1

Laboratory Practices

2

Objectives

- Water Quality
- Sampling
- Bacteriological Testing
- Chemical Analysis
- Lab Safety
- QA/QC

3

Terminology

- Reaction time
- Holding time
- Autoclave
- Incubator
- Aseptic technique
- Disinfection
- Coliform density

4

Water Quality

5

Water Quality

- Process control monitoring
  - All public water systems that provide some type of treatment must monitor water quality
- Monitored to ensure safety and integrity
- Monitored to meet state and federal requirements
- Monitor raw, finished, and where you expect a physical/chemical change in your plant
- Monitor in distribution system also
  - Quality can degrade due to contamination or growth of organisms

6

Water Quality Degradation

- Treated water is disinfected, not sterilized
- Disinfection kills or inactivates harmful organisms (pathogens)
- Organisms can grow in distribution system if conditions are right
- To prevent growth of organisms
  - Keep chlorine residuals up
  - Keep excess nutrients out
  - Prevent stagnation
  - Prevent cross-connections

Water Quality Analysis

7

- The first step in water quality analysis is collecting samples which accurately represent the water
  - Representative sample
    - sample which contains basically the same constituents as the body of water from which it was taken
  - Improper sampling is one of the most common causes of error in water quality
- All biological analysis must be kept for 5 years
- All chemical analysis must be kept for 10 years

Types of Samples

8

- Grab sample
  - Single volume of water
  - Representative of water quality at exact time and place of sampling
  - Coliform bacteria, residual chlorine, temperature, pH, dissolved gases
- Composite samples
  - Representative of average water quality of location over a period of time
  - Series of grab samples mixed together
  - Determines average concentration
  - Not suitable for all tests

Sampling

10

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Sample Volume and Storage

11

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out
- If you have questions regarding volume, container or holding times, check *Standard Methods* or contact the lab if you have an outside lab do you analysis

Sample Labeling

12

- Specific location (address)
- Date and time sampled
- Chlorine residual
- pH and temperature
- Sample type
- Name or initials of person taking sample

Sample Labeling

13

Sample Type

- Routine
- Repeat
  - same
  - upstream
  - downstream
- Special sample

Selecting Sampling Points

15

- Raw-water supply
  - Install valve or sample cock on raw-water transmission lines or well discharge pipe
- Treatment plant
  - Sampling from various points helps determine efficiency of processes
  - Sample at every point where a change in water quality is expected
  - Finished water sample point usually at point of discharge from clearwell
- Distribution system
  - Distribution sampling is the best indicator of system water quality
  - Water quality changes in the distribution system

Distribution Samples

16

- Allows operator to determine water quality at customers' taps
- Most common tests are chlorine residual and coliform bacteria
- Number of samples depends on population served and water source

17

Bacteriological Testing

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Collection of Samples

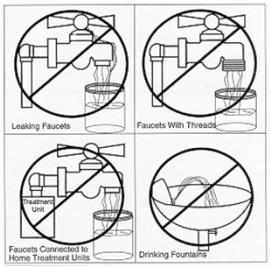
18

- Only approved containers should be used
  - 125 mL volume
  - Pre-sterilized bottles recommended
  - Other bottles sterilized at **121°C @ 15 psi**
    - 15 minutes
  - Should contain **sodium thiosulfate ($Na_2S_2O_3$)**

Bacteriological Samples

19

- Samples should never be taken from a hydrant or hose
- Only collect samples from approved faucets
- Don't collect samples from swivel faucets
- Only use cold water tap
- Front yard faucets on homes with short service lines are best



Bacteriological Samples

20

- Do not flame faucet with torch
  - Use alcohol or bleach solution to clean
- Turn on faucet to steady flow and flush service line (**2-5 min**) – getting water from the main line
- Fill bottle to proper level
- Label bottle with pertinent information
- **Refrigerate to proper temperature, 4°C**
- Test as soon as possible
  - Hold time **< 30 hours**

Collection of Bacteriological Samples

21

1. Remove aerator or screen
2. Collect sample from cold water tap
3. Sample from homes with short service lines
   - Same side of street as water main, preferably
4. Disinfect faucet with sodium hypochlorite
5. Flush service line
6. Adjust flow so that no splashing will occur
   - Do not touch inside of lid of sample bottle
   - Do not set lid down or put it in your pocket
   - Do not rinse bottle or allow it to overflow

Microbiological Indicator Organism

22

TOTAL COLIFORM

- Always present in contaminated water
- Always absent when no contamination
- Survives longer in water than most other pathogens
- Easily identified

EPA Approved Methods

23

- Multiple-Tube Fermentation
- Presence-Absence Test
- MMO-MUG
- Membrane Filter Method
- Enzyme (chromogenic/fluorogenic) Substrate Tests

State Regulations

24

- 0400-45-1-.06(4) Microbiological
  - (a)1. If you collect 40 samples/month, no more than 5% can be positive to be in compliance
  - (a)2. If you collect less than 40 samples/month, no more than 1 sample can be positive to be in compliance
  - (c) If any routine or repeat sample test (+) for total coliform, it must be analyzed for fecal or *E. coli*

State Regulations

25

- 0400-45-1-.07(2) Repeat Monitoring
  - (a) **If a routine sample is total coliform positive, the system must collect a set of repeat samples within 24 hours of being notified of the positive result**
  - (b) **The system must collect one at original site, at least one repeat within five service connections upstream and at least one repeat within five service connections downstream**

Bacteriological Samples

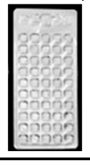
26

- The "MCL" for coliform bacteria is based on presence or absence
- Finished and distributed water should be Zero (absent)
- **Must keep results for 5 years**

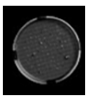
Colilert

Colisure

Colilert Quanti-Tray



Membrane Filtration



Enzyme Substrate Testing

27

- Colilert (P/A)
- Colilert Quanti-Tray
- Colilert-18 (P/A)
- Colilert-18 Quanti-Tray
- E*Colite
- Colisure
- Readycult® Coliforms 100 (P/A) and Fluorocult LMX Broth
- Colitag

Colilert/Colilert 18 for P/A

28

- Equipment needed:
  - Incubator
  - UV lamp
  - Comparator
  - pH meter to check tryptic soy broth
- Sample bottle is used in the testing procedure
- Tests for total coliforms and *E. coli* in one step
  - Sample turns yellow if positive for total coliforms
  - Sample turns fluoresces if positive for *E. coli*

Colilert/Colilert 18 for P/A

29

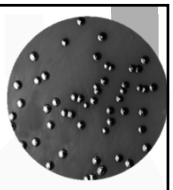
- Detects a single viable coliform per sample
- For Colilert 18, samples need to be pre-warmed to 35°C before incubation period starts
- Colilert 18 can lift boil water notices 6 hours earlier than other methods
- Shelf life is 12 months for media packet

Colisure

30

- Step 1
  - Add reagent (shelf life is 12 months) to sample
  - Incubate for 24 hours
    - if samples are not room temperature, they need to be pre-warmed before incubating
- Step 2
  - Read results
    - yellow = negative
    - magenta = total coliform positive
    - magenta/fluorescent = *E. coli* positive

Membrane Filter Technique

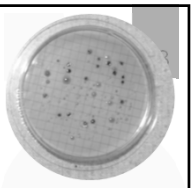


- 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing **M-Endo** broth (food source for bacteria) for **Total Coliforms**
- Petri-dish labeled, turned upside down, placed in incubator at **35° +/- 0.5°C for 24 hours**
- A coliform bacteria colony will grow at each point on filter where a viable bacterium was left during filtering
- **The colonies will appear red with a green-gold metallic sheen**

Membrane Filter Technique

- 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing **M-coli blue** broth (food source for bacteria) for **e. Coli**
- Petri-dish labeled, turned upside down, placed in incubator at **35° +/- 0.5°C for 24 hours**
- A coliform bacteria colony will grow at each point on filter where a viable bacterium was left during filtering
- **The colonies will appear blue**

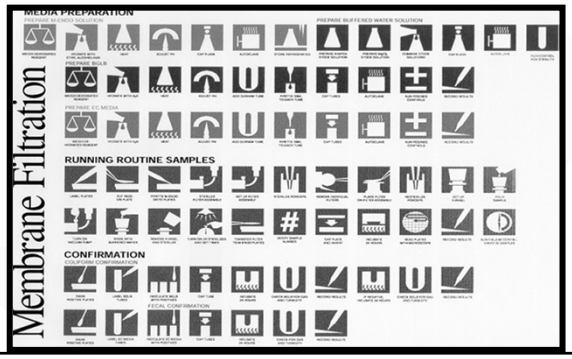
Fecal Coliform Determination



- Membrane filtration test
- More reliably indicates the potential presence of pathogenic organisms
- Same procedure as Total Coliform, 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing **mFC broth**
- Incubation at **44.5° +/- 0.2°C for 24 hrs**
- **Bacterial colonies appear blue**
- Looks for heat tolerant bacteria

Membrane Filtration Pictorial

39



Colilert Method Pictorial

40

Colilert®

Water Quality Analyses

41

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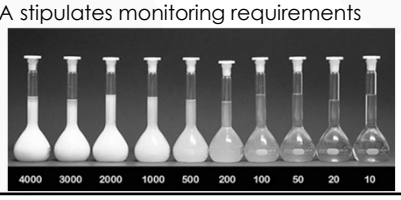
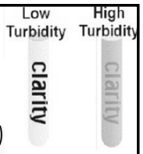
Turbidity

42

- Physical cloudiness of water
  - Due to suspended silt, finely divided organic and inorganic matter, and algae
- Nephelometric method measures scattered light
  - unit - NTU
- SDWA stipulates monitoring requirements



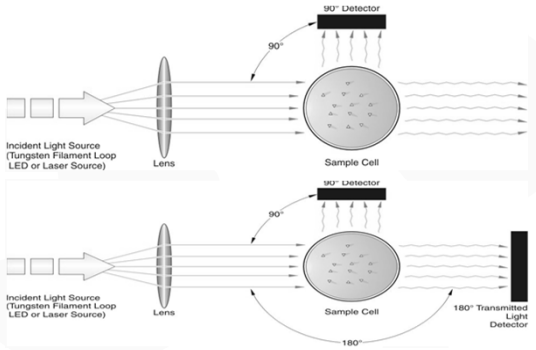
Turbidity



- Measure samples ASAP (within 15 minutes)
  - Turbidity can dissolve and skew the reading
- Keep sample tubes clean and scratch free
- Gently mix samples prior to reading
- Calibrate meter every 90 days → Primary standard
- Verify meter daily → Secondary (gel) standard
- Records must be retained minimum 5 years

Turbidimeter

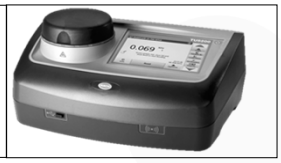
44



Turbidimeters

45

Hach TU5200 Laboratory Laser Turbidimeter



Hach 2100 N

Free Chlorine Residual

46

- Free chlorine residual must be tested and recorded when bacteriological samples are collected
- Two most common tests:
  - Amperometric titration
    - less interferences as color and/or turbidity
  - Colorimetric
    - DPD (N,N-diethyl-*p*-phenylenediamine)
- Analysis should be performed ASAP
  - Holding time < 15 minutes
- Exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual

Free Chlorine Residual

- Colorimetric (DPD) method is most commonly used
  - Match color sample to a standard
  - ***Swirl sample for 20 seconds*** to mix
  - Reaction time: Within ***one minute*** of adding reagent, place sample into colorimeter
    - Different than Total Residual Chlorine
- Must maintain a free residual of 0.2 mg/L throughout entire distribution system
  - "Chlorine residual must not be less than 0.2 mg/L in more that 5% of samples each month for any two consecutive months"

Total Residual Chlorine

48

- Has a separate method than free chlorine
- Has minimum reaction time of 3 minutes
  - vs free chlorine that has a maximum reaction time
  - Holding the free chlorine sample for three minutes DOES NOT make it a total chlorine reading
  - The tests are independent of each other and looking for different constituents
    - Free Chlorine
      - $HOCl$ & OCl^-
    - Total Chlorine
      - monochloramine, dichloramine, nitrogen trichloride and other chloro- derivatives

pH

49

- Power of hydrogen
  - Measurement of the hydrogen concentration
  - Each decrease in pH unit equals 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- pH probe measures milivolts, then converts into pH units
  - Temperature affects milivolts generated, therefore you need a temperature probe as well for corrections

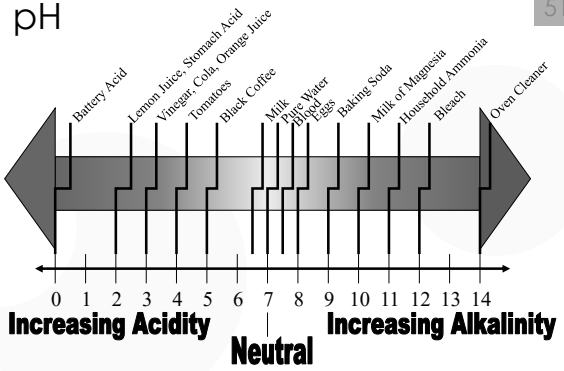
pH

50

- Calibrate daily with **fresh buffers**
  - Use at least two buffers
- Gel filled probes are not recommended for water industry
  - Water is too clean for probe to make an accurate measurement
- Store probe in slightly acidic solution
- Replace probes yearly

pH

51



Fluoride

52

- Added to drinking water for the reduction of dental caries (cavities)
- Interferences
- Primary MCL = 4.0 mg/L
- Secondary MCL = 2.0 mg/L
- State of Tennessee recommends 0.7 mg/L
  - Fluoridation of drinking water in the state of Tennessee is not required

Fluoride Analysis

53

- Colorimetric (SPADNS)
  - interferences are more common with this test
  - aluminum and polyphosphate complexes can interfere
- Ion Selective Electrode (ISE)
  - TISAB removes most of the aluminum interferences
    - Total Ionic Strength Adjustment Buffer
    - Contains CDTA – used to tie up interferences
  - store probe in a standard, the higher the better
  - probes can last 3-5 years
  - can clean with toothpaste

Alkalinity

54

- A measure of the ability of the water body to neutralize acids and bases and thus maintain a fairly stable pH level
  - The buffering capacity of a water body
- Due to presence of
  - Hydroxides (OH^-), Carbonates (CO_3^-), and Bicarbonates (HCO_3^-)
- Many water treatment chemicals (alum, chlorine, lime) alter water quality, including pH and alkalinity

Alkalinity

55

- Measured by titrating sample with 0.02 N H_2SO_4 (sulfuric acid) to a pH endpoint
  - Expressed in mg/L as $CaCO_3$
- Analysis - titration using sulfuric acid (H_2SO_4)to pH endpoint
- Endpoints
  - Phenolphthalein alkalinity pH = 8.3
  - Total alkalinity pH ≈ 4.5
- Can use color change indicator to show pH endpoint

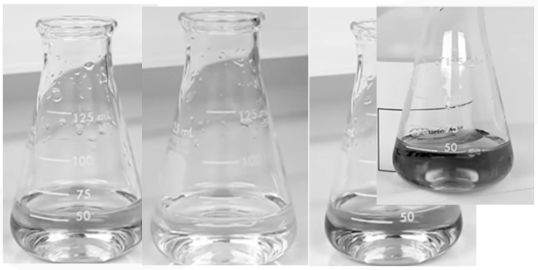
Alkalinity

56

- Phenolphthalein Alkalinity (pH = 8.3)
  - Reagent: Phenolphthalein color indicator
    - Color change: Pink → clear
- Total Alkalinity (pH = 4.5)
  - Reagent: Methyl orange
    - Color change: Orange → peach
  - Reagent: Bromcresol green-methyl red
    - Color change: Blue/green → light pink
  - If testing a chlorinated sample using bromcresol green-methyl red, sodium thiosulfate must be added to remove chlorine that will interferes with the color change

Alkalinity

57

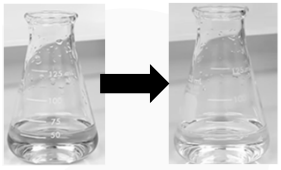


Alkalinity Color Changes

58

Phenolphthalein Alkalinity

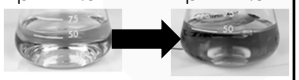
pH > 8.3 pH = 8.3



Total Alkalinity

Bromcresol green-methyl red

pH > 4.5 pH = 4.5



Methyl Orange

pH > 4.5 pH = 4.5

Hardness

59

- Characteristic of water caused by the salts of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in solution
  - Bicarbonate, carbonate, sulfate, chloride, and nitrate
- Measured in mg/L as $CaCO_3$
- Total hardness analysis may involve titration of sample to an endpoint
  - Titrant: 0.02 N EDTA
  - Color change endpoint: red → pure blue
  - Metal ions may interfere, so an inhibitor may be needed

Hardness

60

Iron and Manganese

61

- Can precipitate out in distribution system due to oxidation
- Elevated levels in water can cause staining of plumbing fixtures and laundry
- sMCL for iron is 0.3 mg/L
- sMCL for manganese is 0.05 mg/L

Lead and Copper Rule

62

- Established by EPA in 1991
- All community and non-community water systems must monitor for lead and copper at customers' taps
- If aggressive water is dissolving these metals, system must take action to reduce corrosivity
- Samples must be taken at high-risk locations
  - Homes with lead service lines
- Water must sit in lines for at least 6 hours
  - First draw sample
- One liter of sample collected from cold water tap in kitchen or bathroom
- Test results must be maintained for 12 years

Lead and Copper Rule

63

- Action levels
  - Lead - 0.015 mg/L
  - Copper - 1.3 mg/L
- If action level is exceeded in more than 10% of samples, steps must be taken to control corrosion
  - Corrosion control program
  - Source water treatment
  - Public Education
  - and/or Lead service line replacement

Phosphates

64

- Orthophosphates work well for lead and copper protection
- Polyphosphates work as *sequestering agents* – tie up iron and manganese to prevent color and taste complaints
  - Tie up calcium carbonate as a catalyst
  - Calcium (from alkalinity) is required as a catalyst
  - If low alkalinity, need a blend of polyphosphate and orthophosphate
- **Orthophosphate coats pipe; polyphosphate sequesters**

Phosphates Analysis

65

- Total phosphates
  - Colorimetric test
  - Sample needs to be digested before they can be analyzed
- Ortho-phosphates
  - Also called reactive phosphates
  - Colorimetric test
  - Easily done with Hach test kit

Total Organic Carbon (TOC)

66

- High temperature combustion at 950°C
- Sample is injected into a heated reaction chamber packed with oxidative catalyst such as cobalt oxide
- Water is vaporized and the organic carbon is oxidized to CO_2 and H_2O
- CO_2 is transported in the carrier-gas streams and is measured by means of a nondispersive infrared analyzer (NDIR)
- Samples are preserved with sulfuric or phosphoric acid and cooled to 4°C

Disinfection By-Products (DBPs)

68

Trihalomethane (THM or TTHM)	Haloacetic acids (HAA5)
Chloroform	Monochloracetic acid
Dibromochloromethane	Dichloroacecitic acid
Bromodichloromethane	Trichloroacetic acid
Tribromomethane	Monobromoacetic acid
	Dibromoacetic acid
MCL = 0.080 mg/L	MCL = 0.060 mg/L

Cryptosporidium (Crypto)

71

- Protozoan parasite
- Common in surface water
- Resistant to traditional disinfectants
- Can pass through filters
- Causes cryptosporidiosis
- Filtration and alternative disinfectants can remove and/or inactivate

74

Lab Safety

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Lab Safety

- Read SDS for all chemicals used in lab
- Store chemicals properly
- Know where safety equipment is stored
- Never pour water into acid
- CPR and First Aid Training (TOSHA requirement)
- Clean chemical spills immediately
- Follow published lab procedures (*Standard Methods*)
- Read and become familiar with Safety SOP

Safety Data Sheets (SDS)

76

- Keep on file for all chemicals purchased
  - According to the Americans with Disabilities Act of 1990, SDS's should be kept for a minimum of 30 years
- Includes all information shown on chemical label and more

Safety Data Sheets (SDS)

77

- Must be readily available for employee review at all times you are in the work place
  - The can't be locked in an office or filing cabinet to which you don't have access to
  - If they are on a computer, everyone must know how to access them
- If you request to see an SDS for a product you use at work and your employer can't show it to you, after one working day you have the right refuse to work with that product until you are shown the correct SDS

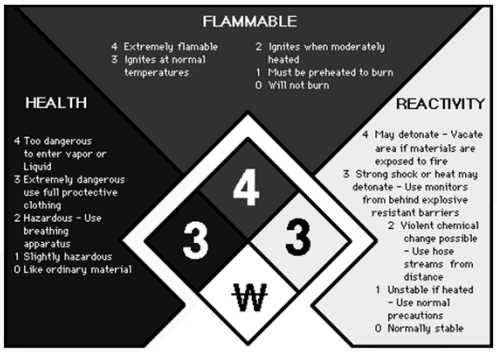
Safety Data Sheets (SDS)

78

- Information provided:
  - Identification
  - Hazards identification
  - Composition
  - First aid measures
  - Fire-fighting measures
  - Accidental release measures
  - Exposure controls/personal protection
  - Physical & chemical properties
  - Stability and reactivity
  - Toxicological information
  - Other information, including date of SDS preparation or last revision

NFPA Chemical Label

79



80

Quality Assurance/Quality Control

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QA/QC Program

81

Three Phases

- Record Keeping
- Quality Assurance Plan
  - Addresses the entire **laboratory** process, from the time a sample arrives in your facility, to the moment results are recorded and reported
  - Will ensure that test results obtained are as correct as possible
- Quality Control Program
  - Those **laboratory** practices that are undertaken specifically to achieve accurate and reliable analytical results
  - Tests to demonstrate precision and accuracy

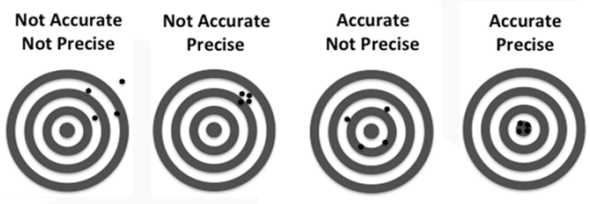
Quality Assurance/Quality Control

82

- A QA/QC program consists of the procedures that ensure the precision and accuracy of tests performed on a daily basis
- Precision - repeatability
  - Shooting at a target and hitting the same spot repeatedly
- Accuracy – closeness of test results to the correct (known) value
  - Shooting at a target and hitting the bull's eye

Accuracy vs Precision

83



Quality Assurance Program

84

Record Keeping

- Maintain a complete and accurate list of exact locations of all sampling sites
- Maintain a complete and accurate list of all test procedures used
  - Record method numbers on bench sheets
- Write in pen
- Initial your entries
- Use a notebook

Quality Control Tests

85

- Duplicates
- Blanks
- Lab standards
- Unknown lab standards
- Spikes

Duplicates

86

- Simplest form of QC test
- Run two tests on one sample
  - This shows how precise the analyst's procedure is
  - Sample results should yield very close results
    - goal is to have no difference
- General recommendation is to run a duplicate every 10 samples

Duplicates

87

Common Sources of Error

- Sample size - should be same size
- Insufficient mixing
- Dirty glassware
- Calculation errors
- Reagents
- Titration - misreading burette
- Weighing
- Calibration
- Reagent water

QC Blanks

88

- Can show test interference
- Should be treated as a sample
  - Take through all procedures
  - Add all reagents or incubate along with other samples
- Target value for a blank is zero
- Positive blanks show a problem
  - Bad reagents
  - Bad technique
  - Unclean glassware
  - Bad distilled water

Membrane Filtration Blanks

89

- A blank should never be positive
- Blanks should be run before you filter samples and when you are done filtering samples
  - If the pre-sample blank has colony growth, the equipment was not properly sterilized
  - If the post-sample blank has colony growth, the equipment was not cleaned well enough between samples

Laboratory Standards

90

- Determines accuracy
- If the test value agrees with the true value, the test has been performed accurately
- Mix onsite or purchased from supplier
  - Purchased standards should be the preference because this can reduce the possibility of having mixing errors
  - They also come with a certificate of analysis
- Perform along with duplicates
  - One every 10 samples

Unknown Laboratory Samples

91

- EPA quality control unknowns
- Commercially available
- Gives confidence to analyst
- Can show deficiencies in the testing procedure

Spikes

92

- Determine accuracy
- A known amount of standard is added to a sample
- The results should equal the sample value plus the added known amount
- Goal is to have 100% recovery of spike and sample
- If you use Hach methods, most have directions on how to spike a sample
- If your sample result was 100 mg/L and you added 50 mg/L into the sample
  - you should yield 150 mg/L

Split Samples

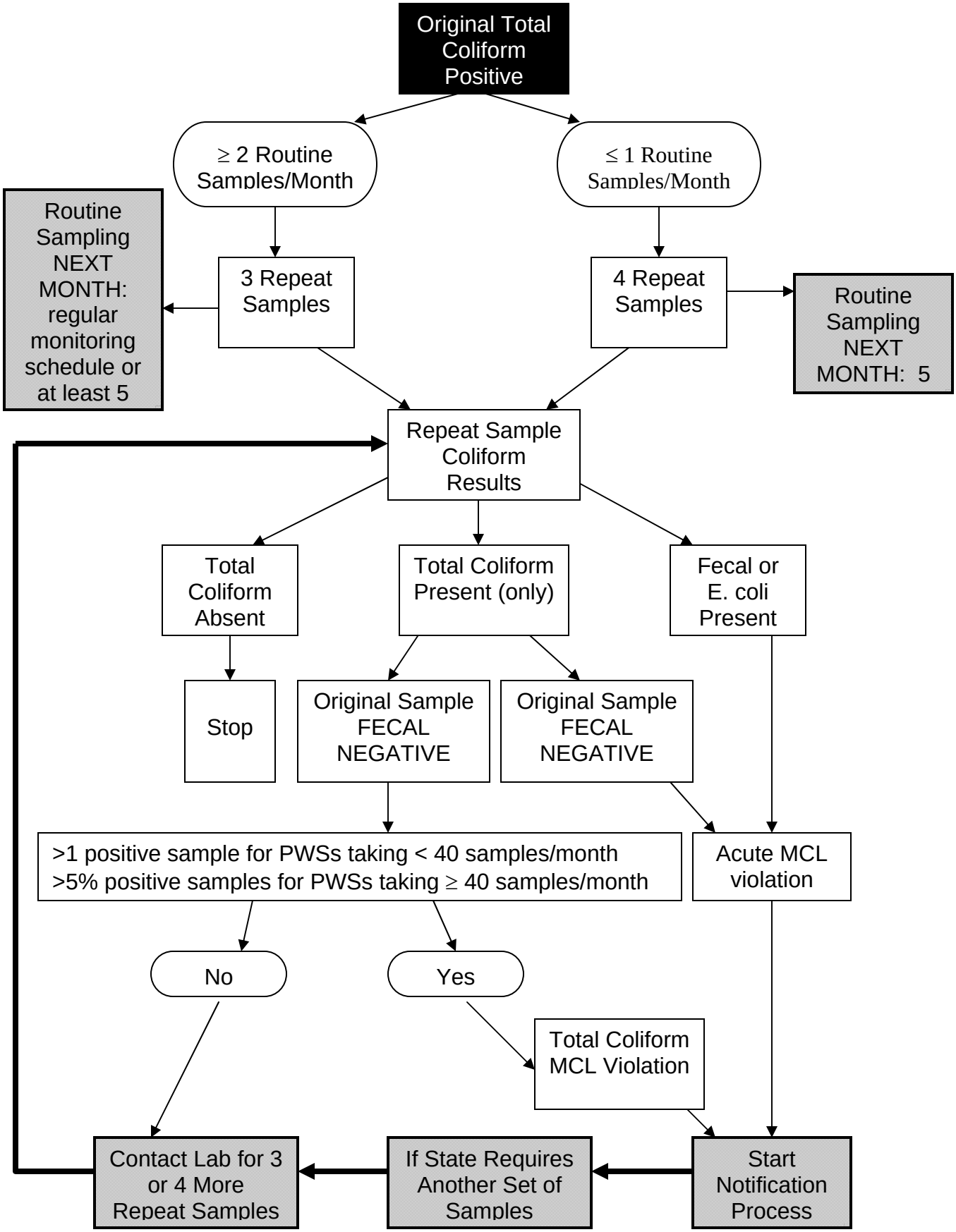
93

- Some labs split samples with other labs to check the accuracy of the testing procedure
- If you are concerned that your contract lab is getting wrong values, send in a known standard as a sample
  - This does double your cost, but you can see how close they are to the known value
  - Don't tell the contracted lab that the second sample is a known

Total Coliform Monitoring Frequency for Community Water Systems

Population Served	Minimum Number of 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
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

Total Coliform Action Flow Chart



Water Treatment and Distribution
Laboratory Practice Quiz

1. The MCL for total coliform bacteria is based on their _____ .
   a. Concentration in mg/L
   b. Concentration in colonies per 100 mL
   c. Presence or absence
   d. All of the above
   e. None of the above

2. The sample volume to be used when running a membrane filter test for coliform bacteria is _____ .
   a. 20 mL
   b. 40 mL
   c. 60 mL
   d. 80 mL
   e. 100 mL

3. Records of bacteriological analyses must be kept at least _____ .
   a. Until the next sanitary survey
   b. Three years or until the next sanitary survey
   c. Five years
   d. Ten years
   e. Twelve years

4. Analysis of samples for determining bacteriological quality of the water must be started within _____ hours of collection.
   a. 24
   b. 30
   c. 36
   d. 42
   e. 48

5. A bacteriological bottle contains a white powder which is placed in the bottle in order to _____ .
   a. Keep the bottle clean
   b. Kill any bacteria present
   c. Remove any chlorine residual
   d. All of the above
   e. None of the above

6. When the membrane filter method for coliform analysis is used, a typical coliform colony will be pink to dark red with a distinctive _____ .
   a. Greenish metallic sheen
   b. Dull bluish coating
   c. Shape
   d. All of the above
   e. None of the above

7. Any sample that contains coliform bacteria is a _____ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

8. Any sample that does not contain coliform bacteria is a _____ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

9. For bacteriological sample to be useful, it must contain essentially the same constituents as the body of water from which it was taken. This type of sample is called a _____ sample.
   a. Grab
   b. Flow-proportional time composite
   c. Representative
   d. Time composite

10. To remove any stagnant water from the customer's service line, and to make certain that water from the distribution main is being sampled, flush the faucet for _____ minutes.
    a. 1 – 3
    b. 2 – 5
    c. 5 – 7
    d. 7 – 9
    e. 10 – 15

11. Bottles for collecting samples for bacteriological analyses should _____ .
    a. Not be rinsed before use
    b. Be rinsed before use
    c. Be completely filled
    d. All of the above
    e. None of the above

12. Bottles for collecting samples for bacteriological analyses contain _____, which destroys any chorine residual in the sample.
    a. Sodium arsenite
    b. Sodium chloride
    c. Sodium fluoride
    d. Sodium hydroxide
    e. Sodium thiosulfate

13. Samples for bacteriological analysis should not be taken from _____.
    a. Swivel faucets
    b. Leaking faucets
    c. Faucets with aerators, strainers or hose attachments
    d. All of the above
    e. None of the above

14. A sample which consists of a number of grab samples taken from the same sampling point at different times and mixed together before analysis is called a _____ sample.
    a. Composite
    b. Grab
    c. Flow-proportional time composite
    d. Representative
    e. Time composite

15. High fluoride readings can result from all of the following causes except _____.
    a. Polyphosphates can interfere with the SPADNS method, resulting in high fluoride readings
    b. Not accounting for natural fluoride in the water
    c. Dilution of water which has been fluoridated with unfluoridated water in storage tanks
    d. All of the above
    e. None of the above

16. What is the secondary maximum contaminant level for fluoride?
    a. 0.2 mg/L
    b. 0.4 mg/L
    c. 2.0 mg/L
    d. 4.0 mg/L

17. The maximum permissible level of a contaminant in water as specified in the regulations of the Safe Drinking Water Act is the _____ .
    e. Maximum contaminant level
    f. Saturation point
    g. Zeta potential
    h. All of the above
    i. None of the above

18. _____ is an indicator used when measuring the total alkalinity concentration on a water sample.
    j. EDTA
    k. Eriochrome black-T
    l. Bromcresol Green Methyl Red
    m. Phenolphthalein
    n. Sodium thiosulfate

19. A(n) _____ is a device that sterilizes laboratory equipment by using pressurized steam.
    a. Autoclave
    b. Beaker
    c. Buret
    d. Nepholometer
    e. Pipet

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