Small Water Systems

Short Course

Fleming Training Center

http://tn.gov/environment/fleming

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Small Water Systems Operator Certification Training

Fleming Training Center

Introduction

Water operators must be certified

- The correct operation of water and wastewater plants is required to protect public health.
- This is required by the Water Environmental Health Act

"It shall be unlawful for any person, firm, organization both municipal and private to operate a water treatment plant or distribution system unless the operator is duly certified by the department."

Overview

- By becoming certified you are verifying that you posses enough knowledge to make process decisions that will result in the provision of safe drinking water to the ultimate customer.

Definitions

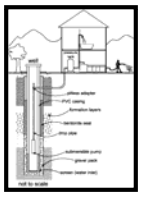
Public Water System:

" A public water system means a system for the provision of piped water for human consumption, that serves 15 or more connections or which regularly serves 25 or more individuals daily at least 60 days out of the year."

Definitions

Small Water System :

“ All water systems which have a ground water source, not under the direct influence of surface water and serves less than fifty (50) service connections.”



Public Water Systems

Community Water System : (CWS)

“means a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least (25) twenty –five year round residents.”

Non-Community Water System: (NCWS)

“means a public water system that is not a community water system.”

There are two types of non-community water systems **Transient** and **non-transient**

Public Water Systems

Non-Transient Non-Community Water System : (NTNCWS)

“means a non-community water system that regularly serves at least 25 of the same persons over six month of the year.

- Example, an elementary school served by a well that serves 60 students and faculty nine months out of the year.

Public Water Systems

Transient Non-Community Water System: (TNCWS)

“ means a non-community water system that serves 15 connections or 25 persons at least 60 days out of the year.”

- For example, a campground that serves water to 100’s of different campers from mid May- September.

Primary Drinking Water Regulations

- Applies to public water systems
- Specifies **contaminants** which, in the judgment of the department, may have an adverse affect on the health of persons.
- Specifies a **maximum contaminant level or (MCL)** allowed in water
- Specifies **treatment techniques** to be used by public water systems
- Establishes other criteria such as water quality monitoring, water system design and reporting requirements.

Secondary Drinking Water Regulations

- Means a regulation which applies to public water systems and which specifies the **secondary maximum contaminant levels or (SMCL)** which in the judgment of the department are required to protect the public welfare.
- Such regulations may apply to any contaminant in drinking water: which may affect the odor or appearance of such water and cause people to discontinue to use or may otherwise affect public welfare.

Primary and Secondary MCL's

Fluoride and several chemicals have both primary and secondary MCL's.

The primary MCL for Fluoride is 4.0 mg/L.

- Levels above 4.0 mg/L can have harmful effects on human health, such as skeletal fluorosis, a painful bone disease.

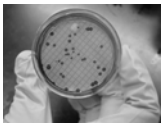
The secondary MCL for Fluoride is 2.0 mg/L.

- Levels above 2.0 mg/L are not harmful to health but may cause mottling or staining of teeth.

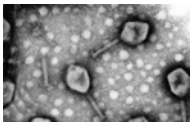
Bacteriological Monitoring Requirements

Reason for Testing:

"To look for potential disease causing organisms in drinking water such as viruses and bacteria, and to make sure that disinfection techniques are adequate."



Coliform bacteria



Viruses

Bacteriological Monitoring Requirements

How often do you test?

- Non- community systems serving less than 1000 people and using ground water not under the influence of surface water test quarterly.
- Community systems test monthly according to the population they serve.

Population served	Samples per month
25-1000	1
1001-2500	2
2501-3300	3

Bacteriological Monitoring Requirements

Where do you get sample bottles?

The nearest state lab will mail the bottles to you.

What if you don't receive the bottles?

- Failure to take the sample will not be excused if sample bottles are lost in the mail.
- Make sure you have the number for the lab to get new bottles, make sure you take your samples early enough so that you have time to get replacements if necessary.

Sampling Procedure: What precautions should you take?

- Don't touch the mouth or rim of the bottle, or the inside of the lid.
- Don't rinse the bottle
- Be sure the lid has been tightly closed during shipment.
- Keep filled sample containers out of direct sunlight.
- Do not return sample containers by certified mail.

Sampling Biological – When to take samples?

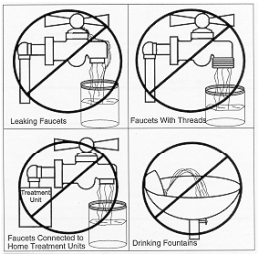
- Take samples on Monday, Tuesday or Wednesday.
- Take samples early in the month or quarter.
- Avoid taking samples a day or two before state holidays.
- Always use first class mail.
- Take the sample at the time of day near mail dispatch time.
- The sample must reach the lab in as short a time as possible. **No longer than 30 hours from collection**.

Collecting the Sample

Find a suitable faucet.

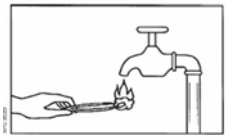
Avoid:

- Faucets that are leaking
- Faucets with large threads
- Water fountains
- Swivel faucets, that control hot and cold.
- Faucets attached to home treatment systems, softeners



Collecting the Sample

1. Turn on the cold water tap.
2. Let it run for 1-2 minutes.
3. Take chlorine residual reading.
4. Sterilize the tap, with either a butane lighter, rubbing alcohol, or 1% bleach solution.

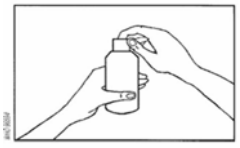


Collecting the Sample

5. Let the water run for 1-2 more minutes.
6. When collecting the sample, adjust the flow so that it doesn't splatter back on the faucet or sample container, a pencil size stream.
7. Check the sample bottle. Don't use bottles that have had loose caps.
8. Tilt the bottle slightly and place it into the stream of water. Fill it to the shoulder of the bottle, the 100 mL mark.

Collecting the Sample

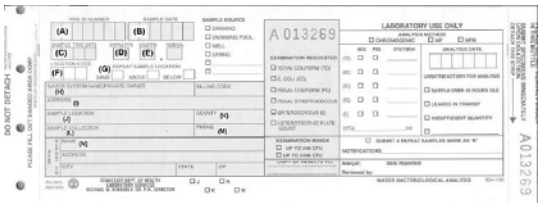
9. Holding the cap face downward to prevent contamination , place the cap on the bottle and close tightly.
10. Fill out the report form.
11. Ship or drive the samples to the lab within 30 hours of collection.



How to Complete Report Forms

- Use a Ball Point Pen and press hard since you are making four copies.
- Fill out all the boxes colored light pink.
- If you chlorinate, be sure to report the chlorine residual at the time you take the sample.

Filling out the Coliform Report Form



A. PWSID number, each water system has there own ID number.

B. Sample date, format December 6, 2008 = 12/06/08

C. Sample Time, use military time.

D. Sample type, D = distribution routine sample, R = repeat, N = new lines F = field

Filling out the Coliform Report Form

E. Chlorine residual, mg/L

F. and G. Lab will fill out if repeat samples are necessary.

H. Water System or Utiliy Name

I. Address of water system or utility

Filling out the Coliform Report Form

J. Sample Location, be specific, the address or description of location in a building, kitchen sink in mess hall, or 123 Green St.

K. County

L. The person who collected the sample.

M. Daytime phone number in case the lab needs to contact you.

N. Name and address to whom the results should be sent.

Total Coliform Rule

All samples will be tested to determine the presence (positive sample) or absence (negative sample) of Total Coliform bacteria.

Total Coliform Bacteria is the indicator organism

- Always present in contaminated water
- Always absent when contamination is absent
- Survives longer in water than other pathogens

Total Coliform Rule/ Sampling Plan

- Each public water system must have a state approved written bacteriological sampling plan.

Plan must contain:

- Areas to be sampled, must include dead end lines, residential areas, areas near storage tanks.
- Frequency of samples, whether monthly, or quarterly
- Plan should require that samples are collected throughout the system so that no area of the system is neglected during the year.

Total Coliform Rule: If a sample is positive

- If a routine or a repeat sample is positive for total coliform than the sample will also be tested for Fecal Coliform or E.coli.
- If a sample is positive for total coliforms, 4 repeat samples must be collected and sent to the state laboratory.
- All repeat samples must be collected on the same day and within 24 hours of being notified of the positive result.

Total Coliform Rule: Repeat Samples

- One sample must be taken from the same tap where the positive sample was collected.
- One sample from within 5 service connections upstream of the positive sample,
- One from within 5 service connections downstream of the positive sample.
- The fourth sample may be collected anywhere within the 5 upstream and 5 downstream service connections.

Total Coliform Rule: Increased Monitoring

- All water systems are required to take **5** microbiological samples during the month following any month in which there is a positive sample.
- Even if you only take one sample per month or one sample per quarter normally.
- It is the water system's responsibility to ensure that the increase in sampling rate is met. Failure to do so will result in a monitoring violation.

Total Coliform Compliance

- All samples both distribution and repeat are used in determining compliance.
- All small water systems collecting 39 or fewer samples each month can only have one positive total coliform sample.
- Two or more positive total coliform samples places the system in violation of the standard.

Compliance continued

- A public water system which exceeds the MCL for total coliform must report the violation to the state no later than **the end of the next business day** after discovering the violation.
- A PWS which failed to comply with the coliform monitoring requirements must report the monitoring violation to the state within **ten days** after the system discovers the violation and also notify the public of the violation as soon as possible, and **within 30 days.**
- A system that has more than 2 positive total coliform samples but does not have any samples come back positive for fecal coliform or E. coli will have a **non-acute total coliform violation** and will be required to notify the public of the violation as soon as possible, and **within 30 days.**

Coliform compliance continued

- A fecal coliform violation shall occur if either of the following event should happen:
- The system has a positive total coliform repeat sample following a positive fecal coliform or E. coli routine sample; or
- The system has a positive fecal coliform or E. coli determination on a positive total coliform repeat sample.

Compliance continued

- A system that has a fecal Coliform violation will be classified as having an **acute total coliform violation** and will be required to give the appropriate public notice for an acute violation, as soon as possible, **within 24 hours.**
- A public water system must notify the state by the **end of the business day** if E. coli or fecal coliform are found in any routine or repeat samples.

Sampling for Nitrate and Nitrite

- A small amount of Nitrate and Nitrite in water can be harmful to babies who are younger than 6 months.
- Nitrate and Nitrite in the water interferes with a baby's ability to use the oxygen in the air it breathes, resulting in blue baby syndrome.
- All public water systems must monitor for nitrate. The MCL is 10 mg/l.

Sampling for Nitrate and Nitrite

Sampling Frequency

System type	Contaminant	Frequency
Groundwater	Nitrate	Annually
Surface	Nitrate	Quarterly
Groundwater	Nitrite	Once, more if deemed necessary by State
Surface	Nitrite	Once, more if deemed necessary by State

Nitrate Sampling and Testing: Reduced Monitoring

- Water systems using surface water my be allowed by the state to reduce the sampling frequency to annually if all the analytical results from four consecutive quarters are less than 50% of the MCL.
- A surface water system must return to quarterly monitoring if any sample is greater than 50% of the MCL.

What is Turbidity? and Why is it important?

Turbidity :

" cloudiness of water caused by tiny particles of dirt, organic material, microorganisms, etc."

- The human eye can not detect turbidity in water until more than 5 turbidity units are present.
- While the particles may not be harmful themselves, the more important aspect is that these particles often shield harmful bacteria from disinfection.

Are you required to monitor turbidity?

Your water source is the basis for this requirement:

- If you obtain your water from a surface supply, a ground water source under the direct influence f surface water, or if the State has specifically designated your system for turbidity monitoring , then you must monitor for turbidity at least once each day that you obtain water form a stream, lake, spring, or other source.
- The MCL for turbidity is 0.3 nephelometric turbidity units, or 0.3 NTU as measured with a nephelometric turbidimeter.

Who does turbidity testing?

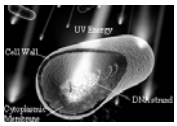
- Since you are required to perform this test at least once every day your water system is in operation, it might be necessary to purchase a turbidimeter.
- In order for the results to be acceptable, the person performing the analysis must be approved by the state.
- There are several turbidimeters with easy step by step instructions on how to use their equipment.
- You can contact your local environmental field office or Fleming Training Center if you require assistance learning to use the equipment.

Disinfection is required for your water system

1. If you use surface water or ground water under the influence of surface water
2. If you have serve water to more than 50 service connections or 150 persons.
3. If you have had positive total coliform samples and have trouble meeting the coliform MCL.

Disinfection

- Chlorine is the recommended disinfection agent.
- Other things such as ultraviolet light, ozone or iodine will be considered by the department provided their effectiveness is recognized and test procedures exist.
- Systems that disinfect must maintain a free chlorine residual of 0.2 mg/L in all parts of the distribution system.
- Chlorine residual must be measured at the time coliform samples are collected.



How to Disinfect

- Most people use chlorine compounds such as found in household bleach. Use only NSF approved chemicals.
- Hypochlorinators are small pumps that pump chlorine compounds in solution into water.
- Peristaltic, or positive displacement pumps are the most reliable.
- Avoid the use of copper tubing with concentrated chlorine compounds.

Sampling and testing for free chlorine residual

- You need a DPD (N, N Diethyl–p–phenylene diamine) test kit
- Free chlorine residual is the chlorine that remains in the water after it reacts with any compounds or organisms present in the water.
- Any loss of chlorine residual indicates a problem and should be investigated immediately.
- A free chlorine residual should be restored immediately. It may be necessary to increase the chlorine feed rates to restore the free residual.

Free Chlorine Residual continued

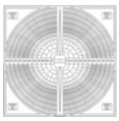
- Follow the instructions that come with the test kit.
- Chlorine in water is not stable. You must read the sample immediately, never wait more than 15 minutes after taking the sample to read it.
- Avoid agitation of the water and avoid excess exposure to light.

Free Chlorine Residual continued

- Fill the sample tube with water.
- Add the reagent for free chlorine, mix the sample and reagent and read the concentration according to your test method.
- Record the results on the bacteriological sample slip and MOR if required.
- Rinse out your sample cell after the test or it will stain the glassware and give false readings.

Record keeping

- Obtain a log book to schedule, record and check yourself on all sampling activities
- Establish a permanent file location for all results of biological, chemical, and sanitary survey results
- Label all charts with date, time, place, scale of instrument if continuous measurements are made.



Record Keeping

- Bacteriological results – 5 years
- Chemical analyses – 10 years
- Sanitary surveys – 10 years
- Action taken to correct violations – 3 years

Groundwater Protection Wells And Springs

- Limit public access to the well or spring to prevent vandalism.
- Well casing must extend 24 inches above the 100 year flood plain.
- Wells must be properly grouted and have a sanitary seal.
- Springs must be properly landscaped to prevent entry of surface water
- All vents on springs, wells and tanks should be screened to keep out animals and insects.
- Pitless adapters should be used on wells with submergible pumps.

Groundwater Protection Wells and Springs

- Don't install wells near obvious sources of contamination such as septic tanks, field lines, fuel storage tanks or landfills
- Don't allow chemicals such as fertilizers, pesticides or solvents to be stored or applied near a well or spring.
- Don't allow any chemicals or waste materials to be dumped into nearby sinkholes.
- Fence animals at least 100 feet away from springs and wells.
- Always disinfect the well, pumps and plumbing after repairs
- Don't allow lead to be used to repair pipes or fixtures.

Groundwater under the direct influence of surface water

How is it determined to be under the influence?

- Biological- the presence of Giardia, cyptrosporidium, algae, rotifers, insects and other living organisms normally found in surface waters.

- Temperature- Fluctuations of 4 degrees over the course of a year, true ground water stays relatively constant.

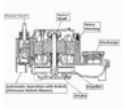
- Chemical parameters- rapid fluctuations in pH, conductivity, hardness and other chemicals.
- Turbidity- if turbidity changes with rain events or if the raw water turbidity is greater than 5 NTU.

Operation and Maintenance Rules

- Daily operations records of the water system shall be recorded on forms, called MOR's and submitted to the State by the 10th of the following month.
- You must keep all equipment necessary for providing water to the public, including pipes, pumps, and tanks in good working order.
- It is a good idea to have a back up in case you have a breakdown.

Operation and Maintenance Rules

- Newly constructed or repaired lines must be properly disinfected and tested for bacteria before being put into service.



- Any construction, changes, or improvements to the water system must have written plans submitted and must be approved by the State.

- Storage tanks must be professionally inspected every 5 years, and must be properly vented and screened.

Cross Connections

Cross connection:

" defined as actual or potential connections between a potable and non-potable water supply (water of unknown quality)"

- Cross connections are a serious public health hazard.
- The common garden hose is responsible for many cross connections.
- **Backflow:** is the unwanted reverse flow of non-potable water back into a water system.
- Backflow can allow bacteria, chemicals or physical contaminants to enter the water system if CCs are uncontrolled

Cross Connections

How can cross connections be prevented?

- **Air gap**
- Most effective method.
- An air gap is considered the maximum protection available but is not always practical and can easily be bypassed.
- **Reduced Pressure Backflow Preventer**
- Most effective device.
- An RPBP is effective against backpressure backflow and backsiphonage and may be used to isolate health or non-health hazards.

Disinfection

Water Treatment Process That Destroys Pathogens

1

Objectives

- Principles and methods of disinfecting drinking water
- Chemistry of disinfection
- Application points of disinfectants
- Regulations regarding disinfection
- Operating and control tests

2

Disinfection Vs. Sterilization

- Disinfection - the destruction of pathogenic organisms
  - To prevent waterborne disease outbreaks
  - Destroys only disease-causing organisms
- Sterilization - the destruction of all organisms in the water

Not all microorganisms are bad!

3

Destroying Pathogens in Water

- Some pathogens can survive long enough in water to cause disease outbreaks
- Some pathogens form cysts and become inactive, survive longer

4

Detecting Pathogens in Water

- Coliform bacteria analysis is required for water systems to determine the presence or absence of fecal contaminants in the distribution system
- This test does not indicate P/A of other pathogens, e.g. *Cryptosporidium*, viruses

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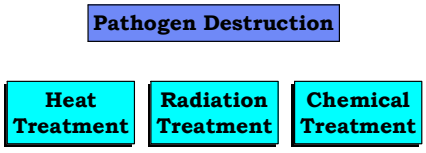
Methods of Disinfection



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Heat Treatment

- Boiling water in emergency
- "Boil Order" may be issued
- Rolling boil for 5 minutes
- Only practical for small amounts of water

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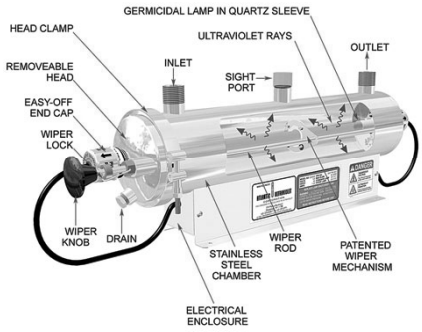
Radiation

- UV lamps (UV disinfection)
- Requires relatively clear water
- Water must pass close to lamp
- Lack of residual



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UV Advantages

- No problems of overdosing.
- Low initial capital cost as well as reduced operating expenses when compared with similar technologies such as ozone, chlorine, etc.
- Immediate treatment process, no need for holding tanks, long retention times, etc.
- Extremely economical, hundreds of gallons may be treated for each penny of operating cost.
- Low power consumption.

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UV Advantages

- No chemicals added to the water supply - no by-products (i.e. chlorine + organics = trihalomethanes).
- Safe to use.
- No change in taste, odor, pH or conductivity nor the general chemistry of the water.
- Automatic operation without special attention or measurement, operator friendly.
- More effective against viruses and cryptosporidium than chlorine.

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How does it work?

- Ultraviolet is one energy region of the electromagnetic spectrum, which lies between the x-ray region and the visible region.
- UV itself lies in the ranges of 200 nanometers (nm) to 390 nanometers (nm). Optimum UV germicidal action occurs at 260 nm.

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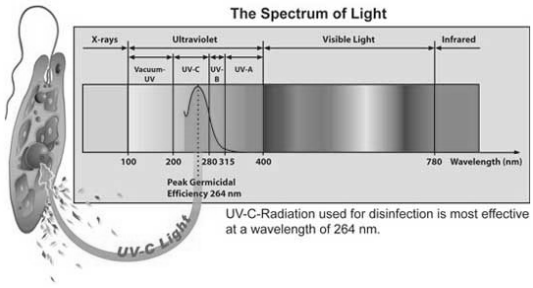

UV-C-Radiation used for disinfection is most effective at a wavelength of 264 nm.

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How does it work?

- Electrical energy is used to power a low pressure mercury vapor "hard glass" quartz lamp. Electrons flow through the ionized mercury vapor between the electrodes of the lamp, which then creates UV light.
- As UV light penetrates through the cell wall of a pathogen it destroys the pathogen's DNA, which prevents it from reproducing. If the cell cannot reproduce, it is considered dead.

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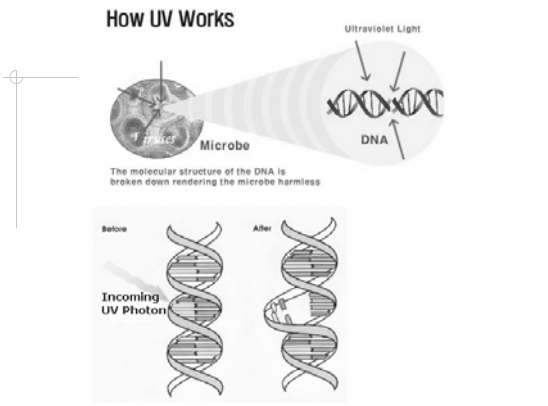

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Disadvantages

- There is no residual left in the water as there is with chemical disinfection.
- Iron and manganese will cause staining on the quartz sleeve and prevent the UV energy from transmitting into the water at levels as low as 0.03 ppm of iron and 0.05 ppm of manganese.

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Disadvantages UV

- Calcium and magnesium, in high amounts, have a tendency to build up on the quartz sleeve, again impeding the UV energy from penetrating the water.
- Turbidity is the inability of light to travel through water. In the case of UV, levels over 1 NTU can shield microorganisms from the UV energy, making the process ineffective.

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UV Operation and Maintenance

- Good for systems with true groundwater avoiding chlorine disinfection.
- Will help prevent the triggered source water monitoring with the new Groundwater Rule.
- May need filtration before the unit if iron and manganese are a problem.

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UV Operation and Maintenance

- UV units should be installed on the cold water line before any branch lines and should be the last point of treatment.
- All points of the distribution system after the sterilizer must be chemically "shocked" to ensure that the system is free from any downstream microbial contamination.

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UV Operation and Maintenance

- Lamps should be changed as lamp output monitor indicates, but at least every 10 to 12 months.
- Note: depending upon systems purchased, lamp output monitors are optional, but recommended.
- Filter changes are done according to the water quality, but usually it is three to six months.

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UV Operation and Maintenance

- Quartz sleeves should be inspected at least every 6 months.
- If minor deposits have formed, the sleeves should be wiped down with a soapy solution. Do not leave fingerprints on the quartz sleeve!
- It is imperative to follow the manufacturer's guidelines on the UV equipment.

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Chemical Treatment

Chemical Oxidants:

- Bromine
- Ozone
- Chlorine Dioxide
- Miox
- Chlorine liquid
- Iodine
- Potassium Permanganate
- Chlorine gas
- Hypochlorite

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Iodine (I_2)

- Blue-black solid, violet vapor
- Chlorine-like odor
- Good for emergencies, used at campgrounds
- Can be used in saturator type feeders
- Not recommended for long term consumption

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Ozone (O_3)

- Must be manufactured on-site
- Bluish, toxic gas with pungent odor
- ☺Powerful disinfectant, produces no THMs
- ☺Works well for color, taste, and odor control
- ☺Aids in coagulation
- Extremely unstable
- Leaves no residual, limited by solubility
- Requires large amounts of energy to generate

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Chlorine

- Most commonly used disinfectant in U.S.
- Maintains residual
- Chlorine gas, Cl_2
- Calcium hypochlorite (HTH), $Ca(OCl)_2$
- Sodium hypochlorite (bleach), NaOCl

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Chlorine Gas

- Cl_2
- 100% pure
- 2.5 times as dense as air
- Pungent, noxious odor
- Greenish-yellow color
- Highly irritating to eyes, nasal passages, and respiratory tract

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Hypochlorite (Liquid)

- Sodium Hypochlorite [NaOCl]
- Bleach
- Clear, light-yellow color
- Costs 3 times as much as chlorine gas
- Shelf life 60-90 days
  - 5.25% Chlorine to 12.5% Chlorine — Clorox / Pool bleach

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Hypochlorination Equipment

- Bleach solution tank:
- Various sizes are available
- Positive displacement pump
- Also called : tube pumps, peristaltic pumps and Stenner pumps.
- Chemical feed lines
- Scale

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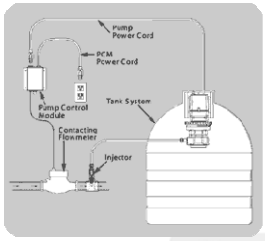
Hypochlorination Equipment



29

Hypochlorite (Solid)

- Calcium Hypochlorite [$Ca(OCl)_2$]
- Solid, granular, or tablet
- White or yellow-white in color
- Most dangerous - fire hazard
  - High Test Hypochlorite (HTH)
  - 65% pure

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Calcium Hypochlorite

- Most often used for line and tank disinfection.
- Used to shock the equipment at high doses.
- Highly chlorinated water must be diluted or dechlorinated prior to disposal.

31

Chemistry of Chlorination

$Cl_2 + H_2O \rightarrow HOCl + HCl$

hypochlorous acid — hydrochloric acid

- Hypochlorous acid
  - Most effective disinfectant
  - Prevalent at pH less than 7

    Dissociates at higher pH:

    $HOCl \rightarrow H+ + OCl-$

    hypochlorite ion
  - Hypochlorite ion is only 1% as effective as hypochlorous acid.

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Chemistry of Hypochlorination

$NaOCl + H_2O \rightarrow HOCl + NaOH$

hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

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Chemistry of Chlorination

- Chlorine reacts with reducing agents in the water
  - organic matter
  - iron and manganese
  - nitrites
- No free residual will be formed until all reducing agents are destroyed
- Chlorine also reacts with ammonia and organics to form combined residuals
- These are not as effective as free residual

34

Residual Formation

- The breakpoint is the point at which the chlorine dosage has met the demand
- Any additional chlorine will result in a free residual

35

Chlorine Demand

- Chlorine Demand
  - The difference between the chlorine added to the water and the amount of residual chlorine remaining after a given time

Dose = Demand + Residual

36

Chlorination Principles

- Five factors important to success of chlorination:
  - Chlorine concentration
  - Contact time — most important
  - Water temperature
  - Water pH
  - Foreign substances in the water

37

Disinfection

"kill" is proportional to C x T

- Destruction of organisms depends on the concentration of chlorine added and the amount of time the chlorine is in contact with the organisms
- If one is decreased, the other must be increased to ensure that kill remains the same.

38

Interferences

- Chlorine is only effective if it comes in direct contact with organisms
- Turbidity protects pathogens from chlorine
- Substances such as ammonia and organic matter reduce effectiveness of chlorine

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Disinfection Application Points

- Pre-chlorination
  - Begins process of killing or inactivating pathogens
  - Minimizes biological growth throughout process
  - Oxidizes minerals, gases, organics, etc.
  - Increases contact time
  - May improve coagulation
  - High potential for DBP production

40

Disinfection Application Points

- Post-chlorination
  - Application of chlorine to treated water
  - Required to meet state and federal requirements for residual
  - Applied at or immediately before clearwell
  - Clearwell must minimize short circuiting to meet C x T values

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Disinfection Application Points

- Distribution System
  - Some systems may require booster chlorination
  - Added at storage tank discharge
- Additional Application Points
  - Feeding 2 or more types of disinfectants at different points may help meet requirements
  - Oxidants other than chlorine can be used early in treatment process to reduce DBPs

42

Disinfection Application Points

- Groundwater systems
  - Often require no treatment other than chlorination
  - Apply chlorine just past wellhead
  - Hypochlorite most commonly used

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Regulations

- Surface Water Treatment Rule (1989)
  - Applies to all surface water plants and groundwater plants under the influence of surface water (GWUI)
- Purpose - to protect public from waterborne disease outbreaks
- Goal - removal or inactivation of all disease-causing organisms
- Requires operating and monitoring with best available technology, disinfection, and filtration

44

Regulations - SWTR

- Most surface and GWUI plants must provide filtration and disinfection to meet treatment techniques
- Turbidity requirements
  - Must not exceed 0.3 NTU in 95% of samples
  - No sample exceeding 5 NTU
- Systems serving 3300 or more people - disinfectant residual must be monitored constantly and must not be below 0.2 mg/L for more than 4 hours

45

Regulations - SWTR

- Disinfectant residual
  - must be measured at coliform sampling points
  - must not be undetectable in more than 5% of samples each month for 2 consecutive months
- Total coliform Rule
  - December 31, 1990, new coliform P/A became effective
  - If a routine sample is coliform positive, it must be tested for presence of fecal or E. coli

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Chloroganics

Organic material + Cl_2 = trihalomethanes

- Organics found in all surface and groundwaters
- Humic and fulvic acids from decomposing plant material
- THM's are potential carcinogens

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Trihalomethane Limits

- Current MCL for total THM = 0.08 mg/L
- Applies to community water systems
- Population 10,000+
- Adds a disinfectant (chlorine)
- Preferred method of controlling THM's is to prevent the formation
- Microbiological safety of the water must not be compromised

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Other Disinfection By-products

- Disinfection by-products other than THM's can be formed from chlorine
- Other disinfectants produce by-products
- The Enhanced SWTR addresses some of these, others still being studied

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Disinfection Control Tests

- Chlorine Residual
  - Presence of residual
  - Free or combined
  - Concentration
  - By amperometric titration (most accurate, not affected by color or turbidity) or DPD method
- Bacteriological Test
  - Indicates fecal contamination
  - Coliforms are more resistant to chlorine than other fecal bacteria, if coliforms are not present, other fecals will not be present either

50

Corrective Measures

- increase chlorine levels immediately
- take samples and identify contaminants
- check distribution system to locate contaminant source or other causes for drop in residual.

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Disinfection Math for Small Water

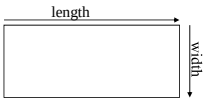
Fleming Training Center

Area

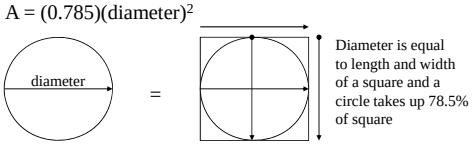
- surface of an object
- two dimensional
- measured in square inches, square feet, square meters, etc.

Area Formulas

- Rectangle
  A = (length)(width)



- Circle
  A = (0.785)(diameter)^2



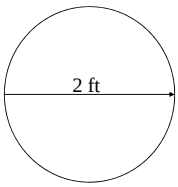
Area of a Rectangle

A = (l)(w)

A = (10 ft)(5 ft)

A = 50 ft^2

Area of a Circle



Diameter = 2 ft

A = (0.785)(D)^2

A = (0.785)(2ft)^2

A = (0.785)(4 ft^2)

A = 3.14 ft^2

Volume

- The amount of space an object occupies
- Volume = (area)(third dimension) or

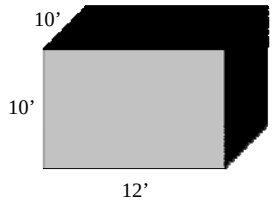
  V = (l)(w)(d)
- Measured in cubic inches, cubic feet, gallons, acre-feet, etc.

Volume of a Rectangular Tank

V = (length)(width)(depth)

V = (12 ft)(10ft)(10ft)

V = 1200 ft^3



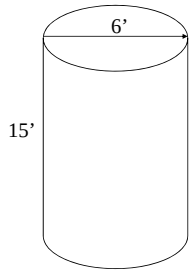
Volume of a Cylinder

V = (0.785)$(D)^2$(height)

V = (0.785)$(6\ ft)^2$(15 ft)

V = (0.785)$(36\ ft^2)$(15 ft)

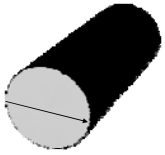
V = 424 ft^3



Note

- When calculating area and volume, if you are given a pipe diameter in inches, convert it to feet.

$$8\ \cancel{in.} \times \frac{1\ ft}{12\ \cancel{in}} = 0.6667\ ft$$

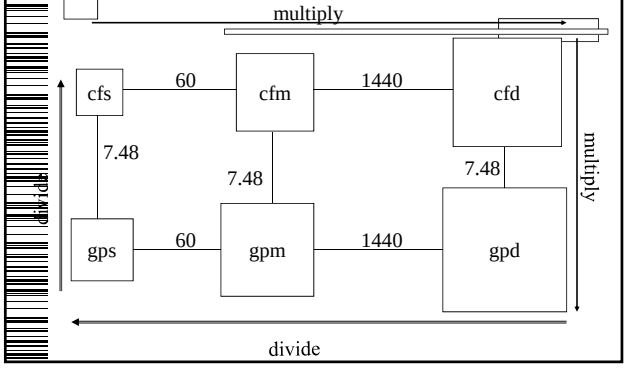


Diameter = 8 in

Conversions

- Need to know:
  - The number that relates the two units
- Ex: 12 inches in a foot, 454 grams in a pound, 3785 mL in a gallon
- Need to know:
  - Whether to multiply or divide
- Ex: smaller to larger or larger to smaller

Flow Conversions – Box Method



Finding Volume (Rectangle)

- You need to find the volume of a rectangular storage tank in gallons.
- The tank is 10 ft long, 4 ft wide and 4 ft deep.
- Volume, gallons = (L ft) (Wft) (d ft) (7.48 gal/ft^3)
- Volume, gallons = (10 ft) (4 ft) (4 ft) (7.48 gal/ft^3)
- Volume, gallons = 1196.8 gallons

Finding Volume (Cylinder)

- You need to find the volume of water in gallons in a 2 inch diameter pipe that is 50 ft long.
- Vol, gal = (0.785) (D, ft)^2 (length ft) (7.48 gal/ ft^3)
- Convert 2 inches to ft 2÷12 = 0.1666 ft
- Vol, gal = (0.785) (0.1666 ft) (0.1666 ft) (50 ft) (7.48 gal/ft^3)
- The diameter has to be squared, or the number times itself.
- Vol, gal = 8.14 gal

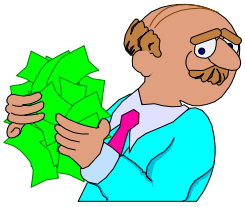
Chlorine

- Chlorine and chlorine compounds are the most commonly used disinfectants for water systems in the U.S.
  - Chlorine, Cl_2
  - Calcium hypochlorite (HTH), $Ca(OCl)_2$
  - Sodium hypochlorite (liquid bleach), NaOCl

Purpose of Chlorination

- Chlorination does not destroy all organisms in the water
- Chlorine only destroys pathogenic, or disease-causing organisms.

Formula Booklet



Disinfection formulas are on pages 12-13

Chlorine Demand

- If the chlorine dosage is 4.5 mg/L and the residual is 1.2 mg/L, what is the demand?

Cl_2 demand = Cl_2 dose, mg/L - Cl_2 residual, mg/L

= 4.5 mg/L - 1.2 mg/L

= 3.3 mg/L

Hypochlorination

- How many pounds of 65% HTH are required to make 10 gallons of 1% solution?

$$\text{lbs HTH} = \frac{(\%\text{ desired conc.})(\text{desired gal})(8.34\text{ lb/gal})}{\%\text{ available HTH}}$$

$$= \frac{(.01)(10\text{ gal})(8.34\text{ lb/gal})}{.65}$$

= 1.28 lb HTH

Dilutions

- How many gallons of 15% bleach will be required to make 60 gallons of 5% bleach?

gal = (% desired conc., as decimal)(desired vol., gal)
% bleach conc., as decimal

= (.05)(60 gal)
.15

= 20 gal

Substitutions

- A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 43 gal/day of 15% sodium hypochlorite, how many pounds per day will they use of Cl_2?

lbs Cl_2 = (% bleach, as decimal)(gal bleach)(8.34 lbs/gal)

= (.15)(43 gal)(8.34 lbs/gal)

= 53.8 lbs Cl_2

Substitutions

- A water plant has run out of calcium hypochlorite for disinfecting a storage tank. If they needed 75 lbs HTH, how many gallons of 15% NaOCl will they need?

gal bleach = (%HTH, as decimal)(lbs. HTH)
(% available bleach)(8.34 lbs/gal)

= (.65)(75 lbs.)
(.15)(8.34 lbs/gal)

= 39 gallons NaOCl

Storage Tank Disinfection

- A 500,000 gallon storage tank is disinfected with 50 mg/L using 65% HTH. How many pounds of HTH are required?

lbs HTH = (dosage,mg/L)(MG)(8.34 lbs/gal)
% HTH

= (50 mg/L)(.5MG)(8.34)
.65

= 320.8 lbs

Water Main Disinfection

- How many pounds of 65% available HTH will be needed to disinfect a section of pipe 250 feet long and 12 inches in diameter with a dose of 50 mg/L?

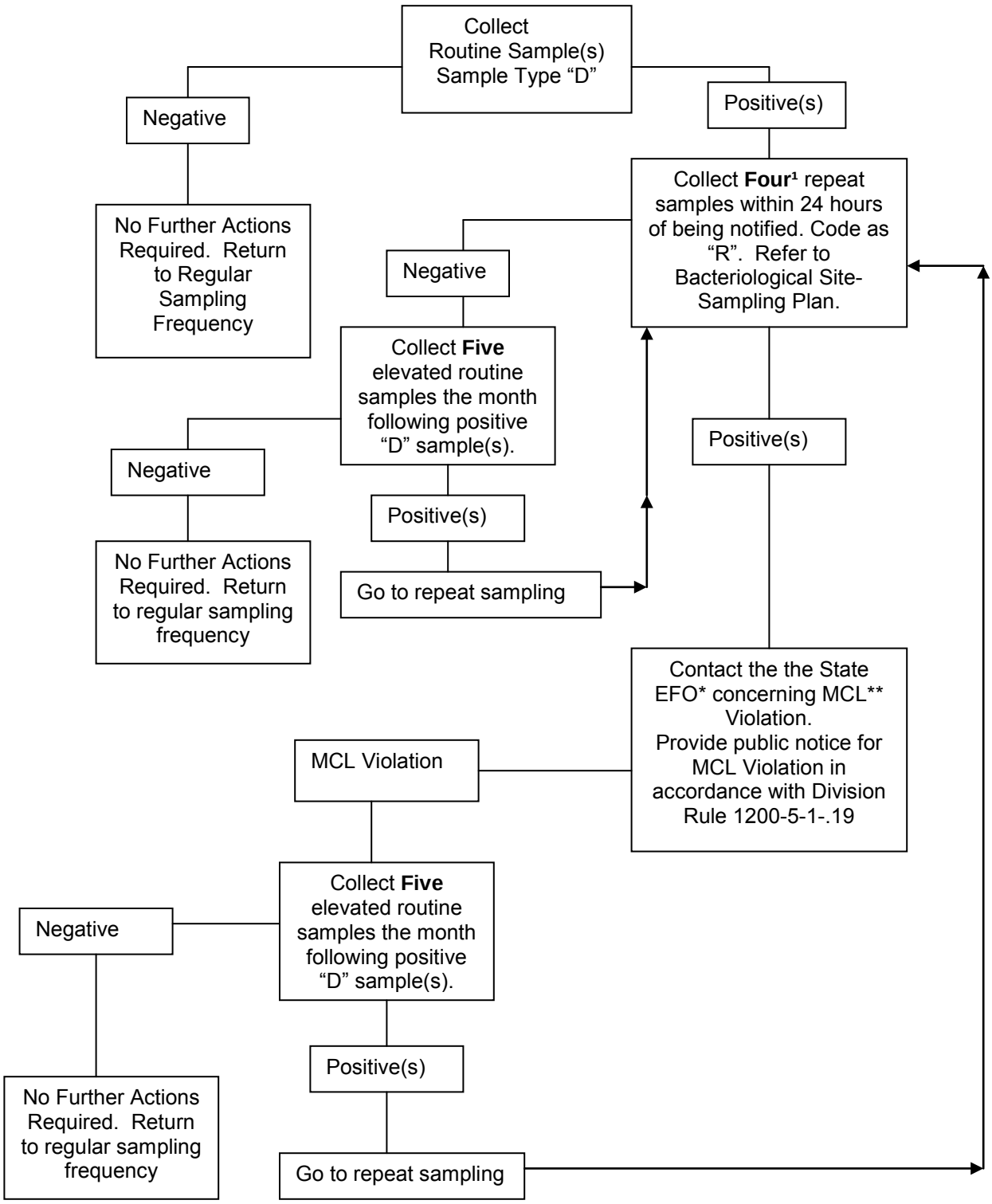
volume = $(0.785)(\text{diameter})^2(\text{third dimension})$
$= (0.785)(1\text{ ft})^2\,(250\text{ ft})(7.48\text{gal/ft}^3)$
= 1466 gal

lbs = (dosage, mg/L)(volume, MG)(8.34 lbs/gal)
% available, as decimal

= (50mg/L)(.001466MG)(8.34lbs/gal)
0.65

= 0.94 lbs HTH

Bacteriological Sampling Flow Chart



[1] Three (3) repeat samples if system is required to collect more than one (1) monthly or quarterly samples.
* EFO= Environmental Field Office
**MCL= Maximum Contaminant Level

Bacteriological Sampling Plan

Objectives:

It is the primary objective of this water system to provide our customers with water that meets their needs in terms of quantity and quality and to comply with all state and federal drinking water standards and regulations.

It is the objective of this water system to take bacteriological samples that are representative of the entire distribution system including dead end lines, low use areas, residential areas, and areas near storage tanks.

Description of Water System

The system has_____ connections and serves approximately _____ persons.

The system is required to take _____ bacteriological sample(s) per month.

Total Coliform Monitoring Frequency, Community Water Systems

Minimum Number of Population Served, Samples Per Month

25 to 1,000..... 1
1,001 to 2,500..... 2
2,501 to 3,300..... 3
3,301 to 4,100..... 4
4,101 to 4,900..... 5
4,901 to 5,800..... 6

Sample Locations to be Avoided

Avoid sampling from hydrants.

Avoid faucets that are attached to water softeners or home treatment systems such as Pūr or Britta.

Avoid leaking faucets, faucets with large threads, faucets that swivel between hot and cold, and drinking fountains.

Avoid faucets close to the ground or sink bottom because they may not allow space to place the sample bottle below the stream without touching the inside of the bottle.

Sample Collection Procedure

Bacteriological samples will be collected on the first or second Monday of every month. This is to avoid problems with repeat samples.

If a faucet has a strainer, aerator, or other attachment it must be removed before sampling.

Let the water run for 3-5 minutes to insure that you are sampling water from the main and not the customer's plumbing. Take the free chlorine residual reading using the DPD method and record the reading.

Disinfect faucet with either a dilute bleach spray, rubbing alcohol, or by flaming the faucet with a butane lighter or torch.

Reopen the faucet and let the water run in a stream about the size of a pencil to prevent splashing during sampling.

The sample bottles are sterile and contain sodium thiosulfate to neutralize chlorine. Do not rinse out the sample bottle. If you feel that the bottle has been contaminated dispose of the bottle and sample with a new bottle.

Hold the sample bottle with one hand near the bottom of the bottle, and with the other hand remove the lid being careful not to touch the inside of the bottle or lid.

Hold the bottle under the faucet allowing a small, steady stream to flow from the faucet. Collect 100 ml of water, the water meniscus should touch the 100 ml mark on the sample bottle, under and overfilled bottles may be rejected.

Immediately remove the filled bottle from the stream and replace the lid.

Document the required information from the sample site and fill out the slip that is attached to the sample bottle.

- Time and date collected, use military time or designate am or pm.
- Specific location or address where sample was collected.
- Free chlorine residual in mg/L.
- Collector's name and contact information.
- Sample type: Distribution (D), Repeat (R), etc.

Immediately take the sample to the laboratory, **all bacteriological samples must be analyzed within 30 hrs of collection.**

Laboratory Contact Information

Lab Name: _____

Phone: _____

Address: _____

Personal contact: _____

Alternate Laboratory

Lab Name: _____

Phone: _____

Address: _____

Personal contact: _____

Positive Samples

If a routine distribution sample comes back positive for total coliform than the system will take 4 repeat samples within 24 hours of being notified of the positive result.

One repeat sample must be collected from the same location where the positive sample occurred. One sample must be collected 5 connections upstream of that location and one sample must be taken 5 connections downstream of the location. The forth sample may be taken anywhere in the distribution system.

If one or more of the repeat samples is also positive for total coliforms than the water system will continue taking sets of 4 repeat samples within 24 hours of the positive result until all 4 repeats come back negative or until the MCL has been exceeded and the State is notified.

The MCL is exceeded when more than one sample in a month is total coliform positive. The water system will notify the State no later than the end of the next business day after learning of the MCL violation.

Fecal coliform/ E. Coli

If the routine distribution sample or repeat sample is positive for total coliforms it will also be analyzed for the presence of E. coli or another fecal coliform indicator.

If a sample is positive for E. coli or fecal coliform bacteria than the system will notify the State within 24 hours of learning of the positive result.

Increased Monitoring

If the system has a total coliform positive sample than the system will increase monitoring frequency in the month following the positive sample from one bacteriological sample to a total of five bacteriological samples.

Total Coliform Rule and MCL Violations

The water system is in violation of the total coliform MCL if more than one sample in a month is positive for total coliforms.

The water system will notify the State of the violation by the end of the following business day.

The water system is in violation of the total coliform rule if it fails to take any of the required samples or fails to report the results to the State.

Requiring a Tier 1 Public Notice

Violation of the MCL for total coliforms occurs when fecal coliform or E. coli are present in the water distribution system as specified in 1200-5-1-.06.

Violations occur when the water system fails to test for fecal coliforms or E. coli, or when any repeat sample tests positive for total coliforms as specified in 1200-5-1-.07

Public Notification

Provide a public notice as soon as practical but no later than 24 hours after the system learns of the violation.

Contact the DWS field office as soon as practical, but no later than 24 hours after the public water system learns of the violation or situation, to determine additional public notice requirements.

Comply with any additional public notification required by the DWS.

The water system will provide the public notice within 24 hours in a form and manner reasonably calculated to reach all persons served.

The form and manner used by the public water system are to fit the specific situation, but must be designed to reach residential, transient, and non-transient users of the water system.

In order to reach all persons served, water systems are to use, at a minimum, one or more of the following forms of delivery:

1. Appropriate broadcast media (such as radio and television)

2. Posting of the notice in conspicuous locations in the area served by the water system

3. Hand delivery of the notice to persons served by the water system

Examples of Public Notification/ Specific language

Total Coliform
If your public water system exceeds the MCL for total coliform as a minimum the following public notice must be delivered to your customers:

Public Notice

_____
(Date posted)

The United States Environmental Protection Agency (EPA) requires that we send you this notice on the level of total coliforms found in your drinking water.

(blank #) of sample(s) were collected and analyzed during (month and year). (blank #) contained total coliforms.

The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that the presence of total coliforms is a possible health concern. Total coliforms are common in the environment and are generally not harmful themselves. The presence of these bacteria in drinking water, however, generally is a result of a problem with water treatment or the pipes which distribute the water, and indicates that the water may be contaminated with organisms that can cause disease. Disease symptoms may include diarrhea, cramps, nausea, and possible jaundice, and any associated headaches and fatigue. These symptoms, however, are not just associated with disease-causing organisms in drinking water, but also may be caused by a number of factors other than your drinking water. EPA has set an enforceable drinking water standard for total coliforms to reduce the risk of these adverse health effects. Under this standard, systems that collect fewer than 40 samples per month and have only one total coliform-positive sample per month are not violating the standard. Drinking water that meets this standard is usually not associated with a health risk from disease-causing bacteria and should be considered safe.

For further information contact (operator name) at your water system.
Name, address, phone number.

Fecal Coliforms
This notice shall be used by systems that violate the maximum concentration limit for fecal coliform/E.coli in 1200-5-1-.06(4)(b) or both 1200-5-1- .06(4)(a) and (b) and shall contain the following language.

Public Notice

_____
(Date Posted)

The United States Environmental Protection Agency (EPA) requires that we send you this notice on the level of fecal coliforms/E.coli found in your drinking water. (blank #) sample(s) were collected and analyzed during (month and year). (Blank #) sample(s) contained fecal coliform or E.coli.

The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that the presence of fecal coliforms or E.coli is a serious health concern. Fecal coliforms and E.coli are generally not harmful themselves, but their presence in drinking water is serious because they usually are associated with sewage or animal wastes. The presence of these bacteria in drinking water is generally a result of a problem with water treatment or the pipes which distribute the water, and indicates that the water may be contaminated with organisms that can cause disease. Disease symptoms may include diarrhea, cramps, nausea, and possible jaundice, and associated headaches and fatigue. These symptoms, however, are not just associated with disease causing organisms in drinking water, but also may be caused by a number of factors other than your drinking water. EPA has set an enforceable drinking water standard for fecal coliforms and E.coli to reduce the risk of these adverse health effects. Under this standard all drinking water samples must be free of these bacteria. Drinking water which meets this standard is associated with little or none of this risk and should be considered safe. State and local health authorities recommend that consumers take the following precautions: (To be inserted by the public water system, according to instructions from State or local authorities).

For further information contact (name operator) at your water system.

Name, address, phone number.

Water System Distribution Map

Information Required on Maps

- Street or building names
- Pressure zones: dead ends, low usage, high usage
- Sample sites numbered
- Alternate sample sites numbered

Annual Sampling Schedule

Sites required to be sampled annually

- At least 30 % of sites in residential area
- Dead end lines
- Low use areas
- Areas near storage tanks
- Samples distributed so that no area is neglected during the year.

RECORD KEEPING, REPORTING, AND DOCUMENTATION

How to get organized.

WHY KEEP RECORDS ORGANIZED?

- It's the law, on sanitary surveys, the inspector will deduct points for missing or poorly maintained records.
- It could be the difference between an approved or unsatisfactory rating for your system.
- Records document changes that occur in the water system that can help with process control.
- Accurate records can help resolve customer complaints.
- Accurate records are useful in planning for the future of the water system.

GOOD RECORD KEEPING PROCEDURE.

Records can be kept on the computer

Advantages:

- There are several computer based reporting forms available, ask your local field office for electronic versions or reporting forms.
- Some of the forms will do the calculations if you enter your data.
- Electronic documents are easier to add to or update.
- Computer data loggers may be easier to read than strip charts.

GOOD RECORD KEEPING PROCEDURE

Records can be kept on the computer

Disadvantages:

- Computer systems are expensive.
- Not all water system operators have computers easily available to them.
- A power failures or computer malfunction make accessing the records difficult or impossible.
- Not all records can be kept on the computer.
- You may need additional equipment such as a high quality scanner to enter Bac-T slip results.

GOOD RECORD KEEPING PROCEDURE

Records can be kept in a filing cabinet
Hanging files, manila files, etc.

- Easy to access if properly labeled.
- Relatively inexpensive

GOOD RECORD KEEPING PROCEDURE

Records can be kept in spiral binders or notebooks.

- Easy to access if properly labeled
- Do not take up a lot of space if you have shelves.
- Relatively inexpensive

How to Organize records.

Bacteriological Records

- Should be kept together.
- Bac-T slips should be organized by month/or quarter taken, and then by year taken.
- Organize with the most recent sample records first.
- Also keep bacteriological results for new lines, repaired lines, de-watered storage tanks, etc.
- KEEP ALL BACTERIOLOGICAL RECORDS FOR NO LESS THAN **5** YEARS.

Bacteriological Sampling Plan

Required for all public water systems.

Includes the following:

- Map of the distribution system with labeled sampling locations
- Sample taking procedure
- Sample taking schedule so that all parts of the system are sampled during the year
- What to do in case of positive samples
- When to give public notices
- The plan should be updated regularly, at least every three years.

How to Organize records.

Chemical Records

Should be kept together. Group by chemical type.

- Nitrate/Nitrite
- Inorganics (arsenic, barium,etc)
- Synthetic organics (SOC's)
- Volatile Organics (VOC's)
- Secondary's (pH, taste, odor)
- Radionuclides
- Disinfection Byproducts (THM and HAA5's)

How to Organize records.

Chemical Records

- Not all systems need to test for all these chemicals.
- Find out what chemical tests are required for your system from your local field office.
- KEEP ALL CHEMICAL RECORDS FOR **10** YEARS.

How to Organize records.

Lead and Copper

Keep these records in a group of their own.

- Mostly for Community and Non-Transient Non-Community Water Systems.
- KEEP LEAD AND COPPER RECORDS FOR **12** YEARS.

How to Organize records.

Correspondence from the State.

Sanitary survey letters

- KEEP SURVEY LETTERS FOR 10 YEARS.

Actions regarding violations, NOV's, LOA's, director's orders, commissioner's orders, etc.

- KEEP THESE FOR 3 YEARS.

How to Organize records.

Public Notices
- KEEP COPIES OF PUBLIC NOTICES FOR 3 YEARS.

How to Organize records.

Correspondence with the State.

Variances, waivers, and exemptions
- KEEP FOR 5 YEARS

Notices of Construction
- KEEP FOR 3 YEARS

How to Organize records.

MOR's, daily worksheets, shift logs, strip charts
- KEEP FOR 5 YEARS.

Turbidity records, strip charts
- KEEP FOR 5 YEARS.

Calibration records for lab equipment
- KEEP FOR 5 YEARS

Maintenance records
- KEEP FOR 5 YEARS

How to Organize records.

Storage Tanks
Tank Inspection Records
- KEEP FOR 5 YEARS

Tank maintenance records
- KEEP FOR THE LIFE OF THE TANK

How to Organize records.

Cross Connection Control
Community Water Systems should have a cross connection control plan, a policy or ordinance.
- KEEP THE PLAN UPDATED, EVERY 5 YEARS.

Cross connection records, visual inspection of system, device testing, etc.
- KEEP FOR 5 YEARS.

How to Organize records.

Source Water Protection Plan

Wellhead Protection Plan

Emergency Operations Plan

- All of these plans should be kept updated.
- AT LEAST EVERY 3 YEARS.

How to Organize records.

Distribution Map
- Should be updated regularly.
- A copy of the map must be submitted to the DWS every 5 years.

Flushing program, and flushing records
- KEEP FOR 5 YEARS

New tap records
- KEEP FOR 5 YEARS

How to Organize records.

Standard Operating Procedures
Water Plant SOP's
Distribution SOP's
Disinfection SOP's for lines and storage tanks

- KEEP UPDATED
- AT LEAST EVERY 3 YEARS

How to Organize records.

For Community Water Systems

Consumer Confidence Reports (CCR)
- KEEP FOR 3 YEARS

Customer Complaint Files
- KEEP FOR 5 YEARS

Reporting

Monthly Operation Reports (MOR's)
- MOR's are due to be submitted to the State within 10 days after the end of the month.

Public Notices
- Copies of public notices are due to be submitted to the State within 10 days of completing the public notice.

Reporting

- The water system is responsible for insuring that copies of chemical and other monitoring records are submitted to the State.

- If a State laboratory conducts the analysis, the laboratory will submit the results to the State.

Reporting

All public waters systems are required to report to the Division of Water Supply within 48 hours if they:

- Fail to monitor for bacteria
- Fail to monitor for free chlorine residual

Or if the system
- Exceeds maximum contaminant levels
- Fails to meet treatment technique requirements

Reporting

Public water systems must report to the Division of Water Supply immediately if any of the following occur:

- A major breakdown of failure or equipment in the water treatment process that affects the quality or quantity of water being supplied.
- A serious loss of water due to the failure of transmission or distribution lines/ facilities.

Reporting

Public water systems must report to the Division of Water Supply immediately if any of the following occur:

- A situation within the water system that has caused or has the potential to cause endangerment to health.
- Nitrate exceeds the MCL
- Turbidity exceeds 5 NTU
- Fecal coliform or E. coli is detected in the water system.

Documentation

The State assumes that if there is no record of an action, it did not occur.

Always document:

- The date and time that you do things
- Line disinfection procedures
- Power outages
- Flushing times
- System start-up and shut-down, can explain turbidity spikes or why you did not monitor every 4 hours.

Documentation

Don't fudge the numbers!!

If you exceed an MCL, or fail to monitor for a contaminant the penalty received is much less severe than the penalty for data falsification.

Data falsification can lead to large monetary fines and in some cases some time in jail.

Record Category	Type of system	Time frame required to keep records
Microbiological Records		
Routine distribution	All	5 years
Line repair records	All	5 years
New line records	All	5 years
Bacteriological sampling plan	All	Keep updated, at least every 3 years
Chemical Analysis		
Nitrate/Nitrite	All	10 years
Inorganics/ secondaries	All	10 years
SOC's	All	10 years
VOC's	All	10 years
THM's and HAA5's	CWS and NTNCWS	10 years
Radionuclides	CWS	10 years
Lead and copper	CWS and NTNCWS	12 years
Miscellaneous		
Sanitary surveys	All	10 years
Public Notices	All	3 years
Action regarding violations	All	3 years
Variances or Exemptions	All	5 years
Notice of Construction	All	3 years
New tap records	CWS	5 years
Flushing records	All	5 years
Daily worksheets, strip charts, shift logs	All	5 years
MOR's	All	5 years
Maintenance Records	All	5 years
Turbidity charts, records	All	5 years
Calibration records	All	5 years
Cross connection policy	CWS	5 years
Cross connection records	All	5 years
Source Water Assessment/ Protection Plan	All	keep updated
Welhead Protection Plan	All	keep updated
Distribution map	All	Keep updated, submit copy to DWS every 5 years
Tank inspection records	All	5 years
Tank maintenance records	All	Life of tank
Emergency Operation Plan	CWS	2 years or personnel change
Complaint file	CWS	5 years
Consumer Confidence Reports	CWS	3 years
Disinfection Profile	All	10 years
Plant SOP	All	Keep updated
Distribution SOP	All	Keep updated
Disinfection SOP	All	Keep updated

Chlorine Residual

Water Treatment Lab

1

Chlorination

- Chlorination is the process of adding chlorine to water for the destruction or inactivation of pathogenic (disease-causing) organisms

2

Chemistry of Chlorination

$Cl_2 + H_2O \rightarrow HOCl + HCl$

hypochlorous acid — hydrochloric acid

- Hypochlorous acid
  - Most effective disinfectant
  - Prevalent at pH less than 7

    Dissociates at higher pH:

    $HOCl \rightarrow H^+ + OCl^-$

    hypochlorite ion
  - Hypochlorite ion is only 1% as effective as hypochlorous acid.

3

Chemistry of Hypochlorination

$NaOCl + H_2O \rightarrow HOCl + NaOH$

hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

4

Chemistry of Chlorination

- Chlorine reacts with reducing agents in the water
  - organic matter
  - iron and manganese
  - nitrites
- No free residual will be formed until all reducing agents are destroyed
- Chlorine also reacts with ammonia and organics to form combined residuals
- These are not as effective as free residual

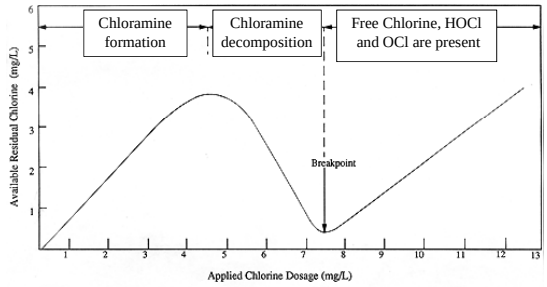
5

Residual Formation

- The breakpoint is the point at which the chlorine dosage has met the demand
- Any additional chlorine will result in a free residual

6

Breakpoint



Source: Wolfe et al. 1984

Figure 3.6 Theoretical breakpoint chlorination scheme (1.0 mg/L ammonia-nitrogen; pH 7; temperature 25°C; contact time 2 hours)

7

Chlorine Demand

- Chlorine Demand
  - The difference between the chlorine added to the water and the amount of residual chlorine remaining after a given time
    - Dose = Demand + Residual

8

Chlorine Demand

- Chlorine demand can be measured by using separate samples (same source, divided up into separate samples) each dosed with a series of increasing doses of chlorine
- After appropriate contact time, measure free chlorine residual
- Demand is determined by the difference between the original dose and the final free residual concentration

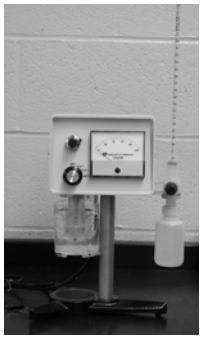
9

Disinfection Control Tests

- Chlorine Residual
  - Presence of residual
  - Free or combined
  - Concentration
  - By amperometric titration (most accurate, not affected by color or turbidity) or DPD method
- Bacteriological Test
  - Indicates fecal contamination
  - Coliforms are more resistant to chlorine than other fecal bacteria, if coliforms are not present, other fecals will not be present either

10

Amperometric Titration



- Accurate and unaffected by sample color or turbidity
- Takes greater skill to use than DPD method with colorimetric devices

11

Amperometric Titration Procedure

- Fill burette with 0.0056N phenylarsine oxide (PAO)
- Measure 200 mL samples into cell and place in the holder on the titrator
- Unless sample pH is known to be between 6.5 and 7.5, add 1 mL of pH 7 phosphate buffer to produce pH of 6.5 – 7.5
- Turn on stirrer and adjust control knob until meter reads max on scale

12

Amperometric Titration Procedure

- Add PAO in 0.1 mL increments
  - This should cause the meter reading to deflect downward
- Adjust the control knob as needed to keep the pointer on the scale
- End-point is reached when the addition of titrant no longer results in a downward deflection

13

Amperometric Titration Procedure

- Read the burette
  - Subtracting the last amount added (that did not cause a downward deflection)
  - The burette reading in mL equals the free chlorine residual in mg/L

14

DPD Colorimetric Method

- Easiest method
- Detection of chlorine residual at 0.02 – 2.00 mg/L (depending on instrument and DPD)
- Zero instrument on sample before adding DPD
- Swirl to mix the DPD for 20 seconds
- Within one minute, read sample

15

DPD Colorimetric Method

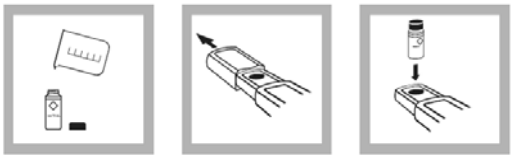
- Pocket Colorimeter can read low and high range
  - Low range is 0 – 2.00
  - High range is
    - Pocket Colorimeter = 0 – 4.5
    - Pocket Colorimeter II = 0.1 – 8.0

16

Pocket Colorimeter

17

0 – 2.00 mg/L Cl_2



1. Fill a 10-mL cell to the 10-mL line with sample (the blank). Cap.

Note: *Samples must be analyzed immediately and cannot be preserved for later analysis.*

Note: *Be sure the instrument is in the low range mode. See page 37.*

2. Remove the instrument cap.

Note: *For best results, zero the instrument and read the sample under the same lighting conditions.*

3. Place the blank in the cell holder with the diamond mark facing you. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).

Note: *Wipe liquid off sample cells.*

18

0 – 2.00 mg/L Cl_2

4. Press: **ZERO**

The instrument will turn on and the display will show - - - then **0.00**.

Note: *The instrument automatically shuts off after one minute and the last zero is stored in memory. Press* **READ** *to complete the analysis.*

5. Remove the cell from the cell holder.

6. Fill a 10-mL cell to the 10-mL line with sample.

19

0 – 2.00 mg/L Cl_2

7. Add the contents of one DPD Free Chlorine Powder Pillow to the sample cell (the prepared sample). Cap and shake gently for 20 seconds.

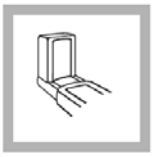
Note: *Accuracy is not affected by undissolved powder.*

Note: *Shaking dissipates bubbles that may form in samples with dissolved gases.*

8. Within 1 minute after adding DPD to the sample, place the prepared sample in the cell holder.

Note: *A pink color will develop if chlorine is present.*

Note: *Wipe liquid off sample cells or damage to the instrument may occur.*



9. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).

20

0 – 2.00 mg/L Cl_2

10. Press: **READ**

The instrument will show - - - followed by the results in mg/L free chlorine.

Note: *If the sample temporarily turns yellow after reagent addition, or shows overrange (flashing* **2.20***), dilute a fresh sample and repeat the test.*

21

0 – 4.5 mg/L Cl_2

- To access the alternative range mode, press both the **ZERO** and **READ** keys simultaneously.
- After one second, release the **ZERO** key and continue to hold the **READ** key until the letters **HI** or **LO** appears in the display.
- These letters designate the calibration range the instrument will use to determine chlorine in samples.

22

0 – 4.5 mg/L Cl_2

1. Fill a 1-cm/10-mL cell to the 10-mL line with sample.

Note: *Samples must be analyzed immediately and cannot be preserved for later analysis.*

Note: *Be sure the instrument is in the high range mode. See page 37.*

2. Add the contents of two DPD Total Chlorine Powder Pillows to the sample cell (the prepared sample). Cap the cell and shake gently for 20 seconds.

Note: *Shaking gently dissipates bubbles which may form in samples containing dissolved gases.*

3. Wait 3 minutes. During this period, proceed with steps 4–8.

Note: *A pink color will develop if chlorine is present.*

Note: *Accuracy is not affected by undissolved powder.*

23

0 – 4.5 mg/L Cl_2

4. Fill another 1-cm/10-mL sample cell to the 10-mL line with sample (the blank). Cap.

5. Place the blank into the cell holder, with the diamond mark facing you and the tab to the side. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).

Note: *Wipe liquid off sample cells.*

6. Press: **ZERO**

The instrument will turn on and the display will show - - - followed by **0.0**.

Note: *High range displays only to tenths mg/L.*

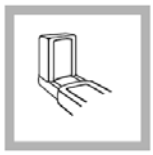
Note: *The instrument automatically shuts off after 1 minute. If this occurs, the last zero is stored in memory. Press* **READ** *to complete the analysis.*

24

0 – 4.5 mg/L Cl_2

7. Within three minutes after the 3-minute period, place the sample cell from *step 2* into the cell holder.

Note: *Wipe liquid off sample cells.*



8. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).

9. Press: **READ**

The instrument will show - - - followed by the results in mg/L chlorine (Cl_2).

Note: *If the sample temporarily turns yellow after reagent addition or shows overrange (flashing 5.0), dilute a fresh sample and repeat the test. A slight loss of chlorine may occur. Multiply the result by the dilution factor.*

25

Pocket Colorimeter II

26

0.02 – 2.00 mg/L Cl_2

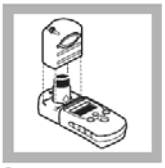
1. Fill a 10-mL cell with sample (the blank). Cap.

Note: *Samples must be analyzed immediately and cannot be preserved for later analysis.*

2. Press the **POWER** key to turn the meter on.

The arrow should indicate the low range channel (LR).

Note: *See page 2—4 for information on selecting the correct range channel.*



3. Remove the meter cap. Place the blank in the cell holder with the diamond mark facing the keypad. Fit the meter cap over the cell compartment to cover the cell.

Note: *Wipe excess liquid and finger prints off sample cells.*

27

0.02 – 2.00 mg/L Cl_2

4. Press **ZERO/SCROLL**.

The display will show "- - - -" then "0.00".

Remove the blank from the cell holder.

5. Fill a second 10-mL cell to the 10-mL line with sample.

Note: *Do not use the same sample cells for free and total chlorine analysis without thoroughly rinsing the cells with sample between free and total tests.*

6. Add the contents of one DPD **Free** Chlorine Powder Pillow or one DPD **Total** Chlorine Powder Pillow to the sample cell (the prepared sample).

Note: *SwifTest™ Dispensers for Free or Total Chlorine can be used in place of powder pillows.*

28

0.02 – 2.00 mg/L Cl_2

7. Cap and shake gently for 20 seconds.

Note: *Shaking dissipates bubbles that may form in samples with dissolved gases.*

Note: *A pink color will develop if chlorine is present.*

8. For **free** chlorine, place the prepared sample cell in the cell holder. Cover with the instrument cap and proceed to step 10 within **one** minute after adding the DPD Free Pillow.

Note: *Accuracy is not affected by undissolved powder.*

Note: *Wipe off sample cells.*

9. For **total** chlorine, place the prepared sample in the cell holder and cover the cell with the instrument cap. Wait **three to six** minutes after adding the DPD Total Pillow.

Proceed to step 10.

29

0.02 – 2.00 mg/L Cl_2

10. Press **READ/ENTER**.

The instrument will show "- - - -" followed by the results in mg/L chlorine.

Note: *If the sample temporarily turns yellow after reagent addition, or if the display shows overrange (page 2—12) dilute a fresh sample and repeat the test. A slight loss of chlorine may occur because of the dilution. Multiply the result by the appropriate dilution factor.*

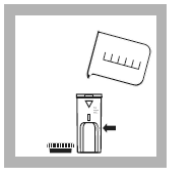
30

0.1 – 8.0 mg/L Cl_2

- Press the MENU key.
- The display will show “SEL”.
- A flashing arrow indicates the current range.
- Press the READ/ENTER key to toggle between ranges.
- Press MENU again to accept and exit back to the measurement screen.

31

0.1 – 8.0 mg/L Cl_2



1. Fill a 1-cm/10-mL cell with sample (the blank). Cap.

Note: *Samples must be analyzed immediately and cannot be preserved for later analysis.*

2. Press the **POWER** key to turn the meter on.

The arrow should indicate the high range channel (HR).

Note: *See page 2–4 for information on selecting the correct range channel.*

3. Remove the meter cap. Place the blank into the cell holder, with the diamond mark facing the back of the cell holder. Cover the cell with the cap.

Note: *Wipe liquid off sample cells.*

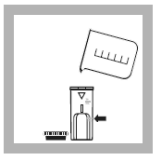
32

0.1 – 8.0 mg/L Cl_2

4. Press: **ZERO/SCROLL**

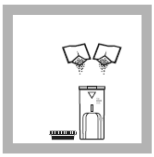
The display will show “- - - -” followed by “0.0”.

Remove the blank.



5. Fill another 1-cm/10-mL sample cell to the 5-mL line with sample. Cap.

Note: *Do not use the same sample cells for free and total chlorine without thoroughly rinsing the cells between the free and total tests.*



6. Add the contents of two DPD **Free** Chlorine or two DPD **Total** Chlorine Powder Pillows to the sample cell (the prepared sample). Cap the cell and shake gently for 20 seconds.

Note: *Gentle shaking dissipates bubbles which may form in samples containing dissolved gases.*

33

0.1 – 8.0 mg/L Cl_2

7. For **free** chlorine, place the prepared sample cell in the cell holder and cover with the instrument cap within **one** minute after adding the DPD Free Pillow.

Proceed immediately to step 9.

Note: *The SwifTest™ Dispenser can be used in place of the powder pillow (see page 1–38).*

8. For **total** chlorine, place the prepared sample in the cell holder and cover with the instrument cap. Wait **three to six** minutes after adding the DPD Total Pillows. Proceed to step 9.

Note: *Wipe off sample cells.*

9. Press **READ/ENTER**.

The instrument will show “- - - -” followed by the results in mg/L chlorine (Cl_2).

34

10 – 200 mg/L Cl_2

High Range Chlorine Test Kit 10–200 mg/L

WARNING: Handling chemical samples, standards, and reagents can be dangerous. Review the Material Safety Data Sheets before handling any chemicals.

Note: *Very high organic matter content may make the endpoint difficult to detect.*

English

1. Fill the plastic measuring tube to the top with sample.

Pour the sample from the measuring tube into the square mixing bottle.

2. Add the contents of one Potassium Iodide Powder Pillow to the bottle. Swirl to mix.

3. Add the contents of one Sulfamic Acid Powder Pillow to the bottle.

Swirl gently to mix. A yellow color will develop if chlorine is present.

4. Add the Sodium Thiosulfate Solution drop by drop while swirling the mixing bottle. When the color changes from yellow to colorless, record the number of drops added.

5. Multiply the number of drops added by 10 to obtain the chlorine concentration in mg/L.

35

DPD Accuracy Check

- Pre-made Gelex Standards
  - Similar to turbidity secondary standards
  - Make sure to check expiration dates

36

DPD Accuracy Check

- Potassium permanganate solutions
  - Weigh out 0.891g of reagent grade $KMnO_4$
  - Transfer to 1000 mL volumetric flask, fill with distilled water and mix
  - Transfer 10 mL of this solution to 100 mL flask, fill with distilled water and mix

37

DPD Accuracy Check

- Potassium permanganate solutions
  - Prepare a series of standards:

Amount of working standard	Size of volumetric flask	Chlorine equivalent
0.5 mL	100 mL	0.5 mg/L
1 mL	100 mL	1.0 mg/L
2 mL	100 mL	2.0 mg/L
4 mL	100 mL	4.0 mg/L

  - Perform chlorine analysis for each of the standards

38

TURBIDITY

Laboratory Workshop

1

Turbidity

- A measure of the clarity of water
- It is an expression of the optical property that causes light to be scatter and absorbed in water
- It is caused by particulate, such as silt, clay, organic matter, algae and other microorganisms
- Amount of light absorbed is proportional to the concentration of particulate in the sample

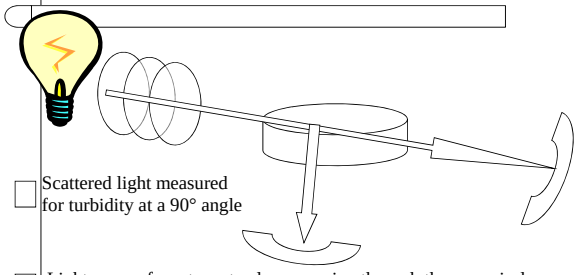
2

Turbidity

- Caused by suspended and colloidal matter in water
- It is expression of light that is scattered or absorbed through a sample
- Does not indicate the number or size of particles in a sample
- General indicator of overall effluent water quality and a good process control test for operator

3

Turbidimeters



Scattered light measured for turbidity at a 90° angle

Light source from tungsten lamp passing through three precisely aligned lenses, the light is focused in a narrow, collimated beam

4

Importance

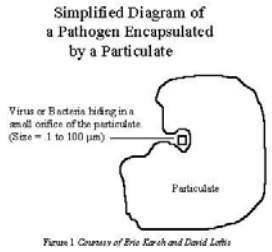


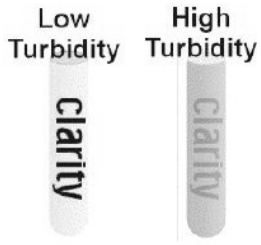
Figure 1 *Courtesy of Eric Karch and David Lettis*

- Supports growth of microorganisms
- Reduces effectiveness of chlorination
- Interferes with chemical and microbiological analysis

5

Importance

- Is unacceptable for aesthetic reasons
- Is related to coagulation and filtration
- Is unacceptable for most industrial water



6

Measuring

- Use an instrument for measuring and comparing turbidity of liquids
- Nephelometers are instruments which measure turbidity by comparing the amount of light in a sample to the amount of light scattered by a standard
- The amount of scattered light is measured and converted to units of turbidity or NTU's (Nephelometric Turbidity Units)

7

Instruments

HACH 2100-N Laboratory Turbidimeter Benchtop

Portable Turbidimeter

8

Measuring Notes

- Always cap the sample cell to prevent spillage into instrument
- Close the sample compartment lid during measurement
- Do not leave sample cell in the cell compartment for extended periods of time
- Leave the instrument on 24 hours a day if instrument is used regularly

9

Measuring Notes

- Always use clean, scratch free sample cells and caps
- Always use silicone oil
- Measuring samples immediately to prevent changes in sample characteristics
- Remove air bubbles in sample cells
- Discard sample cells with scratches

10

Calibrations

- Use Gelex Secondary Turbidity Standards for periodic checks
- Primary Stable Cal Standards
  - Formazin Solution Primary Standards and Procedure for making solutions
- Record keeping requirements and recommendations for operators
- Calibrate at least quarterly

11

Calibrations

- Labtronix recommends a "Cold Start" when calibrating
  - Sets instrument back to factory settings
  - Erases past calibrations and any other manipulation of instrument
  - Hold Cal button down, turn off instrument, continue holding down Cal button and turn instrument back on

12

Test Taking Tips

- Get a good night's sleep before the exam and be sure to eat breakfast. Being tired and hungry can affect how your brain works.
- Bring at least two pencils with good erasers, a calculator with good batteries.
- Bring a watch to the test with you so that you can better pace yourself.
- Keep a positive attitude throughout the whole test and try to stay relaxed, if you start to feel nervous take a few deep breaths to relax.
- When you first receive your test, do a quick survey of the entire test so that you know how to efficiently budget your time.
- Do the easiest problems first; don't stay on a problem that you are stuck on especially when time is a factor.
- Don't rush, but pace yourself, read the entire question and look for keywords.
- Always read the whole question carefully, don't make assumptions about what the question might be.
- If you don't know an answer skip it, go on with the rest of the test and come back to it later, maybe on another part of the test there'll be something that will help you out with that question.
- Don't worry if others finish before you; focus on the test in front of you.
- When you are finished, if you have time left look over your test, make sure that you have answered all the questions.
- **Never change an answer** unless you are absolutely positive it is wrong because you misread or misinterpreted the question. The first answer that you put is usually the correct one.

Small Water Systems Exam (Practice)

1. Turbidity in water results from the presence of
   a. Finely divided organic material
   b. Hardness
   c. pH
   d. Plankton
   e. None of the above

2. What is a cross connection?
   a. A connection between a drinking water system and a raw water source.
   b. A connection between a drinking water system and an unapproved supply.
   c. A connection between a pump and a distribution system.
   d. A connection between two drinking water systems.

3. What is the most widely used test to indicate the bacteriological quality of water?
   a. Coliform
   b. *Cryptosporidium*
   c. *Giardia*
   d. Hepatitis

4. What are the potential sources of groundwater contamination?
   a. Agricultural drainage systems
   b. Improper disposal of hazardous wastes
   c. Seepage from septic tank leaching systems
   d. All the above

5. What is the purpose of disinfection of drinking water?
    a. The cleansing of organisms from drinking water
    b. The complete destruction of all organisms
    c. The removal of coliform organisms
    d. The destruction or inactivation of pathogenic organisms

6. Which diseases are transmitted by water?
    a. Cryptosporidiosis
    b. Dysentery
    c. Giardiasis
    d. Salmonellosis
    e. All the above

7. The Total Coliform Rule is based first on:
    a. Presence or absence of coliforms in a sample
    b. Density of coliforms in a sample
    c. Type of coliforms in a sample
    d. Presence of fecal coliforms in a sample

8. Fluoride is added to water
    a. To prevent corrosion
    b. To add alkalinity
    c. To prevent dental caries in children
    d. To adjust pH

9. If you have 15 or more service connections OR your water system provides water regularly for 25 or more persons at least 60 days out of the year, you are a:
    a. Community Water System
    b. Non-transient Non-community Water System
    c. Public Water System
    d. Non-public Water System

10. If you use a well or spring not under the direct influence of surface water and serve less than 50 service connections, you are a
    a. Grade 1 Water Treatment System
    b. Small Water System
    c. Grade 1 Distribution System
    d. None of the above

11. When collecting bacteriological samples, the white powder already in the bottle
    a. Dechlorinates the water sample
    b. Acidifies the water sample
    c. Kills the bugs in the water sample
    d. Needs to be rinsed out before sampling

12. Bacteriological analysis records are to be maintained for how long?
    a. 1 year
    b. Until the next sanitary survey
    c. 5 years
    d. 10 years

13. The most common way to disinfect water is by
    a. Use of Copper and Silver ions
    b. Ozonation
    c. Chlorination
    d. Potassium Permanganate

14. The primary origin of coliforms in water supply is
    a. Fecal contamination by warm-blooded animals
    b. Natural algae growth
    c. Industrial solvents
    d. Acid rain

15. All public water systems which use a surface water source are required to have a full time operator in attendance unless certain continuous monitoring equipment approved by the state is installed.

    A. True
    B. False

16. All operators in direct responsible charge of a public water supply system must be certified by the department to operate the system.

    A. True
    B. False

17. What is the major health risk for nitrates in drinking water?
    a. Gastrointestinal distress
    b. Bladder cancer
    c. Nervous system damage
    d. Blue baby syndrome

18. Monthly Operation Report (MOR's) must be received by the State within:
    a. 10 days after the end the reporting period
    b. 1 day after the end of the reporting period
    c. 30 days after the end of the reporting period
    d. MOR's do not have to be received by the State

19. The recommended agent of disinfection agent in Tennessee is:
    a. Ultra-violet radiation
    b. Chlorine
    c. Ozone
    d. Bromine

20. All community water systems, using ground water as a raw water source and serving more than 50 connections or 150 persons shall continuously chlorinate and shall maintain a free chlorine residual in all parts of the distribution system in the amount of no less than:
    a. 0.2 mg/L
    b. 0.5 mg/L
    c. 1.8 mg/L
    d. 4.0 mg/L

21. If a water line is dewatered to make a repair than the line must be disinfected and a bacteriological sample must be taken before returning the line to service.
    a. True
    b. False

22. Chemical analysis records are to be maintained for how long?
        a. 1 year
        b. Until the next sanitary survey
        c. 5 years
        d. 10 years

Classify the following as community (CWS), transient non-community (TNCWS), or non-transient non-community (NTNCWS).

23. A campground near the Great Smoky Mountains serves 20 campsites with drinking water from May 1st to October 31st each year. This water system is classified as:
    A. CWS
    B. TNCWS
    C. NTNCWS

24. Hidden Spring Trailer Park serves water to 30 trailers year round. The water system is classified as:
    A. CWS
    B. TNCWS
    C. NTNCWS

25. Cedar Hill Youth Academy is a private school for boys; the school serves water to 150 students and 20 faculty and staff from September 1st to May 31st. The water system is classified as:
    A. CWS
    B. TNCWS
    C. NTNCWS

Name _____

Small Water Systems Exam

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Small Water Systems Exam Answers

1. A
2. B
3. A
4. D
5. D
6. E
7. A
8. C
9. C
10. B
11. A
12. C
13. C
14. A
15. A
16. A
17. D
18. A
19. B
20. A
21. A
22. D
23. B
24. A
25. C