Can We Drink the Water? Field Assessments of Water Quality

designing a world of hope

Introduction

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- EMI and other projects in Belize, El Salvador, Gabon, Guatemala, India, Kenya, Philippines, and Tanzania

Course Description

Civil engineers on EMI teams are frequently tasked with evaluating drinking water quality for client ministries or communities.

This course provides an overview of the importance of water quality, relevant water quality properties, and methods for assessing those properties.

Learning Objectives

1. Recognize the level of access to clean water globally
2. Identify the main water quality characteristics of interest in majority world applications
3. Identify field testing methods for key chemical properties of water
4. Conduct sanitary surveys and field testing to assess biological water quality
5. Interpret the results of biological methods

Motivation

Drinking water ladder

SAFELY MANAGED

Drinking water from an improved water source which is located on premises, available when needed and free from faecal and priority chemical contamination

BASIC

Drinking water from an improved source, provided collection time is not more than 30 minutes for a roundtrip including queuing

LIMITED

Drinking water from an improved source for which collection time exceeds 30 minutes for a roundtrip including queuing

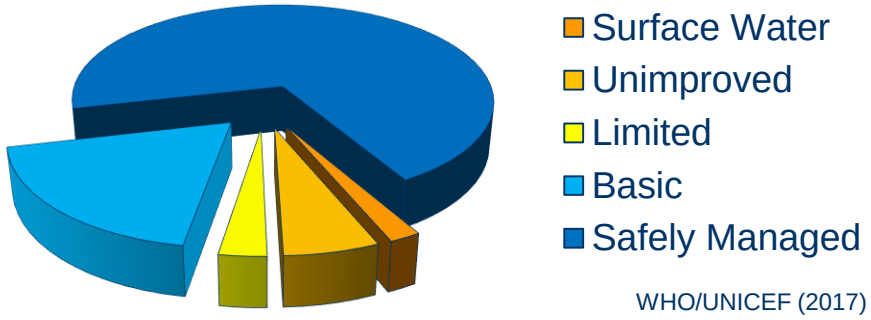
UNIMPROVED

Drinking water from an unprotected dug well or unprotected spring

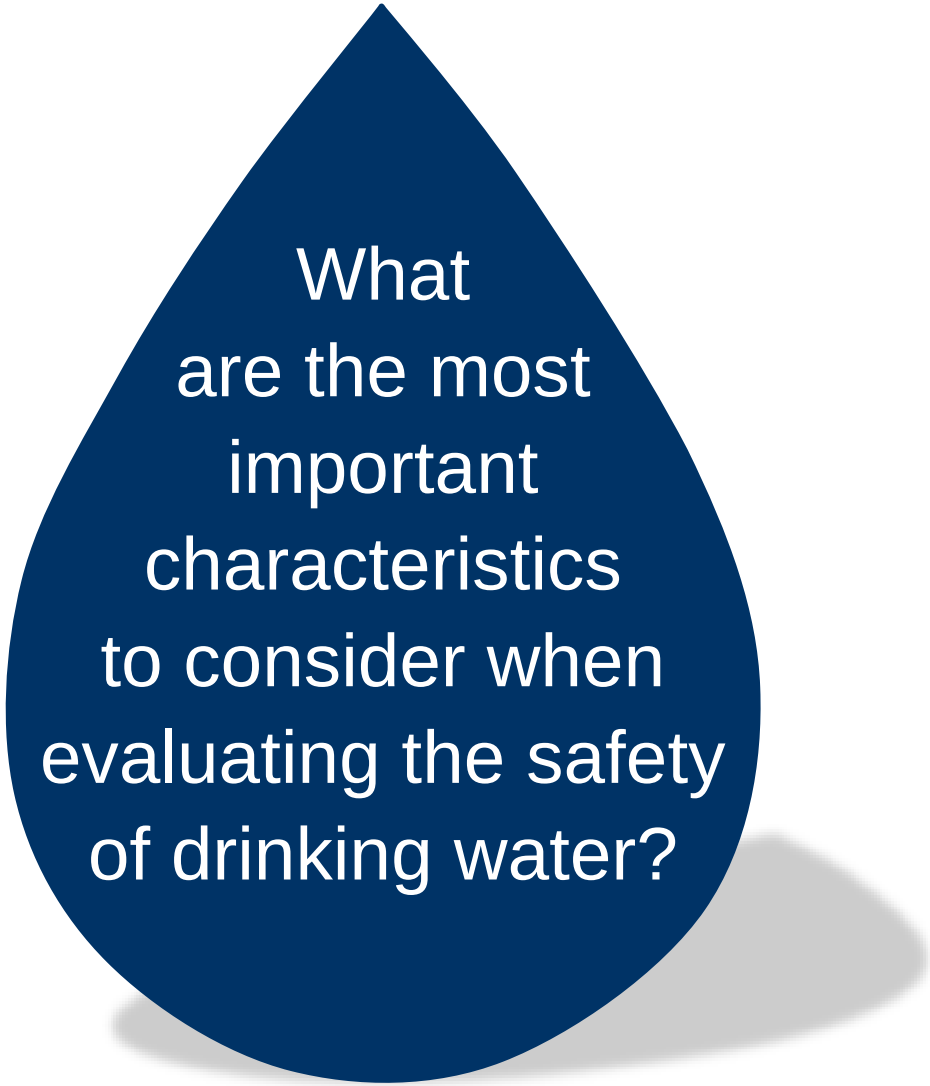
SURFACE WATER

Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

WHO/UNICEF



- 11% of the world's population lacks access to at least a basic drinking water system
- 30% of the world's population lacks access to a safely managed water system


What
are the most
important
characteristics
to consider when
evaluating the safety
of drinking water?

Chemical Characteristics

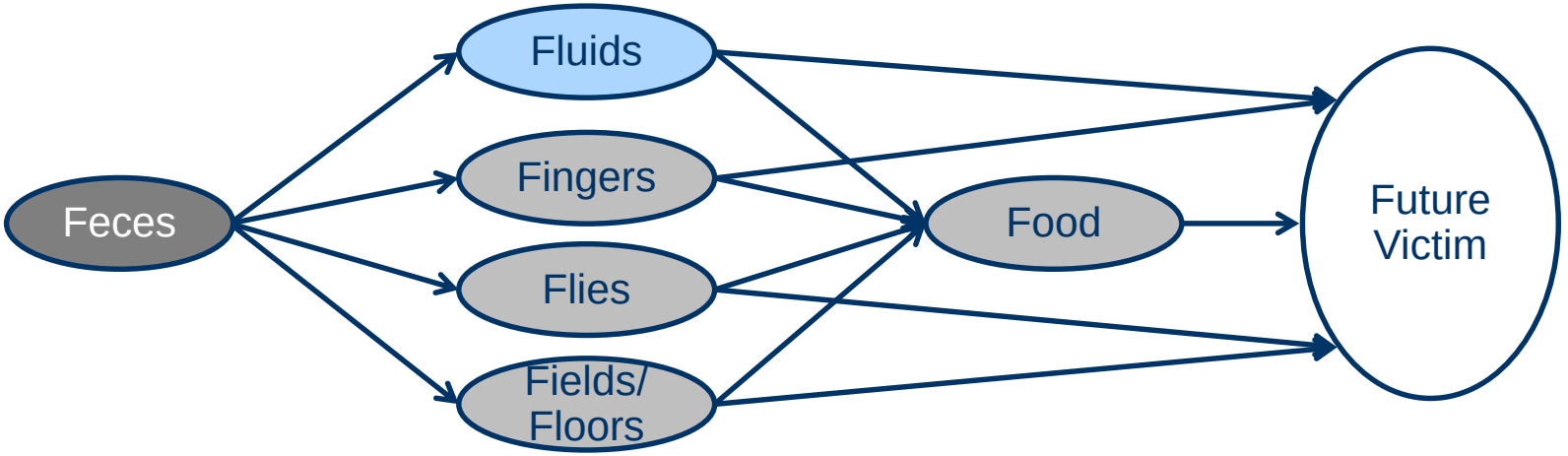
- Include: minerals, salts, chemicals
- Some have health impacts, but many affect acceptability
- Key for health
  - **Arsenic:** skin damage, cancer, heart disease, cognitive effects (0.01 mg/L)
  - **Fluoride:** bone deformities (1.5 mg/L)
  - **Nitrate & nitrite:** cancer, reduction of blood's ability to carry oxygen (50 mg/L & 3 mg/L)
- Key for acceptability
  - **Iron:** taste & staining (0.3 mg/L)
  - **Manganese:** taste & staining (0.1 mg/L)
  - **pH:** corrosion, ineffective chlorination (8)
  - **Hardness:** taste (100-300 mg/L)
  - **Turbidity:** appearance (4 NTU)

Chemical Characteristics

- Field measurements
  - **Arsenic:** test strips (0, 10, 30, 50, 70, 300 , 500 ppb)
  - **Fluoride:** specialized test kit
  - **Nitrate/nitrite:** test strips (0, 1, 2, 5, 10, 20, 50 mg/L nitrate; 0, 0.15, 0.3, 1, 1.5, 3 mg/L nitrite)
  - **Iron:** test strips (0, 0.15, 0.3, 0.6, 1, 2, 5 mg/L)
  - **Manganese:** specialized test kit
  - **pH:** test strips (6.2 - 8.4)
  - **Hardness:** test strips (0-425 mg/L)
  - **Turbidity:** turbidimeter (0-50 NTU at 0.01 NTU resolution)

Biological Characteristics

- Includes: viruses, bacteria, protozoa, and worms
- Most important for health
- Cause most waterborne diseases (cholera, typhoid fever, diarrhea, etc.)
- Diseases transmitted by ingesting water contaminated by feces



Biological Characteristics

- Field measurements: **total coliform**
  - Live in the intestines of warm-blooded animals
  - Also live in the environment
  - Historically used to assess biological quality because they are easy to culture and include coliform of fecal origin
  - However, research has shown low correlations with waterborne illnesses
  - They are now regarded as: “an indicator for cleanliness and integrity of distribution systems” (WHO Water Quality Guidelines, 4th edition)

Biological Characteristics

- Field measurements: **E. coli**
  - A large portion of fecal coliform are E. coli (references vary, 80-95%)
  - Most strains of E. coli are harmless, but some do cause waterborne illness (diarrhea)
  - E. Coli is the WHO's preferred indicator organism
  - Low correlation with presence of viral and protozoan pathogens, which are more resistant in environment and to treatment

Biological Requirements

- WHO guidelines (4th Edition)
  - No observed E. coli

- WHO guidelines (2nd Edition)
  1. In any year, at least 95% of 100 mL samples do not contain any coliform bacteria
  2. No 100 mL sample contains E. coli
  3. No 100 mL sample contains more than 10 coliform organisms of other types
  4. Coliform are not detected in any two consecutive 100 mL samples

Methods to Assess Biological Quality

1. Analysis of water sample
   - Measures water characteristics
   - Gives water quality at a specific location and time

2. Sanitary survey
   - Field inspection (and interviews) to identify contamination risks
   - Gives clues about long-term quality (contamination is often intermittent)

Use both methods together

Sanitary Survey

- What are some hints that water might be biologically contaminated?

People washing in supply

Waste disposal near water supply

“Hazard factors”

Sanitary Survey

- What are some hints that water might be biologically contaminated?

Open tank

Leaking pipe

“Pathway factors”

Sanitary Survey

- What are some hints that water might be biologically contaminated?

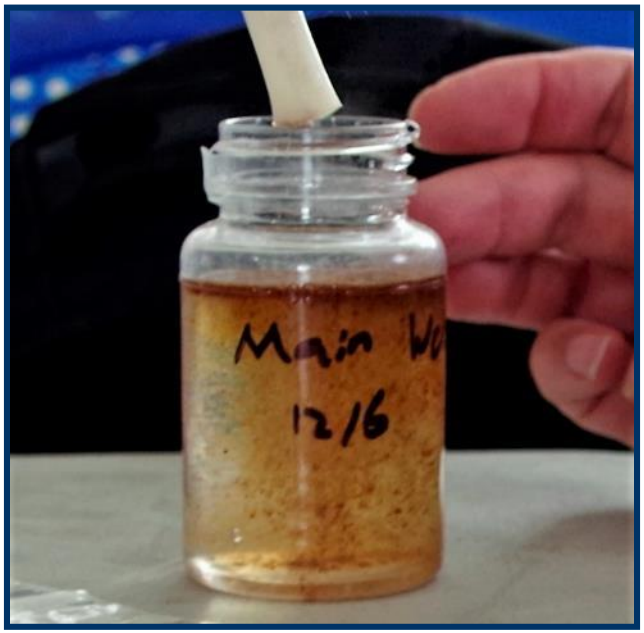
Inadequate fencing

Reliance on collection vessels

“Indirect factors”

Analysis of Water Sample

1. Hach PathoScreen Test
   - Add nutrient powder to 100 mL sample
   - If color changes from yellow to brown within 48 hours, then hydrogen-sulfide producing bacteria are present



Advantages

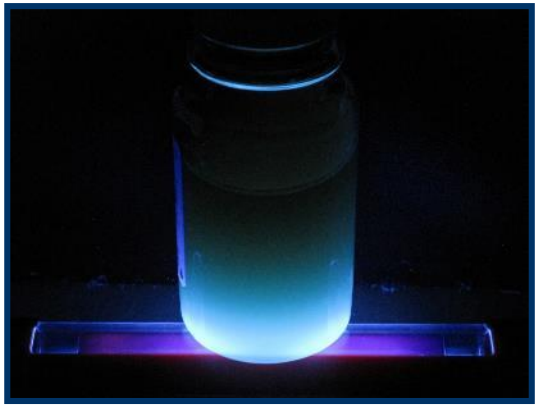
Cheapest (~$2 US)
Large sample
No incubation

Disadvantages

Considers very broad class of bacteria
Does not provide counts

Analysis of Water Sample

2. Hach MUG Test
   - Add sample to bottle until reaching the fill line (~100 mL)
   - Keep at body temperature for 48 hours
   - If color changes to yellow, then coliform are present
   - If fluoresces under UV light, E. coli are present



Advantages

Evaluates coliform and E. coli
Large sample

Disadvantages

Expensive (~$6 US)
Requires incubation
Does not provide counts

Analysis of Water Sample

3. Aquagenx Compartment Bag Test
   - Add nutrient powder to 100 mL sample
   - Pour sample to fill compartment bag
   - After 48 hr, if color is blue then E. coli are present; if fluoresces under UV light then coliform are present
   - Pattern of blue compartments gives most probable number of E. coli per 100 mL

Advantages

Evaluates coliform and E. coli
Large sample
No incubation
Provides E. coli count

Disadvantages

Very expensive (~$9 US)
Does not provide coliform count

Analysis of Water Sample

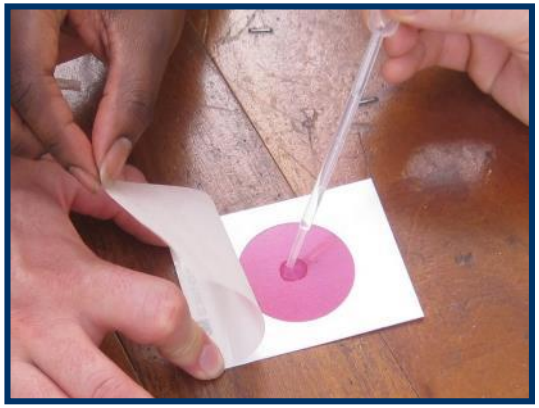
4. 3M Petrifilm Test
   - Add 1 mL of water to nutrient cycle with sterile pipette
   - Roll film down and distribute water with plastic spreader
   - Keep at body temperature for 24 hours
   - Blue colonies with gas bubbles are E. coli
   - Red colonies with gas bubbles are other coliforms

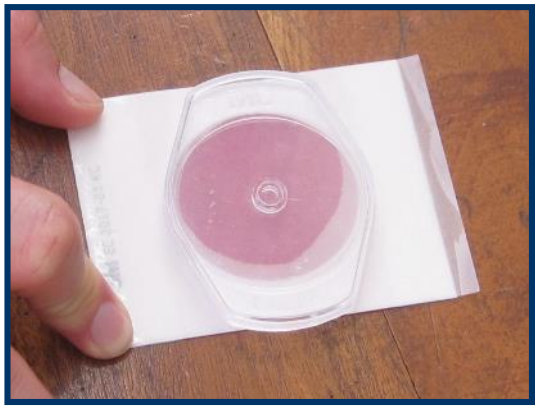
   Advantages

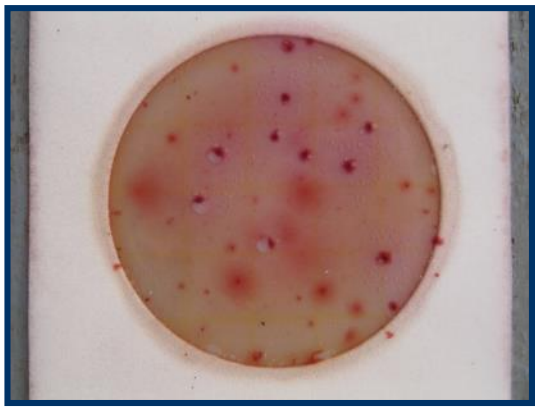
   Cheap (~$3 US)
   Evaluates coliform and E. coli
   Provides counts

   Disadvantages

   Small sample
   Requires incubation

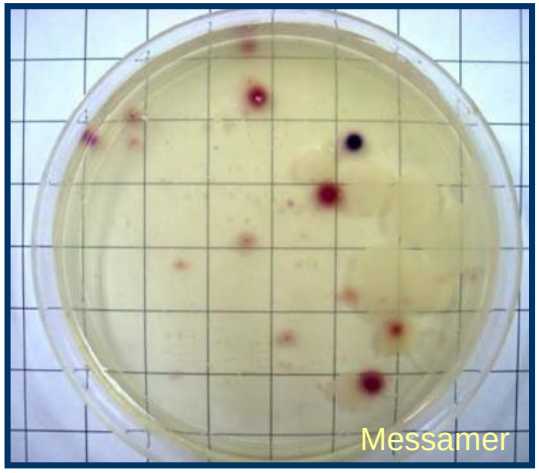






Analysis of Water Sample

5. Micrology Coliscan Easygel Test
   - Add 1-5 mL of water to gel bottle
   - Swirl and pour into petri dish
   - Solidifies in 45 minutes
   - After 48 hours, purple colonies are E. coli and pink colonies are other coliforms



Advantages

Cheap (~$4 US)
Evaluates coliform and E. coli
No incubation
Provides counts

Disadvantages

Small sample
Difficult
Counts can be difficult to estimate

Analysis of Water Sample

6. Hach Membrane Filter Method
   - Pour 100 mL of water into funnel
   - Suck through filter with pump
   - Remove filter and place on Petri dish with growth medium
   - Keep at body temperature for 24 hours
   - Blue colonies are E. coli
   - Red colonies are other coliform

   Advantages

   Evaluates coliform and E. coli
   Large sample
   Provides most reliable counts

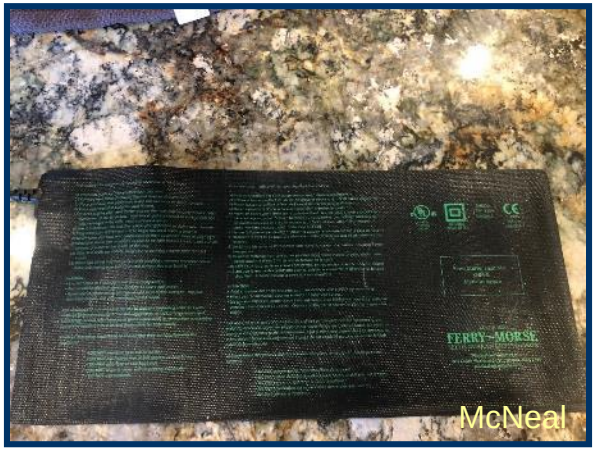
   Disadvantages

   Most expensive (~$14 US)
   Requires incubation

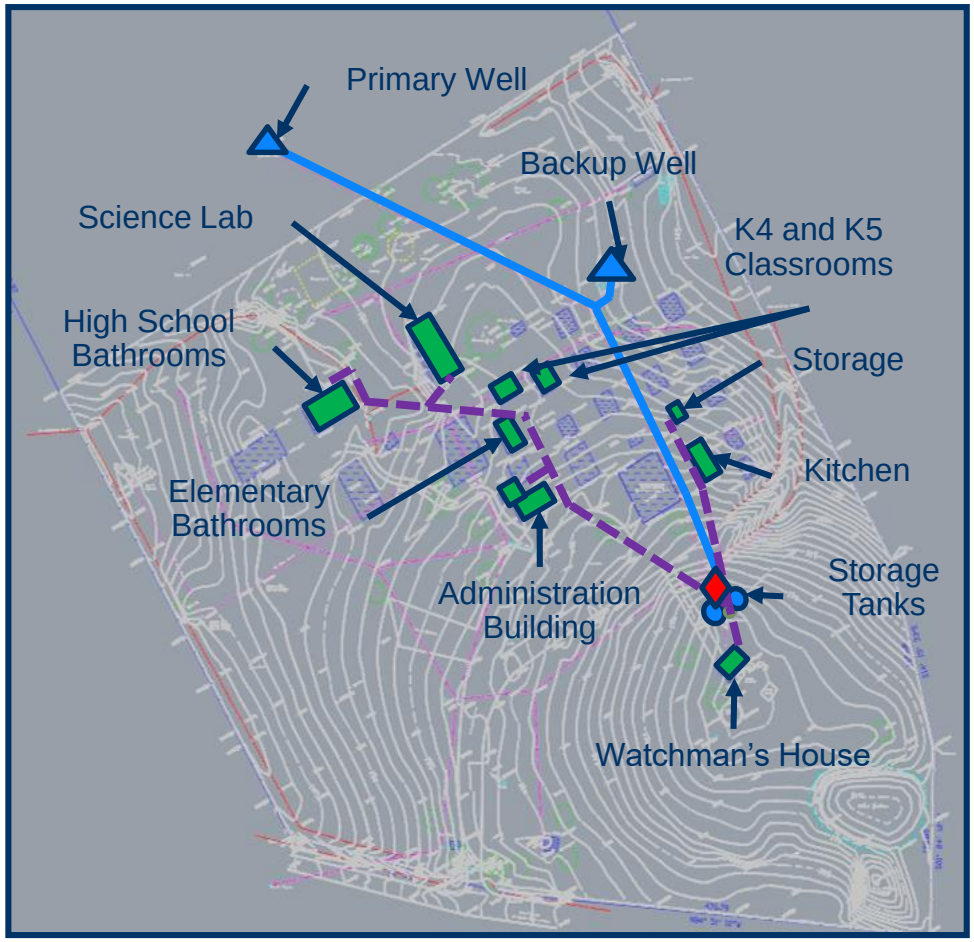
Bill McNeal's Incubator

- 2.4 x 4.7 x 4.7 cm (6 x 12 x 12 in) U.S. Postal Service mailing box
- 17-W seed starter mat (23 x 7.7 cm or 9 x 19.5 in)
- Knocked down box and mat lay flat in a suitcase
- It maintains ~34-37 °C (94-98 °F) in a 21 °C (70 °F) room

bill.McNeal@Coffman.com



Where to Collect Water Samples



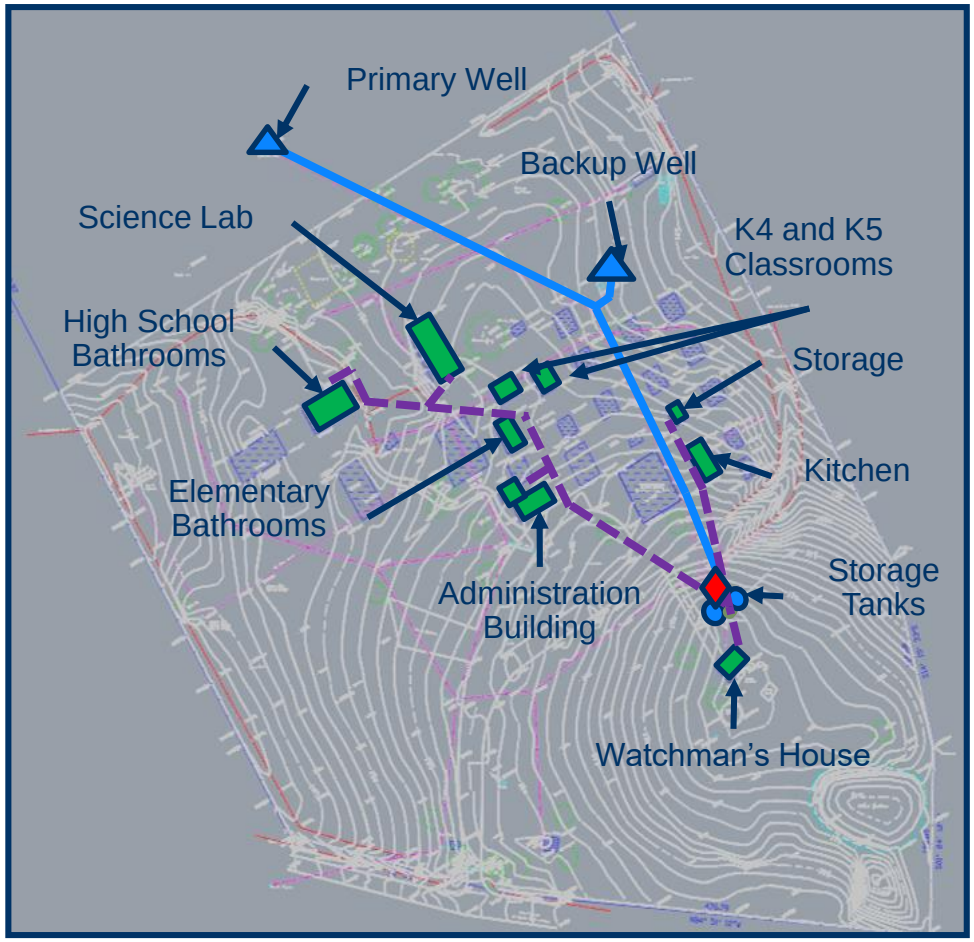
Existing Water Supply System

- Well
- Chlorinator
- Storage Tank
- Served Building
- Known Pipe
- Guessed Pipe

Purple = Distribution

Primary Well

Where to Collect Water Samples

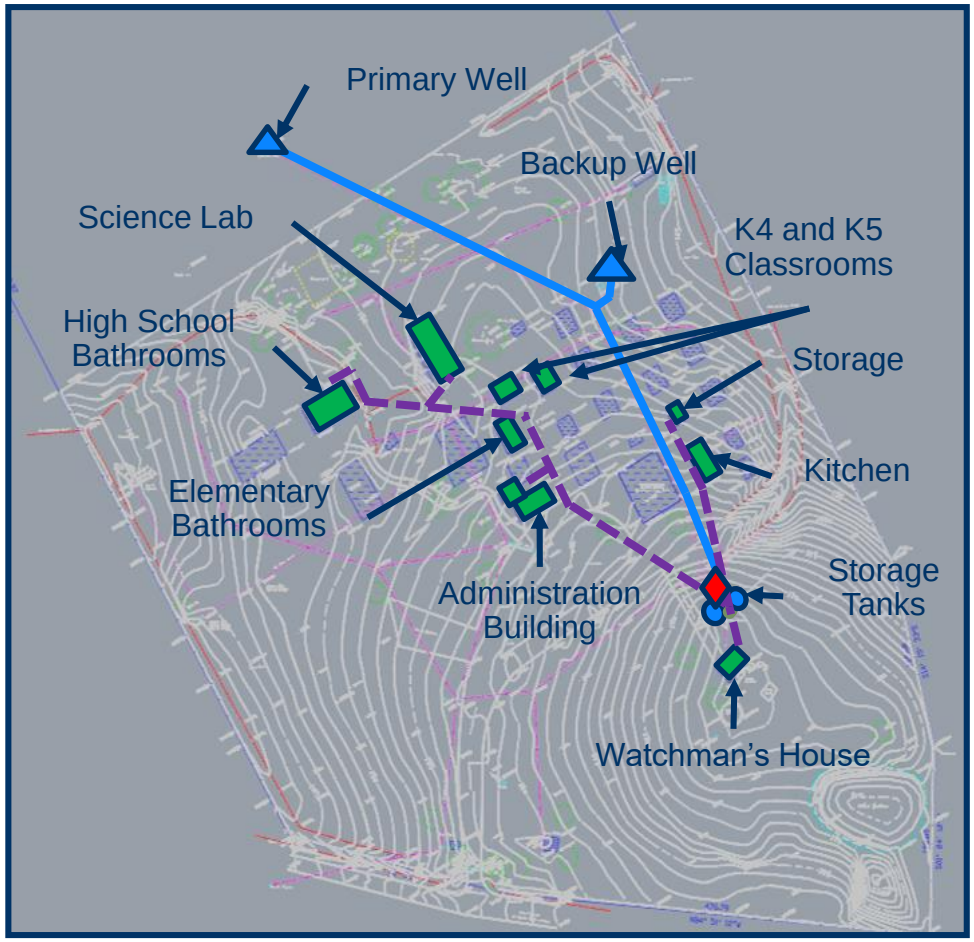


Existing Water Supply System
- Well
- Chlorinator
- Storage Tank
- Served Building
- Known Pipe
- Guessed Pipe

Purple = Distribution

Backup Well

Where to Collect Water Samples



Existing Water Supply System

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- Storage Tank
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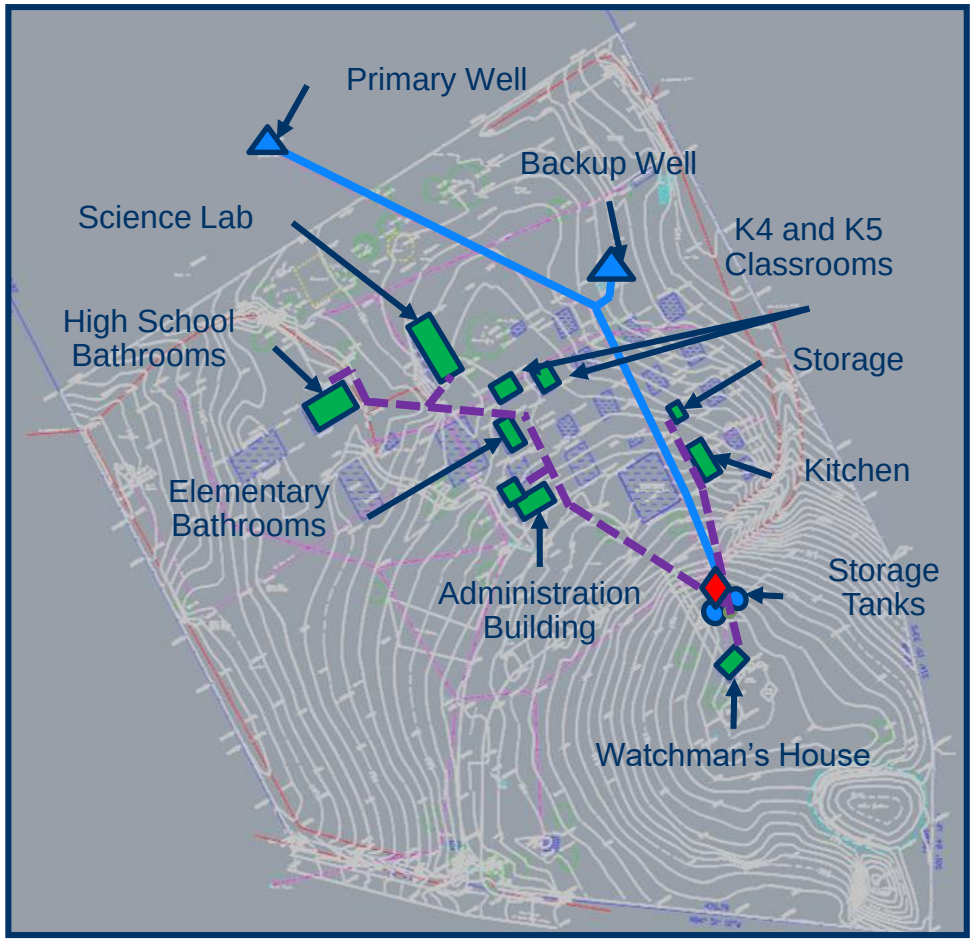
- Known Pipe
- Guessed Pipe

Purple = Distribution

Storage Tanks

Where to Collect Water Samples



Existing Water Supply System

- Well
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Purple = Distribution

Tablet Chlorinator

Where to Collect Water Samples

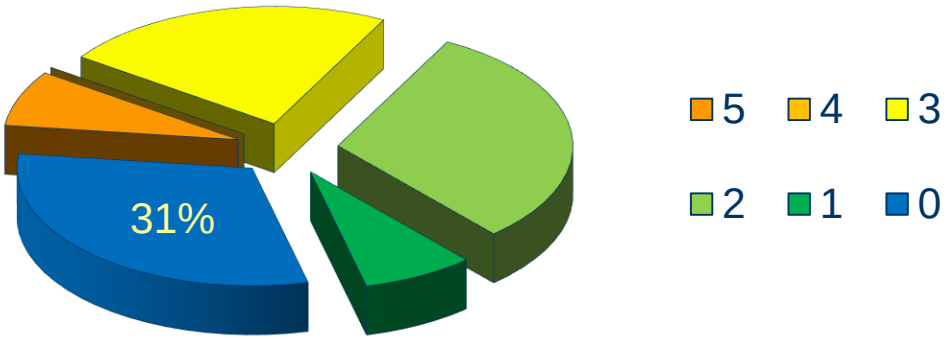
Existing Water Supply System
- Well
- Chlorinator
- Storage Tank
- Served Building
- Known Pipe
- Guessed Pipe
- Purple = Distribution

- Current/potential sources
- After treatment
- Priority locations
- Most distant points in system
- Suspected problem areas (e.g., low pressure or leakage)

Interpreting Results

- Tests performed on stormwater pond in Fort Collins, Colorado
  - Implemented: Hach MUG, Aquagenx Compartment Bag, Petrifilm, and Coliscan
  - 24-30 trials of each test

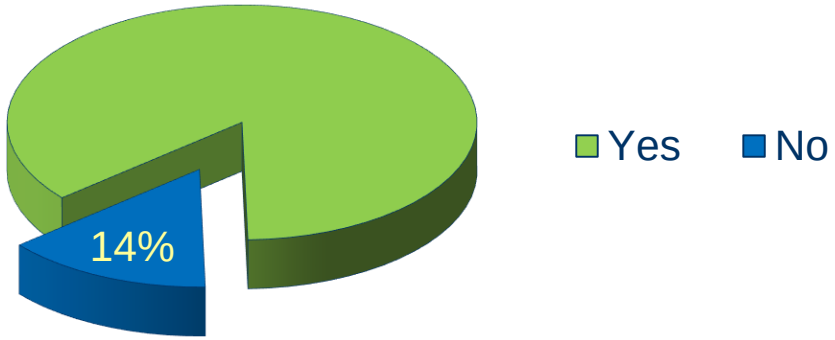
Aquagenx Compartments



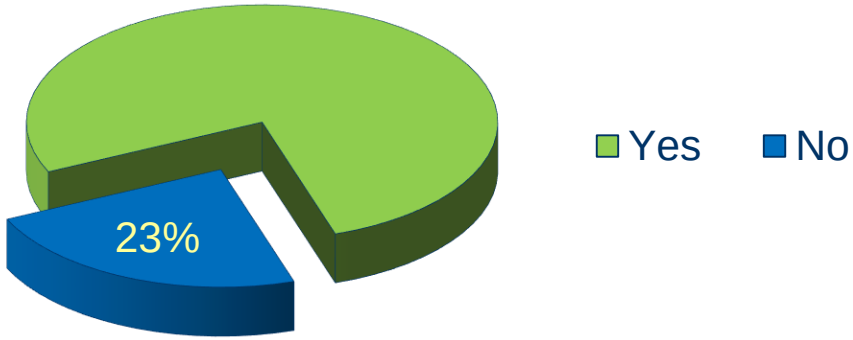
Most probable number of E. coli is ~14/100 mL

Interpreting Results

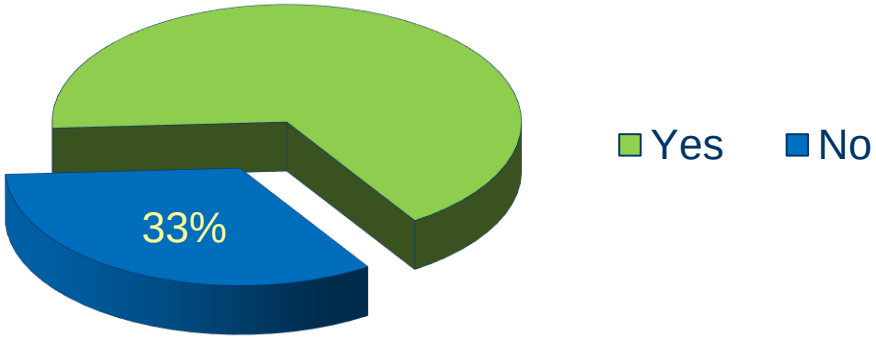
Hach Coliform (~100 mL)



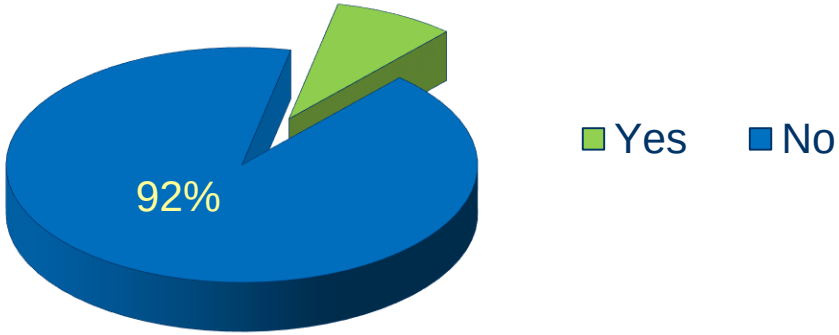
Petrifilm Coliform (1 mL)



Coliscan Other Coliform (1 mL)

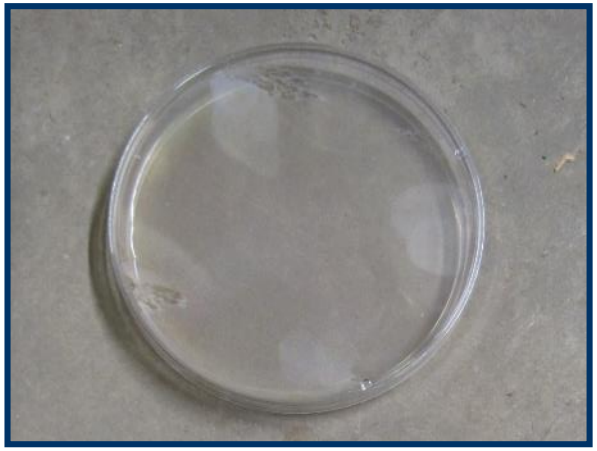


Coliscan E. Coli (1 mL)



Interpreting Results

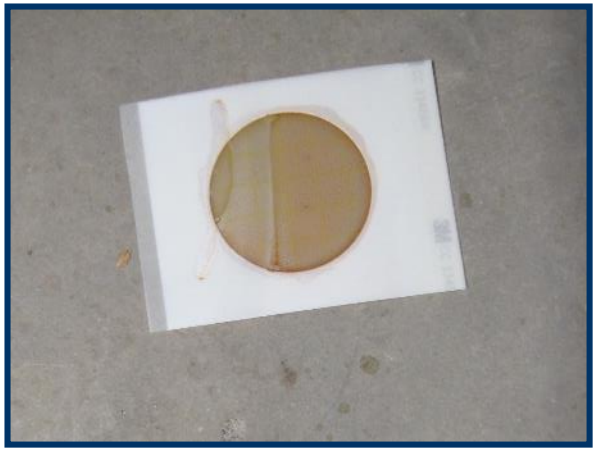
Coliscan



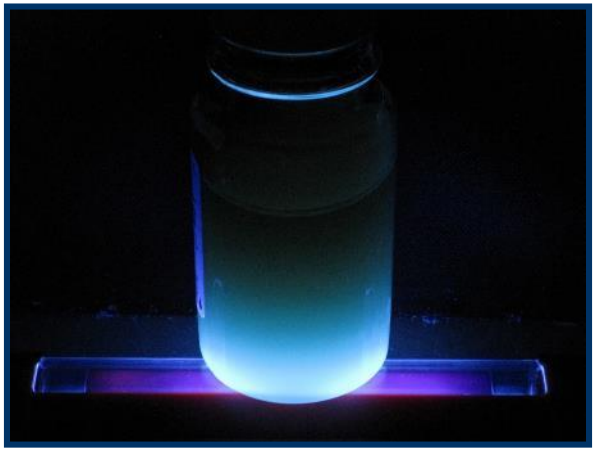
Hach MUG

Aquagenx

Petrifilm



Hach MUG



Aquagenx

Final Thoughts

- Type of test matters
- Sample size matters
- Storage before testing matters
- Incubation matters
- Movement of Coliscan matters
- Keep Coliscan out of sun
- Consider using multiple tests
  - 100 mL presence/absence
  - 1 mL counts
- Don’t be overconfident in test results
- Share results in a constructive manner