antifriction type bearings (ball or roller) will promote friction and heat.
- The main job of grease in anti-friction bearings is to protect steel elements against corrosion, not friction.
- Lubricant should be changed in accordance with the manufacture's recommendations or before it's too worn or becomes too dirty.
- Some utilities analyze oil to identify the amount of metal wear to optimize lubrication and lubrication scheduling.

21

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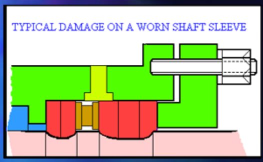
Problems With Defective Mechanical Seals or Packing



- Loss of suction due to air leak
- Shaft or sleeve damage from wear
- Water contamination of bearings
- Severe leakage causing flooding of building or pumping facility

22

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Common Pumping Problems

- Blockage
- Air Lock
- Vibration
- Water Hammer
- Cavitation

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23

Air Locks

- An accumulation of air that impedes the flow of water.
- Air locking is caused by air being trapped in the volute of the pump.
- These gasses collect becoming compressed creating an artificial head pressure within the pump housing.
- This artificial head will continue to build as more air is sucked into the pump until the maximum discharge head pressure (shut off head) is reached completely restricting the flow of water.
- Air locking is most often caused by leaks in the suction line

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Excessive Vibration

- Pumps should run smoothly. Excessive vibration causes expedited and excessive wear especially on bearings.
- Vibration is typically caused by misalignment or base problems
- Vibration can be measured with specialized equipment

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Water Hammer

Pipe Broken from Water Hammer

- Water hammer is caused by the rise and fall of pressure caused by the rapid change of a valve position.
- Water hammer can cause pipes to rupture and damage equipment
- This condition should always be corrected by adjusting the check valve

26

26

Cavitation

- Cavitation is a condition that can cause a drop in pump efficiency, vibration, noise, and rapid damage to the impeller.
- Cavitation is usually caused when:
  - Pump inlet pressure drops below the design inlet pressure.
  - Pump is operated at flow rates considerably higher than design flows
- Cavitation occurs when the pump starts discharging water at a rate faster than it can be drawn into the pump.
- This situation is normally caused by the loss in discharge head pressure or an obstruction in the suction line.
- When cavitation occurs, immediate action must be taken to prevent the impeller from being damaged

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Air Compressors

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Air Compressors Operation

- Used for activation of pump controls, for valve operators, to pressurize small water systems and to power portable pneumatic tools.
- Types include: diaphragm, rotary, piston and sliding vane.

Two Stage Piston Compressor 29

29

Compressor Maintenance Considerations

- Air filter inspection at least monthly replace at least at 3-6 mo.
- Lubrication; crankcase reservoirs, oil cups, grease fittings or separate pump. Must be inspected daily. Drip at proper rate and force feed oilers at proper pressure; compressors designed to use oil! Do not overfeed crankcase!
- Compressor heat breaks down oil; change oil at 3 months.
- Clean cylinder fins weekly to ensure proper cooling.
- Unloader allows compressor to come up to speed without load; should hear change; if not, compressor will stall or burn belts.
- Pop off valve (safety valve) are located on air receiver or storage tank; Some compressors have high pressure, low oil and high temperature cutoff switches; Record settings.
- Drain condensate daily!
- Check belt tension; tightness causes overheating and excessive wear. Check while locked out-at ¾ inch.
- Inspect operating controls; record settings.
- Clean monthly to prevent dirt from entering system.

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Record Keeping
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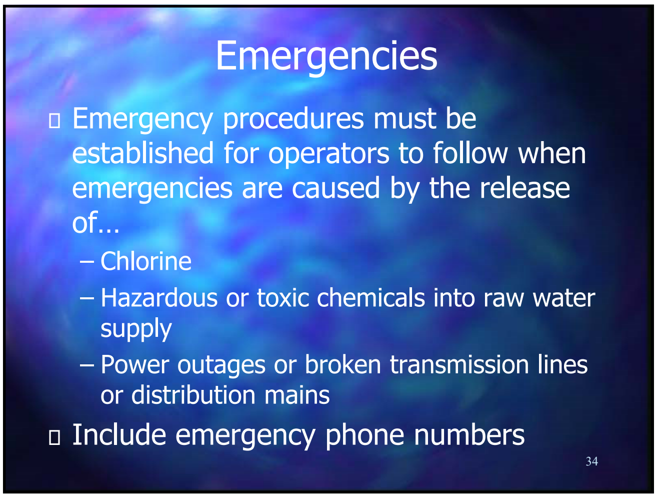
Record Keeping
Don't rely on memory
Keep up to date on a daily basis
Track all equipment and treatment processes
Compare the information for consistency
32

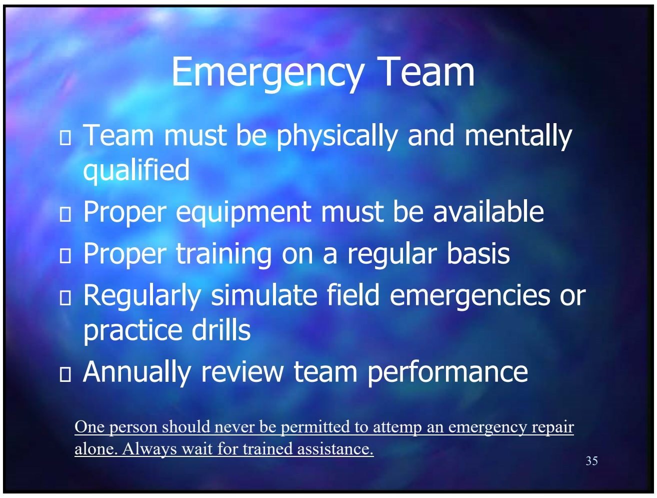
32


Library of Manufacturers' Operation and Parts Manual
A plant library can be helpful information to assist in plant operation
Material should be cataloged and filed for easy use and include…
– Plant operation and maintenance instruction manuals
– Plant plans and specifications
– Manufacturers' instructions
– Reference books on water treatment
– Professional journals and publications
– First-aid book
– Reports from other plants
– A Dictionary
33

33


Emergencies
Emergency procedures must be established for operators to follow when emergencies are caused by the release of…
– Chlorine
– Hazardous or toxic chemicals into raw water supply
– Power outages or broken transmission lines or distribution mains
Include emergency phone numbers
34

34


Emergency Team
Team must be physically and mentally qualified
Proper equipment must be available
Proper training on a regular basis
Regularly simulate field emergencies or practice drills
Annually review team performance
One person should never be permitted to attemp an emergency repair alone. Always wait for trained assistance.
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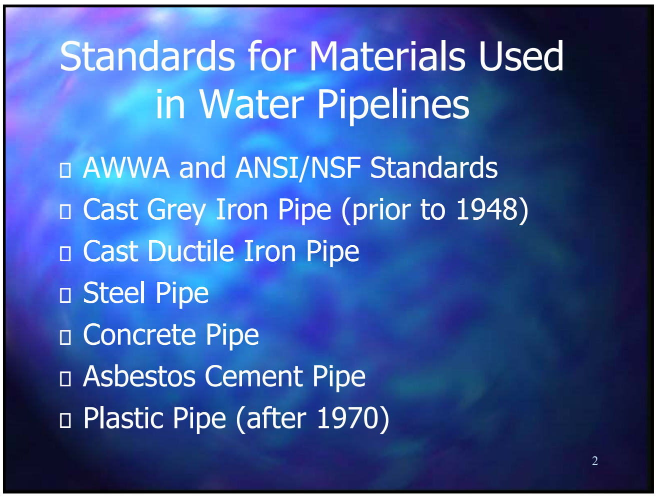
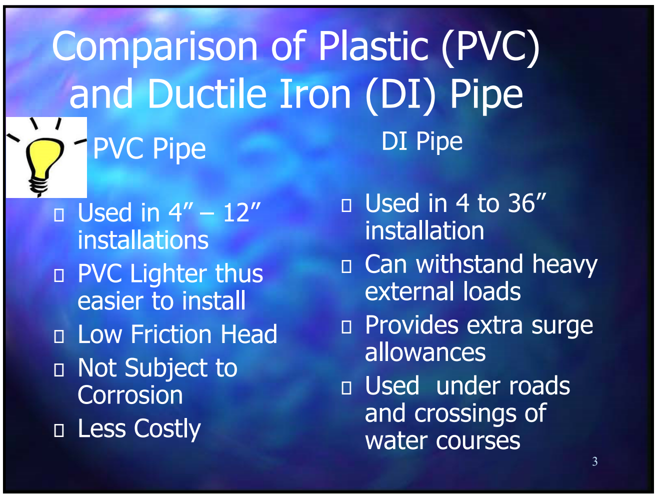
35


Water Transmission and Distribution for Water Treatment Plant Operators
1

1


Standards for Materials Used in Water Pipelines
AWWA and ANSI/NSF Standards
Cast Grey Iron Pipe (prior to 1948)
Cast Ductile Iron Pipe
Steel Pipe
Concrete Pipe
Asbestos Cement Pipe
Plastic Pipe (after 1970)
2

2


Comparison of Plastic (PVC) and Ductile Iron (DI) Pipe
PVC Pipe
Used in 4" – 12" installations
PVC Lighter thus easier to install
Low Friction Head
Not Subject to Corrosion
Less Costly
DI Pipe
Used in 4 to 36" installation
Can withstand heavy external loads
Provides extra surge allowances
Used under roads and crossings of water courses
3

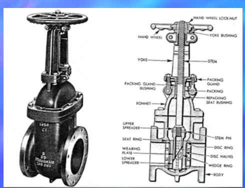
3

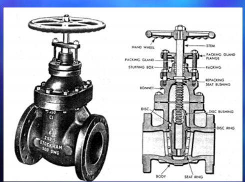
Valves Used in Water Systems

Type	Application	Size	AWWA Standard
Butterfly (rotary)	Isolation and throttling. Water mains typically larger than 8″. Have movable disc.	3″ and up	C504 Rubber Seated Butterfly Valves
Ball (rotary)	Isolation. Used in water service lines to provide an on or off position.	6″ and below	C507 6″ – 48″ and for pressures to 300 psi
Plug (rotary)	Isolation. Water service lines.	6″ and below	
Globe (linear stroke)	Throttling. Efficient in either flow or pressure regulation	6″ and below	
Gate (linear stroke)	Isolation. Most common valve in Dist. System. Should never be used for throttling. Vee-ported gate valve can be used in controlling flows	3″ and up	C500 3″ – 48″

4

Gate Valves





Rising Stem

- Has companion threads in the valve bonnet
- As valve is opened, the stem is threaded out, lifting the wedged disc

Non-rising Stem

- The stem is held in place in the bonnet by a collar
- The stem is threaded with companion threads in the wedged disc

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Check Valves

- There are three basic designs of the check valve:
  - the swing check valve,
  - the horizontal and vertical lift check valve,
  - and the ball check valve.
- Ensures water flows in one direction to prevent contamination
- Exert highest amount of friction

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Swing Check Valve

- Most popular
- Little resistance to flow when open
- Not recommended for frequent flow reversal, causes valve chatter
- Can cause "Water Hammer" if not properly adjusted

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Horizontal/Vertical Lift Check Valve

Horizontal Lift Check Valves

- installed in a horizontal position
- Often used with smaller piping
- Used in frequent flow reversal applications

Vertical Lift Check Valves

- similar to horizontal lift check valves
- designed for vertical pipe installation
- foot valves are nearly always of the vertical lift disc design
- foot valves may be installed on the inlet of the pump suction pipe to keep the pump and suction line full of water

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Pipes Used for Service Lines

- Galvanized Steel Pipe
- PVC (schedule 40; thick wall, glued joints)
- Polybutylene (compression or banded Joints)
- Copper (Type K; soft and Type L; hard)

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Importance of Leaks in Water Systems (60 psi)

Leak Size	Gallons/Day	Gallons/Month
1/8 "	300	11,160
1/4 "	3,096	95,976
3/8 "	8,424	261,144
1/2 "	14,952	463,512

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Leaks in Water Mains

- Lost Revenue (typical $5.00/1,000 gallons)
- Chemical and Electrical Costs at Water Plant (typical 66% of cost)
- Capital Cost for System Upgrades (from $3M to $5M per MGD)

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Water Loss and Unaccounted for Water

- Typical Water System 10% loss is acceptable
- Meter Comparison Used to Calculate Efficiencies
- Unaccounted by Authorized Losses are Estimated
- > 10% loss indicates problem

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Meter Service Life

5/8" Meter	Normal Use	7 – 15 years
5/8" Meter	High Use	5 - 7 years
> 5/8" Meter	Normal Use	7 - 10 years

- Meters should be tested on both life span and registered consumption
- Meters such as venturi, propeller, ultrasonic and magnetic, are used to measure the amount of water passing through them.

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Domestic Meter Testing AWWA C700

5/8	Flow Range	Gallons/ Minute	Low Range	High Range
1.	Max. Rate	15 GPM	98%	101.5 %
2.	Int. Rate	2 GPM	98%	101.5 %
3.	Low Rate	1/4 GPM	95%	101.0 %

14

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Identifying Leaks in Water Mains

- Customer Complaints
- Physical Inspections
- Standing Water in Dry Periods
- Continuous Flow in Storm Sewers
- Ponding in Low Areas
- Use of Leak Detection Equipment

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Pipeline Systems

- Must Comply with "Ten State Standards" and DEP FAC Chapter 62 Pipelines
- Pipelines must meet AWWA Standards for materials used in construction
- Pipelines designed to carry at Max 5 fps
- Pipelines must be restrained at changes in direction
- Pipelines require proper bedding and bedding material

16

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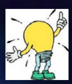
Water Distribution DEP System Requirements



- Maintain 20 psi in distribution system at service connection except for break or extraordinary conditions.
- > 350 people or 150 connections

  Document program for exercising all system valves

  Have quarterly dead-end system flushing program

  Program for responding to complaints

  Map locations of valves, fire hydrants and facilities

  Emergency Preparedness Plan for system

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Cross-Connections

"CROSS-CONNECTION" means any physical arrangement whereby a public water supply is connected, directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture, or other device which contains or may contain contaminated water, sewage or other waste, or liquid of unknown or unsafe quality which may be capable of imparting contamination to the public water supply as the result of backflow.

- By-pass arrangements, jumper connections, removable sections, swivel or changeable devices, and other temporary or permanent devices through which or because of which backflow could occur are considered to be cross-connections.
- A cross connection is a improper connection between a contaminated water source and the public water system.
- A connection between an approved and an unapproved water supply.

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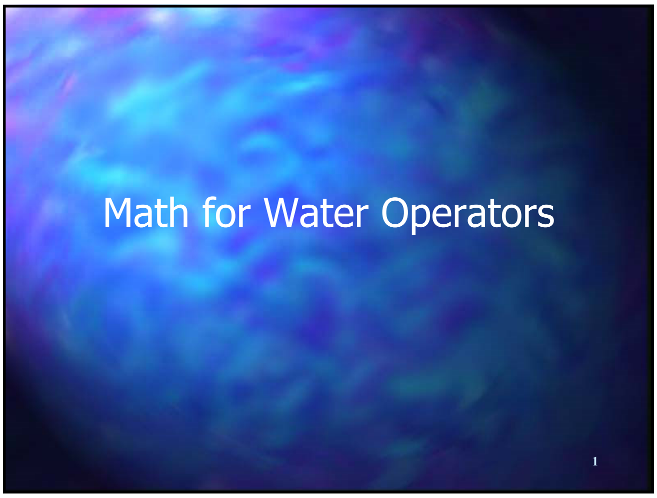
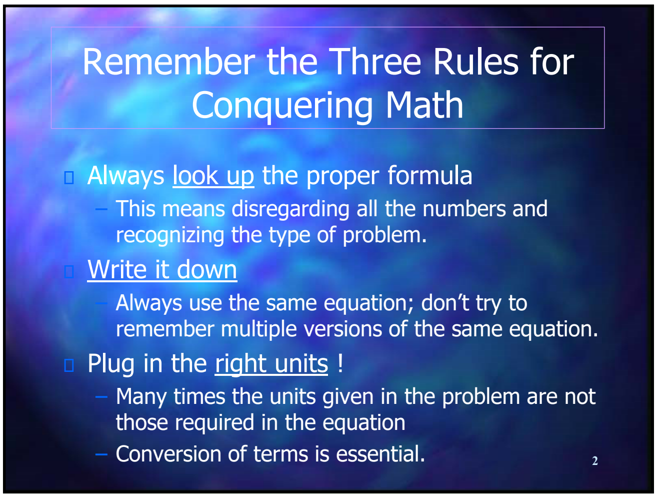
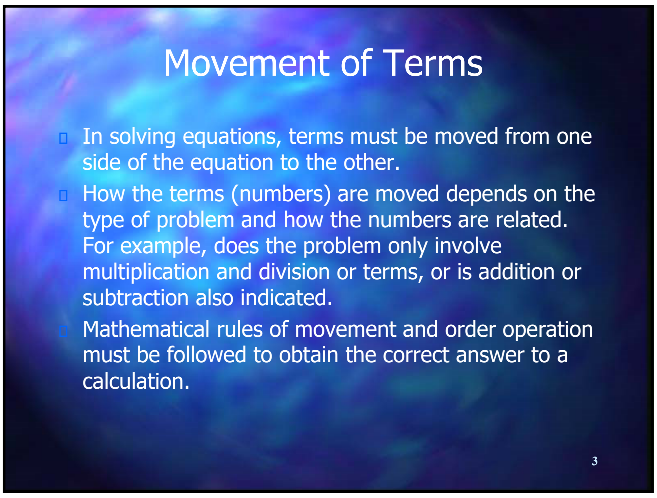

Math for Water Operators
1

1


Remember the Three Rules for Conquering Math
Always look up the proper formula
– This means disregarding all the numbers and recognizing the type of problem.
Write it down
– Always use the same equation; don't try to remember multiple versions of the same equation.
Plug in the right units !
– Many times the units given in the problem are not those required in the equation
– Conversion of terms is essential.
2

2


Movement of Terms
In solving equations, terms must be moved from one side of the equation to the other.
How the terms (numbers) are moved depends on the type of problem and how the numbers are related. For example, does the problem only involve multiplication and division or terms, or is addition or subtraction also indicated.
Mathematical rules of movement and order operation must be followed to obtain the correct answer to a calculation.
3

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Order of Operations - How do I remember what to do first?

PEMDAS

P - Parenthesis first

E – Exponents (i.e. powers and sq roots)

MD – Multiplication/Division (left to right)

AS – Addition/Subtraction (left to right)

You can remember by saying "**P**lease **E**xcuse **M**y **D**ear **A**unt **S**ally".

4

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Equations

- These are the formulas that operators deal with every day.
- Every part of the formula has a numerator (top) and a denominator (bottom)
- When no denominators are shown, a one is assumed to be the denominator of the fraction

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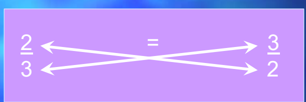
Multiplication and Division Problems

- Move terms diagonally from one side of the equation to the other.



- Only one type of movement is permisssible: Diagonal
- Example: Solve Q = VA for A

6

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Addition and Subtraction

- What you do to one side of an equation you have to do to the other.
- Applies to terms or numbers

  Example: A = B, add C to each side

  A+C = B+C

  Example: 3 = 4–1, add 2 to each side

  3+2 = 4-1+2

  5 = 5

7

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Example

- What would you do to rearrange the disinfection formula to solve for demand?

  Dose = Demand + Residual

- Subtract Residual from each side

  Dose – Residual = Demand + ~~Residual~~ - ~~Residual~~

  Dose – Residual = Demand

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Some Basics

- Multiplying either side of an equation by 1 doesn't change the sides being equal it only changes the units.
- All of the conversions shown on the formula sheets are equal to 1!

  Length =12 inches

  $\text{Length} = 12\ \cancel{\text{in}} \times \dfrac{1\ \text{ft}}{12\ \cancel{\text{in}}} = 1\ \text{ft}$

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Terminology

- ft^2 of ft^3
- π
- Radius
- Diameter
- Circumference
- Express inches in feet

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Conversions - Box Method

- Many times people get confused on whether to multiply or divide
- The box method is an aid in making that decision. To use it first set up the boxes, with the smaller box on the left.

- Because multiplication is associated with increasing a number, we use multiplication when moving from the smaller box to the larger box
- When moving from the larger box to the smaller box, division is indicated (number gets smaller)

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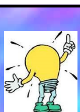


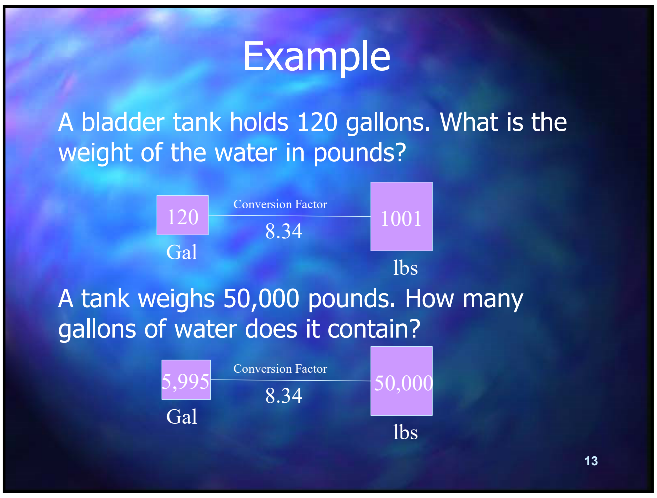
Example

To see how this works, convert 100 grains/gal to mg/l.

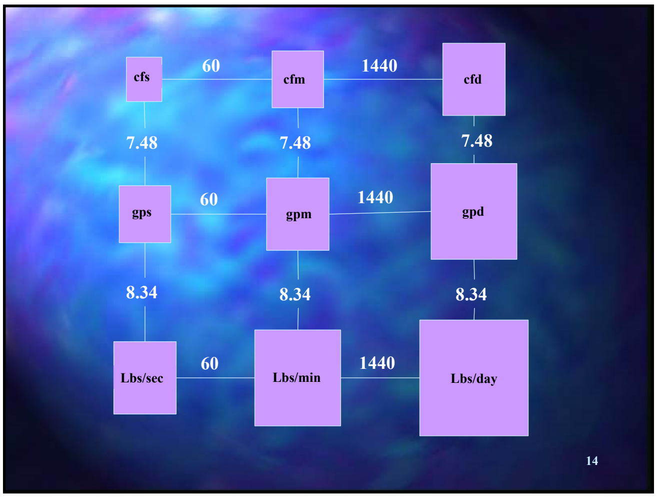
Going from left to right, do you multiply or divide? We are going from the smaller box to the larger box, so using the association that the number is getting bigger, we multiply.

12

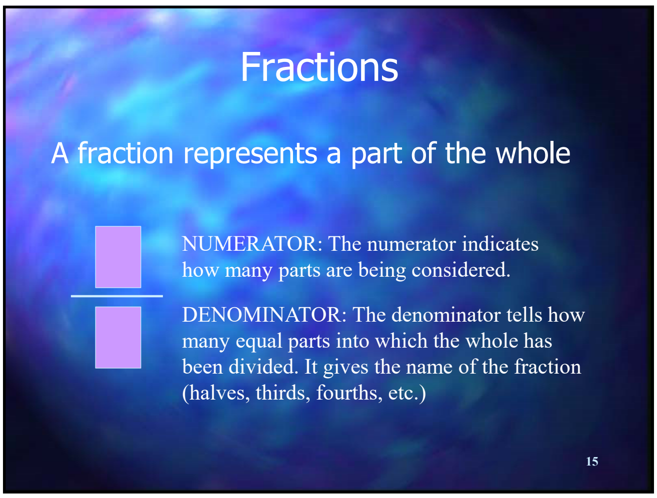
12


Example
A bladder tank holds 120 gallons. What is the weight of the water in pounds?
120
Gal
Conversion Factor
8.34
1001
lbs
A tank weighs 50,000 pounds. How many gallons of water does it contain?
5,995
Gal
Conversion Factor
8.34
50,000
lbs
13

13


cfs
60
cfm
1440
cfd
7.48
7.48
7.48
gps
60
gpm
1440
gpd
8.34
8.34
8.34
Lbs/sec
60
Lbs/min
1440
Lbs/day
14

14


Fractions
A fraction represents a part of the whole
NUMERATOR: The numerator indicates how many parts are being considered.
DENOMINATOR: The denominator tells how many equal parts into which the whole has been divided. It gives the name of the fraction (halves, thirds, fourths, etc.)
15

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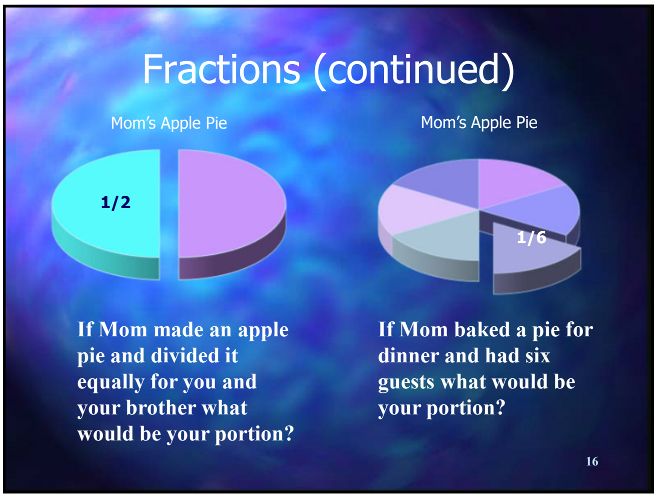
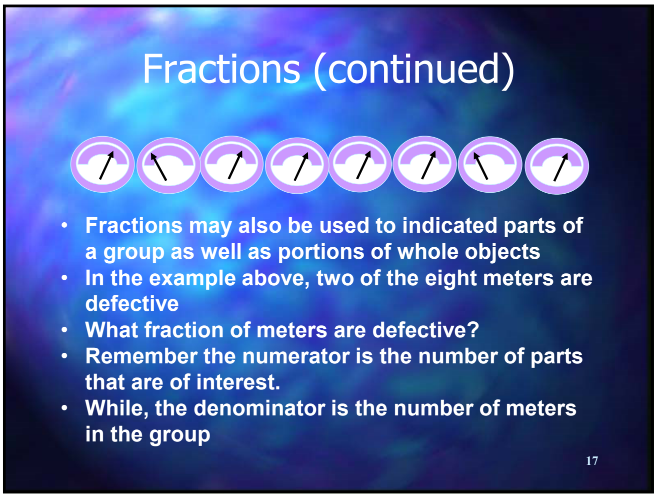

Fractions (continued)
Mom's Apple Pie
Mom's Apple Pie
1/2
1/6
If Mom made an apple pie and divided it equally for you and your brother what would be your portion?
If Mom baked a pie for dinner and had six guests what would be your portion?
16

16


Fractions (continued)
• Fractions may also be used to indicated parts of a group as well as portions of whole objects
• In the example above, two of the eight meters are defective
• What fraction of meters are defective?
• Remember the numerator is the number of parts that are of interest.
• While, the denominator is the number of meters in the group
17

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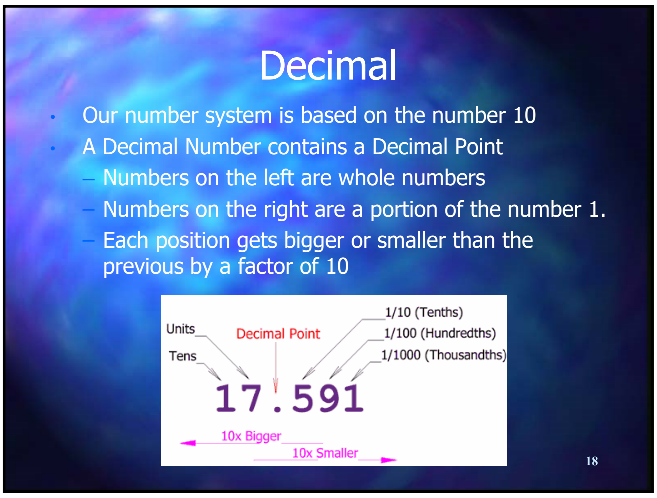
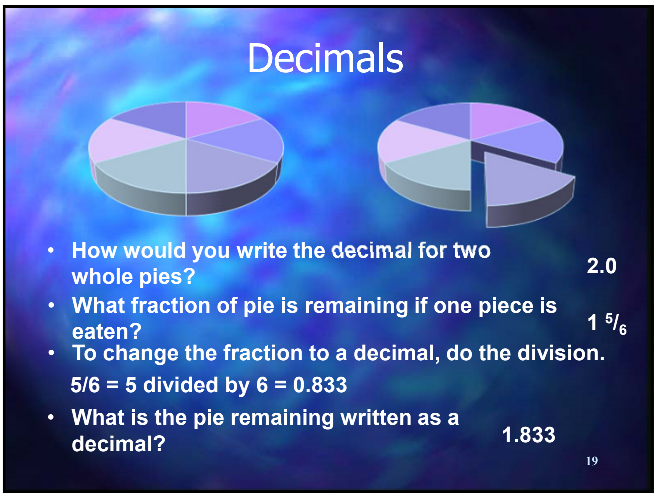
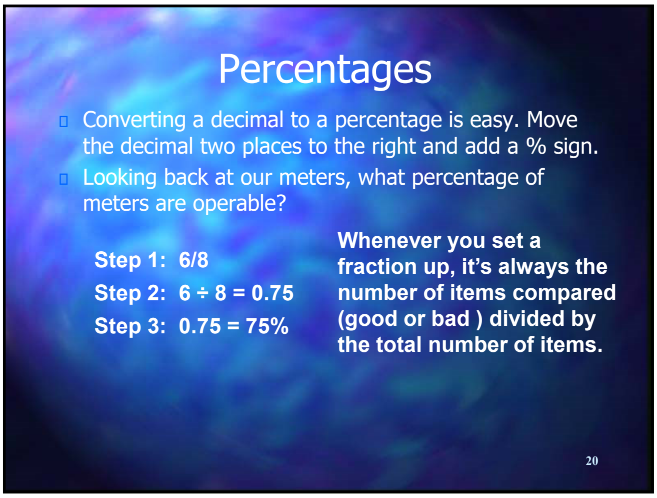

Decimal
• Our number system is based on the number 10
• A Decimal Number contains a Decimal Point
– Numbers on the left are whole numbers
– Numbers on the right are a portion of the number 1.
– Each position gets bigger or smaller than the previous by a factor of 10
Units
Tens
Decimal Point
1/10 (Tenths)
1/100 (Hundredths)
1/1000 (Thousandths)
17.591
10x Bigger
10x Smaller
18

18


Decimals
How would you write the decimal for two whole pies?
2.0
What fraction of pie is remaining if one piece is eaten?
1 5/6
To change the fraction to a decimal, do the division.
5/6 = 5 divided by 6 = 0.833
What is the pie remaining written as a decimal?
1.833
19

19


Percentages
Converting a decimal to a percentage is easy. Move the decimal two places to the right and add a % sign.
Looking back at our meters, what percentage of meters are operable?
Step 1: 6/8
Step 2: 6 ÷ 8 = 0.75
Step 3: 0.75 = 75%
Whenever you set a fraction up, it's always the number of items compared (good or bad) divided by the total number of items.
20

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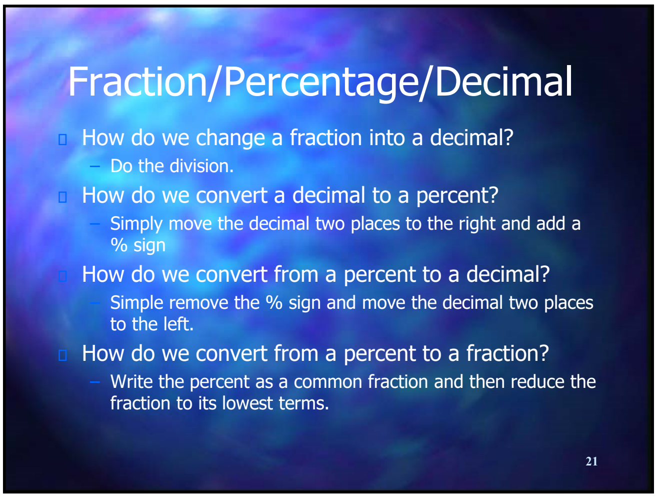

Fraction/Percentage/Decimal
How do we change a fraction into a decimal?
– Do the division.
How do we convert a decimal to a percent?
– Simply move the decimal two places to the right and add a % sign
How do we convert from a percent to a decimal?
– Simple remove the % sign and move the decimal two places to the left.
How do we convert from a percent to a fraction?
– Write the percent as a common fraction and then reduce the fraction to its lowest terms.
21

21

Percentage Problems

1. 25% of the chlorine in a 30 gallon vat has been used. How many gallons are remaining in the vat?
2. How many pounds of 67% calcium hypochlorite are required to make the equivalent of 50 pounds of pure chlorine?
3. A 2% chlorine solution is what concentration in mg/l?
4. A water plant produces 84,000 gallons per day. 7,560 gallons are used to backwash the filter. What percentage of water is used to backwash.
5. The average day winter demand of a community is 14,500 gallons. If the summer demand is estimated to be 72% greater than the winter. What is the estimated summer demand?
6. An operator mixes 40 lb of lime in a 100-gal tank that contains 80 gal of water. What is the percent of lime in the slurry?

22

22

Proportions

- Setting up a proportion
  - First group like terms (gallons to gallons and lbs to lbs)
  - Place the smallest numbers of each unit in the numerators (top)
- To solve a proportion
  - Get the x term (unknown) in the numerator
  - Get the x by itself

23

23

Example: 0.5 lbs of chlorine are dissolved in 45 gallons of water. To maintain the same concentration, how many pounds of chlorine would have to be dissolved in 100 gallons of water?

- First group the terms

$$\frac{\text{Gallons}}{\text{Gallons}} = \frac{\text{lbs}}{\text{lbs}}$$

- Place smallest numbers on top

$$\frac{45 \text{ gal}}{100 \text{ gal}} = \frac{0.5 \text{ lbs}}{x \text{ lbs}}$$

- Solve for x

$$x = \frac{0.5 \text{ lbs} \times 100 \text{ gals} = 50}{45 \text{ gal}} = 1.1 \text{ lbs}$$

24

24

It takes 3 men 60 hours to complete a job. At the same rate, how many hours would it take 5 men to complete the job?

- First group the terms

  $\frac{\text{men}}{\text{men}} = \frac{\text{hours}}{\text{hours}}$

- Place smallest numbers on top

  $\frac{3 \text{ men}}{5 \text{ men}} = \frac{x \text{ hours}}{60 \text{ hours}}$

- Solve for x

  $x = \frac{3 \text{ men} \times 60 \text{ hours} = 180}{5 \text{ men}} = 36 \text{ hours}$

25

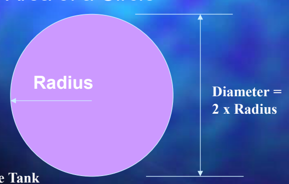
25

Calculating the Area of a Tank or Pipe

- Area or Surface Area of a Round Shape

  Area may be expressed as ft^2 or as sq.ft.
  These terms are synonymous.

Area of a Circle



Storage Tank or Pipeline Shape

Make sure that all units are expressed in feet!

Area = π x R^2

= π x R x R

= 3.14 x R (ft) x R (ft)

26

26

What are some of the conversion factors that I might need to find the area?

- 1 ft = 12in

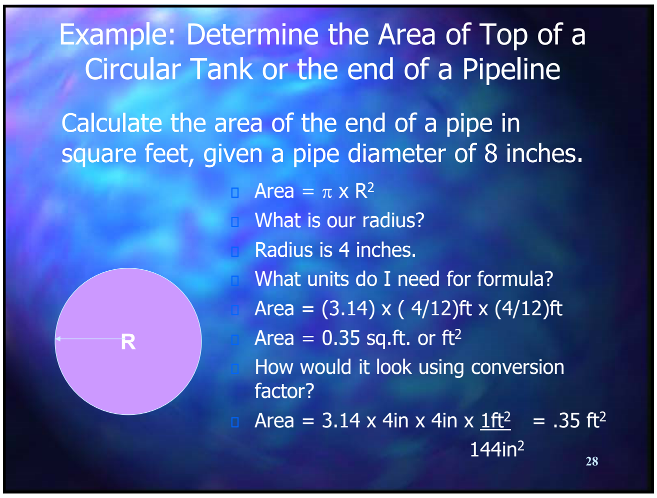
What about ft^2? How do I get there?

- Multiply each side by itself or square each side.
- 1 ft x 1 ft = 12 in x 12 in
- 1 ft^2 = 144 in^2

- Let's work a problem!

27

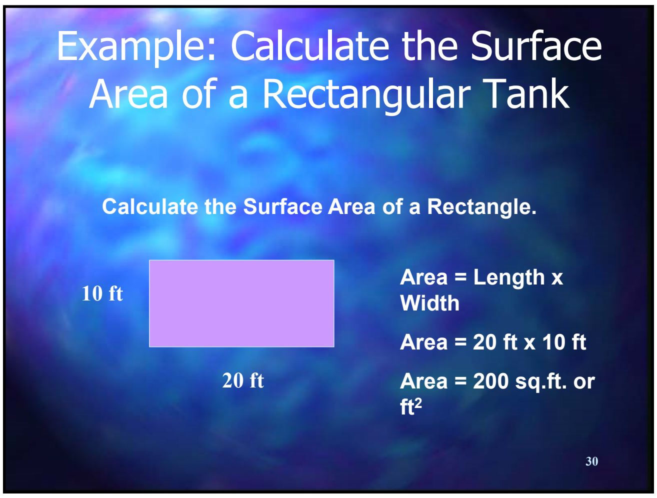
27


Example: Determine the Area of Top of a Circular Tank or the end of a Pipeline
Calculate the area of the end of a pipe in square feet, given a pipe diameter of 8 inches.
Area = π x R2
What is our radius?
Radius is 4 inches.
What units do I need for formula?
Area = (3.14) x (4/12)ft x (4/12)ft
Area = 0.35 sq.ft. or ft2
How would it look using conversion factor?
Area = 3.14 x 4in x 4in x 1ft2 = .35 ft2
144in2
R
28

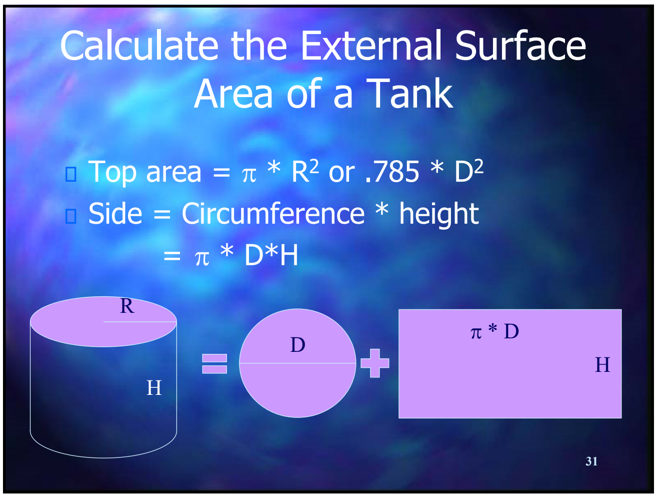
28


Determine the Surface Area of a Rectangular Tank/Basin/Filter
Calculate the Surface Area of a Basin. Remember the units for area are ft2 or in2.
Make sure that all units are expressed in feet!
Length
Width
feet
feet
Area = Length x Width
= Length (ft) x Width (ft)
29

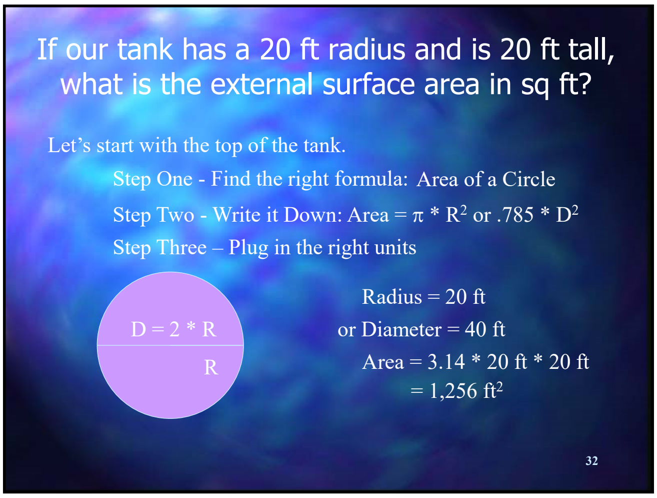
29


Example: Calculate the Surface Area of a Rectangular Tank
Calculate the Surface Area of a Rectangle.
10 ft
20 ft
Area = Length x Width
Area = 20 ft x 10 ft
Area = 200 sq.ft. or ft2
30

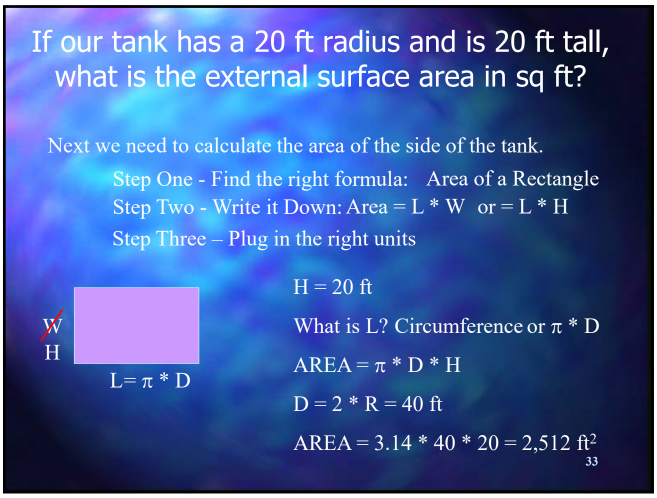
30


Calculate the External Surface Area of a Tank
Top area = π * R2 or .785 * D2
Side = Circumference * height
= π * D*H
R
H
D
π * D
H
31

31


If our tank has a 20 ft radius and is 20 ft tall, what is the external surface area in sq ft?
Let's start with the top of the tank.
Step One - Find the right formula: Area of a Circle
Step Two - Write it Down: Area = π * R2 or .785 * D2
Step Three – Plug in the right units
D = 2 * R
R
Radius = 20 ft
or Diameter = 40 ft
Area = 3.14 * 20 ft * 20 ft
= 1,256 ft2
32

32


If our tank has a 20 ft radius and is 20 ft tall, what is the external surface area in sq ft?
Next we need to calculate the area of the side of the tank.
Step One - Find the right formula: Area of a Rectangle
Step Two - Write it Down: Area = L * W or = L * H
Step Three – Plug in the right units
W
H
L= π * D
H = 20 ft
What is L? Circumference or π * D
AREA = π * D * H
D = 2 * R = 40 ft
AREA = 3.14 * 40 * 20 = 2,512 ft2
33

33

What is the Total External Area of the Tank?

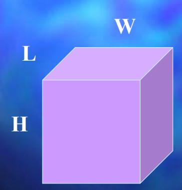
- From previous:
  - Area of Top = 1,256 ft^2
  - Area of Side = 2,512 ft^2
  - Total area is = 3,768 ft^2
- If one gallon of paint covers 500 ft^2, how many gallons of paint are required to paint our tank?
  - $(3{,}768\ ft^2) / (500\ ft^2/\ gal) = 7.5$ or 8 gallons

34

34

Determining the Volume of a Rectangular Tank

- Volume of a Rectangular Shape, ft^3



Make sure that all units are expressed in feet!

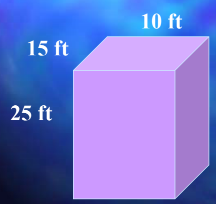
Volume = Length x Width x Height

35

35

Calculation of the Volume of a Rectangular Tank

Calculate the Volume of a Rectangular Tank with the dimensions of 15 feet long by 10 feet wide by 25 feet deep.



Volume = Length x Width x Height

= 15 ft. x 10 ft. x 25 ft.

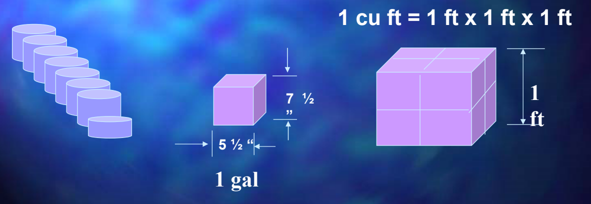
= 3750 c.ft. or ft^3

36

36

Volume can also be expressed in Gallons

- What conversion factor do we use?
- VOLUME: 7.48 gal = 1 ft^3



37

37

Example: Convert Cubic Feet to Gallons

Determine # Gallons in 78,500 ft^3 Tank

VOLUME : 7.48 gal = 1 ft^3

78,500 ~~ft^3~~ x $\frac{7.48 \text{ gal}}{\text{ft}^3}$ = Gallons of Water

= 587,180 Gallons

How many millions of gallons is this?

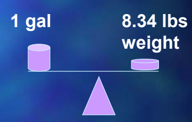
= 587,180 gals / 1,000,000 = .587 million gallons

38

38

Volume can be Converted to Weight

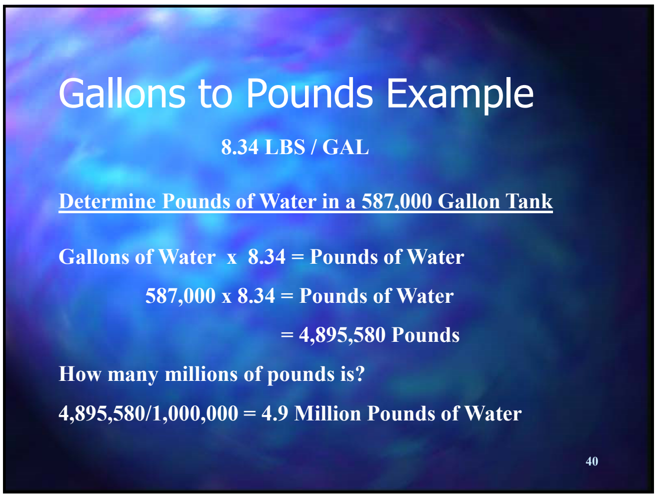
- What conversion factors do we use?
- Weight: 62.4 lbs = 1 ft^3
- or 8.34 lbs = 1 gal



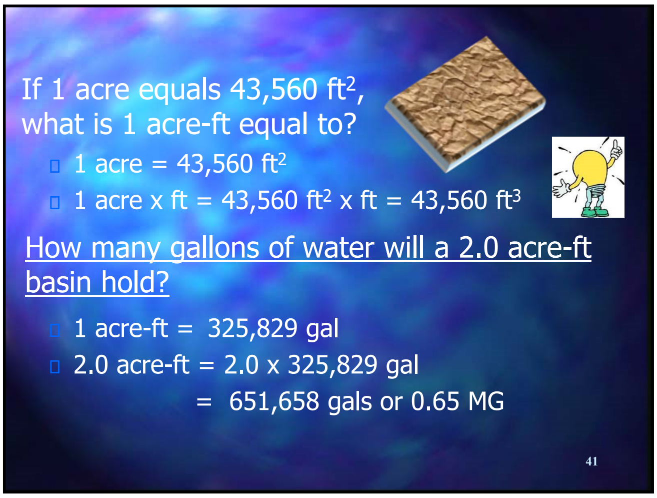
- What is the relationship between the two?
- 1 ft^3 = 7.48 ~~gals~~ x $\frac{8.34 \text{ lbs}}{\text{gals}}$
- 1 ft^3 = 62.4 lbs

39

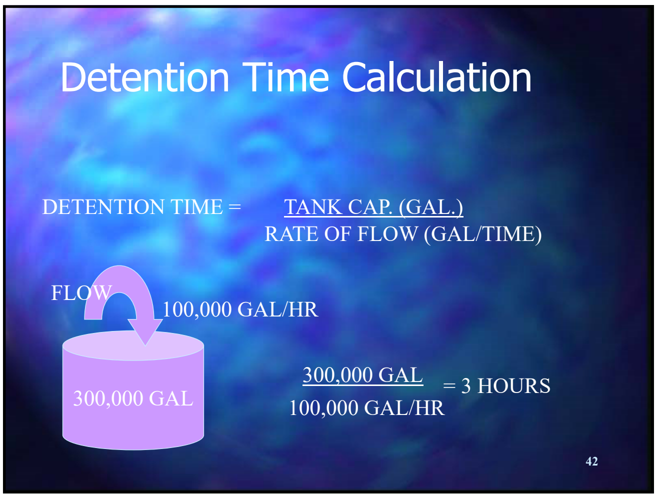
39


Gallons to Pounds Example
8.34 LBS / GAL
Determine Pounds of Water in a 587,000 Gallon Tank
Gallons of Water x 8.34 = Pounds of Water
587,000 x 8.34 = Pounds of Water
= 4,895,580 Pounds
How many millions of pounds is?
4,895,580/1,000,000 = 4.9 Million Pounds of Water
40

40


If 1 acre equals 43,560 ft^2, what is 1 acre-ft equal to?
1 acre = 43,560 ft^2
1 acre x ft = 43,560 ft^2 x ft = 43,560 ft^3
How many gallons of water will a 2.0 acre-ft basin hold?
1 acre-ft = 325,829 gal
2.0 acre-ft = 2.0 x 325,829 gal
= 651,658 gals or 0.65 MG
41

41


Detention Time Calculation
DETENTION TIME = TANK CAP. (GAL.) / RATE OF FLOW (GAL/TIME)
FLOW
100,000 GAL/HR
300,000 GAL
300,000 GAL / 100,000 GAL/HR = 3 HOURS
42

42

Detention Time Calculation

WHAT IS THE DETENTION TIME IN HOURS?

DETENTION TIME = $\dfrac{\text{TANK CAP. (GAL.)}}{\text{RATE OF FLOW (GAL/TIME)}}$

$= \dfrac{.785 \times 60\text{ft} \times 60\text{ft} \times 25\text{ft} \times 7.48\text{gal/ft}^3}{5{,}500{,}000 \text{ gal/day}}$

= .096 Days

= .096 Days x 24 hours/day

= 2.3 hours

43

43

Detention Time Calculation

What is the detention time in minutes for a 6 inch water main, $^1/_2$ mile long with a flow of 15 cfm?

Detention Time (days) = $\dfrac{\text{Volume, gallons}}{\text{Flow, gpd}}$

Detention Time (min) = $\dfrac{\text{Volume, cu ft}}{\text{Flow, cfm}}$

Volume, ft^3 = .785 x Diameter^2 x Length

= .785 x .5^2 x 2640

= 518 ft^3

DT (min) = $\dfrac{518 \text{ ft}^3}{15 \text{ cfm}}$ = 34.5 minutes

44

44

Chemical Feed

Feed lbs/day = Flow (MGD) x Dose (mg/l) x 8.34 (lbs/gal)

Dose (mg/l) = $\dfrac{\text{Feed lbs/day}}{\text{Flow (MGD)} \times 8.34 \text{ (lbs/gal)}}$

Flow (MGD) =Feed lbs/day / (Dose (mg/l) x 8.34 (lbs/gal))

45

45

Raw water is flowing into a plant at a rate of 750,000 gallons per day and is prechlorinated at 5mg/l. How many pounds of chlorine are used per day?

Feed lbs/day = Flow (MGD) x Dose (mg/l) x 8.34 (lbs/gal)

Dose = 5 mg/l

Flow = 750,000 gpd = $\frac{750{,}000 \text{ gal/day}}{1{,}000{,}000}$ = .75 MGD

Chlorine feed lbs/day = 5 mg/l x .75 MGD x 8.34 lbs/gal
= 31.3 lbs/day

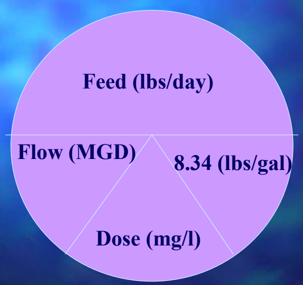
Is there another way of looking at this?

46

46

Chemical Dose Wheel

Feed = Flow x Dose x 8.34



47

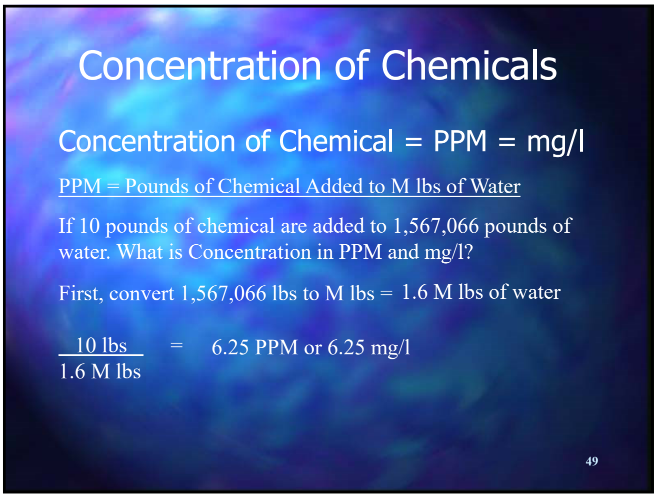
47

Converting Percent to mg/l

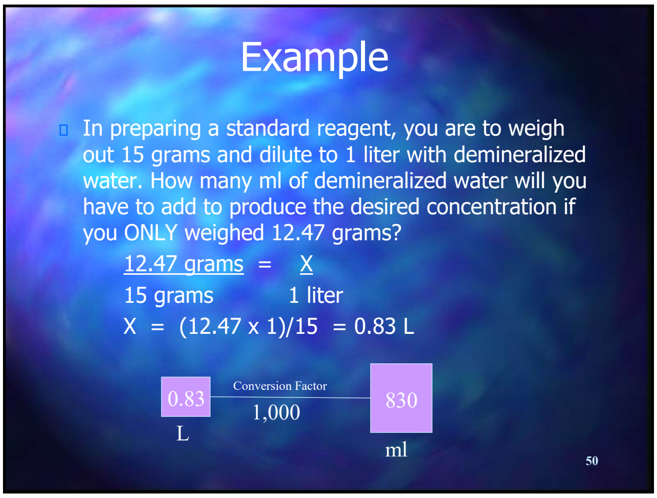
- Percent concentration is a percent of 1,000,000 or parts per million (PPM)
  - Thus 1% is equal to 0.01 and therefore
    0.01 x 1,000,000 = 10,000 mg/l
  - Hence, 1% = 10,000 mg/l
- Concentration may be referred to as dosage
  - Where 1 ppm = 1 mg/l
- Example: What is the concentration in mg/l of 2.89%?

48

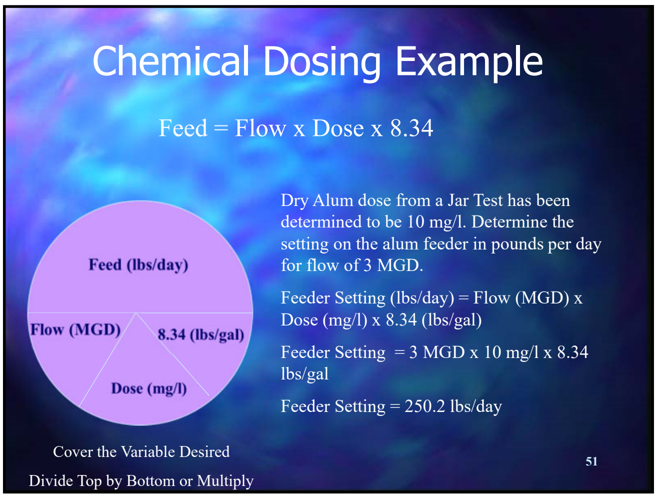
48


Concentration of Chemicals
Concentration of Chemical = PPM = mg/l
PPM = Pounds of Chemical Added to M lbs of Water
If 10 pounds of chemical are added to 1,567,066 pounds of water. What is Concentration in PPM and mg/l?
First, convert 1,567,066 lbs to M lbs = 1.6 M lbs of water
10 lbs / 1.6 M lbs = 6.25 PPM or 6.25 mg/l
49

49


Example
In preparing a standard reagent, you are to weigh out 15 grams and dilute to 1 liter with demineralized water. How many ml of demineralized water will you have to add to produce the desired concentration if you ONLY weighed 12.47 grams?
12.47 grams / 15 grams = X / 1 liter
X = (12.47 x 1)/15 = 0.83 L
0.83
L
Conversion Factor
1,000
830
ml
50

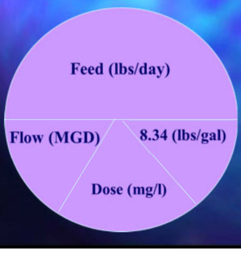
50


Chemical Dosing Example
Feed = Flow x Dose x 8.34
Feed (lbs/day)
Flow (MGD)
8.34 (lbs/gal)
Dose (mg/l)
Dry Alum dose from a Jar Test has been determined to be 10 mg/l. Determine the setting on the alum feeder in pounds per day for flow of 3 MGD.
Feeder Setting (lbs/day) = Flow (MGD) x Dose (mg/l) x 8.34 (lbs/gal)
Feeder Setting = 3 MGD x 10 mg/l x 8.34 lbs/gal
Feeder Setting = 250.2 lbs/day
Cover the Variable Desired
Divide Top by Bottom or Multiply
51

51

Fluoridation Example

- A flow of 4 MGD is to be treated with a 20% solution of hydrofluosilicic acid which contains a fluoride purity of 79.2%. The water to be treated contains no fluoride and the desired fluoride concentration is 1.8 mg/l. Assume the hydrofluosilicic acid weighs 9.8 lbs per gallon. What should be the feed rate of hydrofluosilicic acid? Calculate the feed rate in lbs/day and gal/day.



Feed = Flow x Dose x 8.34

Note: In this problem the dose quality has to adjusted. It comes from a 20% solution and is only 79.2% pure.

52

52

Fluoridation Example

- A flow of 4 MGD is to be treated with a 20% solution of hydrofluosilicic acid which contains a fluoride purity of 79.2%. The water to be treated contains no fluoride and the desired fluoride concentration is 1.8 mg/l. Assume the hydrofluosilicic acid weighs 9.8 lbs per gallon. What should be the feed rate of hydrofluosilicic acid? Calculate the feed rate.

$$\text{Feed (lbs/day)} = \frac{\text{Flow x Dose x 8.34}}{\text{(Acid solution) x (purity)}}$$

$$\underset{\text{(lbs/day)}}{\text{Feed Rate}} = \frac{4.0\ \text{MG}}{\text{Day}} \times \frac{1.8\ \text{mg}}{\text{l}} \times \frac{8.34\ \text{lbs}}{\text{gal}} \times \frac{1}{.2} \times \frac{1}{.792}$$

Feed Rate = 379 lbs acid/day

What is the feed rate in gallons/day?

$$\text{Feed rate, gal/day} = \frac{\text{feed rate, lbs/day}}{\text{chemical sol'n, lbs/gal}} = \frac{379\ \text{lbs/day}}{9.8\ \text{lbs/gal}} = 39\ \text{gal/day}$$

53

53

Chemical Dose Calculation Example

A chlorinator is set to feed 12 lbs/day of chlorine to a flow of 0.750 MGD. What is the chlorine dose in mg/l?

PARTS PER MILLION = mg/l

$$\text{mg/l} = \frac{\text{pounds of chemical per day}}{(\ 8.34\ \text{lbs/gal * MGD})}$$

$$\text{Dose} = \frac{12\ \text{lbs}}{\text{day}} \times \frac{\text{gal}}{8.34\ \text{lbs}} \times \frac{\text{day}}{.75\ \text{MG}}$$

Dose = 1.9 PPM = 1.9 mg/l

54

54

Determining Height of Water in Tank with Pressure Gauge

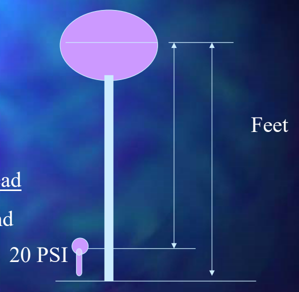
From conversion table 1 psi = 2.31 feet

(this means one pound per square inch of pressure will raise water 2.31 feet)

A pressure gauge is two feet off the ground and has a reading 20 psi, how high will the water be raised?

20 psi X 2.31 = 46.2 feet of head

And about 48 ft from the ground



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Temperature Conversions

- Degrees Celsius = [(°F – 32)(0.555)] or
- Degrees Celsius = $\frac{(°F - 32)}{1.8}$
- Degrees Fahrenheit = [(°C)(1.8) + 32]

56

56

Temperature Conversions

Convert 90°F to Celsius:

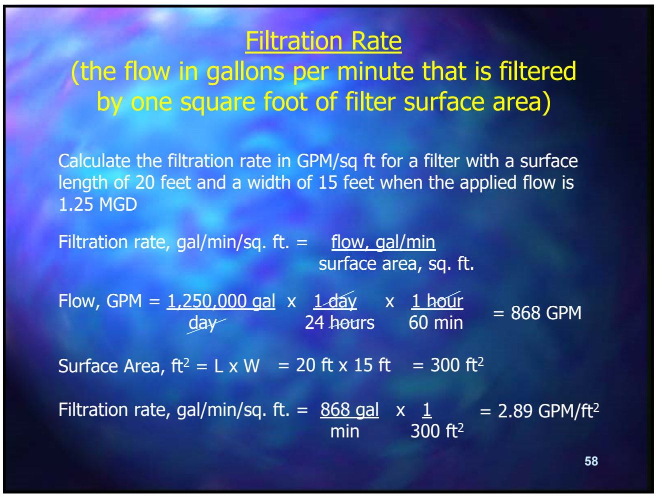
- °C = [(90 – 32)(0.555)] = 32.2°
- °C = $\frac{(90 - 32)}{1.8}$ = 32.2°

Convert 20°C to Fahrenheit

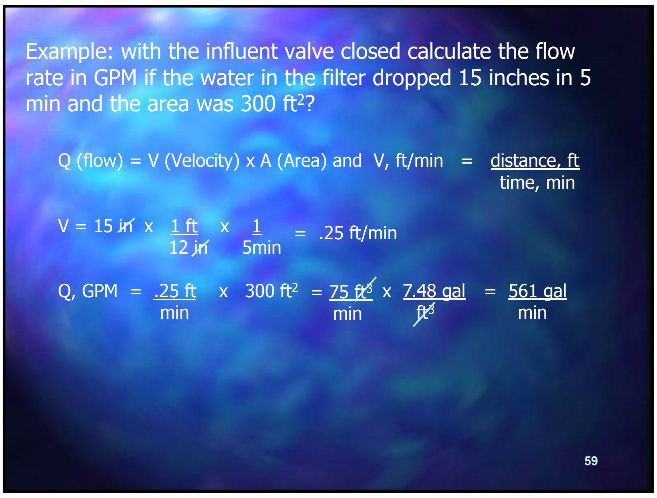
- °F = [(20)(1.8) + 32] = 68°

57

57


Filtration Rate
(the flow in gallons per minute that is filtered by one square foot of filter surface area)
Calculate the filtration rate in GPM/sq ft for a filter with a surface length of 20 feet and a width of 15 feet when the applied flow is 1.25 MGD
Filtration rate, gal/min/sq. ft. = flow, gal/min / surface area, sq. ft.
Flow, GPM = 1,250,000 gal / day x 1 day / 24 hours x 1 hour / 60 min = 868 GPM
Surface Area, ft² = L x W = 20 ft x 15 ft = 300 ft²
Filtration rate, gal/min/sq. ft. = 868 gal / min x 1 / 300 ft² = 2.89 GPM/ft²
58

58


Example: with the influent valve closed calculate the flow rate in GPM if the water in the filter dropped 15 inches in 5 min and the area was 300 ft²?
Q (flow) = V (Velocity) x A (Area) and V, ft/min = distance, ft / time, min
V = 15 in x 1 ft / 12 in x 1 / 5min = .25 ft/min
Q, GPM = .25 ft / min x 300 ft² = 75 ft³ / min x 7.48 gal / ft³ = 561 gal / min
59

59