Water Quality Testing

Procedures and Information Packet

Introduction

Dear Friend of Water:
Thanks for purchasing our water quality testing packet.

This is a set of downloadable files which will help you:

1) Learn water testing techniques which are a an optimal combination of simple, inexpensive and accurate
2) Improve the design of your testing program
3) Learn what the limitations of testing are, and how to better use water testing as a tool to understand what is really happening in a natural or man-made water system
4) Get more out of your interpretation of water testing results

Who needs this information?

This information should be especially useful for lay people who have taken an interest in the quality of natural waters or a water system, including water quality activists, surfers, managers of small water systems (particularly those attempting to meet the onerous new clean water act requirements for surface water supplies), rural homeowners, development workers, aid workers and other water guardians who want to learn to test water or improve their existing testing program.

The suppliers of water quality testing supplies seem to assume that users are well-versed in all applicable lab techniques. They also seem to assume that users don't care how much the tests cost, or how much trash is generated.

This packet is designed to give your water quality testing effort a boost by sharing what we've learned about doing cheap, materials-efficient tests that help give an accurate picture of what is going on.

These tests are somewhat, but not too technically involved. If you think you could do high school chemistry lab experiments well if you did them over and over, you'll be fine. Detail orientation and persistence are the keys.

This packet covers:

- How to estimate water flow
- How to test for electrical conductivity (total dissolved solids, or TDS)
- How to test for turbidity (suspended solids, or SS)
- How to test for general and fecal coliform bacteria
- Sources for recommended equipment and materials
- Editable field data entry forms
- Editable computer data entry / analysis forms
- Examples of hundreds of water samples, showing how they were coded, described, plated, and counted

The examples include samples showing the quality of natural waters, including:

- Oceans, beaches, lagoons, estuaries, surf breaks, and swimming holes
- Beaches
- Rain, tree canopy drip, natural surface runoff

- Groundwater
- Springs, seeps, creeks and rivers
- Natural pools and swimming holes
- Floodwaters

They also include samples from water and wastewater systems, including:

- Spring boxes, raw water pipes, treated water pipes
- Tank inlets, outlets
- The effect of ozone treatment
- Wells
- Ornamental fountains and pools
- Chlorinated water
- Roof runoff
- Harvested rainwater
- Road runoff
- Reverse osmosis tap water
- Raw sewage
- Clarified septic tank effluent
- Constructed wetland effluent
- Greywater

Table of Contents

What this packet consists of:

Three files:

WaterQualityTesting.pdf

A printer-friendly version of all files—
This intro
Sources for equipment and supplies
And printer friendly versions of everything below

WaterTestProcedures.doc

Editable version of water/wastewater testing procedures for:
Flow
Total Dissolved Solids
Turbidity
General and fecal coliform bacteria

WatertTestFormsExamples.xls

Several worksheets (below) in one excel file; you can access them from the tabs at the bottom of the window:

Editable Field data entry form
Editable Computer data entry and analysis form
Coliform math
Example: Various locations in Santa Barbara, California
Example: Indigenous Village in Mexico
Example: Eco Village in Mexico
Example: Mountain community in California
Example: Fecal Coliform Calculations

There is also more information of interest on our web site at:
http://oasisdesign.net/water

Disclaimers

- If you want to do less than ten tests, you're probably better off hiring someone than learning how to perform tests yourself.
- This packet is not intended as a substitute for information from manufacturers of water quality testing supplies, but a supplement.
- If you're a professional microbiologist or a worker in a certified lab this packet isn't really targeted for your needs. You'd probably find the approaches described here primitive, but thought provoking.
- At present there isn't any interpretation of the examples, and there aren't any explanatory photos or graphics
- This item is new and still somewhat ragged around the edges. We're considering it a "public beta," until we hear back that it is working well for people. If we'd found it at the start of our water testing program, this would have saved us thousands of dollars of time. We hope it will be useful for you. Please let us know if you've found it highly useful, incomprehensible, or whatever, using our Feedback page.

Where these procedures came from

I've been attracted to clean, wild water my whole life. Ecological systems design has been my day job since 1980, and my major focus since 1990 has been the design of water and wastewater systems.

For twenty years I've been immersed in natural and man-made water systems in twenty different countries, covering a large span of applications in wide range of natural and cultural conditions.

One of the things I've always been interested in is how water quality changes as it moves through natural and engineered systems.

I felt I'd developed a strong intuitive sense of what was happening in different systems—but was it right?

I wanted to test my hunches, see what I could learn, and refine my water intuition.

The conventional approach to testing water is to take a relative handful of samples, and subject them to expensive and precise tests done in a certified lab.

Precision, however, is not the same as accuracy:
Precision: How exact and consistent your measuring tools are
Accuracy: How close to the truth your results are

For Example, if your electrical conductivity meter gives you a consistent reading of 380.21, that is very precise. If the actual electrical conductivity is 380.22, it would also be quite accurate. If the actual electrical conductivity is 375, your meter would be precise but not accurate. If another electrical conductivity meter gives readings which vary from 373 to 377, this meter's readings are less precise but more accurate. There is a different, more common and serious issue with water quality tests. Suppose the actual electrical conductivity was 265 shortly upstream, and 400 downstream? A single measurement, however precise, would fail to show this trend. The trend might be more significant than the values themselves. Even worse, suppose that electrical conductivity is not the most relevant factor–then you can really get far astray.

As Ianto Evens says, "It is better to be approximately right that precisely wrong."

The conventional, "high precision" approach can easily miss the deeper truths of what is happening, because it is too expensive to do enough tests this way to reveal fine-scale patterns of how water quality changes over short distances or time spans.

Examples of sampling procedures

The following examples illustrate the application of different approaches to sampling water:

Example: Government beach water quality monitoring in Santa Barbara

In my town of Santa Barbara, California there is a lot of interest in water quality at the beaches. The water is sampled at each beach each day, right in front of the creek mouth, in knee-deep water. This is great so far as it goes, but with this sampling procedure you've got no idea what water you're really testing. With each wave, the mix of ocean to creek water changes. The creek is generally filthy compared to the ocean, so different mixes will yield wildly varying results. The high precision of this test, which is probably ±1%, is wasted. If the sampler had taken the test one wave later, or two feet away, the number of fecal coliform bacteria could easily be twice as many or half as many.

The main point of this test is to decide whether bacteria levels warrant closing the beach or not. Since the advisory refers to the ocean, not the lagoon, this test design is the best way to fulfill this primary goal.

When it comes to understanding *why* the beach is closed, and where the contamination is coming from, this testing program has little to offer; the resolution is too coarse, the data points too few and far between.

Example: Changing the procedure above to better pin down where the beach water contamination is coming from and going to

The general and fecal coliform bacteria tests I like to use are cheap; the materials are under two dollars. The principle cost is time, which water guardians typically have more of than money. The results aren't very precise, but you can afford to take enough samples to see how the quality changes over short distances and time spans, which will help get a better of sense of what is happening in reality.

With results of samples from the creek a quarter mile inland, the beginning and end of the lagoon, the open ocean up current 100 feet out, and the shore just up current and just down current of the creek, you'd have enough data points to start to form a picture of what's happening.

Once you've established that the ocean contamination is coming from the creek, you could test every 200 yards up the creek to the source, to get an idea where the contamination is entering the creek. If there are big spikes in between certain data points, you could go back and test each ten yards between them to pinpoint the source...you get the idea.

Based on this more accurate picture, you can modify the design of future tests to get the most information with the fewest samples in the future. For example, with tests of the lagoon water, up current and down current beach water, and a few key creek points you could determine if beach water quality advisories or warnings were necessary, *and* keep a finger on the pulse of where the contamination was coming from.

What you're really trying to do is improve your water intuition

As a practical matter, the only affordable, available tool capable of considering so many variables is intuition.

When I take a water test, I'm interested only secondarily in the results of the test. My primary interest is to **train and hone my water intuition. Water intuition is the way to** picture what is happening the *gaps between tests*. If you think about it, the area covered by the testing gaps is the vast majority of the system, something you can ill afford to ignore. Even if you have taken coliform tests all over the place, what about nitrate? phosphate? actual pathogens? A complete certification test for bottled water is several thousand dollars and covers hundreds of parameters.

When you consider that two feet away it could be totally different, it should be clear that it economically hopeless even for a deep pocket organization to gain a complete, quantitatively accurate understanding of what is happening in a complex, ever changing natural or man-made water system.

What if you need certified, quantitative results to achieve your objective? When your water intuition, backed up by tests, has given you and accurate cognitive map of what is happening, *then* you can design a test with a handful of samples to send to that expensive, certified lab so that they'll listen to you at the regional water quality control board, or whatever.

More on where to test-Tap water

If the county health department checks your rural domestic water supply, they'd probably take it from your kitchen tap. If I tested your water, I'd take it from the innermost recess of your spring, the spring water diversion point, the storage tank inlet, the storage tank outlet, your kitchen tap (sterilized first with a torch) and maybe from the glass you usually drink from for good measure.

Chlorinated tap water from a municipal system is much less interesting and diverse. It is pretty much all dead from where the chlorine is added until it touches your lips. In the entire Santa Barbara city water system, for example, they did not find *one* general coliform bacteria in 2003.

For chlorinated tap water, I'd test the untorched tap, and retest it torched if it was positive for general coliforms. It is also interesting to test downstream of water filtration that removes chlorine.

Another example: testing swimming holes in our creek and at the river

One hot day I went with a gaggle of young children to our local swimming hole. After hours of play, I gathered a sample from the outlet of the main pool, and the inlet of the preceding pool.

A few days later I counted the number of colonies of general and fecal coliform bacteria in the plates.

Here's the picture: creek with about 30 gpm of crystal clear water, two eight to ten foot deep pools carved from bedrock, about 40,000 gallons of water between them. The lower pool in particular is a looking a bit tired after several hours of play of several wild children and a couple adults. So, which do you think was cleaner? The inlet or the outlet? (Obviously it's a trick question or I wouldn't be asking it like this). Well, I'll be damned if the outlet wasn't cleaner. At a loss for an explanation, I concluded that I'd switched the labels and re-tested. This time I tested the inlet, the pure surface of the water (where all the dust and stuff floats), the water column six inches down, the outlet, and even the water column at the bottom, braving the colder day to dive down ten feet to un cap and recap the sample bottle.

Same counter intuitive results: water six inches down below the outlet cleanest, followed by the surface, the bottom, and finally, in last place, the inlet.

Combing my memory banks for an explanation, I recalled...

I once did a fairly extensive set of water tests at the Huehuecoytl eco village, a project I worked on at 7000 feet in the mountains of central Mexico. This community has zero water income for six to eight months of dry season. No rain, no creek, no springs, not even reachable groundwater (the World Bank dug a four hundred foot deep well at the village next door, and it was just dust at the bottom). All their water is from storage in big cisterns.

Anyway, when the rain finally comes, they would usually dump the old, stale water, and fill the big cistern with fresh, clean water from their waterfall.

Only problem was, when I tested it, the old water was cleaner.

When you store water in good conditions, the number of pathogens and indicator bacteria decrease over time. This is because they 1) settle to the bottom and 2) die off more rapidly that they reproduce...this latter because most human pathogens are designed to thrive in the human body, not a cold, nearly nutrient-less water tank, which is filled with countless organisms better adapted to this environment, all hungry to eat ill-adapted human pathogens..

So, what I think was going on in our creek is this: the pools, which are so big relative to the current that if you emptied them they'd take days to fill, had a bigger purifying effect than the contaminating effect of (ahem) all those cute little butts in the water.

Another lazy swim day, I tested water at several places along the Santa Ynez River, at White Rock. The entry to the pools, the outlet, a spring on the opposite bank, water which had spent at least a hundred yards percolating through gravel before coming the foot of a gravel bar.

I had my money on the spring, but the gravel bar water was the cleanest.

When you consider than a 20 x 15 x 2.5 foot sand mound can purify septic tank effluent to the point where you could swim in it, it isn't really that surprising that river water cleans up nicely as it passes through hundreds of feet of natural sand or gravel bar.

Considering these results from our creek, and the river, I saw the beauty of nature's design. A series of gravel / sand bars and pools, with the flow varying from 10% to 90% underground, getting pushed in and out of gravel and sand, being purified, exposed, then re-purified, then purified in a different way in the sand, the pools and by the roots on the sides (see *Understanding Wild Water Systems* to learn about how soil and roots have over a million times more treatment capacity per foot than a river).

So what did the Army Corps of Engineers used to do? Give the river uniform concrete sides. No more sandbars, no more gravel, no pools, and no roots. Just having read this, your water intuition should be well enough developed already to realize what effect this would have on water quality.

Water profile

This is a powerful combination of several techniques to give a profile of a natural or man made water system. It can be done by one person or a large group, on one day or over time. Here are the elements, illustrated by an example:

Goals, assumptions, means,

What you hope to achieve by creating the water profile, and what assumptions are behind this, and how you are going to achieve this in general terms. For example:

Goal:

Achieve cleaner dry season bathing conditions at Arroyo Burro Beach and the Arroyo Burro lagoon

Assumptions:

We're assuming that contamination comes from a variety of point and distributed sources, and are hoping that at least some of these can be pinpointed and remedied

Means

Zero in on particular sources by taking samples at intervals along the entire urban watershed, then re-sampling at finer and finer intervals and following tributaries in an effort to pinpoint remediable pollution sources.

Program, materials and methods

The detailed test design, for example:

Proceed with several volunteers downstream from the urban boundary, taking samples approximately every 200 meters (at locations marked on a topo map, located in the field by GPS or by measuring tape).

The sample locations may be moved up or downstream slightly to catch or exclude nearby tributaries or probable pollution sources.

Interesting tributaries or pollution sources will also be tested directly.

At each sample location, we will gather the following:

Written narrative description of the water

Including vegetation type, degree of shading, geology, pollution sources in evidence (homeless camps, drains, dog feces, etc.)

A high resolution digital image of the sample location and surrounds

Time

TDS

Flow

Temperature

Turbidity

Samples to plate for general and fecal coliforms

Sample info: code, date, time, quantity plated, etc.

(one slick way to keep the samples straight is to take a close up digital photo of the sample container, showing it's code, at the end of the photo sequence showing the surrounds of that sample location. This keys the photographic record to the physical sample, and also to the time sequence (by the time of the photo in the camera) and can help unsnarl things if you later get confused).

This field information can all be entered straight into a laptop or palmtop computer, at one extreme, transferred from paper to computer, or done all on paper and left there, the old fashioned way.

After the samples are plated and incubated, you can take high resolution digital image of the ripe plates, either before and/or after marking the counted colonies. The serial number of the plate should be written on something that ends up in photo frame.

The complete profile consists of:

A spreadsheet showing all the data collected, including the narrative, and the results of the general and fecal coliform counts

Graphs showing the levels of the different parameters versus time or distance, including fecal coliform levels converted from number of organisms to approximate amount of feces (see Coliform Standards and Conversions in spreadsheet)

The photos showing the sample locations

Interpretation of the data and the implication of the results

Suggested actions

Interpretation — Do the math, use common sense

Whenever evaluating the results of any water test, particularly fecal coliform testing, it is good practice to do the math to convert from the concentration of fecal coliform bacteria to the approximate actual amount of feces. This measurement is much easier to relate to, giving a foothold for your common sense to evaluate the results and quite possibly avoid an embarrassingly wrong conclusion.

The two sections on "Fecal Coliform Bacteria Counts: What They Really Mean" and "Rincon Point and the Three Million Dollar Disposable Diaper" in the appendix expand on this at length...

Sally forth...

Arm yourself with the equipment and procedures that follow. Hone your water intuition and you'll be set to help guard our precious wild water systems and better design and manage human water systems...

Please help guide future enhancements to this work

This packet is the first public draft of what may well turn out to be a product that is refined and expanded quite a bit.

Would you please help guide our efforts by letting us know what you'd like to see added or changed?

Here's some ideas we've had. If these would add value for you, please let us know and we'll work to include them:

- Photos of testing equipment and procedures
- One or more samples of full profiles of a water system, with photos and test results
- Tutorial for learning how to count coliscan easy gel plates and membrane filtration filters
- Integration with our other information on understanding wild water systems, design of water systems, etc.

Water Testing Procedures

General

Water has thousands of parameters which can be measured. Completely describing water in scientific terms is a nearly hopeless task.

To come close to completely describing one liter of water would cost thousands of dollars of testing and take days...not to mention that a short distance from that sample point in space or time the water could be significantly different.

Even if you made a $10,000 profile of the water every few inches and every few minutes, you'd still be missing crucial elements: the *potential* of what the quality could be if conditions were slightly different; and the magic of water as it moves dynamically through a living system.

Whatever other purpose I have for doing a water test, the main purpose is to **refine my water intuition**. Intuition is the best tool for turning a 99.9% incomplete data set into useful information.

To develop your water intuition, **record a written guess** of the result for every test you take. This will get you to **think about all the variables which can influence the results**, for example:

- Choosing a sample location/time which won't give you the clearest read on what you're looking for
- Flaws or oversights in your technique
- Unclear or incomplete notes which lead to later misinterpretation
- Touching with dirty hands
- Contaminated sample containers or apparatus
- Mixing up containers
- Flow rate
- Flow rate trend–rising/falling hydrograph
- Rainfall
- Runoff
- Temperature
- Humidity
- Wind
- Sun
- Pressure
- Animal and human influences
- Plant and soil influences
- Influence of microorganisms

With practice, the gap between what you guess and what the tests yield will narrow. More importantly, **the cells in your brain will grow new wiring connections so that what you see, hear, smell, taste, and feel about the water will give you a clearer and clearer sense of what is happening in the water system you test. To paraphrase the Chinese: "The master tests the least yet understands the most."**

This process could be compared to keying animals or plants from a detailed field guide. The key draws your attention to finer and finer distinctions, and lets you know how close your original guess was. After a while, your intuition takes over, and you can discern a vulture from a red tail hawk from a split second sighting through a small gap in the trees, or tell a coast live oak from a valley oak from a mile away.

As you come to know the relative importance of different influences, you will be able to get more out of less future testing, by being more targeted, and to be able to predict how quality will be affected by influences on or changes to the system.

Good technique

Good technique is methodical, focused and detail-oriented, yet still aware of the big picture.

The foundation of good technique is a good system, the rest is just following that system accurately.

First, get clear on what your purpose is. What do you hope to learn from testing? I suggest you write a sentence describing the purpose. Now design a test to fulfill it: What is the minimum number of tests for what parameters which will do? Testing is tedious and expensive, and the byproducts are an awkward kind of trash (biohazard compost spread over plastic). The less testing the better.

Write down your procedure and follow it. A good form for capturing data is key. A list of required materials is helpful.

Procedures for testing for these parameters follow:

- Temperature, TDS
- Flow
- Turbidity
- General and fecal coliform bacteria
- Smell, Taste, Feel, Magic energy

Materials for all tests

- Sharpie
- Field data entry log
- Watch

Procedures for all tests

Get Clean

Wash hands with soap before handling and at frequent intervals

Codes & collection

Label the sample container, plate and data log with the same code. I like to use a letter for the project, and a number for the sample, e.g., for the 14th sample on the Santa Ynez River, the code is SYR14, with the numbers in chronological sequence.

Collect the sample in a clean container, rinsing several times before filling. 1 pint drinking water bottles make good containers, as do sterilized empty Coliscan bottles. To sterilize reused containers, rinse out with clean water, then fill the cap with hydrogen peroxide. Dump the cap full of H_20_2 inside of the bottle, shake it and leave it.

Note the location, date and time collected, as well as any of the other info on the narrative log. (see table and narrative log forms)

Refrigerate the sample if it is more than one hour before it is plated. If the sample is not plated right away, its storage history (times at different temperatures) should be noted on the log.

Temperature, Total dissolved solids

Purpose

The temperature can tell you something about where the water came from, and what influences have been acting on it. A shady creek will be cooler than an open one, a deep spring will be cooler in summer than a shallow one.

Total dissolved solids (TDS) lets you know how much minerals are dissolved in the water. I've used this to help me figure out if a seep on the side of a canyon was water from the creek that took a short side trip through a crack in the rock, or a spring from a separate source.

TDS also tells you a lot about suitability of the water for different purposes.

Hand held probe technique

Hand held probes measure TDS indirectly via electrical conductivity. These probes generally give a readout for temperature as well.

Materials

- Probe

Testing a spring in Mexico for TDS

Procedure

- Record your guess of the temperature and TDS. TDS for potable water can be estimated by tasting it.
- Insert the probe in the water and wait for the reading to stabilize. The reading should take less than a minute.
- If the water is salty or nasty, rinse the probe with clean water afterward.

Flow

Purpose

To determine the amount of water passing though a given point per unit of time, and how it varies with weather, rainfall, ET, and season, also how much flow is above or below the surface.

Timing captured volume technique

This works well with low flows and / or containers of known size. It can be quite precise.

Materials

- Container of known volume
- Watch
- Whatever you need to get the water into the container; piece of pipe and rags, for example
- Under difficult conditions it helps to have two people

Procedure

- Locate a place where bedrock forces all or nearly all the flow to the surface.
- Record your guess of the flow.
- Funnel the water into a bucket or container, possibly using rags packed around a pipe if there is no natural feature that concentrates the flow into one neatly bucket capturable stream.
- Measure the amount of time it takes to fill your known volume, then convert it to gallons per minute, liters per hour, or whatever units are appropriate. For example, if it takes 27 seconds to fill a one gallon jug, the flow is 60/27 or 2.22 gallons per minute.
- (Note that the stated volume of virtually all standard containers does not include the "head space," the air above the liquid. Picture the level of milk in your gallon jug and fill to the same point. On a five gallon bucket the five gallon line is usually a few inches from the top. If you want to determine the volume of your container accurately, weigh the added water on a scale, and mark the container accordingly.)

Timing flowing volume technique

This works well with large flows but is not very precise.

Materials

- Tape measure
- Watch
- Under difficult conditions it helps to have two people

Procedure

- Locate a place where the flow is somewhat uniform, and in a channel with a uniform, measurable cross-section for some distance.
- Record your guess of the flow.
- Measure the cross sectional area. Suppose it is a ten meters wide, and averages one meter deep, it's cross sectional area is 10 square meters.

Toss something in the middle of the current and time it's passage through the channel. The average flow will be about half of this value. If it takes your object 200 seconds to float 10 meters down the channel, the average current is a meter every ten seconds. Multiplying by the cross section, the flow is a cubic meter per second.

Turbidity

Purpose

Turbidity is a measure of the suspended solids in the water (not settled to the bottom, not floating on the surface nor dissolved, but floating in mid water column). Solids in the water are a good indicator of cruddiness. Crystal clear water can contain pathogenic organisms, but it is less likely. Pathogens in turbid water are a more pernicious problem, as the solids can shelter pathogens from disinfection.

Secchi disk and turbidity tube are other good techniques which are not covered here.

Visibility technique

Materials

Eyes
Enough water that you can't see all the way through it
Mask if you're under water (necessary if the surface is agitated)
Tape measure (optional)

Procedure

Look through the water. If the visibility is over ten feet, the turbidity is probably under 1 NTU (the drinking water standard). If the visibility is a hundred feet, the turbidity is probably below 0.1 NTU...virtually nothing suspended in the water.
If the visibility is 22 inches, the turbidity is around 10 NTU.
If the visibility is 10 inches, the turbidity is around 30 NTU.
If the visibility is 2.5 inches, the turbidity is around 240 NTU.

Look through the water

Materials

Glass container
Sun or bright direct light

Procedure

Fill the jar and shake it. The moving specs are in the water, the stationary ones are on the jar. The silver specs which rapidly dissipate towards the top are tiny bubbles.
The drawback of this technique is that it isn't very quantitative, though with practice you can get within a factor or two or three of the actual reading.
The nice thing about this technique is that it is qualitative; to some extent you can see what the stuff is. Even water which is 0.1 NTU will have clearly noticeable things swirling around. Check them out. Are they big? Small? Long thin fibers? Animal? vegetable or mineral?
An amount of suspended solids which looks like one of those snowstorm Christmas displays is about 40 NTU.
An amount of suspended solids which looks like a shaft of light illuminating the dust in a very clean room is one NTU or less.

Hand held turbidimeter technique

Most turbidimeters send a light beam through water in a sample cell and measure how much goes straight through and how much scatters to the side off of the suspended solids.

Materials

Turbidimeter (This procedure is for Hach 2100P hand held turbidimeter–see resources listing)
Clean cotton cloth
Sample cells
Silicone oil
Lint free cloth

Procedure

Only handle vial by top 1/2" and bottom (otherwise you'll scratch and smudge the glass at that sample cell will be useless).
Rinse vial and lid 3x and fill sample cell
Wipe off all water with grit-free clean soft cotton rag, including water by lid
Wipe vial with silicone oil and lint free cloth (more important for accurate low readings)
Hold to sun and visually estimate the turbidity reading. Check vial for dust, re-wipe if necessary.
Record your guess of the turbidity.
Place turbidimeter level and still, out of direct sun, and place sample vial in receptacle with arrow towards tick mark.
Record guess, turbidity reading, vial number.

General and fecal coliforms

Fecal coliform bacteria themselves are generally not harmful. However, the presence of **fecal coliform bacteria indicate contamination of the water with mammalian feces, which means there could be some serious pathogens present.** Do not forget, however, that **coliforms are indicators, not a direct measure of pathogens present**. It is off one way or the other, the only question is by how much.

General coliform bacteria are present on all plant life and in the soil. Their presence in the water indicates that the water has been exposed to living things. The absence of general coliform bacteria is equated with potability in much of the overdeveloped world, a stance I'm not in agreement with. The purest spring water has coliforms in it, the rankest recycled Mississippi sewage water won't, if it's been sufficiently chlorinated. The only water which I've tested which didn't have coliforms was straight from a deep well, freshly sterilized with heat or ozone, or had a chlorine residual.

The quantity of general coliforms does provide useful information about how thick the soup of life is in a particular water sample. If it's really thick, it might be more than you want to drink.

The overdeveloped world standard for potability is zero general coliforms per hundred milliliters.
I'd endorse water with zero fecal coliforms and under 1000 general coliforms for drinking by all but the most immuno-compromised individuals.
I do fine drinking water with up to ten fecal coliforms.
People in the third world generally develop problems when drinking water with 40 or more fecal coliforms.

Presence/ Absence test for general and fecal coliforms

Will tell us if there are **more than one, or zero general and/or one fecal coliform per 100 ML, which roughly equates with one part per billion of feces.**

This is not a quantitative test. If there are 10,000 coliforms or 1, the result will be the same (though you can trick it into being somewhat quantitative by doing all your samples at the same time, incubating them at the same temperature, and seeing how fast it takes each jar to turn).

What I generally use this test for is:

1) Confirmation that a surface water source contains less than 1 part per billion mammalian fecal matter (as shown by a negative result for fecal coliforms)
2) Confirmation that a well is totally sealed to the surface environment (as shown by negative result for general coliforms)
3) Confirmation that sterilization is working (as shown by negative result for general coliforms)

This procedure is for the Hach 24016 presence absence broth with MUG

Materials

Hach 24016 P/A broth with MUG vials –see resources listing
Torch
Lighter
Goggles
Incubator
Black light

Procedure

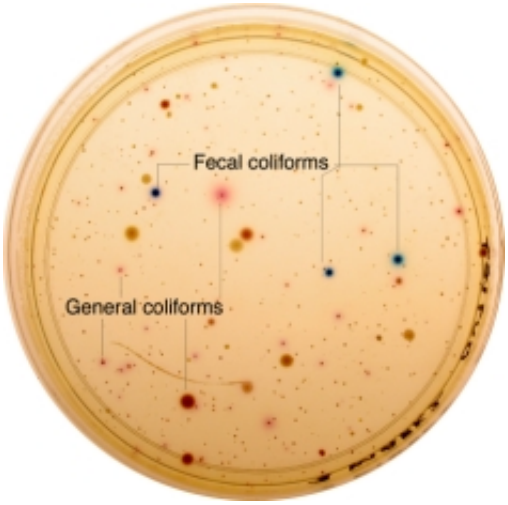
If you care about general coliforms, you must follow impeccable lab technique, as they are on the surface of the soil and every plant and animal (including your figures) and the slightest contamination will give you a false positive.
There will probably be general coliforms growing on the tap which you collect the sample from. The preferred technique is to sterilize it with heat using a torch before collecting the sample. If you use hydrogen peroxide, you need to flush the tap after sterilizing it.
If the body of water is open, you should know by now that you don't need to test for coliforms to know that they are in there.
Re-wash your hands if necessary.
Label P/A vial.
Remove lid with extreme care not to touch inside surface. Place it upside-down where nothing will fall in it. Remove the seal with care not to touch the edges of the bottle.
Fill the bottle to the line with care that no water splashes from any surface into the bottle, including the outside of the bottle. Do not scoop water up with the bottle—use a heat sterilized ladle instead. Seal the bottle. Don't scoop up sterilized water with the P/A vial. The general coliforms from your hand or the outside of the vial may give you a false positive;
Incubate at about 100°F
Record the time of incubation and the temperature Check for color change after 24 and 48 hrs.
If the color changes from purple to yellow, it is positive for general coliforms. (note that you can get a vaguely quantitative reading by how long it takes to turn)
If the bottle hasn't turned in three days it may be discarded.
If a change of color is observed, place the bottle in a dark location and check for fluorescing with the UV lamp.
Illuminate yellow colored vial with a black light. If it fluoresces clearly, it is positive for fecal.
Record the date and time of color change/ fluorescing in the data entry sheet or spreadsheet.

Coliscan easy gel technique

Gives a quantitative reading of general and fecal coliforms above 20 per 100ML with a precision of perhaps ±25%. Sample size is one drop to 5 ML. Cheap and easy except for counting colonies, which can be time consuming and confusing.

Materials

For collection:
Pipettes
Sample vials
Hydrogen peroxide
For plating:
Coliscan easy gel –see resources listing)
Plates
Incubator
For counting:
Fine tip sharpie for labeling petri dishes and marking counted colonies
8x magnifying Loupe (like the ones commonly used for slides)
White, black backgrounds
Comparison chart
Separate dyes for confirmation
Watch
Data log in spreadsheet



Coliscan easy gel plate

Procedure-sampling

Label sample vial w/ test #

Record your guess of the number of general and fecal coliforms in the water. For Coliscan and membrane filtration tests, this guess is critical for the success of the test, as you will base the amount of water you add to the petri dish on how many coliforms you think are in it (see *plating*, below).

If you guess low, you may get a dish so crowded that it is totally unreadable (300 colonies is considered the maximum for reportable results).

If you guess high, there will be few bacteria in your dish or you may miss them entirely, lowering the accuracy of your results.

Besides helping the test at hand to work, guessing helps improve the accuracy of your water intuition, as mentioned before.

Rinse sample vial and lid ten times to purge water and fill (or collect direct from source).

Note the location, date and time collected, as well as any of the other info on the narrative log. (see table and narrative log forms)

Refrigerate the sample if it will be more than one hour until it is plated. If the sample is not plated right away, its storage history (times at different temperatures) should be noted on the log.

Procedure-plating

Plate and incubate coliform samples within one hour of collection, or within 24 hours with refrigerated sample .

Wash hands

Label plates with numbers on the side of the plate where it will not interfere with reading.

Fill Coliscan media bottle with one drop to 5 mL from sample vial or source with a sterile pipette.

How big of a sample should you plate? Plate an amount of water which you suspect contains 100-300 coliforms, up to the maximum of 5 ml. If you think there are much less than 100 coliforms in 5 ml, you may have to use membrane filtration to get a usable result.

Move the water using a sterile pipette. In some instances you can pipette it directly from the source without using a sample bottle.

In most cases the amount of sample seems to end up being 5 ml. If you don't know within a factor of five how many to coliforms expect, you can do multiple platings of different amounts from the same sample, e.g., 5 and 0.5 ml, or 5, 2.5, 0.5 and 0.25 ml

Here are some guidelines to get you started:

- 5ml—clear surface water, raw domestic water…
- 1 ml –suspect surface water, treated, non-disinfected effluent
- A few drops —seriously contaminated surface water, sewage
- 100 ml —treated domestic water, raw well water, exceptionally pristine surface water, disinfected effluent (as this is 20 times more water than you can use for Coliscan easy gel, you'll have to use membrane filtration, instead).

If possible, save the refrigerated sample for re-testing if the first test used an inappropriate quantity of water, or otherwise went awry, or to confirm a seemingly outrageous result.

Swirl the sample into the medium, then pour it onto the plate, taking care that the whole surface is covered.

Keep the plate level; any bacteria that slosh onto the sides will be hard to read.

Record the time of incubation and the temp

Incubation must be below 100°, above 70°. 90-95° is ideal for fastest, clearest results.

If you don't mind taking a chance on jeopardizing the integrity of your results to save a few pennies worth of trash, you can reuse the pipette for samples which you expect to be dirtier water.

With less risk, you can reuse the empty Coliscan bottles as sample vials.

To sterilize the sample container for later use, rinse out with clean water, then fill the cap with hydrogen peroxide. Dump capful of H_2O_2 inside, shake it and leave it until you need to use it.

Procedure-counting

Default count times are 24 and 48 hours after plating.

Before opening the incubator, check the temperature and adjust if necessary.

You can count through the back, experimenting with white, black, and illuminated backgrounds

General coliforms can be any shade and intensity of pink to red. Fecal coliforms are grape purple. Blue colonies have no red in them at all.

Mark colonies already counted with a pen; use different marks if there is room. I use little triangles for fecal, squares for blue, circles for pink, and I ignore the white ones. If there are questionable colonies, you can put a question mark by them (see confirmation, below)

If there are more than 300 colonies on a plate, it is non-reportable, however you can get an approximate count by counting "n" colonies in an area marked off with a pen and ruler. Enter the

count in the spreadsheet with a multiplier equal to the ratio in between the *total area/representative area counted.* 1 quarter (count is 4n) one square inch (9n), 1 cm2 (36n) divisions drawn on the back of the plate.

Don't count anything which first shows up after 36 hours at high temp.

Procedure Confirmation

Questionable colonies should be confirmed. To do this you'll need two bottles of confirmation dye, one red only, one blue only.

Mark the back of a plate with a line dividing it in two, one half labeled "red" and the other "blue" Dribble lines or dots of each of the appropriate dyes on the appropriate sides. (dots are ideal as they preclude the migration of enzyme from one test to another, even if you use the confirmation plate for a bunch of confirmations over time).

After the gel has hardened, flip the plate over and label each pair of drops with a letter or number; A(red), A (blue), B (red) etc.

On the sample plates, label the colonies being confirmed with the corresponding letter (A, B, etc.) and on a confirmation log, note the letter and the plate code, e.g. A-SYR14, B-SYR14, C-SYR-15, etc.

Heat a thin metal probe to glowing red (if it is really thin it heats and cools nice and fast) and touch it to the colony you want to confirm, taking care that it does not touch any colonies nearby. Then plunge this into the gel at, e.g., dot A (red) and dot A (blue). If it forms a red colony but not blue it's general coliform, if it forms red and blue colonies, it's fecal.

These generally go off very fast, as there are many bacteria to start with, so confirmation can be obtained within 12-18 hours if incubated.

General and fecal coliforms Membrane filtration

Gives a quantitative reading of general and fecal coliforms from 0 to 100ML with a precision of perhaps ±25%.

Materials

For collection:

- Pipettes
- Sample vials
- Hydrogen peroxide

For plating:

- Coliscan Membrane Filtration kit –see resources listing)
- MF Plates
- Incubator

For counting:

- Fine tip sharpie for labeling petri dishes and marking counted colonies
- 8x magnifying Loupe (like the ones commonly used for slides)
- White, black backgrounds
- Comparison chart
- Separate dyes for confirmation
- Watch
- Data log in spreadsheet

Procedure-sampling

Exactly the same as for Coliscan easy gel, above, except you need more water: I typically collect in reused 500 ml water bottles, of which 100 are used on the test and the rest remains for retesting or what have you.

Procedure-plating

Please follow instructions below and from the manufacturer.

How big of a sample should you plate? Plate an amount of water which you suspect contains up to 300 general coliforms, or, the maximum for the test, which in this case is as much as you have patience and fastidious technique to vacuum through the membrane….conceivably up to 500 ml or more, though I've never done more than 200 ml.

If possible, save the refrigerated sample for re-testing if the first test used an inappropriate quantity of water, or otherwise went awry, or to confirm a seemingly outrageous result.

Pipette dye into the pad which goes under the membrane. Place the membrane sterilely onto the pad. Mark the plate.

Record the time of incubation and the temp

Incubation must be below 100°, above 70°. 90-95° is ideal for fastest, clearest results.

Procedure-counting

Same as for easy gel, above.

Procedure Confirmation

Same as for easy gel, above.

Computer Data entry

Make a "save as " of the spreadsheet, e.g. from spreadsheetEA to spreadsheetEB to create a backup. Record the information entered on the field data collection sheet into the spreadsheet. Enter flows into the cell as a calculation using the raw data.

Enter notes about unusual conditions in the description of the sample affected, or as a numbered note (1) in all of many samples affected.

Smell, Taste, Feel, Magic energy...

You don't need to taste most US municipal tap water to recognize it—the chlorine smell about knocks you over when you get close.

Rotten egg smell is due to hydrogen sulfide.

Algae smell is from...algae.

Septic tank smell is indicative of anaerobic conditions, not necessarily sewage (though it could be). If you dig down into fine sand in a creek bed you'll often hit a black, fetid smelling zone a few inches down where the oxygen doesn't reach.

Electric motor smell is ozone.

Noticeable perfumy 1950's laundry detergent smell is characteristic of greywater running down the streets of Mexican colonias.

Plastic taste is...plastic.
Hose taste is butyl rubber.
Mineral taste is hardness, typically calcium and magnesium.
Light salt taste is characteristic of softened water.

I find hard water less satisfying to my thirst than soft.

There is a magic energy I sense around the cleanest natural waters. Invariably, when I've tested the water from particular springs and swimming holes that I'm powerfully drawn to, they are cleaner than any other water around.

Evaluating Results

See the Introduction, and the coliform standards, conversions, examples spreadsheet.

Equipment and materials

Information current as of May 2004

General and fecal coliform testing materials

Do you need an incubator?

In order to get:

- any results in cold conditions
- best results in hot conditions
- reliable results from the PA tests

you need an incubator. A lab incubator costs several hundred dollars.

However, an inexpensive incubator for baby chickens works, if you've got the patience to set the temperature carefully and you keep it away from temperature swings and extremes.

hovabator 1602n incubator weight 4lbs 7.5 x18 x18 $33.95 912 236-0651 fax 234-9978.

A lightweight styrofoam incubator. It has it's own adjustable thermostat and provision for humidifying the interior, which can help keep petri dishes from drying out in arid conditions.

General and fecal coliform levels from 20 to 20,000 per 100 ml—A cheap and easy test

Use Coliscan® Easygel®.

Coliform Easygel (28001) - Coliform growth medium- 10 tests/set $13.50

Coliscan media have a refrigerated shelf life of 6 months. Frozen, they last a year or more. At room temperature, a couple weeks.

You also need:

1 mL Dropper - # DRP01 Dropper, sterile/individually wrapped -Price: $0.12 ea

or

3 mL Dropper - # DRP03 Dropper, sterile/individually wrapped - Price: $0.14 ea

See Micrology Labs contact info at bottom of next listing.

General and fecal coliform levels from 1 to 100 per 100ml-A somewhat more difficult and time consuming test

Use Coliscan® Membrane filtration kit.

The apparatus is more involved, the materials are still cheap.

Coliscan MF Water Monitoring Kit - # CMFK2:

The kit comes complete. Kit includes: 1 Filtering apparatus, 1 Syringe with hose (vacuum device), 2 Coliscan MF bottles, 20 membrane filters, 20 dishes w/ absorbent pad, 20 3 mL Dropper, 5 filter support pads, Instruction and interpretation guide. $39.50

Coliscan media have a refrigerated shelf life of 6 months. Frozen, they last a year or more. At room temperature, a couple weeks.

http://www.micrologylabs.com 1 888 easygel 327-9435

Micrology labs is a small operation; you can get people who really know what they are talking about on the phone.

General and fecal coliform levels, presence/ absence in up to 100ml

Presence/Absence Test, with MUG, disposable, twelve pack

Product #: 2401612, $ 40.30

In order to check for fecal coliforms, you also need a UV lamp:

Hand-held, battery-operated, long-wave UV lamp. Uses four AA batteries not included.

Product #: 2584600, $ 18.85

http://www.hach.com 800 227-4224

Electrical conductivity, TDS and Temperature

I like the DiST® 5 handheld EC/TDS/Temp meter. It has these featues:

- Adjustable TDS ratio
- Temperature in °C and °F
- Completely waterproof, can be fully immersed in water
- Easy-to-read Custom Dual-level LCD
- Temperature Compensation (BETA B adjustable from 0.0 to 2.4)
- Replaceable Electrode
- Stability Indicator
- Battery Level Indicator
- Automatic calibration
- Auto shut-off

HI98311: DiST®5 supplied complete with protective cap, 4 x 1.5V batteries and instructions.... $78.00

http://www.automatedaquariums.com/h_98311.htm

Automated Aquarium Systems,™ Inc.
545 South Pacific Street
Tustin, CA 92780 USA
email: sales@automatedaquariums.com
phone/fax: (714) 669-1196

Turbidity

If you have to have EPA reportability, this is the cheapest solution I know of:

2100P Portable Turbidimeter

Features

- Lab Quality Results in a Portable Unit
- Range: 0 to 1000 NTU
- Selectable signal averaging mode compensates for fluctuations in readings caused by movement of large particles in the light path
- Pre-programmed calibration procedure, with microprocessor-controlled adjustment of calibration curve. No potentiometers to adjust
- Electronic zeroing: compensates for electronic and optical offsets. No manual adjustments are required
- Direct digital readout in NTU
- Meets or exceeds USEPA method 180.1 criteria
- Comes with six sample cells, 4 sealed vials of StablCal Primary Standards (<0.1, 20, 100, and 800 NTU), Secondary Gelex Standards, silicone oil and oiling cloth
- Two-year warranty

Product #: 4650000 $ 837.00

http://www.hach.com 800 227-4224

Air travel with water quality testing materials

Important note:If you're travelling by air with your water test equipment, be sure to take MSDS sheets and a convincing story about how you are a water guardian, not a bioterrorist.

MSDS's are readily obtainable from the manufacturers.

Appendix

Fecal Coliform Bacteria Counts: What They Really Mean About Water Quality

Few people understand the commonly used measurements for microbiological water quality...

What the heck does it mean that there are "52 MPN fecal coliforms/100ml of water?

Is it good to drink? To wash dishes in? To bath in? Irrigate with?

The average person, or even engineers and scientists who don't have a public health or microbiology background wouldn't have a clue.

In fact, these units are so obscure that even people who work with them every day for years and make important decisions based on test results often have little sense of how to relate contamination either to cause or effect in a quantitative way.

- If a kid sneaks a swim in an un-chlorinated 50,000 gallon drinking water tank without wiping their butt, what is the likely level of contamination?
- If there is a bear poop bleeding into the edge of a swiftly flowing river (250 gallons per minute), how likely are you to get sick from drinking the water?
- If you irrigate your fruit trees with kitchen sink water, how likely is a kid to get sick from eating the dirt under the trees?

Most public health professionals would say that there would be a hazard. But they would be hard pressed to come up with an assessment of the size of the hazard that was accurate within a factor of a hundred. Many would be off by a factor of ten thousand. (Read on and then see how these questions are worked out below).

Concentration blindness

Further obscuring the picture, **almost all standards are expressed in terms of concentration, not total quantity** of organisms.

A spokesman for the Santa Barbara sewage treatment plant once calmly explained that discharge of untreated sewage to the ocean during intense rainfall was not an issue, because *"the dilution factor is so great."* This is an exceptionally clear case of "concentration blindness."

50,000 kilograms of fecal matter flushed to the ocean in a billion gallons of storm water is no less harmful to swimmers than 50,000 kilograms in a million gallons of sewer water. The amount of water that carries it to the ocean is irrelevant considering the relative size of the ocean—what matters is how much feces are being added. If anything, feces delivered in a giant slug of fresh water are worse, as the large flow of less dense fresh water might tend to float on the surface where exposure is more likely.

However, according to standards for effluent, which are based on concentration, the latter scenario appears a thousand times worse.

Indicator connection varies

General coliforms, E. Coli, and Enterococcus bacteria are the "indicator" organisms generally measured to assess microbiological quality of water. However, these aren't generally what get people sick. Other bacteria, viruses, and parasites are what we are actually worried about.

Because it is so much more expensive and tedious to do so, actual pathogens are virtually never tested for. Over the course of a professional lifetime pouring over indicator tests, in a context where all standards are based on indicators, water workers tend to forget that the indicators not the thing we actually care about.

What are these indicators?

- **General coliforms** indicate that the water has come in contact with plant or animal life. General coliforms are universally present, including in pristine spring water. They are of little concern at low levels, except to indicate the effectiveness of disinfection. Chlorinated water and water from perfectly sealed tube wells is the only water I've tested which had zero general coliforms. At very high levels they indicate there is what amounts to a lot of compost in the water, which could easily include pathogens (Ten thosand general coliform bacteria will get you a beach closure, compared to two or four hundred fecal coliforms, or fifty enterococcus).
- Fecal coliforms, particularly E. coli, indicate that there are mammal or bird feces in the water.
- Enterococcus bacteria also indicate that there feces from warm blooded animals in the water. Enterococcus are a type of fecal streptococci. They are another valuable indicator for determining the amount of fecal contamination of water.
  According to studies conducted by the EPA, enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to "die off" in saltwater.

The more closely related the animal, the more likely pathogens excreted with thier feces can infect us.

Human feces are the biggest concern, because anything which infects one human could infect another. There isn't currently a quantitative method for measuring specifically human fecal bacteria (expensive genetic studies can give a presence/absence result).

Ingesting a human stranger's feces via contaminated water supply is a classic means for infections to spread rapidly. The more pathogens an individual carries, the more hazardous their feces. Ingesting feces from someone who is not carrying any pathogens may gross you out, but it can't infect you. Infection rates are around 5% in the US, and approach 100% in areas with poor hygiene and contaminated water supplies.

Keep in the back of your mind that **the ratio of indicators to actual pathogens is not fixed**. It will always be different, sometimes very different. Whenever you are trying to form a mental map of reality based on water tests, you should include in the application of your water intuition an adjustment factor for your best guess of the ratio between indicators and actual pathogens.

"Best guess?!" I can imagine precision obsessed regulators cringing. Well, it can hardly be better to ignore the fact that the number and virluence of pathogens present in samples with the same number of fecal coliform indicators can be different by a factor of ten to a hundred or more, simply because checking for the pathogens themselves is too cumbersome.

These are the factors to include in your mental **indicator to pathogen adjustment factor**:

- Feces of non-human origin are of less concern to humans (this is why spreading manure on your vegee garden is not considered insane)
- Feces from human populations with higher infection rates are of greater concern (a currently low rate is not a reason to condone a *new* fecal to oral disease transmission route—which will raise the infection rate over time)
- All treatment methods and environmental conditions affect pathogens and indicators differently. For example, chlorinated sewage

effluent may have zero indicators and zero pathenogenic bacteria, but be laden with nearly all its original viruses.
Pathogens (and indicators) can "hide" from treatment inside suspended solids. If treated water is turbid, the saftey of the water and the suspended solids can be very different. If the samples don't capture the suspended solids, the reading will be low.

Policy is being made and facilities built with incomplete understanding of hazards

Important public health and engineering decisions are often made with a fuzzy idea of the hazards.

There is a tendency to tighten policy and overbuild facilities until the number of coliforms per 100ml at some point in the process is zero. If the actual sense of the hazard is not in focus, seeking the simple assurance of a zero reading is understandable.

However, this is a poor design guide compared to real understanding. Consider:

- A sewage treatment plant which removes indicator bacteria may not remove viruses; **it will test safe but not be safe in reality.**
- A beach front community with septics in Santa Barbara is being pressured to hook up to sewers, because a study found about 80 human fecal coliforms per 100 ml in the lagoon water. Sounds awful, whatever it means. But what it means is there was a half-teaspoon of human feces in the 30,000 or so gallons of the lagoon. All the feces for the duration of the study could have come from one disposable diaper, and not from the septics at all. **Millions of dollars might be spent on sewer connections for no benefit.**
- A study which turned up 84,000 fecal coliform bacteria per 100 ml of kitchen sink water did not consider the possibility that indicators were multiplying and there wasn't really that much feces (or pathogens) in the water. If they realized this equates to about a teaspoon a day of feces down the kitchen sink, they might have paused to consider if this much poop was really being dumped in the kitchen sink. But based on this study, **the law did not allow kitchen sink water greywater systems, but it might be OK in reality.**

Alternative measurements that broaden understanding

In order to incorporate water quality considerations into my designs in a quantitative way, I first had to convert the measurements to units I could understand. Most other water quality measurements are ratios: parts per million, or billion.

The beauty of this kind of measurement is that by multiplying the concentration by the volume of water it is possible to figure out how much actual stuff you're talking about, as in the kitchen sink and beachfront septics examples above.

It turns out that one fecal coliform bacteria per 100 milliliters closely equates to one part per billion of feces, or one milligram per cubic meter (you can see how I did the conversion below).

One part per billion of fecal matter is an infintesimal amount of contamination; about a grain of sand in five 55 gallon drums, or about what someone drinks in three years. However, this is worth worrying about; it fails the minimum standard for drinking water quality in most of the developed world, which is zero general coliforms per 100mL.

Converting to concentration and absolute quantities enables you to estimate what could account for a given level of contamination, or what level of contamination would result from a given action. For example, a buttwipe (ahem) diluted in a swimming pool of water yields a feces concentration of about 1 part per billion.

Measuring organisms per 100 mL, you can't easily relate a case of contamination either to cause or effect in a quantitative way.

Without further ado, here is a table which shows conventional units and standards, and their conversion to parts per million, parts per billion, and the novice-friendly units of of buttwipes or turds per swimming pool...

Standards, unit conversions, and examples of Fecal Coliform levels in water

	Conventional units *(understandable only to microbiologists)* **Fecal coliforms/ 100 ml**	**Conversions to new novice user-friendly units**				Approximate conversion to units understandable by other scientists	
		Buttwipes/ swimming pool	Buttwipes/ Bathtub	Turds per swimming pool	Buttwipes/ bottle	mg feces /m3 water ppb feces	g feces/ m3 h20 ppm feces
Typical first world standards							
For drinking water coliforms are to be less than 1 per 100 ml	**1**	**1**	0.001			**1**	0.001
	10	10	0.010	0.001		10	0.010
surface water in watershed for unfiltered drinking	50	50	0.050	0.005	0.001	50	0.050
shellfish growing waters	70	70	0.070	0.007	0.001	70	0.070
Full contact/swimming. Many bathtubs probably are out of compliance	200	200	0.200	0.020	0.002	200	0.200
	1,000	1,000	**1.000**	0.100	0.010	1,000	**1.000**
Partial contact/boating, same as for treated sewage discharge	2,000	2,000	2.000	0.200	0.020	2,000	2.000
Sample measurements							
Typical level in chlorinated waters I've tested	0	0	0.000	0.000	0.000	0	0.000
Level often found in water used untreated for drinking in third world	100	100	0.100	0.010	0.001	100	0.100
Level in crystal clear Santa Ynez river water we swam in all day	2,500	2,500	2.500	0.250	0.025	2,500	2.500
First flush puddle of urban runoff in center of Mexican village	3,360	3,360	3.360	0.336	0.034	3,360	3.360
Typical greywater readings from Arizona greywater study	4,000	4,000	4.000	0.400	0.040	4,000	4.000
High reading from Arroyo Burro beach in Santa Barbara.	10,000	10,000	10.000	**1.000**	0.100	10,000	10.000
First flush of river in Michoacan, Mexico, after seven month dry season	25,600	25,600	25.600	2.560	0.256	25,600	25.600
Level in bath water according to CA Dept Health services study	400,000	400,000	400.000	40.000	4.000	400,000	400.000
Possible reading in raw sewage	5,000,000	5,000,000	5000.000	500.000	**50.000**	5,000,000	5,000.000
Pure feces	3,000,000,000	off the top of the scale				1,000,000,000	

To find the conversion factor from any unit to any other, find the **bold number 1's**, then read across to the other column.

For example:

- 1 fecal coliform/ 100ml = 1 ppb = 0.001 ppm = 1 buttwipe per swimming pool = 0.001 buttwipe per bathtub
- 1 turd/ swimming pool = 10,000 mg feces/ m3

Examples of using these units to understand reality better

Back to the questions we opened with:

If a kid sneaks a swim in an un-chlorinated 50,000 gallon drinking water tank without wiping their butt, what is the likely level of contamination?

Layperson version: 50,000 gallons is twice as big as a swimming pool. One buttwipe per swimming pool is the drinking standard, so half a

buttwipe per swimming pool does not exceed the drinking standard.

Scientist version: 50,000 is about 200 m3. A buttwipe is about 100 mg. So there is about 0.5 mg per m3, which does not exceed the drinking standard.

Additional considerations: If the kid is known to have an infectious condition, the cause for alarm is greater. Also, the amount of fecal matter may not be average, it probably won't all come off in the water, and the part of it that does will not be evenly distributed. Most likely, the particles will sink to the bottom or top. If the geometry of the inlets and outlets is designed optimally, almost none of it will make it into the water distribution system.

If there is a bear poop bleeding into the edge of a swiftly flowing river (25,000 gallons per minute), how likely are you to get sick from drinking the water?

Layperson version: That's a swimming pool every minute. If The bear poop takes 1000 minutes, (16 hours) to dissolve, that's a thousandth of a turd per swimming pool - ten times the drinking standard.

Scientist version: The bear bowel movement is 1,000,000 milligrams. The flow is about 100 m3 per minute, times 1000 minutes = 100,000 m3 of water. 1,000,000 divided by 100,000 is 10 mg feces/ m3 - ten times the drinking standard.

Additional considerations: A bear poop is probably bigger than a human poop. However, bear pathogens are less likely to infect humans. The swift flow will probably distribute the fecal matter pretty evenly through the water column before long, without much settling. This illustrates a feature of rivers: while on average they are likely to be clean, infectious level pulses of pathogens are likely to come through.

(Note: you can estimate flow by multiplying the width times the depth of the channel times half the speed of the surface. Ten meters wide, two meters deep on average and a meter per second is about ten cubic meters per second)

If you irrigate your fruit trees with kitchen sink water, how likely is a kid to get sick from eating the dirt under the trees?

A risk assessment analysis of this scenario is viewable in the Arizona greywater study. Note that they assume from the high level of indicators that there is a level of pathogens in the water corresponding to nearly a *gram a day of fecal matter* entering the kitchen sink. This could be accounted for by ten people wiping their butts with thier hands only and washing them off in the kitchen sink—an unlikely scenario, I dare say. (If nothing else, few houses have ten people in them!) Also, note that they assume that 100% of the dirt the child eats will come from the greywater-irrigated area, 365 days in a row.

Considering that even with these wild assumptions, the risk was on the order of 1 in 10,000 of the kid getting sick, the risk is probably not significant.

For more examples of water test results & interpretations see: Water test results- Maruata

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Unit derivation notes for the scientifically inclined

The numbers were jiggled so the alternative units came out to be even orders of magnitude from the conventional units and each other.

In some cases the number used was close to the middle of the range, in others it is off the average by 30% or more. Overall, the alternative measures which are represented as equivalent on the table are within a factor of two or three of actual equivalency.

This degree of precision is in line for this area of study.

The conventional measurements use indicator organisms. There is a few orders of magnitude difference in coliforms per gram of feces for different mammals, so *the precedent for allowing imprecision of a large order is well established.*

Here's the assumptions and math:

- These are typical numbers of fecal coliform bacteria per gram of wet feces: dog=23 million, human 13 million, pig 3.3 million, cow a quarter million)
- Since human feces and easy math are of greatest concern, I assumed 10 million fecal coliform bacteria per gram. This assumption builds into the conversion an overstatement of a factor of 1.3 if the bacteria are of human origin.
- Thus, one coliform bacteria weighs one ten millionth of a gram. Diluted in 100ml=100g of water, that's one part per billion.
- 100 m3 water per swimming pool (a typical swimming pool is more like 75 m3 or 20,000 gallons)
- An average buttwipe is 0.1 gram (based on a few measurements which averaged 0.13 grams)
- Bowel movement is 1000g (one source gave 1113g as the average daily production of feces)
- A bath is 100 L; this is about 8" of water in an average bathtub. Full capacity is about twice this, depending on the displacement of the bather(s).
- 1 turd = 10,000 buttwipes =1,000 grams = 1,000,000 milligrams
- 1 swimming pool = 1000 bathtubs=100,000 bottles = 100 cubic meters = 100,000 liters

Buttwipes/ swimming pool	Buttwipes/ Bathtub	Turds per swimming pool	buttwipes/ bottle
=.1 g/ 100m3	=.1 g/ 100 L	=1000 g feces 100 m3	=0.1g/ 1L

Rincon Point and the Three Million Dollar Disposable Diaper

As an ecological systems designer specializing in water and wastewater systems, I'm pleased to see a broad coalition rally to the clean water cause. Most of the content of the debate I agree with. However, at times it seems there Isn't enough technical understanding to keep the discussion firmly anchored in reality. Lest we find ourselves taking multiple steps back for each step forward, I'd like to share some general ecological design principles, and use the question of how to improve water quality at Rincon to illustrate their application.

A fundamental principle of ecological design is to Consider the Whole Picture

The temptation to avoid the big picture is strong, because it is difficult. Of a hundred ways to make the ocean cleaner, only a handful will make things cleaner overall. It is easiest to clean up an area by sweeping the impact somewhere else. But often the total impact is then greater, because of the added impact of sweeping.

Heal the Ocean has done a service to the community by raising awareness of water quality problems so that everyone agrees that SOMETHING should be done. The water is dirty because of too much human disturbance. Building systems to relocate the disturbance (e.g. a sewer line) creates an ecological disturbance of its own: the production of miles of pipe, pumps, filters, electronics etc., digging up streets, sidewalks, gardens, and native burial grounds, and the ongoing consumption of electricity, chemicals, and burned out pumps, forever.

By removing the constraint of on site wastewater disposal from this area, the scale of and density of development is free to attain a much higher level—with a sewer line, the sky is the limit. Reduction of an ecological impact on water quality is being used to justify a system which has an extremely strong tendency to /increase/ ecological impacts of all kinds by spurring development. If property owners want more development, they can and should do it without exporting their waste problem.

Ecological Designs are Context Specific

What is appropriate in one place is inappropriate in another—everything depends on context. Are sewers bad? Is pooping directly in the ocean bad? it depends. Even on the high seas, flushing directly to the ocean sounds bad, but if you analyze it you'll find that it is improbable the ocean could be affected. Does this mean it is OK to dump DDT in the ocean? It would have the same dilution initially, but re-concentrate in the food chain—so no. Is it OK to poop directly in the ocean when you're in the harbor? No, the water is too confined. Pumping the sewage from the harbor to the treatment plant is better. Does that mean that if you live by the beach, you should pump your sewage to a treatment plant? It depends. If you live in Florida or Hawaii, the answer is yes. Florida has fissured limestone aquifers. The bedrock is a network of open, water filled caves which channel water rapidly without treatment directly to the ocean. In Hawaii, it is the same except the pipes are lava tubes. If you live on the coast in Santa Barbara, the ecological solution is probably to use a septic tank, because our climate and soil are optimal for septic systems. If the context is such that the septic tank is failing or likely to fail, it may need some help in the form of reducing the flow or enhancements to its treatment capacity.

Santa Barbara just approved a new septic tank ordinance, citing studies from Florida and Hawaii and saying "we cannot assume Santa Barbara is any different from the rest of the world." But septic effluent which travels ten miles in a day in Florida might move a foot in Santa Barbara. Inspecting septic tanks to make sure they are working optimally is a good idea. Hooking Santa Barbara houses to sewers because septics don't work in Florida is not. Santa Barbara would be bucking a promising national trend towards effective on-site treatment by supporting sewer conversion.

In Main's Snits Beach, there is a half-mile long sand spit a hundred yards wide, with the Pacific on one side and an ecologically sensitive lagoon on the other. It is all sand, and no point is even ten feet above the water. The spit is covered with large houses, all on septic tank/ sand mound systems, all inspected annually, all working. This is a more appropriate inspiration for coastal problem areas in Santa Barbara.

The purification capacity of soil for fecal bacteria is astounding. According to tests by the World Health organization, you could fill a dry pit with feces and it would not affect a creek or ocean twenty feet away—they found almost no lateral migration. The same studies showed maximum extent of bacterial plumes from feces in flowing groundwater of forty feet. Tests of land treatment have found it to be effective against viruses, something treatment plants are not very good at (references and the calculations behind the paragraphs below).
Over six hundred pounds of feces are treated by Rincon Point septic tanks every day. Using data from the Lower Rincon Creek Watershed Study by Santa Barbara County Public Health and Heal the Ocean, I did a "back of the envelope calculation" to convert their findings on lagoon contamination from the obscure units given (79 fecal coliform mpn/100ml) to the more easily grasped half-teaspoon of human feces in the 30,000 or so gallons of the lagoon. This study produced no firm evidence that the septic tanks are contaminating the lagoon. It does show that IF they are, the maximum amount of contamination is still well under the standard for swimming. Fecal matter would come out of

failing septics in a fairly steady stream. The study noted that forty percent of the human feces were from one sampling event—so it is possible that one casually tossed diaper is costing Rincon homeowners three million dollars..

Of the 74 septic systems at Rincon, If any are polluting the lagoon, it can only be a few partly failing systems. According to the sewer proponents' own study the amount of nasties entering the lagoon is at most /four thousandths of one percent/ of what goes into the septic tanks. If hooked to the sewer, 100% of the sewage would go into the ocean with enough chlorine to kill the fecal coliform indicator bacteria, but not enough to kill all the viruses. If there is a very hard rain, power failure or pipe break once every eighty years, the sewage treatment plant will dump more raw feces from Rincon point into the ocean than eighty years worth of the maximum contamination the septics could be causing. A sewer will also increase the amount of effluent, by removing incentive for indoor water conservation and enabling more building. Not a great water quality improvement, and certainly not cost-effective at three million dollars—to clean up at most a diaper a month worth of feces.

In literature supporting sewer conversion, Heal the Ocean states that "it's like sweeping ones house—getting all the dirt and dust into one pile (getting the septics into one disposal area) then picking it up into a dustpan (sewage plant)." They further state that the key to their program is their long term vision that 100% of sewer effluent will be reclaimed.

The spirit is commendable but there are technical glitches. First, septic tank effluent is a special kind of "dust" which is harmlessly returned by soil to nutrient and water cycles precisely if the concentration is not too great, as their study shows is happening now. Getting it all "into one pile, " i.e., too concentrated for soil to deal with, is exactly the wrong thing to do with a material of this type. Second, the vision of 100% wastewater reclamation (which is still under investigation) could only be attained with aggressive sewer flow reduction. What are you going to do with several thousand acre-feet of reclaimed water during the rainy season? Heal the Ocean's goals would be better served by aggressively fostering effective on-site treatment wherever feasible—any other approach is plain bad design.

Choose the Most Inherently Simple Solution and Implement It as Well as Possible

I was informed by Heal the Ocean that on-site treatment was probably ideal, but it would take too long to implement. The most simple, cost effective, and immediate measure possible would be for Rincon homeowners to conserve water indoors, and divert greywater from their septic tanks. The load on Rincon septic tanks could easily be reduced 80%. The impact on the ocean would be reduced more, say 90% (not only is the flow smaller, but the remaining flow receives much higher treatment as it takes longer to pass through septic tank and soil). This would eliminate most capacity problems and could be done for a few thousand dollars per house. Any water quality improvement would occur immediately. The techniques tend to be far simpler and cheaper, and nothing begins to compare with flow reduction for improving overall impact.

This would increase the effectiveness of the systems from the 99.997% (minimum) measured by the study to perhaps 99.9997%. If the remaining problem septic tanks (if any) were then identified, they could be improved with sand mound or other proven on-site treatment systems at a cost per house which was substantially lower than the $40-$60,000 for hooking to sewer. The overall cost for the community would be dramatically lower—maybe $500,000 instead of $3,000,000 plus. The contamination of the Rincon would be reduced without making someplace else dirtier, improvement could start immediately, very little electricity and no chemicals would be required, roads would stay intact...

A colleague with extensive experience constructing wastewater treatment facilities says they are 10% technology and 90% politics. The intense desire to DO SOMETHING about water quality may push Rincon Point sewerification onward. When Heal the Ocean finishes studying sewage reclamation and finds out the amount of flow reduction required to make it feasible, that SOMETHING may turn out to be an expensive education in the way NOT to take care of areas where septic tanks work fine with a little care.

Art Ludwig

About Giardia

Perhaps as part of our general alienation from nature, paranoia about catching cooties from natural waters is itself epidemic. This is an excerpt from *Giardia Lamblia and Giardiasis. With Particular Attention to the Sierra* Nevada By Robert L. Rockwell, January 21, 2002, which can be found at http://www.californiamountaineer.com/giardia.html. It is one of the few articles which seemed to me to see the threat without bug-eyed glasses.

...The disease has been referred to as "beaver fever" because of a presumed link to those water-dwelling animals known to be carriers. However, it has been suggested that it is more likely that humans have carried the parasite into the wilderness and that beavers may actually be the victims. In particular, there is a growing amount of data showing that beavers living downstream from campgrounds have a high Giardia infection rate compared with a near-zero rate for beavers living in more remote areas.

In any case, beavers can and do contract giardiasis. Being water-dwellers, they are thus able to contaminate water more directly than an animal that defecates on the ground.

Other animals that can harbor Giardia are bighorn sheep, cats, cattle, coyotes, deer, dogs, elk, muskrats, pet rabbits, raccoons, and squirrels. But not horses and domestic sheep. And naturally occurring infections have not been found in most wild animals including badgers, bears, bobcats, ferrets, lynxes, marmots, moose, porcupines, rabbits, and skunks.

How many cysts does it take to get the disease? Theoretically only one, but volunteer studies have shown that 10 or so are required to have a reasonable probability of contracting giardiasis: About one-third of persons ingesting 10 – 25 cysts get detectable cysts in their stools.

However, most infected individuals have no symptoms at all! In one incident studied by the CDC, disruption in a major city's water disinfection system allowed the entire population to consume water heavily contaminated with Giardia. Yet only 11 percent of the exposed population developed symptoms even though 46 percent had organisms in their stools. These figures suggest that (a) even when ingesting large amounts of the parasite, the chance of contracting giardiasis is less than 1 in 2, and (b) if you are one of the unlucky ones to contract it, the chance of having symptoms is less than 1 in 4. But perhaps the most telling statistic is that drinking heavily contaminated water resulted in symptoms of giardiasis in only 1 case in 9.

Recall that San Francisco water can contain a concentration of 0.12 cysts per liter [24], a figure now seen to be higher than that measured anywhere in the Sierra. San Francisco city officials go to great lengths to assure their citizens that the water is safe to drink, and if true—as it most assuredly must be—this comparison alone is quite revealing.

Field Data Entry Sheet

Code	Date & time mm/dd/yy hh:mm	Exact location	Conditions, appearance, odor, rainfall, etc	Enter your guesses in these boxes first! Hardness	Flow	Temp	Bottle #	pressure psi	NTU	P/A Coliscan mL	Fecal guess Time plated	General guess inc. temp
UW1	6/9/03 13:06	Mark's water bottle	West cammino well water in nalgene bottle. Bottle is	*500*	*na*	*65°f*			*0.75*		*0*	*1000*
5 years in use, six months since last wash (he washes it when it starts to smell bad)												
UW2	13:58	Community pool outlet, 6" below surface	Approx 64°, overcast ceiling, light drizzle all day	*700*	*25gpm*	*60°f*			*0.50*			
wind 0, humidity 95%, water crystal clear, probably no swimmers since last time Art went in three days ago.									0.30			

Computer Data Entry Sheet

Code	Date & time	Exact location	Conditions, appearance,	ppm	°C		Bottle	pres-sure	de-assed?		NTU		Time	inc.	Count	Count	P/A	Blue/Purp F coli		Pink G coli		Spread W Sur	P Sub	E coli/	G coli/
																		factor		factor					
Examples:																									
156	1/17/02 11:00	**Uppermost spring**	Clear sky, clear water; P/A, C, T				6	0	n	0.50	0.16	2.5000	15:00	98°	1/19/02	14:00	G	0 1		16 1				0	640
158	1/17/02 12:25	**Bedrock spring**	Clear sky, clear water; P/A, C, T				6	0	n	1.00	0.58	2.5000	15:00	98°	1/19/02	14:00		0 1		4 1				0	160
168	1/25/02 18:19	**Treated Spring test tap**	P/A no MUG; overflow starte between 16:00 and 18:00			3.12	5	0	n		1.60	7.0000	19:25	94			A	0 1		4 1				0	57
169	1/26/02 8:01	**U/C springs at treated tank test tap**	P/A no MUG - 50 mL; C; T;			3.02	5	0	n		0.51	5.0000	9:38	94	1/28/02	11:30	G	0 1		0 1				0	0
169	1/26/02 8:01	**U/C springs at treated tank test tap**	MF (plated 1/27/02 13:15 after refrigeration)									*100.0000*	13:15		2/1/02	11:00		0 1		4 1				0	4
169b	1/26/02 0:00	**U/C springs at treated tank test tap**	I believe pipe adds turbidity to initial flow, high flow. Left tap on high.			10g/m	5	0	n		1.55							0 1		2 1				#DIV/0!	#DIV/0!
170	1/26/02 8:31	**U/C springs at raw tank test tap**	C/T				5	0	n		1.55	5.0000	9:40	94	1/28/02	11:30		0 1		7 1				0	140
173 note 1/28/2002 5:26 am opened spring line drain												5.0000			1/30/02	11:00		0 1		29 57				0	32,886
173	1/28/02 5:26	**Spring line drain**	T/C Water stored in pipe, brown, presumed from a few hours of runoff yesterday, + dislodged crud from rapid pipe flush. A few 1mm± chunks of rust visible, most material is fine.			*150.00*		150	y-time	30.00	353.00													
174	1/28/02 5:34	**Spring line drain**	T/C Same as 174 but less flow - C too numerous to count			*25.00*		150	y-time	20.00	183.00	5.0000			1/30/02	11:00								
174 note	1/28/02 5:35	Spring line drain	T/C Same as 174 but less flow, flow suddenly stable			*5.00*																		
175	1/28/02 5:41	**Spring line drain**	Water suddenly much clearer; presumed to be current flow from spring.			*3.00*		0	y-time	1.80	5.44	*2.5000*			1/30/02	11:00		0 1		41 2				0	3,280
175note	1/28/02 5:42	Shut spring line drain.																							

Red	Suspect datum or result
Italic	Guesstimate
A	Scratched turbidity sample bottle
B	Hard to draw line between colonies of too small size or too light pink color
C	Coliform test
T	Turbidity test
P/A	Presence Absence test (with MUG)
	Multipliers

Coliform standards, conversions, examples

Conventional units (understandable only to microbiologists)	New novice user-friendly units				Approximate conversion to units understandable by other scientists		
Fecal coliforms/ 100 ml	Buttwipes/ swimming pool	Buttwipes/ Bathtub	Turds per swimming pool	Buttwipes/ bottle	mg feces /m3 water ppb feces	g feces/ m3 h20 ppm feces	
Conversions							**Typical first world standards**
1	**1**	0.001	0.000	0.000	**1**	0.001	For drinking water coliforms are to be less than 1 per 100 ml
10	10	0.010	0.001	0.000	10	0.010	
50	50	0.050	0.005	0.001	50	0.050	surface water in watershed for unfiltered drinking
70	70	0.070	0.007	0.001	70	0.070	shellfish growing waters
200	200	0.200	0.020	0.002	200	0.200	Full contact/swimming. Many bathtubs probably are out of compliance
1,000	1,000	**1.000**	0.100	0.010	1,000	**1.000**	
2,000	2,000	2.000	0.200	0.020	2,000	2.000	Partial contact/boating, same as for treated sewage discharge
							Sample measurements
0	0	0.000	0.000	0.000	0	0.000	Typical level in chlorinated waters I've tested
100	100	0.100	0.010	0.001	100	0.100	Level often found in water used untreated for drinking in third world
2,500	2,500	2.500	0.250	0.025	2,500	2.500	Level in crystal clear Santa Ynez river water we swam in all day
3,360	3,360	3.360	0.336	0.034	3,360	3.360	First flush puddle of urban runoffin center of Mexican village
10,000	10,000	10.000	**1.000**	0.100	10,000	10.000	High reading from Arroyo Burro beach in Santa Barbara.
25,600	25,600	25.600	2.560	0.256	25,600	25.600	First flush of river in Michoacan, Mexico, after seven month dry season
100,000	100,000	100.000	10.000	**1.000**	100,000	100.000	Possible reading in raw sewage
1,000,000,000	off the top of the scale						Pure feces

Unit derivation note for the scientifically inclined:

The numbers were jiggled so the units were even orders of magnetude. In some cases the number used was close to the middle of the range, in others it is off the average by 30% or more. However, the ranges are huge; a few orders of magnetude in fecal coliforms per gram of feces for different organisms; the presumed indicator, so an imprecision of even a factor of two is of little practical consequence.

Buttwipes/ swimming pool	Buttwipes/ Bathtub	Turds per swimming pool	buttwipes/ bottle
=.1 g/ 100m3	.1 g/ 100 L	=1000 g feces 100 m3	0.1g/ 1L

1 turd=10,000 buttwipes

1 swimming pool = 1000 bathtubs=100,000 bottles

assumed:10 million fecal coliforms per gram of wet feces (dog=23 million, human 13 million, pig 3.3 million, cow a quarter million...)

assumed: 100 m3 water per swimming pool (a typical swimming pool is more like 75 m3

assumed: an average buttwipe is 0.1 gram (extensive research and literature search revealed this to be true-just kidding. The one buttwipe measured was 0.13 grams.

assumed: bowl movement is 1000g (one source gave 1113g as the average daily production of feces)

assumed: a bath is 100 L; this is about 8" of water in an average bathtub. Full capacity is about twice this, depending on the displacement of the bather(s).

EXAMPLE: Indigenous community in Mexico

Code	Location, exact location, weather turbidity, color, odor, context, uses Intuitive sense	mL	Date	Time	Time plated	temp	Count date	Count time	Purp F coli factor 1&2	Pink G coli factor 3&4	Blu/grn Enterobacteriaceae Sur fact 5&6	White Sur factor 7	Spread W Sur 9	P Sub 10	E coli/ 100mL	G coli/ 100mL	Ent/ 100mL	
Rain, Runoff																		
M19	**Rain-First roof wash**	5.0000	6/25/99	3:42am	5 hrs	78°	6/26/99	12:00	1 1	60 36	1	1		h	20	43,220	0	not such a great count
	Storage area roof, corrugated felt, 4:12 pitch, no branches above, first 10 min of first rain in several days?								±%	±% a	±%	±%	±%					
	This water felt like it was getting clean, though not the roof not yet rinsed enough. There is much less dust in the rainy season								1	1	1	1			0	0	0	
	This sample was put in the coliscan while there was still a piece of ice in it. Agar folded over while evacuating first lab								±%	±%	±%	±%	±%					
M28	**Rain-Emilio's Gutter**	100.0000	6/26/99	11:15	20min	76°	6/27/99	10:23	15 1	23 18	6 1	? 1			15	429	#VALUE!	
	After 20cm rain on cement tiles. Was being collected in small bucket for dishwashing.								±15%	±30%	±50%	±%	±%					
	Looked sort of clean, not completely. I'd would have drank a bit if pressed, as it was rinsed by a LOT of rain and has good pitc								1	1	1	1			0	0	0	
	Touched back side of cotton with thumb by accident, but no extra colonies seemed to sprout in this area.								±%	±%	±%	±%	±%					
M29	**Rain-Phone caseta roof**	100.0000	6/26/99	11:30	10min	76°	6/27/99	10:23	3 1	24 18	6 18	1			3	435	108	
	Same time as M28. Cement slab roof. Some junk stored on top. Ladder on side; probably occasional traffic for phone ante								±%	±%	±%	±%	±%					
	No particles.						adj. for false positives on con		0 1	24 18	6 18	1			0	432	108	
									±%	±%	±%	±%	±%					
M27	**Rain-Natural surface runoff**	0.5000	6/26/99	10:00	60min	79°	6/27/99	10:10	30 4	29 36	6 4	23 36			24,000	232,800	170,400	
	After downpour. collected 10 cm from Neighbor's spring. Fenced 10 m up hill, then lots of animal traffic just outs a,b								±20%	±30%	±15%	±30%	±%					
	This runoff was flowing right into the spring. Light yellow-straw color (1/2 urine color), low ss.								1	1	1	1			0	0	0	
	Collected in used cooking oil bottle after ten rinses.								±%	±%	±%	±%	±%					
M24	**Rain-urban runoff-Puddle on side of sc**	0.0714	6/25/99	10:30	20min	82°	6/26/99	12:30	6 4	31 36	2 4	17 36			33,613	1,596,639	868,347	
	After first 3 cm rain in two weeks; the second flush of 7 months of accumulated pig feces, greywater...Big brown puddle								±20%	±25%	±20%	±30%	±%					
	Felt truly evil. Many nearly naked kids running barefoot over broken glass, rolling tires								1	1	1	1			0	0	0	
	which were spinning this stuff in all directions. They looked fully alive, healthy, happy. Collected by Emilio. 0.25 ml=7 drop								±%	±%	±%	±%	±%					
Wells, pit																		
M1	**Well, pit-community drinking & cookin**	5.0000	6/23/99	13:00	<10min	90°			3 1	47 1	4 1	12 36			60	1,000	8,720	These fecals unconfirmed
	Fenced pit hand dug 1.5 m well with bottomless 2 gal galv bucket In regular use; water preferred by villagers for cooking,								±%	±%	±%	±% 15	±%					
	and drinking, supposedly after boiling. Crystal clear. Accidentally kicked in 0.5 g sand before last ML water.								1	1	1	1						
	Upriver from palapas, Geometry (funnel channeling debris into water) funky but water crystal clear; I'd drink it if I had too.								±%	±%	±%	±% 15						
M14	**Well, pit-communal laundry/ dish pit in**	3.0000	6/23/99	19:30	20 min	81°	6/24/99	16:30	1 1	6 36	23 2	140 36			33	7,233	169,533	
	Water looked crystal clear, but unrestricted access by grazing animals, etc. made me feel like								±%	±%	±%	±%	±%					
	washing dishes was as close as I'd ever want to get to drinking this water.								1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
M35	**Well, pit-Freshly re-dug community dri**	3.0000	6/26/99	21:00	21:37	75°	7/28/99	15:00	0 1	37 4	1 1	8 36			0	4,933	9,633	
	About 4 m from chocolate river, 3 m from old well, which, when the groundwater level rose, filled wi refrig. 7/27 20:00								±%	±%	±%	±% b	±%					
	The water looked clear and was being collected for drinking (after boiling, they said) by several villagers.								1	1	1	29 1			0	0	967	
	I felt very leery of this water due proximity to the river; people waded through, then stood with dripping legs right by the								±%	±%	±%	±% l	±%					
Wells, corrugated steel lined																		
M2	**Well-water from Nati's well**	5.0000	6/23/99	13:00	<10min	90°	19 hrs		1 1	30 36	3 1	90 36			20	21,620	64,860	a,b, d
	at hose stream at laundry pila. Used for laundry, bathing, toilet handwash, some dishwash. 72°								+0-1	±% 15	±%	±% 30	±%					
	Water in 70 cm deep in pila itself looked slightly milky; hose flow looked fine (of course)								1	1	1	1						
	I didn't like the look of this for drinking.																	
M4	**Well-water in Nati's kitchen Pila**	5.0000	6/23/99	1:30	<10min	90°			0 1	30 36	0 1	90 36			0	21,600	64,800	a,b
	Appeared to not be in very regular use but had been recently for dishes, meat washing, etc.								±%	±%	±%	±%	±%					
	It felt better than the laundry pila, worse than the community well.								1	1	1	1						
									±%	±%	±%	±%	±%					
M20	**Well-from pila of Don Anarato's**	5.0000	6/24/99	19:44	<10min	82°	6/25/99	21:00	0 1	16 36	10 1	40 36			0	11,520	29,000	
	Bucket w/ rope lost in bottom. Electric pump, crud in well.								±%	±%	±%	±%	±%					
	Used continually for dishwashing, laundry, bathing. Pila full, clear.								1	1	1	1			0	0	0	
	Didn't look that great to me; I'd definitely prefer my dishes to be dry first, though sometimes they weren't								±%	±%	±%	±%	±%					
M16	**Well-Emilio's house**	5.0000	6/24/99	21:00	10min	82°	6/25/99	21:00	11 1	16 36	20 1	200 36			220	11,740	144,400	
	From bucket on rope & roller; they said it was dirty, but it didn't look too bad.								±%	±%	±%	±%	±%					
	This is one of the better made and sealed wells. They have been using it only when water is not								1	1	1	1			0	0	0	
	coming down from the spring. The water did feel less clean than from the pipe; I definitely wouldn't like to drink it.								±%	±%	±%	±%	±%					

EXAMPLE: General and Fecal coliforms at mountain community in Mexico

E coli/ 100mL Rain	G coli/ 100mL	Ent/ 100mL	Coliform test log Code	Location	mL	Date	Time	Time plated	temp	Count date	Count time	Purp F coli 1&2	factor	Pink G coli 3&4	factor	Blu/grn Enterobacteriaceae Sur 5&6	factor	White Sur 7	factor	Spread W Sur 9	P Sub 10
0	4,120	25,920	H1	**Rain, end of B's copper downspout**	5.0000	7/1/99	8:00	9:01	82°	7/3/99	9:00	0	1	103	2	0	1	36	36		3
				at rain water cistern filter, during light rain after 4 day rain, second of season.																	
				Water light straw colored, seemed probably bacteriologically clean but it didn't look like it would taste good.																	
0	800	5,200	H8	**Rain- Lavadero tap**	1.0000	7/2/99	15:21			7/4/99	12:30	0	1	8	1	0	1	52	1		
				almost all last year's water, plus muddy water from roof repair.								±%		±%	15	±%		±%		±%	
				Water looked very muddy.									1		1		1		1		
20	12,260	14,640	H5	**Rain-Tinaco East Roof**	5.0000	7/2/99	15:20		78°	7/4/99	12:30	1	1	17	36	3	1	20	36	9	9
				first flush, 3 min rain (also rained yesterday)								±%	0	±%	30	±%		±%	15	±%	
Cascada-flows originating at the main Huehuecoyotl waterfall																					
0	580	10,800	H12	**Cascada-Outlet drain of Tinaco W**	5.0000	7/2/99	21:38			7/4/99	12:30	0	1	29	1	0	1	15	36		9
				last of last year's water						Not clear		±%		±%		±%		±%	5	±%	20
0	100	2,520	H11	**Cascada-Llave, kitchen of Svante**	5.0000	7/2/99	21:37			7/6/99	18:30	0	1	5	1		1	62	2	2	
				last years' water				7/4 13:00 nothing to count				±%		±%		±%		±%		±%	
0	280	3,280	H4	**Cascada- Tinaco East inside**	5.0000	7/2/99	15:10			7/4/99	12:30	0	1	14	1	1	1	40	4	3	
				Nearly full, nearly all last of last year's water,								±%		±%		±%		±%	15	±%	
				2m visibility...I'd left this dirty but it had been filled a few times									1		1		1		1		
0	520	20,160	H6	**Cascada-Tinaco East to B's kitchen tap**	5.0000	7/2/99	15:11			7/4/99	12:30	0	1	26	1	0	1	28	36		
				light straw colored								±%		±%	5	±%		±%	5	±%	
0	433	2,467	H7	**Cascada-Tinaco East to B's hot kitchen**	3.0000	7/2/99	15:14			7/6/99	18:30	0	1	13	1	1	1	35	2	3	2
								7/4/1999 13:00 nothing to count				±%		±%		±%		±%		±%	
250	50,650	27,350	H3	**Cascada-Man-made pool at bottom of**	2.0000	7/1/99	8:35	9:07	82°	7/3/99	9:00	5	1	28	36	7	1	15	36		
				1m deep h2o, mix of last week's rain, 50 cm vis, dark tea colored...								±%		20±%		±%		±%	20	±%	
				little mud, a fair bit of plant matter on bottom.									1		1		1		1		
60	8,700	36,120	H2	**Cascada-light flow**	5.0000	7/1/99	8:30	9:06	82°	7/3/99	9:00	3	1	12	36	3	1	50	36	3	
				First waterfall 7/24, this was the last falling water NOT diverted.										±15%				±30%		±20%	
0	3,440	8,880	H13	**Cascada-slow**	5.0000	7/5/99	14:42	16:20				0	1	43	4	6	1	12	36	6	
				20 lpm?								±%		±%		±%		±%		±%	
0	172,800	1,000	H14	**Cascada-fast**	5.0000	7/6/99	17:40	18:20				0	1	60	144	25	2		1		
				200 lpm? soon after downpour								±%		±%	30	±%	10	±%		±%	
Wetland (blackwater treatment)																					
16,000	2,096,000	3,672,000	H10	**Constructed wetland inlet**	0.0125	7/2/99	17:00			7/4/99	12:30	2	1	65	4	0	1	57	8	3	
				against wall near inlet, water 20 cm down, sample from 25 cm,								±1		±%	10	±%		±%	30	±%	
				Cloudy, no odor									1		1		1		1		
100	24,100	76,900	H9	**Constructed wetland outlet**	1.0000	7/2/99	17:00		70°	7/4/99	12:30	1	1	30	8	0	1	96	8	1	
				against wall near outlet, water 20 cm down, sample from surface								±%		±%	20	±%		±%	20	±%	
				Looked slightly cloudy, no odor									1		1		1		1		
Octotitlan springs-water supply for nearby village																					
40	7,400	5,680	H15	**Chipuilote-spring**	5.0000	7/14/99	19:00		70°	7/17/99		2	1	46	8	4	1	35	8		
				Drinking water spring-fed pool of Ocotitlan								±%		±%		±%		±%		±%	
				Just before afternoon rain									1		1		1		1		
20	2,020	7,420	H16	**Chipuilote-seasonal creek**	5.0000	7/14/99	19:00			7/17/99		1	1	25	4	1	1	46	8	2	
				Leaf-filled, surface-stagnant pool from which villiage								±%		±%		±%		±%		±%	
				cistern is filled by 2.5" hose about 1km long. Lots of Chloro bottles, supposedly for laundry, they say.									1		1		1		1		

EXAMPLE: Santa Barbara coliform test log

Code	Location, exact location, weather turbidity, color, odor, context, uses Intuitive sense	mL	Date	Time	Time plated	temp	Count date	Count time	Purp F coli 1&2	Pink G coli 3&4	Blu/grn Enterobacteriaceae 5&6	White Sur 7	Spread W Sur 9	P Sub 10	E coli/ 100mL	G coli/ 100mL	Ent/ 100mL	
									factor	factor	factor	factor						
SB20	**Drinking fountain spring**	5.0000	7/18/99	13:00	72hr r	95°	7/23/99	12:32	0 1	15 1	0 1	33 4			0	300	2,640	Only four big size pinks
	Crack in rock weeping 4 lpm± cool, clear water into 4 cm deep by 30 cm x 10 cm pool. Subject								±%	±% 15	±%	±% 15	±%					
	to collecting crud falling from hillside, algae growth. Algae, rocks, sand removed by hand every few days								1	1	1	1						
	as best as possible. I was leery of this water for fear it was acutally creek water seeping through a crack from just a fe								±%	±%	±%	±% 15						
SB21	**Waterfall into emerald pool**	5.0000	7/18/99	13:00	72hr r	95°	7/23/99	12:32	4 1	70 8	0 1	25 36	104		80	11,280	20,080	All
	50 lpm ± clean, crystal clear flow into pool w/ bottom crystal clear at 2 m.								±%	±%b 30	±%	±%ab 50	±%					
	I'd drink it if it wearn't a sunny sunday in swimming season, though this is just above the popular swimming holes.								4 1	24 1	1	85 4			80	560	6,800	Big only
									±%	±% >.2m	±%	±% >.5m	±%					
SB22	**Community outlet**	5.0000	7/18/99	13:00	72hr r	95°	7/23/99	12:32	2 1	35 1	0 1	33 36			40	740	23,760	All
	Taken from 5 cm below surface. Same comment as SB 21, but I'd be more concerned as this is downstream.								±%	±%	±%	±%	±%					
	Sediment was stirred up to the point of 4 m visibility, but settled again an hour before sample,								2 1	19 1	1	22 4			40	420	1,760	Big only
	when 16 people (8 kids) got out of swimming hole.								±%	±% >.2m	±%	±% >.5m	±%					Apparently settling purifies water, even with added contamination of swimming?
SJC25	**Community pool outlet**	5.0000	8/2/99	4:45	5:25	100°	8/4/99	1:30	0 1	17 1	0 1	50 8		1	0	340	8,000	
					refrigerated since 8/3 eve					±20%	±%	±15% b	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SJC26	**Community pool bottom**	5.0000	8/2/99	4:46	5:28	100°	8/4/99	1:30	0 1	31 4	0 1	14 36		1	0	2,480	10,080	
					refrigerated since 8/3 eve				±%	±% 20	±%	±% 30	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SJC27	**Community pool inlet**	5.0000	8/2/99	4:48	5:30	100°	8/4/99	1:30	0 1	46 1	0 1	87 8		1	0	920	13,920	
					refrigerated since 8/3 eve				±%	±% 25	±%	±% 15	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SYR28	**White Rock middle of upper pool**	5.0000	8/4/99	9:10	12:15	98°	8/6/99	17:00	1	1	1	1			0	0	0	
	Used same dropper (rinsed) for all bottles								±%	±%	±%	±%	±%					
	Refrigerated from 9 am								1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SYR29	**White Rock spring by lower pool**	5.0000	8/4/99	9:15	12:16	98°			1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SYR30	**White Rock lower pool outlet**	5.0000	8/4/99	9:20	12:17	98°			1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SYR31	**White Rock river branch exiting gra**	5.0000	8/4/99	9:23	12:18	98°			1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
SYR32	**White Rock upper pool inlet**	5.0000	8/4/99	9:30	12:19	98°			1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
MC 33 a	**Rain over oak canopy into steel bo**	5.0000	2/23/00		17:00		2/2/4/00	21:00	0 1	8 36	30 1	100 36			0	5,760	72,600	
									±%	±%	±%	±% 30	±%					
									1	1	1	1			0	0	0	
									±%	±%	±%	±%	±%					
MC 34 b	**Rain in cistern from roof runoff**	5.0000	2/23/00		17:00		2/2/4/00	21:00	1 1	10 36	4 1	4 1		2	20	7,220	160	
									±%	±%	±%	±%	±%					
									0 1	1	0 1	1			0	0	0	
									±%	±%	±%	±%	±%					

MC 35	**Spring at high water**	2.0000	2/23/00		17:00		2/2/4/00	21:00	0	1	35	1	0	1	3	36			0	1,750	5,400	
c									±%		±%		±%		±%		±%					
										1		1		1		1			0	0	0	
									±%		±%		±%		±%		±%					
d									±%		±%		±%	1	±%	30	±%					
										1		1		1		1			0	0	0	
									±%		±%		±%		±%		±%					
MC 37	**Cistern from hose**	5.0000	2/23/00		17:00		2/2/4/00	21:00	0	1		1	0	1		1			0	0	0	CL?
a									±%		±%		±%		±%		±%					
										1		1		1		1			0	0	0	
									±%		±%		±%		±%		±%					
MC 38	**street runoff**	2.0000	2/23/00		17:00		2/2/4/00	21:00	1	1	13	36	0	1	100	1			50	23,450	5,000	
b									±%	1	±%		±%		±%	30	±%					
										1		1		1		1			0	0	0	
									±%		±%		±%		±%		±%					
MC 39	**tap water**	150.0000	2/23/00		17:00		2/2/4/00	21:00	0	1	0	1	0	1	0	1			0	0	0	
									±%		±%		±%		±%		±%					
										1		1		1		1			0	0	0	
									±%		±%		±%		±%		±%					
MC 40	**B filtered in PUR filter**	150.0000	2/23/00		17:00		2/2/4/00	21:00	0	1	1	1	0	1	5	160			0	1	533	
									±%		±%		±%		±%		±%					
									22	1	10	1		1	5	160			15	21	533	
									±%	22	±%		±%		±%		±%					
MC 41	**Drinking rain**	150.0000	2/23/00		17:00		2/2/4/00	21:00	0	1	0	1	0	1	2	160			0	0	213	
									±%		±%		±%		±%		±%					
										1		1		1		1			0	0	0	
									±%		±%		±%		±%		±%					
SB23	**Fountain in Chase Palm Park at Ga**	100.0000	7/31/99	19:00	10:00	97°	8/2/99	10:00	0	1	0	1	0	1	2	1			0	0	2	
									±%		±%		±%		±%		±%					
							8/4/99	1:30		1		1	1	1	3	1			0	0	4	
					refrigerated				±%		±%		±%		±%		±%					
SB24	**Bathroom Sink Chase palm park**	413.0000	7/31/99	19:00	10:00	97°	8/2/99	10:00	0	1	0	1	0	1	1	1			0	0	0.24	
									±%		±%		±%		±%		±%					
							8/4/99	1:30		1		1		1	1	1			0	0	0	
					refrigerated				±%		±%		±%		±%		±%					

Codes

A	too numerous to get good count
B	Colonies very small
C	Difficult call
D	Easy call
E	whole plate pink; hard to differnentiate white & pink
r	refrigerated
f	frozen
G	on recount appeared to be blues

Springs-waters originating at El Chorrito, before rains																			
M7	**Spring-Neighbor's hand-cut depression**	5.0000	6/23/99	16:40	45r	84°	6/24/99	9:00	2	1	6	4	0	1	56	36			**40**	520	40,320	
	30 cm diameter, 25 cm deep hand cut well in solid rock, overflowing by springs through cracks in sides at approx. 5 lpm.								±%	c	±%		±%		±%		±%					
	Sample taken from middle 5 cm below surface. Sides damp w/ first 20 min light rain, no runoff.									1		1		1		1						
	Water crystal clear; felt good but highly subject to catching surface runoff and debris falling down slope.								±%		±%		±%		±%		±%					
	Ineffective wooden lid. I'd hesitate to drink it unless it were regularly bailed out and cleaned, or remade more protected from runoff. I'd drank a small amount.																					
M8	**Spring-El Chorrito-Old springbox tap**	100.0000	6/23/99	17:00	45r	84°	23 hrs		3	1	22	18	5	1	62	18	0	0	**3**	399	1,121	
	1" tap a few feet from 6x5m funky concrete springbox, recently repaired and sealed as well as possible								±%		±%		±%		±%		±%					
	but still subject to surface water contamination.									1		1		1		1						
	I'd been drinking the water with some confidence (but with some minor symptoms) after sealing and before rains.								±%		±%		±%		±%		±%					
M9	**Spring-El Chorrito-New springbox**	100.0000	6/23/99	17:00	45r	84°	23 hrs		3	1	22	18	5	1	62	18	0	0	**3**	399	1,121	a
	Pool inside, immediately before outlet. Freshly built 1 x 1 x 7 m horizontal well in swampy area, in newly								±%		±%		±%		±%		±%					
	disturbed soil in newly fenced area formerly frequented by grazing animals. Lid still had not been placed									1		1		1		1						
	in rear. Has been through 1 heavy rain this season. I'd drink the water with confidence in the dry season, take it off line								±%		±%		±%		±%		±%					
M18	**Springs-Storage tank at crossing**	150.0000	6/24/99	21:45	1 hr	82°	6/25/99	21:00	17	1	18	1	12	1		1			**11**	23	8	
	Tank had just drained, and this sample was from incoming water which crossed the floor and pooled								±%	?	±%		±%		±%		±%		**False +**			
	at the outlet. Looked and felt clean, though I don't know if I'd drink it with enthusiasm.						6/27/99	10:34	0	1	18	41	12	1		1			**0**	492	8	
	In found bottle, well-rinsed with H202. Also put h2o2 on pad in MF unit.						Adj. false pos on conf.		±%		±%	??	±%		±%		±%					
M17	**Spring-Pipe from El Chorrito at Emilio's**	5.0000	6/24/99	21:00	15 min	82°	6/25/99	21:00	1	1	8	1	0	1		1			**20**	180	0	i
	Last dribbles from hose; they'd just shut valve at the big pila, and had just filled the								±%		±%		±%		±%		±%					
	pila, so this is probably about as well-cleaned as the pipe gets.						6/26/99	12:00	3	1	9	36	?	1	6	36		h	**60**	6,540	#VALUE!	
	This water felt clean, though not for drinking. All bacteria in middle 1/2 of radius of plate-why?						h		+0-3		±%		±%		±%		±%					
M6	**Spring fed creek outside fence**	5.0000	6/23/99	16:45	45min	r 82°	6/24/99	19;00	7	4	30	36	60	36		1			**560**	22,160	43,200	a
	Taken from flow just before papaya farm diversion pool. Crystal clear, but animal feces visible on sides and in water.								±%		±%	e	±%	e	±%		±%					
	water. No rain 36 hours, light rain just starting but no runoff yet.									1		1		1		1						
	I felt no hesitation stepping in this water or washing hands, but would hate to drink it.								±%		±%		±%		±%		±%					
Springs-waters originating at El Chorrito, after moderate rain																						
M21	**Spring-Old springbox**	5.0000	6/25/99	10:00	30min	80°	6/25/99	12:00	2	1	15	36	0	1	18	36		h	**40**	10,840	12,960	
	5 hrs after finish of about 3 cm rain.								±%		±%		±%		±%		±%					
										1		1		1		1			**0**	0	0	
									±%		±%		±%		±%		±%					
M22	**Spring-New horizontal well**	5.0000	6/25/99	10:00	30min	80°	6/26/99	12:00	15	1	31	4	1	1	22	36			**300**	2,780	15,860	
	5 hrs after finish of about 3 cm rain.								±%		±%		±%		±%		±%					
										1		1		1		1			**0**	0	0	
									±%		±%		±%		±%		±%					
M23	**Spring-Community storage tank**	5.0000	6/25/99	10:30	20min	82°	6/26/99	12:00	26	4	12	36	12	4	61	36		h	**2,080**	10,720	44,880	
	including all runoff from 2 hr rain								±20%		±30%		±%		±30%		±%					
										1		1		1		1			**0**	0	0	
									±%		±%		±%		±%		±%					
Springs-waters originating at El Chorrito, after heavy rain																						
M25	**Spring-Old springbox during heavy rain**	4.0000	6/26/99	10:00	60min	78°	6/27/99	10:00	16	8	15	144	3	8	25	144			**3,200**	57,200	90,600	
	During heavy rain (2-3 cm/hr) after about 20 cm of rain overnight.						a, b		±20%		±25%		±50%		±50%		±%					
	About 1.5-2x normal flow. appeared clear. No evidence of runoff entering, however runoff clearly ran over the top in quantity.									1		1		1		1			**0**	0	0	
	I'd be real nervous about drinking this due to near certainty of some surface runoff entering., lots of animals just outside t								±%		±%		±%		±%		±%					
M26	**Spring-New horizontal well during heav**	4.0000	6/26/99	10:00	60min	78°	6/27/99	10:04	16	4	16	36	2	1	27	36			**1,600**	16,000	24,350	
	Same as m25 except no surface runoff in vicinity, flow at least double. Water clear.						b,		±10%		±20%		±10%		±25%		±%					
	There was plywood over back access hole.									1		1		1		1			**0**	0	0	
	No runoff in natural channel above. Small watershed? Agar folded in about 10% of area.								±%		±%		±%		±%		±%					
Greywaters																						
M5	**Greywater-Nati's kitchen, Laundry out**	0.2500	6/23/99	2:00	<10min	90°			a	1	a	1	a		a	1			**#VALUE!**	#VALUE!	#VALUE!	
	in mid trench in old greywater slimepit. Cloudy grey, mildly anaerobic, green filimentacious algae,								±%		±%		±%		±%		±%					
	strong anaerobic smell when pigs wallow. This water looked pretty evil. I would step in it only under duress.									1		1	45	1		1						
									±%		±%		±%	l	±%		±%					
M33	**Greywater from shower stall**	0.0938	6/26/99	19:00	21:29	75°	7/28/99	16:00	2	1	25	72	1	36	a	36			**2,133**	1,922,133	#VALUE!	
	at Nati's. This poorly constructed shower has stagnant pools inside, which felt like a breeding ground and also smelled a l								±%	a,b	±%		±%		±%		±%					
	For greywater it looked pretty good-pipe is only 30 cm from stall to mulch basin.									1		1		1	10	36			**0**	0	384,000	
	Used for irrigation; looked great for that. Used 3 drops. 8 drops=.25 ml. 2ml sediment (sand) on bottom of sample conta								±%		±%		±%		±%	l	±%					

River																	
M15	**River-First flash flood**	0.2500	6/23/99	22:30	<10min	78°	6/24/99	16:30	16 4	a 1	a 1	a 1			25,600	#VALUE!	#VALUE!
	45 minutes after first front of water passed (unnoticed in dark). River went from dry bed to over 30 m wide								±% a	±%	±%	±%	±%				
	and average 25 cm deep. The river does not normally come down until october. This first flush cleared seven dry								1	1	1	1			0	0	0
	season months worth of human and animal feces in a swath a few dozen meters wide by a few dozen km long.								±%	±%	±%	±%	±%				
	Dark chocolate brown, visibility less than 1 mm. Maybe it was our imagination, but our legs tingled after fording.																
M31	**River-Second flush**	0.0357	6/26/99	19:00	21:18	75°	7/28/99	16:00	7 1	24 36	7 1	a 1			19,608	2,439,776	#VALUE!
	Looked like melted chocolate, just like first flush. 1mm visibility. Lots of ss.								±%	±%	±%	±%	±%				
	Tingly hot legs after numerous crossings, though maybe psychosomatic.								1	1	1	1			0	0	0
	This stuff looks super nasty; I washed my legs after.								±%	±%	±%	±%	±%				
M32	**River-Second flush, minus sediment**	0.0357	6/26/99	19:00	21:23	75°	7/28/99	16:00	8 1	15 36	1 36	a 1			22,409	1,535,014	#VALUE!
	Same as M31 except allowed to settle for one hour.								±%	±% a	±%	±%	±%				
									1	1	1	1			0	0	0
									±%	±%	±%	±%	±%				
Beaches																	
M10	**Beach-Nude beach**	5.0000	6/23/99	19:13	10min	81°	6/24/99	19:02	0 1	9 4	4 1	1			0	720	80
	Taken in 1 m deep water in a state of extreme wave agitation (3 m closed out shorebreaks); water was turbid,								±%	±%	±%	±%	±%				
	and depth ranged from minus 0.5 m to 1 m in this spot every minute. The whole beach felt						6/25/99	9:00	1 1	52 4	14 1	86 4			20	4,180	7,160
	very clean to me, and seemed to be upcurrent of the contamination from Mauruata. I didn't worry about								±%	±%	±%	±%	±%				
	drinking little bits or carrying it around in my ears. No trash, little organic debris on this beach.																
M11	**Beach-Middle beach**	5.0000	6/23/99	19:30	30 min	81°	6/24/99	19:02	1 1	6 1	2 1	43 4			20	140	3,480
	Taken in 1 m deep water. This beach is normally calm enough for distance swimming								±%	±%	±%	±%	±%				
	but had 2 m waves this day. Felt and looked clean but not as clean as nude beach.						6/25/99	9:00	3 1	42 4	2 1	64 4			60	3,420	5,160
									±%	±%	±%	±%	±%				
M12	**Beach-Long beach**	2.0000	6/23/99	19:30	90min	81°			2 1	200 2	0 1	300 2			100	20,100	30,000
	50 paces from estuary inlet. This beach had 1.5 m waves, looked and felt much dirtier than others.								±%	±% ?a	±%	±% ?a	±%				
	The water was turbid with organic debris and fine black sand. Numerous palapas directly on the beach,								1	1	1	1			0	0	0
	fishing boats, dead fish, vultures all around. I didn't particulary want to get into the water, but when my daughter did I go								±%	±%	±%	±%	±%				
M13	**Beach-Estuary**	1.0000	6/23/99	19:30	120min	81°	6/24/99	16:30	4 1	20 4	0 1	34 36			400	8,400	122,400
	Across from last palapa, in 50 cm water. Visibility 30 cm. Looked and felt dirty, especially if you thought								±% G	±%	±%	±%	±%				
	about the area it drains (the toilet bushes of town)						6/25/99	9:00	1 1	20 1	14 1	34 36			100	2,100	123,800
									±%	±%	±%	±%	±%				
M34	**Beach-Nude Beach after day of heavy**	1.0000	6/26/99	20:45	21:37	75°	7/28/99	15:00	3 1	36 4	5 1	26 36			300	14,700	94,100
	Light brown colored band of runoff-mixed salt water clearly visible along entire coast.						refrig. 7/27	20:00	±%	±%	±%	±% b	±%				
	This beach felt less clean, but still way cleaner than the long beach, which seemed to be downcurrent from the river.								1	1	1	16 4			0	0	6,400
	Not so much land debris on beach. We froliced in this water for at least 3 hours in the rain.								±%	±%	±%	±% l	±%				
Bottled Water																	
M30	**Bottled water-brand new**	150.0000	6/26/99	11:45	1min	76°	6/27/99	10:20	0 1	5 1	0 1	0 1			0	3	0
	Used careful sterile technique, except the same white pad reused from beginning.								±%	±%	±%	±% j	±%				
	This is what we and half the villagers were drinking. (the other half drink spring water).						6/28/99	15:00	0 1	5 1	0 1	26 41			0	3	711
							refrig 12:00-15:00		±%	±%	±%	±% k	±%				
M3	**Bottled water garafon**	5.0000	6/23/99	13:00	<10min	90°			0 1	1 1	0 1	45 72			0	20	64,800
	opened 20 hrs w/ 1cm2 slit in plastic cap								±%	±%	±%	B±%	±%				
	From bottling plant in Tecoman which supplies whole villiage								1	1	1	1					
	Felt fine for drinking. With continual refilling w/o cleaning, small bottles would develop a "live" taste								±%	±%	±%	±%	±%				

Notes

A	too numerous to get good count
B	Colonies very small
C	Difficult call
D	Easy call
E	whole plate pink; hard to differentiate white & pink
r	refrigerated
f	frozen
G	on recount appeared to be blues
h	Funky count-agar folded over while evacuating lab 1
i	early count
j	lots of teeny white colonies
k	these colonies light orange in color!
l	big colony count only

Next time

for rain samples, note rain intensity.

Rincon Point Sewer Calculations Summary

		79	Average Lagoon fecal coliform concentrations for all dates, mpn/100ml
0.07	oz	**2**	amount of human fecal matter in lagoon in grams
131	lbs	**59200**	Grams feces introduced into septic tanks near the lagoon per day
		99.996747%	Minimum percentage effectiveness of septic tanks, assuming 100% of human feces in the lagoon ARE from septic tanks
		99.999675%	Postulated effectiveness of septic tanks if flow is reduced 80%
		1	Approximate number of tightly rolled disposal diapers required to contaminate entire lagoon to this level
		519	Approximate number of days one person's bowel movement could comtaminate the lagoon to this level
		30743.64	Number of days of maximum septic tank contamination equalled by one day of 100% raw sewage flow
		84.23	Number of years of maximum septic tank contamination equalled by one day of 100% raw sewage flow
4,034	$/oz	**142.2789777**	Project cost in dollars per gram of feces removed

Rincon Point Sewer Calculations—Detail

			Average Lagoon fecal coliform concentrations by date, mpn/100ml (from lower Rincon Creek
	5/20/99	30.7	watershed study by SB Co. Health and Heal the Ocean)
	5/24/99	60.6	
3	5/25/99	35	
	5/26/99	110	
	5/27/99	102.4	
	6/1/99	144	
	6/4/99	72	
			Average Lagoon fecal coliform concentrations for all dates, mpn/100ml (calculated from
	a	**79**	data above)
			Percent of (a) which is human, based on matches from study. It was not clear if this
	b	**20%**	extrapolates, but it seems like a reasonable number.
	c	16	Average concentration of fecal coliforms of human origin mpn/100ml (a*b)
			Approximate conversion factor from fecal coliform mpn/100ml to parts per billion of feces
	d	1	(see assumptions below)
			assumed:10 million coliforms per gram of wet feces (dog=23 million, human 13 million...)
			assumed: 1000g feces/person/day (one source gave 1113g as the average daily production of feces)
	e	**16**	Average concentration of fecal matter of human origin in ppb (same as mg/m3) (c*d))
			Approximate volume of lagoon in m3. It was approximately 60m long, 4.5 m wide and .5 m
32,076	gal	**122**	deep, average at the time of the study
	g	1926	amount of human fecal matter in lagoon (mg) (f*g)
0.07	oz	**2**	amount of human fecal matter in lagoon in grams (g/1000)
	i	74	Number of houses (from study)
	j	4	Average number of people per house (guess)
			Daily feces production per person, grams (one source gave 1113g as the average daily
	k	1000	production of feces)
	kk	20%	Percentage of septic tank effluent which are closer to the lagoon than the ocean (guess)
131	lbs	**59200**	Grams feces introduced into septic tanks near the lagoon per day (i*j*k*kk)
			Assumption: the lagoon water is changed each day by flow (this is highly variable)
	m	**0.003253%**	(h/l)
			Minimum percentage effectiveness of septic tanks for preventing contaminated water from
	n	99.996747%	going into the lagoon, assuming 100% of human feces in the lagoon ARE from septic tanks
	o	99.999675%	Postulated effectiveness of septic tanks if flow is reduced 80% (n *1/90%)
			Approximate number of tightly rolled disposal diapers required to contaminate entire lagoon
	p	1	to this level
			Approximate number of days one person's bowel movement could comtaminate the lagoon
	q	519	to this level
			Number of days of maximum septic tank contamination equalled by one day of 100% raw
	s	30743.64	sewage flow (l/h)
			Number of years of maximum septic tank contamination equalled by one day of 100% raw
	t	84.23	sewage flow (l/h)
	u	3,000,000.00	Cost of project in dollars
	v	30	Lifespan in years
	w	21085.33564	Maximum grams of feces kept out of the lagoon in thirty years h*365*30
4,034	$/oz	142.2789777	Dollars per gram u/w