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FACT SHEET

Water quality in freshwater aquaculture ponds

Water quality includes all physical, chemical and biological factors that influence the beneficial use of water. There are many water quality variables in pond fish culture. All other things being equal, a pond with good water quality will produce more and healthier fish than a pond with poor quality.

Fish and crayfish perform all bodily functions in water which include eating, breathing, excreting wastes, reproducing and taking in or removing salts. Water quality within aquaculture ponds can affect these functions and therefore will determine the health of the fish and consequently the success or failure of a fish farming operation.

Water quality within an aquaculture pond is continuously changing depending on certain conditions. These behavioural changes are referred to as "Pond Dynamics" and must be understood if a pond system is to be managed effectively.

Water quality is divided up into physical, biological and chemical characteristics. Each one will be discussed separately.

Physical characteristics

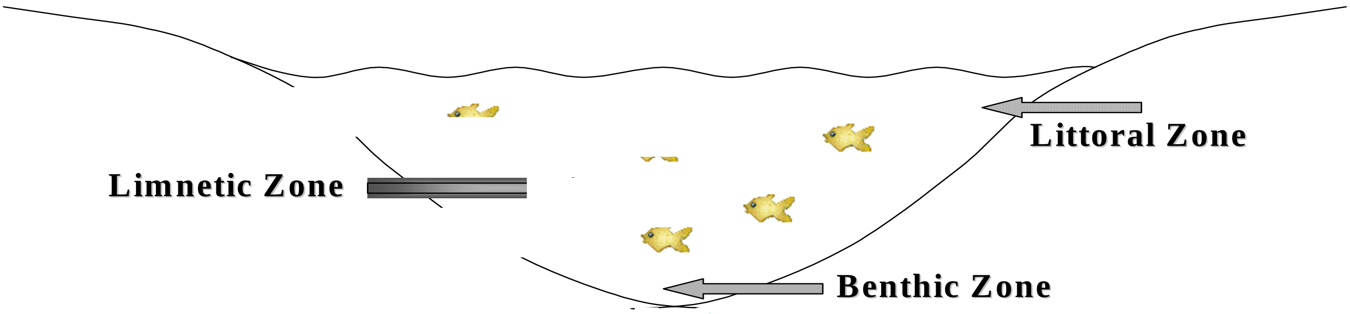

Fig 1: Physical zones within an aquaculture pond.

Physical characteristics of an aquaculture pond refers to its structure or "zones" (Fig 1). A pond is divided up into different zones, each with their own biological and chemical characteristics

The pond wall is known as the "littoral zone". Within this region aquatic plants thrive as they are able to access sunlight. Aquatic plants can be important in aquaculture ponds as they provide oxygen to the pond water, and food and shelter for some aquaculture species. However it is important not to allow aquatic plants to overrun your pond.

The "limnetic zone" is commonly referred to as the water column of the pond. Aquatic organisms such as phytoplankton, zooplankton and fish will inhabit this area. It is within this zone that the majority of water quality measurements are taken.

The "benthic zone" or pond bottom is perhaps the most forgotten area within aquaculture ponds. However this area is extremely important particularly for freshwater crayfish culture. Pond soil must be kept in good condition otherwise a build up of decaying organic matter can lead to oxygen problems within a pond. This will be discussed in more detail further on.

Biological characteristics

Biological characteristics of an aquaculture pond refers to the aquatic organisms that live within the pond. This includes both plants and animals.

The relationship between aquatic plants and animals is known as a trophic level or a food chain (*ie* who consumes who). This relationship is a continuous cycle as shown in Fig 2.

Bacteria form the base of the food chain within an aquaculture pond. Bacteria break down organic matter to produce nutrients such as phosphorus and nitrogen, and carbon dioxide (CO_2). These products are then utilised by phytoplankton, microscopic algae, to produce oxygen via photosynthesis. Oxygen and phytoplankton are then consumed by zooplankton which are tiny aquatic organisms. Fish and crayfish feed on zooplankton as well as larger aquatic plants and supplementary feed that may be added to the aquaculture ponds. Uneaten supplementary feed, dead aquatic organisms (including planktonic organisms and aquaculture species) and animal wastes will settle on the pond floor. Bacteria will feed on this decaying organic matter and the cycle will commence again.

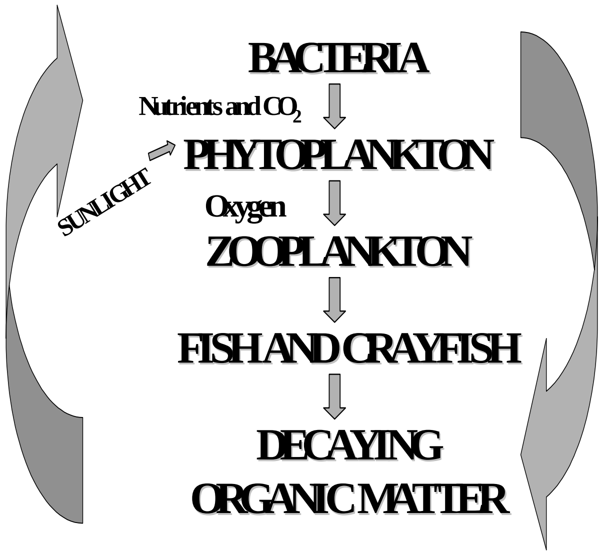

Fig 2: Trophic levels within an aquaculture pond.

Inorganic or organic fertilisers consisting of nitrogen and phosphorus can be added to aquaculture ponds to stimulate the growth of phytoplankton. This in turn will promote zooplankton growth. Before fish fry can be stocked within a pond, there must be a sufficient amount of zooplankton for them to feed on if the fry are to survive and grow.

The individual biomass of aquatic organisms within an aquaculture pond will vary over time (Fig 3). It is therefore important to have a good understanding of the population dynamics within your pond to stabilise population numbers of aquatic organisms and to ensure that the system will not crash.

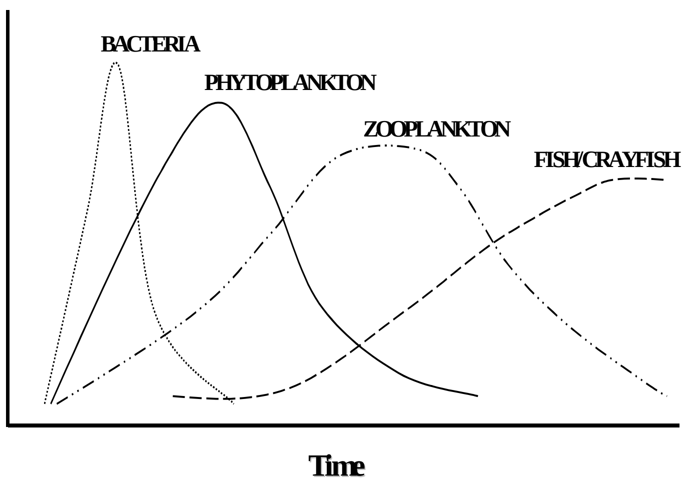

Fig 3: Phases in the succession of different organisms during the development of an aquaculture pond community (Ingram et al 1997).

Chemical characteristics

Chemical characteristics refer to the water quality parameters that are measured within an aquaculture pond. Water quality in ponds change continuously and are affected by each other along with the physical and biological characteristics that have been mentioned previously.

With this in mind water quality should be monitored regularly. This can be achieved by recording simple visible water characteristics such as water colour, clarity, plant and animal life. Alternatively relatively inexpensive testing kits and recording probes (more expensive) can be purchased from analytical supply stores.

The following water quality parameters are considered to be the most important in aquaculture.

Dissolved oxygen

Dissolved oxygen is probably the most critical water quality variable in freshwater aquaculture ponds. Oxygen levels in ponds systems depend on water temperatures, stocking rates of aquaculture species, salinity, and the amount of aquatic vegetation and number of aquatic animals in the ponds.

Dissolved oxygen concentrations will vary throughout the day. Dissolved oxygen in the water is obtained through diffusion from air into water, mechanical aeration by wind or aeration systems, and via photosynthesis by aquatic plants (Fig 4).

$6CO_2$	+	$6H_20$	+	Sunlight	➔	$C_6H_{12}O_6$	+	$6O_2$
Carbon Dioxide		*Water*				*Sugar*		*Oxygen*

Fig 4: Plants utilise carbon dioxide, water and sunlight to form simple sugars and oxygen – a process known as photosynthesis.

Oxygen is also lost from the system via respiration where oxygen is consumed by aquatic organisms (both plants and animals), and by decaying organic matter on the pond floor.

Declining oxygen levels can be caused by a number of factors. This includes large blooms of phytoplankton and zooplankton, high stocking rates, excessive turbidity that will limit the amount of photosynthesis occurring and high water temperatures. Levels of dissolved oxygen will also decrease after a series of warm, cloudy, windless days.

Low dissolved oxygen can be lethal to our aquaculture species. Some effects include stress, increased susceptibility to disease, poor feed conversion efficiency, poor growth and even death.

A number of measures can be put in place to help alleviate low oxygen problems. There are a number of different types of aeration systems that when installed in ponds will help circulate and oxygenate the water. The majority of existing growers use Airlift pumps however other systems include Paddle wheels, Aspirator pumps and Diffused air systems. Flushing ponds with fresh water and reducing feeding rates will also help increase oxygen levels within the ponds.

When taking measurements of dissolved oxygen within an aquaculture ponds it is important to note that readings will alter depending on the time of day, the amount of plant growth within in the pond, and the position in the pond from where the measurement was taken. This is due to the following reasons.

Aquatic plant life, algae or phytoplankton are present in large numbers will produce high oxygen levels within a pond during the day due to photosynthesis occurring. However at night without the presence of sunlight, these organisms will be consuming oxygen rather than producing it via photosynthesis which may result in dangerously low oxygen levels (Fig 5). Therefore if the pond has extremely high oxygen levels during the day there may be a good chance they will drop considerably at night.

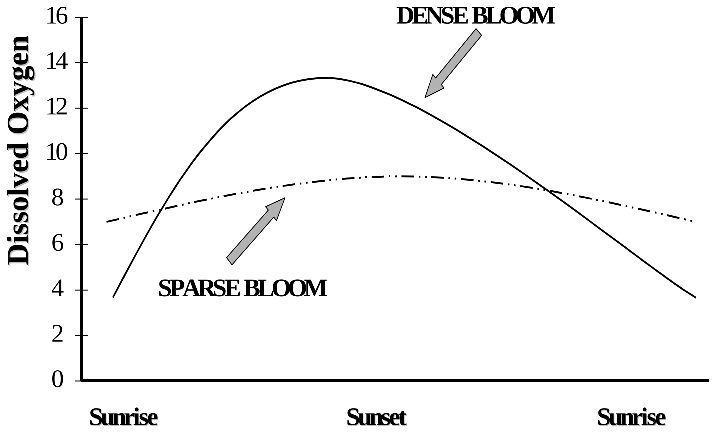

Fig 5: This graph shows the impact of algae blooms on dissolved oxygen readings of a pond. It is important to note that the time of day that dissolved oxygen readings are taken is extremely important and that the lowest readings are usually recorded at dawn.

Another factor which may affect the reliability of a dissolved oxygen reading is the location of the measurement taken within the pond. An aquaculture pond can undergo stratification where the pond's water column will split into two separate layers (Fig 6). The top layer will heat up however oxygen levels will still remain high due to oxygen diffusing from the air into the water. The bottom layer of the pond will remain colder and oxygen levels will deplete due to decaying organic matter on the bottom of the pond essentially sucking oxygen from the water. The top and bottom layers which are separated by a barrier known as a thermocline, will not mix due to the lack of mechanical movement within the pond's water column.

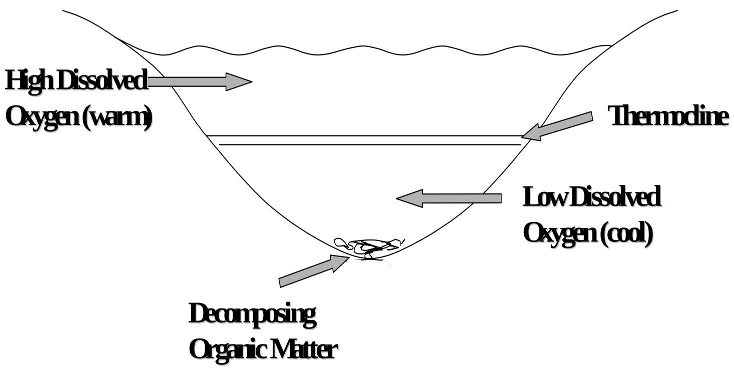

Fig 6: Stratification within an aquaculture pond. Oxygen levels within the bottom layer of the pond can drop to lethal levels especially for bottom dwelling culture animals such as freshwater crayfish.

Pond stratification may occur during periods of hot, still weather and is usually more prevalent in deeper, highly turbid ponds. Pond stratification is more likely to be avoided by installing aeration systems within the ponds to ensure that water is circulated during the critical periods of time, and making sure that pond depth is no greater than around two metres.

Water temperature

Fish and crayfish are ectotherms as heat is obtained from their external environment. Therefore the body temperature of culture animals is usually the same as that of the water temperature.

Temperature will affect all chemical and biological processes. Temperature therefore has a direct effect on important factors such as growth, oxygen demand, food requirements and food conversion efficiency. The higher the temperature, the greater the requirement for oxygen and food and the faster the growth rate.

Optimum temperature conditions will depend on the species of fish that is cultured. These conditions will need to be met to ensure optimal growth and reproduction success. It is therefore important to select a culture species that is best suited to the climate in your area for pond culture, or in the case of tank culture, be prepared to heat or cool the water supply.

pH levels

The pH is the measure of the hydrogen ion (H^+) concentration in soil or water. The pH scale ranges from 0 to 14 with a pH of 7 being neutral. A pH below 7 is acidic and an pH of above 7 is basic. An optimal pH range is between 6.5 and 9 however this will alter slightly depending on the culture species.

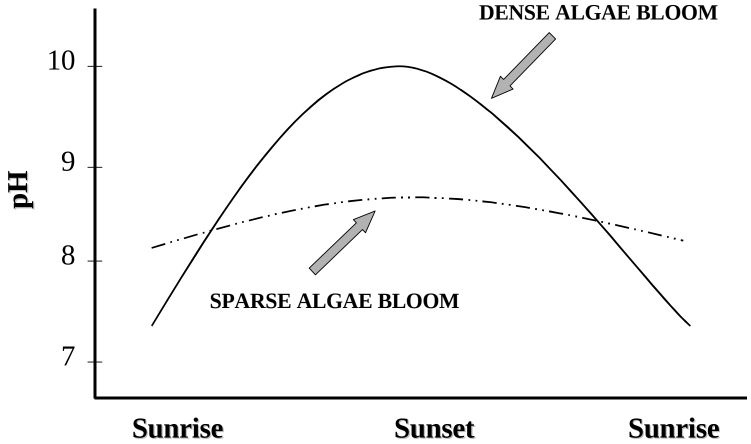

Fig 7: Diurnal fluctuations of pH will occur due to the amount of aquatic life within a pond. With higher algae concentrations, more CO_2 is removed from the system and hence pH levels will rise. The reverse will occur at night when more CO_2 is produced therefore leading to a drop in pH levels.

pH will vary depending on a number of factors. Firstly pH levels of the pond water will change depending on the aquatic life within the pond. Carbon dioxide produced by aquatic organisms when they respire has an acidic reaction in the water. The pH in ponds will rise during the day as phytoplankton and other aquatic plants remove CO_2 from the water during photosynthesis. The pH decreases at night because of respiration and production of CO_2 by all organisms. The fluctuation of pH levels will depend on algae levels within the pond (Fig 7).

Sub-optimal pH has a number of adverse affects on culture animals. It can cause stress, increase susceptibility to disease, low production levels and poor growth. Signs of sub-optimal pH include increase mucus on the gill surfaces of fish, damage to the eye lens, abnormal swimming behaviour, fin fray, poor phytoplankton and zooplankton growth and can even cause death.

In the case of freshwater crayfish low pH levels will cause the shell to become soft. This is due to the shell of the crayfish being composed of calcium carbonate which reacts with acid.

Sub-optimal pH levels are usually caused by acidic water and soils, poorly buffered water (will be discussed further on) and increased CO_2 production.

Treatment methods will depend on whether there is a high pH problem or a low pH problem. To treat a pond with low pH, a pond can be limed with agricultural limestone or fertilised to promote plant growth. To decrease a high pH, the pond can be flushed with fresh water, feeding rates can be reduced to decrease nutrient input into the pond, gypsum ($CaSO_4$) can be added to increase the calcium concentration, or alum ($AlSO_4$) can be added in extreme cases.

Salinity

The term salinity refers to the total concentration of all dissolved ions in the water, it is not, as many people think, the concentration of sodium chloride in the water.

Measurements of salinity are referred to as mg/l or ppm. When salinity is high, it is common to report it as ppt. For a point of reference, seawater is approximately 35ppt.

Units of measurement			Conversions		
“mg”	=	milligrams	1 g/l	=	1000mg/l
“l”	=	litres	1 ppt	=	1000ppm
“ppm”	=	parts per million	1 mg/l	=	1 ppm
“ppt”	=	parts per thousand	1 g/l	=	1 ppt
“gpg”	=	grains per gallon	1 gpg	=	14 mg/l (or 14 ppm)

Each species has an optimal salinity range. This range allows the fish to efficiently regulate their internal body fluid composition of ions and water. This process is known as osmoregulation (Fig 8).

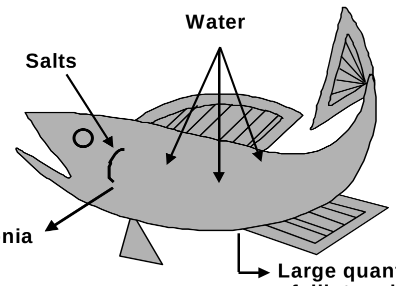

Fig 8: A freshwater fish will gain water via osmosis. Excess water is excreted in the urine and ion uptake is through the gills.

If salinity is too high, the fish will start to lose water to the environment. As freshwater fish are not physiologically adapted to osmoregulate within a saline water source, decreased growth and survival can occur under these conditions.

The salinity of the water source that is to be used for aquaculture should be tested before a project commences. Salinity tolerances will vary amongst species therefore it is important to chose an aquaculture species that is best suited to the salinity of the water source.

Turbidity

Water turbidity in freshwater ponds is caused by phytoplankton and zooplankton (microscopic plants and animals) and suspended solids such as clay and silt particles in the water column.

Water turbidity is important as it determines the amount of light penetration that occurs in the water column of a pond. This in turn will have an affect on the temperature of the water and the amount of vegetation and algae that will grow in the pond itself. For example a highly turbid pond will allow less light penetration therefore the temperature of the water will be lower. A combination of less sunlight and lower temperatures will result in a decreased amount of vegetation present with in the ponds which depend on sunlight and warmth to grow. A low turbid pond will of course have the opposite affect.

Turbidity is measured in centimetres using a sechii disk which consists of a round plate divided into alternate black and white “pie” sections. This disk is attached to a graduated rope or a metal handle divided into measuring units (usually at 2 cm intervals). The disk is lowered into the water until it can not be seen and then raised until it re-appears. Sechii depths between 20cm and 60cm are recommended for optimal management of freshwater ponds.

Water alkalinity and hardness

Alkalinity refers to amount of carbonates and bicarbonates in the water and water hardness refers to the concentration of calcium and magnesium. As calcium and magnesium bond with carbonates and bicarbonates, alkalinity and water hardness are closely interrelated and produce similar measured levels.

Waters are often categorised according to degrees of hardness as follows:

0 – 75 mg/l	*soft*
75 – 150 mg/l	*moderately hard*
150 – 300 mg/l	*hard*
over 300 mg/l	*very hard*

It is recommended that alkalinity and hardness levels are maintained around 50 to 300 mg/l which provides a good buffering (stabilising) effect to pH swings that occur in ponds due to the respiration of aquatic flora and fauna (Fig 9).

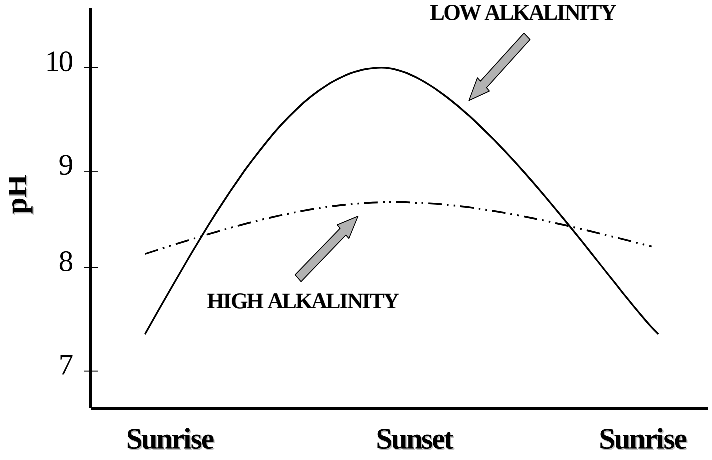

Fig 9: An optimum alkalinity level within the pond will prevent extreme diurnal pH fluctuations.

A lack of calcium in the water will also result in soft shelled marron as they rely on the intake of calcium from the water column to harden their shells after moulting.

Water alkalinity and hardness can be increased by liming ponds which involves adding a measured amount of lime to the pond. However there is no practical way of decreasing alkalinity and hardness when they are above desirable levels.

Ammonia

Ammonia in ponds is produced from the decomposition of organic wastes resulting in the breakdown of decaying organic matter such as algae, plants, animals and uneaten food. Ammonia is also produced by fish and crayfish as an excretory product.

Ammonia is present in two forms in water – as a gas NH_3 or as the ammonium ion (NH_4^+). Ammonia is toxic to culture animals in the gaseous form and can cause gill irritation and respiratory problems.

Ammonia levels will depend on the temperature of the pond's water and its pH. For example at a higher temperature and pH, a greater number of ammonium ions are converted into ammonia gas thus causes an increase in toxic ammonia levels within the freshwater pond.

If high levels are ammonia are present within the pond's water, a number of measures can be taken. These include:

- reduce or stop feeding,
- flush the pond with fresh water,
- reduce the stocking density,
- aerate the pond,
- in emergencies – reduce the pH level.

The amount of ammonia present in a pond can be calculated by recording the total ammonia-nitrogen (TAN), pH and temperature (Table 1).

For example to obtain the concentration of NH_3: Water at pH 8.4, 28^0C and 2mg/l of TAN (sampled measurement) contains 15% NH_3 (from table). Therefore 2mg/l x 15% / 100 = 0.3 mg/l of NH_3.

Table 1: Percentage of TAN in the toxic unionised form NH_3 at different temperature and pH levels. Boyd (1982) "Water quality management for pond fish culture".

PH	Temperature °C						
	8	12	16	20	24	28	32
7.0	0.2	0.2	0.3	0.4	0.5	0.7	1.0
8.0	1.6	2.1	29.	3.8	5.0	6.6	8.8
8.2	2.5	3.3	4.5	5.9	7.7	10.0	13.2
8.4	3.9	5.2	6.9	9.1	11.6	15.0	19.5
8.6	6.0	7.9	10.6	13.7	17.3	21.8	27.7
8.8	9.2	12.0	15.8	20.1	24.9	30.7	37.8
9.0	13.8	17.8	22.9	28.5	34.4	41.2	49.0
9.2	20.4	25.8	32	38.7	45.4	52.6	60.4
9.4	30.0	35.5	42.7	50.0	56.9	63.8	70.7
9.6	39.2	46.5	54.1	61.3	67.6	73.6	79.3
9.8	50.5	58.1	65.2	71.5	76.8	81.6	85.8
10.0	61.7	68.5	74.8	79.9	84.0	87.5	90.6
10.2	71.9	77.5	82.4	86.3	89.3	91.8	93.8

Nutrient levels

Nutrient levels refer to the amount of phosphorus and nitrogen that is present in the water column. Nutrients are important as they promote healthy plankton blooms which are necessary to maintain turbidity levels and provide feed for fish. Nutrient levels can be increased in the ponds by adding inorganic or organic fertilisers in measured doses.

Increased levels of nutrients however may be harmful. It can cause excessive plankton growth, potential blue-green algae blooms and oxygen depletion.

High levels of nutrients can be caused by high stocking densities, over feeding (very common especially during winter), high productivity, and dead plant and animal matter. To decrease high nutrient levels, feeding rates should be decreased (or stopped) and the pond may need to be flushed with clean water.

Table 2: Acceptable Concentration Ranges for Dissolve Inorganic Substances in Aquaculture Pond Waters Boyd (1998) "Water Quality for Pond Aquaculture".

Element	Form in water	Desired concentration
Oxygen	Molecular Oxygen (O_2)	5 – 15 mg/l
Hydrogen	H^+ [-log(H^+) = pH]	PH 7 – 9
Nitrogen	Molecular Nitrogen (N_2) Ammonium (NH_4^+) Ammonia (NH_3) Nitrate (NO_3^-) Nitrite (NO_2^-)	Saturation or less 0.2 – 2 mg/l < 0.1 mg/l 0.2 – 10 mg/l < 0.3 mg/l
Sulfur	Hydrogen Sulfide (H_2S) - rotten egg gas Sulfate (SO_4^-)	Not detectable 5 – 100mg/l
Carbon	Carbon Dioxide (CO_2)	1 – 10 mg/l
Calcium	Calcium Ion (Ca^{2+})	5 – 100 mg/l Can be higher in crustacean ponds
Magnesium	Magnesium ion (Mg^{2+})	5 – 100 mg/l
Sodium	Sodium ion (Na^+)	2 – 100 mg/l
Potassium	Potassium ion (K^+)	1 – 10 mg/l
Bicarbonate	Bicarbonate ion (HCO_3^-)	50 – 300 mg/l
Carbonate	Carbonate ion (CO_3^{2-})	0 – 20 mg/l
Chloride	Chloride ion (Cl^-)	1 – 100 mg/l
Phosphorus	Phosphate ion (HPO_4^{2-} , $H_2PO_4^-$)	0.005 – 0.2 mg/l
Silicon	Silicate ion (H_2SiO_3 , $HSiO_3^-$)	2 – 20 mg/l
Iron	Ferrous iron (Fe^{2+}) Ferric iron (Fe^{3+}) Total iron	0 mg/l Trace 0.05 – 0.5 mg/l
Manganese	Manganese ion (Mn^{2+}) Manganese dioxide (MnO_2) Total manganese	0 mg/l Trace 0.05 – 0.2 mg/l
Zinc	Zinc ion (Zn^{2+}) Total zinc	< 0.01 mg/l – 0.05 mg/l
Copper	Copper ion (Cu^{2+}) Total copper	< 0.005 mg/l 0.005 – 0.01 mg/l
Boron	Borate (H_3BO_3 , $H_2BO_3^-$)	0.05 – 1 mg/l

This fact sheet aims to give the reader a brief overview on water quality in freshwater ponds. The following books are highly recommended for aquaculturists seeking further information on water quality:

Boyd, C.E. (1990). Water Quality in Ponds for Aquaculture. Birmingham Publishing Company, Birmingham, Alabama.

Boyd, C.E. (1998). Water Quality for Pond Aquaculture. Research and Development Series No. 43. International Center for Aquaculture and Aquatic Environments, Alabama Agricultural Experiment Station, Auburn University, Alabama.

Ingram, B.A., Hawking, J.H. Shiel, R.J. (1997). Aquatic Life in Freshwater Ponds; A guide to the identification and ecology of life in aquaculture ponds and farm dams in South-Eastern Australia.
Co-operative Research Centre for Freshwater Ecology, Albury, NSW, Australia.

Walker, T. (1994). Pond Water Quality Management: A Farmer's Handbook. Turtle Press Pty Ltd, Tas, Australia.

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