Sea Water Chemistry

Introduction and background knowledge before diving in

The following pages provide more information on:

- Background to Sea Water
- Composition of Sea Water
- Explanation of life support parameters Salinity (S.G.), pH
- Important elements in salt - Alkalinity, Calcium, Magnesium, others
- Undesirable nutrients - Phosphates, Nitrates

Background to Sea Water

Having a successful coral reef aquarium is dependent upon maintaining the physical and chemical water parameters of a natural reef environment. Therefore the choice of reef-salt formula is the most fundamental issue in the setup of any seawater aquarium.

Sea water is not just a solution of sodium chloride (table salt) and water, but is a complex mixture of virtually every substance that can be found on earth. Latest studies have identified up to 80 elements in oceanic sea water, however the elemental composition around the thriving natural reefs vary slightly to the open ocean. While much is already known, the effect of many of these elements in the physiology of marine life is yet to be determined providing the basis for ongoing research. The correct level, in particular regarding trace elements can be critical.

For example, very small amounts of **copper**, precisely those amounts normally found in natural sea water, are absolutely necessary for the correct functioning of the respiratory pigment in arthropods and mollusks. However, a slight increase in the amount of copper in the water surrounding the organisms will result in a similar increase in the internal cellular environment resulting in the denaturation of other cellular agents, killing these same organisms.

Bio-tech note:

At the basic cellular level, all life is dependent upon the proper functioning of a complex series of coupled chemical reactions. These reactions are regulated and controlled by specific biological agents whose capabilities are determined by the properties of the internal cellular environment. In many marine creatures, the internal cellular environment is directly dependent upon the sea water medium that surrounds the organism. Changes in salinity, for example, are often directly responsible for changes in cellular metabolism. Additionally, chemicals dissolved in the sea water medium may directly affect the cellular functionality. This is particularly true of metal ions in sea water.

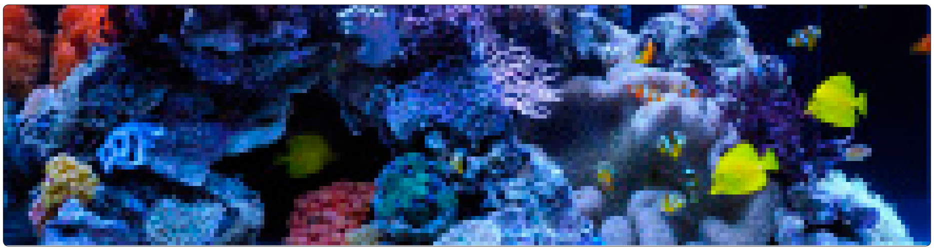
In the proper amounts, various metal ions ensure that the biological agents are of the correct shape and have the appropriate function. When found in the wrong concentrations, however, many metal ions may interfere with, and change, the structures of the biological agents. These changes generally cause serious problems to the organism.

Recommended parameters of artificial salt water

Parameter	Artificial salt water	NSW
Salinity	33-36 ppt	Variable
pH	8.2-8.4	8.0-8.3
Alkalinity *	2.5-4.5 meq./l 7-15dKH	2.5 meq/l 7 dKH
Calcium *	410 -460ppm	420 ppm
Magnesium *	1250-1400ppm	1280 ppm
Potassium *	380-410 ppm	390 ppm
Phosphate	< 0.1ppm	0.005ppm
Ammonia	< 0.1ppm	Variable (typically < 0.1ppm)
Nitrite	< 0.2ppm	Variable (typically < 0.0001ppm)
Nitrate	< 1 ppm	Variable (typically < 0.1ppm)
Silica	< 2ppm	< 0.06 – 2.7ppm
Strontium	7-12ppm	8ppm
Iron	0.01-0.1ppm	0.000006ppm
Iodine	0.05 – 0.07 ppm	0.06ppm total of all forms

* Dependant on Marine (fish only) or Coral Reef Aquarium.

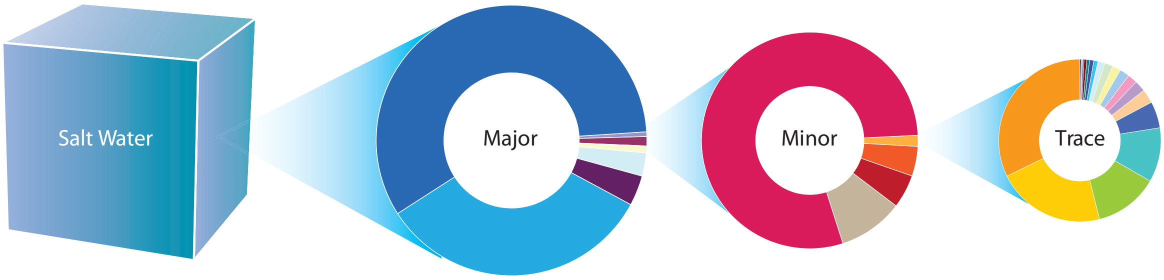
Due to the significant difference between the natural reef environment and the artificial reef system in the availability of elements some parameters must be maintained at levels different to those found in NSW



The composition of sea water

Chemical elements in seawater are commonly grouped into three general categories: major, minor and trace. The distinction between the categories is arbitrary and different authors will use different concentrations for the dividing lines.

Note: The following tables relate to an elemental analysis of seawater. This is not a formula of chemicals used to create a sea salt mix.



Major elements >100ppm		100ppm < Minor elements < 0.5ppm	
Chloride (Cl-)*	19353	Bromide (Br-)*	67
Sodium (Na+)*	10781	Carbon	28
Sulfate (SO4--)*	2712	Strontium (Sr+)	8.5
Magnesium (Mg++)*	1284	Boron	4.6
Calcium (Ca++)	419	Fluoride (F-)*	1.3
Potassium (K+)*	390	Silicone	0.5

Trace elements:

Element	Symbol	ppm
LITHIUM	Li	0.178
RUBIDIUM	Rb	0.12
IODINE	I	0.06
BARIUM	Ba	0.05
SELENIUM	Se	0.004
ARSENIC	As	0.002
CESIUM	Cs	0.002
ZIRCONIUM	Zr	0.0014
VANADIUM	V	0.0012
ALUMINIUM	Al	0.001
MOLYBDENUM	Mo	0.001
NICKEL	Ni	0.0007
IRON	Fe	0.0005
ZINC	Zn	0.0005
CERIUM	Ce	0.0004
CHROMIUM	Cr	0.0004
LEAD	Pb	0.0004
GALLIUM	Ga	0.0003
LANTHANUM	La	0.0003

Element	Symbol	ppm
MANGANESE	Mn	0.0003
ANTIMONY	Sb	0.0002
COPPER	Cu	0.0002
URANIUM	U	0.00015
CADIUM	Cd	0.0001
TUNGSTEN	W	0.0001
COBALT	Co	0.00007
GERMANIUM	Ge	0.00005
SCANDIUM	Sc	0.00004
GOLD	Au	0.00003
INDIUM	In	0.00003
TIN	Sn	0.00003
SILVER	Ag	0.00002
YTTRIUM	Y	0.000013
NIOBIUM	Nb	0.00001
HOLMIUM	Ho	0.000008
HAFNIUM	Hf	0.000007
TANTALUM	Ta	0.000007
MERCURY	Hg	0.000005

Element	Symbol	ppm
RHENIUM	Re	0.000004
THALLIUM	Th	0.000002
BERYLLIUM	Be	0.000001
DYSPROSIUM	Dy	0.0000009
ERBIUM	Er	0.0000008
YTTERBIUM	Yb	0.0000008
GADOLINIUM	Gd	0.0000007
RUTHENIUM	Ru	0.0000007
PLATINUM	Pt	0.0000006
PRAESIDIUM	Pr	0.0000006
THULIUM	Tm	0.0000002
BISMUTH	Bi	0.0000001
TERBIUM	Tb	0.0000001
TITANIUM	Ti	0.0000001
SAMARIUM	Sm	0.00000005
EUROPIUM	Eu	0.00000002
RADIUM	Ra	0000000001

Life Support Parameters - Salinity

- The recommended salinity in a coral reef tank for optimal calcification: 33-36 ppt.
- The recommended salinity in a fish only tank: 30-38 ppt.

Salinity must be monitored at least twice per week. The natural evaporation of the H2O from the sea water in an aquarium, unless replenished regularly will cause an increase in the salinity of the aquarium water.

Salinity is critical to the health of marine organisms because of the process of osmoregulation that enables the organism to maintain the correct level of dissolved ions inside the body fluids. Salinity has a direct influence on marine organism's metabolism and internal processes such as coral calcification.

Bio-tech note:

Osmoregulation is the active regulation of the osmotic pressure of an organism's fluids to maintain the homeostasis of the organism's water content; that is it keeps the organism's fluids from becoming too dilute or too concentrated. Osmotic pressure is a measure of the tendency of water to move into one solution from another through a membrane by osmosis. The higher the osmotic pressure of a solution the more water wants to move into the solution. Pressure must be exerted on the "higher salinity" side of a selectively-permeable membrane to prevent diffusion of water by osmosis from the "lower salinity" side. Organisms that are exposed to an environment with the incorrect salinity will be under stress as they will be expending a disproportionate amount of energy in maintaining their osmotic

Definition and Measuring salinity

Salinity is the summery of the mass of all of the dissolved salts in specified volume of water. It is expressed in terms of ppt (part per thousand) = g/L (gram per liter) = ‰ = psu, and can be measured with a refractometer or a Conductivity meters (mS).

The more common method in the hobby is measuring the Specific Gravity or S.G. which is the ratio of the density of the salt water solution and the density of the same volume of pure water at 4°C. S.G. doesn't have units and it is measured by hydrometer. The S.G. measurement is temperature dependant and therefore it is a meaningless number without knowing the actual temperature of the water sample.

Note: A solution with a fixed salinity will have a lower S.G at a higher temperature.

Table showing the salinity from a known S.G, and temperature:

Observed Reading	25.0	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30
1.0210	30.2	30.3	30.6	30.7	30.9	31.1	31.3	31.5	31.7	32.0	32.1
1.0220	31.5	31.7	31.9	32.0	32.2	32.5	32.6	32.9	33.0	33.3	33.4
1.0230	32.8	33.0	33.2	33.4	33.5	33.8	33.9	34.2	34.5	34.6	34.8
1.0240	34.2	34.3	34.5	34.7	35.0	35.1	35.4	35.5	35.8	35.9	36.2
1.0250	35.5	35.6	35.9	36.0	36.3	36.4	36.7	36.8	37.1	37.2	37.5
1.0260	36.8	36.9	37.2	37.3	37.6	37.7	38.0	38.2	38.4	38.6	38.8
1.027	38.1	38.4	38.5	38.8	38.9	39.1	39.3	39.5	39.8	39.9	40.2
1.0280	39.4	39.7	39.8	40.1	40.2	40.5	40.7	40.8	14.1	41.2	41.5
1.0290	40.8	41.0	41.2	41.4	41.6	41.8					

Professional conductivity meters will also measure temperature and will therefore give a reading that is adjusted for the temperature. The reading may already be translated into salinity (ppt) or may give the actual conductivity reading in millisiemens. The table below converts mS to salinity (S.G @ 25°C):

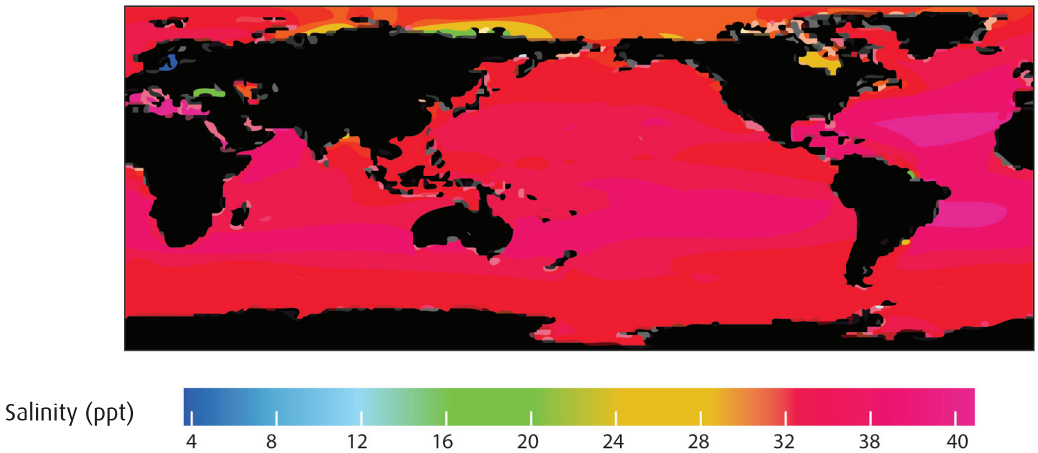
mS to Salinity conversion (S.G. @ 25°C)

Salinity ppt	Conductivity mS	S.G.
32.00	49.000	1.0210
32.74	50.000	1.0216
33.47	51.000	1.0221
34.21	52.000	1.0227
34.95	53.000	1.0233
35.00	53.065	1.0235
35.70	54.000	1.0238

Salinity ppt	Conductivity mS	S.G.
36.44	55.000	1.0244
37.19	56.000	1.0250
37.94	57.000	1.0255
38.69	58.000	1.0260
39.45	59.000	1.0267
40.21	60.000	1.0270

Salinity of the world's oceans.

- The salinity of the natural coral reefs ranges from 33 to 40 ppt
- The salinity of the Red Sea (the source of Red Sea's salts) is 40 ppt



Life Support Parameters - pH

- The recommended pH in a coral reef tank for optimal calcification: 8.2-8.4
- The recommended pH in a fish only tank: 7.8 – 8.4

The pH should be monitored every other day A drop in pH can be fatal to marine organisms. pH drops are caused by: excessive CO_2, decrease in Alkalinity, excessive nitrification & a build-up of organic matter.

All biological processes occur in specific narrow range of pH, even the slightest changes in pH can affect fundamental processes in many marine organisms, such as calcification and the deposition of calcium carbonate skeletons. For example:

- Optimal Calcification pH: 8.3
- Optimal ammonia removal from gills: 7.8-8.4 (marine fish).

Chem-tech note:

pH is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. pH is an important indicator of water that is changing chemically.

Dissolved carbon dioxide (CO_2) & alkalinity substances have a direct influence on pH levels in seawater due to the dynamic equilibrium that exists between molecules of carbonic acid, bicarbonate and carbonate

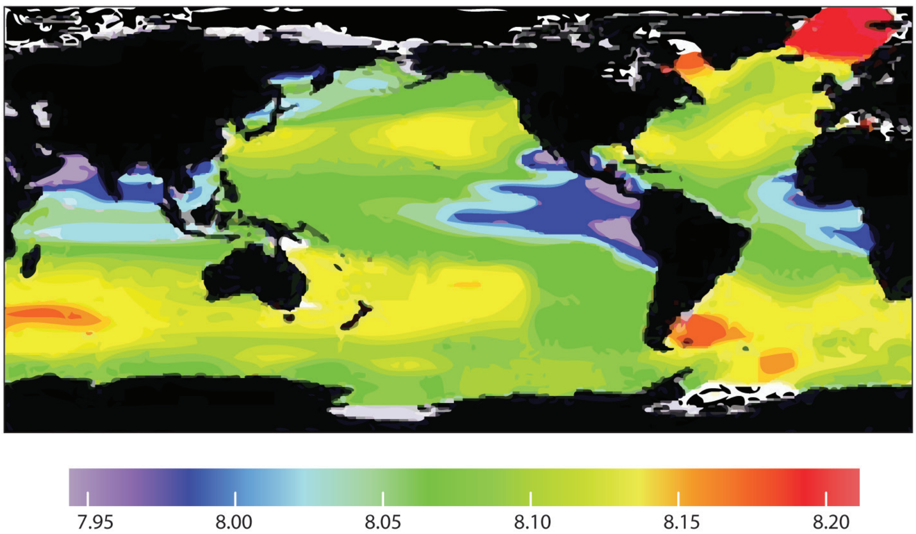
$$CO_2 + H_2O <=> H_2CO3 <=> H^+ + HCO3- <=> 2H^+ + CO3^{2-}$$

(1%) (93%) (6%) - (equilibrium percentage in seawater)

When the dissolved CO_2 levels increase, the equation shifts to the right and more H^+ ions are released to the water and the pH drops. When you have more alkalinity substances, such as $CO3^{2-}$ The equation shifts to the left and the pH will climb.

pH of the world's oceans.

- The pH of the natural coral reefs ranges from 8.05 – 8.12



Important elements in salt:

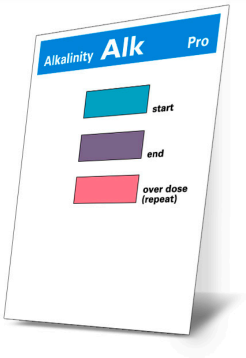
Alkalinity / Carbonate Hardness (dKH)

- The recommended Alkalinity (dKH) in a coral reef tank for optimal calcification: 3-4.5 (9-15 dKH)
- The recommended Alkalinity in a fish only tank: 2.2- 3 (6 - 8 dKH)

Alkalinity (also referred to as “pH Buffer”) refers to the amount of acid required to lower the pH. It indicates the store of bicarbonate (HCO_3^-) and carbonate (CO_3^-) in the water which help to maintain a stable pH. Alkalinity is measured in milliequivalents/liter (meq/l) or carbonate hardness (dKH).

1 meq/l = 2.8 dKH

The prevailing wisdom among marine biologists favors the notion that certain organisms calcify more quickly at a higher alkalinity than naturally occurs in seawater, therefore Red Sea recommends a higher alkalinity level (see spec for Coral Pro) for a Coral Reef Aquarium.



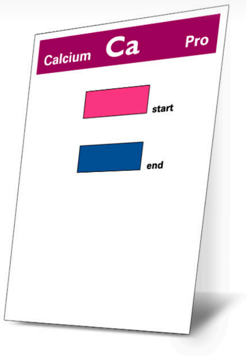
Bio-tech note:

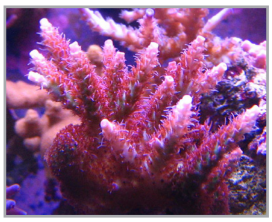
Corals absorb bicarbonate as building blocks for their skeleton, by converting it to carbonate and then combine the carbonate with calcium to form calcium carbonate skeletons. Bicarbonate intake thus becomes a limiting factor in the calcification rate among many corals. This stems partially from the fact that both photosynthesis and calcification compete for bicarbonate, and the bicarbonate concentration starts out low. You should maintain alkalinity in the 3 -4.5 meq/L (9-15 dKH) range. Higher levels, although they do not adversely affect the coral, increase the likelihood of decreased calcium concentration.

Calcium

- The recommended Calcium level in a coral reef tank for optimal calcification: 440 – 460 ppm
- The recommended Calcium level in a fish only tank: 380 - 460 ppm

As mentioned above, corals primarily use calcium carbonate to form their skeletons. Most of the calcium comes from the surrounding water. Consequently, aquaria with growing coral, calcareous algae and giant clams (tridacnids), rapidly become depleted of calcium. Once the calcium level drops below 360ppm, corals can no longer absorb enough of it, and they stop growing. Calcium level should be maintained between 420-460ppm. Higher levels, although they do not adversely affect the coral, increase the likelihood of decreased alkalinity.





Magnesium

- The recommended Magnesium level in a coral reef tank for optimal calcification: 1250 – 1400 ppm
- The recommended Magnesium level in a fish only tank: 1100 – 1400 ppm

Some corals and coralline algae deplete magnesium by absorbing it into their growing skeletons however Magnesium's primary importance lies in its effect on the alkalinity/calcium balance in reef aquaria.

Chem-tech note:

Seawater and reef aquarium water ideally have calcium carbonate at super-saturation levels. This naturally causes calcium to precipitate out of solution, forming crystals that cannot re-dissolved at the natural pH of seawater. Magnesium binds to these crystals, effectively blocking their surface and preventing further precipitation that would otherwise pull more calcium out of the seawater. This helps keep calcium and alkalinity at natural levels and therefore Magnesium can be referred to as the buffer of the buffer.

Potassium, Strontium, Iodine, Iron & Manganese

All of these elements play an important role in the calcification process, the photosynthesis of the zooxanthellae and coloration of the corals. Therefore these elements and must be present in the correct levels

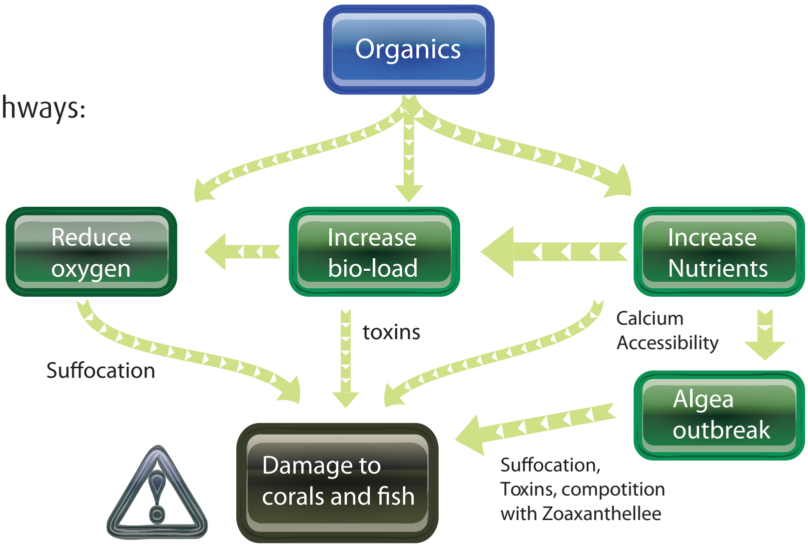
Undesirable nutrients in sea water or salt

Coral reefs develop and flourish only in clear, unpolluted oligotrophic ocean areas i.e. areas with limited nutrients in the water.

In the natural reef environment, the major nutrients nitrogen (ammonia, nitrites & nitrates), phosphorus (phosphates) and carbon are only available for the zooxanthellae (Coral symbiosis).

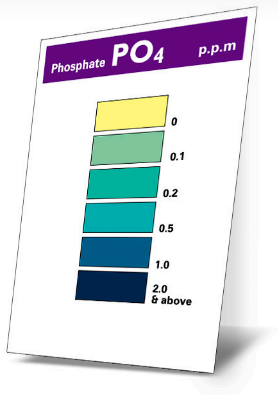
In a reef aquarium nutrient levels above those required by the zooxanthellae will enhance the population of bacteria and algae which further reduces water quality

Pollution pathways:



Phosphorus (Phosphates)

- The recommended maximum Phosphate level in a coral reef tank: 0.1 ppm
- The recommended maximum Phosphate level in a fish only tank: 1 ppm



Inorganic orthophosphate occurs in aquaria in several chemical forms (PO_4^{3-}, HPO_3^{2-})

These phosphate forms enter the aquarium with through the decomposition of organic matter, fish waste, tap water, supp., salt mixes, live rocks, substrates and some methods of calcium and alkalinity supplementation.

If allowed to accumulate above the recommended levels phosphates will cause the following problems:

1. Direct damage to corals by reducing available Ca ions for coral skeletogenesis. The formation of Calcium Phosphate $Ca_3(PO_4)2$ will inhibit the formation of Calcium Carbonate $CaCO_3$ skeleton.
2. Increase zooxanthellae densities – reduce available nutrients to corals (bicarbonate)
3. Eutrophication – release of toxins to the water by algae.

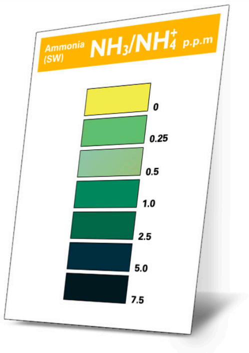
Nitrogen (ammonia, nitrites & nitrates):

Ammonia

- The recommended maximum Ammonia level in all marine tanks: 0.1 ppm

Ammonia results from the decomposition of organic matter and from fish waste. It is highly toxic to marine life.

In an established aquarium, the nitrifying bacteria rapidly convert ammonia to nitrite, nitrate and nitrogen gas, compounds with much less toxicity to fish than ammonia itself.



Nitrite

- The recommended maximum Nitrite level in all marine tanks: 0.1 ppm

As an intermediate product of ammonia oxidation, nitrite demands little or no attention from the reef aquarist. Nevertheless, tracking nitrite can prove instructive by demonstrating the biochemical processes at work in the aquarium.

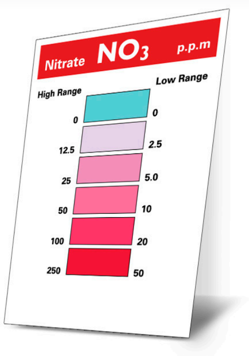
Nitrate

- The recommended maximum Nitrate level in a coral reef tank: 1.0 ppm
- The recommended maximum Nitrate level in a fish only tank: 10 ppm

The nitrification process ends with the production of nitrate. Nitrate abundance usually results in the growth of algae and potential pests such as dinoflagellates, whose growth are spurred by nitrate. At the levels normally found in reef aquaria, nitrates carry no particular toxicity; in fact the zooxanthellae corals consume it as a nitrogen source. The negative effects of high nitrate levels are:

Indirect damage to corals by increasing zooxanthellae densities:

1. Increase zooxanthellae densities – reduce available nutrients to corals (bicarbonate)
2. Intensive photosynthesis – high levels of oxygen radicals.
3. Eutrophication – release of toxins to the water by algae



The Red Sea

The Red Sea is located between Asia and Africa and stretches over 1000 miles from the Gulf of Aquaba/Eilat in the north to join the Indian Ocean between Ethiopia and Yemen in the south.

To anyone standing on its shore and gazing out across its heavenly waters, the Red Sea may seem to be a misnomer. Its blueness is eternal and anything less red cannot be imagined. The Red Sea, where the desert meets the ocean, is truly one of the planet's most exotic and fascinating natural seascape environments. Beneath its crystal blue surface the Red Sea holds an oasis of living creatures, reefs, and coral formations.