A MONITOR'S GUIDE TO

WATER QUALITY

The Gordon Foundation is a philanthropic charity with a long history of protecting Canada's freshwater and promoting citizen engagement in policy and decision-making.

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A MONITOR'S GUIDE to WATER QUALITY

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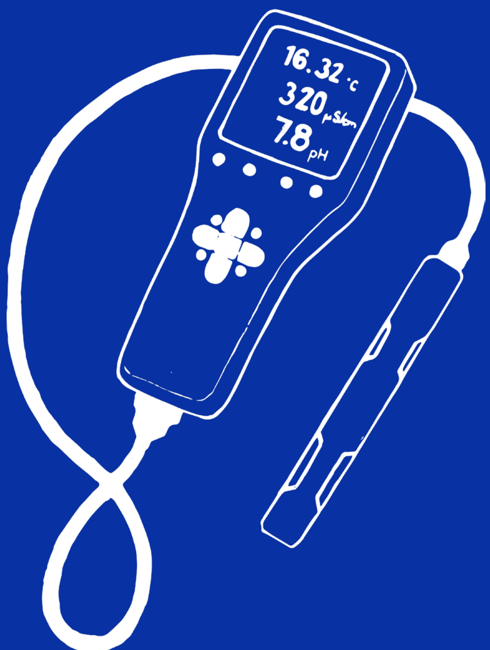
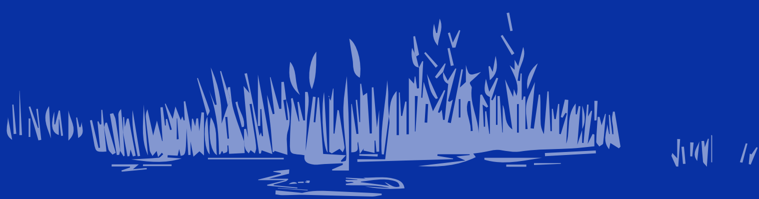


WATER: OUR SOURCE OF LIFE

The water that circulates in our world today – through the air, the land, and our bodies – has been here for billions of years. Water is unique in that it can dissolve and carry within it more substances than any other liquid. Wherever water travels it picks up and transports chemicals, minerals and nutrients. This is how healthy waters help sustain all life on Earth.

These unique properties of water also illustrate how our actions and the ways we live can have far-reaching and long-lasting impacts on water; and the profound responsibility we have to take care of this water that connects and sustains us all.

This guidebook provides an introduction to some of the most important and commonly monitored aspects of water quality. Alongside local, place-based, and Traditional/Indigenous knowledge, this information can support decision-making and action to help protect our waters, so they remain healthy for generations to come.

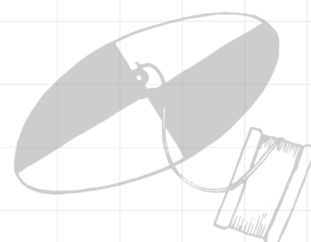


WATER QUALITY

To assess water quality in rivers, lakes and wetlands, we typically look at a number of different *characteristics* of the water. These include **physical properties** (such as water clarity and temperature), the concentration of various **chemical substances** (including nutrients, metals, minerals and pollutants from human activity), as well as **biological characteristics** (like the amount and types of bugs, bacteria, algae and other organisms that live in the water).

Taken together these measurements can give us an indication of how healthy the water is and, importantly, how it may be changing over time.

In assessing water quality, it is helpful to know what "normal" levels are for key characteristics in a given river or lake. This provides a baseline for comparison so we can detect and better understand impacts of development activities, climate change or restoration efforts.



INFLUENCES ON WATER QUALITY

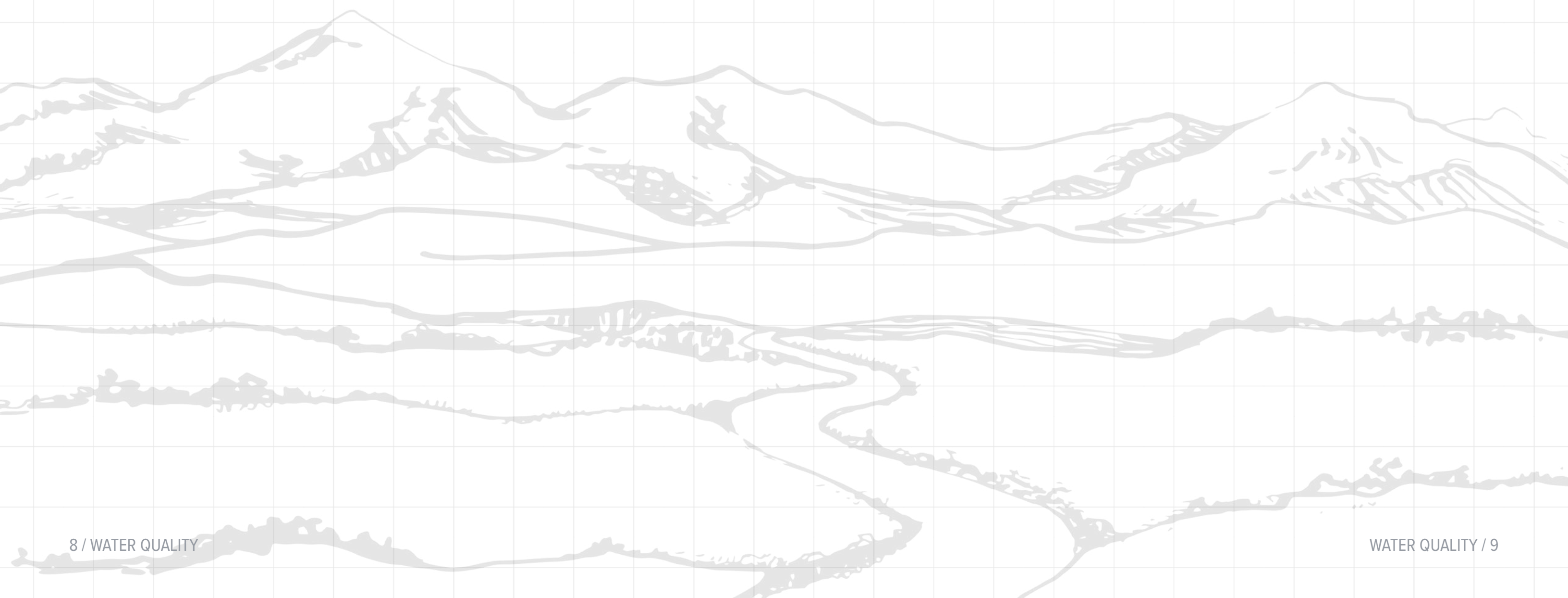
The physical, chemical and biological characteristics of a water body are greatly influenced by the land that water travels through (such as the type of rock, soil and land cover) and the activities taking place there (such as urban or industrial development, agriculture, logging and mining), as well as the seasons and climate.

Water vapour can travel long distances through the atmosphere on wind currents, picking up and carrying a variety of substances along the way before it falls back to the ground as rain and snow. This means that some elements of water quality can also be influenced by activities taking place far away, in areas otherwise disconnected from the rivers and lakes we are monitoring.

NATIONAL GUIDELINES

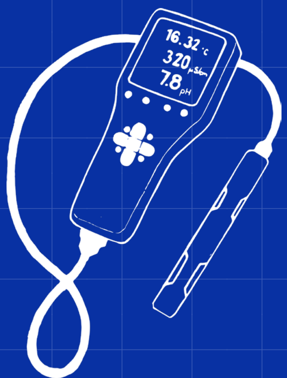
The Canadian Council of Ministers of the Environment (CCME) sets national water quality guidelines for the protection of aquatic life in Canada. These guidelines provide recommended ranges for some of the physical, chemical and biological characteristics that are commonly monitored.

These guidelines are intended to be broadly applicable across the country. However, unique conditions in some places mean that the guidelines may be over- or under-protective in some areas. For example, normal background levels of a substance may be naturally higher than the guideline and may not have any harmful effect on locally adapted aquatic organisms that live there. In addition to national guidelines, some provinces and territories have also developed their own water quality guidelines.



MEASURING WATER QUALITY

Water quality measurements can be taken directly when out on the water ("in the field"), by samples sent to a lab for analysis, and by sensors that are left in the water over time. These are some of the most common types of equipment used to measure water quality.

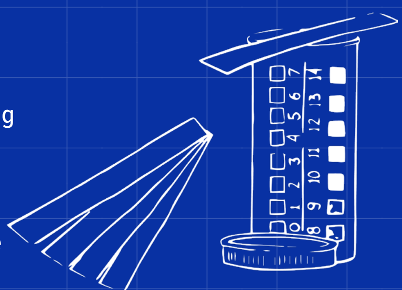


HANDHELD SONDE

These devices have a probe (sonde) that is lowered into the water. Specialized sensors inside the probe typically measure basic physical and chemical characteristics such as pH, temperature, conductivity and dissolved oxygen.

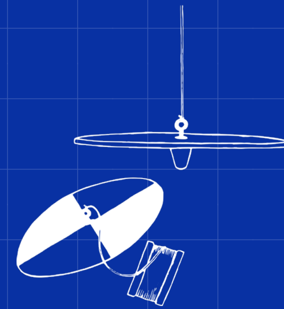
pH STRIPS

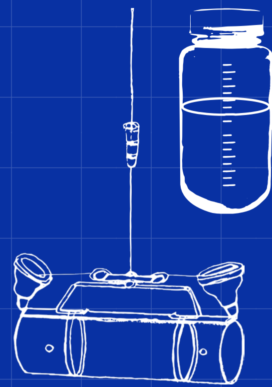
Some characteristics, like pH, can be measured using test strips that change colour when placed in the water. The colour is compared against a guide to estimate the pH value.



SECCHI DISK

Secchi disks have been used to assess water clarity in lakes and oceans for over 100 years. This is a standard, simple and inexpensive method where the depth at which the disk can no longer be seen is recorded.



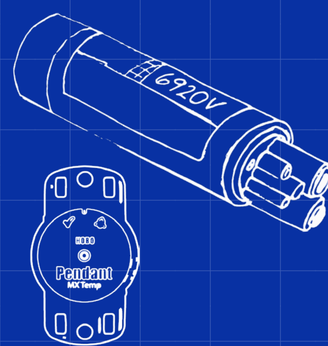


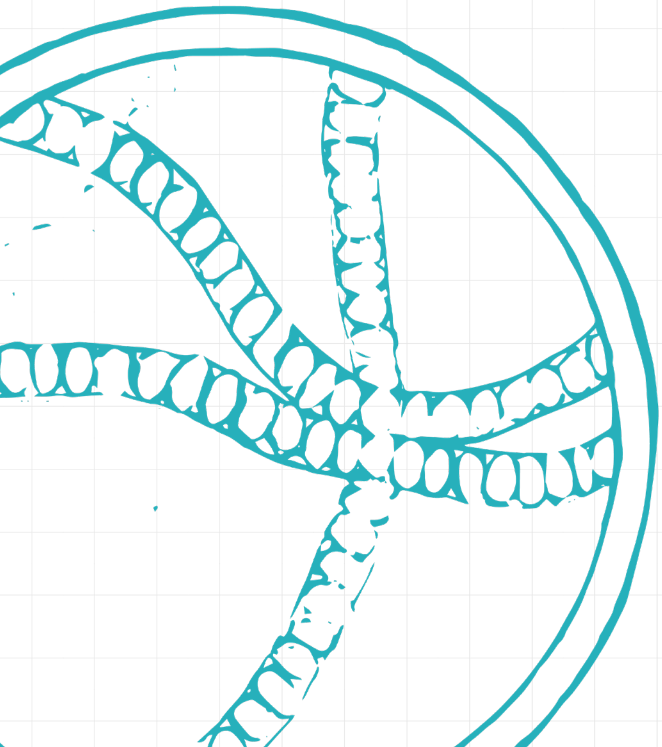
GRAB SAMPLE

These are water samples that are sent to a lab for analysis. Certain protocols need to be followed to ensure reliable and representative sample collection. Grab samples can be taken at the surface or using equipment that allows a sample to be collected at depth.

DEPLOYABLE SENSORS

These devices are left in the water over a period of time to collect measurements, often continuously or at set intervals. Calibration protocols and reporting are important to ensure good quality data.





BIOLOGICAL

Biological characteristics tell us about the biota of an aquatic ecosystem – the things that live in the water, like bugs, algae, fish and bacteria. The amount and types of organisms that live in rivers and lakes are influenced by the physical and chemical characteristics of the water, and vice versa. Changes in biota can therefore reflect and also influence changes in water quality.

CHLOROPHYLL

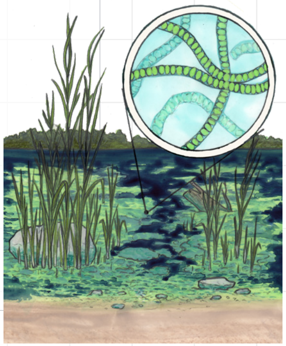
WHAT IS IT?

Chlorophyll is a green pigment found in all green plants and cyanobacteria (blue-green algae). Chlorophyll is essential to photosynthesis, a process where plants convert sunlight into chemical energy.

Along with phosphorus, chlorophyll is often used to estimate ***productivity*** in a water body. Productivity refers to the amount of plant and animal life that a lake or river can support. Low productivity lakes are called *oligotrophic*, while high productivity lakes are called *eutrophic*.

We tend to see algae blooms and associated fish die-offs in lakes that are eutrophic and hypereutrophic.

Algae blooms happen more often in lakes and rivers where human activities contribute to increased nutrients coming into the water (e.g., sewage and agricultural runoff). Algae blooms are also more common in warm temperatures and in still water.



WHY DOES IT MATTER?

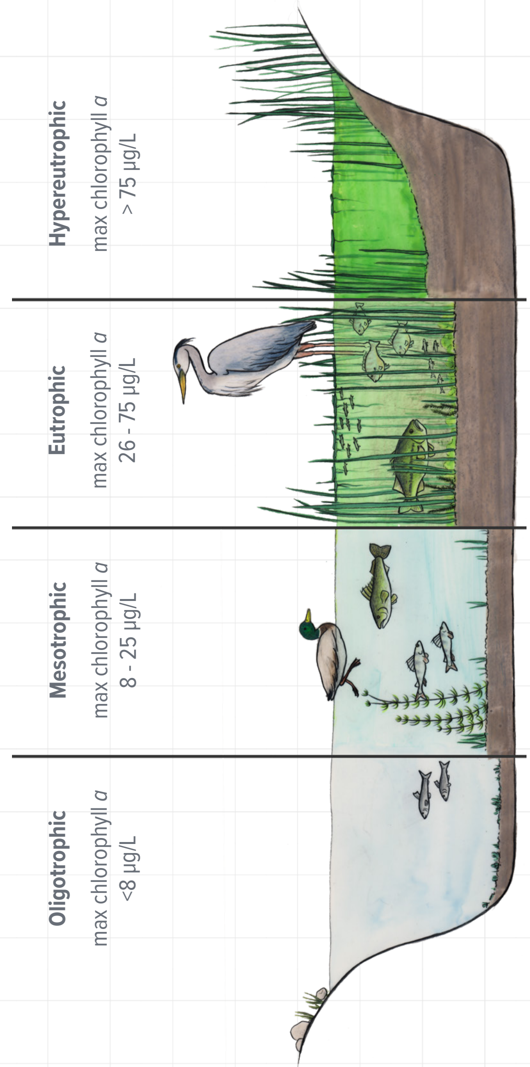
More chlorophyll in lakes and rivers indicates more algae. Algae are important because they form the base of the food chain, but too much algae can be harmful.

Under certain conditions, algae can grow quickly and cause a “bloom” which can cover lakes with green scum or make the water look greener than normal. When algae die, bacteria decompose them and use up oxygen in the water. These low oxygen conditions are harmful to fish and other aquatic life. Certain species of blue-green algae (cyanobacteria) can also produce harmful toxins.

HOW IS IT MEASURED?

Chlorophyll is measured by a specialized sensor. It is typically measured from a water sample sent to the lab, but some field sensors exist. *Chlorophyll a* is a specific type of chlorophyll that is commonly measured.

The amount of chlorophyll in water is usually highest in summer and lowest in winter, so it is important to monitor it in different seasons.



The ***trophic state*** of a water body describes the amount of biological productivity in a water body. ***Eutrophication*** happens when lakes and rivers become enriched by nutrients which spur plant and algae growth.

Some water bodies have naturally high levels of chlorophyll whereas others have naturally low levels of chlorophyll. In general, lakes and rivers in the Arctic tend to have naturally low chlorophyll, but this is not always true. Values over 75 ug/L indicate hypereutrophic conditions that are not healthy.

- **CHLOROPHYLL IS INFLUENCED BY:**
  water temperature, phosphorus, at times nitrogen

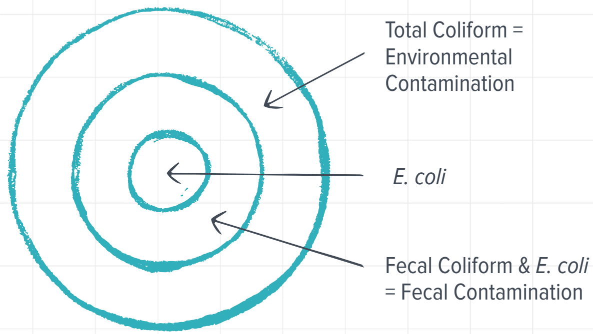
- **CHLOROPHYLL INFLUENCES:**
  dissolved oxygen, organic carbon

COLIFORM BACTERIA

WHAT IS IT?

Coliform bacteria are a type of bacteria mainly found in the intestines of people and warm-blooded animals (and excreted in feces). They are also found in soils. There are different measures of coliform bacteria including *total coliform* (which includes all types), *fecal coliform*, and *Escherichia coli* (*E. coli*), a type of fecal coliform.

Numbers of fecal coliform bacteria (including *E. coli*) in water are influenced by human or animal waste entering the water, such as through farm runoff and poorly treated human sewage. Fecal coliform bacteria can also come from droppings from birds like ducks and geese.



Total coliform is a measure of all types of coliform bacteria, including fecal coliform. *E. coli* is a specific type of fecal coliform bacteria and is of particular concern because some strains (e.g., *E. coli* O157:H7) can make people sick.

WHY DOES IT MATTER?

The detection of fecal coliform bacteria (including *E. coli*) in water indicates recent fecal contamination. This suggests that other fecal pathogens (e.g., parasites and viruses) may be present, which can pose a health risk to people.

The amount of *E. coli* in lakes and rivers is often used to assess the safety of water for recreational purposes such as swimming, boating and fishing. It is also an important measure of drinking water quality.

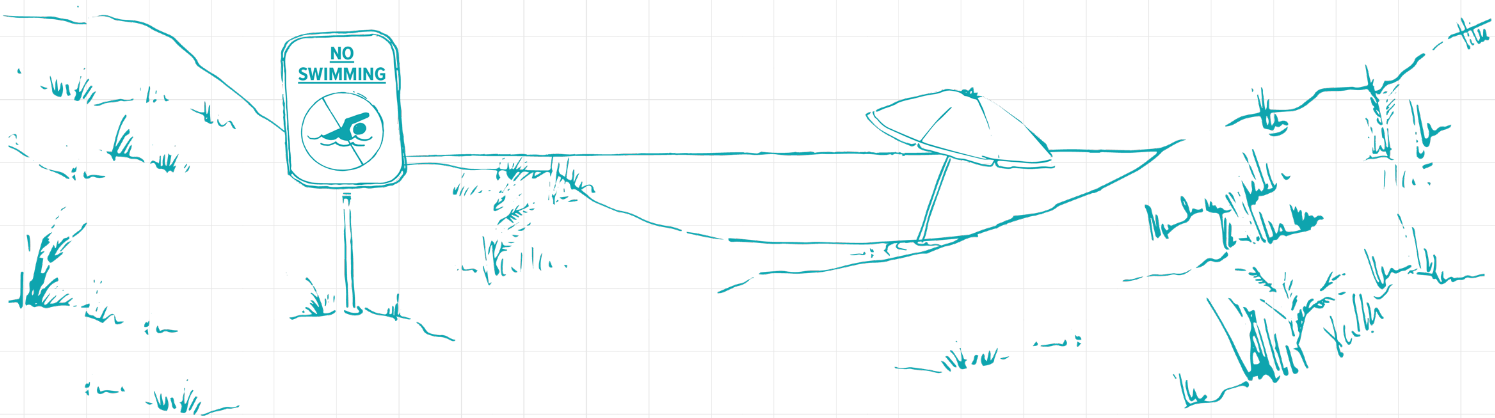
Fecal coliform bacteria typically don't survive more than a few days in a river or lake. If there are infrequent inputs of fecal coliform (e.g., following heavy rains that cause stormwater and agriculture runoff) then we would expect to see high bacteria counts for a few days and low counts the rest of the time.

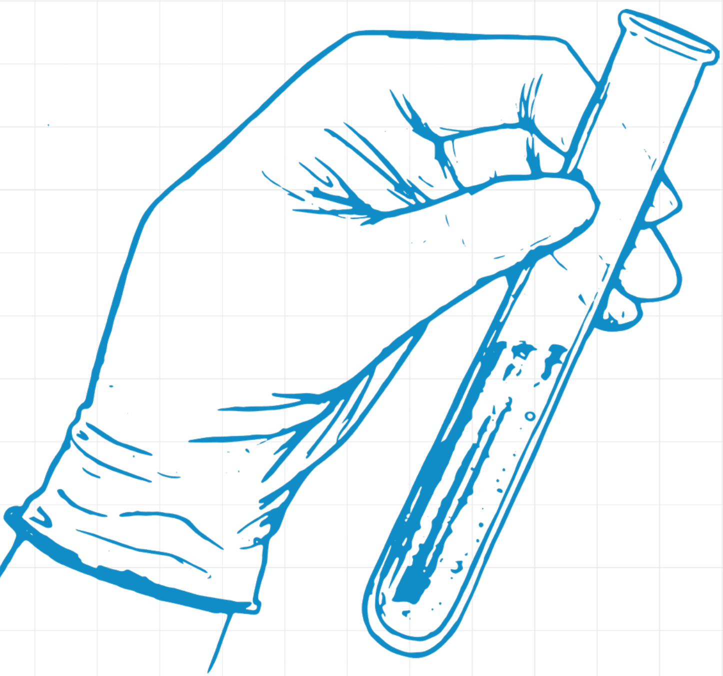
If fecal coliform levels are consistently high, it indicates that the source of contamination is entering the water regularly.

HOW IS IT MEASURED?

Coliform bacteria are measured from a water sample sent to the lab for analysis. Some tests will simply report whether it is present or not, but it is also possible to estimate the number of bacteria by allowing them to grow. The coliform count is often reported as the number of bacterial colonies that grow per 100 millilitres (mL) of water.

Regional recreational water quality guidelines for average *E. coli* abundance vary across Canada, ranging between about 100-200 per 100 mL of water. There are even lower thresholds for drinking water, where no *E. coli* should be detected per 100 mL of water.





PHYSICAL & CHEMICAL

Physical and chemical characteristics of water help shape the nature of aquatic ecosystems. Physical characteristics include things like temperature, pH and water clarity. Chemical substances in water include ions, metals and nutrients, and can occur naturally or may be caused by human activities. Together, physical and chemical characteristics of water influence what can live in rivers and lakes.

CONDUCTIVITY

WHAT IS IT?

Conductivity measures how easily electricity flows through water. Just like metal, water can conduct (transport) electricity. This is because there are salts dissolved in the water. If you have pure water with no salts, conductivity will be zero.

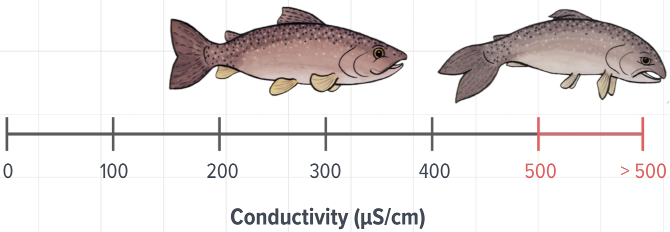
The salts in rivers and lakes come from rocks that get broken down over time. The types of rock and soil in an area will influence the conductivity of the water. Rocks that break down more easily will raise conductivity.

SEASONAL FACTORS

Conductivity often fluctuates seasonally. As water gets warmer, conductivity goes up. Additionally, if lakes do not receive enough rain or stream water, conductivity increases. This is because evaporation takes water away but does not take salts away.

When ice forms on a lake in winter, the water below may also become saltier because salts are not incorporated into the ice. When the snow and ice melts in the spring, conductivity usually goes down because the meltwater dilutes the concentration of salts.

WHY DOES IT MATTER?



Conductivity is an indirect measure of the saltiness of the water. Fish and bugs that live in freshwater cannot tolerate large increases in saltiness because they are not adapted to saline (salty) water, like marine fish are.

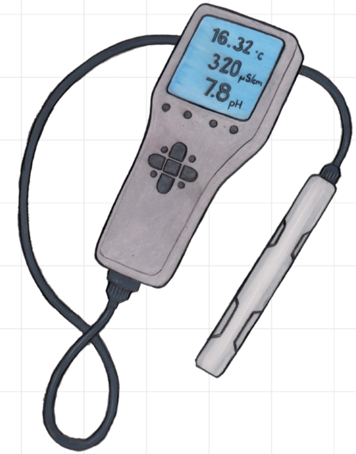
Conductivity in lakes and streams generally ranges between 0 to 200 µS/cm, while in major rivers conductivity may be as high as 1000 µS/cm. Very high conductivity (1000-10,000 µS/cm) is an indicator of saline (salty) conditions.

Each lake and stream tends to have a relatively constant range of conductivity. This can be valuable information to have as a baseline for comparison. Significant changes in conductivity outside normal seasonal ranges could indicate a source of pollution.

For example, sewage entering the water would raise conductivity whereas an oil spill may lower conductivity. In urban areas, winter road salt can be a major source of increased salts in the water, especially during spring melt.

HOW IS IT MEASURED?

Conductivity is best measured directly in the lake or river using a probe with a conductivity sensor. Conductivity is typically measured in microsiemens per centimeter of water (µS/cm). It can also be measured as *specific conductivity* -- a standardized measure that shows what the conductivity value would be at 25°C.



RELATED TO CONDUCTIVITY:
total dissolved solids (TDS) and, to a lesser extent, hardness

CONDUCTIVITY IS INFLUENCED BY:
concentrations of dissolved ions (salts), water temperature

DISSOLVED OXYGEN

WHAT IS IT?

Oxygen from the atmosphere dissolves in the water of rivers and lakes. Fish and other aquatic animals depend on this oxygen to breathe.

DISSOLVED OXYGEN LEVELS DEPEND ON MANY FACTORS:

- Whether water is flowing or still
- Whether there are rocks or other obstacles for water to flow over
- How many plants are in the water
- Water temperature, ice cover, and depth

Dissolved oxygen levels are higher in very cold water compared to very warm water. But if a lake or river has ice cover, oxygen is usually low because air from the atmosphere cannot get in. In the open water season, oxygen levels decrease the deeper you get in a lake.

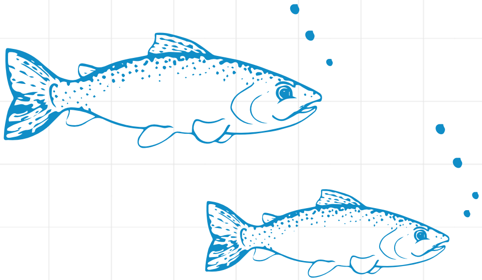
Plants in the water take up carbon dioxide and release oxygen, just like they do on land. But if there are too many plants in the water, all of the oxygen will get used up by the bacteria that decompose them after they die.

WHY DOES IT MATTER?

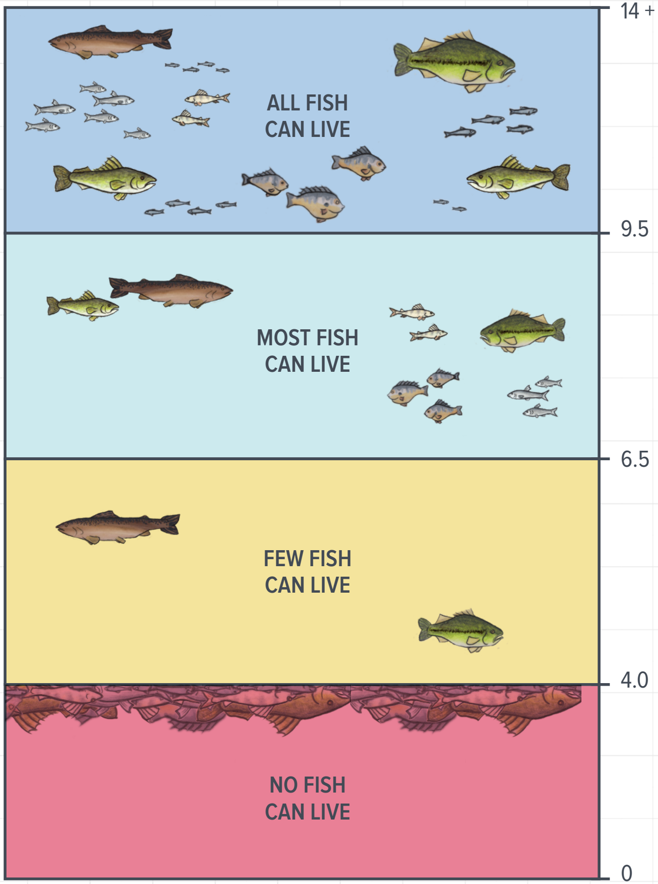
If dissolved oxygen levels are too low, fish and other aquatic animals may suffocate and die. Very low oxygen levels in lakes and rivers happen most often at the end of winter after a long ice-cover period, or at the end of summer when algae growth has peaked and is beginning to degrade.

In polluted systems with too many nutrients, an overgrowth of plants, animals, and bacteria cause the oxygen to be used up quickly, sometimes causing fish to suffocate.

Healthy water should generally have dissolved oxygen concentrations above 6.5-8 mg/L and dissolved oxygen saturation between about 80-120 %.



Dissolved Oxygen (mg/L)



Dissolved oxygen below 5.5mg/L will negatively affect most fish and fish life stages. Each type of fish requires a different amount of dissolved oxygen to live.

HOW IS IT MEASURED?

Dissolved oxygen is best measured directly in the water using a calibrated dissolved oxygen sensor. Dissolved oxygen can be measured in milligrams per litre (mg/L) or as a percentage of the calculated (or expected) amount at saturation, referred to as dissolved oxygen saturation (%DO).

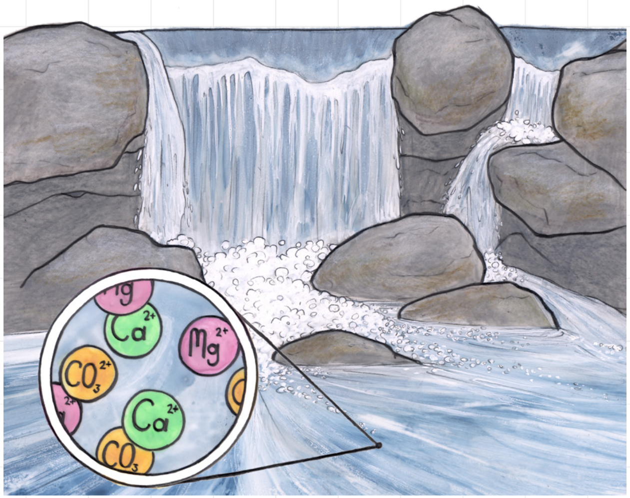
- **DISSOLVED OXYGEN IS INFLUENCED BY:**
  water temperature, algae growth (e.g., chlorophyll)
- **DISSOLVED OXYGEN INFLUENCES:**
  the forms and toxicity of certain metals (e.g. dissolved metals) and concentrations of certain chemical constituents (e.g., sulphide and ammonia)

HARDNESS

WHAT IS IT?

Hardness is a measure of dissolved minerals in water – primarily calcium and magnesium. The types of rocks and minerals in an area will influence the hardness of the water. For example, limestone is rich in calcium and is easily eroded by water.

Other types of rocks do not contain as much magnesium or calcium, and do not erode as easily. Lake and river water in these areas would most likely have low hardness and would be considered “soft”.



The hardness of water in lakes and rivers is heavily influenced by the geology (the types of rocks and minerals) of the watershed.

WHY DOES IT MATTER?

Water hardness is often a concern because it can cause a buildup of solid minerals in water systems and pipes, and because it reduces the effect of soaps and detergents.

However, the concentration of dissolved minerals in water may also help determine the sources of water to a given river or lake. In general, groundwater often has higher hardness than surface waters because it is in close contact with rocks and minerals for long periods of time. Water hardness also reduces the toxicity of some metals to aquatic life.

HOW IS IT MEASURED?

Hardness is measured in the lab from a water sample collected in the field. It is generally reported as a concentration of calcium carbonate equivalents (mg/L $CaCO_3$), although there are many different hardness scales and reporting units.

HARDNESS VALUES:

SOFT:
0-60 mg/L $CaCO_3$

MEDIUM HARD:
61-120 mg/L $CaCO_3$

HARD:
121-180 mg/L $CaCO_3$

VERY HARD:
>180 mg/L $CaCO_3$

HARDNESS IS INFLUENCED BY:
mineral concentrations, especially calcium and magnesium

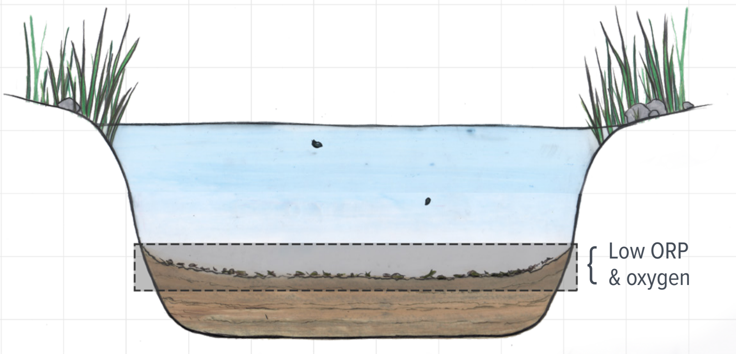
HARDNESS INFLUENCES:
toxicity of certain metals (e.g., cadmium, copper, lead and nickel)

OXIDATION-REDUCTION POTENTIAL (ORP)

WHAT IS IT?

Oxidation-reduction potential (ORP) measures the ability of a lake or river to cleanse itself or breakdown waste products. When ORP is high, there is a lot of oxygen present in the water. This means that bacteria that decompose dead tissue and contaminants can work more efficiently.

In general, the higher the ORP value, the healthier the lake or river is. However, even in healthy lakes and rivers, there is less oxygen (and therefore lower ORP values) as you get closer to the bottom sediments.



Oxygen and ORP decrease quickly within the sediment at the bottom of rivers and lakes. This is because there are many bacteria working here to decompose organic matter, and they use up oxygen in the process.

Certain wetlands can have water with naturally low ORP, especially those containing *Sphagnum moss* (pictured here).

WHY DOES IT MATTER?

ORP depends on the amount of dissolved oxygen in the water, as well as the amount of other elements that function chemically like oxygen (e.g., sulfur, nitrate, iron). When ORP and dissolved oxygen are low there will be lots of dead and decaying material in the water that cannot be cleared or decomposed. Low ORP also influences the form and persistence of certain contaminants, which affects their toxicity to aquatic life. These conditions can negatively impact fish and aquatic bugs.

ORP is often measured in addition to dissolved oxygen because ORP can provide additional information about water quality and degree of pollution, if present.

HOW IS IT MEASURED?

ORP is measured directly in the water using an ORP sensor. ORP is measured in millivolts (mV) and can either be above zero or below zero.

In healthy lakes and rivers, ORP should be relatively high between 300-500 mV. In contrast, certain wetlands can contain water with naturally low ORP.

ORP IS INFLUENCED BY:
dissolved oxygen and other elements that may function chemically like oxygen (e.g., nitrate, sulfur, iron)

ORP INFLUENCES:
the form and toxicity of certain metals

pH

WHAT IS IT?

pH measures the degree to which water is *acidic* (like lemon juice) or *basic* (like bleach or soap). pH is measured on a scale that ranges from 0 (strongly acidic) to 14 (strongly basic). In the middle is 7, where the pH is *neutral* (like in pure water).

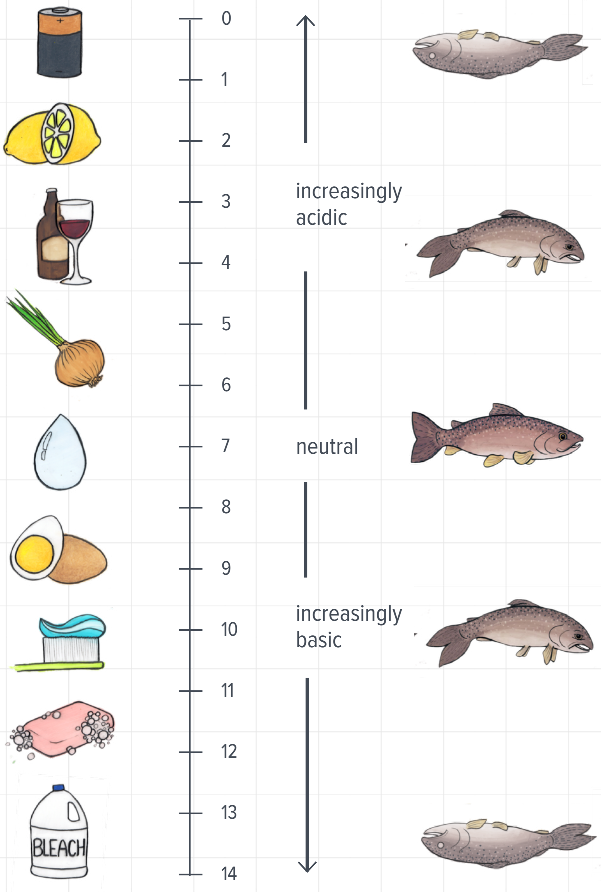
WHY DOES IT MATTER?

pH in freshwater systems is affected by naturally occurring organic acids or by impacts from human activities, such as ***acid rain*** and ***acid rock drainage***. When water is more acidic (has a lower pH) it can make certain chemicals and metals more toxic than normal. This is because acid waters make these elements more soluble – that is, they become more easily dissolved in the water and in this way become more biologically available to fish and other organisms.

Acid rain occurs when certain pollutants in the air (sulfur dioxide and nitrogen oxides) react with water to form acids. These acids are then deposited to the land, lakes, and rivers by rain and snow.

Acid rock drainage is a common problem in and around mines. Acidic conditions arise when sulphur-rich rocks are exposed to air and water (e.g. in tailings and waste rock piles). The acid often dissolves minerals, including metals, from the rock and both the acid and the metals can drain into waterways.

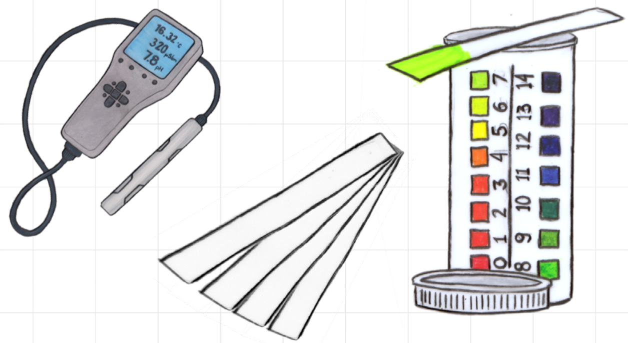
pH Scale



> Most North American rivers, lakes and streams fall within the range of pH 6.5-8.2. National guidelines recommend pH of 6.5-9.0 for the protection of aquatic life in freshwaters.
>
> Most fish prefer to live in water that ranges in pH from around 6.4 to 8.4. Fish eggs grow and survive best at a narrower range of pH; from 6.0-7.2.

HOW IS IT MEASURED?

pH can be assessed using pH strips that change colour based on how acidic or basic the water is. The colour is evaluated against a guide to determine the approximate pH range of the water. pH can also be measured directly in a lake or river using a water quality meter with a pH sensor. Before use, this sensor is calibrated using standard solutions of known pH (typically pH 4, 7 and 10).



- **RELATED TO PH:**
  alkalinity, oxidation-reduction potential (ORP)
- **PH IS INFLUENCED BY:**
  background water chemistry - especially carbonate, bicarbonate and naturally-occurring acids
- **PH INFLUENCES:**
  dissolved concentrations of many metals and metalloids in water

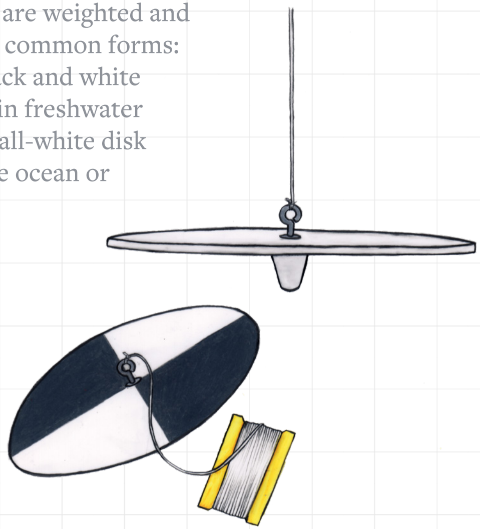
SECCHI DEPTH

WHAT IS IT?

Secchi depth refers to the depth at which a disk lowered into the water can no longer be seen from the surface. Secchi depth is related to water clarity and is a measure of how deep light can penetrate into the water.

This depth can range from a few centimetres to several metres and is influenced by the amount of suspended solids (e.g., silt, algae), or if the water has a lot of colour (e.g., brown "tea-stained" water, common in boreal lakes).

Secchi disks are weighted and come in two common forms: a smaller black and white disk for use in freshwater and a larger all-white disk for use in the ocean or great lakes.



WHY DOES IT MATTER?

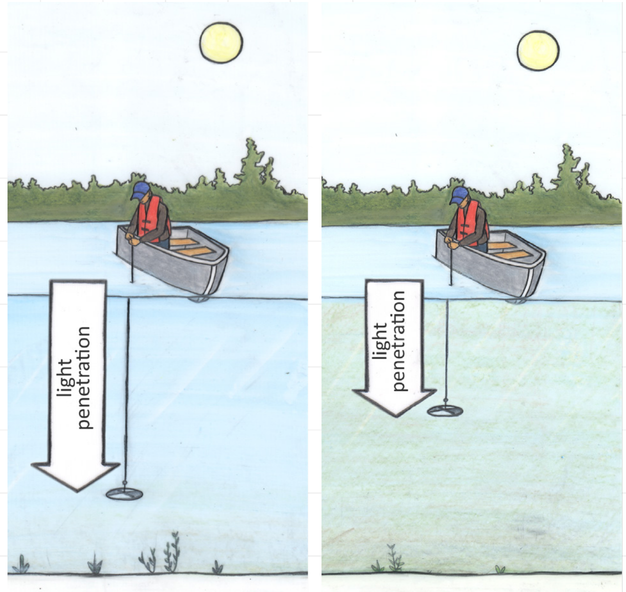
The availability of light underwater is important because algae and other aquatic plants need light for photosynthesis. Therefore, the productivity of a lake (how much plant and animal life it can support) is in part dependent on the clarity of the water.

Because water clarity is also affected by the amount of algae, Secchi depth can in turn be an indicator of lake productivity, especially if measurements are taken at times of the year when algae are most abundant.

HOW IS IT MEASURED?

Secchi depth is measured as the depth at which the Secchi disk is no longer visible when lowered into water from the shaded side of a boat, and the point at which it reappears after raising it. Often a few Secchi depth measurements are made and the average is reported.

Secchi depth has been measured in lakes and oceans for over a hundred years. While there are other more technologically advanced ways to measure water clarity, Secchi depth is a standard, simple and inexpensive method, and is still in frequent use today.



Penetration of light through water will be reduced if there are abundant suspended solids (e.g., silt) or algae in the water, or if the water has high-colour (e.g., brown "tea-stained" water, common in boreal lakes).

RELATED TO SECCHI DEPTH:
turbidity

SECCHI DEPTH IS INFLUENCED BY:
chlorophyll, total suspended solids (TSS), water colour

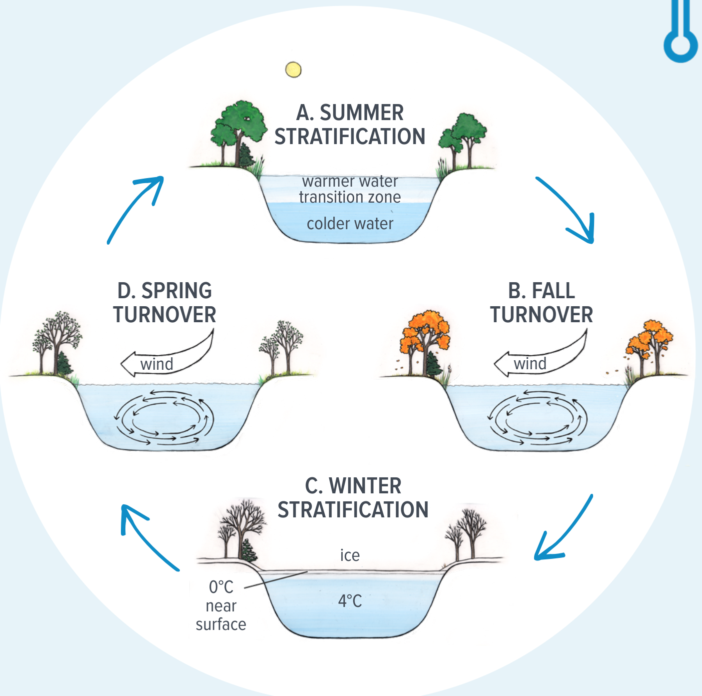
TEMPERATURE

WHAT IS IT?

Temperature is a measure of how warm or cold the water is. This influences what types of fish and bugs are present in a river or lake. Temperature also influences how water mixes in a lake.

Sometimes lakes can have distinct layers of water with different temperatures. This is called ***thermal stratification***.

Thermal stratification in lakes typically follows a seasonal pattern. However, lakes of different sizes and in different climatic regions will have varying levels of mixing. For example, shallower lakes do not stratify in the summer. In colder climates, some lakes may not warm above 4°C and will only mix once in the summer; others may remain covered with ice year-round.



A. As the surface waters of a lake warm in the summer, they become underlain by a colder, denser layer of water. Once this occurs, there is little mixing between the warm surface layer on the top and the cooler layer below.

B. In the fall, surface waters begin to cool and become more dense and heavy. This causes the water to mix through the depth of the lake, referred to as "fall turnover".

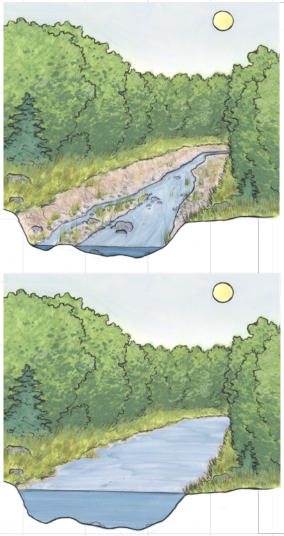
C. As ice begins to form on the lake, the lake may stratify again. However, this time the surface waters (at or near freezing, 0°C) are underlain by slightly warmer water (about 4°C). This happens because water is most dense at 4°C.

D. In the spring as the ice cover breaks up, the water temperature becomes more uniform from the surface to bottom. This causes another period of mixing referred to as "spring turnover". Then as the water at the top begins to warm even more, these stratification and mixing cycles are repeated.

WHY DOES IT MATTER?

Water temperature is important because it can determine where certain plants and animals can live. For example, some fish can only live in colder water and when water temperatures increase in the summer, these fish will move to deeper areas where the water is still cold. Some plants and animals will become dormant if water temperatures drop very low but will grow very quickly in the summer when water temperatures increase.

Temperature also has an important influence on the amount of dissolved oxygen in water, since colder water can hold more oxygen than warm water.

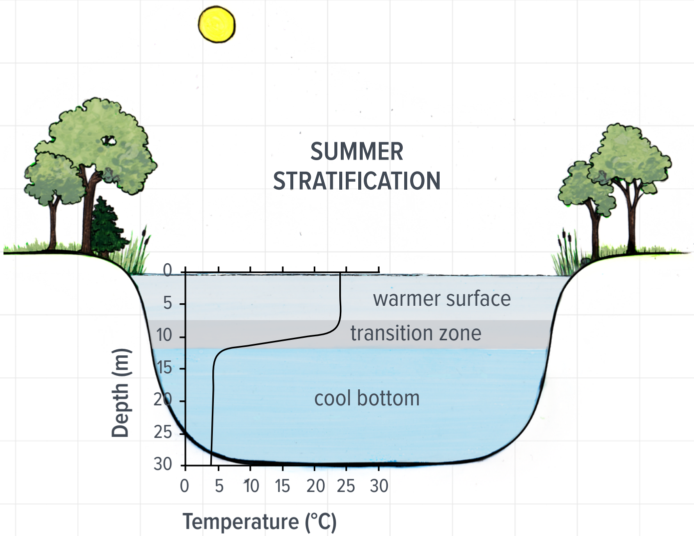


Low vs high flow conditions

Smaller, shallower lakes and streams change temperature more quickly than large lakes and rivers since there is less water to be heated or cooled. This means low flow levels in a river can have an impact on water temperatures, especially during warm, dry periods. In some rivers and streams, upwelling groundwater provides areas of cooler water for fish.

HOW IS IT MEASURED?

Water temperature is best measured directly in the water – either by thermometer or using a probe with a temperature sensor. In lakes, water temperature should be taken at several depths since lake water does not always mix completely from top to bottom.



WATER TEMPERATURE IS INFLUENCED BY:
water clarity (e.g., Secchi depth, water colour), water levels/ flow

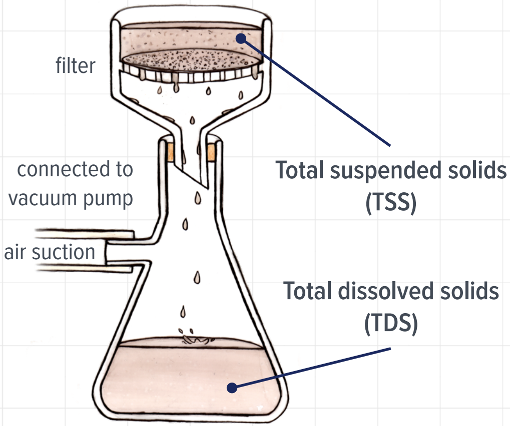
WATER TEMPERATURE INFLUENCES:
dissolved oxygen, productivity measures

TOTAL SUSPENDED SOLIDS (TSS) & TOTAL DISSOLVED SOLIDS (TDS)

WHAT IS IT?

TSS and TDS measure the amount of particulate matter (tiny pieces of things) floating in water. In lakes and rivers this can include particles from algae, other organic matter, silt and clay, and other inorganic substances (such as minerals, salts and metals).

These particles, or 'solids', can be divided into two types by passing the water through a filter. The particles that are large enough to be held back by the filter are called *total suspended solids* (TSS), while the particles that pass through the filter are called *total dissolved solids* (TDS).

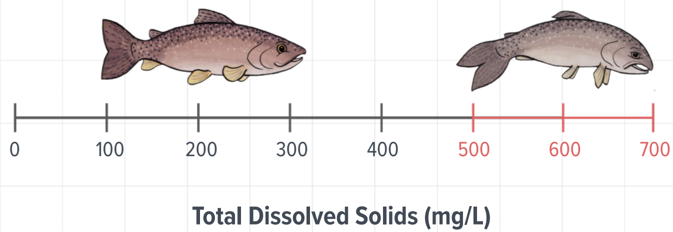


WHY DOES IT MATTER?

Total suspended solids (TSS) values are often related to the turbidity (cloudiness) of water. If TSS is high and the water is murky then light from the sun will not travel well through the water, making it difficult for plants and algae to grow.

This, in turn, can reduce productivity (the amount of plant and animal life that a river or lake can support) and oxygen generation. Lots of soil and silt in the water can also clog fish gills and, if it settles to the bottom, bury fish eggs.

Total dissolved solids (TDS) include dissolved minerals and salts in the water. As a result, TDS is often closely related to conductivity, salinity, alkalinity, and hardness measures. Most freshwater fish and bugs cannot tolerate high TDS because they are not adapted to saline (salty) water, like marine fish are.



HOW IS IT MEASURED?

TDS and TSS are usually measured from a water sample in the lab, because it is necessary to filter the sample. The size of the particles that don't pass through the filter (and are therefore considered to be TSS) depends on the specific filter used but may range in size between about 0.5 to 2 micrometres (μm). Measures of TDS and TSS are reported as a concentration (e.g., mg/L).

- **RELATED TO TOTAL SUSPENDED SOLIDS:** turbidity, chlorophyll, water clarity (e.g., Secchi depth, water colour)
- **RELATED TO TOTAL DISSOLVED SOLIDS:** conductivity, salinity, alkalinity and hardness, metals concentrations

TURBIDITY

WHAT IS IT?

Turbidity is a measure of water clarity. It describes the amount of light scattered or blocked by particles floating in the water. These particles cause the water to look cloudy or murky. In rivers and lakes, these particles can come from algae and other plant material, soils, silt and clay, and other substances in the water like salts, minerals and metals.

Increased turbidity in lakes and rivers can be caused by heavy rains that wash soil and other materials into the water, erosion, snowmelt, windstorms, or fires. It can also be caused by activities such as logging, mining, agriculture, or dredging.

SEASONAL FACTORS

Turbidity can vary throughout the seasons. For example, large rivers can be very low in turbidity during the winter below the ice, but turbidity usually increases dramatically during snowmelt when water carries soil off the land into rivers and streams.

Lakes can also become more turbid in the summer as algae and small animals (e.g., zooplankton) grow quickly and increase their activity.

WHY DOES IT MATTER?

High turbidity can have negative impacts on fish and other aquatic life. Algae and other aquatic plants need light to grow and high turbidity will decrease underwater light availability.

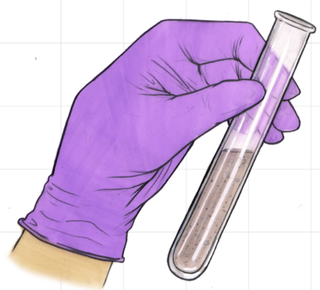
If there is a lot of floating algae in a lake, this can block out light that other plants need to grow. High turbidity due to algae can also affect fish because when large amounts of algae die, oxygen is used up to decompose them, leaving less oxygen for the fish.

High turbidity can also make it difficult for fish to see and catch prey. Large amounts of suspended soils or clay may clog the gills of fish and bury and kill fish eggs. Pollutants and harmful bacteria may also be attached to particles that cause turbidity.

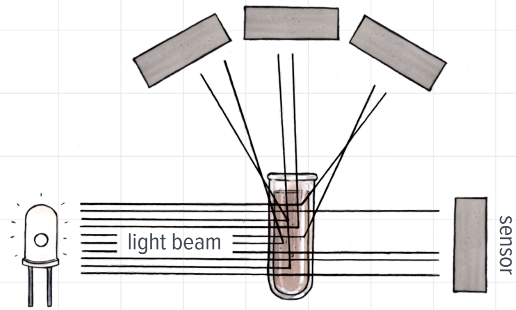
HOW IS IT MEASURED?

Turbidity is best measured on site directly in the water but can also be measured in a sample sent to the lab. A turbidity sensor shines light into the water and measures how quickly that light is scattered by particles in the water. The results are reported in units called Nephelometric Turbidity Units (NTU).

Turbidity may also be measured using slightly different methods and units, such as Formazin Turbidity Units (FTU).

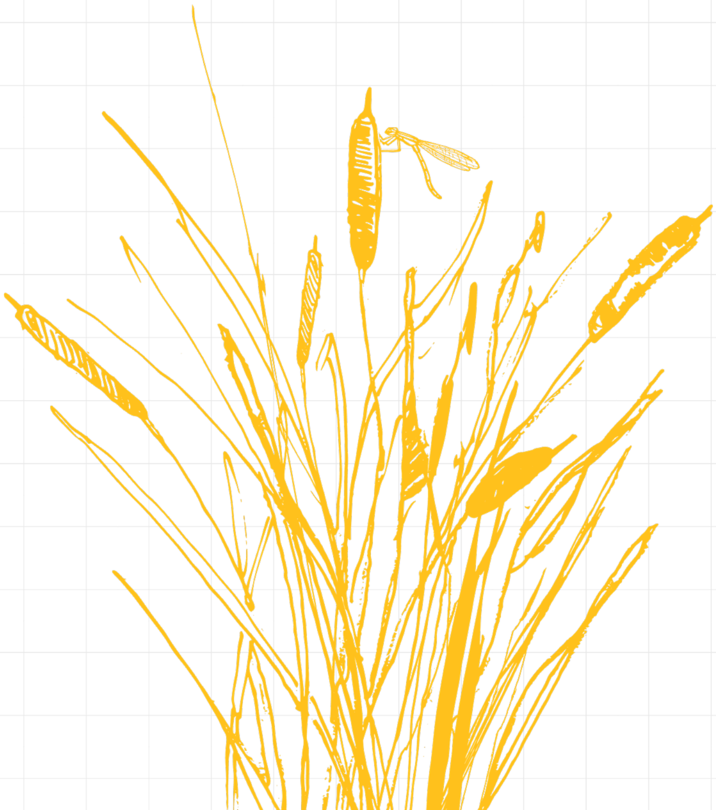


Turbidity can vary widely between each river and lake, and also over time. For this reason, most government guidelines provide a maximum allowed increase from background levels for each water body. Turbidity values less than 10 NTU are considered low, a value of 50 NTU would be considered moderately turbid, and very high turbidity values can be more than 100 NTU.



RELATED TO TURBIDITY:
Secchi depth, water clarity

TURBIDITY IS INFLUENCED BY:
chlorophyll, total suspended solids (TSS), water colour



NUTRIENTS

Nutrients are a category of chemical characteristics that can be measured in water. The primary nutrients in aquatic ecosystems are phosphorus, nitrogen and carbon. Nutrients are important because they are essential for the things that live in water, especially plants and bacteria. However, excessive nutrients can result in poor water quality conditions.

PHOSPHORUS

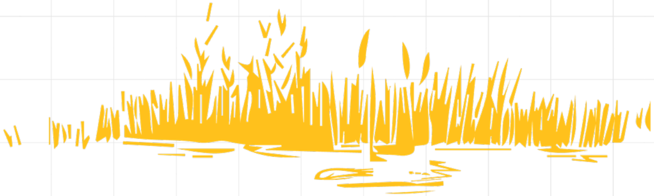
WHAT IS IT?

Phosphorus is an important nutrient for plant growth. In lakes and streams, phosphorus can be dissolved in the water, attached to particles floating in the water and found in the bodies of all living organisms.

Different forms of phosphorus include *total phosphorus* (a measure which includes all the different forms), *orthophosphate* (PO_4) (also called *phosphate*) and the related measure *soluble reactive phosphorus*.

Orthophosphate (or phosphate) is the most ***bioavailable*** form of phosphorus, meaning it is most easily used and taken up by organisms that live in the water.

Things like sewage, agricultural runoff and fertilizers can contribute to higher levels of phosphorus in water bodies. Phosphorus can also come from erosion of rocks and soils and from decaying organic material.



WHY DOES IT MATTER?

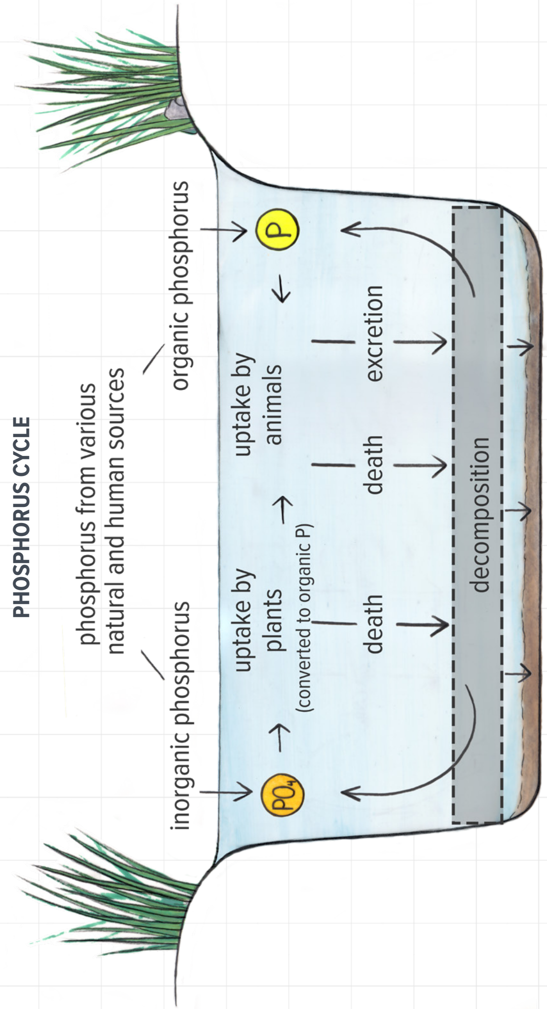
Algae and aquatic plants need phosphorus to grow. However, there doesn't need to be a lot of available phosphorus to support normal growth in aquatic ecosystems.

In lakes and streams that receive extra phosphorus, algae and plant growth can increase to the point that it causes problems, like algae blooms, reduced oxygen levels and fish die-offs.

Phosphorus entering a lake may eventually get deposited in the sediments at the bottom. This phosphorus can then get re-released into water for many years to come (referred to as internal loading). For this reason, it can take several years of reducing phosphorus inputs to a lake before we see a reduction in harmful algae blooms.

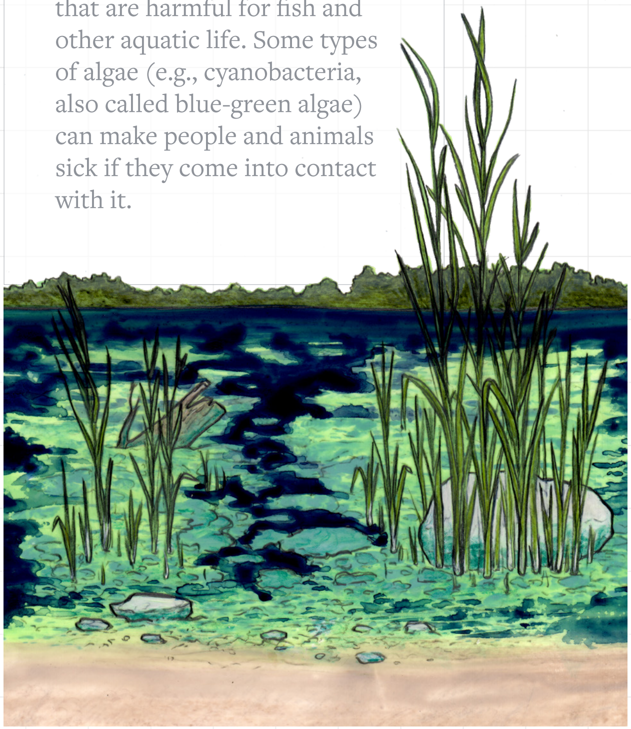
> ***Phosphorus loading*** refers to the amount of phosphorus entering a lake or a river over a period of time, like a year. It is important to measure and manage phosphorus loads to ensure that lakes and waterways can function as good habitat for the fish, bugs and other organisms that live there.

Increased phosphorus loading contributes to ***eutrophication*** (see p.17). Eutrophication happens when a body of water becomes overly enriched with nutrients, often due to runoff from the land. This leads to excessive algae growth, or algae blooms.



Once phosphorus enters a lake or stream it is often contained in a closed loop.

Too much phosphorus in water can cause harmful algae blooms. When bacteria consume decaying algae, they use up oxygen in the water causing low oxygen conditions that are harmful for fish and other aquatic life. Some types of algae (e.g., cyanobacteria, also called blue-green algae) can make people and animals sick if they come into contact with it.



HOW IS IT MEASURED?

Phosphorus is measured from a water sample sent to the lab. The water sample may or may not be filtered before analysis. This determines, in part, what form of phosphorus is being measured (e.g., *particulate phosphorus* is that portion of the sample that is held back by a filter) so it is important to record and report this information with the results.

Different forms of phosphorus behave differently and can have different impacts on water quality, so it is important to know what form of phosphorus is being measured.

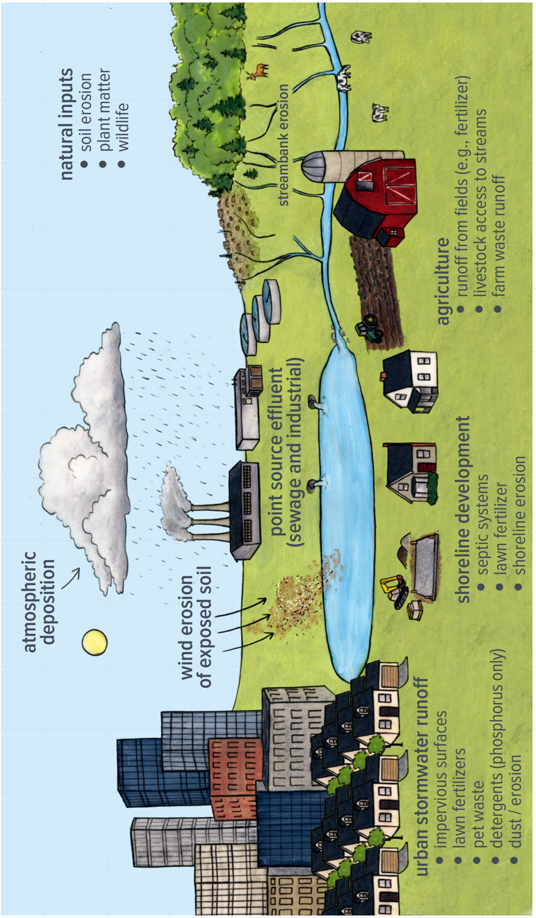
Some forms of phosphorus can also be estimated using test strips that change colour when placed in the water. The colour is evaluated against a guide to determine the approximate phosphorus concentrations.

The concentration of total phosphorus in most surface waters that are not significantly affected by human activity ranges from about 10-50 µg/L, but this can vary.

RELATED TO PHOSPHORUS:
total suspended solids (TSS), water colour, iron (iron can join up with phosphorus in the water and cause it to settle in sediment at the bottom)

PHOSPHORUS INFLUENCES:
chlorophyll

SOURCES OF PHOSPHORUS AND NITROGEN



Human activity has far-reaching impacts on the concentration of phosphorus and nitrogen in lakes and streams.

NITROGEN

WHAT IS IT?

Nitrogen, like phosphorus, is an important nutrient for plant growth. In rivers and lakes, nitrogen can be dissolved in the water, attached to particles floating in the water and found in the bodies of all living organisms.

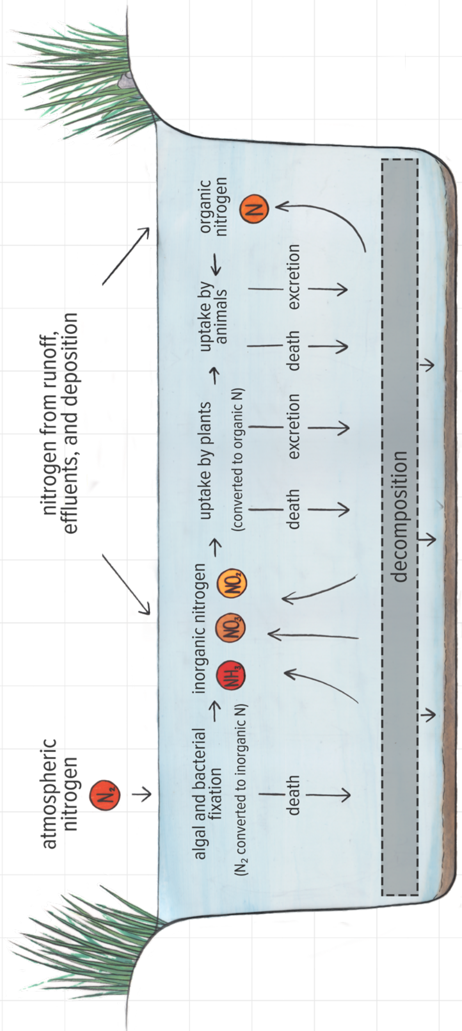
Forms of nitrogen in freshwater systems include inorganic nitrogen: *nitrate* (NO_3), *nitrite* (NO_2), *ammonia* (NH_3) and *ammonium* (NH_4). These inorganic forms of nitrogen are the most ***bioavailable***, meaning they are most easily used and taken up by organisms that live in the water. Organic nitrogen is another form of nitrogen. *Kjeldahl nitrogen* includes ammonia, ammonium and organic nitrogen together.

WHY DOES IT MATTER?

High concentrations of certain forms of nitrogen – including nitrate, and especially nitrite and ammonia – can be toxic to the organisms that live in the water. The toxicity of ammonia varies with pH and water temperature.

Nitrogen may also contribute to excess algae growth. However, research has found that in most cases reducing nitrogen inputs to a lake has little impact on algae blooms when phosphorus inputs continue. In estuaries, the role of nitrogen as a plant nutrient has been found to be more important, while in northern lakes and in some river systems, both phosphorus and nitrogen can act together as important plant nutrients.

NITROGEN CYCLE



Nitrogen is converted into different forms as it cycles through aquatic ecosystems.

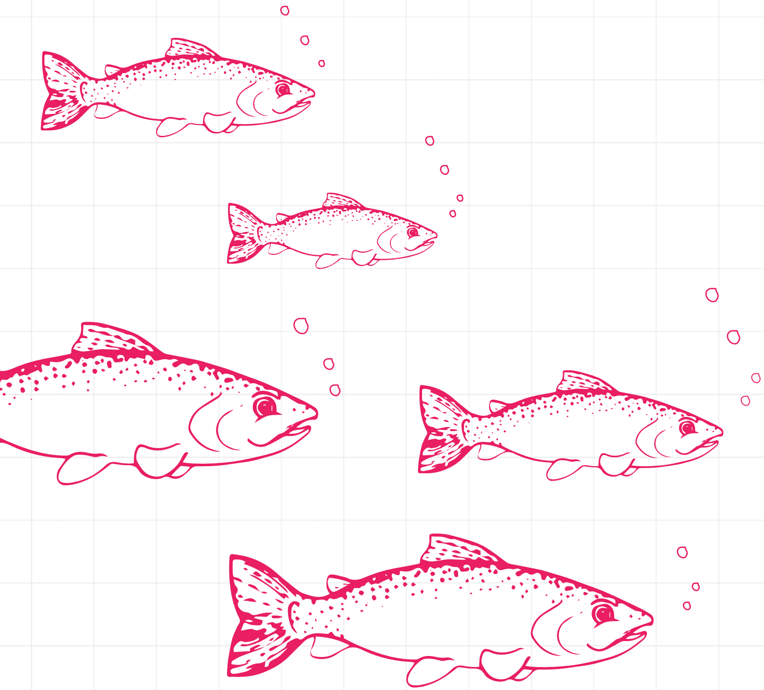
HOW IS IT MEASURED?

Nitrogen is measured from a water sample sent to the lab. The sample may or may not be filtered before analysis. It is important to know what form of nitrogen is being measured, because the more bioavailable inorganic forms (nitrate, nitrite and ammonia/ammonium) behave differently and have different impacts on water quality compared to organic forms.

Naturally occurring nitrate (NO_3) concentrations in lakes and streams are typically less than 4 mg/L, and the concentration of nitrite (NO_2) is generally much lower. The concentration of ammonia (NH_3) in natural waters is generally less than 0.1 mg/L.

RELATED TO NITROGEN:
water colour, total suspended solids (TSS)

NITROGEN INFLUENCES:
chlorophyll



METALS

Metals are a diverse group of elements that can occur naturally in water or be contributed to water from human activities. Some of these elements are required in very small (trace) amounts by things that live in water, but at higher concentrations they can be toxic. Some metals are toxic to living things in any amount, like mercury. Metals do not degrade, but they can change form and move between water and sediments in aquatic systems.

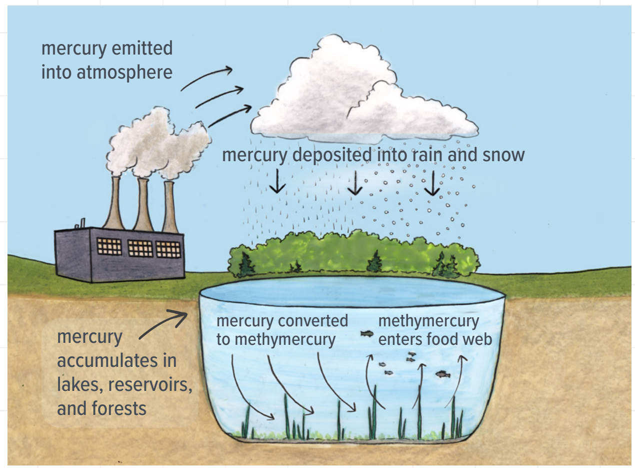
MERCURY

WHAT IS IT?

Mercury is a metal that is toxic and extremely persistent in the environment. Mercury is released naturally through weathering of rocks, forest fires, and volcanic activity. But human activity has contributed significantly to the amount of mercury in the environment. Coal-burning power plants, waste incineration, metal mining, and smelting all release mercury into the atmosphere.

In vapour form, mercury can travel long distances through the air before it is deposited on land and in water. Mercury in the atmosphere exists mostly as *elemental mercury*, one of its less-toxic forms. However, it can be converted to other forms once deposited onto the landscape.

MERCURY PATHWAYS IN THE ENVIRONMENT

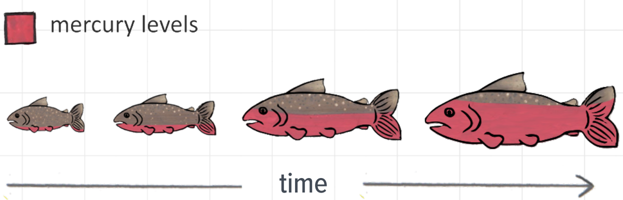


WHY DOES IT MATTER?

Bacteria convert mercury to *methylmercury*, a more bioavailable and highly toxic form of mercury. This often happens in waters where minimal oxygen is present such as at the bottom of lakes and in wetlands, or where soils and other organic material become submerged (e.g., at newly created hydroelectric dam reservoirs).

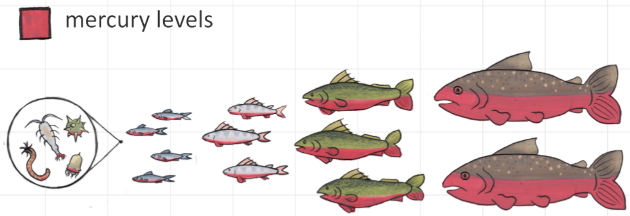
Once methylmercury is present in water bodies, it is easily absorbed by small aquatic organisms and fish. Since methylmercury does not break down in these organisms, it accumulates in their tissues over time and this is referred to as ***bioaccumulation***.

BIOACCUMULATION



Methylmercury concentrations also progressively increase up the food chain in a process called ***biomagnification***. This happens when large predatory fish eat smaller fish that contain methylmercury, and then birds and mammals (including humans) in turn eat these larger fish. The toxic effects of mercury primarily target the nervous systems (brain and nerves) of people and animals.

BIOMAGNIFICATION



Larger predatory fish consume many smaller fish, accumulating methylmercury in their tissues. The older and larger the fish, the greater the potential for higher mercury concentrations.

HOW IS IT MEASURED?

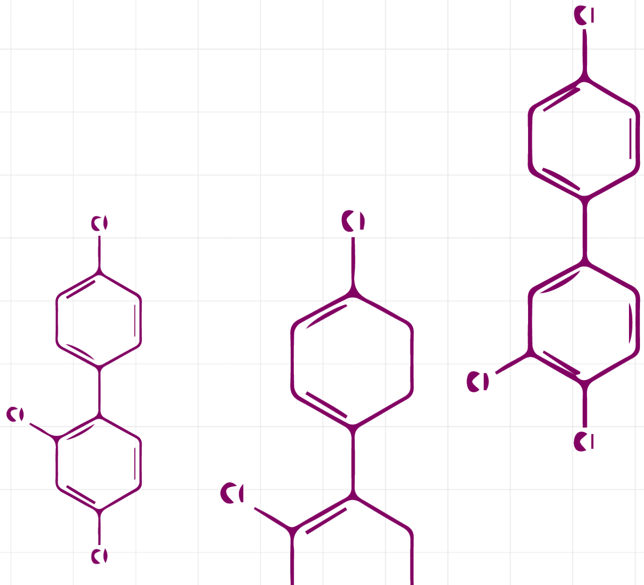
Mercury and methylmercury samples are collected in the field in glass or specially coated plastic bottles, which are then sent to a lab for analysis. Specific procedures are used when collecting the sample to prevent contamination, which can easily occur.

A ***field-blank sample*** is also often taken, where a bottle filled with clean distilled water will go through all the steps as the others but will not be used to collect an actual sample. Analysis of this blank sample helps the lab determine if mercury contamination was present apart from the water samples taken. Mercury and methylmercury concentrations are often reported in very small units, such as nanograms per litre (ng/L).

National guidelines recommend less than 0.026 µg/L of mercury in water for the protection of aquatic life. The guideline for methylmercury is even lower, at 0.004 µg/L.

ORGANIC POLLUTANTS

Organic pollutants are another category of chemical characteristics that can be measured in water and include things like hydrocarbons, polychlorinated biphenyls (PCBs), and many types of pesticides. Organic pollutants can be harmful to aquatic ecosystems and some types are persistent in the environment for a long time. These are referred to as persistent organic pollutants (POPs).



PESTICIDES

WHAT ARE THEY?

Pesticides are substances used to control organisms that are considered pests, such as insects, bacteria, fungi, plants and animals. Pesticides are designed to deter or harm the organisms they target, but they often have negative impacts on other organisms as well, including humans.

Many pesticides that are in widespread use are ***organic compounds***, and these are often grouped into categories like *organochlorines*, *organophosphates* and *carbamates*. Organochlorines include the well-known pesticide DDT (dichlorodiphenyltrichloroethane), which was widely used until the 1960s and 1970s, when its use was phased out.

Chemical compounds can be organic or inorganic. This depends on what ***elements*** they are made of. Elements are substances that cannot be broken down into simpler substances. There are 118 known chemical elements and all matter on earth is made up of some combination of them.

Organic compounds are substances made up mostly of hydrogen and carbon (or hydrocarbon). **Inorganic compounds** *do not* contain hydrocarbon, and most do not contain carbon.

WHY DO THEY MATTER?

By their very nature, pesticides negatively impact organisms. Certain pesticides have toxic effects only at very high concentrations, while others are toxic at very low concentrations. The effect they have on plants, animals and humans varies depending on the type of pesticide.

Organochlorine pesticides are generally persistent in the environment and they can bioaccumulate (build up in the tissues) in organisms. Organophosphorus pesticides are less persistent.

Some organochlorine pesticides that are persistent in the environment can end up in remote rivers and lakes far away from areas where pesticides are being used. This happens when these pesticides evaporate from soils in warm weather and travel through the atmosphere on wind currents. When temperatures cool, they fall back to the ground in rain or snow.

In rivers and lakes, many organochlorine pesticides tend to accumulate primarily in the sediments and in the tissue of some aquatic organisms, rather than in the water. Because of this, national guidelines for these types of pesticides apply to how much is present in sediments and biological tissues. In contrast, other pesticides dissolve easily in water and these have guidelines that apply to how much is present in the water.

Organic compound pesticides with national guidelines set by the Canadian Council of Ministers of the Environment (CCME).

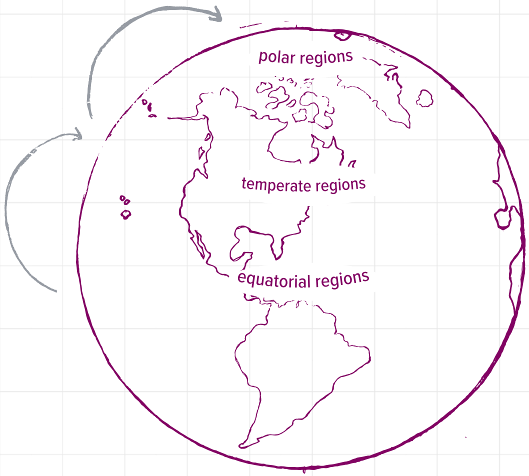
PESTICIDE GROUP	EXAMPLES
Organochlorine	Aldrin*, Chlordane*, DDT* (and its metabolites DDE and DDD), Dieldrin*, Endosulfan, Endrin*, Heptachlor*, Lindane, Metolachlor, Permethrin, Toxaphene*
Organophosphorus (includes organophosphates)	Chlorpyrifos, Dimethoate, Glyphosate
Carbamates	IPBC, Aldicarb, Carbaryl, Carbofuran, Triallate
Triazine	Atrazine, Cyanazine, Metribuzin, Simazine
Benzonitrile	Bromoxynil
Dinitroaniline	Trifluralin
Aromatic Carboxylic Acid	Dicamba
Other Organic Pesticides	Bromacil, Chlorothalonil, Deltamethrin, Diclofop-methyl, DDAC, Dinoseb, Linuron, MCPA, Phenoxy herbicides, Picloram, Tebuthiuron

* These pesticides do not have applicable CCME water guidelines, but do have sediment and/or tissue guidelines.

HOW ARE THEY MEASURED?

In aquatic ecosystems, pesticide concentrations can be measured in the water, in sediment and in the tissues of aquatic organisms like fish. Samples are sent to a lab for analysis.

GLOBAL DISTILLATION



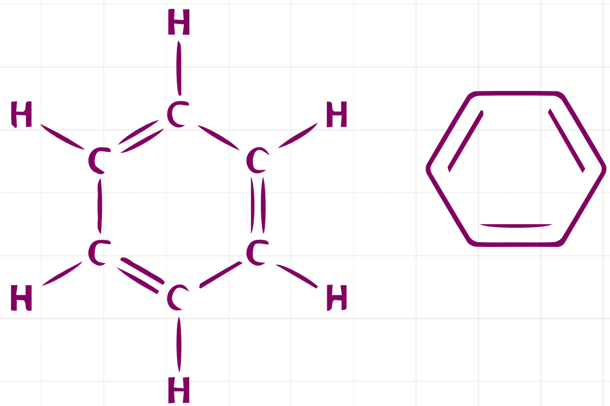
Persistent organic pollutants (POPs) are transported from warmer regions to colder regions through a process called global distillation (also described as the grasshopper effect). POPs evaporate more readily in warmer environments and travel on wind currents before being deposited back to the land and water in cooler environments. This keeps happening until they arrive where temperatures are not warm enough to cause further evaporation. This explains why relatively high concentrations of these pollutants have been found in cold polar regions and on mountain tops.

HYDROCARBONS

WHAT ARE THEY?

Hydrocarbons are a diverse group of organic compounds made up of hydrogen and carbon atoms. Hydrocarbons are formed from very old degraded algae, plants and other biological matter. Hydrocarbons can be gases, liquids and solids, and are generally used as a combustible fuel source.

Crude oil is a complex mixture of hydrocarbons and other constituents (like metals) that can be processed to produce various fuels, solvents, and polymers (or plastics), among other products.



The chemical structure of a benzene ring (the structure on the right is a shorthand version). The benzene ring is present in all BTEX and PAH hydrocarbons.

Hydrocarbons with applicable Canadian Council of Ministers of the Environment (CCME) environmental guidelines.

HYDROCARBON GROUPS	CONSTITUENTS WITH CCME GUIDELINES (WATER AND SEDIMENT)
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes (soil only)
Polycyclic Aromatic Hydrocarbons (PAHs) or Poly-cyclic Aromatic Compounds (PACs)	2-Methylnapthalene (sediment only), Acenaphthene, Acenaphthylene (sediment only), Acridine (water only), Anthracene, Benz(a)anthracene, Benzo(a) pyrene, Chrysene (sediment only), Dibenz(a,h) anthracene (sediment only), Fluoranthene, Fluorene, Naphthalene, Phenanthrene, Pyrene, Quinoline (water only)

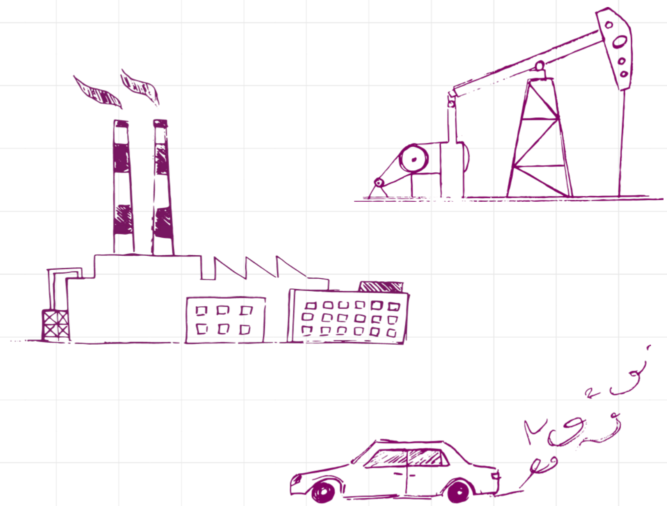
Hydrocarbons behave differently in the environment depending on their structure.

BTEX hydrocarbons dissolve easily in water. However, they are not very persistent over time in part because they evaporate so easily. Despite this, BTEX substances can persist in aquatic ecosystems for days or weeks, and can have negative impacts on the organisms that live in the water.

PAHs are more persistent in aquatic ecosystems, and accumulate in sediments and in some organisms. PAHs can easily attach to particles in the air, so they can be transported through the air and deposited in locations far away from their source.

Polycyclic Aromatic Hydrocarbons (PAHs) are generally released from the combustion of things like gasoline and diesel in engines, oil, coal, wood, and tobacco. They can also be released in the environment through effluents, oil spills and landfill seepage.

BTEX hydrocarbons (benzene, toluene, ethylbenzene, and xylenes) are constituents of gasoline and crude oil, and are used as solvents and to manufacture many different products (e.g., plastic, pesticides, and pharmaceuticals). BTEX are released to the air from the combustion of petroleum fuels especially in vehicle exhaust, and evaporation of solvents. They are released to water and soil through leakage from underground fuel storage tanks, spills, and pesticide application. There are also some natural sources of BTEX as well (e.g., volcanoes, forest fires).



WHY DO THEY MATTER?

Hydrocarbons can be harmful to aquatic ecosystems and to humans. BTEX hydrocarbons can be toxic to aquatic life if present in sufficiently high concentrations. Benzene is carcinogenic (cancer causing) in humans, and toluene is toxic to the nervous system.

Several PAHs are considered probable or possible human carcinogens and have been found to cause certain cancers, mutations and birth defects in fish and other animals.

HOW ARE THEY MEASURED?

In aquatic ecosystems, BTEX and PAHs can be measured in water or sediments. Some can also be measured in the tissues of organisms like fish. Hydrocarbon samples must be submitted to a lab for analysis.

BTEX hydrocarbon results are usually reported individually as benzene, toluene, ethylbenzene and xylenes. There are many different PAH compounds and they can be reported individually, or grouped together according to their “parent” PAH compound (e.g., napthalene).

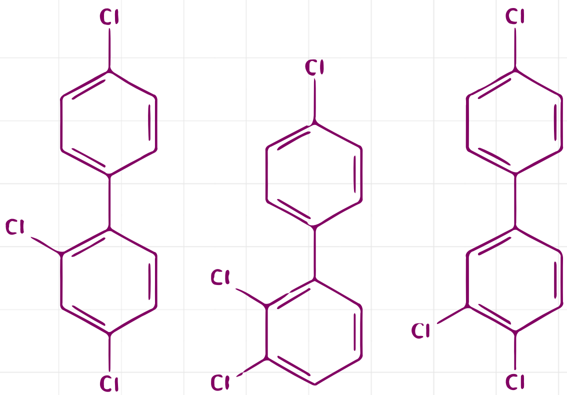
POLYCHLORINATED BIPHENYLS (PCBs)

WHAT ARE THEY?

Polychlorinated Biphenyls (PCBs) are human-made chemicals that are highly toxic and persistent in the environment. They were once widely used in electrical, heat transfer and hydraulic equipment, and in some commercial products like paint, plastics, adhesives and surface coatings. In the 1970s and 1980s, their use was severely restricted due to their harmful environmental impacts, and in 1980 Canada banned their import.

Because PCBs are very stable and do not break down easily, they are still present in the environment today. PCBs can still be found in industrial equipment and electrical installations, and may be released (along with other toxic chemicals) through fires. PCBs can enter aquatic ecosystems through leaks and spills, industrial effluent, and leaching from uncontained landfills. PCBs can also become airborne and travel long distances on wind currents before they are deposited back to land and water in rain and snow.

PCBs are organic molecules that contain chlorine atoms. There are 209 numbered ***congeners*** or subtypes of PCBs. These can be organized into groups according to the number of chlorine atoms in each molecule (e.g., *monochlorobipenyls* have one chlorine atom per molecule, trichlorobiphenyls have three chlorine atoms per molecule).



Three different trichlorobiphenyl molecules, each containing three chlorine atoms.

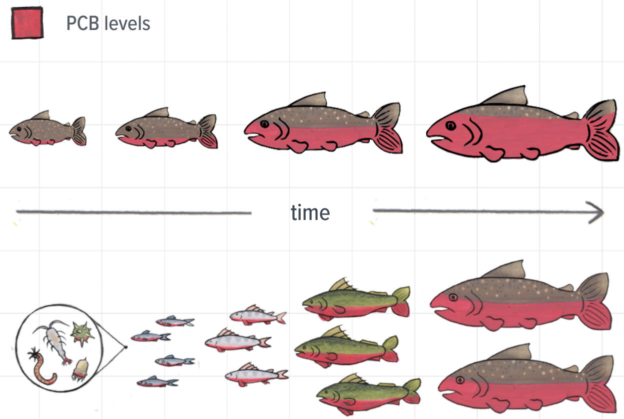
WHY DO THEY MATTER?

PCBs are toxic to fish at low concentrations and are probable human carcinogens (cancer-causing substances). Certain congeners are more toxic than others, but PCBs are almost always found as complex mixtures of multiple congeners.

In rivers and lakes, PCBs tend to accumulate primarily in sediments. Because of this, national guidelines for PCBs apply to how much is present in the sediment, rather than in the water.

PCBs bioaccumulate in organisms, especially those organisms that live in sediments or feed on the bottom of lakes and rivers. PCB concentrations also progressively increase, or biomagnify, up the food chain.

BIOACCUMULATION & BIOMAGNIFICATION OF PCBs



PCB concentrations increase over time in fish and when larger predatory fish eat smaller fish that have PCBs in their tissues.

HOW ARE THEY MEASURED?

In aquatic ecosystems, PCBs can be measured in water, in sediments and in the tissues of organisms like fish. These samples must be submitted to a lab for analysis. PCB concentrations may be reported by labs as total PCBs, or individually by congener or congener groupings.

RELATED TO PCBs:
The greater the organic matter content of sediments, the more likely they are to accumulate PCBs if exposed

SHARING YOUR RESULTS

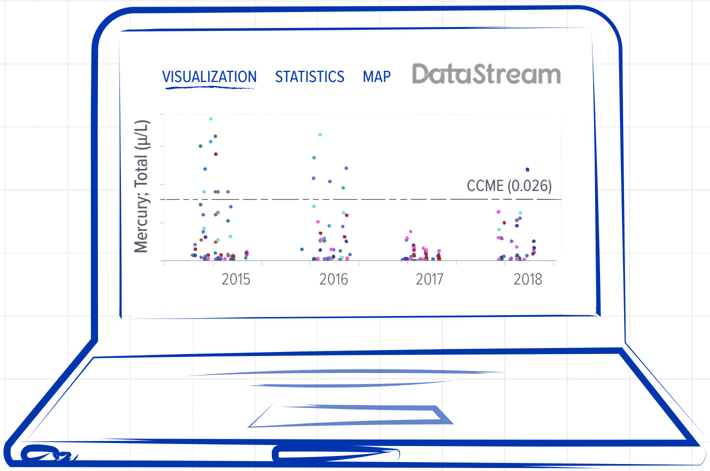
Across the country, water is continuously moving through vast river and lake networks. Because of the size and scale of freshwater ecosystems, it is extremely valuable to bring the findings from multiple monitoring programs together in one place.

ABOUT DATASTREAM

DataStream (www.DataStream.org) provides a place to store, view and share water monitoring results being collected by communities and governments across Canada. And, it is free and open for anyone to use.

DataStream ensures all the results are stored in a harmonized format and provides a secure and sustainable home for data, so information doesn't get lost over time.

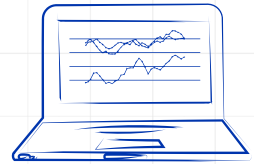
It's also a great place to learn what others are doing in your area, and beyond!



Interactive data visualizations are easy to create and enable comparison between monitoring results and national CCME guidelines for the protection of aquatic life.

HERE'S HOW IT WORKS:

Communities, governments and researchers are collecting valuable information through diverse water monitoring programs.



DataStream is an open-access platform for organizing, storing and visualizing water quality data that monitoring groups want to share.

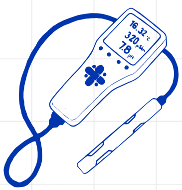
By bringing this data together in one place, we can get a clearer picture of watershed health from the local to regional scale.

Learn more at www.DataStream.org.

DataStream is led nationally by The Gordon Foundation and carried out in collaboration with regional partners and monitoring networks, including the Government of the Northwest Territories, the Atlantic Water Network and the Lake Winnipeg Foundation.

ADDITIONAL RESOURCES

- Atlantic Water Network. 2019. *WET-Pro Online Water Quality Training Modules*. https://wet-pro.ca
- Canadian Council of Ministers of the Environment. 2011. *Protocols Manual for Water Quality Sampling in Canada*. ISBN 978-1-896997-7-0. http://protocols.ccme.ca
- Canadian Council of Ministers of the Environment. *Canadian Environmental Quality Guidelines*. https://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/
- Government of the Northwest Territories. *Water Quality Parameters and Contaminants Fact Sheets*. https://www.enr.gov.nt.ca/en/services/water-management-and-monitoring/reports-and-publications-water-management
- Government of the Northwest Territories. 2012. *Experiential Science 30 – Freshwater Systems*. Pacific Educational Press, Faculty of Education, University of British Columbia.
- Northern Ecological Monitoring and Assessment Network (EMAN-North). 2005. *Northern Waters: A Guide to Designing and Conducting Water Quality Monitoring in Northern Canada*.



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