WATER

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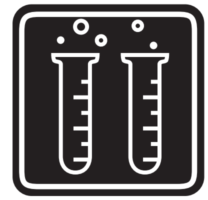
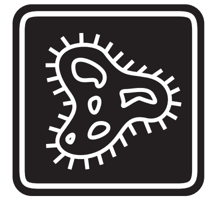
Why Do We Care About Water Quality?

Clear and Present Danger

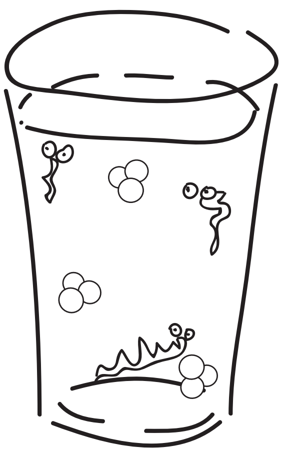
Even when the water looks completely clear, it may be contaminated. There are two classes of contaminants: *chemical* and *biological*.



While all water contains some chemicals, unusual or dangerous chemicals dissolved in the water are *chemical contaminants*. Some chemicals can make water taste good or add flavor. Sugar and salt are both chemicals which can invisibly change the flavor of water. Other chemicals can make water poisonous to plants and animals.



Biological contaminants are microscopic organisms that can live in water but are usually invisible to the human eye. Biological organisms in water can be beneficial to humans: Nitrosomonas bacteria helps break down ammonia, a chemical contaminant. But when biological organisms are harmful or unusual in water, we say they contaminate the water. Biological contaminants can be deadly: Cryptosporidium parvum and Giardia are both one cell parasitic organisms which cause a waterborne stomach illness that visits cramps, watery diarrhea, and fever on its victims.



Sources of Chemical Contaminants

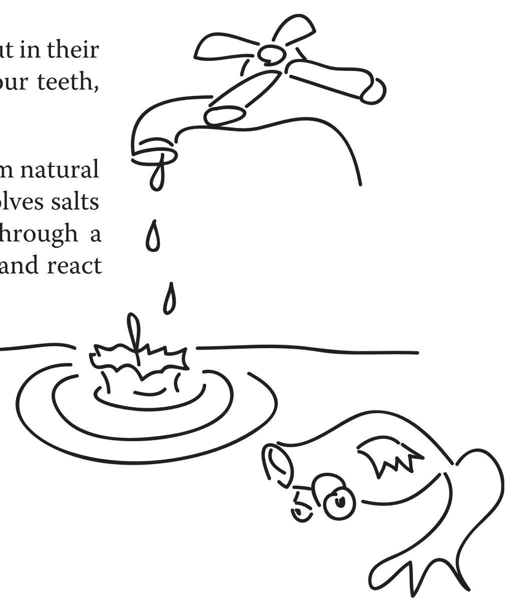
Free-flowing water, which includes oceans and all the water that flows into them, can suffer from many sources of chemical contamination. These sources are broadly divided into two categories: human generated pollutants and additives, and natural sources of contamination.

Human-generated chemical pollutants are all the chemicals that end up in the water as a by-product of human activity. We'd rather these pollutants weren't there, but as a society, we are unwilling to give up the benefits that the activities that lead to these pollutants give us. We know that automobiles, for example, release poisonous chemicals into the air, which then rain down and mix with free-flowing water, but we still drive cars. We judge the benefits of cars as outweighing the harm they cause.

Unlike pollutants, sometimes we put chemicals into the water on purpose. Chlorine, a chemical which can be deadly if swallowed directly, is put into swimming pools to kill the biological contaminants that would otherwise grow there. Without chlorine, pools start to grow green, and bacteria and viruses that can cause bad infections flourish in the water. But while chlorine kills things we don't want to grow in our pools, it also stops us from stocking our pools with goldfish or drinking the pool water while we swim. Chlorine is also famous for stinging the eyes, releasing an unpleasant smell, and turning hair green.

All chemicals are "natural." Mercury is natural but it is also deadly to humans.

Chlorine is not the only chemical additive that people put in their water. Fluoride can kill fish, but because it's good for our teeth, it's often added to our drinking water.



Sometimes chemical contamination of water comes from natural sources. When water seeps through the ground, it dissolves salts and minerals from its surroundings. Water flowing through a natural copper deposit will dissolve some of the metal and react with it, possibly turning a sparkling stream into deadly liquid. A natural lake in the former U.S.S.R. became famous for killing campers as they slept on its banks. A natural mercury deposit poisoned the early morning mist that rose from the contaminated waters. The few campers who survived were rendered insane by the effects of the toxic mercury fumes.

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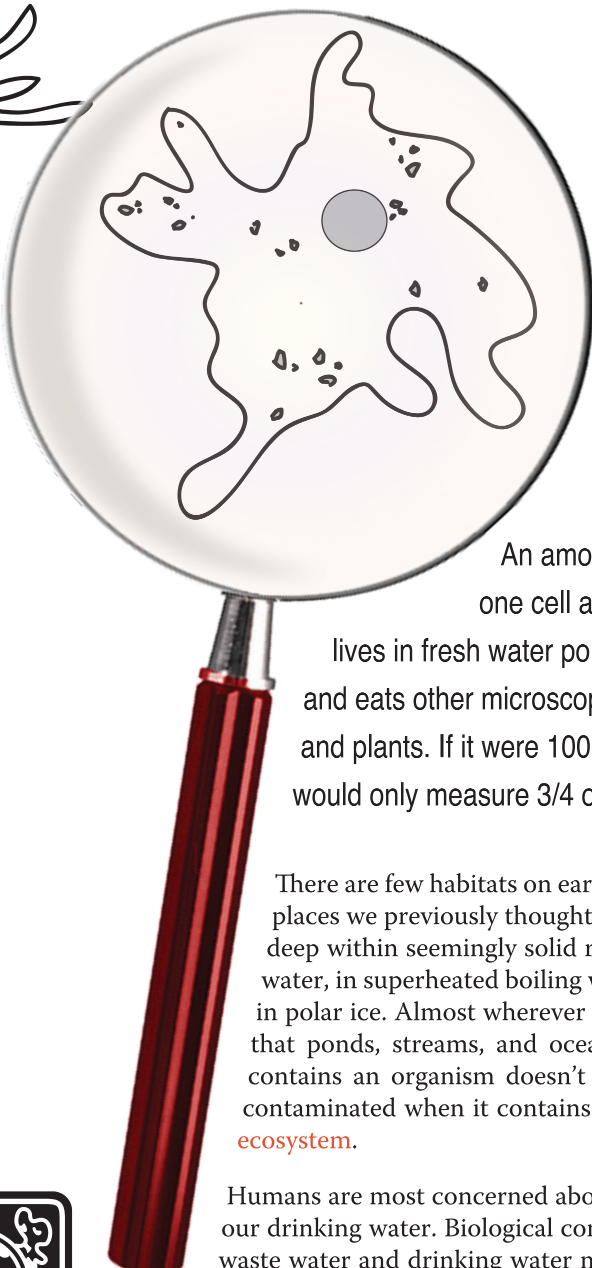
Biological Contaminants

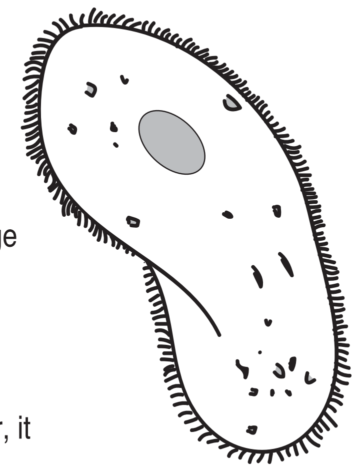
Sources of Biological Contaminants

There are many different organisms that live in fresh and ocean water. Fish, crab, mollusks, sponges, and kelp—these are life-forms we can see. They are made up of hundreds of millions of cells. Humans are made from cells, too. The human brain alone has about 12 billion cells. There are other living organisms that consist of very few cells. Amoeba and paramecium are each just a one cell organism commonly found in fresh water ponds. Hydras are tiny multicellular creatures that also live in ponds and are very difficult to see even with a strong magnifying glass.



A paramecium is a slipper-shaped, one cell organism. It uses little hair-like structures called cilia to propel itself through water. If it were 100 times larger, it would only measure 1/4 of an inch.

An amoeba is a large one cell animal that lives in fresh water ponds. It hunts and eats other microscopic animals and plants. If it were 100 times larger, it would only measure 3/4 of an inch.



Hydras are relatives of jellyfish, corals, and sea anemones. They live in small ponds and eat what they can catch with their tentacles called nematocysts. You can “catch” hydras by taking a few leaves from a pond plant and putting the leaves in a glass of water. After a short while, hydras will attach themselves to the inside wall of the glass. They will be barely visible to your naked eye.

There are few habitats on earth that are not colonized by life. We find life even in places we previously thought must be barren: in drilled core samples taken from deep within seemingly solid rock, under the crushing pressure of miles of ocean water, in superheated boiling water next to underwater volcanic vents, and frozen in polar ice. Almost wherever we look on Earth, we find life. So it’s not a surprise that ponds, streams, and oceans would teem with life. But just because water contains an organism doesn’t mean it’s contaminated. We only consider water contaminated when it contains an organism that doesn’t belong in that particular ecosystem.

Humans are most concerned about health effects caused by dangerous organisms in our drinking water. Biological contaminants can get into our water supply when our waste water and drinking water mix together. This is a problem in many developing countries where people may use a river to both wash and drink. Bacteria from people living upstream spreads to those living downstream, introducing biological contaminants into the water supply.

But it’s not only people who are responsible for biological contamination. Animals die. Fish die. Plants die. Their bodies decompose and sometimes enter water sources. And sick animals can spread disease through excrement and body fluids as they visit sources of water.

In the United States, where possible, we treat drinking water by careful filtering, by adding chemicals that kill harmful organisms, and by fencing reservoirs to keep people from introducing contaminants into the water either by accident or on purpose.

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Fish Do It in the Water

The Nitrogen Cycle

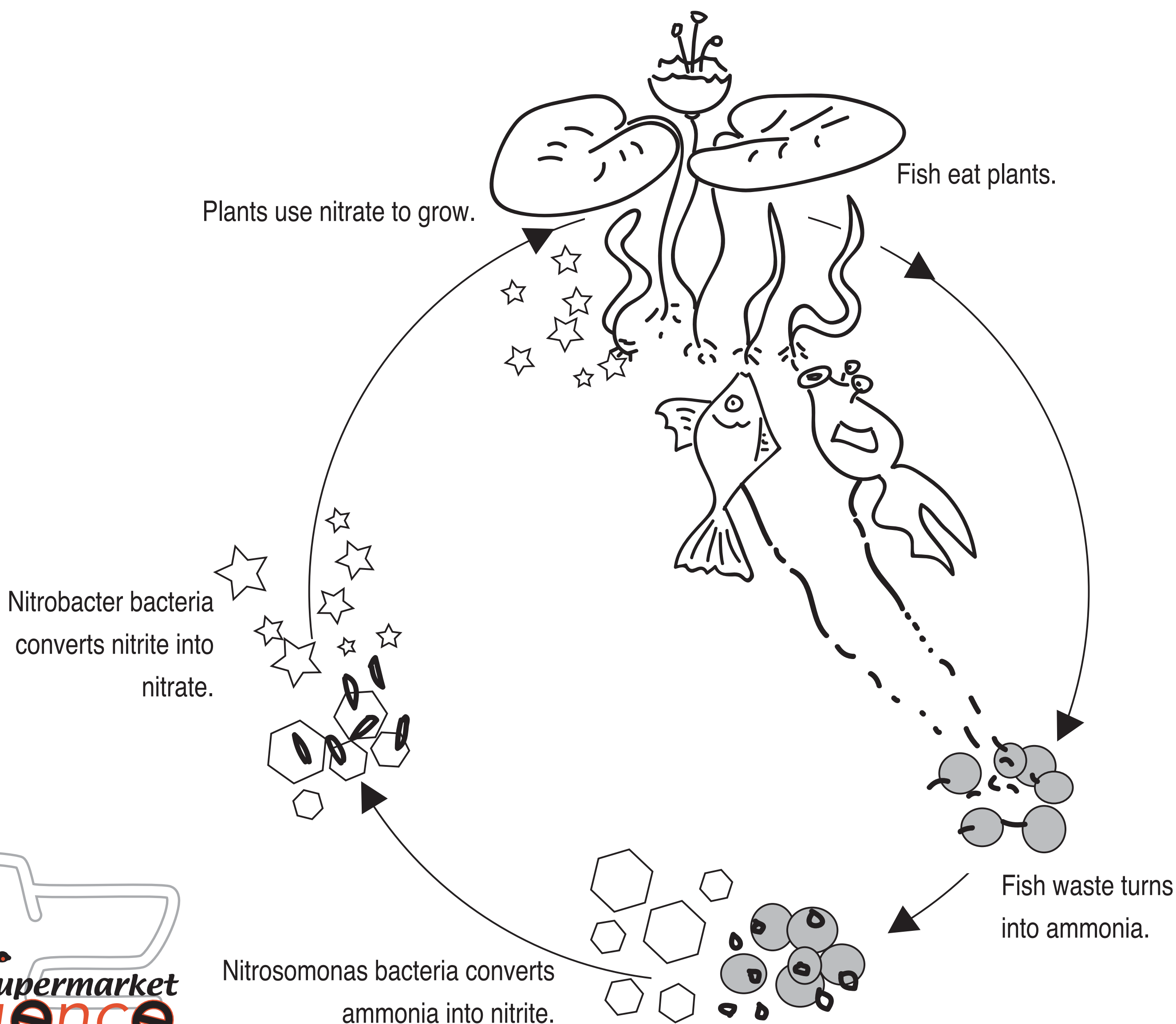
Fish eat, sleep, live, and defecate in the water. Fish waste is a major source of ammonia in water. Ammonia is nasty stuff with an intense distinctive odor. It's a strong chemical that's commonly used to clean bathrooms and sinks. Cleaning products that contain ammonia have warning labels about how harmful this chemical can be.

But if fish introduce ammonia into the water, isn't it "natural?"

There are lots of "natural" things that can kill you. The bubonic plague was natural, and it managed to wipe out millions of people during the middle ages. And the flu is "natural," but we all try to avoid getting it. COVID-19 is also natural, and we are working as hard as we can to eliminate this disease from the world. Beyond diseases, many plants and animals produce natural chemicals that are deadly poison to humans. *Natural* is not same as beneficial.

So if fish produce a lot of ammonia, why don't all the fish die of ammonia poisoning?

The answer is ammonia-loving bacteria: Nitrosomonas bacteria. These microscopic organisms live off the waste products of fish, turning them into nitrites. Nitrite is another chemical, less deadly to us than ammonia, but still not so good. But there is yet another bacteria that comes to the rescue! Nitrobacter is a micro-organism that loves to consume nitrites, turning them into nitrates—a chemical that plants need to survive. Plants drink up nitrate from the water, growing healthy leaves and stems in the process. Fish eat plants and excrete their waste back into the water, raising the levels of ammonia. It's that whole "circle of life" thing.



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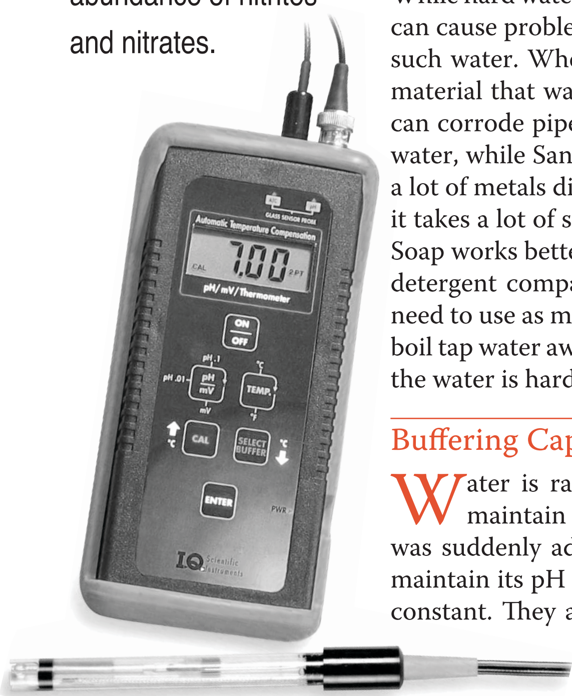
Testing the Waters

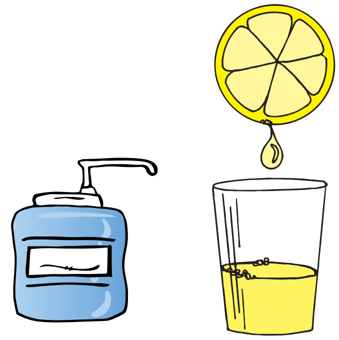
There are many different types of pH meters. Some look like instruments, but others are just strips of test paper which turn colors when dipped into the sample liquid. Most pH meters also test for hardness, buffering capacity, and the abundance of nitrites and nitrates.



Water has some easily testable properties that can be used to assess its environmental health. Four of these properties that can be tested with a standard pH meter are *pH*, *hardness*, *buffering capacity*, and the levels of *nitrites* and *nitrates*.

pH

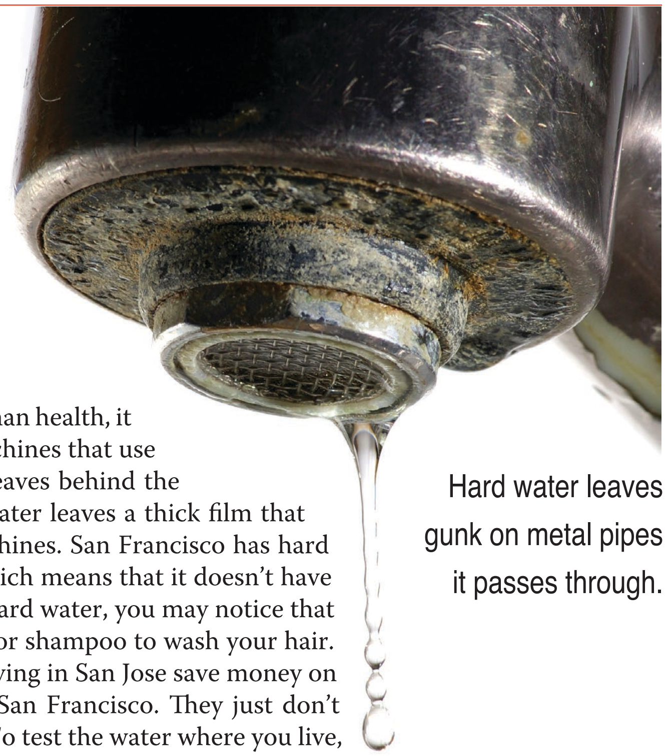
Liquids can be either acidic, basic, or neutral. Lemon juice is an example of a weak acid, while liquid soap is a weak base. The strongest acid would measure 1 on the pH scale while the strongest base would top the scale at 14. Both strong acids and strong bases can burn human flesh and etch metal. Neutrality is defined as pH=7. Most fish can only tolerate a narrow range of pH from about 6 to 8.



When you measure the pH of ordinary liquids, you will find interesting variation. Tap water measures around pH=7. Lemonade is acidic and so will have a lower pH of about 5. Liquid soap is basic and so will measure about 10.

Hardness

Water *hardness* measures how much metal, usually calcium and magnesium, is dissolved in the water. Water is good at dissolving stuff, it's sometimes called a universal solvent. As water flows through the ground and through pipes, it washes away small bits of metal from its surroundings. The water is said to be "hard" when it contains a lot of metal particles.



Hard water leaves gunk on metal pipes it passes through.

While hard water is not dangerous to human health, it can cause problems for pipes and for machines that use such water. When water evaporates, it leaves behind the material that was dissolved in it. Hard water leaves a thick film that can corrode pipes and clog washing machines. San Francisco has hard water, while San Jose's water is "soft," which means that it doesn't have a lot of metals dissolved in it. If you use hard water, you may notice that it takes a lot of soap to wash your hands or shampoo to wash your hair. Soap works better in soft water. People living in San Jose save money on detergent compared to people living in San Francisco. They just don't need to use as much to get things clean. To test the water where you live, boil tap water away and watch if it forms a residue. A lot of residue means the water is hard.

Buffering Capacity

Water is rarely pure. The many different chemicals usually present in water can help water maintain a certain pH level. These are called pH stabilizing compounds. If a lot of acid or base was suddenly added to a pond, for example, the fish in that pond would die if the water couldn't maintain its pH level. pH stabilizing compounds react with acid or base and act to keep the pH level constant. They act like a buffer which protects the water from pH fluctuations. The more of these stabilizing compounds are present in water, the more tolerant the wildlife is to acidic or basic pollutants. *Buffering capacity* measures the amount of pH stabilizing compounds in a liquid.

Nitrites and Nitrates

The amount of the chemicals *nitrite* and *nitrate* that are in water indicates how much useful bacteria is present in the water. Certain useful bacteria breaks down harmful ammonia into less toxic, and ultimately necessary compounds through a process called the "Nitrogen Cycle."

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pH of Household Liquids

Our homes are filled with different kinds of liquids: milk, tap water, bottled water, liquid detergent, soda pop.

Can you think of a few more?

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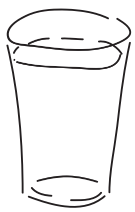

Collect four small samples of different liquids from around the house: vinegar, juice, liquid soap, and tap water. Make a guesstimate and write down what you think the pH measurement for these samples would be. Using a pH meter or pH paper determine the actual pH of your samples.

	Guesstimate	*Actual Reading*
Vinegar pH=	______________ ,	______________
Juice pH=	______________ ,	______________
Liquid Soap pH=	______________ ,	______________
Tap Water pH=	______________ ,	______________

Did you guess well? ______________________________

____

What You Need:

pH tester

liquid samples

Do you think what juice you used matters? Would apple juice be different from orange juice?

____

Why? ______________________________

____

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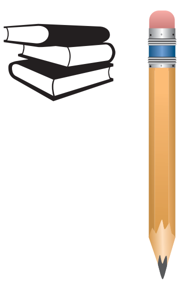
The Smart Aleck Guide to Self Comprehension

Answer the following questions about water quality. Do your parents know the answers? Do you understand well enough to explain these ideas to them or to others?

What You Need:



If the lemonade tests at pH=8, would it taste good? Why?

Your mom puts half a cup of detergent into a full load of dirty laundry. After the clothes goes through the last spin cycle, the water from the washing machine still looks soapy. What can you deduce about the quality of tap water in your neighborhood?

The fish in your tank keep dying no matter how much you feed them or how often you change the water in the tank. You local pet supply store clerk tells you to check for Nitrites in your tank. What is he talking about?

A delivery truck full of backing soda overturns into a local creak. The park ranger says that she hopes that the buffering capacity of the creak is high. Why?

On your camping trip, your friend dares you to drink lake water. It looks clear. It smells okay. Should you do it? Why or why not?

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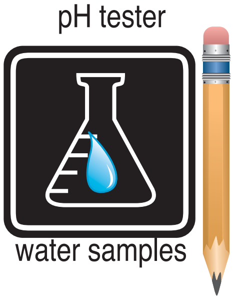
pH of Household Liquids

Testing the pH values of different liquids around our homes is interesting. But testing the pH of ground water, rain water, and water in the nearby natural sources like lakes and rivers provides information about the health of our environment. If the rain water tests too low (pH=5 or less), then we are being exposed to acid rain. If the water in our lakes and rivers is too basic or too acidic, then the fish living there may die. If the ground water—water found underground and in the soil—is too far from neutral, some plants won't be able to grow in it.

What You Need:

pH tester



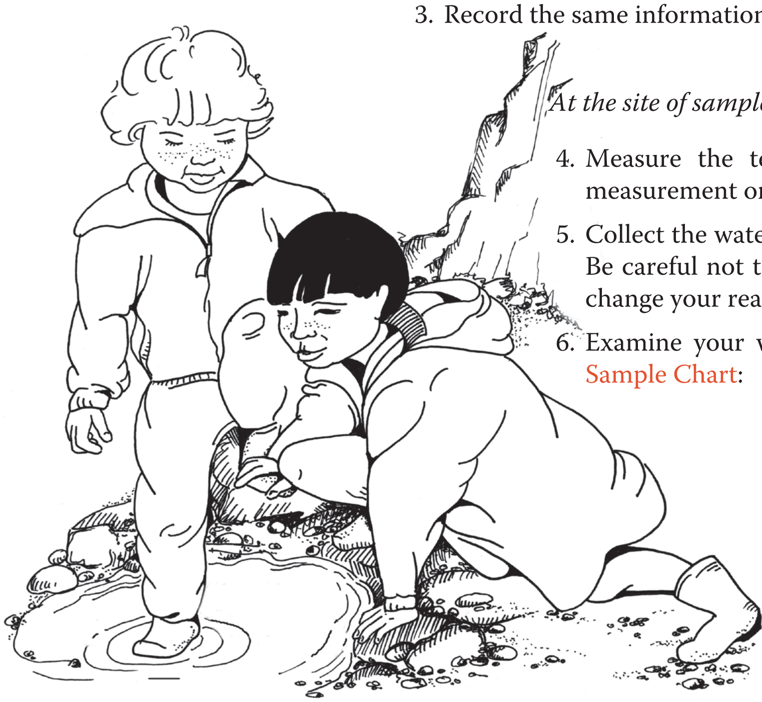
water samples

Using small glass jars, collect samples of water from your neighborhood. Take careful notes where you collected your sample and label your sample jars. You can also create a small map of where you gathered your water samples and indicate the location of where each sample came from. Use a pH meter to test your samples of water. If you're using an instrument, make sure to carefully wipe the meter between each test. Fill in the Sample Chart with as much data as you can gather. Use more than one Sample Chart if you need more space.

Instructions for Data Collection

At school or at home:

1. Carefully wash and dry all of the sample jars and put labels on them.
2. On each sample jar's label, write the date, location, and number.
3. Record the same information on the Sample Chart.



At the site of sample water collection:

4. Measure the temperature of the water at the site of collection. Record the measurement on your Sample Chart.
5. Collect the water sample at each of your locations. Make sure to use the correct jar. Be careful not to introduce dirt or plant debris into your water sample as it might change your readings.
6. Examine your water sample carefully. Record the following information in your Sample Chart:
   - Is the water clear? If not, how cloudy is it on the scale on 0 to 5 with 0 being perfectly clear?
   - Does the water contain visible particulate matter (small bits of stuff floating inside)?
   - What color is the water?
   - Does it have a smell? If it does, how would you describe it (sweet, foul, fresh, etc.)? How strong is the smell on the scale of 0 to 5 with 0 signifying no smell at all?

Go outside after the rain and collect water from puddles. What is the pH level of the rain water in your neighborhood?

Back at school or at home:

7. Use the pH paper or meter to measure the pH level of each sample. Rip a small strip of pH paper from the roll. Each strip can only be used once.
8. Record the data in the Sample Chart.

Do more:

9. Use a paper test kit or an instrument to measure the hardness, buffering capacity, and nitrite and nitrate level of your water samples. Add your data to the Sample Chart.

What conclusions can you make from the data you've collected? Use additional sheet of paper to record your conclusions.

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Sample Chart

What You Need:
pH meter

water samples

liquid samples

Sample #	Date	Location	Temperature	pH Level	Clarity (0-5)	Particulates	Color	Smell (0-5)

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Water Filters

What You Need:

Parent Helpers

The tap water we get from our faucets is highly regulated—this means that it needs to meet a certain standard of cleanliness and safety before it is allowed to reach our homes. Surprisingly, bottled water is not highly regulated and so might contain surprising amount gunk, even if that gunk is not easily visible to the human eye. Tap water tends to be safer...if the government does a good job of monitoring our municipal water supply.

But what it you wanted to drink some water from a creek? Don't do it! Even clear-looking water can hide things that can really hurt us: bad micro-organisms and dissolved chemicals. Still, we can make even the water from a creek drinkable if we work hard enough to purify it.

Make a Water Filter

Most of the time, the water gathered from a creek is not clear—it has obvious gunk floating in it. To clean the water, we need to filter it. You can make a water filter yourself from materials easily found around your home or a neighborhood store. To make a water filter, all you need is a large soda bottle with the bottom cut off, a few cotton balls, activated carbon (you can find activated carbon at any aquarium supply store), sterilized fine sand (2 cups), and sterilized fine gravel (2 cups). And of course, you will need to make some dirty water to test your filter!

Stuff the cotton bolls into the neck of the soda bottle. Make sure they fit snugly. Now fill the bottle with a 3 inch layer of activated carbon. The cotton balls will keep the grains from falling out. Next, add about 4 inches of fine sterilized sand on top of the activated cotton. Now add 3 inches sterilized fine gravel. Congratulations, you've made a water filter!

Dump some dirt into water and mix well. Pour your dirty water slowly through your filter. It will come out clear! But you still have to boil the water to kill off any bacteria hiding inside. Only then will the water be drinkable!

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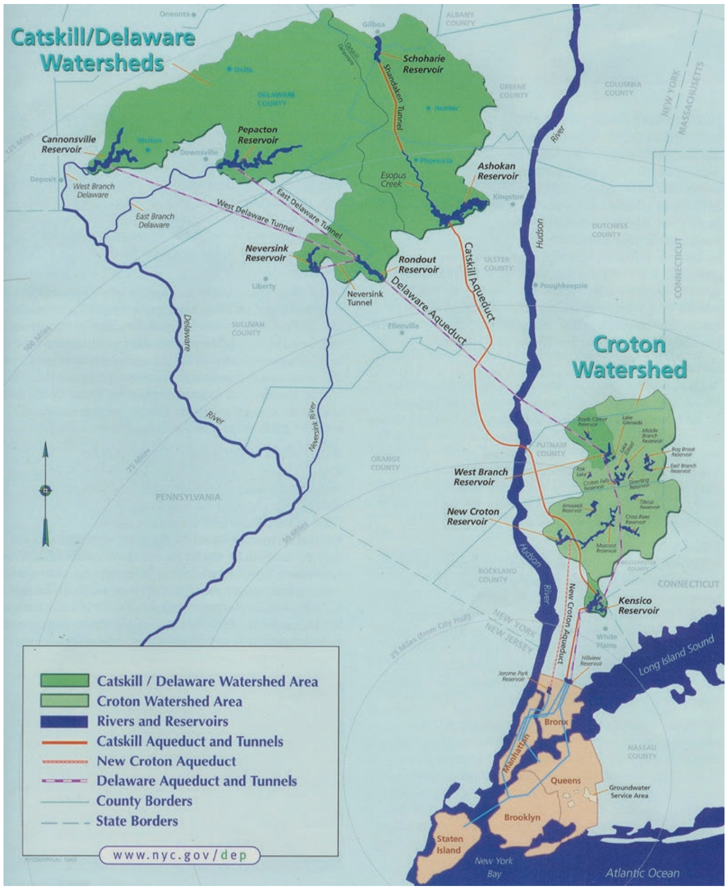
NYC Tap Water

While the water that comes out of our taps is strictly regulated—it would be bad public policy to make people sick if they drink tap water not to mention people might die—different municipalities and states have different rules about their drinking water. For example, New York City supplies potable (drinkable) water to millions of its residents. But the water that comes out of its taps is not filtered—it looks clear to the naked eyes, but not if you look under the microscope. If New Yorkers ever decided to filter their water, it would cost them approximately $1,000,000 per day! So due to the high costs of filtration, New York City's water system is the largest unfiltered drinking water in the U.S. And it's not only New York City; Westchester, Orange, Ulster, and Putnam Counties all use the same water supply, 1.2 billion gallons of water per day! And all these people drink their water unfiltered.



But where does all that water come from?

The water that collects in New York City's reservoirs comes from several watersheds—an area of land that separates waters flowing to different reservoirs. Catskill/Delaware Watershed and Croton Watershed serve the people of New York City and its surrounding counties. The water from rainfalls, and snowfalls in winter, collects in large reservoirs that then distribute it via giant pipes to different cities, neighborhoods, and buildings. It's a very complicated system. There are thousands of people who try to keep this system working properly and to insure that the water that coming into people's home is safe-enough to drink.

New York City Water Board, the agency responsible for the health of its water and sewer systems and for the health of the people using them, conducts more than 500,000 (that's half a million) tests of its tap water every year—that's more than 1,370 tests every day!

What does New York City do to keep its tap water safe?

Like other municipalities, New York City adds various chemicals to make its tap water safer: chlorine to kill bad bacteria, fluoride for healthy teeth, orthophosphate to reduce the amounts of lead (a toxic metal) in the water, and sodium hydroxide (also called lye) to keep the water pipes from corroding. But that's not all! New York City tap water is irradiated with ultraviolet light—another measure to kill deadly pathogens. But wait, there's more...

Mosquito larva live in stagnant or slow-flowing waters.

Are those little shrimps in my drinking water?

Mosquito larva love to live in the slow-moving waters of New York City's reservoirs. And not only would mosquito larva flow out the household taps if left unchecked, mosquitoes would descend on the people of New York City by the billions, bringing with them not only irritating bites but a host of diseases. So to kill the mosquito larva, New York City adds microscopic crustaceans—tiny shrimps called copepods—to its municipal water. These shrimps eat the mosquito larva and solve the pest control problem. And these copepods are so tiny (1 to 2 millimeters long and nearly transparent), that most people are not even aware that they are eating a raw shrimp cocktail with every sip of New York City's tap water.

Copepods are tiny shrimps that eat mosquito larva.

Image by Uwe Kils

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Word Puzzle

contaminants
chemicals
organisms
Nitrosomonas
bacteria
Cryptosporidium
parvum
Giardia
pollutants
additives
organisms
cells
amoeba
paramecium
hydras
cilia
ecosystem
decompose
ammonia
Nitrosomonas
microscopic
nitrites
Nitrobacter
nitrates
acid

M	D	D	T	N	C	M	A	D	P	D	S	S	S	P
B	U	S	D	I	I	M	U	A	I	A	D	T	E	O
A	Z	I	L	E	M	T	R	V	N	C	C	N	V	L
C	G	I	D	O	C	A	R	O	R	A	A	A	I	L
T	A	I	N	I	M	O	M	O	B	A	U	N	T	U
E	C	I	A	E	R	O	M	E	B	Z	P	I	I	T
R	A	E	C	R	S	O	O	P	J	A	K	M	D	A
I	W	I	L	O	D	M	P	E	O	B	C	A	D	N
A	U	T	R	L	A	I	S	S	U	S	S	T	A	T
M	Q	T	T	X	S	Q	A	I	O	N	E	N	E	S
M	I	S	E	T	I	R	T	I	N	T	U	O	U	R
N	S	L	A	C	I	M	E	H	C	A	P	C	P	O
M	I	C	R	O	S	C	O	P	I	C	G	Y	V	Z
E	C	O	S	Y	S	T	E	M	H	D	S	R	R	A
P	G	N	I	T	R	A	T	E	S	E	H	V	O	C

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Word Puzzle

base
neutrality
calcium
magnesium
solvent
evaporates
dissolve
additives
pathogens
municipality
potable
watershed
reservoir
chlorine
fluoride
orthophosphate
lead
lye
irradiated
ultraviolet
larva
crustaceans
copepods

U	W	P	T	D	F	E	W	N	N	L	M	G	E	C
E	L	O	A	E	E	E	V	E	Q	U	G	T	Y	R
N	B	T	S	T	C	T	U	L	I	D	A	B	W	U
I	C	A	R	T	H	T	A	S	O	H	C	A	W	S
R	B	A	U	A	R	O	E	I	P	S	T	D	O	T
O	A	Q	L	A	V	N	G	S	D	E	S	L	S	A
L	A	V	L	C	G	I	O	E	R	A	V	I	A	C
H	H	I	R	A	I	H	O	S	N	E	R	Z	D	E
C	T	X	M	A	P	U	H	L	N	S	L	R	R	A
Y	T	Q	H	O	L	E	M	T	E	B	K	Y	I	N
L	N	O	H	J	D	A	D	D	I	T	I	V	E	S
J	O	T	M	U	N	I	C	I	P	A	L	I	T	Y
B	R	I	O	V	R	E	S	E	R	L	E	A	D	J
O	S	E	T	A	R	O	P	A	V	E	E	B	A	I
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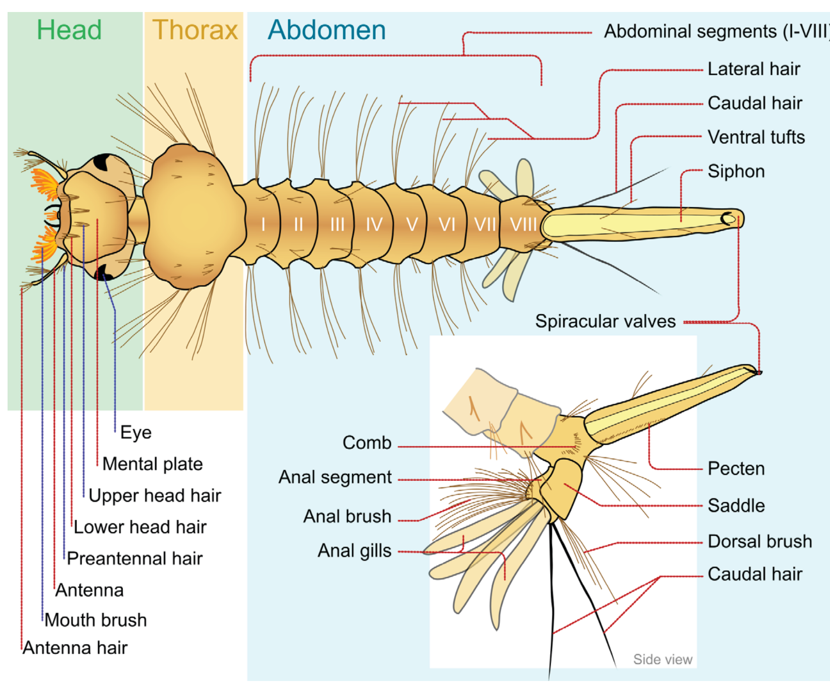

Diagram of mosquito larva anatomy by LadyofHats.

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