Information about Water Quality Parameters Relevant to the CDC SWS Program

Parameter 1: Microbiological Sampling

The principal human health risk associated with drinking water is infectious disease contracted from water contaminated with fecal material. In order to determine the health impact of the CDC SWS, two water quality parameters are commonly measured: 1) microbiological indicators, and 2) chlorine residual. The presence of microbiological indicators in drinking water indicates contamination with fecal material, and their absence indicates a safe water supply. Sampling procedures for chlorine residual are detailed *** here.

When conducting microbiological sampling, it is important to remember that the results *do not show* that all disease-causing bacteria, viruses, protozoa, and helminthes have been inactivated (a table detailing common waterborne diseases, the microbe responsible for the disease, and their susceptibility to chlorine is included as Appendix A). Microbiological indicators test for bacteria that have been shown to be associated with disease-causing organisms. Thus, these samples do not test directly for viruses, protozoa, or helminthes. Four microbiological indicators are currently commonly sampled: total coliform, fecal (thermotolerant) coliform, production of hydrogen sulfide, and *E. coli*. Total and fecal coliform are laboratory-method defined groups of bacteria (some disease-causing and some not), the production of hydrogen sulfide indicates that members of the group of bacteria that produce hydrogen sulfide are present, and *E. coli* is one particular bacteria that causes gastroenteritis.

The World Health Organization (WHO) has established guideline values and the United States Environmental Protection Agency (USEPA) and the European Union (EU) have established standards for microbiological indicators and residual chlorine (Table 1). The standard unit for microbiological indicators is colony forming units per 100 milliliters of sample (cfu/100 mL).

Table 1. WHO Guideline Values, USEPA and EU Standards

	WHO Guideline Value	USEPA Standard	EU Standard
Total Coliform	0	0	
Fecal Coliform	N/A	N/A	
Production of hydrogen sulfide	N/A	N/A	N/A
E. coli	0	0	

The following sections detail the methods and equipment necessary to conduct the on-site sampling for these parameters, and information necessary to accurately interpret the results.

Laboratory Methods

There are three different laboratory methods used to test for microbiological indicators: 1) presence/absence, 2) most probable number, and 3) membrane filtration. *Standard Methods for the Examination of Water and Wastewater* (APHA/AWWA/WEF, ***) provides detailed laboratory procedures for each of these methods. All three methods involve the collection of a sample, processing of a sample and addition of a specific media to encourage growth of the indicator you are looking for, and incubation of the samples for 24-72 hours to await the growth of the indicator.

1. **Presence/Absence (P/A)** testing is the simplest of the three methods to test for microbiological indicators, yet provides the least amount of data. As the name implies, this method provides information on whether bacteria are present in a sample or not. The procedure involves adding a liquid or powder media to 100 mL of water and incubating for 24-72 hours. A color change or UV-fluorescence indicates the presence of bacteria.
    - Advantages to this method include simple procedure, minimal equipment, simple method of analyzing results, and wide range of temperature for incubation.
    - Disadvantages include lack of numerical results and false negatives (inability to accurately identify small numbers of bacteria as a positive) (reference this).

- "P/A testing was developed for and is applicable where most tests provide a negative result. Where a significant proportion of tests provide a positive reaction quantitative testing is preferred in order to determine relative health risk and therefore relative priority of need for correction, such as by improved or greater treatment or by finding a higher quality source water for supply" (Sobsey, year).
- Not recommended by WHO (WHO, 1993).

2. **Most probable number (MPN)** testing utilizes statistics in order to provide quantitative microbiological data by completing multiple presence/absence tests. In this method, multiple vials or wells are filled with the sample water and a media. The vials or plates are incubated for 24-72 hours, and then each vial or well is assessed for a color change or UV-fluorescence. The number of positive and negative vials or wells is compared to a table provided with the directions with the media and a numerical value (in cfu/100 mL) is assigned. It is important with this methodology to know the range that the specific test is capable of identifying. For example, if you are using a test with a range of 0-84 cfu/100 mL in highly contaminated water, the result you will obtain is >84 col/100 mL.
    - Advantages include simple procedure, simple method of analyzing results, and wide range of temperature for incubation.
    - Disadvantages include many vials (if not using a disposable plate) and, depending on the method used, a small range of numerical values.
3. **Membrane filtration (MF)** testing provides quantitative data on the actual number of colonies forming units in a volume of water. A measured volume is water is filtered through a 0.45 micron (0.00000045 meter) filter. The filter is then placed in a petri dish over a pad impregnated with a specific growth media and incubated at a specific temperature for approximately 24 hours. Colonies grow in specific colors, and are manually counted.
    - Advantages include quantitative identification of microbiological indicators.
    - Disadvantages include complexity of the procedure and inappropriateness for turbid waters.

Incubation

As can be seen, all three of these methods require incubation to allow the bacteria to grow. In general, the requirements for incubation are more stringent using MF than while using the MPN and P/A testing. Many of the MPN and P/A tests have a wide temperature range for incubation, for example 25-35 degrees Celsius. MF testing is dependent on the maintenance of an exact temperature, depending on the specific test.

Incubation in developing countries with poor access to electricity can be difficult, as well as expensive. A number of incubation methods can be used, depending on the resources available. It is important to check that the temperature is maintained within the correct range throughout the incubation period with a thermometer. The USEPA recommends the use of non-mercury thermometers, which are now widely available (reference this).

1. If electricity and funding is available
    - Consider the use a commercially available incubator or any method in the following sections.
2. If electricity is available and you are not using the MF methodology
    - Consider the use of improvised heat sources, such as: a heating pad in a cooler, the exhaust of a refrigerator, or ?? It is especially important when using these sources to regularly monitor the temperature with an independent thermometer. These sources can not be used with the MF methodology.
3. If no electricity is available and funding is available
    - Consider the use of a commercially available incubator that can run on battery power. Note: often car batteries can be used as power in the developing world.
4. If no electricity is available
    - Consider the use of a phase-change incubator developed by Amy Smith at MIT that utilizes boiling water to heat a material that maintains its temperature at 35 degrees Celsius for up to 48 hours. Contact is mmadinot@mit.edu.
5. If no electricity is available and you are not using the MF methodology
    - Research the ambient temperatures in the environment you will be sampling in and determine if those temperatures will be within the required range of your specific test. It is especially important when using this source to regularly monitor the temperature with an independent thermometer. Ambient temperature can not be used with the MF methodology.

Cost estimates for some commercially available incubators are included in Appendix C.

Microbiological Indicator Selection

All three of the above methods can be used to sample for the four common microbiological indicators: 1) total coliform, 2) fecal (thermotolerant) coliform, 3) production of hydrogen sulfide, and 4) *E. coli.* Thus, the question becomes, which is the most appropriate indicator to use? The answer to that question is that it depends on the situation. An important note is that the WHO and USEPA definitions for the laboratory defined total coliform and fecal coliform groups are slightly different, and as such the methods for analysis are slightly different.

Total Coliform

Disease-causing organisms can be present in small numbers in feces and water and still pose a human health risk. Because of this, indicators of the presence of disease-causing organisms present in higher concentrations were initially targeted to assess the safety of drinking water. Because there are numerous coliform bacteria in the intestinal tracts of human, and each person discharges between 100 – 400 billion coliform bacteria per day, the group was initially chosen as the indicator organism for other human wastes.

The total coliform test is defined by the laboratory method, and not the biology. In the United States, total coliform is defined as species of gram-negative rod bacteria that, at 35 ± 0.5 degrees Celsius, either: 1) ferment lactose with gas production (for MPN and P/A testing), or 2) produce a distinctive colony on a suitable medium (for MF testing). This definition includes members of the *Escherichia, Klebisella, Citrobactor,* and *Enterobacter* families. Of these families, *Escherichia* is most associated with waterborne disease.

*** European definition different – find that file

Although total coliform has historically been the standard used to assess drinking water safety, the USEPA, WHO, and EU have all moved away from the use of this indicator as an assessment of human health risk. This is because total coliform is naturally present in the environment, especially in tropical countries, and the presence of total coliform does not always indicate presence of human and animal wastes. However, total coliform is still a valuable indicator for some purposes, including:

1. Routine sampling in a treatment plant with a history of compliance to regulations,
2. Determination of the efficiency of a treatment process, and
3. Assessment of risk when *E. coli* is not present.

Fecal (Thermotolerant) Coliform

In order to provide a more accurate indicator of human health risk, the fecal coliform group was developed. The group is also laboratory method defined, and is those gram-negative rod bacteria that, at 44 ± 0.2 degrees Celsius, either: 1) ferment lactose with gas production (for MPN and P/A testing), or 2) produce a distinctive colony on a suitable medium (for MF testing). This subgroup includes the genus *Escherichia*, and some species of *Klebsiella*, *Enterobacter*, and *Citrobacter*. The fecal coliform test has fallen into disfavor for the assessment of human health risk for many of the same reasons as the total coliform group: presence in the normal environment (especially in developing countries). Thus, fecal coliform is still a valuable indicator for some purposes, including:

1. Routine sampling in a treatment plant with a history of compliance to regulations,
2. Determination of the efficiency of a treatment process, and
3. Secondary assessment of human health risk.

E.coli

E. coli is an actual bacteria that causes gastroenteritis in humans, and is abundant in human and animal feces (up to 1,000,000,000 *E. coli's* per gram of fresh feces). "The presence of *E. coli* in water always indicates potentially dangerous contamination requiring immediate attention" (WHO, 1993). The USEPA, WHO, and EU all recommend *E. coli* as the indicator of choice to assess human health risk. One word of caution is that, in some environments, there is not enough *E. coli* present to provide statistical assessments of efficiency of treatment processes, and when trying to assess both human health risk and filter efficiency both total coliform/fecal coliform and *E. coli* testing may need to be completed.

Production of hydrogen sulfide

A relatively new, and widely promoted, microbiologic test is measuring the production of hydrogen sulfide. Mark Sobsey of the University of North Carolina has completed an extensive

and excellent review of the current research on this method and excerpts from that report are presented here (year). The full report is available at http://www.who.int/water_sanitation_health/Documents/H2S/h2s5.htm.

> The H_2S method in various modifications has been tested in many places in different waters and produced results reported as indicating it to be a reasonable approach for testing treated and untreated waters for fecal contamination. It offers advantages including low cost (estimated at 20% of the cost of coliform assays), simplicity and ease of application to environmental samples.
>
> …
>
> It has not been suggested as a replacement for other testing procedures for fecal contamination of water. Because it has not been adequately tested in regions with temperate and cold climates nothing can be said about its applicability in those regions.
>
> …
>
> Because it offers the potential for testing water in places where other testing methods are not feasible, its promotion, dissemination and use have been encouraged by many developers and evaluators. However, as is apparent from the review and analyses presented here, H_2S tests have not been evaluated and judged according to the generally accepted criteria of an indicator of fecal contamination, except perhaps indirectly and by comparison. Because of these deficiencies, it is not possible to widely and unequivocally recommend H_2S tests for the determination of fecal contamination in drinking water. There remain too many uncertainties about the reliability, specificity and sensitivity of the test for detecting fecal contamination of drinking water and its sources.
>
> …
>
> There are good reasons to support the further investigation and use of H_2S tests under certain circumstances and in certain settings. In particular, if the alternative to H_2S testing is no water quality testing at all for fecal contamination, the H_2S test is recommended for use, with caution. The caution concerns possible false positive results due to H_2S presence or formation in water from sources other than fecal contamination. In addition, H_2S testing also is recommended with caution for educational and motivational purposes to promote water sanitation and hygiene education in outreach and dissemination programs. Again, it must be established or verified that the test will give correct results with respect to water classification as suitable or unsuitable when applied to the treated or untreated drinking waters being tested.

In summary, Sobsey concludes that the test is worth investigating further, yet currently not enough is known to recommend this test as a replacement for the total coliform, fecal coliform, *E. coli* paradigm.

Cost Comparison

Now that we have covered the theory of microbial indicators and how they are sampled, the question to answer is: What methods are available to sample these indicators in the field in the developing world, and how much does each sample cost? The following table details the available methods, with a cost estimate per test and a cost estimate for non-consumable equipment for each type of sample/test combination.

Table 2. Types of Sampling Available and Cost per Sample

	Presence/Absence	**Most Probable Number**	**Membrane Filtration**
Fixed Costs	Incubator: 0 – 1,100 General cleaning, safety, and laboratory supplies: 200		
Fixed Costs	Bottles: 4.31/test	Vials: 9.21/test	Fitration Apparatus DelAgua: ??? Hach: 750
Total Coliform	Hach: 1.80 2.54 (disposable)		Hach: 2.98
Fecal Coliform	N/A	Hach: 6.18	Hach: 2.94
Production of H_2S	Hach: 0.67	Hach: 4.66	N/A
Total Coliform and E. coli	Hach: 2.34 3.18 (disposable) Colilert: Disposable Bottles	Hach: 6.18 Colilert: Disposable trays	Hach: 3.46

Quality Assurance/Quality Control

The importance of quality assurance/quality control (QA/QC) procedures in microbiological sampling in the field can not be overestimated. In addition to normal variability in concentrations of microbiological indicators between samples which should be accounted for, there exists the possibility of contamination in every step in the procedure. The following techniques will ensure that the data you have gone through so much trouble to obtain is reliable:

1. Blank samples (using dilution water) should be run each time you complete a sampling run. If the blanks show bacteria, you have contamination in your procedure, and data from that run needs to be discarded. Dilution water can be prepared by: bringing it with you (in 99 mL or larger) bottle, finding it in country, boiling low-turbidity water for 10 minutes, or bringing small packets of chemicals to mix with ** water to create dilution water with you.
2. Positive controls (using unclean water at hand) should be run each time you complete a sampled run where there is the possibility that all results will show no growth of bacteria. If the positive controls do not show bacterial growth, then either the media has degraded or your incubation temperature is not correct, and all data from that run needs to be discarded.
3. If financially possible, all samples should be duplicated. There is normal variability in the microbiological concentration between one 100 mL sample and the next. In addition, duplicates provide additional quality assurance and allows for averaging of two samples for more accurate results. At an absolute minimum, 10 percent of the samples should be duplicated. For microbiological sampling, 25 percent is much more preferable minimum. A step-wise duplication process could also be implemented. For example, in the first runs all samples should be duplicated to ensure that the procedure is being completed correctly. If all duplicate samples agree, then the percentage of duplicate samples can be reduced in the subsequent run. If duplicates begin to disagree, then 100 percent duplication should again be implemented.
4. If at all possible, send a duplicate sample to an independent laboratory and compare the results between your method and the independent laboratory.

Sufficient quality assurance/quality control procedures (duplications, blank samples, and positive controls) could up to double the cost of your sampling program. However, this is a small price to pay when compared to the cost of disregarding your entire sampling program because of questionable results and inadequate quality assurance.

Data Analysis

You have collected your data – now what does it mean?

Summary

In summary, the selection of both the microbiological indicator to sample and the method with which to sample that indicator depends on the goals of the study, the resources available to complete the study, and the intended purpose of the data. If you have any questions about this document, please feel free to email safewater@cdc.gov.

1st Edition: May 28, 2003

Appendix A: Waterborne Diseases and Susceptibility to Chlorine[1]

Microbe	Disease	Effects	Ct Value
Bacteria			
Campylobacter jejuni		Watery diarrhea	
Escherichia coli	Gastroenteritis	Diarrhea	
Legionella pneumophila	Legionellosis	Acute respiratory illness	
Leptospira	Leptospirosis	Jaundice, fever	
Mycobacterium			
Pasteurella tularensis			
Salmonella typhi	Typhoid fever	Fever, diarrhea	
Salmonella	Salmonellosis	Food poisoning	
Shigella dysenteriae	Shigelloisis	Bacillary dysentery	
Staphylococcus aureau			
*Vibrio cholerae (*smooth strain)	Cholera	Heavy diarrhea, dehydration	
*Vibrio cholerae (*rugose strain)			
Yersinia enterolitica	Yersinosis	Diarrhea	
Viruses			
Adenovirus	Respiratory Disease		
Coxsackie			
Enteroviruses (67 types)	Gastroenteritis, heart anomalies, meningitis		
Hepatitis A	Infectious hepatitis	Jaundice, fever	
Norwalk virus	Gastroenteritis	Vomiting	
Parvovirus			
Poliovirus			
Reovirus	Gastroenteritis		
Rotavirus	Gastroenteritis		
Protozoa			
Balantidium coli	Balantidiasis	Diarrhea, dysentery	
Cryptosporidium parvum	Cryptosporidiosis	Diarrhea	
Entamoeba histolytica	Amebiasis	Diarrhea, bleeding	
Giardia lamblia	Giardiasis	Diarrhea, nausea, indigestion	
Naegleria fowleri			
Helminthes			

Ascaris lumbricoides	Ascariasis	Roundworm infestation
Enterobius vericularis	Enterobiasis	Pinworm
Fasciola hepatica	Fascioliasis	Sheep liver fluke
Hymenolepis nana	Hymenolepiasis	Dwarf tapeworm
Taenia saginata	Taeniasis	Beef tapeworm
T. solium	Taeniasis	Pork tapeworm
Trichuris trichiura	Trichuriasis	Whipworm

1. Adapted from MEI, 1992 and .

Appendix B: Equipment Lists and Sample Procedures for Microbiological Sampling

P/A or MPN testing using vials or bottles:

This sampling methodology was used with Hach Pathoscreen© total coliform and *E. coli* media and Hach hydrogen-sulfide production packets in rural Nicaragua. Quality control measures, including duplicate sampling, blank sampling, and comparison with duplicate samples analyzed in a laboratory in Managua, showed no contamination of samples and excellent correlation. Although this method is specific for these two media, the procedures and mentality for conducting microbiological analysis in rural areas of the developing world are accurately represented here, and will be useful no matter the media or specific test that is completed.

Sample collection:

1. Remove WhirlPak sampling bag from sealed larger bag.
2. Label WhirlPak bag with date, time, and sample identification number in permanent ink.
3. Wash hands with hand alcohol.
4. Open WhirlPak bag without touching the lip of the bag.
5. Fill WhirlPak bag with sample without touching anything to the lip of the bag.
6. Whirl bag three times quickly, and cinch the sides closed.
7. Place WhirlPak bag upright in a cooler with ice.
8. Analysis of sample must be completed within 8 hours.

Cleaning of bottles:

1. If reusing vials or bottles, inactivate previous sample by addition of bleach or boiling for 10 minutes. Dispose of previous sample in an appropriate location.
2. Scrub the vials or bottles with isopropyl alcohol and a scrub brush until no color remains.
3. Boil vials or bottles and lids in boiling water for 10 minutes.
4. Remove vials or bottles from boiling water using tongs sterilized with alcohol. Do not touch the inside of the vial, bottle, or cap at any time with any object.
5. Place vials or bottles (with lids lightly placed on top of vial or bottle) on a garbage bag coated with isopropyl alcohol to cool.
6. Place plastic bag with alcohol on it on top of vials or bottles and lid.

7. Let vials or bottles dry.
8. After vials or bottles are dry, close the lids and place vials or bottles in clean ziplock bags and zip.
9. The use of plastic bottles instead of glass vials has the advantage of easier handling and lighter weight. Plastic, however, can retain the smell of the growing bacteria, although results showed that the retained smell did not influence subsequent tests.

Fixing samples:

1. Wash hands with hand alcohol.
2. Place new garbage bag on surface and coat with isopropyl alcohol.
3. Remove WhirlPak bags from cooler with ice.
4. Wipe down WhirlPak bags with alcohol soaked paper towel before placing on garbage bag to prevent any cross-contamination if any of the WhirlPak bags have leaked or sweated.
5. Remove and label sterilized bottles from ziplock bag.
6. Arrange your lab space with samples and bottles lined up.
7. Aseptically (do not touch your hands do the lip of the WhirlPak) open WhirlPak bags and pour sample into bottle. Do not let any piece of the WhirlPak touch the sample bottle.
    a. Place caps facing up on the garbage bag while filling sample bottle. Replace when completed.
8. For P/A with Mug Pathoscreen© test:
    a. Wash hands with hand alcohol.
    b. Remove glass vial from container not touching the part where you will break it.
    c. Wipe down glass vial with isopropyl alcohol soaked paper towel.
    d. Break vial (careful!) using paper towel.
    e. Pour media into 100 mL of sample, cap.
    f. Repeat a – e.
9. For hydrogen sulfide test:
    a. Wash hands with hand alcohol.
    b. Remove powder pillow touching only one end.
    c. Wipe other end with alcohol soaked paper towel.
    d. Snip open powder pillow with clippers sterilized in candle.
    e. Pour into sample bottle, cap, and shake.
    f. Repeat a-e.
10. Incubate for 12 – 48 hours.

11. Read samples at 12, 24, 36, and 48 hours. Record results on data sheet.

Equipment List for Presence/Absence or Most Probable Number sampling:

Equipment	**Laboratory Equipment**
Ziploc bags	WhirlPak bags
Paper towels	Bottles or vials with lids
Alcohol – Isopropyl and Hand	Growth Media
Pot to boil water in	Clippers to open packets
Tongs to remove bottles	Incubator and thermometer
Garbage bags	UV light
Candle and matches	Dilution Water
Data Sheets	
Labeling marker	
Cooler and Ice	

Membrane Filtration Sampling Procedure

This sampling methodology was used with Millipore mColiBlue24 media with the Millipore filtration stand for enumeration of total coliform and *E. coli* in rural Haiti. Quality control measures, including duplicate sampling or all samples and blank sampling, showed no contamination of samples and excellent correlation. Although this procedure is specific for this media, the procedures and mentality for conducting membrane filtration in rural areas of the developing world are accurately represented here, and will be useful no matter the media or specific test that is completed.

Sample collection:

1. Remove WhirlPak sampling bag from sealed larger bag.
2. Label WhirlPak bag with date, time, and sample identification number in permanent ink.
3. Wash hands with hand alcohol.
4. Open WhirlPak bag without touching the lip of the bag.
5. Fill WhirlPak bag with sample without touching anything to the lip of the bag.
6. Whirl bag three times quickly, and cinch the sides closed.
7. Place WhirlPak bag upright in a cooler with ice.
8. Analysis of sample must be completed within 8 hours.

Fixing samples:

1. Wash hands with hand alcohol.
2. Place new garbage bag on surface and coat with isopropyl alcohol.
3. Set up filtration apparatus and light candle.
4. Remove WhirlPak bags from cooler with ice.
5. Wipe down WhirlPak bags with alcohol soaked paper towel before placing on garbage bag to prevent any cross-contamination if any of the WhirlPak bags have leaked or sweated.
6. Label petri dishes with date and time of analysis, dilution factor, and sample identification number.
7. Arrange your lab space with samples and petri dishes lined up.
8. Complete analysis of each sample:
    a. Open media packet and pour entire packet into petri dish, taking care to cover all of the pad with the media.

b. Sterilize tweezers in candle, and pick up and sterilize carbon fritt in the candle.
c. Sterilize tweezers in candle, and carefully open new filter package, pulling away package and paper without touching filter with hands.
    i. If you touch filter, discard.
d. Pick up filter with tweezers and carefully center on filtration apparatus.
e. Place new funnel on top of filter and filtration apparatus.
f. Carefully pour sample from WhirlPak into the funnel without touching WhirlPak to funnel. Close and set aside the rest of the sample in case it is needed later.
    i. Some samples will need to be diluted because the concentration of bacteria is to high to count on the filter. The general guidelines for dilution are: ***
    ii. Use a pipetter and a pipette in order to add sample to the funnel, and then fill the funnel with dilution water to at least ** mL in order to not concentrate the bacteria in one part of the filter.
g. Pull sample through the filter, expelling the wastewater into waste bucket or ground.
h. Sterilize tweezers, remove filter funnel from apparatus and discard, pick up filter by the edge with tweezers and place in labeled petri dish. Be careful to avoid air bubbles under the filter.
i. Repeat a-h.

9. Incubate samples for 24 hours, along with background and blanks.
10. Total coliform colonies appear as red and blue, *E. coli* colonies appear as blue. A maximum of 200 colonies should be present on the filter. Record results on data sheet.

Equipment	**Laboratory Equipment**
Plastic trash bags	WhirlPak Bags
Labeling marker	Sterile dilution water
Candle and matches	Filtration apparatus
Alcohol – Isopropyl and Hand	Petri dishes, Funnels. and Filters
Data sheets	Growth Media
Paper towels	Pipetter and pipettes
Cooler and Ice	Tweezers
	Incubator and thermometer
	Mask and Magnifying glass

Appendix C: Laboratory Equipment Cost Estimates

Equipment	Cost (per test)	Company	Order Number
Portable Incubator	850.00	Hach	25699-00
Battery for Incubator	163.00	Hach	25803-00
Rack (P/A, MPN, or MF)	12.00	Hach	25805-00
			25805-01
			25805-02
Thermometer (non-Mercury)	28.85	Hach	26357-02
UV-lamp (for PA and MPN *E. coli)*	38.50	Hach	24152-00
WhirlPak bags (w/ dechlorinating agent)	0.1855	Hach	20753-33
Presence/Absence Testing			
Bottles (100 mL polycarbonate)	4.31	Hach	23243-73
Total Coliform & E.coli			
P/A Broth Ampules with MUG	2.34	Hach	24955-25
P/A Broth with MUG disposable bottles	3.18	Hach	24016-50
Total Coliform			
P/A Broth Ampules	1.8	Hach	24949-25
P/A Broth disposable bottles	2.54	Hach	23232-50
Production of hydrogen sulfide			
Pathoscreen P/A pillows	0.67	Hach	26106-96

Most Probable Number (assuming 5 vials per test)			
20 mL Vials	9.21	Hach	2327-06 21667-06
Total Coliform and E. coli Lauryl Tryptose with MUG	6.18	Hach	21014-15
Fecal Coliform A-1 Medium	6.18	Hach	25609-15
Production of hydrogen sulfide Pathoscreen MPN Pillows	4.66	Hach	26107-96
Membrane Filtration			
Portable Filter Assembly	625.00	Hach	25862-00
Hand-vacuum apparatus – Syringe	13.55	Hach	25861-00
Hand-vacuum apparatus - Valve	12.00	Millipore	XXEM 00104
Hand-vacuum apparatus - Tubing	2.00	Millipore	XX10 03751
Forceps	20.50	Hach	21411-00
Dilution water	1.57	Hach	14305-98
Pipets (sterile, disposable)	0.42	Hach	20926-28
Funnels and Filter	1.24	Hach	25863-00
Petri dish with pad	0.295	Hach	14717-99
Total Coliform & E.coli			
m-ColiBlue24 (2 mL plastic)	1.50	Hach	26084-50
m-ColiBlue24 (100 mL bottle)	0.78	Hach	26084-12
2 mL disposable syringes	0.35	Hach	22287-25
Total Coliform m-Endo (2 mL plastic)	1.02	Hach	23735-50

Fecal Coliform			
m-FC (2 mL plastic)	0.98	Hach	23732-50

Company Information:

Ben Meadows	www.benmeadows.com	800.241.6401
Hach	www.hach.com	800.227.4224
Colilert	www.idexx.com	