

# Water Quality Tests Summary

## Contents

Water Quality Tests	13
Water Quality Index	14
Temperature	17
pH	17
Chloride and Salinity	19
Turbidity	19
Nitrate	20
Phosphates	21
Water Hardness – Calcium and Magnesium ions	21
Dissolved Oxygen (DO)	21
Total Dissolved Solids	23
Bibliography	23

## Water Quality Tests

**Temperature:** can determine the rate of biochemical reactions in the aquatic environment or whether they can occur at all.

**pH:** scale used to measure the acidity of water. Most aquatic organisms have a limited pH range with most surface water between 6 and 8 units

**Chloride and Salinity:** Chloride,  $\text{Cl}^-$ , is usually present in fresh water as well as salt water. Sources include dissolving minerals and industrial pollution. Salinity is the total of all non-carbonate salts dissolved in water.

**Dissolved Oxygen:** a measure of how much oxygen is dissolved in water. It is vital to aquatic life as a necessary component of cellular respiration. Most aquatic organisms have an optimal range of dissolved oxygen and it is a key indicator of water quality.

**Turbidity:** a measure of the water's lack of clarity. Highly turbid water reduces light penetration therefore affecting levels of photosynthesis, warming is increased due to absorption of sunlight, and it is generally aesthetically displeasing. Stormwater contributes to increased turbidity because of sediments and phytoplankton suspended in it.

**Nitrate:** is an essential nutrient for aquatic plants and animals and is the form in which plants utilise nitrogen, therefore can have a great influence on the amount of plant growth in water.

**Phosphates:** phosphorus is an essential nutrient for aquatic plants and animals. Excess phosphorus in water can be harmful by stimulating plant and algal growth. Sewage, detergent use and fertiliser runoff are common sources.

**Calcium and Water Hardness:** Calcium ions,  $\text{Ca}^{2+}$  are introduced into water as it flows over calcium containing rock such as limestone. Magnesium ions,  $\text{Mg}^{2+}$ , also contribute to hard water. "Hard" water contains excess  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ .

**Ammonium ion:**  $\text{NH}_4^+$  is a byproduct of animal waste, decaying organic matter, and fertilisers.

**Total Dissolved Solids:** many important components of healthy aquatic ecosystems are in the form of dissolved solids. Nutrients such as nitrates and phosphates, and dissolved salts such as sodium chloride, contribute to total dissolved solids.

## Water Quality Index

**From:** Wilkes University Center for Environmental Quality Environmental Engineering and Earth Sciences

<http://www.water-research.net/watrqualindex/index.htm>

Water quality index is a 100 point scale that summarizes results from a total of nine different measurements:

- Temperature
- pH
- Dissolved Oxygen
- Turbidity
- Nitrates
- Total Phosphates
- Total Suspended Solids
- Biochemical Oxygen
- Fecal Coliform

Some factors were judged more important than others, so a weighted mean is used to combine the values. When test results from fewer than all nine measurements are available, the relative weights for each factor are preserved and the total scaled so that the range remains 0 to 100.

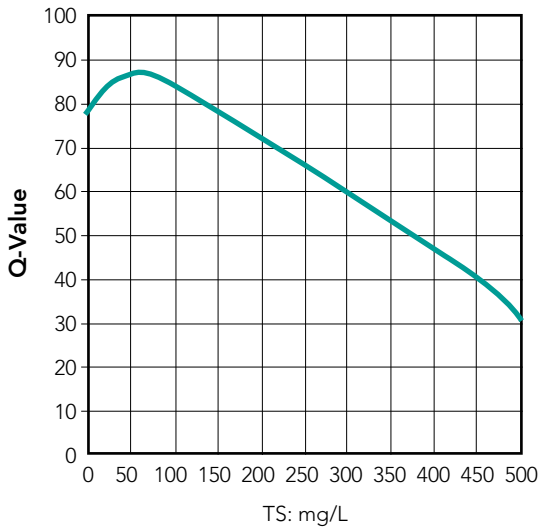
The 100 point index can be divided into several ranges corresponding to the general descriptive terms shown in the table below.

Water Quality Factors and Weights	
Factor	Weight
Dissolved oxygen	0.17
Fecal coliform	0.16
pH	0.11
Biochemical oxygen demand	0.11
Temperature change	0.10
Total phosphate	0.10
Nitrates	0.10
Turbidity	0.08
Total solids	0.07

Water Quality Index Legend	
Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

### Water Quality Index: Total Solids

Chart 9: Total Solids (TS) Test Results

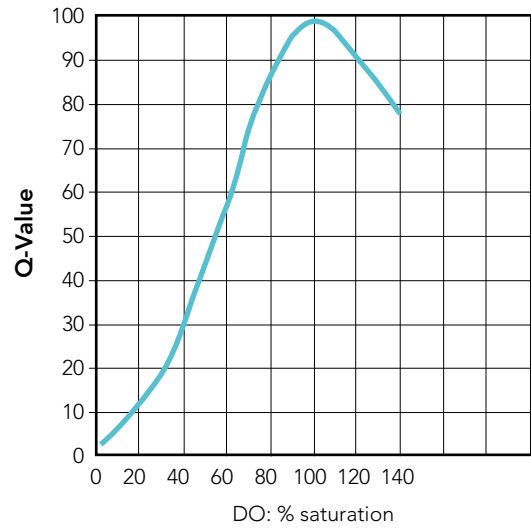


**Note:** If total solids is greater than 500 ppm, the quality index equals 20.

### Water Quality Index: DO sat (%)

#### Weighting Curve Charts

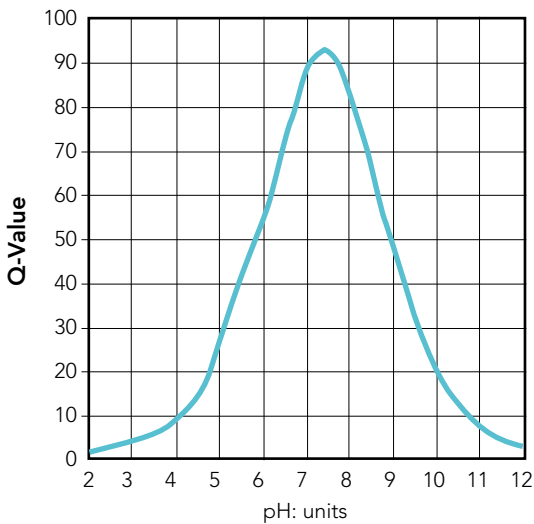
Chart 1: Dissolved Oxygen (DO) Test Results



**Note:** If dissolved oxygen is greater than 140%, the quality index equals 50.

### Water Quality Index: pH

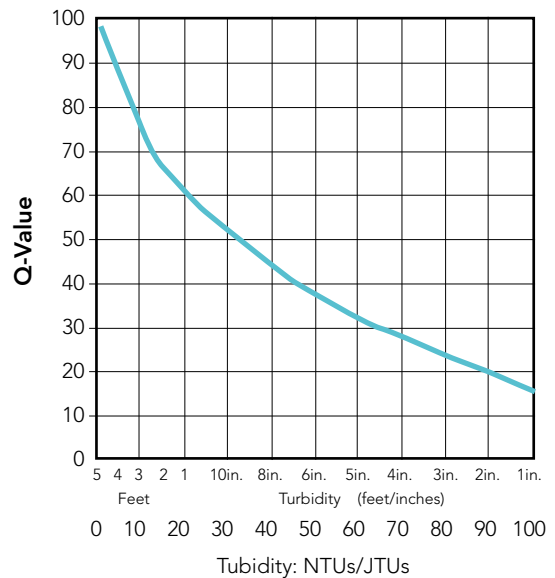
Chart 3: pH Test Results



**Note:** If pH is less than 2.0 or greater than 12.0, the quality index equals 0.

### Water Quality Index: Turbidity

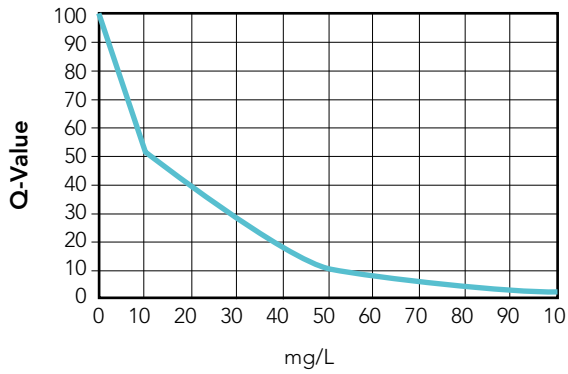
Chart 8: Turbidity Test Results



**Note:** If turbidity is greater than 100 ntu, the quality index equals 5.

## Water Quality Index: Nitrate

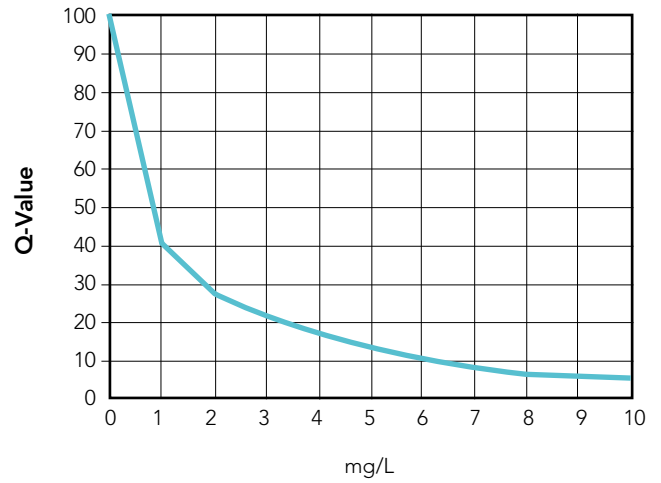
Nitrate Results



Note: If nitrate nitrogen is greater than 100 ppm, the quality index equals 1.

## Water Quality Index: Total Phosphate

Phosphate Results



**Note:** If total phosphate is greater than 10 ppm, the quality index equals 2.

For Temperature Calculation - Please go to: [The Temperature Website](#)

The tables and Graphs above are taken from:

Wilkes University Center for Environmental Quality Environmental Engineering and Earth Sciences, 2007



## Temperature

The temperature of a body of water influences its overall quality as it can harm aquatic organisms if it is outside the normal range. Temperature should be measured at different locations and a change in temperature determined. Temperature changes could indicate thermal pollution eg industrial pollution, runoff from parking lots and rooftops, contributing to increase in overall temperature.

Shade is important to the health of the water body as it reduces the warming effect of direct sunlight. Some human activities remove shade trees from the area, allowing more sunlight to reach the water, causing the temperature to rise.

Temperature of the air above the water body may affect water temperature depending on the depth of the water. Shallow water bodies are more susceptible to temperature changes than deep water.

### Factors affecting water temperature:

- Air temperature
- Amount of shade
- Soil erosion increasing turbidity
- Thermal pollution from human activities
- Unknown chemical reactions that weren't previously occurring in the water

### Effects of water temperature:

- Solubility of dissolved oxygen – more gas can be dissolved in cold water than warm, therefore animals requiring a high level of dissolved oxygen will only thrive in cold water
- Rate of plant growth – increased water temperature can cause an increase in the photosynthetic rate of aquatic plants and algae, which can lead to increased plant growth and algal blooms, and harm the local ecosystems
- Metabolic rate of organisms
- Resistance in organisms – if water becomes too hot or too cold, organisms become stressed, lowering their resistance to pollutants, diseases and parasites

## Ph

pH value of water is determined by the relative concentrations of H<sup>+</sup> ion and OH<sup>-</sup> ion. Water with a pH of 7 has equal concentrations of H<sup>+</sup> ion and OH<sup>-</sup> ion and is considered to be a neutral solution. If a solution is acidic (pH<7), the concentration of H<sup>+</sup> ion is greater than the concentration of OH<sup>-</sup> ion. If a solution is basic (pH>7), the concentration of H<sup>+</sup> ion is less than the concentration of OH<sup>-</sup> ion. A change from pH7 to pH8 in a lake represents a ten-fold increase in the OH<sup>-</sup> ion.

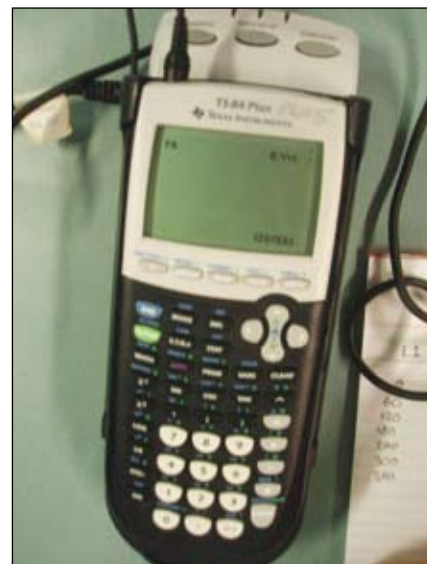
Rainfall generally has a pH value between 5 and 6.5. Natural is 5.6 in non-polluted areas. It is acidic because of dissolved carbon dioxide and air pollutants such as sulphur dioxide or nitrogen oxides. If rainwater flows over soil containing hard-water minerals, its pH usually increases. Bicarbonate ions, HCO<sub>3</sub><sup>-</sup>, resulting from limestone deposits react with water to produce OH<sup>-</sup> ions according to



This results in lakes often being basic with pH values between 7 and 8, sometimes as high as 8.5

Acid rain causes an acidification of the soil which goes unchecked if no bases are present. Clays also play a role here with leaching of singularly charged ions occurring in an ion-exchange process causing heavier and more charges metallic ions eg Fe<sup>3+</sup> and Al<sup>3+</sup> to dominate soil content. K<sup>+</sup> in particular is lost in these circumstances. (K Blake, 2009).

The measure of pH is very important as an indication of water quality due to the sensitivity of organisms to the pH of their



environment. Small changes in pH can endanger many kinds of plants and animals as they may not survive or reproduce outside of that range (refer table below):

Effects of pH Levels on Aquatic Life	
pH	Effect
3.0 – 3.5	Unlikely that fish can survive for more than a few hours in this range, although some plants and invertebrates can be found at pH levels this low
3.5 – 4.0	Known to be lethal to salmonids
4.0 – 4.5	All fish, most frogs, insects absent
4.5 – 5.0	Mayfly and many other insects absent. Most fish eggs will not hatch.
5.0 – 5.5	Bottom-dwelling bacteria (decomposers) begin to die. Leaf litter and detritus begin to accumulate, locking up essential nutrients and interrupting chemical cycling. Plankton begin to disappear. Snails absent. Mats of fungi begin to replace bacteria in the substrate
	Metals (aluminium, lead) normally trapped in sediments are released into the acidified water in forms toxic to aquatic life
6.0 – 6.5	Freshwater shrimp absent. Unlikely to be directly harmful to fish unless free carbon dioxide is high (in excess of 100mg/l)
6.5 – 8.2	Optimal for most organisms
8.2 – 9.0	Unlikely to be directly harmful to fish, but indirect effects occur at this level due to chemical changes
9.0 – 10.5	Likely to be harmful to salmonids and perch if present for long periods
10.5 – 11.0	Rapidly lethal to salmonids. Prolonged exposure is lethal to carp, perch
11.0 – 11.5	Rapidly lethal to all species of fish

From Johnson, R.L, Holman, S, Holmquist, D.D Water Quality with CBL 1999

#### Factors that affect pH levels:

- Acidic rainfall – may have little effect if the region is rich in minerals that result in high alkalinity values eg higher concentrations of carbonate, bicarbonate, and hydroxide ions from limestone can provide a natural buffering capacity capable of neutralising many of the H<sup>+</sup> ions from the acid. Other regions may have low concentrations of alkalinity ions to reduce the effects of acids in the rainfall area. Fish can be affected if water is very acidic as heavy metals may be released into the water and can accumulate on the gills or cause deformities that reduce the likelihood of survival. In some cases, older fish will continue to live but will be unable to reproduce because of the sensitivity of the reproductive portion of the growth cycle.
- Algal blooms – generally cause water to be more basic
- Level of hard-water minerals
- Releases from industrial processes – depends on whether acids or bases are released
- Release of detergents into water
- Carbonic acid from respiration or decomposition
- Oxidation of sulphides in sediments – generally more acidic

### Expected levels:

- Between pH7 and 8 for lakes and streams
- Levels between 6.5 and 8.5 are acceptable for most drinking water standards
- Areas with higher levels of water hardness (higher concentrations  $Mg^{2+}$ ,  $Ca^{2+}$ , and  $HCO_3^-$ ) often have higher pH values between 7.5 and 8.5 (often detergent damage is present as well).

## Chloride and Salinity

### Chloride:

Chloride, in the form of the  $Cl^-$  ion is one of the major inorganic anions (negative ions) in saltwater and freshwater.



In drinking water, the salty taste produced by chloride depends on the concentration of the chloride ion. Water containing 250mg/L of chloride may have a detectable salty taste if the chloride came from sodium chloride.

### Sources of Chloride ions:

- River or lake beds with salt-containing minerals
- Irrigation water returned to lakes / rivers
- Mixing of seawater with freshwater
- Chlorinated drinking water – often increases chloride levels
- Water softener regeneration - often increases chloride levels

### Salinity:

Salinity is a measure of the total salt concentration, comprising mostly of  $Na^+$  and  $Cl^-$  ions as well as small quantities of other ions (eg  $Mg_2^+$ ,  $K^+$ , or  $SO_4^{2-}$ ). It is the total of all non-carbonate salts dissolved in water, was expressed in parts per thousand (1ppt = 1000mg/L or 1g/L) but is now generally expressed in parts per million (ppm).

The salinity of seawater is fairly constant, at about 35000 ppm.

- Highly saline water ranges from 10000ppm to 35000ppm.
- Moderately saline water ranges from 3000ppm to 1000ppm
- Slightly saline water ranges from 1000ppm to 3000ppm
- Freshwater is less than 1000ppm

Freshwater has lower levels of "salt ions" such as  $Na^+$  and  $Cl^-$ , and these are often lower in concentration than hard-water ions such as calcium ( $Ca^{2+}$ ) and bicarbonate ( $HCO_3^-$ ).


Saltwater organisms can survive in salinity levels up to 40000 ppm but many freshwater organisms cannot live in salinity levels above 1000 ppm.

## Turbidity

Turbidity is a measure of the water's lack of clarity. Water with high turbidity is cloudy, while water with low turbidity is clear. The more particles in the water, the more light is reflected off the particles and therefore the higher the turbidity or cloudiness.

High turbidity decreases the amount of sunlight able to penetrate the water, thereby decreasing the rate of photosynthesis. Reduced clarity also makes the water less aesthetically pleasing, making it less desirable for many water uses eg drinking

When water is cloudy, sunlight will warm it more efficiently because suspended particles absorb the sunlight, warming the water. This can lead to problems associated with increased water temperature.



Sources of  $\text{Fe}^{3+}$  and  $\text{Al}^{3+}$  can be used as flocculation agents to clear turbid water.

Although clear water looks suitable for drinking, it may be unhealthy due to the possible presence of unseen toxins or unhealthy levels of nutrients.

#### Causes of Turbidity:

- Soil erosion – silt and clay deposition
- Urban runoff – road grime; rooftops; parking areas
- Industrial waste – sewage treatment effluent; particulates
- Abundant bottom-dwelling organisms eg catfish stirring up the sediment built up on the bottom of the lake.
- Organic matter – microorganisms; decaying plants and animals; petrol, diesel or oil from roads

#### Effects of Turbidity:

- Reduces water clarity
- Aesthetically unpleasant
- Decreases rate of photosynthesis
- Increases water temperature

#### Expected Levels:

Turbidity is measured in *Nephelometric Turbidity Units*, NTU. The turbidity of surface water is usually between 1 NTU and 50 NTU. Turbidity is often higher than this, especially after heavy rain when the water levels are high. Turbidity can be lower than expected in still water where suspended particles have settled. Water is visibly turbid at levels above 5 NTU. The standard for drinking water is 0.5 NTU to 1.0 NTU.

**Activity** refer to Moodle: [Effect of runoff on water turbidity compare results from practical to results collected from Lake Indawarra.](#)

## Nitrate

Nitrate ions ( $\text{NO}_3^-$ ) found in freshwater samples result from a variety of natural and manmade sources. Nitrates are an important source of nitrogen necessary for plants and animals to synthesize amino acids and proteins.

Through the process called the Nitrogen Cycle, nitrogen ( $\text{N}_2$ ) from air is converted to useable forms for plants and animals. These conversions include industrial production of fertilisers, as well as natural processes such as nitrogen fixation by legumes plants, plant and animal decomposition, and animal waste.

Sources of Nitrate ions:

- Agricultural runoff
- Urban runoff
- Animal feedlots and stock yards
- Municipal and industrial wastewater
- Automobile and industrial emissions
- Decomposition of plants and animals

Nitrate levels in freshwater are usually less than 1mg/L but manmade sources of nitrate may elevate levels above 3mg/L. Levels above 10mg/L in drinking water can cause a potentially fatal disease in infants called *methemoglobinemia*, or Blue-baby Syndrome (nitrate converts haemoglobin into a form that can no longer transport oxygen).

High nitrate concentrations (and phosphates from grey water/sewage) also contribute to *eutrophication*, ie excessive growth of aquatic plants and algae. Unpleasant odour and taste of water, as well as reduced clarity often accompany this



process. Eventually dead biomass accumulates at the bottom of the lake where it decays, compounding the problem by recycling nutrients. If other nutrients are present, algal blooms can occur with as little as 0.5mg/L  $\text{NO}_3^-$ -N.

#### Expected Levels:

Nitrate level in freshwater is usually found in the range of 0.1 to 4 mg/L  $\text{NO}_3^-$ -N. Unpolluted waters generally have nitrate levels below 1 mg/L. The effluent of some sewage treatment plants may have levels in excess of 20mg/L.

## Phosphates: Ortho – and Total

A small amount of phosphorus is an essential nutrient for all aquatic plants and algae but in high levels, phosphorous can be considered a pollutant. Phosphorous concentration determines the level of eutrophication (increased plant and algal growth due to an excess of nutrients such as phosphorous and nitrates).

Most phosphorous in surface water is in the form of phosphates. The most common sources of phosphorous in water include:

- Human and animal waste – from sewage and excrement from animals living near on in the water body (mainly organically bound phosphates)
- Industrial wastes – condensed phosphates (also called polyphosphates) such as P3O10<sup>5-</sup> that are sometimes added to water to prevent formation of scaling and to inhibit corrosion. These were common in detergents of the past.
- Agricultural wastes – fertilisers contain high levels of phosphates (particularly orthophosphates eg  $\text{PO}_4^{3-}$ ,  $\text{HPO}_4^{2-}$ , and  $\text{H}_2\text{PO}_4^-$ ) that enter the water through runoff and erosion, due to disturbances to land and vegetation.
- Human disturbance of land – clearing or disturbance of land vegetation increases erosion resulting in more phosphates being washed out of the soil

High levels of phosphates result in:

- Eutrophication
- Increased algal blooms increased Biochemical Oxygen Demand (BOD)
- Decreased Dissolved Oxygen (DO)

Low levels of phosphate limit plant and algal growth. Plant growth can be stimulated by levels above 0.1mg/L  $\text{PO}_4\text{P}$  (ie phosphorous in the form of phosphates).

## Water Hardness – Calcium And Magnesium Ions



Hardness can be measured as Calcium hardness or total hardness.

Excess Calcium ( $\text{Ca}_2^+$ ) and Magnesium ( $\text{Mg}_2^+$ ) ions contribute to water hardness. An obvious sign of water hardness is a layer of white film deposited on surfaces. The term “hard water” comes from the fact that calcium and magnesium ions in water combine with soap molecules to form a sticky scum that makes it hard for soap molecules to produce suds, resulting in a layer of white film.

Total hardness takes into account both  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions with, On average, magnesium hardness representing about 1/3 of total hardness and calcium hardness representing

about 2/3 total hardness. Total hardness is the sum of calcium and magnesium hardness. Other cations that can cause hard water include  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Sr}^{2+}$ , but as their levels are much lower, they are not typically included total hardness measurements.

Calcium, in the form of  $\text{Ca}^{2+}$  ion, is a major inorganic ion in freshwater as water flows over limestone ( $\text{CaCO}_3$ ), gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) and other calcium containing rocks and minerals. Magnesium, in the form of  $\text{Mg}^{2+}$  ion, occurs from water flowing over Dolomite ( $\text{CaCO}_3\text{-MgCO}_3$ ) and other magnesium containing rocks and minerals. Calcium carbonate is relatively insoluble in water but dissolves better in water containing high levels of dissolved carbon dioxide.

The concentration of  $\text{Ca}^{2+}$  in freshwater is generally in the range of 0 to 100mg/L. The recommended upper level for drinking water is 50mg/L but higher levels do not cause health risks. If the calcium ion concentration in freshwater drops below 5mg/L, the ability of the water to support life is dramatically decreased, resulting in oligotrophic condition. Seawater contains  $\text{Ca}^{2+}$  ions at levels of about 400mg/L. Calcium is an important component of cell walls of aquatic plants and of bones and shells of aquatic animals. Magnesium is a component of chlorophyll in plants and therefore an essential nutrient.

Calcium hardness ( $\text{CaCO}_3$ ):

- |                   |             |
|-------------------|-------------|
| • Soft            | 0-20mg/L    |
| • Moderately soft | 20-40 mg/L  |
| • Moderately hard | 40-80 mg/L  |
| • Hard            | 80-120 mg/L |
| • Very hard       | >120 mg/L   |



## Dissolved Oxygen

The level of oxygen gas dissolved in water (DO) is vital for the survival of most aquatic organisms as it provides them with oxygen to carry out cellular respiration. It is therefore an important indicator of the quality of water quality. Aquatic organisms have different DO requirements. Dissolved oxygen concentrations can range from 0 to 15mg/L depending on the conditions eg in cold mountain streams, DO could be from 7-15mg/L depending on the water temperature and atmospheric pressure, whereas in water closer to sealevel, readings may be between 2 and 11mg/L.

Sources of dissolved oxygen are:

- Diffusion from the atmosphere and water at the surface
- Aeration as water flows over rocks and uneven surfaces
- Aeration through churning action of wind and waves
- Photosynthesis from aquatic plants

The concentration of dissolved oxygen is affected by:

- Plant activity – DO levels fluctuate throughout the day, increasing during the morning and peaking in the afternoon. Decreases occur at night when photosynthesis ceases and plants and animals continue to respire using oxygen.
- Temperature – affects the ability of water to dissolve oxygen due to the different solubilities at different temperatures. Cooler water have a greater capacity to dissolve oxygen than warmer water
- Decaying organic matter in water – decomposition releases heat, warming water and decreasing dissolved oxygen capacity
- Stream flow – the faster the water moves and churns, the greater the amount of oxygen is dissolved
- Altitude/atmospheric pressure – high altitudes and atmospheric pressure reduce dissolved oxygen capacity

- Human activities – removal of shade or the release of warm water used in industrial processes can cause an increase in water temperature, resulting in lower dissolved oxygen capacity

When comparing water quality of different samples at the same temperature and air pressure, percent saturation is generally used instead of mg/L. Percent saturation is the dissolved oxygen reading / 100. Water can be supersaturated for short periods of time ie percent saturation of DO  $\geq 101\%$ ; excellent DO levels are between 90% and 100%; adequate levels between 80% and 89%; acceptable between 60% and 79%; and poor levels percent saturation of DO  $< 60\%$ .

## Total Dissolved Solids

Solids are found in streams and lakes in two forms, suspended and dissolved. Suspended solids include silt, stirred up bottom sediment, decaying plant matter, or sewage treatment effluent. Suspended solids will not pass through a filter, whereas dissolved solids will. Dissolved solids in freshwater include soluble salts that yield ions such as  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ , or  $\text{Cl}^-$ . Total dissolved solids (TDS) is sometimes used as a “watchdog” environmental test. TDS can be determined by evaporating a pre-filtered sample to dryness and then finding the mass of dry residue per litre of sample, or using a probe to determine the ability of the dissolved salts and their resulting ions in an unfiltered sample to conduct an electrical current. The conductivity is then converted to TDS (mg/L).

### Sources of Dissolved Solids:

- Hard water ions -  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$
- Fertiliser in agricultural runoff -  $\text{NH}_4^+$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$ ,  $\text{SO}_4^{2-}$
- Urban runoff -  $\text{Na}^+$ ,  $\text{Cl}^-$
- Salinity from minerals or returned water from irrigation -  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$
- Acidic rainfall –  $\text{H}^+$ ,  $\text{NO}_3^-$ ,  $\text{SO}_3^{2-}$ ,  $\text{SO}_4^{2-}$

If TDS levels are high, especially due to dissolved salts, many forms of aquatic life are affected. The salt acts to dehydrate the skin of animals and high concentrations of dissolved solids can add a laxative effect to water or cause water to have an unpleasant mineral taste.

### Expected Levels:

TDS levels in lakes and streams are typically found in the range of 50 to 250 mg/L. In areas of especially hard water or high salinity, TDS may be as high as 500 mg/L. Drinking water tends to be 25 to 500 mg/L. Fresh distilled water usually has a conductivity of 0.5 to 1.5 mg/L.

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