ORNAMENTAL AQUATIC TRADE ASSOCIATION (OATA)

WATER QUALITY CRITERIA

Version 2.0
March 2008

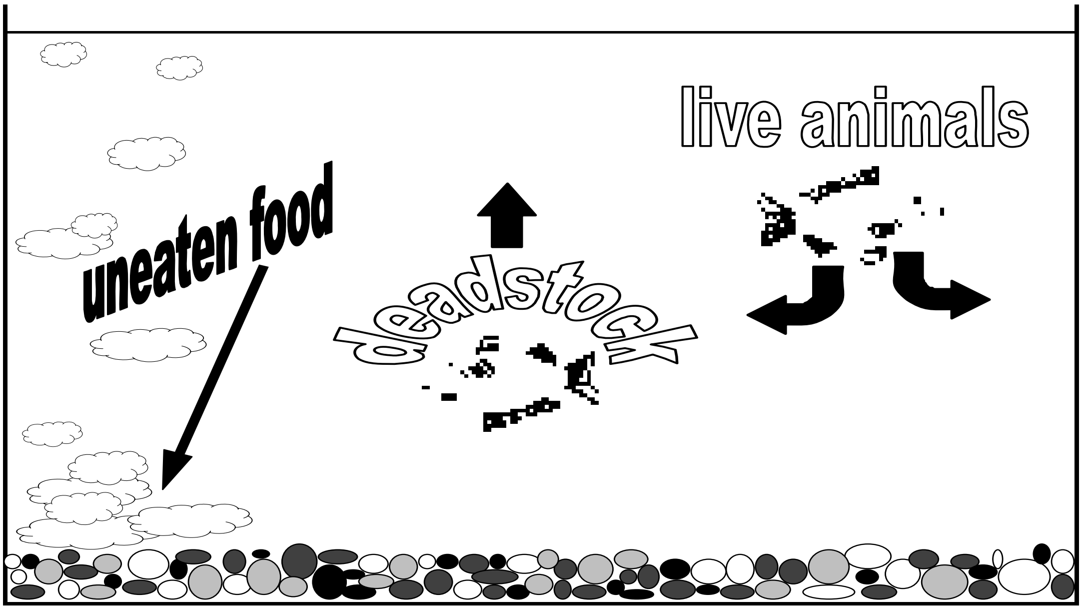
A Company Limited by Guarantee and Registered in England No 2738119 Registered Office Wessex House, 40 Station Road, Westbury, Wiltshire, BA13 3JN, UK, Telephone:+44(0)8700 434013 Fax:+44(0)1373 301236
info@ornamentalfish.org www.ornamentalfish.org

CONTENTS

Note: 1ppm = 1mg/l

1. AMMONIA

1.1. Sources



In aquaria and ponds the principal sources of ammonia are:

- Excretion by fish and other livestock as a normal part of their metabolism
- The breakdown of protein in uneaten food or dead livestock that remains undetected. It is therefore of great importance that careful cleaning is undertaken at suitable intervals.

1.2. Chemistry

As ammonia is released into the water by either of these processes it may take one of two forms:

- Free Ammonia (unionised ammonia, chemical symbol NH_3). This form of ammonia is highly toxic to fish
- Ammonium (ionised ammonia, chemical symbol NH_4^+). This form of ammonia is virtually non toxic to fish

Total Ammonia	Dissolves to become	NH_4+ Ammonium	or	NH_3 Free Ammonia

The balance between Free Ammonia and Ammonium is determined by the pH and temperature of the water and may be summarised:

↗ High temperature	↗ High free ammonia (NH3)
↗ High pH	↘ (low ammonium) (NH_4+)
Dangerous to fish	

↘ Low temperature	↘ Low free ammonia (NH3)
↘ Low pH	↗ (high ammonium) (NH_4+)
Relatively safe for fish	

1.3. Measurement of Ammonia

Test kits and electronic meters usually measure all ammonia present; that is TOTAL AMMONIA. Some test kits measure Ammonium-Nitrogen and apply a conversion factor to determine the ammonia. This will usually be explained in the instructions provided with the test kit.

TOTAL AMMONIA = AMMONIUM + FREE AMMONIA

To determine the amount of Free Ammonia present, pH and temperature MUST be known.

1.4. Safe levels of free ammonia

OATA recommends that FREE AMMONIA should not exceed **0.02mg/l in freshwater** and **0.01mg/l in seawater**.

Above this level free ammonia causes the fish stress and at higher levels it may cause damage to gills and many internal organs, eventually resulting in fish deaths.

Table 1: Levels of TOTAL AMMONIA (mg/l) that maintain FREE AMMONIA at or below 0.02mg/l at a range of pH and temperatures

PH / Temp °C	6	6.5	7	7.5	8	8.5	9
0	250	77	24	7.7	2.4	0.78	0.1
5	154	50	16	5	1.6	0.52	0.07
10	105	34	11	3.4	1.1	0.36	0.05
15	74	23	7.5	2.3	0.75	0.25	0.04
20	50	16	5	1.6	0.52	0.18	0.04
25	35	11	3.5	1.1	0.37	0.13	0.03
30	25	8	2.5	0.8	0.27	0.1	0.03

These figures apply to freshwater. To meet the criteria for marine fish these figures should be halved.

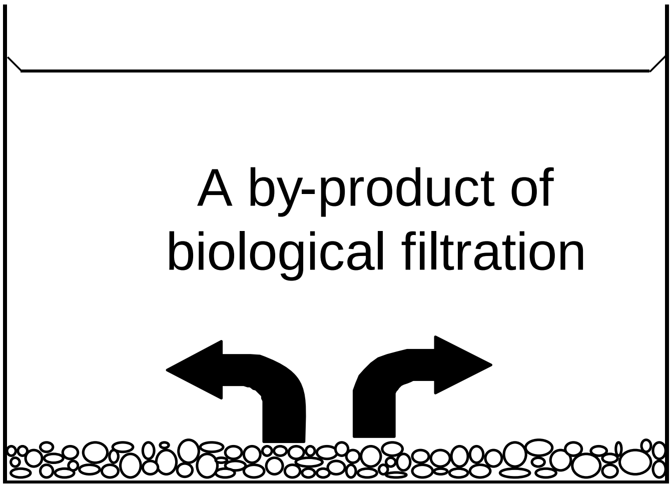
1.5. Reducing the level of Ammonia

Levels can be reduced by:

- Dilution by water changes
- Reduction of stocking densities, improvement of feeding and general husbandry procedures
- Improvement of biological filtration
- Use of ion exchange materials

2. NITRITE (NO_2^-)

2.1. Sources



In aquaria and ponds nitrites are produced by bacteria (including *Nitrosomonas* spp.) when ammonia is broken down.

2.2. Measurement of Nitrite

Test kits are available. Some of these measure Nitrite-Nitrogen, a conversion factor being applied to the result to obtain a true Nitrite reading. Full instructions should be available with the test kit used.

2.3. Safe levels of Nitrite

OATA recommends that Nitrite should not exceed **0.2mg/l in freshwater** and **0.125mg/l in seawater**.

Nitrite poisons fish by binding the haemoglobin in the blood preventing it from carrying oxygen, in effect suffocating the fish. The gills of fish dying as a result of nitrite poisoning are a characteristic brown colour.

In freshwater the toxicity of nitrite may be reduced by the addition of small amounts of certain chloride salts.

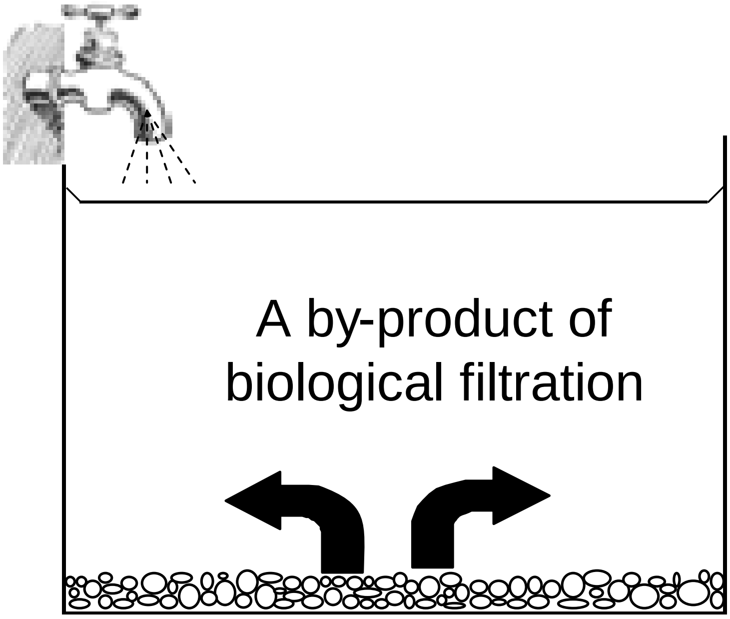
2.4. Reducing the level of Nitrite

Levels can be reduced by:

- Reduction of stocking densities, improvement of feeding and general husbandry procedures
- Improvement of biological filtration
- Dilution by water change

3. NITRATE (NO_3^-)

3.1. Sources



Nitrates are:

- produced as bacteria (including *Nitrobacter* spp.) breaks down nitrites;
- introduced in tap water. In some areas of the country tap water nitrate levels exceed 130mg/l.

3.2. Measurement of Nitrate

Test kits are available. Some measure Nitrate-Nitrogen, a conversion factor then being applied to obtain a true Nitrate reading; full instructions should be available with the kits used.

3.3. Safe Levels of Nitrate

Nitrate is generally of low toxicity though some species, especially marines, are sensitive to its presence. When nitrate levels are high, as a result of biological filtration, other chemicals produced in this process may be present at levels that adversely affect fish health.

OATA recommends that nitrate levels in **freshwater** systems do not exceed those in the tap water supply by more than **50mg/l** and that levels in **marine** systems never exceed **100mg/l**.

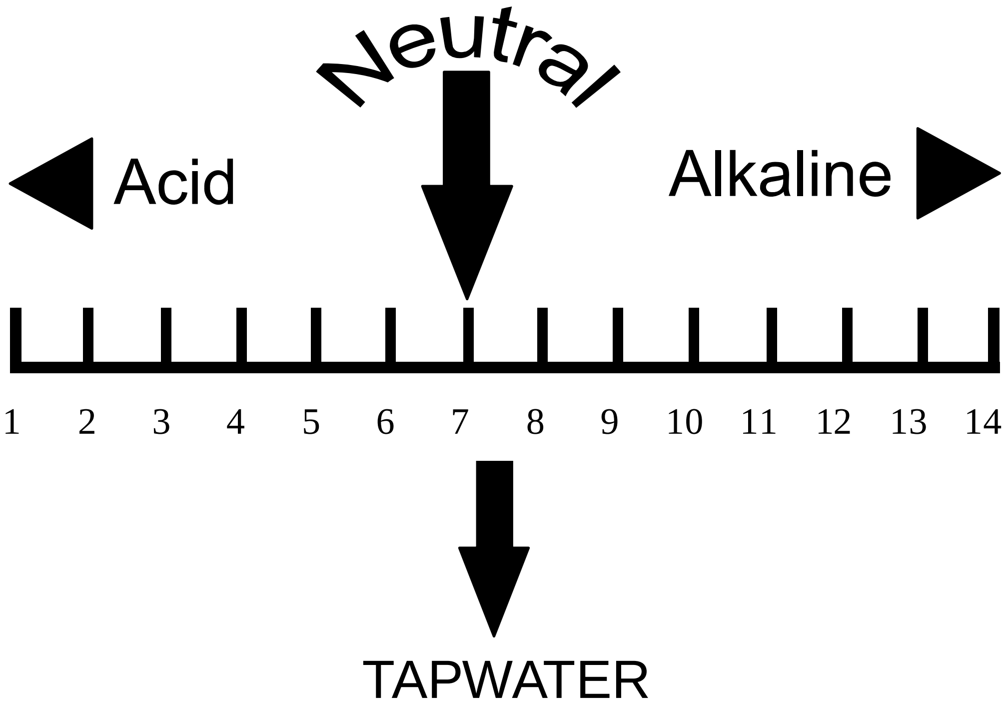
3.4. Reducing the level of Nitrate

Levels can be reduced by:

- Dilution by water change, (ensure water used for change has a lower nitrate level)
- Use of ion exchange materials
- Increase plant density
- Use of denitrifying biological filtration

4. PH

4.1. The pH Scale



The pH scale is logarithmic.

This means that there is a x10 change in acidity or alkalinity for each change of 1 unit in pH.

Thus pH5 is 10x more acid than pH6

And pH5 is 100x more acid than pH7.

5. CHANGING PH

Active biological filters tend to lower the pH of the systems they are part of.

Hard water and seawater contain dissolved materials that prevent rapid change in pH.

A buffering system in seawater is overcome at about **pH 8.1**. Once the buffering system runs out a very rapid fall in the pH may occur jeopardising livestock.

5.1. Rising pH

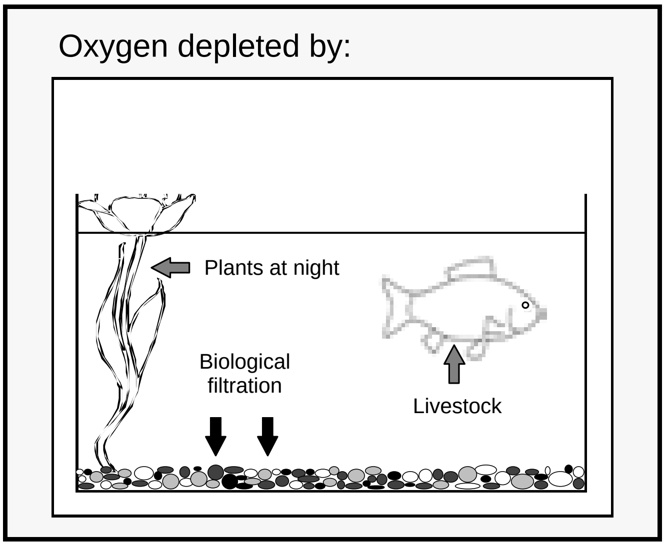
At low pHs the toxicity of ammonia is low. Low pHs may be brought about by carbon dioxide, produced by animals all the time and by plants at night, dissolving in water and forming carbonic acid.

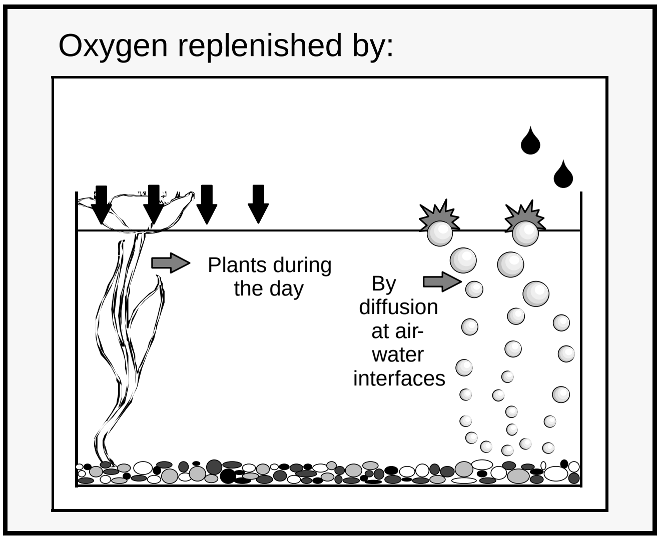
If water of a higher pH is added then there may be a sudden increase in pH. Associated with this rise will be a rapid increase in the toxicity of any ammonia present. This situation may arise during the transport of livestock and subsequent acclimatisation to either hard water or seawater.

6.DISSOLVED OXYGEN

1 litre of oxygen weighs 1,428mg
1 litre of air contains 285mg oxygen
1 litre of freshwater contains 14.6mg oxygen at 0°C

Water is therefore an oxygen-poor environment. It contains only 5% of the oxygen that the same volume of air does.





In the absence of adequate aeration, stock held in vessels with a low surface area to volume ratio are likely to suffer low oxygen most easily. Such systems should be monitored particularly carefully.

6.1. Saturation

If a beaker of sterile freshwater is left to stand at 25ºC then the normal maximum amount of oxygen that it can dissolve is 8.2mg/l. At this point the water sample is said to be 100% SATURATED. If it contained only 4.1mg/l then it would be 50% saturated. A level of dissolved oxygen of **6mg/l** as recommended in the OATA 'Water Quality Criteria' is equivalent to **73% saturation** at 25ºC.

6.2. Solubility of oxygen

The table below demonstrates that as the water temperature rises, the amount of oxygen it may dissolve before becoming saturated diminishes.

Seawater dissolves less oxygen than freshwater before it becomes saturated.

Table 2: Solubility of oxygen

Temp C	Mg/l oxygen freshwater	Terms of % saturation at OATA criteria	Mg/l oxygen saltwater	Terms of % saturation at OATA criteria
0	14.6	41	11.7	47
5	12.8	47	10.4	52
10	11.3	53	9.3	58
15	10.1	59	8.5	65
20	9.1	66	7.8	71
25	8.2	73	7.1	77
30	7.5	80	6.5	85

Altitude and atmospheric pressure play a small part in determining oxygen solubility. For practical purposes both may be ignored.

6.3. Increasing levels of dissolved oxygen

The water in an aquarium should be given ample opportunity, through aeration, movement, and agitation, to mix freely with fresh air to maximise saturation with oxygen and to allow removal of excess CO_2. A persistently low oxygen reading may suggest:

- Inadequate aeration or water movement/agitation to allow this equilibration of gases to happen

And/Or

- Poor ventilation and fresh air renewal around the aquarium and/or its filtration elements.

If either of these conditions applies then stocking levels should be reduced until the situation is rectified and parameters measured return to within recommended levels.

6.4. Weather

Sunlight may increase water temperature and hence decrease oxygen solubility.

Freezing ice seals the surface preventing the entry of oxygen and the escape of toxic gases.

During still periods (when there is little wind, such as before thunderstorms) the rate of diffusion of oxygen is diminished by the reduction of the pond surface area (ripples in a light wind may increase the surface area of a pond by two or three times).

6.5. Measurement of dissolved oxygen

Chemical test kits and electronic meters are available.

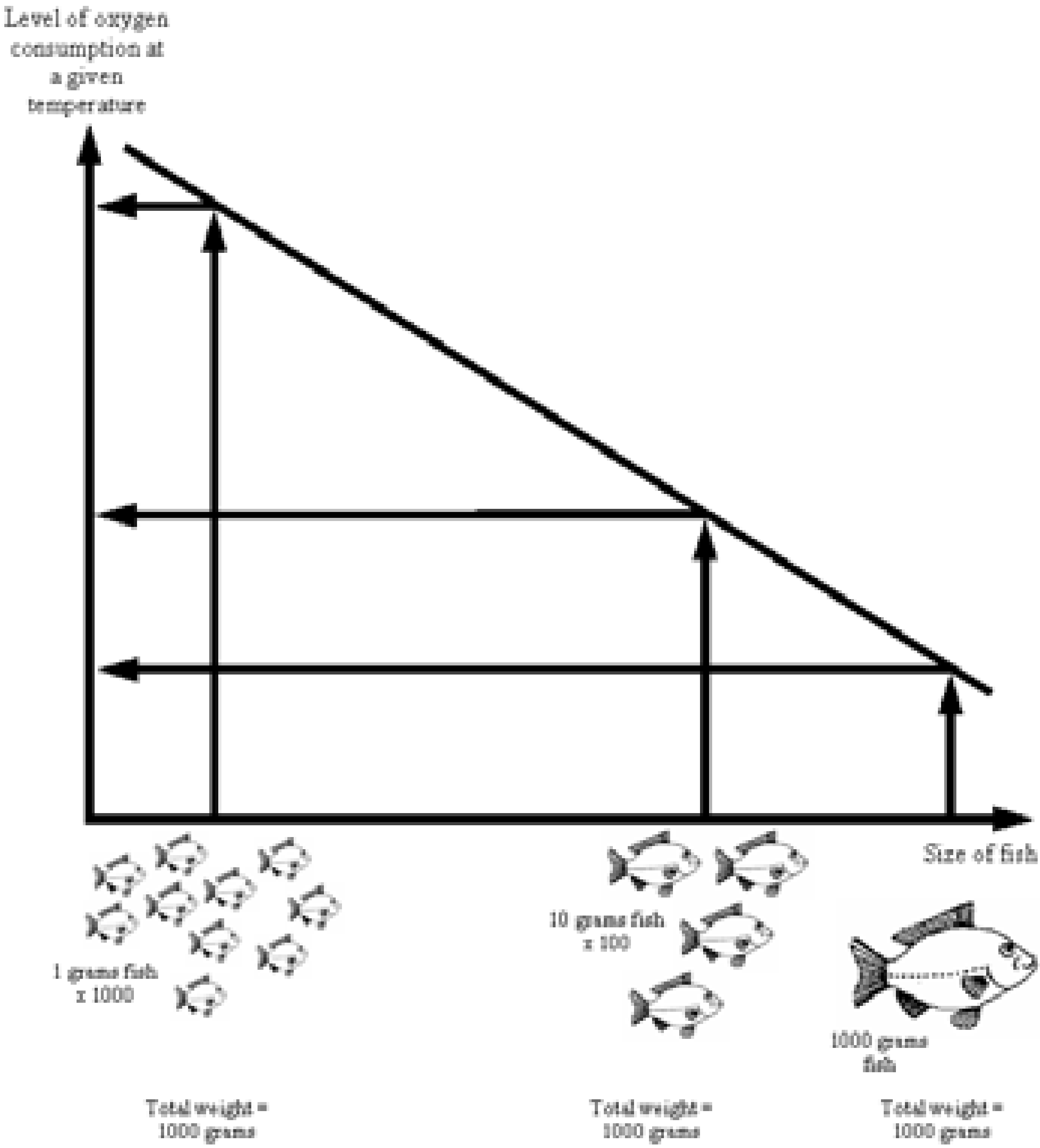
6.6. Oxygen consumption

Oxygen consumption is affected by the following factors:

- Size of livestock – small fish use relatively more oxygen than large fish.
- Total weight of livestock
- Temperature – oxygen consumption of livestock doubles for each 10ºC rise in temperature. But oxygen availability is reduced as its solubility is also reduced by the temperature rise.

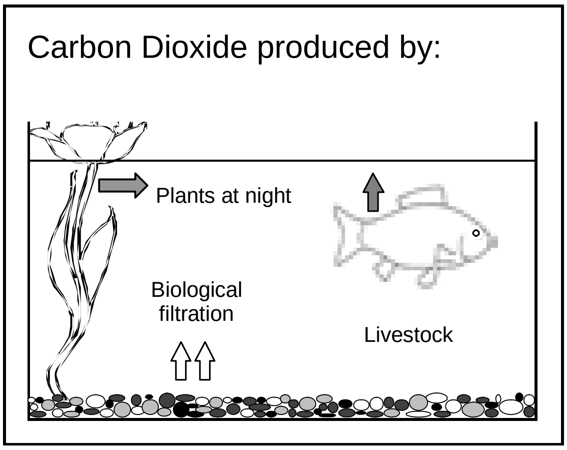
N.B. Biofilter activity and ammonia production mirrors oxygen consumption.

Oxygen Consumption at a Given Temperature

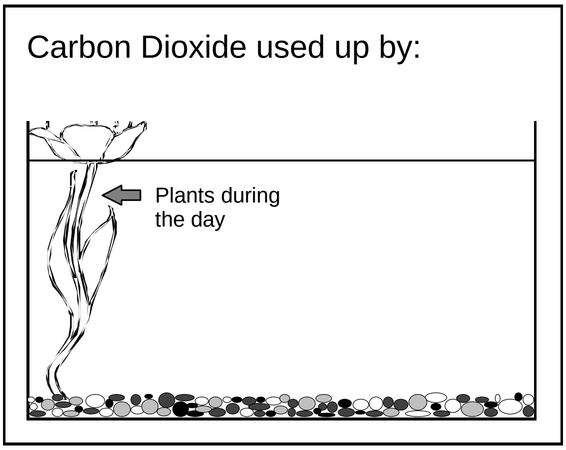


7. CARBON DIOXIDE CO2

Carbon dioxide is produced by



Carbon is used up by



Carbon dioxide may also be removed from aquarium or pond systems by agitation of the water or aerator.

7.1. Carbon dioxide

CO2 is a HIGHLY soluble gas, approximately 1000 times more so than oxygen, which, when it dissolves in water, forms carbonic acid. Excess carbon dioxide has a suffocating effect on fish. The carbonic acid also tends to lower the pH of any system, especially insufficiently buffered systems, and this pH drop can also have harmful impacts on organisms.

7.2. Decreasing levels of Carbon dioxide

The water in an aquarium should be given ample opportunity, through aeration, movement, and agitation, to mix freely with fresh air to maximise saturation with oxygen and to allow removal of excess CO_2. A persistently low oxygen or pH reading may suggest:

- Inadequate aeration or water movement/agitation to allow this equilibration of gases to happen

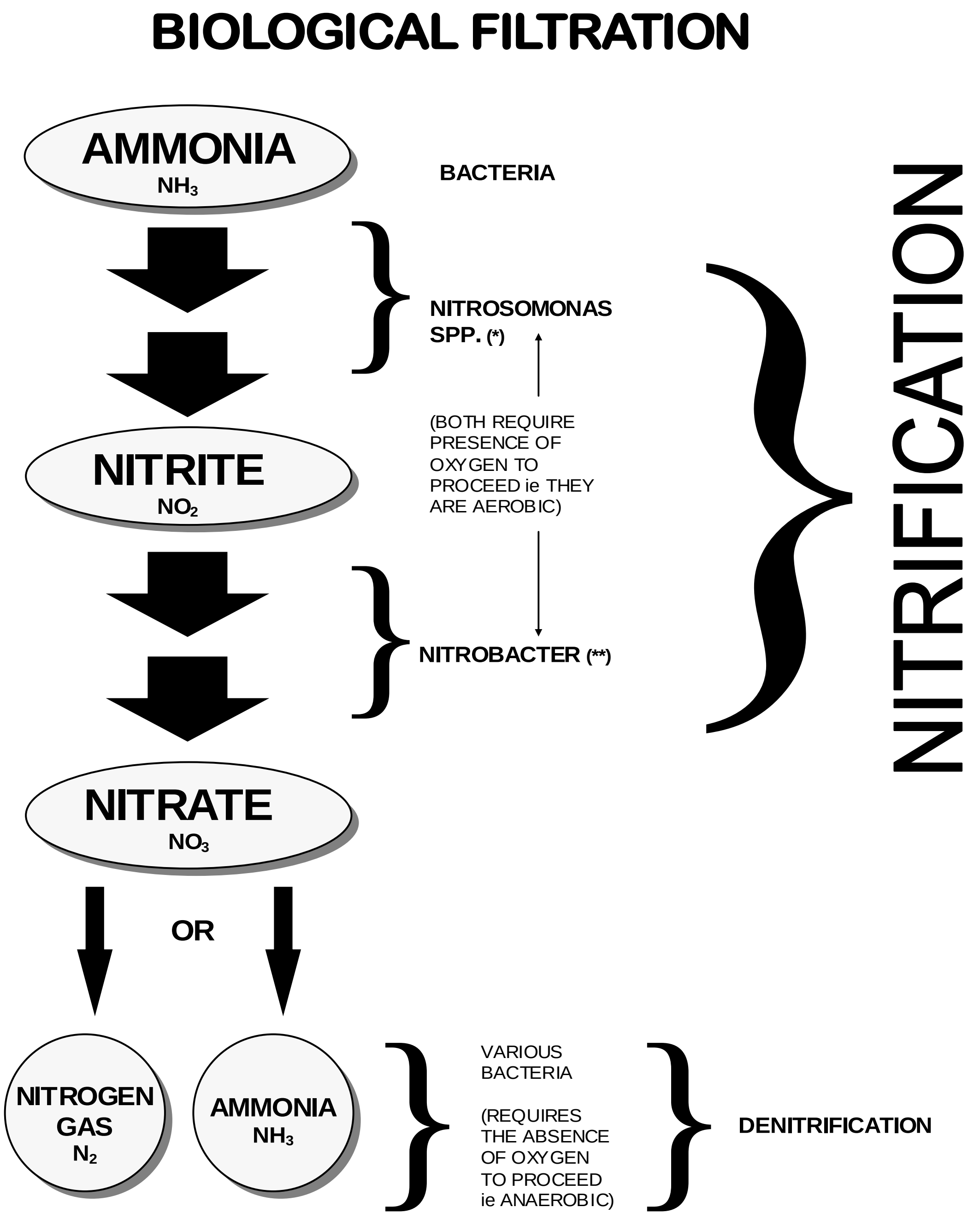
And/Or

- Poor ventilation and fresh air renewal around the aquarium and/or its filtration elements.

If either of these conditions applies then stocking levels should be reduced until these parameters are measured within recommended levels.

8. BIOLOGICAL FILTRATION

Biological filtration is the process by which waste products, principally ammonia, in ponds and aquaria are broken down by bacteria.



(*) It is common to use the term *Nitrosomonas* for all the Ammonia-Oxidizing Bacteria (AOB) including, among others, the genera *Nitrosospira*, *Nitrosococcus*, and *Nitrosolobus*.

(**) It is common to use the term *Nitrobacter* for all the Nitrite-Oxidizing Bacteria (NOB) including, among others, the genera *Nitrospira*, *Nitrospina*, and *Nitrococcus*.

The bacteria that are responsible for **nitrification** require:

- A surface on which to grow (the larger the surface area, the greater the population which may grow)
- A good supply of dissolved oxygen (an active filter may use more oxygen than the livestock in the water it processes)
- A supply of nutrients – ammonia and nitrites

A filter may be said to be mature when any ammonia entering a tank is instantaneously converted to nitrite and then in turn to nitrate.

Biological filters are only mature for specific conditions: if the stocking density or feeding increases then the filter needs a further period of maturation.

The bacteria responsible for **denitrification** require:

- A surface on which to grow;
- A supply of nutrients
    - Principally nitrates;
    - Secondarily, if methanol or a similar chemical is present, nitrogen gas will be formed;
    - If other organic materials are present, ammonia may be formed.

Oxygen kills the bacteria responsible for the denitrification.

9. APPENDIX A

9.1. Stocking Densities – Ornamental Fish

It is virtually impossible to determine the quantity of fish to be kept in a system purely on weight, or number of fish per unit volume, or area of water surface.

The variation in holding system used, the quality of husbandry and types of fish stocked vary so greatly that it would render any such system too complicated to be practical, or too simple to be useful.

The maintenance of water quality standards can be used to determine working stocking densities.

Water Quality Testing:
Water quality testing should be carried out at least once a week in centralised systems. In individually filtered aquaria or holding vats at least 10% of them should be tested in the same way at least once a week. Unsatisfactory results must be recorded in a register together with the corrective action taken. Further tests must be carried out when visual inspection of the tanks indicates the need. While no general rule for the normal behaviour of all fish can be given, if they are gasping at the surface, or normally active species are lethargic, then water quality testing or other investigation may be necessary.

Tests should be undertaken at different times of the day to ensure that the readings are representative of normal conditions in the aquarium or pond.

9.2. Water quality Criteria

Cold Water Species

*Free Ammonia	- max 0.02mg/l
*Nitrite	- max 0.2mg/l
Dissolved Oxygen	- min 6mg/l
Nitrate	- max 50mg/l above ambient tap water

Tropical Freshwater Species

*Free Ammonia	- max 0.02mg/l
*Nitrite	- max 0.2mg/l
Dissolved Oxygen	- min 6mg/l
Nitrate	- max 50mg/l above ambient tap water

Tropical Marine Species

*Free Ammonia	- max 0.01mg/l
*Nitrite	- max 0.125mg/l
*pH	- min 8.1
Dissolved Oxygen	- recommended 5.5mg/l (never lower than 4.0mg/litre)
Nitrate	- max 100 mg/l

Factors marked * should be measured in the first instance, if they prove satisfactory, and the fish appear healthy, then further investigation may not be necessary.

9.3. Fish Under treatment

It may not be possible to maintain levels given when effective disease treatments are in use.

10. APPENDIX B

10.1. Guide Stocking Densities

The water quality standards should not be met at the expense of a correct feeding regime.

Cold Water Species

8kg/1000 l

Tropical Freshwater Species

Fish up to 5cm (2”) – 1.5kg/1000 l
Fish over 5cm (2”) – 2.5kg/1000 l

Tropical Marine Species

Fish up to 5cm (2”) – 1kg/1000 l
Fish over 5cm (2”) – 2kg/1000 l

Guide stockings are ADVISORY only. They may be exceeded if the water quality standards are satisfied. When the water quality standards are exceeded at a lower stocking, this must be considered as the maximum stocking density permissible.

The TOTAL volume of the system must be measured and taken into account in determining actual stocking densities.

10.2. Technical Note

The above figures should be read in the following manner:
Free Ammonia as NH_3
Nitrite as NO_2^-
Nitrate as NO_3^-

Other documents that may be used in association with this Water Quality Criteria document include the follow.