FAQ & **compendium**
Water parameters within reef aquariums
(FAQ: **F**requently **A**sked **Q**uestions)

Tanks with tropical seawater fish, corals, anemones and other invertebrates are fascinating people worldwide. Anybody undertaking this hobby with enthusiasm will sooner or later also have to touch on the complex topic of water parameters.

The target of this FAQ is to combine and publish all relevant information in an easy and understandable way, but still with a high level of detail.
A clear arrangement of the topics will help you finding the things of interest to you.

This FAQ was brought to you by Martin Kuhn (GER) and Gary Chapbell (UK)

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<u>Symbols</u>

Information* / *Hint

Warning: text passages that carry extra importance or things frequently misunderstood

Ban: Things to be avoided

Text passages explaining complex behavior in detail * Plan some time for reading

Recommendations given are according actual state of knowledge of the Author.
There is no guarantee for correctness.
Liability in case of correct or incorrect use will be dismissed.

PART 1 – Water values, test kits and measuring processes

1.1) Which water parameters are worth measuring in my reef tank and how often should I measure them?

Water value	Formula	Measuring interval	Comment
Ammonia (Ammonium)	NH_3 (NH_4^+)	Just to check if start-up phase has ended and in emergency	(not normally needed)
Calcium	Ca	Start with once per week If consumption stays stable, test less often (min. 1xmonth)	Important for adjustment of Ca concentration
Magnesium	Mg	Start with 1x/week If consumption stays stable, test less often (1xmonth or 1x/2months)	Important for adjustment of Mg concentration
Nitrite	NO_2^-	Only in start-up phase and in emergency case	(not normally needed)
Nitrate	NO_3^-	Start with 1x/week 1xmonth for stable running tanks	
Phosphate	PO_4^{3-}	1x/week	Important - especially for stony corals
pH-value	-	1x/week, for young tanks, less often if tank is stable	Time for measurement to be regarded (it will be different in the morning/evening)
Salinity	-	1xweek plus before/after each water change	Very important water value, which influences other values. Also measure temperature if measuring either with aerometer/spindle, hydrometer or conductivity sensor
Silicate	Si/SiO_2	1xmonth	Good to check the quality of your water purification unit
Carbonate hardness/ Alkalinity	-	Start with 1xweek If consumption stays stable less often (min. 1x/month)	
Water temperature	-	Steadily	Especially in summer (risk of overheating)

Annotation: Table shows recommendations for sensible reef tanks. Depending on your own livestock, you might not need to measure all values, or you can reduce measuring intervals. In fish-only tanks or tanks without stony corals, you can reduce this recommendation.

For new tanks, especially within the first few weeks, water values are not significant. But you should check they are all OK before adding fish or invertebrates.

It is quite common with reefers who are new to the hobby to buy several test kits or poor quality stuff. Corrective measures after the first losses of livestock are not only expensive, but an indication of irresponsibility for your animals.

Equipment for a reef aquarium is expensive, but you must be willing to spend money on all relevant tests (high-quality test kits only), measurement tools for salinity and temperature and reference solutions to calibrate those test kits.

1.2) Which water parameters are less important?

The following parameters are not as important to measure, or the available test kits are thought to be not accurate enough.

- Potassium (accuracy of available test kits is in question)
- Strontium
- Iodine
- Boric
- Redox-Potential
- Iron
- Overall hardness (only for seawater or to check your purification unit)

1.3) Which are the optimal water parameters?

This chart, in alphabetical order, shows recommended water values for reef tanks as seen in natural seawater

Water value	Within reaf tank - recommended range - optimal value/range	Natural sea water	Einheit
Ammonia	0 - 0.1 **0**	0.0 .. 0.1	[mg/l]
Calcium at 34,8 psu	360 - 480 **400 – 450**	420	[mg/l]
Iodine	Hard to measure	0.06	[mg/l]
Magnesium at 34,8 psu	1100 - 1400 **1280 – 1350**	1280-1400	[mg/l]
Nitrites	0 - 0.10 **0**	0.0001	[mg/l]
Nitrates	0 - 20 **2 – 10 (≠ 0 !)**	0.01 .. 0.5	[mg/l]
Phosphates	0 - 0,20 **0.01 – 0.10 (≠ 0 !)**	0.001 .. 0.1	[mg/l]
pH-value	7.7 - 8.5	8.2	- Should vary not more than 0,5 between day/night
Salt concentration a) Salinity or b) Density at 25°C or c) specific. Gravity at 25°C or d) conductivity at 25°C	 33.0 - 36.0 **34.5 – 35.0** 1.021 - 1.024 **1.0233** 1.024 - 1.027 **1,0263** 50.4 - 54.5 **53**	 Depending on location. Average 34 .. 35 1.0225 .. 1.024 1.0255 .. 1.027 51.7 .. 54.5	 [psu] [g/cm³] [] [ms/cm]
Silicates	0,0 - 0.3 **0,0**	In Open water: 0-10 At reefs: 0.08-0.22	[mg/l]
Carbonate hardness /Alkalinity a) Method-1 in °dH oder b) Method-2 in mEq/l at 34,8 psu	 5 - 10 **6-8** 1.8 - 3.6 **2.2-2.9**	 6.5 2.3	 [°dH] [mEq/l]
Water temperature	23.5 - 28.3 **24.0 – 26.0**	Location / Time of year 23 .. 29	[°C]

Recommendations given are for sensitive reef tanks.
(Can be reduced for fish-only tanks or if not taking care of sensitive corals)

Measuring salt water for some elements is dependent on the salinity:

Higher salinity → you will measure a higher concentration of Ca, Alk, Mg
Lower salinity → you will measure a lower concentration of Ca, Alk, Mg

Recalculate to normal salinity for better comparability.

$$Concentration_{normalised\ @34,8\,psu} = Concentration_{measurment} \times \frac{34,8\,[psu]}{Salinity_{measurement}\,[psu]}$$

You can calculate salinity also if measuring from density, specific density/gravity and conductivity.
(see chapter: *Can I recalculate from one unit to another?*)
Hint: You also need the water temperature when it is measured.

Table: ***Elements with highest concentrations within natural seawater.***
Based on weight, this is 3.33%. The rest is (nearly) pure water.

Element	Name	Concentration in natural sea water [mg/l]
Cl	Chlorine	19357.2
Na	Natrium	10782.2
Mg	Magnesium	1280.9
S	Sulphur	897.8
Ca	Calcium	411.6
K	Potassium	398.8
Br	Bromine	67.1
C	Carbon	27.0
Na	Nitrogen	8.3
Sr	Strontium	7.8
Br	Boric	4.5
O	Oxygen	2.8
Si	Silicium	2.8
F	Fluoric	1.3
Ar	Argon	0.6
NO3	Nitrate	0.4
Li	Lithium	0.2
Rb	Rubidium	0.1
P	Phosphor	0.1
I	Iodine	0.1

1.4) Which test kits should I buy?

This personal recommendation is done by regarding this criteria:

- Accuracy
- Clearest interpretation of results possibile (eg by distinct colour indication)
- Easy to use
- Price/quality ratio

Test kit for	Eleme nt	Product / Manufacturer (in alphabetical order)
Ammonia/ Ammonium	NH_3 NH_4^+	Tropic-Marin
Calcium	Ca	Gilbers-Umwelttechnik, RedSea, Salifert, Tropic-Marin
Magnesium	Mg	Gilbers-Umwelttechnik, RedSea, Salifert, Tropic-Marin
Nitrites	NO_2^-	JBL, Salifert, Sera, Tetra, Tropic-Marin
Nitrates	NO_3^-	Salifert, Tropic-Marin, Visocolor Eco von Machery Nagel
Phosphates	PO_4^{3-}	Gilbers Umwelttechnik, Rowa , Salifert, Tropic-Marin,
pH-value	-	Several manufacturers testkit or ph-gauge *1)
Silicates	Si/SiO_2	Salifert, Tropic-Marin
Alkalinity /carbonate hardness	-	Gilbers-Umwelttechnik, RedSea, Tropic-Marin

Recommendations in blue = my preferred/used test kit (compromise between accuracy and price/reach)

*1) Test kits having a resolution of 0.2 or better preferred (eg: Tropic-Marin pH-Test, JBL 7,4-9,0)
or having a decent colour indication (eg: Salifert)

1.5) What can I do to be sure to measure correctly?

Unfortunately, it happens that results from test kits show too low or too high results. This can be fatal for your tank, because you might make some corrections to your parameters based on wrong information, or you just miss seeing some deviant values.

These are only some of the reasons for wrongly interpreted or wrongly measured water parameters:

- Poor quality test kit used or faulty production lot
- Test kit not stored as recommended in instructions for use
- Test is over its shelflife
- You made an error while reading the results

I recommend calibrating EACH new test kit PRIOR to its first use with a **standard solution**. After using the test kit for a longer time, you should repeat this process.

A **standard solution** (also called reference solution or multi-reference) is a seawater sample which is adjusted to a certain concentration level. This level should be close to the optimum parameters you are looking for.

Procedure:

1. Use your test kit to measure a sample of the reference solution
(the amount of standard solution you need depends on the test kit you want to test)

2. a) Value you measured is identical or very close to the values the manufacturer of the standard solutions guarantees * Very good, you should trust the results of the test kit.

   b) Value you measured is different to the values the manufacturer of the standard solution * Evaluate the difference between standard solution and value measured

ex:	guaranteed value of standard solution	1350 mg/l
	measured value of standard solution	1300 mg/l
	Δ = 1350mg/l – 1300 mg/L = 50 mg/L	
	* test kit showing 50 mg/l too little.	

You should write this down directly on the packaging or instruction of the test kit. Regard this data for future measurements.

ex:	measured value of your tank's water	1180 mg/l	
	test kits Δ (as above)	Δ = 50 mg/L	
	realistic value of your tank's water	1230 mg/l	(1180+50)

Annotation: This process works only if the test kit is genereally able to measure but only inaccurate, meaning it has a certain offset. Rule of thumb: if Δ is bigger than the test result you should not use this test kit (use your guarantee). THIS NEEDS DOUBLE CHECKING MARTIN******END OF EDITED COPY****

Nightsun standard solutions for Calicum, Magnesium, Phosphates, Nitrates and Silicates. Price per 100ml ca €7 (each)

Fauna-Marin multi-reference for measuring several parameters with only one standard solution (Calcium, Magnesium, Alkalinity, Potassium and Silicates)
Price per 100ml ca. €20.

1.6) Which methods that measure my tank's salt concentration are available?

There are several options to measure salt concentration:

- Refractometer
- Spindle / hydrometer
- conductivity sensor and display unit

These tools will measure salt concentration by three totally different methods (optical refraction, buoyancy, electrical conductivity) and will also result in different measurement values. Later on you will see how values coming from one measurement system can be converted into results from another one.

Basically all three methods are OK, but there is a clear difference between usability and accuracy of the results measured. You have to decide which method you prefer.

Method of measurement	Refractometer	Spindle (hydrometer)	Conductivity
			
Price	€50-100	€15-50	€250-1000
Measured quantity and unit	Difference in refraction between sea/salt water (thus without unit, first) will result in [psu] or [‰] most tools will also display spec. gravity [-]	Two different types of tools are available. a) showing density [g/cm³] b) showing relative density /specific gravity [-]	Electric conductivity (= el. resistance^{-1}) [ms/cm]
Temperature-compensation	Yes	No, you have to know the measured water's temperature	Yes or No (depending on your tool) For non-temperature compensated tools you have to know the measured water's temperature
Steadily measurement possible	No	No	Yes
Time needed for measuring	Little	Needs some time	Very little
Miscellaneous - Disadvantage + Advantage	- Beware of low-quality tools (eg from China) - Needs to be calibrated before use (best with referenced salt water of exactly known salinity)	- sensitive to breaking - Needs another container where you can measure the water (Don't measure directly in your tank)	- Sensor must be calibrated again and again - Only expensive tools measure accurately + Can be attached to aquarium computers

1.7 What are the differences between the tools for measuring salt concentration?

For reef tanks, a salt concentration (salinity) of 34,8 is optimal. This would be reached by adding exactly 34,8 gramm of salt into one litre of reverse osmosis water.
Salinity, specified in [psu] (practical salinity unit) is independent from the measuring temperature, which means that water measured eg at 20°C with a saility of 34,8 [psu], has the same at 30°C.

Some tools CANNOT measure salinity, but density, relative density/specific gravity or conductivity. These measured quantities are dependent on the temperature.

Reason is that water, in the range we use it, slightly reduces its density getting warmer. This is similar to a volume expansion.

Temperature	Density of water at temperature specified [g/cm³]
3,98°C	1,0000
10°C	0,9997
15°C	0,9992
20°C	0,9983
25°C	0,9971
30°C	0,9957

The result is different displayed readings at different water temperatures.

For better understanding:

a.) Density

$$\rho = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$$

in [g/cm³] or [dm³/kg]

ρ: density

b.) Relative density / specific gravity

$$d = \frac{\rho}{\rho_0}$$

without unit [/]

ρ: Measured value for density
ρ_0: Density at a specific temperature (related temperture)

c.) Conductivity

$$G = \frac{1}{R}$$ [ms/cm]

G = electrical conductivity
R = electrical resistance

Salt water with <u>identical salinity</u>, measured at different temperatures will give you <u>different values for density, relative density/spec. gravity and conductivity</u>.

example:

Measured value Unit	at 20°C	at 25°C (normal temperature rteef tank)	at 30°C
Salinity [psu] oder [‰]	34,8	34,8	34,8
Density [g/cm³]	1,0246	1,0232	1,0216
Relative density [/]	1,0276	1,0262	1,0246
Conductivity [ms/cm]	47,67	52,80	58,05

Indication of the density, relative density and conductance is only meaningful if the water temperature at which the measurement was taken is given at the same time as the measured value.

So, always talking about salinity (in [psu]) would be best.
(no room for interpretation or need to add, "measured at xx °C/F")

On the other hand there are several very accurate and inexpensive measurement tools available which do not directly show us salinity in [psu] but values in other units.

It is decisive to know WHICH value the tool used for measuring salt concentrations is displaying.

1.8 How can I know if my spindle/hydrometer is displaying "density" or "relative density/specific gravity"?

	Displaying in **Density**	Displaying in **relative density/spec. gravity**
Designation	Dichte Density	Spezifisches Gewicht oder relative Dichte Specific Gravity / SG
Unit	[g/cm³]	[-] without unit !
Misc	Designation of related temperature 25/4°C or only 25°C (typical if bought in Europe)	Designation of related temperature 25/25°C (typical if bought in USA/UK)

1.9 Which tool should I trust most?

I recommend not believing blindly in a new tool. As referencing source (calibration), it is best to check values measured against values which have measured with a big spindle (eg from Tropic marin, Aqua Medic, JBL,..), also measuring temperature in parallel.

Once you have calibrated your source of measurement, you can use this for your weekly measurements if more comfortable than measuring with the spindle each time.

I do not recommend using any

- hydrometers from platics

- cheap refraks from China

Tips for using refractometers:

1.) Calibrate your refractometer regularly, but at the very minimum before the first use. One way is to adjust it to “0 [psu]“ by using purified water. Even better would be calibrating it in the area of measurement with salt water that has a defined salinity (multi-reference).

2.) Clean your refractometer measuring area before each measurement.

3.) Reading the measured value, DO NOT take the value of (spec.) gravity which is also displayed, but use only the value given in [psu] /[‰] which is the salinity.

3.) Buy only recfractometers calibrated to “seawater“ not others which might be for example calibrated to NaCl.The difference in values displayed is ~ 1 [psu].

4.) Use only refractometers with ATC (automatice temperature conversion).

Tips for using spindles:

1.) Buy a big spindle, which allows for a much more accurate reading of the value for density.

Organise a separate, transparent, long ad tall vessel where you can perform your measurement (never measure directly within your tank). A 500ml big, tall measuring cylinder (as available in chemical stores) or a tall beer glass is fine.

Ensure you also have an accurate thermometer available.

2.) I recommend buying a spindle, measuring in “density“ not “relative density/spec.gravity“ because they are more common.

3.) Clean your spindle from salt and dry the upper part before each use to get accurate measurements.

Tables for converting salinity see appendix of this FAQ

- Density → Salinity
- Rel.density/spec. gravity → Salinity
- Conductivity → Salinity

1.10) Can I use tap water for my reef tank? Does a water purification unit make sense?

You should use tap water ONLY if you are sure that it is free of any harmful substances AND that it will be the case all times of the year. Spending money for a good puryfing unit is well invested.

Several waterworks have seasonal deviations of water quality. Having good water in summer must not mean also having good water in winter and vice versa.

If you want to rely on tap water, check its quality carefully.

Harmful:
- Raised values for nutrients and other trace elements (Nitrate, Phosphate, Silicates...)
- Availability of heavy metalls (iron, copper, lead…) even in small doses
- Chlorine (typically in summer months)

Acceptable:
- Calcium
- Sulphate
- Chloride (converted from Chlorine)
- Sodium
- Carbonates (Carbonate hardness)

.. because being part also of natural seawater.

Most other water parameters published by your waterworks are not too important for reef tanks.

Nearly all seawater mixes available are designed to bring optimal water parameters if using purified water. Using tap will mean that you raise the concentrations coming by the salt mixture by the concentrations being already within your tap water. This might result in getting concentrations above the recommended ones.

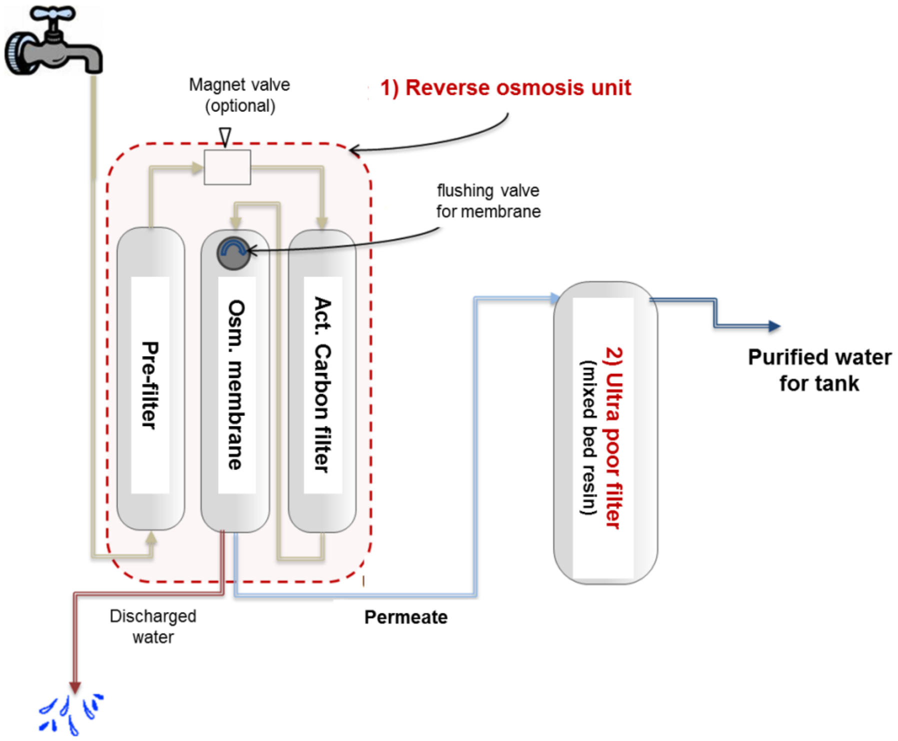
In a lot of cases the water quality of tap water is not sufficient for running reef tanks.
I recommend a water-purifying unit as one of the basic items for a reef tank.

For smaller tanks, buying purified water might be a better idea than buying such a unit, because costs (including maintenance) and the required space are not available. Check that the water you buy is OK for use in reef tanks (distilled water is fine and should be done according DIN 57 510/VDE 0510 or DIN 45530, EN 285).

For medium-sized tanks **reverse osmosis unit** (= RO unit) with additional **water filter** is a reasonable and, quality wise, very good solution. Besides removing nearly all kinds of inpurities it will also remove unwanted bacteria.

Most available RO units have a pretty good quality level. Buying criteria should be:

- Flow rate $\geq$ 150L per day
- Size/Volume of the two filtering containers
  (including price if exchange is needed vs Filtervolume)
- Cleaning/Flushing valve available



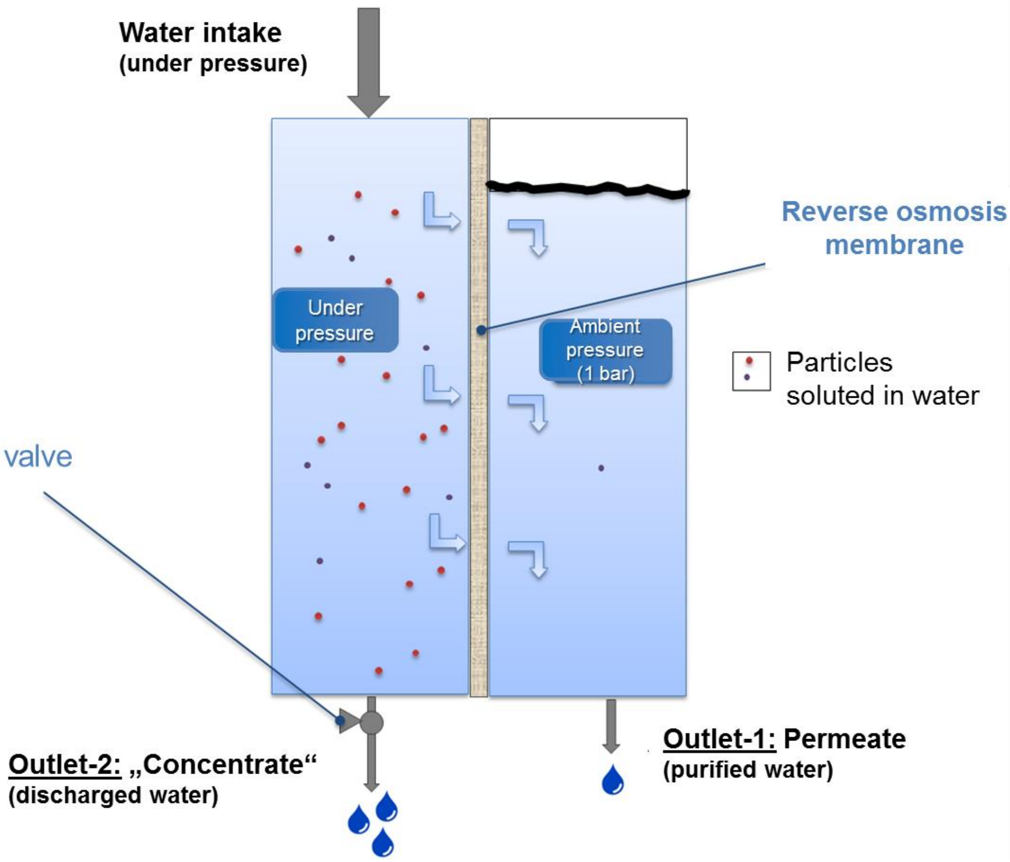
Even an RO unit without ultrapoor water filter will remove nearly all impurities. As an example, see removing rate of an "AquaCare TFC Polyamid Membran"

Element	Removed [%]	Element	Removed [%]	Element	Removed [%]
Aluminium	96-98	Cyanide	85-95	Nitrates	90-95
Ammonium	80-90	Iron	96-98	Phosphates	95-98
Bacteria	>99	Fluoride	92-95	Polyphosphates	96-98
Lead	95-98	Overall hardness	93-97	o-Phosphates	96-98
Boric	50-70	Potassium	92-96	Quicksilver	94-97
Borate	30-50	Silicic acid	80-90	Radio activity	93-97
Bromid	80-95	Copper	96-98	Silver	93-96
Cadmium	93-97	Magnesium	93-98	Silicium	92-95
Calcium	93-98	Manganese	96-98	Sulfate	96-98
Chloride	92-95	Sodium	92-89	Thiosulfates	96-98
Chromate	85-95	Nickel	96-98	Zinc	96-98

⚠ Silicates are not removed totally by RO. For this reason an ultrapoor unit is recommended. In this unit, that is the last filter, water is squeezed through a mixed-bed resin, which is an expendable item that has to be replaced once being used up.

You could also use an ultrapoor unit alone. Because the resin is being used up much faster, this is more expensive in combination with an RO unit.

The following sketch explains the functioning principle of a reverse osmosis membrane. To get the maxium possible surface, these membranes are rolled up in most avalaible units to have an even bigger surface and thus better efficiency.



- An RO membrane is different to strainers or particle filters which would not work with particles soluted in water.
- Unpurified water entering the membrane from the left side (water intake) has to be under pressure. The higher the pressure, the more effective the membrane will work: 3-4bar coming from your pipings is sufficient. Even better would be higher pressure eg. coming form a booster pump. The right chamber operates without any pressure.
- Part of the water, because of the so-called osmotic pressure (between the left and right chamber), will move through the membrane into the pressureless right chamber. Water molecules will penetrate through the membrane easily, but the differently loaded ions will not. This is the cause for the filtering effect of an RO membrane.
  Only “purified water“ will leave the membrane (presureless) as so called permeate (Outlet-1).
- The other part of the water will remain in the left chamber first. This water will enrich itself more and more with soluted impurities. To remove this water there is a valve where a certain amount of water can “escape“ the membrane, without reducing the pressure of the left chamber too much.
  Water running out from this chamber (Outlet-2) will have an even higher concentration of impurities than the water from the intake and is thus named concentrate (I will call it discharged water within this FAQ) and can either be disposed or used for non-aquaritic purposes like watering your flowers.

RO Units need being maintained regularly. If you miss this, rate of permeate will drop and you will get more and more discharged water.
You will notice this because the time needed to get a certain amount of purified water will get longer.
Recommendations for maintenance intervals can only be rule of thumb, because of being strongly dependent on how much purifed water you need and also from the quality of your intake water.

Finefilter/Pre-filter: is holding back mechanical impurities and thus can get stuck.
Typical maintenance interval: 2 years.

Activated carbon filter: Although there is no typical wearout for this filter, it should be exchanged together with the pre-filter.
Chlorine can be within tapwater. This filter converts chlorine to chloride but only for a limited amount before it is used up.
Chlorine can damage the RO mebrane and is also toxic for fishes
Maintenance interval: 2 years or more often if your tap water contains lot of chlorine

RO membrane: There is typically no wearout.
It is recommended to flush it for 5 minutes every 2 weeks. I personally never did and had no problems.
In case you had problems with the pre-filter or activated carbon filter, the RO membrane can be stuck or damaged and thus must be replaced.

Ultrapoor filter: Replace mixed-bed resin once being chemically used up.
(brown algae in the tank is a good indicator)

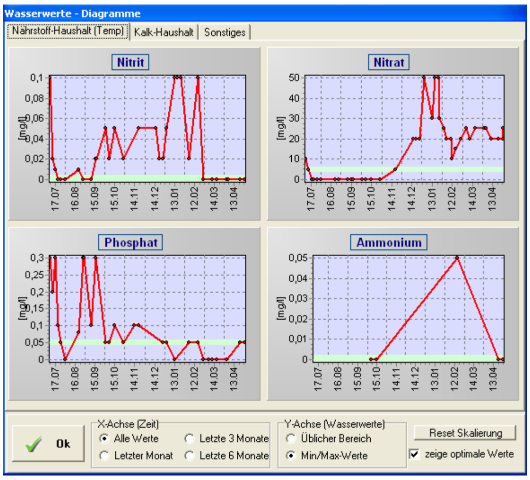
How can I check if my RO unit still works properly?

- Conductivity of permeate $\leq$ 5% of conductivity of tap water
- KH-Test should have a result betwen (0 .. 2 °dH)
- Concentration of silicates can be $\geq$ 0 mg/l
- pH value of water is not influenced by RO unit and thus cannot be used to check
(it will be raised by adding a salt mixture)

1.11) Tips for measuring your water parameters accurately

- Do not use no-name test kits (see list of recommended test kits)
- Do not use test kits designed for seawater only
- Regard manufacturers recommendations and instructions for use (some test kits need to be stored cool)
- Measure at the same time of the day each time and, if possible, at identical water temperature and before (not after) feeding your animals.
- Remove water to be tested always from same position within tank or sump.
  Tested water should be clean and free from any visible impurities.
- Measuring concentration of elements soluted in salt water (Ca, Alk, Mg...) are only comparable if measured at identical salt concentration. Lower salinity, lower concentration and vice versa.
- Get the required amount of water to be measured with a syringe (don’t trust in markings on glasses/cuvettes)
- Carefully clean and dry syringes, cuvetttes, spoons and caps after each use.
  Do not exchange between different test kits (you might impurify with chemicals used). Very good test kits have differently coloured syringes
- Measure you use water and chemicals without air bubbles
- Test kits determining concentrations by measuring the amounts of chemicals needed until a colour change is seen: Take care that no chemicals get stuck on housing of cuvettes. Shake well during testing
- To prevent unwanted dropping of chemicals from flasks, either:
  a) turn around flasks besides the measuring flask and allow dropping out or
  b) Give some pressure on the flask with opening rising to the top, then turn around and dose
- Work with clean fingers only and take regard to safety aspects from manufacturer
- Compare colours under strong and natural light if possible. Use identical sources of light each time.
- Also test your tap water from time to time, to detect possible problems of the water purifiying unit.
- No iron in your tank. Measuring sensors should not be from iron or, even worse, from brass or copper. One option istto cover sensors with a diaphragm.

It is recommended to record your measured parameters, helping you to detect creeping deteriorations in your tank with my Software-tool **AquaCalculator**.



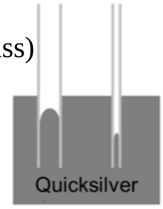
1.12) Tips for measuring with syringes, cuvettes and hydrometers

Surface tension of liquids is causing a rise or even a drop of surface level within small vessels or tubes. This has to be regarded to measure correctly.

<u>Capillarity:</u> Plunging in a thin tube with both sides open (capillary) the water level will rise or sink. The thinner the capillary is, the stronger the effect.

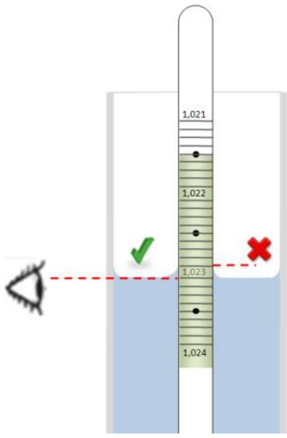
For normal liquids which are wetting the vessel walls (water on glass or plastics) the water level in the tube is rising and forms a concave surface.

Liquids which are not wetting the vessel walls (water on greased glass, quicksilver on glass) the water level is dropping, forming a convex surface.



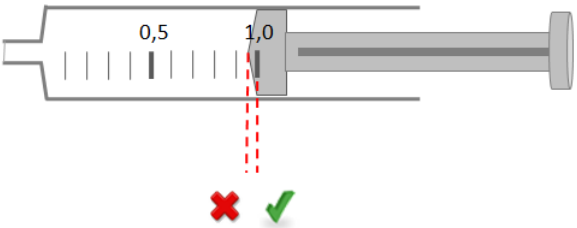
<u>Reversed Capillarity:</u> Plungin an item into a liquid, you are getting the reversed effect. Water surface is arching around the item, which is exactly what happens using a spindle/hydrometer.

F: How do i read a spindle/hydrometer?
A: Read the ***value at the water surface,*** not the meniscus (arching).
Start moving your eyes coming from the bottom and move upwards. Once you see the first elliptical shaped area as a line, this is the correct value to read.
<u>Don‘t forget:</u> measuring salt concentration with a hydrometer needs parallel measurement of the water’s temperature.



F: How to read the filling amount of a syringe?
A: If the syringes piston is not just flat but like an arrow, you have to read the value at the side of the piston, not top of the arrow (see sketch).

Only a very few syringes are different to this recommendation.
In case the syringe’s piston is flat, this is a no-brainer.

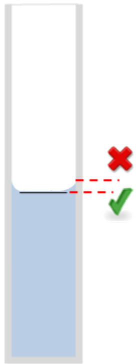


F: My test kits instructions tell me to attach a small top part. Once I draw up the syringe there is an air bubble. Is there something wrong? For what reason do I need that top part?

A: Everything is OK.
The top part is for emptying the syringe more easily. Because it is filled with air in the beginning, this air is also sucked into the syringe. Once emptying the syringe, the air bubble will be pressed out first. What you should do is keep the syringe in vertical position all the time, so that the air buble does not change its position.

F: What is better to read: syringe or curvette?
A: A syringe is easier to fill and also more accurate.

F: How do you read a cuvette?
A: Don’t read the “meniscus“, but below instead



1.13) What about the shortcuts and units?
Can I convert form on unit into another one?

a) Concentrations (e.g. Ammonia, Nitrite, Nitrate, Calcium, Magnesium, Silicates)

The commonly used unit is [***mg/l***] (1/1000g per litre or 1 milligramm per litre)
This is not 100% identical with [***ppm***] (parts per million, equaling mg/kg entspricht).
Cause: 1 litre saltwater weighs ~ 1.023 kg, which means a difference of 2.3%.

100% vs 102.3%) is quite acceptable for aquarists. There is no need for a conversion.

[mg/l] ~ [ppm]

b) Volume

SI/metrical unit	[***l***]	(**l**itre) equailing 1 cube-decimeter [dm³]
GB/USA	[***g***]	(**g**allons)

$$Vol_{Liter} = Vol_{Galleons} * 3{,}78$$

$$Vol_{Galleons} = Vol_{Liter} / 3{,}78$$

c) Weight

SI/metrical unit	[***g***]	(**G**ramm)
GB/USA	[***oz***]	(“**o**unces”)

$$Weight_{Gramm} = Weight_{Ounces} * 28.349$$

$$Weight_{Ounces} = Weight_{Gramm} / 28.349$$

d) Carbonate hardness / Alkalinity

Either	[**°dH**]	(German carbonate hardness/”d*eutsche* ***K****arbonat****H****ärte*”)
or	[**mEq/l**]	(**m**illi **eq**uivalents per **l**itre)

$$mEq = °dH / 2{,}78$$

$$°dH = mEq \times 2{,}78$$

Seawater: **Carbonate hardness ~ Alkalinity**

Annotation: Carbonate hardness test kits are displaying the buffering capability of water which is its alkalinity. They will add acid until pH 4.3 is reached. In sea water, alkalinity is 95% dependent on buffering ions carbonates , hydrogencarbonates and pH-value. Thus, we can equal carbonate hardness and alkalinity

e) Temperature

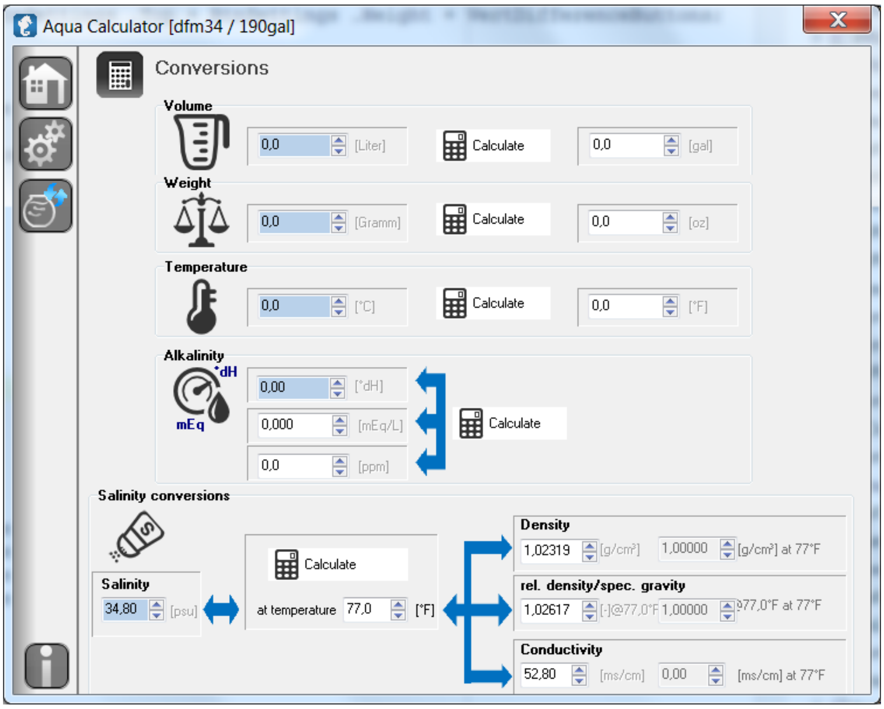
SI/metrical unit	[°**C**]	(degrees **C**elsius)
GB/USA	[°**F**]	(degrees **F**ahrenheit)

$$Temperature_{Fahrenheit} = (Temperature_{Celsius} \times 9/5) + 32$$

$$Temperature_{Celsius} = (Temperature_{Fahrenheit} - 32) \times 5/9$$

f) Salt concentration (Salinity/density/rel.density/conductivity)

Conversion between some units needs mathmetical approximation methods. (There are no simple formulas).
For converting between these units (and also all other units needed for reefers) my tool **AquaCalculator** is recommended.

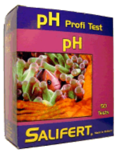


1.14 Which test kits or tools should I buy?

I don’t recommend buying complete measuring sets as offered for example by JBL or Tetra, but buying a mix of high-quality test kits, matched perfectly for reef aquariums:

test kit for	Manufacturer	Ca.-Preis
Nitrite / Nitrate (Kombitest)	Tropic Marin	€15
Phosphate	Umwelttechnik Gilbers	€33
Alcalinity/Carbonate hardness	Tropic Marin	€8
Calcium	Umwelttechnik Gilbers	€19
Magnesium	Umwelttechnik Gilbers	€19
pH-value	Salifert	€7
	Total price	**ca. €100**





To check each test kit prior to use and after a certain time, ***Reference solutions*** for Alkalinity, Calcium and Magnesium
(eg FaunaMarin’s Multi-reference €20 or Nightsun, €7/each)


Big and thus perfectly readable ***spindle/hydrometer***
(eg Tropic Marine’s - Precision Aräometer for €35)

L***ong and tall vessel*** for measuring without current flow influence of your tank
(best is a 500ml plastic-measuring cylinder with 35cm height, €20 or glass measuring cylinder).

Temperature measuring device


+

+


PART 2 – Important processes in reef tanks

2.1 Current flow

This is often underestimated but maybe the most important factor for well-established reef tanks:

⚠ **Current is adapted to the tank's properties and size** and also
the tank's arrangement is adapted for good flow.

Obviously, the flow in our tanks has no influence on salt concentration or concentrations of nutrients and trace elements. BUT: the better the current flow of a tank, the less debris and settlements of any rooting/fouly material. Put another way:

ℹ The more areas with insufficient flow, the higher the risk for rotten material or rotten live rock.

Rotten areas in your tank or sump are not only ugly, but often the cause for rising or continually high nutrients (N_3 and PO_4 levels). Seen over several months, this can even develop as a ticking (phosphate)-timebomb.

ℹ Tanks with long lasting nitrate and/or phosphate concentrations very often have insufficient or wrong flow as initial reason.

ℹ This is also valid for areas which you do not even see, like drains and especially areas behind and within your reef construction (eg behind live rocks).

Looking for more arguments why you should carefully plan and optimise your tank's flow?

- Adapted flow is vital in caring for invertebrates and corals
  - Current flow not strongh enough, or areas within "current shadow"
    - 👎 Insufficient supply of micro-creatures/food
    - 👎 Cleaning effect of filigree coral branches
  - Current is too strong
    - 👎 can lead to mechanical damage of your life stock (especially LPS corals)

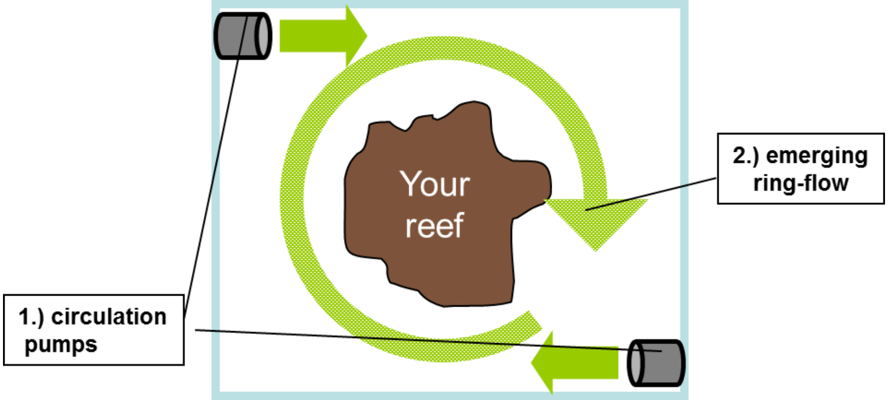
- Adapted flow will provide good circulation of your water surface.
  - 👍 Exchange of oxygen
  - 👍 Improves removal of high tank temperatures
  - 👍 Optically attractive (curling effect on sand while light goes through wavy surface)

- Adapted current flow is a prerequisite for clean gravel.
  - Current flow not strongh enough, or areas within "current shadow"
    - 👎 Sediments assemble.
    - 👎 gravel being compressed, leads to unfavourable accumulation of bacteria and algae
  - Current is too strong
    - 👎 fine gravel might "fly away" and build piles

Now, as you know how important good flow is for your tank, you should learn which are your major influencing criteria to get there:

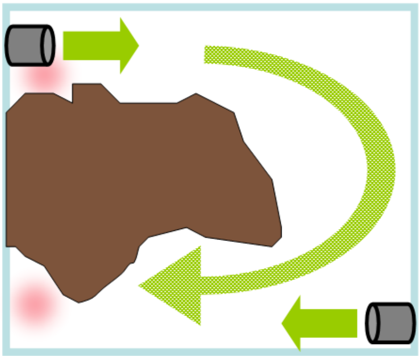
- **Geometry of the tank**
- Geometry of **your reef structure** or other **static tank arrangement** (this is also your corals.)
- Arrangement, strength and number of **pumps**

You will achive the best flow if you are aiming for a "**Ring-flow**" where flowing water reaches ALL areas of your tank (see sketch, light green).

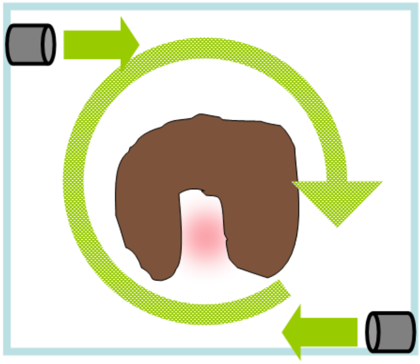


These are examples of limited flow

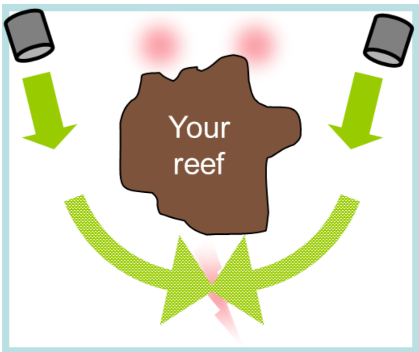
Two areas with limited flow (red)
Because of **disruption of flow**



"**Blind alley**" despite **ring-flow** (red)



Limited flow (red)
Caused by **2 streams eliminating themselves**



Above are only some examples. The situation generated by tank size, reef construction *1) and flow pumps can be quite complex.

*1) including also other static elements of your tank like corals

⚠ Carefully plan the size/geometry of your tank including reef construction and current flow BEFORE planning any other aspects of your tank.

⚠ I suggest making a sketch of your planned tank equipment and pumps enabling you to estimate whether your flow will work or not.

You can select from several options to optimize your tank's flow:

- Select between pumps with punctual or broad flow
- Adjustable pumps make it easier to optimise your flow in the tank (not too strong, not too weak)
- Pump heads adjustable in several axis (eg ball joimted ones) ease the adjustment
- Pumps can be adjusted in several layers of your tank (top/middle/bottom areas)
- You don't like the look of visible flow pumps?
  Then you can hide pumps within reef ceramics or life rock
- Use of invisible flow for "problem areas" (eg flow behind rocks close to the tank walls)
- Use moving pump heads (eg Osci-motion) or wave simulators (eg wave boxes) to reach a realistic flow, streaming/cleaning animals from different sides and intensity.

Some more tips:

➢ Take care about the current consumption of your flow pumps, because they run 24h/day 365days/year. High-quality pumps with a good degree of efficiency pay off pretty soon, taking power consumption and lifetime into regard.

➢ Pure "flow pumps" have a lower current consumption than "feed pumps".

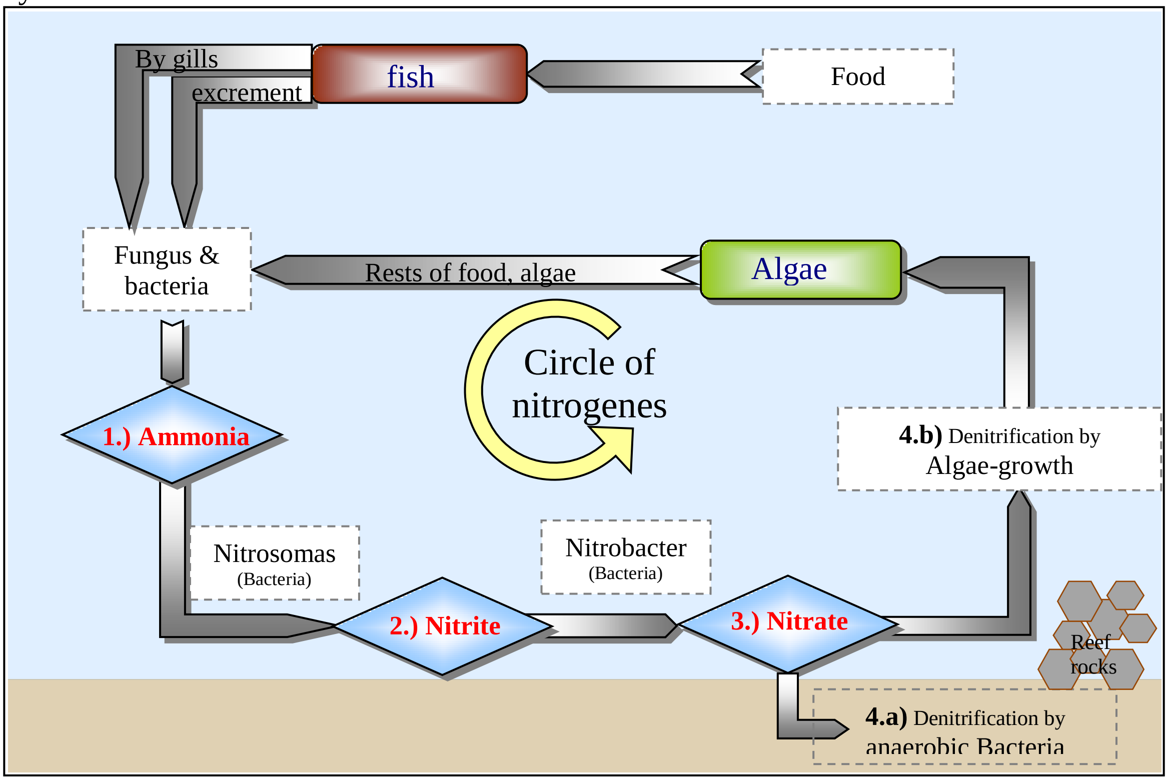
ℹ If you want some additional experience or advice for optimising your flow, ask advanced aquarists or good aquaristic dealers.

⚠ Saving money while designing your tank's flow is a BAD idea and might take its revenge some time later.

2.2 The circle of nitrogens

…describes the most basic process of all salt-water tanks.

Through digestion and fouling processes, there will be harmful substances stressing your tank's inhabitants. The less effective this process is working the more stress you will have for your animals because nutrients will steadily enrich within your tank.
This is the reason why you have to have this process established BEFORE you add sensitive animals to your salt-water tank.



1.) At the beginning of the cycle – and clearly most critical for toxicity – is **Ammonia/Ammonium**.
It comes from transformation of excrement and fouling processes (eg from dead animals).

2.) Ammonia is converted by ammonifying bacteria into less harmful **Nitrite**.
Effect: Ammonia-concentration is reduced, Nitrite-concentration is rising

3.) Nitrite is converted by nitrificating bacteria into the even-less harmful **Nitrate**.
Effect: Nitrite-concentration is reduced, Nitrate-concentration is rising

4.) a) Nitrate can be converted into nitrogen in areas with deficits in oxygen
(=anaerobic areas, eg your gravel, also the porous reef rocks)
Gaseous nitrogen will then escape your tank.

b) Nitrate (and also ammonia) is assimliated into algae growth.
Effect: Nitrate-concentration is reduced

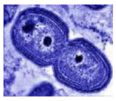
This process is going on all the time.
In "well-started up tanks" the amount of harmful substances which are removed (circle of nitrogens) is equal or even higher than the amount of harmful substances which comes to your tank (feeding, excrements, etc)
If this is not the case, your tank might become unstable (crash) after a certain time.

More detailed description

Ammonia/Ammonium is reduced/removed in two steps to nitrogen (Nitrification/DeNitrification).

A) Nitrification

Nitrification means converting Ammonia to Nitrites first, then from Nitrites to Nitrates.



Nitrosomonas

Oxidation Ammonia to Nitrites $2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$

(ph is lowered by 4 release of H+-Iones)

Oxidation Nitrite to Nitrate $2NO_2^- + O_2 \rightarrow 2NO_3^-$

Nitrobacter

Ammonia/Ammoniium is ***(bio)chemical-wise oxidised*** by waters O_2 into the more-stable Nitrate.
This normally happens without any action from our side by bacteria.
It is also the case that we normally find any Ammonia/Ammonium in our tanks if large animals have died or during the tank's start-up phase.
Nitrate is not able for another reaction with oxygen, because it is already oxidised and thus stable.

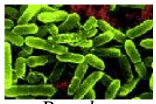
This is the reason why we sometimes have too high nitrate levels, even having a zero concentration of Ammonia/Ammonium and also Nitrite.

B) DeNitrification

Nitrate can be further converted, but only in areas free of oxygen.

Biochemical reduction of Nitrate $5C(H_20) + 4NO_3^- + 4H^+ \rightarrow 5CO_2 + 2N_2 + 2H_2O$

Accrued CO2 reduces pH-value,
converted elementary nitrogen (N_2) escapes the tank as gas



Pseudomonas aeruginosa

What we need is anaerobic zones which is the home for pseudomonas bacteria. This can be:
- within live rock (which is an extremely porous type of rock)
- gravel if several centimeters thick
- Other material that is very porous and having no O_2-contact within its inner areas like Zeolithes or filtering mud.

Your tank's water is already saturated with N_2 (because of the motion on the water surface and skimming). Additional N_2 coming by denitrification is thus arising in small bubbles and escaping your tank through the air afterwards. Doing this, we get rid of Nitrates which are "produced" steadily.

Result: ***Nitrates can be converted.***
(Nitrates can't be adsorbed)

2.3) Phosphor-cycle

Phosphor will come into your tank steadily by feeding, adding unclean water or other inpurities. Two of three possible chemical compositions establish themselves as stable in our tanks and should thus should be removed: HydrogenePhosphate (HPO_4) and (Ortho)Phosphate (PO_4).

Phosphate, different to nitrate, can be precipitated with metal ions loaded positively (eg iron, aluminium) and also with alkaline earth metals (eg calcium).

Depending on where this takes place, the precipitation of phosphate will take place either in:

- gravel or reef construction (eg live rock)
- salt water
- within another absorbing material * and thus can be removed
- algae * and thus can be removed

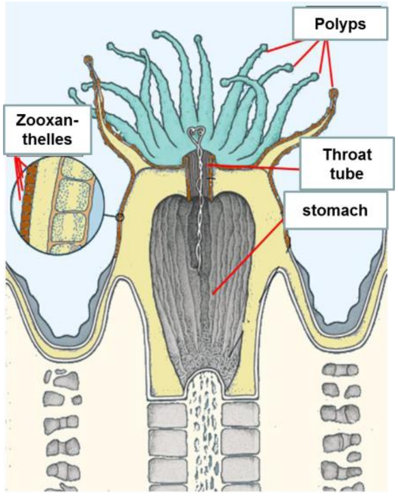
Phosphates soluted in water can be gathered by ***algae and corals***.
Phosphates precipitated can be gathered by ***bacteria and algae***.

The presence of phosphate in your gravel or reef construction (eg live rock) is the cause for some algae plagues, even if you can’t even measure phosphate in your tank water (=soluted phosphate). This is also called having “phosphate depots”.

i Result: **Phosphates can be precipitated** into algae/corals, or absorbers
(Phosphates but they can’t be converted)

2.4) How to get optimal conditions for growth and gaiety of colours for SPS

Be prepared for a complex topic. But if you are able to understand this, it will help you on your way to successfully care and grow the “cream of the crop of corals”.



Graphics www.planet-wissen.de

Corals are different to plants and cannot carry out photosynthesis on their own. So they have to get their energy in an alternative way. Some of them use tentacles to capture oceanic plankton, but most corals within our tanks assemble special monocellular algae at their polyp’s outer skin, which are called zooxanthelles. Zooxanthelles are flushed to the coral with vegetable plankton. ***The coral will then live in symbiosis with its zooxanthelles***. For some reason, however, the coral can also get rid of the zooxanthelles by itself.
Zooxanthelles (different to the coral themselves) ***gather nutrients*** from the surrounding water ***(NO3, PO4)***. They do this through ***photosynthesis*** and thus also produce food/energy in form of ***glucose*** (sugar alcohol, fatty acids, amino acids).

The coral is stimulating its symbiose partner to share part of the ***food/energy for its own consumption***. Doing this together with oxygen will re-utilise CO_2 and water, which zooxanthelles need for their photosynthesis again. Corals are also able to support with nitrogen (ammonium) coming from their own feeding process. Where there is only few nutrients in the water, the coral will supply zooxanthelles with nitrogen and phosphor.

Growth (meaning the growth of zooxanthelles) needs availability of nitrogen to build new proteins. C***oral are able to steer growth and cell division of the algae/zooxanthelles*** (which means it will reduce it) by ***limiting the nitrogen***. At the beginning this will even hinder growth of zooxanthelles.
Good lightning (which is just another form of energy) will boost photosynthesis, resulting in the production of lots of glucose, which is “digestible food for the coral and also zooxanthelles”.
Fortunately, zooxanthelles cannot use it at the moment beacuse of missing nitrogen, thus offering most of the glucose to the coral.
The energy circle is closed now and we have a real symbiosis which is actively controlled by the coral itself. By “feeding” our corals, we automatically also supply their zooxanthelles.

What will happen in the case of too many nutrients in the tank water?
Zooxanthelles are perfectly “fertilized” * More and more zooxanthelles are built, but they have no need to offer food (glucose) to the coral ⌧ The coral will starve. Depending on how much food/glucose is provided, the coral will decrease its own growth and might even die after a longer period of time.

Not always high [constantly low?] concentration of nutrients is a cause for insufficient growth of SPS. It only means that part of the symbiosis process (food/glucose) is not working optimally. Depending on other conditions, corals can get enough food (eg by plankton) and can show good growth.

Importance of a strong source of UV light
As described, zooxanthelles convert light to food/glucose available for its coral. The less light available, the more zooxanthelles will be built in by the coral to utilize the limited energy. The more zooxanthelles have to be fed, the less food can be offered to the corals.

Rule of thumb for SPS/Stony corals: the more light the better.

Zooxanthelles and attractivity
Zooxanthelles have a slightly brownish colour. For this reason, corals appears darker if they have lots of zooxanthelles built in by its polyps. Most reefers prefer bright and colourful corals.

Effects on SPS from phosphate
Another issue is that phosphate acts negatively while building the calcium skeleton of stony corals. It acts as kind of a disturbance to the crystal lattice (skeleton toxin). The more phosphates built in, the more brittle the calcium skeleton/coral will be. This can end in a growth rate up to 0.

How do I get colourful SPS?
Strong shades of colour come from coloured proteins, which can be built by the coral by itself. The coral will do so only if getting enough food/energy and having no need to spend this energy on other things (eg for taking care of its own life and growth).

For successful care, growth and good shade of colour, you should strive for following parameters:

- **System low on nutrients**
  - well-working symbiosis coral and zooxanthelles
  - phosphate especially should be low (toxic for calcium skeleton)
  - low on nutrients BUT not free of nutrients.
    (0 nutrients will most likely kill your SPS)

- **Strong UV illumination**

- **Calcium and magnesium supply** (see separate chapter)

- **An alternative food supply in the water** (eg plankton)

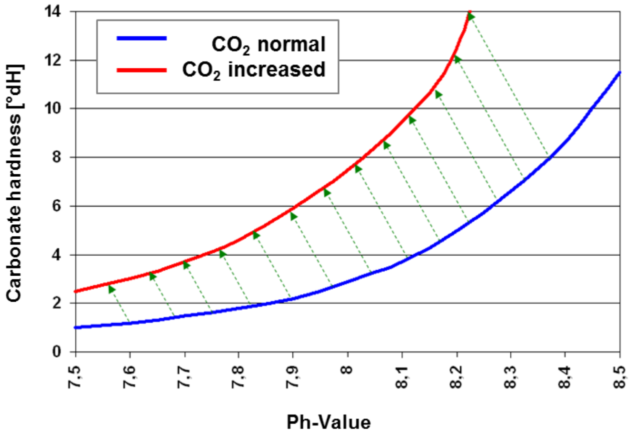
2.5) Correlation between pH-value, alkalinity and CO2 concentration

I will provide a slightly simplified explanation, because the complete chemical correlation is complex. There is a direct correlation between *pH-value*, *alkalinity* and *CO_2 concentration*.

The ***pH-value*** is a measure for the strength of an acid or alkaline effect of a liquid.
pH = 7 is *neutral*, everything below is *acid*, everything above is *basic/alkaline*.

Alkalinity (which is the buffering capability) is defined as amount needed to raise pH-Wert by a certain level. Within salt water, most important is carbonate and hydrogen-carbonate-akalinity, covering >95% of the overall alkalinity. Both are influenced strongly by CO_2 concentration. CO_2 (Carbon dioxide) is a colour-free and odourless gas acting like an acid, thus reducing the pH-value.

The blue line is showing the correlation between pH-value and alkalinity/carbonate hardness.
- CO_2 concentration with direct influence to this correlation
- red curve will establish in case of increased CO_2 concentration



$C0_2$ concentration in our tanks goes up and down because of mechansims *adding $C0_2$* and others reducing *$C0_2$* and in the tank's surroundings.
This is also the reason why ph within our tanks goes up/down each day/night.
Remark: stable systems should have ph variation between 0.1 to max. 0.5.

<u>a) Adding $C0_2$</u>
$C0_2$ concentration of the air should be ~350ppm. In areas above closed tanks and in unventilated rooms it can get much higher (~700ppm).

Causes for high CO2 concentration:
- Buildings with very good thermal insulation
- tanks covered completely
- Calcium reactors adding $C0_2$ in the tank (gathering above the water surface)
- Night-active critters and algae producing CO_2 within their metabolism

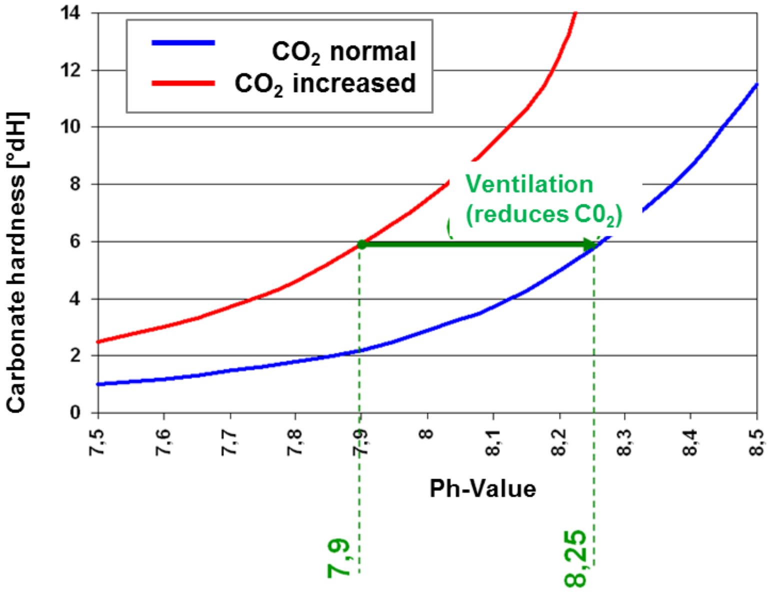
$C0_2$ concentration raised by 100ppm will reduce the pH-value of your tank by 0.09 ph

<u>b) Reducing $C0_2$:</u>
This will happen automatically, during the lights-on phase, by photosynthesis.

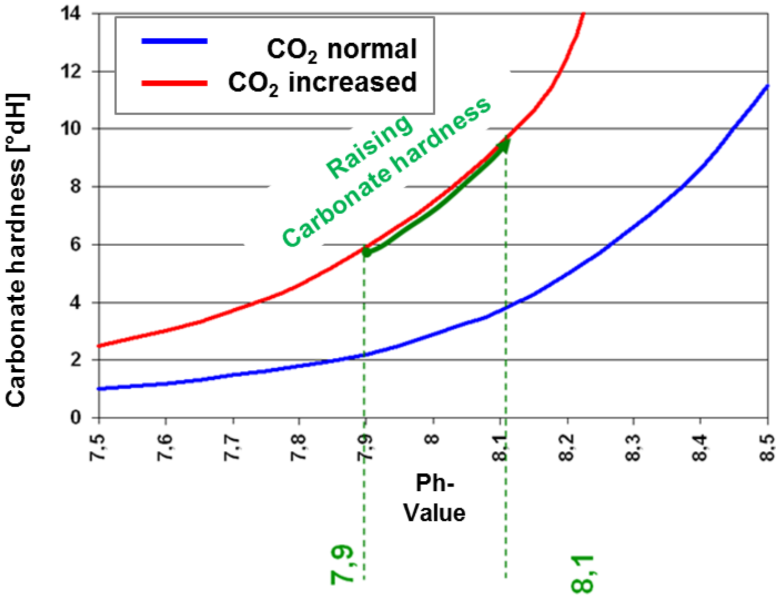
- Changing one of the three parameters (alkalinity, CO_2 concentration or pH-value) and holding a second one constant will alter the third one.

- Changing two parameters at the same time will strongly alter the third.

a) <u>Chart-1:</u> Adaptation pH-value (here: increasing)
by reduction of C0₂ concentration, eg by better ventilation of room



b) <u>Chart-2:</u> Adaptation of pH-value (here: increasing)
by raising alkalinity/carbonate hardness



CHAPTER 3 – Which effects are caused by the single water parameters? What happens if parameters are off the optimal values?

3.1) Alkalinity/carbonate hardness

Definition: Alkalinity (or carbonate hardness) in salt water, is the amount of acid needed to reach a ph-value of 4.3 (at pH=4.3 bicarbonate is converted into carbonic acid, CO_2).
Measuring carbonate hardness we automatically measure other “hardness” (borate, silicate and phosphate hardness), which is acceptable because carbonates make up ~ 95% of the total hardness.

Function:

a) Most hard corals use alkalinity to build up their skeletons. They are using bicarbonates, which are converted to carbonates, being built in into their calcium-carbonate skeletons.
b) High alkalinity = high buffering capability, thus realizing a more stable pH-value.

Hard corals steadily consume alkalinity, which results in the need to artificially balance it. For reef tanks, a system for adapting alkalinity is a must. The most popular methods are:

- Balling
- Calcium reactor
- Kalkwasser

Alkalinity being too high leads to a biotical precipitation of calcium carbonate. This assembles within your tank and tank’s technique (pumps, heater, glass…) and also wastes binded calcium.

3.2 Calcium?

Hard corals build their skeleton from calcium carbonates (calcium & carbonate) from within the salt water. Calcium within the water is, for that reason, steadily reduced. The less calcium the less growth for the corals – and they might even stop growing. Even if different animals are looking for a different calcium concentration, calcium must also not be too high.

Availabilty of calcium concentration within the water is one of the most important parameters for caring for tridacna clams and coraline algae, for example.

3.3) Iodine

Iodine can be found in natural seawater in several organic as well as inorganic forms. Circles of concentrations and interactions have not yet been evaluated in detail.

Main consumers of iodine are micro and macro algae. Iodine acts positively to physical comfort of some invertebrates such as sea urchins, xenia and the skin of crabs.

Whether iodine should be dosed within reef tanks is contested.

3.4) Potassium

Potassium is the element with the sixth highest concentration in natural seawater (~400mg/l). Unfortunately, slight overdosing can be toxic for inhabitants.

Test kits available have been questioned for their accuracy (test kits should be referenced by a reference solution and need routine).
Although several aquarists of SPS tanks dose potassium to get more colourful corals, I do not recommend doing it because it holds a certain risk.

3.5) Magnesium

Calcium and carbonates soluted in salt water is so high that it would precipitate and build solid lime. Magnesium prevents this precipitation, because blocking the surface of calcium-carbonate crystals.

Soft corals and coralline algae consume Magnesium. Sometimes we need to maintain our Mg level by dosing. In case to much Mg is dosed, it will precipitate as Magnesian..

Attention: Some methods, eg limewater/Kalk don't take care of Mg dosing.

Tanks with strong coralline growth typicall have this parameters:
- low on Magnesium
- Calcium high & Alkalinity/Carbonate hardness high & high pH

3.6) pH-Value

pH is the most important value for the well-being of tank inhabitants.
pH values out of the recommended range (especially if too low) cause direct stress for the animals. You should check from time to time, because it is a good indicator for any forthcoming problems. A major reason for adapting new tank inhabitants slowly/carefully is the possible difference in ph-value of the transported water and your tank.

3.7) Phosphate

Phosphate concentration should neither be too high but also not to low (>0 mg/l and < 0,05 mg/l). This is due to two different reaction principles:

Concentration too high: Building of calcium is inhibited/hindered in a chemical way. The result is stagnating growth of all creatures using calcium for building their skeletons. This is especially the case for stony corals and coralline algae.
In this case, stony corals (SPS) assemble more zooxanthelles which are using these nutrients. As a reaction, zooxanthelles will not feed their coral anymore with glucose. Having too many zooxanthelles also gives an unattractive brownish colour.
However, most corals can be very adaptive and get accustomed to higher PO_4 concentrations.

Concentration too low: Reduced growth of normal algae and also zooxanthelles (not coralline algae). Being below a concentration of 0,03 (<0,03 mg/l) the creation of several types of phytoplankton is hindered.

Even more important than having an exact concentration is that PO_4 never changes too fast. Stony corals (SPS and LPS) react by fast stalling of their zooxanthelles/polyps.

Reduction of PO_4 can also be used to control unwanted algae growth.

There are several ways for phosphates to get into our tanks:
- by feeding/food (especially within frozen food)
- by using tapwater
- as part of sea-salt mixtures
- by dying animals
- by poor quality of activated carbon
- by calcium-carbonate granulate for calcium reactors

3.8) Salt concentration

Most salt-water animals can adapt themselves perfectly. Salt-water tanks can run within a broad salinity range. Also, in nature, salinity level differs a lot, eg Pacific Ocean ~ 34psu vs Red Sea ~41 psu.

Some aquarists run their tanks at unusual low salinity levels because this reduces germs and pathogens. For some animals, however, this means physical stress.

More critical than the salinity concentration itself is altering salinity, which can happen as follows:
- Adding new animals
- evaporated water is replaced only seldomly
- too much seawater added to the tank at one time
  (eg if a ATO/niveau control unit is not working properly)

Animals known to be especially sensitive to salinity changes: Any type of shrimps and anemones.

In emergency case (salinity drop or raise) it is most important not to adapt salinity too fast.

3.9) Strontium

Strontium concentration is not too important for corals other than SPS. Even then this is discussed controversially.
We do not really know if strontium is built into coral skeletons because…(MARTIN…UNSURE OF MEANING HERE… fitting into the aragonite crystals ba random, or if really having a positive impact.)

Measuring this concentration as well as doing a strontium adaptation is not really essential.

3.10) Temperature

If temperature is out of scope this might cause:

a) Consumption from animals is raised. As a consequence, they consume more oxygen, CO_2, nutrients, calcium and alkalinity. By higher speed of growth, amount of excrements is also raisied.

b) Temperature influences solutability of several gasses.
Eg oxygen and CO_2 get soluted less well at elevated temperatures.

c) Fish and corals, as in nature, are not too sensitive to temperature changes.
Anemones react more sensitive to temperature drops/raises.

Recommended temperatures are within a range which is easily reachable. I recommend having a temperature between 24.0 and 26.0°C. Thus, even in the case of a failure of the current supply tanks should not become too cold in winter and too warm in summer too fast.

3.11) Ammonia

Toxic Ammonia (NH_3) is in a dynamic balance with non-toxic ammonium (NH_4^+). The higher the pH-value, the more ammonium is converted into the toxic ammonia.
Ammonia is a metabolic product excreted by most creatures living in our reef tanks.

Ammonia is highly toxic for most creatures witin our tanks (critical for animals > 0,2 mg/l, for phytoplankton >0,1mg/l). It will block breathing and other vital functions.

Luckily, some organisms like macroalgae (eg: caulerpa) and bacteria take up ammonia.

In mature tanks, more than enough bacteria (ammoniation) have established to convert ammonia into nitrite all the time. Nitrite is by far less toxic for animals than ammonia.
(See nitrogen cycle).

Ammonia should only be measurable in following situations:

a) Tank is still within its start-up phase
b) You added live rock or live sand recently
c) You stopped using a very effective filtering technology (eg Zeolithe) too abruptly

3.12) Nitrite

Nitrite in reef tanks is much less toxic than ammonia. Healthy animals/fish do not even show any symptoms at slightly elevated nitrite levels. Indication for excessive nitrite concentration within your water is *very fast respiration*, *fish hanging around at water surface* or *having trouble with their own orientation* (tumbling, rotating around own vertical axis).

Hint: Having an elevated nitrite concentration, can mean also that your ammonia level is too high.

Elevated nitrite concentration should only be within your tank during the start-up phase. Because bacteria consuming ammonia have to establish before bacteria consuming nitrites, a nitrite-peak is quite typical. Nitrite reduction should then drop pretty fast to ≤ 0,1 mg/L indicating that enough nitrite consuming bacteria have assembled. If this has happened for certain, it is the very first time you should even think on adding animals into your tank.

In mature tanks, more than enough bacteria (nitrification) have established to convert nitrite into nitrate all the time (See nitrogen cycle).

3.13) Nitrate

Nitrate in reef tanks is not toxic at all, but leads to a higher vulnerability to diseases.

Elevated nitrate concentrations can cause:

- boosted (micro and macro) algae growth
- boosted growth of zooxanthelle of your corals which can, as a result, generate problems for your stony corals
- Increased probability of unwanted types of algae (Dinoflagellates, gold-algae…)

Low nitrate levels are a must for keeping sensitive stony corals and will give SPS a brighter colour. What you should not do is run a tank with nitrate at 0 for a long time.

In mature tanks, more than enough anaerobic bacteria have established to convert nitrate into nitrogen and also algae are buidling in nitrates (See nitrogen-cycle).

3.14) Silicates

Silicates can enter our tanks by tap water. It will enrich steadily in gravel, stones, etc. Silicates lead to ugly coatings, especially of brown algae, which are also a breeding ground for other plagues. On the other hand, a slight silicate concentration can be positive for sponges and mollusks.

Because of the increased risk of getting other plagues and unattractive brown algae, I strongly recommend steadily checking your silicate concentration to be at 0mg/l – or even better use a water purification unit.

CHAPTER 4 – Possibilties for adapting water parameters

4.0) Miscellaneous

In the next chapters, you will get a summary about how to adapt all water parameters. Before hopping to that please respect that:

Each salt-water tank is a complex chemical/biological system.
Changing one parameter might also affect others.
It is extremely important that you can trust the results of your water test kits. Before even thinking about a single adaptation you should be sure you have learned how to measure water parameters correctly and how you can check the accuracy of your test kits (use of reference solutions).

<u>There are several typical mistakes you should avoid:</u>
- Measuring your tank's salt concentration without knowing about the temperature dependance of several measurement tools (eg hydrometers)
- Measuring and adapting concentrations of calcium/magnesium/alkalinity without first having adjusted salinity to a correct level

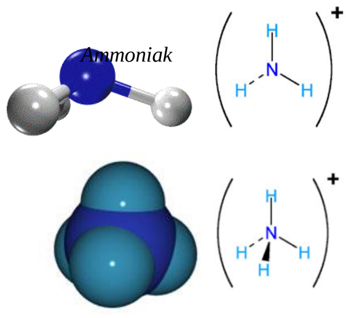
4.1) Alkalinity

Raising Alkalinity:
- 2/3 part / Balling method
- Addition of Natriumhydrogencarbonate (for normal/typical pH-levels, ~ 8)
- Addition of Natriumcarbonate (in case of lower pH-level)

comfortable calculation can be done with **Aqua Calculator**

Reducing Alkalinity:
- Waiting
- Water change with a salt low on alkalinity

4.2) Ammonia/Ammonium



Ammonium

(Intermediate product of nydrogene cycle)
Reduce concentration:
a) Add less Ammonia by;
- Reduce amount of fish
- Reduce feeding
- Reduce your tank's temperature
- Remove any dead animals from tank immediately
- Remove any build up of muck
- Have good flow, also behind your reef
- Either remove or steadily clean mechanical filters like bioballs, sponges etc. Don't allow them to get dry

b) Have a better conversion from ammonia to nitrite
- Add and feed respective bacteria cultures
- Use additives binding ammonia (eg EasyLife or other zeolithe products) then skim!
- add some more live rock with fresh bacteria (only some)

c) In emergency situations: Water changes even up to a high %-age of your tank's volume

4.3) Calcium

Raising calcium:

a) Dose calcium

- Use 2/3-part / Balling method

comfortable calculation can be done with **Aqua Calculator**

- Use $CaCl_2$ $2xH_2O$ or commercially available products
  (Bio-Calcium, Calcium-Pro, …)

b) Use calcium reactor

c) Add Kalkwasser

c) Balance calcium by water changes

- Do frequent and regular water changes
- Use “Pro” or “Reef” salt mixtures having either an elevated Ca-concentration, or where Ca can be raised separately

Reducing Calcium:

- Waiting (will reduce automatically by consumption from corals)
- Water change with a salt mixture with low Ca concentraton or even Ca = 0 (don’t use “Pro” or “reef” salt types now)
- Reduce tank’s salinity (will influence other parameters as alkalinity, Mg too)

4.4) Iodine

Raise iodine concentration:

- LUGOLs solution 0.1%
- PVP-Iodine (Betaisodonna)

4.5) Magnesium

Raising magnesium:

a) Dose magnesium

- Use 2/3-part / Balling method to raise Magnesium by chemicals

comfortable calculation can be done with **Aqua Calculator**

- Using commercially available products
(Magnesium -Calcium, Magnesium-Pro, …)

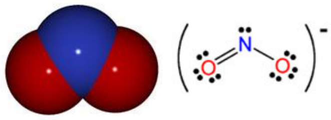
c) Balance magnesium by water changes

- Do frequent and regular water changes
- Use “Pro” or “Reef” salt mixtures having either an elevated Mg-concentration, or where Mg can be raised separately

Reducing magnesium:

- Waiting (this will reduce concentration automatically by consumption of coralline algae and also by some corals).
Hint: For reducing Mg, waiting will take far longer than waiting for KH and Ca to drop.
- Water change with a salt mixture with low Mg concentraton or even Mg = 0
(don’t use “Pro” or “reef” salt types now)
- Reduce tank’s salinity (will influence other parameters as Ca, alkalinity, too)

4.6) Nitrite



(Intermediate product of nydrogene cycle)

Reduce concentration:

a) Add less nitrogen by;

- Reduce amount of fish
- less feeding
- Reduce your tank’s temperature
- Remove any dead animals from tank immediately
- Remove any build up of muck
- Have a good current flow, also behind your reef

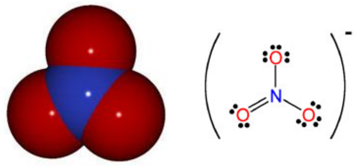
b) Have a better conversion from nitrite to nitrate

- Add and feed respective bacteria cultures (Nitrobacter)
- Have additional places where bacteria can assemble and grow (eg bioballs or filtering sponges) if you can ensure that they are regularly cleaned with salt water.
- add some more live rock with fresh bacteria (only some)

c) In emergency situations: Water changes up to a high %-age of your tank’s volume

4.7) Nitrate

(Intermediate product of nydrogene cycle)



Reducing your concentration:

a) Add less nitrogen by:

- Use fresh water from a water-purifying unit to prevent nitrates from coming in steadily by tap water
- Reduce amount of fish
- Reduce feeding
- Remove any dead animals from tank immediately
- Remove any build up of muck
- Have good flow, also behind your reef
- Either remove or steadily clean mechanical filters like bioballs, sponges etc. Don't allow them to get dry

b) Removal of Nitrate

- Improve skimming
- Use filters effectively reducing nitrates:
  - Miracle mud or macro algae filter, macroalgae within your tank
  - Zeolithe filters/method
  - Specialised nitrate filters (low flow rate anaerobic zone filters)
  - Sand bed filter (DSB)
  - Sulfate-based nitrate filters are not recommended anymore!!
- Tropic Marin – "Bio Actif" powder
- Add respective bacteria cultures
- Stimulate bacteria growth by supplying ethanol or acetate (eg. Vodka method, bio-pellets, nitrate balls, acid bacteria food, etc)

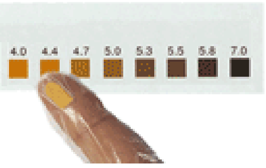
c) In emergency situations: Water changes up to a high %-age of your tank's volume

Raising your concentration:

- Increase your feeding
- Add frozen food into tank directly (Don't wash before)
- Calcium reactor in use?
  - * Use calcium carbonate with mounted PO_4
  - * don't wash calcium carbonate before adding to reactor
- Dose nitrate liquid-solution

comfortable calculation can be done with **Aqua Calculator**

4.8) pH-value



Raising pH value:

a) Remove assemblies of CO_2
- Improve your room's ventilation
  (open windows for a short time more frequently to allow exchange of air)
- ventilation of area above your tank's water surface
- Calcium reactor in use?
  * reactor's CO_2 used drops your tank's ph if it gets into your tank by any reason.
  a) Dropping in [??? MARTIN WHAT DO YOU MEAN HERE?] of calcified water should be well ventilated
  b) Is your reactor missing a CO_2-recirculation?
  Reactors with CO_2-recirculation have better CO_2 usage and thus bring less CO_2 to your tank

b) Improve reduction of your tank's CO_2 by improved photosynthesis
- Increase content of animals carrying out photosynthesis
  (corals, anemones, gorgonian and most algae)
- Improve your tank's illumination (better illumination = more photosynthesis)

c) Reduction of CO_2 by metabolism products of your animals
- Reduce amount of fish/feeding

d) Adding pH-value by chemicals
- raise pH for a short period of time by Kalkwasser
- Commercial products

e) Ensure your fresh water has a suitable ph
Freshwater being used to make salt water should have a ph of ~7
If your ph is ≤ 6, your water/water purifying unit is not suitable for salt-water tanks.

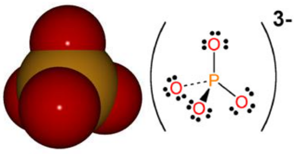
Stabilising/buffering ph:

a) Buffering of pH by raising alkalinity:
Add $NaHCO_3$ (soda) or Na_2CO_3 to reach alkalinity between 8-10 °dH (dosing)
b) Get a choppy water surface (eg by rearranging flow pumps)
c) Use a good skimmer. If possible get air used for skimming from outside of the room.
d) Use airstones
e) Algae refuge illuminated also during night to reduce CO_2 by photosynthesis and thus stabilise ph

Dropping your pH:

Different to salt water aquariums, this is normally not needed in reef tanks.
a) Use contradictory measures as written above
b) Dose CO_2 separately as gas
b) Add commercial products to lower pH-value
c) Add less/no kalkwasser

4.9) Phosphate



Reducing your concentration:

c) Remove any depots of phosphates in your tank
- Get rid of rocks/stones with assembled PO_4
- Avoid having any areas with a build up of muck in your tank by either rearrangement of your reef structure and/or good flow
- Clean areas with muck
- Use a "clean-up crew" to raise muck again and again, which will then be filtered, skimmed or even be eaten up by the crew. Select your crew according your tank's size (eg. all Valencina gobies, A. angulatus, sand dollars, snails…)

a) Reduce phosphates coming into your tank
- Use phosphate-free food only
- If frozen food is used, wash thoroughly before feeding
- use high-quality, phosphate free supplements only

b) Remove phosphate from your tank
- Better Skimming
- Macro Algae or mud filter (eg MiracleMud)
- Vodka method (or similar, somehow risky)
- Zeolithe method
- Macroalgae within tank
  (not really recommended, can get a plague in the tank)
- Phosphate absorbers: Diakat-B 2-4mm, Rowaphos, Contraphos, Elimi-Phos, Timo, PhosStop, etc
- Add respective bacteria cultures. Take care also with feeding them
- Water changes

Adding Kalkwasser, as often recommended, does not remove but only bind PO4. Don't risk having a ticking time bomb because of PO4 depots beeing built up.

Raising your concentration:
- Increase your feeding
- Use food or supplements including phosphates
- Add frozen food into tank directly (Don't wash before)
- Calcium reactor in use?
  * Use calcium carbonate with mounted PO_4
  * don't wash calcium carbonate before adding to reactor
- Dose Phosphate liquid-solution

comfortable calculation can be done with **Aqua Calculator**

4.10) Salt concentration/Salinity

Reduce salt concentration:
a) Add more water to your tank with adding no/only a little amount of salt
b) Remove part of your tank's water and replace with water with only a little or no salt

Raising salt concentration:
a) Add salt
b) do a water change with salt concentration higher than in tank

- Adaptations of salt concentration have to done carefully and slowly (reducing or raising)

- You should measure your tank's salinity as well your fresh salt water's salinity before each adaptation. Depending on your measurement method/tool, you also have to measure water temperature (for density, spec. gravity and conductivity).

- Salt is getting easier soluted if done in warm water (~25°C) and using a pump.
  In case of insufficient solutability, add 100ml soda water per 100L of salt water.
  Salt water can be used directly (no need to wait) but should not be poured directly on corals.

- Amount of salt needed to reach a specific salt concentration is different for different products available.
  Salt mixtures need 38 .. 42 gram per litre water to reach a typical salinity of 34.9 psu.

comfortable calculation can be done with **Aqua Calculator**
which also has a data of most available salt mixtures built in

4.11) Silicate

Reduce concentration:
a) Keep fresh water free of silicates
  - Use a silicate/ultra-poor filter even if you have an RO unit
    Hint: Filter should be behind an RO unit. Mixed-bed resin has to be replaced regularly.
  - Use Ani/Kati water purification
  - Buy purified or distilled water (in case of smaller tanks)

b) Absorb silicates in tank's water (second- best solution only)
  - Using absorbing granulate
    (silicarbon, UltraSil, …any type of phosphate absorber should work)

c) Biological silicate consumers
  - Sponges

4.12) Water changes: The all-in-one solution?

Definition of water change: Replacement of a certain amount of tank water by fresh salt water.

There are several very good reasons to do regular water changes in reef tanks:

- Adding of minerals, nutrients or trace elements
- Harmful substances within your tank's water are diluted and thus removed at least partially
- Soilings, algae, food and other unwanted things within your tank can be exhausted
- If salt concentration is either too high or too low, this can be adapted together with a water change

However, water changes are only useful, if ***water added to the tank*** is closer to ***optimal conditions than the water being replaced***. Therefore, you should be mindful of the following:

- The fresh water being used should not add any impurities. Use of purified water is absolutely recommended for salt-water aquariums (see chapter 1.10)
- You should use only high-quality salt mixtures for salt water aquariums, which are free of impurities and phosphate-free
- Salt mixtures used should match the water parameters of calcium, magnesium and alkalinity you want to have within your tank.
- Check salinity of new water before adding it to your tank.
- Typical water change recommendation: Replace five - 10% of tank's water volume each one-two weeks.
- Emergency cases (eg intoxication): waterchanges >30%

How often should I do water changes?

To find out the best water-changing strategy for your tank, you should know the answers to these questions:

– The actual water parameters are?

– What do you add/replace in your tank by the planned water change, depending on your fresh water and salt mixture used?

– Which parameters are the best for your animals?

– How much Ca, Alk and Mg does my tank consume and is it even possible to adapt this by doing water changes only?

Water changes for reducing the amount of harmful substances

Sometimes we add toxins or other unwanted substances to our tanks by accident. It is very clear that we want to remove them fast, as complete as possible and without causing too much additional stress on our animals.

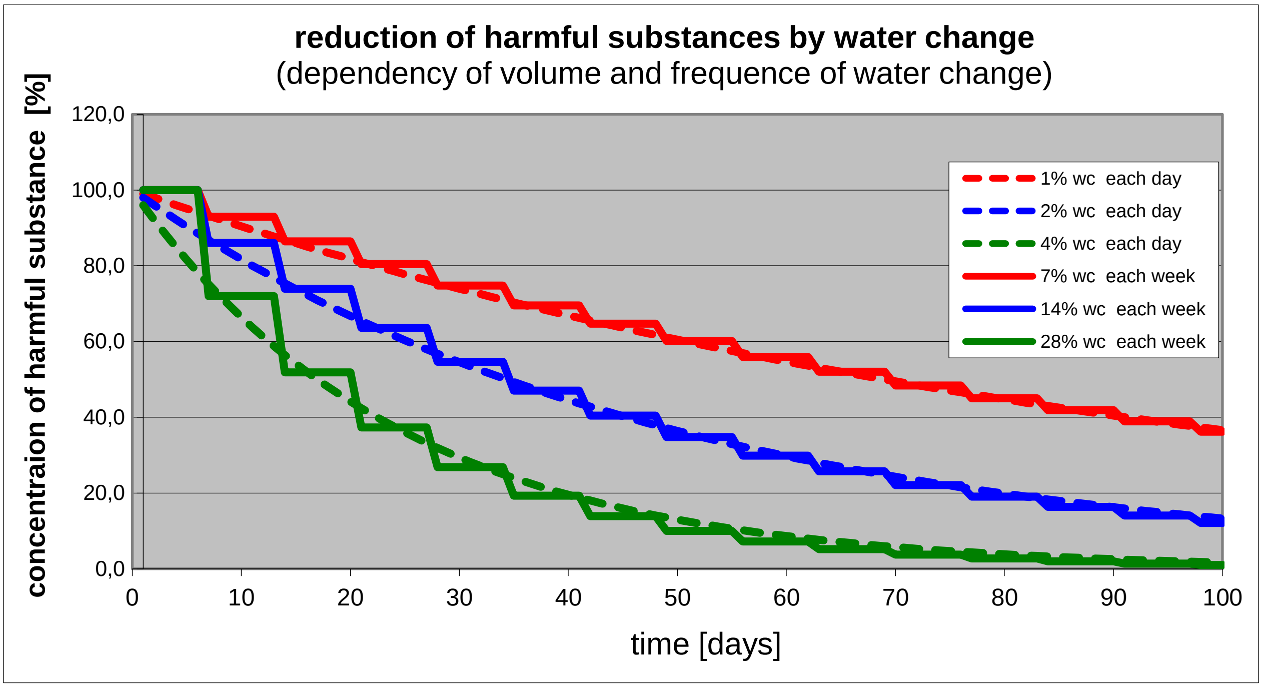
Depending on risk, but also costs, you should decide to remove it by filters, adsorbers or water changes.

Diagram below showing:

- Harmful substance added at a single time (no further bringing in of this substance).
  This substance has its own concentration 100% at the beginning.
- Situation after changing water with only little (red: 1%/day or 7% week), average (blue: 2%/day or 14% week) and large amount of water change (green: 4%/day or 28% week)
  Solid lines: "weekly" water change; dashed lines: "daily" water changes.

Result:

- As expected, the bigger the amount of water change, the faster the harmful substance is removed by replacement (red→blue→green)
- Concentration is reduced faster at the beginning then slowing down.
  Cause effect: Starting with the second water change, you also remove part of the "good salt water"
- Doing water changes less frequent (here weekly) is a bit more effective. Cause effect as before



Water changes for a steadily reduction of harmful substances
(harmful substances added steadily)

In some cases, harmful substances are built up steadily and cannot be reduced enough by the tank's biology or filtering mechanisms. A typical example would be a tank with lots of fish, thus also intense feeding but inefficient filtering.
These sytems are producing more harmful substances than they are able to remove. The logical result is a steady rise of unwanted/harmfull substances, which can even lead to dying animals.

In general, you should identify causes and try to eliminate or improve your filtering mechanisms, but there is also a chance to get to grips with it by doing regular water changes. A big advantage of doing water changes in this case is the ability to act fast. If you plan doing this for a longer time, you should balance time and costs.

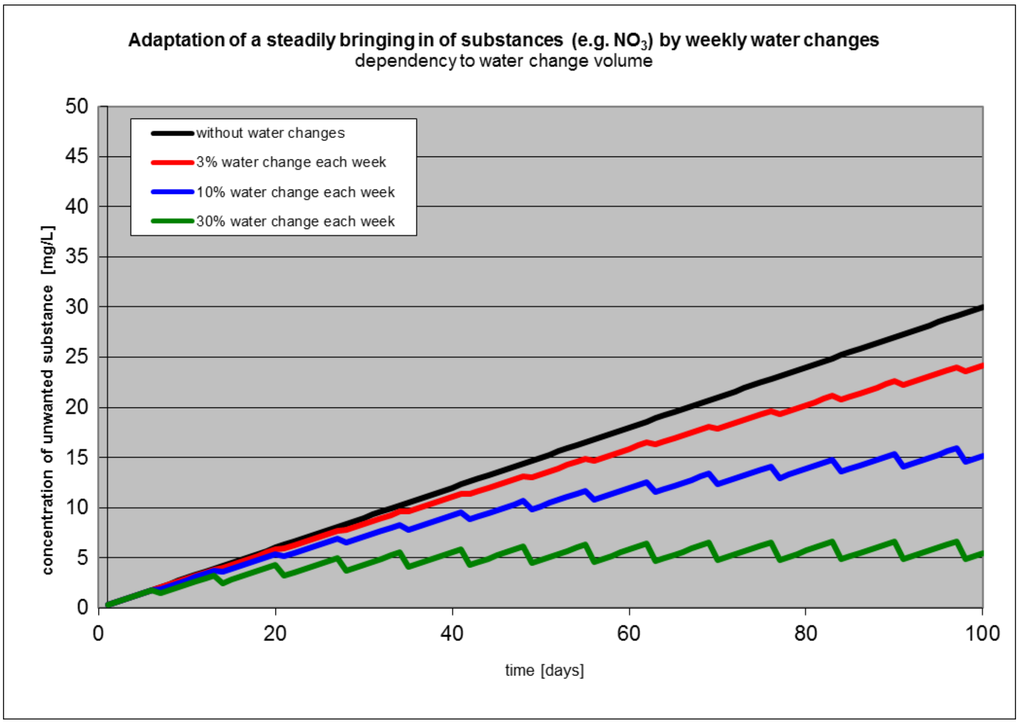
Diagram below showing:

- Steadily bringing in of a harmful/unwanted substance/element
  ⌧ No3 concentration is raised by 0.3 mg/l each day

- Black line: - no water changes
  red, blue, green lines: water changes with 3%, 10% and 30% a week

Result: Depending on the amount of a harmful substance added each day, this can or cannot be adapted by water changes

- green: ok, is levelling off at ~ 5mg/l
- blue: is levelling off at maybe already too high a concentration
- red: not leveling off! Concentration of harmful substance rising slower than without water changes



Water changes to raise concentrations of mass/trace elements

Again, being totally different is the **desired increase** of concentrations of elements such as Ca, Mg and alkalinity (KH) as also of further trace elements (all of this has to be brought in for well-running tanks).

Depending on your corals and other animals, your tank's consumption is STRONGLY different and unique for each tank. Fish-only tanks have a much lower demand than SPS-filled reef tanks. Also, consumption can alter over time.

These are the ***main influencing parameters*** telling you if water changes will be a good way to keep these concentrations up:

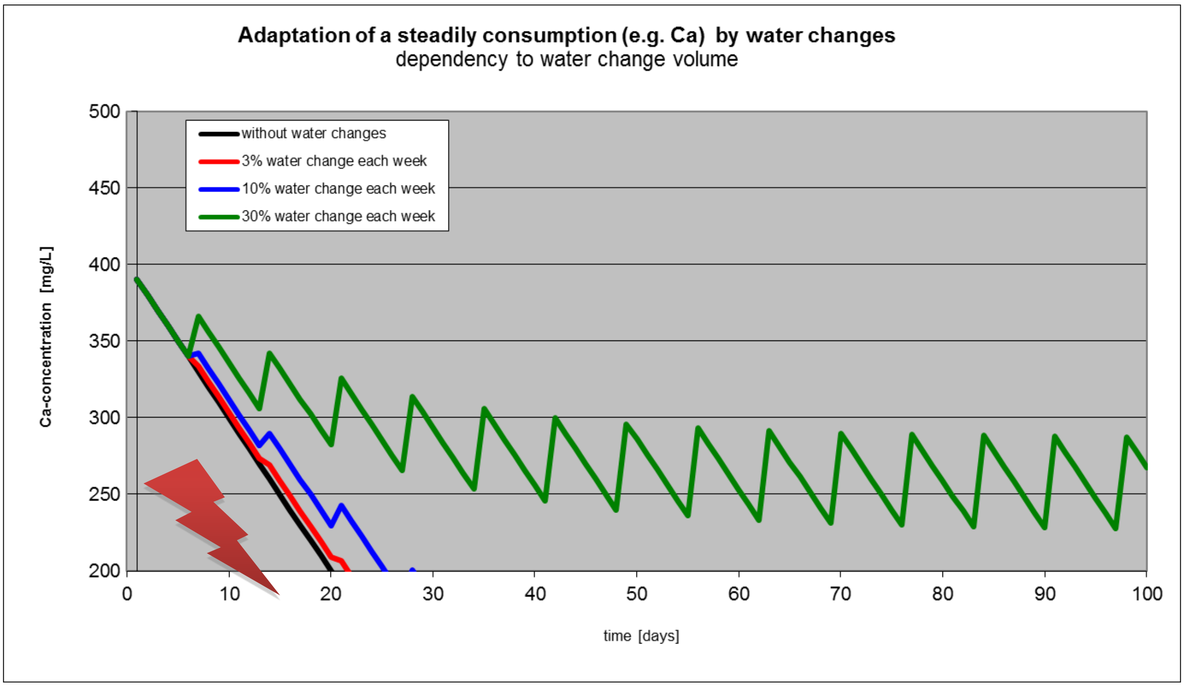
- Concentrations of mass elements (Ca, Alk, Mg) within the salt mixture
- Desired concentration of mass elements (Ca, Alk, Mg) in your tank
- Actual concentration within your tank (Ca, Alk, Mg)
  (primarily to see how long an adaption might take)
- Consumption of your tank (Ca, Alk, Mg)

In case your salt mixture's concentration of Ca, Alk, Mg is lower than your desired values, water changes can even be counterproductive, reducing your concentration.

Diagram: Adaptation of steadily consumption of mass elements by water changes.
example: Ca, starting point: 400 mg/l & Ca-consumption (10 mg/l per day)

<u>Result:</u> Adaptation of Ca, alkalinity by water change is only possible in tanks with little consumption. Tanks with lots of stony corals (SPS) need a separate/alternative way of adding Ca/alkalinity.

<u>Hint:</u> Curves shown are purely hypothetical.
In reality, Ca will never drop to 0, because Ca consuming animals would either die or stop their growth.



4.13) Which salt mixture is best for my tank?

Even if that is very clear for most of us, you should only use special *sea-salt mixtures* developed and produced for aquariums. NEVER use table salts, thawing salts or other non-aquaristic salts.

I recommend using one or more salt mixtures which fit best to your tank's demands. It is not necessary to buy only the most expensive products, but buying high-quality products in general gives you less risk of adding unwanted impurities.

a) For fish-only tanks or tanks without stony corals *normal sea-salt types* are fine.
b) For tanks with lots of SPS and other sensitive animals, I recommend using special "*reef-salt types*" which have higher and more nature-like concentrations of calcium, alkalinity, magnesium and also trace elements. It is also possible, but more time consuming, to buy cheaper sea salt mixtures and bolster it with Ca, Alk, Mg and trace elements separately

Amount of salt needed

Wanting to know how much salt is needed, you need to know:

a) *Volume* of fresh water that should be used
(you get a bit higher volume than that as salt water later, because adding salt ?MARTIN NOT SURE WHAT YOU MEAN HERE?)

b) *Amount of salt needed per litre* to reach *targeted salinity* (if used with purified fresh water) for the salt mixture you are using

c) Your tank's *actual salt concentration*

I recommend aiming a (norm) salinity of 34.8 [psu].

The amount of salt to be added to one litre of fresh water to reach an aimed salinity (eg 34.8 psu) is different for each manufacturer and salt type used.
In general, you need **between 38 and 41 grams per litre to reach a salinity of 34.8 psu.** This is more than you might have expected. The reason is that salt mixtures have not only pure salts but also other elements and trace elements which do not raise salinity 1:1.

In several cases, manufacturers do not publish the required amount of salts, or even publish unrealisticly (low) values. I expect they are doing this for competitive reasons.

Aqua Calculator supports you with comfortable water-change calculations and includes data of nearly all avalibale salt mixtures.

4.14) Sea-salt mixture data for nearly all available salt mixtures (my privately measured results)

NO LIABILITY ASSUMED AT ALL FOR DATA OF SYNTHETIC SEA-SALT MIXTURES or INTEGRATED INTO Aqua Calculator. THEY ARE ONLY TO BE SEEN AS A ROUGH GUIDE. Values can differ to manufacturers' details !

- All values stated are for purified water. In case of using tap water: add tap water's concentrations!
- Most sea-salt mixes come with lot variations and also unmixing, eg by transport, is possible.
- There might be recipe changes of salt mixtures done by manufacturers at any time!
- Results have been measured on objective criteria and best knowledge, but there may be errors.
- Only concentrations that are "measurable" by normal aquarists have been measured. Number of tests per salt mix >= 1.
- Possible lot variations thus have not been determined ?MARTIN?
- Ca/Mg/alkalinity measured with drop tests which have usually a certain deviation.
- Standard/reference solutions have been used to minimize the effect of wrong measurements.
- All concentrations have been "normalised" to a salinity of 34.8 psu.
- If you mix your salt water to a lower/higher salinity, this concentration will be lower/higher.
- Impartiality: I neither sell, nor make an advertisement of any of the products tested.
- In case some distributors do not like their salt-mixture values to be published, I might remove them from Aqua-Calculator.
- Most tests done, have been made with salt samples from friends, not from distributors.
- Results of the salt mixes are no "good" / "bad" evaluation.Ddecide by your own which salt mix might be the best for your tank

Distributor / Type	measured data normalised to 34,8 psu weight for 1 L [g/L]	Ca [mg/l]	Mg [mg/l]	Alk [dKH]	e mer	[gr/1 Liter] needed to reach [psu] 32	33	34	35	34,8
						39,024	40,244	41,463	42,683	
AQ-Systems - Instant Ocean	40,791	420	1175	11,5	M.Kuhr	37,51	38,68	39,85	41,03	40,79
AQ-Systems - Reef Crystals	40,834	405	1280	11,0	M.Kuhr	37,55	38,72	39,90	41,07	40,83
Aqua Craft - Coral Marine sea salt	40,583	275	885	9,6	M.Kuhr	37,32	38,48	39,65	40,82	40,58
Aqua Craft - Marine Environm.2 part reef formula	40,755	440	1050	9,2	M Trace	37,48	38,65	39,82	40,99	40,76
Aquaforest - Reef salt	42,233	385	1360	6,0	M.Kuhr	38,83	40,05	41,26	42,48	42,23
AquaForest - Probiotica Reef salt	41,683	395	1385	6,0	M.Kuhr	38,33	39,53	40,72	41,92	41,68
AquaForest - sea salt	41,865	390	1305	7,1	M.Kuhr	38,50	39,70	40,90	42,11	41,86
Aqua Medic - Reef Salt	39,613	405	1160	8,4	M.Kuhr	36,43	37,56	38,70	39,84	39,61
Aqua Medic - Sea Salt	39,400	265	740	6,4	M.Kuhr	36,23	37,36	38,49	39,63	39,40
AQUA Trace Care - Coral Prem.	41,208	435	1330	8,2	M.Kuhr	37,89	39,08	40,26	41,44	41,21
AquaLight - Aquatic Marine	39,101	450	1290	9,8	M.Kuhr	35,96	37,08	38,20	39,33	39,10
KZ Pohl: Reefers Best Premium	39,355	460	1180	5,9	M.Kuhr	36,19	37,32	38,45	39,58	39,36
Aquarium Schober - Meersalz	40,893	410	1165	10,0	M.Kuhr	37,60	38,78	39,95	41,13	40,89
Ama - Royal Nature trop. sea salt	41,764	450	1285	10,0	M.Kuhr	38,40	39,60	40,80	42,00	41,76
ATI - Coral Ocean	40,212	475	1335	8,1	M -> Ca	36,98	38,13	39,29	40,44	40,21
ATI - Coral Ocean Plus	35,799	440	1340	7,6	M.Kuhr	32,92	33,95	34,98	36,01	35,80
ATS - Quality Premium	42,067	295	1305	6,8	M.Kuhr	38,68	39,89	41,10	42,31	42,07
Brightwel Aquatics - NeoMarine	36,923	390	1220	6,5	M.Kuhr	33,95	35,01	36,07	37,14	36,92
Colombo - Pro Reef Salt	39,344	450	1255	10,0	M.Kuhr	36,18	37,31	38,44	39,57	39,34
Coral Master - Premium Reef	41,852	365	1210	6,9	M.Kuhr	38,48	39,69	40,89	42,09	41,85
Coral-Care - Top sea salt	41,466	390	1320	7,3	M.Kuhr	38,13	39,32	40,51	41,70	41,47
Coral-Reef - Meersalz	42,381	500	1525	7,1	M.Kuhr	38,97	40,19	41,41	42,62	42,38
Coral-Reef - Exclusiv	39,920	495	1155	11,0	M.Kuhr	36,71	37,85	39,00	40,15	39,92
Coral-Shop - Marine Salz	41,802	440	1190	9,4	M.Kuhr	38,44	39,64	40,84	42,04	41,80
Crystal sea - Marinemix	39,828	310	1135	11,0	M.Kuhr	36,62	37,77	38,91	40,06	39,83
Crystal Sea - Marine Mix (Forty Fatmoms)	40,833	300	1060	10,7	M.Kul (	37,55	38,72	39,89	41,07	40,83
Deep Blue - sea salt	38,273	460	1300	11,5	M.Kuhr	35,19	36,29	37,39	38,49	38,27
Dennerle - Nano Marinus reef salt	40,115	390	1135	8,0	M.Kuhr	36,89	38,04	39,19	40,35	40,12
Dupla Marin - Amino Active	38,137	395	1260	7,6	M.Kuhr	35,07	36,16	37,26	38,36	38,14
Dupla Marin - Premium Salt	40,115	455	1385	11,0	M.Kuhr	36,89	38,04	39,19	40,35	40,12
Dupla Marin - Premium sea salt	39,874	355	1375	7,8	M.Kuhr	36,67	37,81	38,96	40,10	39,87
Dupla Marin - Premium reef salt	38,883	405	1240	7,4	M.Kuhr	35,75	36,87	37,99	39,11	38,88
D&D Aquarium solutions - H2Ocean	38,517	435	1320	10,6	M -	35,42	36,52	37,63	38,74	38,52
Elos	39,367	140	500	5,4	M.Kuhr	36,20	37,33	38,46	39,59	39,37
Fauna Marin	40,284	430	1270	8,6	M.Kuhr	37,04	38,20	39,36	40,52	40,28
Grotech - Coral Marine	40,380	305	1295	8,8	M -	37,13	38,29	39,45	40,61	40,38
HP Aquar. - Reef High Energie	41,802	525	1650	8,8	M.Kuhr	38,44	39,64	40,84	42,04	41,80
HW - Marine Mix Professional	41,429	425	1275	8,5	A.Bell(	38,10	39,29	40,48	41,67	41,43
HW - Marine Mix Reefer	41,928	440	1350	8,8	A.Bell(	38,55	39,76	40,96	42,17	41,93
Kent Marine - Reef Salt Mix	40,893	500	1300	10,2	M.Kuhr	37,60	38,78	39,95	41,13	40,89
KZ Pohl: Reefers Best Premium	41,281	405	1270	9,4	Labor T	37,96	39,15	40,33	41,52	41,28
KZ Pohl: Reefers Best Premium	41,306	485	1330	9,3	M.Kuhr	37,98	39,17	40,36	41,54	41,31
MICROBE-LIFT - Reef Salt	38,932	475	1430	6,8	M.Kuhr	35,80	36,92	38,04	39,16	38,93
MICROBE-LIFT - Premium Reef Salt (<=2015)	39,658	395	1280	9,9	M.Kuhr	36,47	37,61	38,75	39,89	39,66
MICROBE-LIFT - Organic Active Salt	39,495	450	1350	7,7	M.Kuhr	36,32	37,45	38,59	39,72	39,49
MICROBE-LIFT - Premium Reef Salt	39,652	430	1295	7,2	M.Kuhr	36,46	37,60	38,74	39,88	39,65

Distributor / Type	weight for 1 L [gr/L]	Ca [mg/l]	Mg [mg/l]	Alk [dKH]		32	33	34	35	
	measured data normalised to 34,8 psu					[gr/1Liter] needed to reach [psu]				
						39,024	40,244	41,463	42,683	
Sera Marin - Reef salt	41,306	460	1260	14,5	M.Kuhn	37,98	39,17	40,36	41,54	41,31
Silbermann - Pro color dKH0	42,118	20	1170	0,5	M -> Ca	38,73	39,94	41,15	42,36	42,12
Silbermann - Pro color dKH5,5	39,658	455	1460	5,4	M.Kuhn	36,47	37,61	38,75	39,89	39,66
Silbermann - Pro color dKH8	39,211	480	1460	8,5	M.Kuhn	36,06	37,18	38,31	39,44	39,21
Terra Nova - Optimum Sea Prof.	37,826	425	1080	7,6	M.K Ca	[illegible]	[illegible]	[illegible]	[illegible]	37,83
Tetra Marin - Sea salt -	40,046	350	1140	12,0	M.Kuhn	36,82	37,97	39,13	40,28	40,05
Timo - Premium Salt	39,828	480	1175	9,5	M.Kuhn	36,62	37,77	38,91	40,06	39,83
Timo - Reef Salt	39,057	490	1250	8,3	M -> Ca	35,91	37,04	38,16	39,28	39,06
Tropic Marin - Bio-Actif Sea Salt (old)	38,937	490	1315	10,7	M.Kuhn	35,80	36,92	38,04	39,16	38,94
Tropic Marin - Bio-Actif Sea Salt	39,090	410	1280	7,8	M.Kuhn	35,94	37,07	38,19	39,31	39,09
Tropic Marin - Sea Salt (Classic)	38,405	395	1285	7,5	M.Kuhn	35,32	36,42	37,52	38,63	38,41
Tropic Marin - Pro Reef (old)	39,886	425	1245	7,3	M.Kuhn	36,68	37,82	38,97	40,12	39,89
Tropic Marin - Pro Reef	38,273	435	1350	6,3	M.Kuhn	35,19	36,29	37,39	38,49	38,27
Tropic Marin - Salt (old)	39,930	345	1160	11,6	M.Kuhn	36,72	37,87	39,01	40,16	39,93
Tropic Marin - Syn Biotic	40,371	420	1285	6,7	M.Kuhn	37,12	38,28	39,44	40,60	40,37
Tropical Wave - Sea salt	39,350	470	1005	9,8	M.Kuhn	36,18	37,31	38,45	39,58	39,35
Welke Salz	37,286	360	1165	8,6	M.Kuhn	34,29	35,36	36,43	37,50	37,29

Example calculation:

Needed amount of a salt mixture for a given salinity

100 liters of water , Target salinity = 35 [psu]; neeed amount of salt for 34,8 [psu] acc. spreadsheet (as above) = 40,8g

→ Needed amount of salt mixture: 100 [L] x 35 / 34,8 x 40,8 [g]= **4103 [g]**

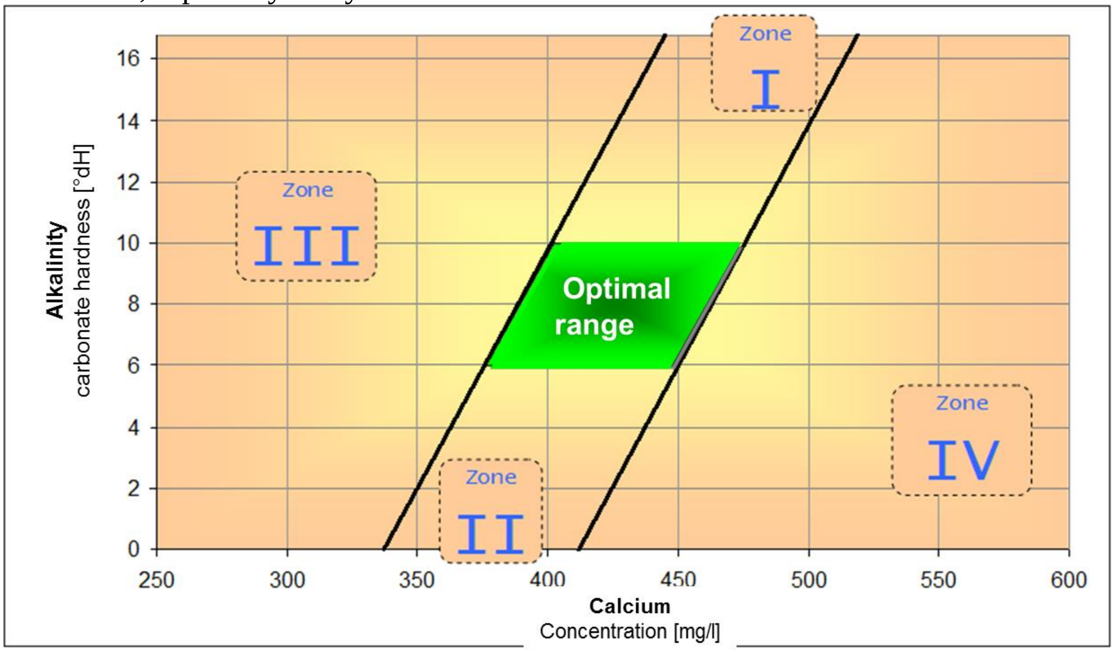
4.15) Adaptations within the natural proportion of calcium vs alkalinity (Four-zone system)

Adapatations to the calcification system are kind of complex. The following graphic explains the ***correlation of calcium-concentration dependent from carbonate hardness/alkalinity***.

a) The ***light-green area*** in the middle shows ***concentrations we should strive for in reef tanks***
→ ***optimal range***

b) The two black lines show a balanced consumption of calcium vs alkalinity, which is especially important if being outside the light-green area
→ This will give us four zones with sub-optimal relation between Ca vs alkalinity.

c) ***Areas marked blue*** (I, II, III and IV) are the different zones where the relation ***Ca vs alkalinity is sub-optimal***. The more you are "off" the green area, the more harmful/stressing for our tank's inhabitants, especially stony corals

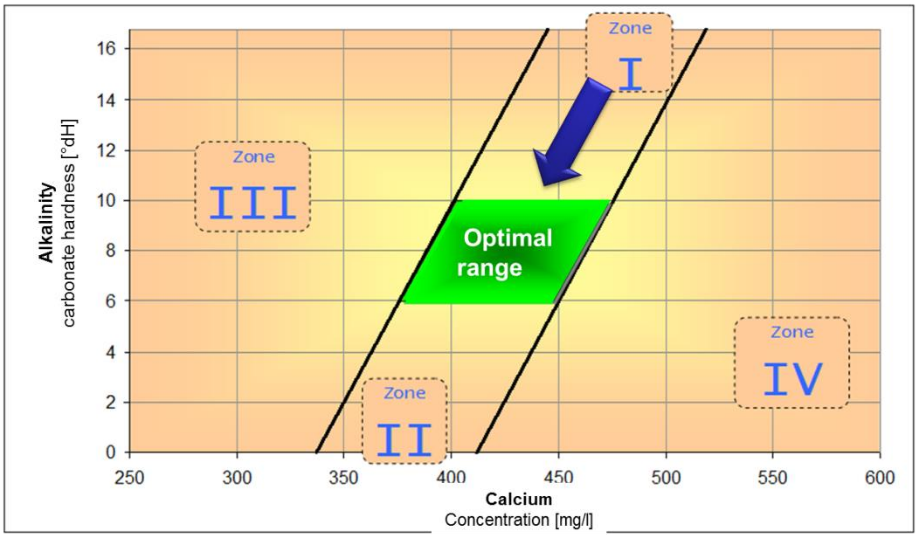


Following chapters will explain:

- Possible reasons for being out of the optimal range
- How to get back into the optimal range

Calcium/alkalinity is within Zone 1

Description: Calcium and alkalinity are too high
Correcting measure: Easy



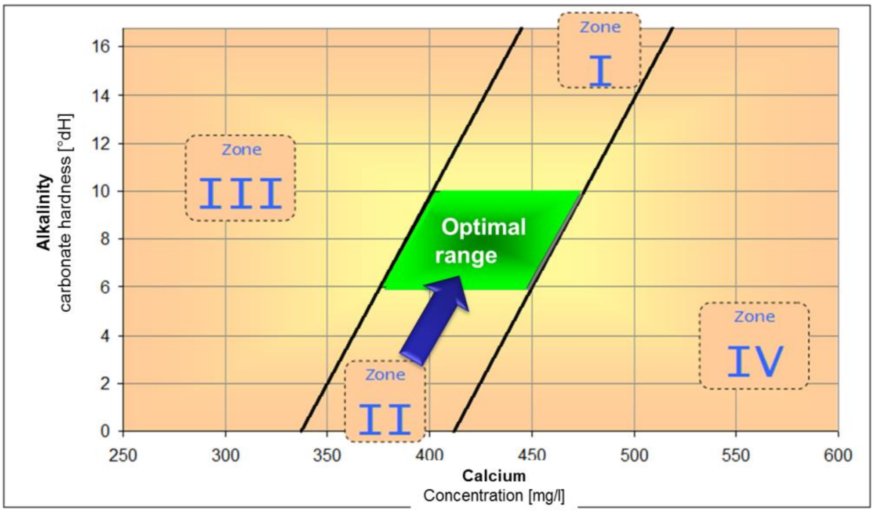
This happens if dosing too many chemicals to raise CA and alkalinity (eg Balling salts), or if you have elements in your tank adding Ca/alkalinity steadily (incompatible rocks, reef ceramics)

Ca and alkalinity will automatically be reduced by tank's consumption. This might be by stony corals building new calcium skeletons, growth of coralline algae.
Ca/alkalinity will most likely drop parallel to both black lines (direction bottom left).

Hint: If there is no dosing of chemicals going through the optimal range, your tank will get into Zone 2 sooner or later.

Calcium/alkalinity is within Zone 2

Description:	Calcium and alkalinity are too low
correcting measure:	easy



Reef tanks have a steady consumption of Ca/alkalinity. You will get into this zone automatically if you don’t take care of your tank’s Ca/alkalinity consumption by adding this two mass elements separately.

Adding chemicals in a so-called ***stoichiometric balanced way*** (which is called Balling method) or adding ***them based on your tank’s specific consumption*** is a very good option to control this consumption. Holding your ph between 7.9 and 8.5, even slight over-dosing shouldn’t be critical for your animals.
Another option is having a ***calcium reactor*** or using ***Kalkwasser*** (see later)

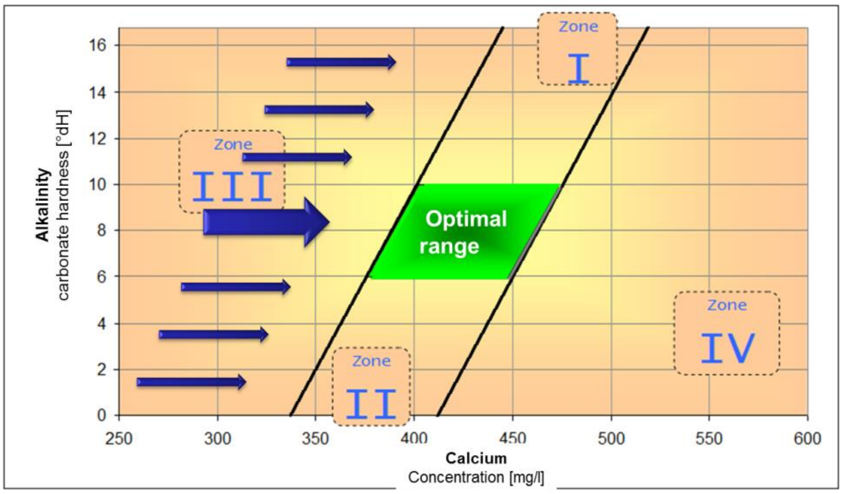
Regular water changes with salt mixtures supporting optimum concentrations are recommended to reduce any risks of wrong dosing and adding other trace elements

If you don’t react to being in Zone 2, you might end up in Zone 3.

Hint: If you don‘t succeed in raising your tank’s Ca/alkalinity, this might be because of magnesium being too low. Not having enough magnesium means preventing the abiotic precipitation of calcium carbonates. Chemicals added will precipitate within the water and are thus not available in a soluted state. Even overdosing of Ca/alkalinity does not help, but furthermore generates precipitations.
* Raise magnesium first to a proper level, then adapt Ca/alkalinity.

Calcium/alkalinity is within Zone 3

Description: Alkalinity is too high related to calcium concentration
This happens if you raise alkalinity more than calcium
correcting measure: Difficult



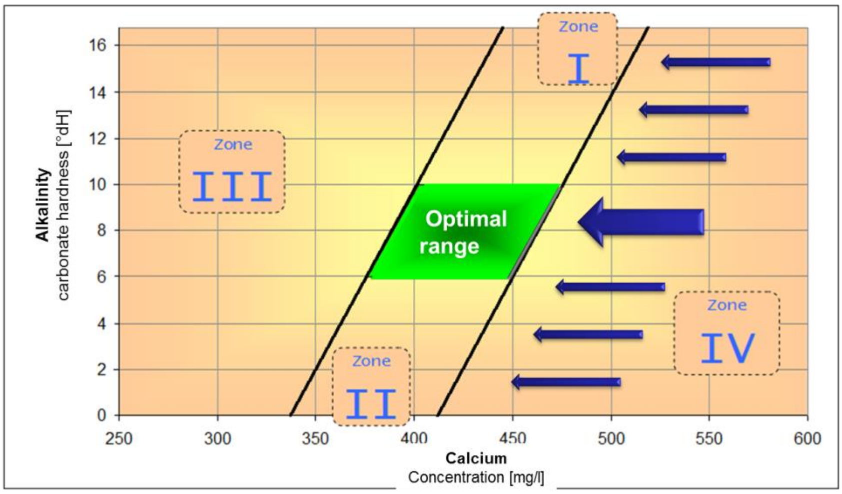
Normally you get this by ***excessively raising alkalinity*** relative to calcium concentration.
Some reefers try to adapat the ph-value, which is also influenced. Adding ph-buffers or chemicals raising ph should NOT be done if pH is already too high.

What you should do is

- Wait for alkalinity to drop into optimal range, if already too high
  (then no further dosing of carbonate-hardness adding chemicals at this point)
- Raise Ca directly by adding $CaCl_2$ x $2H_2O$ (see later chapters)

Calcium/alkalinity is within Zone 4

description: Alkalinity is too low related to calcium concentration
correcting-measure: Difficult



Normally you get this by ***excessively raising calcium concentration*** relative to alkalinity.
What you should do is

- Wait for Ca to drop to an optimal range, if already too high
  (no further dosing of calcium-adding chemicals at this point)
- Raise alkalinity directly only if too low by adding NaHCo3 (soda) or Na2CO3 (see later chapters)

CHAPTER 5 – Adapting your water parameters in real life (Ca, alkalinity and Mg)

5.1) How should I add chemicals to my tank?

Starting with manually dosing (pouring powders or liquids into your tank) and ending with fully automated dosing, everything is possible. You should select your favourite way regarding the following parameters:

- Which and how much different chemicals do you want to add?
- Dosing frequency (only seldom or several times a day?)
- Available space for containers and dosing units
- Budget

5.1.1 You should take care of the following aspects:

- Correctly evaluated water parameters are basic for any dosing
  Use only high-quality test kits and tools. Learn how to measure correctly.
  Measure concentrations like Ca, Alk, Mg only at correct salinity (~34.8 psu).

- Weighing-in of chemicals has to be done with an accurate set of scales
  Don't rely only on the number of digits your scale is displaying, but its measuring accuracy
  (I've seen scales which display 1/100 gramm , but show an incorrect result by 50 grams)
  In general: the smaller your tank is (meaning the smaller the amount you have to dose),
  the more accurate your scales should be.

- Check if there are any timely limitations where you should add a dose of chemicals
  (eg in the morning, in the evening…)

- Take care of incompatibilities of some chemicals or possible precipitations
  (eg: you shouldn't add *CalciumChlorid-DiHydrate* and *NatriumHydrogencarbonate* at the same time and place in your tank)

- The smoother you add chemicals to your tank, the less stress on your animals
  You should not directly pour chemcials directly over animals or raise certain levels too fast

- Pour chemicals into positions with good flow
  to prevent areas with assembly of high concentrations

- Containers used for storing should be food-safe. Some solutions should be mixed after some time of storage.

5.1a Manual dosing
Manual dosing is easy to do and needs no further explanation. Be sure to consider 5.1.1.

5.1b Automatical dosing
Can be done either:

- as liquid
  (eg: pre-mixed trace elements, pre-mixed Balling liquids..)

- as powder

In case you want to dose *powder-like chemicals* by dosing pumps, you have to solute them before use in RO water. Most common dosing is dosing of B*alling liquid solutions*.

5.2 How to calculate a specific dosage?

I strongly recommend using **Aqua Calculator**
to calculate your tank's **specific dosage**.

There are even specific FAQs about how to use Aqua Calculator for this job

Interested in how to calculate manually?
Here you go….

Step 1:

How much of a chemical substance is to be added to reach a defined concentration?

Assuming a dry substance, the weight of this substance is the only thing we can measure easily.

Before starting an adaptation we need the following information:

a) ***Which*** concentrations should be raised (calicium, alkalinity and/or magnesium)
b) By how much [mg/l] should the level(s) be raised * ***Concentration deficit***
c) ***Water volume****1) that has to be adapted

*1) Overall water volume (Volume of water in tank, sump, pipings, etc)

example: Tank with 100 litre water volume
Magnesium should be raised from 1280 mg/l to 1320 mg/l

- Concentration deficit	1320 – 1280 = 40 mg/l
- Overall deficit	40mg/l x 100l /1000 = 4 g

Result: You have to add four grams of magnesium to your tank

Step 2:

It would be too easy if we could just add exactly the calculated amount (overall deficit) of "100% magnesium" right now.
Instead, we use available salts (Balling salts), which are a chemically associated and thus having not only "Mg" but also other ions. Thus we have to add more of the Balling salts than just the calculated overall deficit.

The correct amount then has to be calculatad on a stoichiometric basis (molar masses *1)). Chemical wise this is not to complex, but can't be written in a single formula. Detailed calculation is explained later.

*) Each element in our periodical system has a molar mass. Molar mass is the weight of exactly $6{,}022 \cdot 10^{23}$ parts (*Avogadro-constant, 1 mol*) of this element, based on atomic weights. Molar mass of a chemical association is calculated by adding molar masses of all single elements/ions.

Links: http://en.wikipedia.org/wiki/Molar_mass
http://en.wikipedia.org/wiki/Atomic_weight

Some Balling recipes are even a mixture of more than one Balling salt. The target is to get a formulation which is quite close to natural sea water.

$$DosingAmount = \frac{OverallDefic \times MolarMass_{chemical}}{MolarMass_{Element}}$$

DosingAmount and overalldeficit	in	[g]
MolarMasses	in	[g/mol]

Example: as above (100 litre water volume. Magnesium 1280 mg/l →1320 mg/l)

How much Balling salt $MgCl_2 \times 6H_2O$ do I have to dose?

* Calculate MolarMass of $MgCl_2 \times 6H_2O$	203.3021 g/mol
* MolarMass of Mg (only) is	24.305 g/mol
Overall deficit (as already calculated)	4.00 g

following our example: 4.00g x 203.3021g/mol / 24.305g/mol * 33.458 g

Result: We need **33.5 grams $MgCl_2 \times 6H_2O$** to raise Mg of 100 l water by 40mg/l

Knowing about these basics we should be able to calculate all needed concentrations/dosages on our own now. But this would take some some work.

5.3 Mixing liquid solutions for Ca/Alk/Mg

These are the working steps you need to do:

a) Decice about the (Balling) recipe you plan to use
(decide how man channels of a dosing pump you will need)

b) Calculation of required amounts of Balling salts vs a defined amount of water

c) Calculation of required amounts of liquid solution to adjust your tank's consumption

d) Marking labels of your liquid solutions containers

I recommend to clearly label your liquid solution containers to avoid any mistakes, with labels like this.

Adaptation of: **MAGNESIUM**
ΔMagnesium +10mg/100 Liter ≙ 21 ml
ΔMagnesium +10mg bei 600 Liter ≙ 126 ml

Content : 2000g $MgCl_2$ * 6 H_2O filled up with
RO-water to 5,0 Liter

Dosing-channel: Nr.3

I strongly recommend using **Aqua Calculator**
to calculate your tank's specific **liquid solutions**.

Also, mixing and dosing liquid solutions is covered in details in specific FAQs.

Adjusting your dosing station

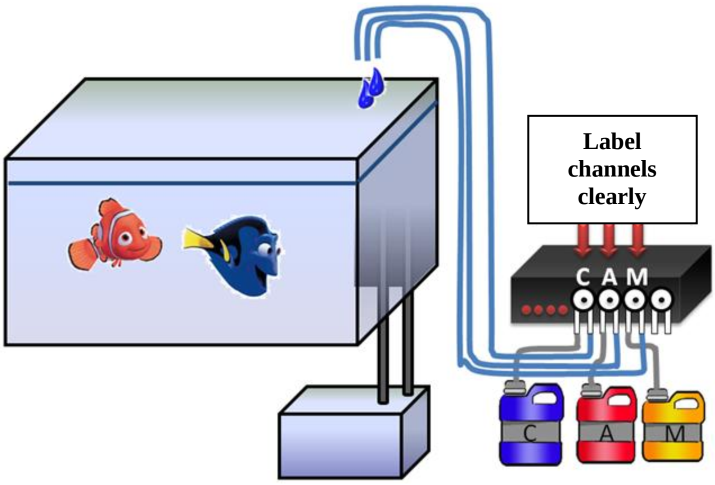
Dosing pumps can be adjusted by software to carry out fully automated dosing

The most comfortable system is a combination from ***dosing containers*** where liquid solutions are pumped out by ***persistaltic pumps***, and then added to your tank by small hoses/airline

Picture: Standard container

picture: comfortable Container System "Lena"
containers can be flipped out and removed of the station, separately, transparent, lay-on surface for dosing pump on top

Picture: Grotech dosing stations TEC-III NG expandable up to 11 channels



⚠ Most dosing pumps sold at aquatic stroes are standard/non-industrial quality peristaltic pumps. The mechanics used are not as robust. Thus these type of pumps should not be used for a 24h/day 7 days a week dosing job.

5.4 Which amounts of chemicals can be soluted in water?

Chart: Recommended and maximum solutable amounts of Balling salts

Chemical formula	Name	Recommen-dation	Max. solutability in H_2O at 20°C
$CaCl_2 * 2H_2O$	CalciumChloride-DiHydrate	800 g/L	986,5 g/L
$NaHCO_3$	NatriumHydrogencarbonate	80 g/L	96 g/L
Na_2CO_3	NatriumCarbonate	≤ 100 g/L	217 g/L
-	NaCl free salt	20g/L	25 g/L
$MgCl_2 * 6 H_2O$	MagnesiumChloride Hexahydrate	836 g/L	1670 g/L
$MgSO_4 * 7 H_2O$	MagnesiumSulfate Heptahydrate	≤ 100 g/L	710 g/L

5.5) The Balling method

H.W. Balling (Dez.2009)

The name of the Balling method is due to *Hans-Werner Balling*, who published it several years ago. His idea was to add a so-called "NaCl-free" salt mixture to make the tank's water more nature-like. Hans-Werner is a very experienced and advanced aquarist and biologist, working several years for the well-known company Tropic-Marin.

Balling ≠ Balling!

You will find tons of information about the Balling method on the internet, books, or even aquatic stores. Only some of them recommend the initial recipe suggested by Hans-Werner Balling but using the name "Balling". Recipes as well as dosing suggestions for liquid solutions differ a lot, but all of them following one target: *Raising your tank's water concentration for Ca, Alk and also Mg by an easy to use and cost effective way*.

Follwing advantages made the Balling method widely known and the best way to control your Ca, Alk and Mg concentration:

- Very accurate dosing and also able to adapt single parameters
  (not only all together)
- Can be started with nearly no needed technique, up to a fully automated solution
- Cost effective

The ***initial Balling recipe*** is adapting ***calcium & alkalinity***. Most users also apply and call also the adaptation of ***magnesium*** doing the Balling method (Adaptation of Mg was not initially suggested by H.W. Balling).

Dosing of **trace elements** in a pretty complicated and not commonly spreaded composition, together with the other chemicals for adapting Ca, Alk, Mg was also suggested by H.W. Balling. This is not described in this FAQ.

You need chemical substances that we call ***Balling salts*** in good aquatic stores, chemical stores or even drugstores. Definition of Balling salts needed * later, see recipes.

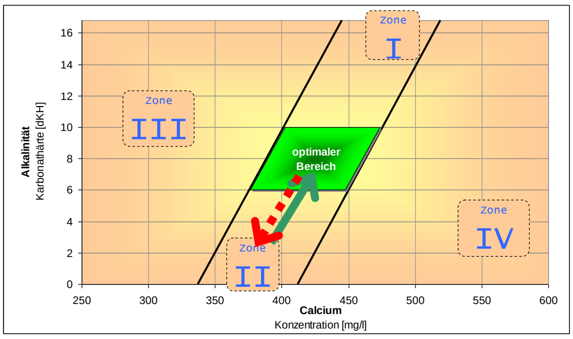
Several manufacturers sell ready packed versions of standard Balling salts under more common names like *BioCalicium*, *Magnesium Plus* etc. Most of them are nothing more than pimped up Balling salts sold more expensively. This might be a good choice for smaller tanks or for your first Balling attempts. For bigger tanks this might get too expensive.

Also, readly mixed Balling salts in purified water (liquid solutions) are sold.
You can easily and much cheaper mix yourself.

5.6) Balling recipe for a stoichiometric-balanced adaptation of *Ca-concentration* and *alkalinity*

In well-running reef tanks, calcium and alkalinity will steadily and quickly drop by coral's consumption. They will drift into Zone-II (red arrow) and have to be raised again (green arrow).

H.W. Balling's recipe suggests raising both values (by adding 2 different Balling salts) in a stoichiometricly balanced way. That means the amount of salts is calculated in a way where there are the least possible unrequired ions available in the water NOT adapting Ca and alkalinity.



Relation between Ca concentration and alkalinity will be raised always in the same way. For most tanks this is OK.

Raising Ca-concentration by corresponds with	10 mg/l
Raising Alkalinity/Carbonate hardness by	1.38 °dH

Recipe suggestion works like this: Ca-concentration is the input parameter; Alkalinity raise will follow with the above factor

- H.W. Balling's stoichiometric-balanced recipe is calculated according to this formula

$$CaCl_2 * 2H_2O + 2\ NaHCO_3 \rightarrow Ca(HCO_3)_2 + 2\ NaCl + 2\ H_2O$$

As result we got **calcium-carbonate** (what we wanted..) plus **table salt + water**

- Working principle:

Ca	Raises calcium concentration
HCO_3	Raises alkalinity/carbonate hardness
NaCl	table salt as follow-up product, (harmless, raises salinity)
H_2O	Harmless water in small amounts as follow-up product

- Needed Balling salts:

$CaCl_2 * 2H_2O$	CalciumChloride-DiHydrate	+
$NaHCO_3$	NatriumHydrogencarbonate	+
NaCl free salt *1)	Optional, not a must!!	

*1) mineral salt mixture (available eg from Tropic Marin, Grotech and Preis) to adapt your water to be like natural sea water and add also trace elements.

As described, chemical reaction will also give us some water and NaCl (table salt).
Only 70% of natural sea water and also salt water mixed with sea salt mixtures is pure NaCl.
For this reason we can add a ***NaCl-free salt*** to get the remaining 30% and thus having a ***mix closer to reality***.
Besides also adding some Ca and Mg, this mixture brings several other salts/trace elements that are also consumed in our tanks by corals.

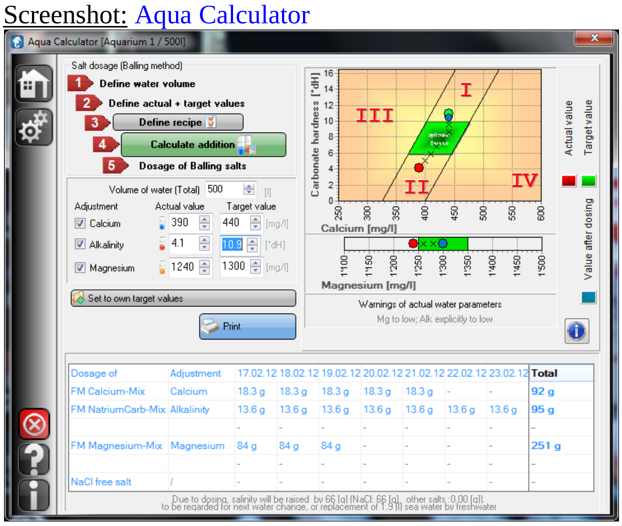
Adding Balling salts will raise your tanks salinity. This is not a big thing, but you have to regard this together with either the next water change or a seperate salinity adaptation. Most Balling-calculators and especially Aqua Calculator, tell you how much salinity is raised based on your specific dosage.

Dosing $CaCl_2 * 2H_2O$ and $NaHCO_3$ at the same time and also at the same place, might lead to precipitations. For this reason, you should either dose the salts, time wise, shifted (min 1 h) or on direct areas within your tank/sump. Best for a balanced ph, dose NatriumHydrogenCarbonate ($NaHCO_3$) in the morning and CalciumChlorid ($CaCl_2 * 2H_2O$) later/at the evening.

Rule of thumb: ***Raise of Ca-concentration*** by 10mg/l
based on stoichiometric-balanced Balling recipe

3.7g	Calcium Chloride	per 100-litre tank water per day
4.2g	NatriumHydrogencarbonate	per 100-litre tank water per day
1.2g	NaCl-free salt	per 100-litre tank water per day

Screenshot: Aqua Calculator



Consumption of Ca/alkalinity in tanks with lots of SPS can be pretty high.

For a typical consumption per week (Ca +50mg/l, alkalinity +6,9 °dH) you can roughly estimate:

water volume / Balling salt	200 Liter	500 Liter	1000 Liter
$CaCl_2$ x $2H_2O$	36.7 g	92 g	183 g
$NaHCO_3$	41.9 g	105 g	210 g
NaCl free salt mixture	12.5 g	31.2 g	62 g

5.7) Adaptation of Ca-concentration only

This is done by adding ***CalciumChlorid-DiHydrat*** ($CaCl_2 * 2H_2O$)

Optimum concentration: 400-450 mg/l

Rule of thumb: for raising Ca-concentration by 10mg/l:

CalciumChloride-DiHydrate:	3.67g / 100 litre water

CalciumChlorid-DiHydrat nicht gleichzeitig mit *Natrium(hydrogen)Carbonat* dosieren.
Risiko der Ausfällung. ?????Martin this needs looking at?????

5.8 Adaptation of alkalinity only (2 options)

This can be done by adding one of TWO (Balling) salts.
You can select, depending on whether you want to correct a low ph value.
Combing of both salts is also possible, acting like a ph stabilizer for your tank.

Optimum Level: 6.0-8.0 °dH

In case of normal ***pH-value*** (≥ 8.2) * dose ***NatriumHydrogeneCarbonate***
In case of ***low pH-value*** (< 8.2) * dose ***Natriumcarbonate***

Rule of thumb: for raising alkalinity/carbonate hardnes by 1°dH:

NatriumHydrogeneCarbonate:	3.02g / 100-litre water
NatriumCarbonate:	1.90g / 100-litre water

Don't dose *Natrium(hydrogen)Carbonate* at the same time/place with *CalciumChlorid-DiHydrat*.
Risk of precipitations!

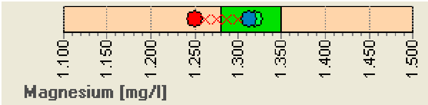
Tip: NatriumHydrogenCarbonate ($NaHCO_3$) can be converted quite easily to NatriumCarbonate (Na_2CO_3)!
NatriumhydrogenCarbonate decomposes to Natriumcarbonate
Carbondioxide (Co2) and water will escape.

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$

1. Place some $NaHCO_3$ on a baking tray
2. Heat up to 180°C-220°C and bake for one hour
   (will work also for higher temperatures and longer baking times)

Use eye protection, Na_2CO_3 is a very light-weighted powder!

5.9) Adaptation of *Mg-concentration* only (2 options)



Magnesium concentration normally drops much slower than Ca/alkalinity. Any how, you should adapt it

Optimum concentration 1280-1350 mg/l

Option-1	$MgCl_2$*6H_2O	→ Mg + Cl_2 + ….
Option-2	$MgCl_2$*6H_2O + $MgSO_4$*7H_2O	→ 2 Mg + Cl_2 + SO_4 + ….

MagnesiumChlorid Hexahydrat	$MgCl_2$ * 6 H_2O
MagnesiumSulfat Heptahydrat	$MgSo_4$ * 7 H_2O

Option 2 was the preferred way of adaptation some years ago. Due to holding the risk of piling up sulfates in your tank, it is not recommended using this option anymore.

Rule of thumb: for raising ***Mg-concentration*** by 10mg/l

Preferred option, option-1

8.4g	$MgCl_2$ x 6 H_2O	per 100-litre tank water per day

Option-2 (risk of sulfate enrichment)

7.6g	$MgCl_2$ x 6 H_2O	per 100-litre tank water per day
1.0g	$MgSo_4$ x 7 H_2O	per 100-litre tank water per day

5.10 Frequently asked questions about the Balling method

F: When should I start with the Balling method?
A: You should not start before having the tank's start-up phase finalised.
Depending on the amount and growth rate of stony corals in your tank, you might not even need to do Balling.

F: Do I really need Balling? Can't I adapt Ca, Alk, Mg also by regular water changes?
A: Modern high-quality reef salt mixtures have perfectly fitting concentrations of Ca/alkalinity/Mg. But you will always replace only part of your water, meaning that you will adapt your tank's water also only partly. The more water you are about to change, the closer you get to the values you want to have (respective the concentration your salt mixture has), but you will never reach them!
Also doing bigger water changes regularly might get very expensive and work intensive.
→ Doing water changes to adapt especially Ca/Alk is only recommended for smaller tanks AND if you don't need adapt Ca/alkalinity/Mg separately.

F: There are so many Balling recipes. Which one should I choose?
A: There is no standard answer.
I recommend either using Armin Glasers recipe from "Ratgeber der Meerwasserchemie" or Fauna Marin's "Balling Light ®" recommendation.

F: Balling Light, Balling Classic, Balling Plus, 2part, 3 part…. What's the difference?
A: Most recipes are more or less just variations of other recipes.
Some are meant to to ease the application, or also to dose trace elements together with the Ca/Alk adaptation. There are even some identical recipes using just different names.

F: Some Balling recipes will also add trace elements. Why's that?
A: H.W. Balling's intention was to get the adaptation as close as possible to natural sea water.
This means that not only the consumed Ca, Alk, Mg (3 biggest mass elements) but also several other (trace) elements are adapted. Several reefers prefer adding trace elements to get the best-possible colours for their SPS, others are fine by just adding Ca/Alk/Mg.
An advantage of tieing trace elements adaptation to the consumption/dosing of Ca/Alk/Mg is that you adapt these in the same per-cent wise concentration like Ca/Alk/Mg.

F: How can I evaluate how much salt I have to add to my tank?
A: An explanation on how these calculations are done is given in previous chapters. But this is a quite tricky work and so I recommend using my application AquaCalculator for all Balling calculations.

F: I am using ready-mixed Balling liquid solutions. How much do I need to dose?
A: There is no universal answer. Your specific dosing amount depends on the concentrations of these solutions and also your tank's specific consumption. Act according to the manufacturer's instructions or, even better: Mix your solutions by your own knowledge, then you know exactly what to dose (AquaCalculator…).

F: I want to start with Balling method but my concentrations are far off recommendations. What should I do?

Check your tanks salinity first and correctif being Off-Track

Option-A: One or more of your concentrations are too high and should be reduced.
Either you wait until your tanks animals „consume“ and thus will lower concentrations, or you replace parts oft he water by waterchanges using salt mixtures low on Ca/Alk.

Optionl-B: One or more of your concentrations are too low and should be raised
→ Add respective balling salts to raise these parameters.
- Magnesium concentration can be raised directly
- Raisung of Ca/Alk must not be done stoicometricly balanced, you can raise them independently from each other
- Don't start raising Ca if Mg is still below ≥ ~1250 mg/Liter

F: Help me, I overdosed chemicals. What should I do?

A: Calm down first! Overheated reactions are counterproductive most of the time.
In emergency cases (heavy overdosing, concentration far above optimal levels)
→ do water changes with normal "sea-salt mixtures" (not with reef/premium salts) to reduce your concentration
In all other cases: Wait until concentration is used up by your tank's inhabitants.

F: Should I buy commercially available products (BioMagnesium, KH-Plus) or just use Balling salts?

A: Philosophers stone is unfortunately not invented yet. Dosing chemicals very often alters more than 1 parameter. Products like "Ca-Plus" may also alter KH etc.
Even if product's description sounds very promising, commercial products are very often identical to normal Balling salts. They are just packed, labeled nicely and available in most aquatic stores. Obviously their price is higher than if buying standard Balling salts.

Tip: Running a smaller tank, the price premium might not bother you too much, thus also buying commercial products might be interesting to you.

F: Dosing according to H.W. Balling's stoichometric-balanced recipe, my alkalinity is constantly too low. What should I do? (same case: but my alkalinity constantly too high)

A: Your tank is consuming more (or less) alkalinity than the fixed ratio of Ca vs alkalinity within this recipe.
- In case of only small deviations, continue dosing in this way.
- For deviations that are getting bigger and bigger, you should move away from a "stoichiometrically balanced recipe", to a "consumption-orientated" recipe.
Doing regular water changes is recommended in this case.

F: Should I use NatriumHydrogenCarbonate ($NaHCO_3$) or NatriumCarbonate (Na_2CO_3)?

A: Both are fine, but NatriumHydrogenCarbonate is more available. Best would be:
If your pH-value is OK/high, it is better to use NatriumHydrogenCarbonate
If your pH-value is already too low, it is better to use NatriumCarbonate

F: What is “Ionic balance” and what do I have to regard?

A: We are using industrial-available chemicals to raise the parameters Ca, alkalinity and magnesium. Besides the desired elements (Ca, Mg, carbonate), they also contain unwanted elements (Na, Cl, SO4...). Within our tanks these elements react as chemical compounds. Besides the desired effect of raising Ca, Mg and alkalinity, the unwanted elements will remain in our tanks.

Most interesting are these Balling salts:

- $CaCl_2 * 2H_2O$
- $NaHCO_3$
- $MgCl_2 * 6H_2O$

- ➢ Ca and carbonates are consumed by corals
- ➢ Some additional “water” (H_2O) is added to the tank
- ➢ Na and Cl will remain (marked red above)

  * NaCl is “sodium chloride” also known as “table salt” * is added to the salt water

- Only a part of natural salt-water salt (70%) is NaCl. There are 30% of “other salts” in sea water
- Adding different amounts of the three different Balling salts can formulate stoichiometric “not totally balanced” chemical compounds (some formulas might not be fully balanced).

These effects are described as “ionic balance”

Some aquarists expect problems to arise by not balancing ions correctly. I personally have not had any proof with ionic balance problems as described. For me, ionic balance is one of the most overvalued symptoms within salt-water tanks.

F: Which water parameters do I have to measure? How often do I have to measure them?

A: You need to be able to measure Ca, Mg and alkalinity correctly. This means that also measuring and adapting salinity beforehand is a must, because it will directly influence these concentrations.

More detailed recommendation (how often to measure) → FAQ Balling Method

F: Why do I have to replace some salt water by fresh water, or regard this for the next water change? Also, do I really need to add NaCl-free salt?

A: As a result of chemical reactions taking place in your water by adding Balling salts, NaCl (table salt) is also evolving. This will raise your tank’s salinity. To prevent steadily raising salinity you have to “replace” this amount of NaCl.
Within natural sea water, 70% of the salinity comes by NaCl.
Add 30% of NaCl-free salt (which is basically “all other salts” being present in natural sea water and thus also several trace elements) and do your Balling adaptation much more “like nature”.

F: Can‘t I dose all chemicals together with only one dosing pump?

A: No, you will get precipitations.

F: Why should I dose Balling-salts/liquid solutions for rasing Ca and alkalinity at different times?

A: Simutaneosuly dosing $CaCl_2 * 2H_2O$ and $NaHCO_3$ at the same psoition of your tank will lead to precipitations. Dose them either with a time difference (min 1 h), or within different positions of your tank.

F: Balling method or calcium reactor? Which one is better?

A: First of all, this is a matter of your own experience, but also a question of your budget.

My personal opinion: *I prefer the Balling method because of being able to adapt all parameters accurately, also at big comsumptions and separate from each other.*
For bigger tanks, however, calcium reactors might be the better option.

Major adavantages of Balling method:

+ Ca, alkalinity and Mg can be adapted independent from each other
+ Cheap if dosing manually (needs just an accurate set of scales)
+ Price effective especially for small-medium tanks
+ Possibility for automatisation (increases purchase price of course)
  (multi-channel dosing pump, dosing liquid solutions from containers)
+ No adding of CO_2 and thus having a higher and more stable pH than for calcium reactors

Disadvantages of Balling method:

- Needs some effort for getting the required know how
- Work/effort for weighing in of salts and mixing/filling liquid solutions
- Maintenance of dosing pumps

Major adavantages of a calcium reactor:

+ Cheaper than Balling for big tanks
+ Possibility for automatisation (CO_2-Controller plus peristaltic pump)
+ Running also for a longer period of time.

Disadvantages of a calcium reactor:

- Alignment to tank's consumption is pretty complicated
- pH value of your tank drops by amount of CO_2 brought into your tank
- Need to dose Balling salts if values are off track
- Can't adjust Ca vs alkalinity
  Mg-concentration adjustable only by adding Mg-granulate
- Several reactors need maintenance to hoses because of getting calcium-carbonate
- Adjustment of pH-sensor (interval: 8 weeks)
- Replacement of empty CO_2-containers

F: Where can I buy Balling salts?

A: In good aquatic stores, drug stores and chemical stores.

F: What are the minimum requirements for Balling?

A: a) High-quality test kits for Ca, Mg und Alkalinity.
b) Tool to measure salt concentration accurately
c) Precise scales (the smaller the amount you have to dose, the more accurate these must be)
d) Dosing instructions and know how, or better Balling calculation software (eg AquaCalculator)

5.11 A recommended recipe for liquid dosage of *Ca/Alk/Mg*

This is the recipe that Armin Glaser is recommending in his *Ratgeber Meerwasserchemie*
For a usage-oriented adaptation of Ca, Alk and Mg

Liquid solutions			Dosage	
Container	**Content/Balling salt**	**Cont. Volume**	**Dosing of**	**Raises**
C Calcium	**800 gramm** $CaCl_2$ * $2H_2O$ (CalciumChloride – Dihydrate) +	Fill with water to get 1 litre	4.59 ml	**Calcium** by +Δ10mg per 100 liter
A Alkalinity	**80 gramm** $NaHCO_3$ (NatriumHydrogencarbonaet)	Fill with water to get 1 litre	37.75 ml	**Alkalinity** by +Δ1.0 °dH per 100 litre
F (NaCl) Free salt	**20 gramm** Na-Cl free salt mixture	Fill with water to get 1 litre	Dosage depending from containers C, A (see below)	(to get a salt water nature like mixture 70% NaCl and 30% other salts)
M Magnesium	**836 gramm** $MgCl_2$ * $6\ H_2O$ (MagnesiumChloride Hexahydrate)	Fill with water to get 1 litre	10 ml	**Magnesium** by +Δ10mg per 100 litre

For an easy calculation of liquid solution of container F calculate as following:

Liquid solution F [ml] = (Liquid solution C [ml] : 125 + Liquid solution A [ml] : 1425) x 662.5

Hint: AquaCalculator calculates dosage for Container F more accurately based on stoichiometric calclations, which are too complex to calculate manually.

Optionally, you can skip adding NaCl-free salt. Doing so will not make your mixture more like “natural sea water”. In this case regular water changes with ~5-10% of water volume each week are recommended.

- Container sizes as above might be too small for bigger tanks, because of running out pretty fast

  Q: How long does a container last? (=container reach)?

  eg: Tank is consuming 50 mg/litre calcium within a week and having 300-litre water volume.
  Dosage as above only raises calcium by 10mg/litre and also only for 100 litre of water.

  We need: 50[mg/L]/10 [mg/L] x 300[L]/100[L] * 7 Tage = 5 x 3 x 7= 105 “times”
  the above dosage of 4.59 ml in one week,
  *: 105 x 4.59 ml = 481.6ml ≙ 0.48 litre

  One liter container: container reach = 1 litre / 0.48 litre = 2.08
  Result: A one-liter container must be refilled each 2 weeks.

  Continue estimating your other container sizes in the same way.

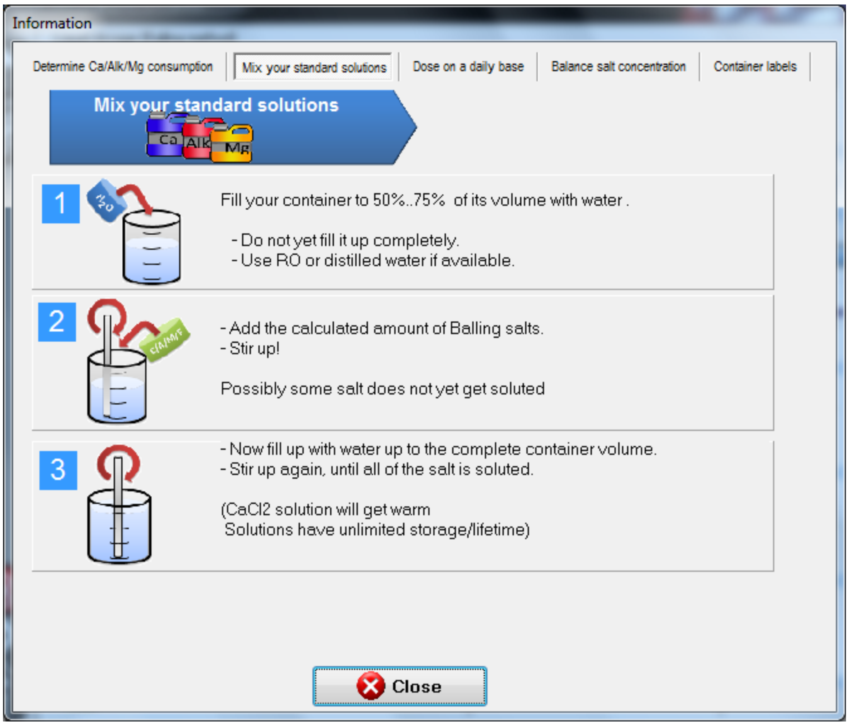
- Hint: Dosage of liquid solutions A and C must be done with 15 minutes time inbetween.

- Consumption of containers C, A and F is clearly higher than of container M.
  This should help you selecting your containers A, C, F, M sizes.

Even if calculations are pretty, I recommend letting AquaCalculator do this job for you.

It is abolutely important to know how to correctly mix your liquid solutions.

Screenshot AquaCalculator: Mixing your liquid solutions correctly



This would be wrong!

- Fill your container with water up to the respective volume
- Add Balling salts and mix

→ you will get more than the desired container size with liquid solution, thus the amount of solution to be dosed will be wrong (less concentrated)

5.12 How do calcium reactors work?

Calcium reactors maintain reef tanks calcifying organisms like stony corals, coralline algae and other.

A filling within the reactor chamber will be soluted by carbon dioxide (CO_2) and is then dropped into your tank steadily. The filling is natural CaCO3 mMedia or industrial available calcium-carbonates.

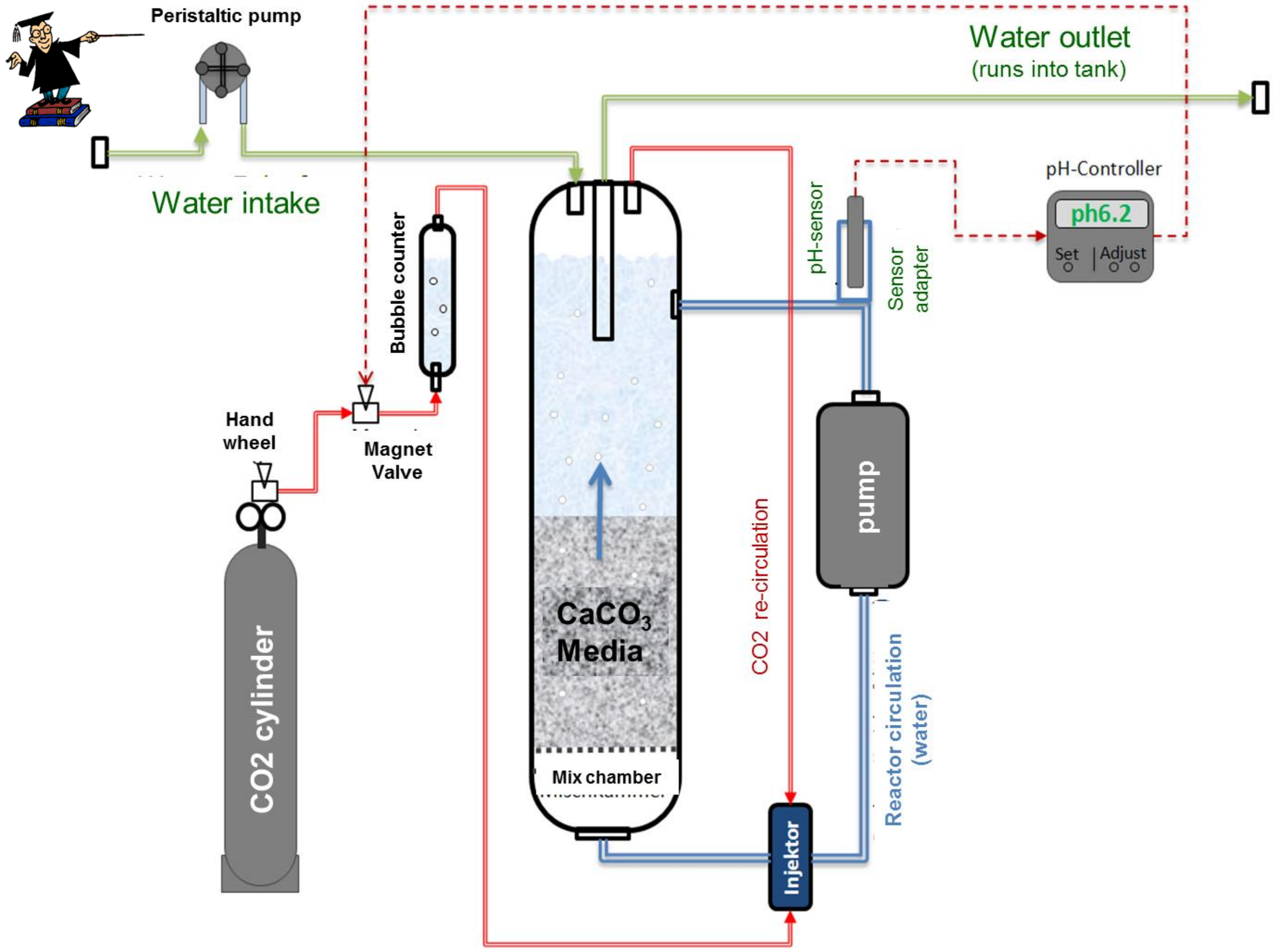
Reaction principle:

$$CaCO3 \rightarrow Ca^{++} + CO_3^{--} \rightarrow Ca^{++} + 2\ HCO_3^{-}$$

HCO_3/HydrogenCarbonate is raising alkalinity (waters buffering capacity) and Ca is raising your calcium concentration.

Adding also special Mg-media, you can supply a higher Mg concentration than the one which is available in natural/synthetic CaCO3 media.

Functioning principle of a fully equipped calcium reactor:



- CaCo₃ media within the reactors main chamber is steadily flown through by salt water. Circulation is done by the reactor's own pump (Blue circulatory)
- CaCo3 is solutued only within acid milieu. An optimal pH is 6,2. (pH too high → bad/no solutability)
  For this reason, CO_2 is added within the reactor's injector (Red circulatory).
  CO_2 streams through the reactor's main chamber bottom up (you should see small gas bubbles). Modern, efficient, reactors also gather gaseous CO_2 in the upper reactor chamber and stream it back to the injector. Most important for the pH value within the reactor is the amount of CO_2 has to be added steadily. For better visibility of this transparent gas, it has to pass a so-called bubble-counter (small water column) first.
  pH-control: To prevent the reactor from getting too low on pH (which is inefficient for the reactor and also bad for your tank's animals) CO_2-supply can be stopped temporarly. pH value is measured constantly within the reactor (not within the tank). If getting too low, a magnet valve stops further CO2 from flowing in. Once the pH is above 6.2, CO_2 flow is started again,
- Water within the reactor now has a much higher CaCO3 concentration than normal sea water. The only thing we have to do is remove a certain part of this water and let it drop into our tank.
  For that reason we will press some of the tank's water through the reactor to do this job. The same amount that is flowing in leaves the reactor as Ca-carbonised water at the end.
  * amount water pushed in = amount of Ca-carbonised water escaping the reactor
  (Green circulatory)

Frequently asked questions about calcium reactors

F: Which reactor should I buy?

A: There is plenty of choice. Unfortunately, several reactors with bad efficiency are sold.

This should help you selecting a good Ca reactor:
- Good quality of plastic parts (not too thin, good mechanical stability)
- Reactor chamber should be transparent
  (to see if $CaCO_3$ media is used up and also to see streaming CO_2 bubbles)
- Reactors pump should have an accurate flow rate at a low power consumption
  (remember, it is running 24h/7 days a week) and should be inaudible
- Adaptation for a pH-sensor available and fitting to your ph sensor?
- Does the reactor have an efficient CO_2 injector/usage?
  Does the reactor own a CO_2 gas recirculation?
- Availability of a valve to remove reactor's water
- Main reactor chamber can be opened easily to change $CaCo_3$ media and for maintenance reasons
- Size

Very good reactors, even if a bit expensive: ***Schuran's JetStream*** series.

F: How to get water to and from the Ca reactor?

A: Every reactor has a thin hose as water intake. The cheapest solution is to have a T-adapter somewhere in your tank's water circulation where you get some water "under pressure".
This will press water into the reactor chamber. Adding a small valve/throttle you can even slightly adjust the amount of water flowing through the reactor.
Once the reactor is filled with water (after start-up) the same amount of water being pressed in is flowing out of the reactor as "Ca carbonised water" .

Due to fact this generates no cost, this is recommended very often.
But you might see that this is not the perfect solution. → see next question

F: Do I really need a dosing pump for my Ca reactor? Which one should I buy?

A: Not at all; some reactors run without one.
Having a dosing pump as a "feed" for the reactor has two major advantages:
- More constant amount of water running to and from the reactor and thus
  Ca/Alk added to your tank more constantly
  (water intake and outlet hoses can get stuck by suspended sediments, algae and especially by assembling calcium/carbonates)
- Amount of water running through your reactor is adjustable
  (if using an automatic timer for your dosing pump or adjustable dosing pumps)

Because of the small amount of water needed, peristaltic pumps are used.
Take care that you buy only a pump that is thought for 24h/7day usage.
Normal dosing pumps will wear out much too fast being used as feeds for Ca reactors.

F: Do I really need a pH regulation for my Ca reactor?

A: Not at all, but having a pH-controller makes things much easier and sustainable.

- Less CO_2 consumption
  - → Less maintenance work changing CO_2-cylinders
  - → Less costs for CO_2
- Less stress for your tank's animals by eventually too low pH without pH-control
- Better permanence of Ca/carbonate content (and Mg) in Ca-carbonised water, also if CO_2 cylinder's pressure is getting lower.

⚠ Adding a pH-controller will generatee additional costs (controller, magnet valve, pH-sensor) and also needs maintenance for calibrating the sensor (recommended each 6-12 weeks).

F: How do I adjust my Ca reactor's ph controller?

A: Control and adjust only the reactor's main chamber pH-value!
By no means you should control/lower the ph-level of your tanks overall water circuit (like you might do in non salt water aquariums).
Your reactor has to have an adaption for a pH-sensor within the reactor's internal water circulation (squeezing valve for pH sensor).

The target is to adjust pH in a way that it:

- can dissolve $CaCO_3$ media perfectly
  but also
- use as less CO_2 as possible
  (because this would also reduce tank's pH),

→ Adjust your controller to get and hold ***pH 6.2 in your reactor*** (see display pH-controller).

⚠ pH-sensors might be covered by Ca-carbonised water, sediments…
To avoid incorrect measurements (and thus incorrect pH control)
you should clean and re-calibrate your pH-sensor each 6-12 weeks.

F: Why do I need a bubble counter?

A: It visualizes the amount and speed of CO_2 gas entering the reactor and also indicates an empty CO2 cylinder (no more bubbles)

F: Which $CaCO_3$ media should I use?

A: I recommend using media with small or no PO_4 secretion, eg Rowalith.
It is also possible to add some additonal Mg media in case your tank is consuming more Mg.

Before adding new media, you should flush it with water several times to remove odd phosphates.

F: How can I adjust my reactor?

A: The target is to have a constant and correct concentration of Ca/Mg and alkalinity in your tank.

Option-1: If your tank's values are too low
→ Increase amount of Ca-carbonised water coming from the reactor

If your tank's values are too high
→ Throttle your Ca reactor's Ca-carbonised water flwoing in to your tank

Be patient, this will take some time …

Option-2: Measure concentration and amount of water of your reactor's Ca-carbonised water outlet (it should have very high concentrations of Ca, Mg and alkalinity). Knowing your tank's actual water parameters, you can calculate your need for Ca/Mg/alkalinity and then adjust the amount of Ca-carbonised water coming from your reactor (increase or throttle).

Regulating variables for more/less Ca, Alk, Mg:
a) Amount of water running in and out of the reactor (flow rate, pulsing)
b) CO_2 concentration/pH-value within reactor (has limited influence)

F: Do I have to adjust my reactor?

A: In case your tank's consumption stays the same and the reactor has no problems Ca reactors need only little maintenance. Even the amount of remaing $CaCO_3$ has only limited influence.

If your tank's consumption is changing (eg more stony corals) you have to re-adjust your Ca reactor.

F: Can I adjust relation of Ca, vs alkalinity, vs Mg added by my calcium reactor?

A: In general, no.
By tendency alkalinity vs Ca is a bit high for non pH-controlled reactors and can be optimised by adding a pH control unit. Using different $CaCO_3$ and Mg media is also an option at least for slightly adjusting Ca vs alkalinity vs Mg.

F: How can I achieve a higher Mg concentration?

A: - By using an additional Mg-media within the reactor chamber besides normal $CaCO_3$.
(eg Fauna Marin – UltraMag, Grotech - Magnesium Pro, ZEOmag etc)
- Sometimes also by just changing to another $CaCO_3$ media.
(Hint: also CaCo3 media has a certain Mg content)

Rule of thumb for elevated mg Level: 90% $CaCO_3$-media & 10% Mg-media.

F: I've refilled my reactor, but Ca, Alk, Mg levels are dropping. Why?

A: New reactor media has to be cauterized first. This can take from hours to days.

Setting up your calcium reactor

Depending on how far your reactor is equipped, adjustment is more or less easy.
Reactors with a minium of installed technique are running well together with a lot of tanks worldwide (w/o CO_2-controller, w/o dosing pump). Other aquarists note that adjustment is not as easy and that there is a ceratin misalignment within its use, in case of not controlling reactor's pH value and not having a dosing pump. Decide on your own what's your preferred Ca reactor equipment.

CO2-Controller (ph-regulation)	Dosing pump	Accuracy of adjustment	Stability within use	Effort for maintenance	Purchase cost
√	√	Very high	Very high	Very low	High
√	-	Very High	Average	Average	Averagel
-	√	High	High	Very low	Average
-	-	Average	Low – average	Average	Low

A) Calcium reactor equipped with pH-controller & dosing pump

- Adjustment of amount of Ca-carbonised water is done by
  water volume brought into the reactor in a controlled way

Regulated variable-1: Rate of flow of reactor's dosing pump
(needs a controllable dosing pump)
Regulated variable-2: Dosing interval, dosing duration of reactor's dosing pump
(Adjusted by automatic timer, aquarium computer etc)

- pH-value in reactor chamber is controlled by pH controller.
  Rate of CO_2 has to be adjusted only roughly (~100 bubbles/minute)

Maintenance:	- Calibrate pH-sensor	(each 6–12 weeks)
	- Maintenance/spare parts for dosing pump	(each 1–2 years)

B) Calcium reactor equipped with pH-controller (w/o dosing pump)

- Adjustment of amount of Ca-carbonised water is done by
  water volume brought into the reactor in a controlled way

Regulated variable: Rate of flow through reactor
- Type and size of T-connector before reactor intake;
  Flow rate and pressure of water at this position
- Throttling-valve/ball-valve at reactor's water outlet

- pH-value in reactor chamber is controlled by pH controller.
  Rate of CO_2 has to be adjusted only roughly (~100 bubbles/minute)

This setup is suboptimal because intake and outlet hoses can get glogged up by sediments, algae and especially by Ca-carbonised water of reactor itself. Most reactors need a "milking" of the hoses to keep them clear.

Maintenance:	- Calibrate pH-sensor	(each 6 -12 weeks)
	- Milking of hoses	(~ 1 x week)

C) Calcium reactor equipped dosing pump (w/o pH-controller)

- ***Manually adjusted amount of CO_2 (bubble counter)***
  Regulated variable: Amount of CO2 bubbles per minute

- Adjustment of amount of Ca-carbonised water is done by ***water volume brought into the reactor in a controlled way***
  Regulated variable-1: Rate of flow of reactor's dosing pump
  (needs a controllable dosing pump)
  Regulated variable-2: Dosing interval, dosing duration of reactor's dosing pump
  (Adjusted by automatic timer, aquarium computer etc)

Adjusting your reactor with this set up is more difficult. You need to adjust the amount of CO_2 bubbles with the CO_2 cylinder's hand valve, which takes some time. Also, the amount of CO2 and thus pH within the reactor is changing from time to time (CO_2 bottle getting more and more empty, altering pressure within the reactor).

If dosing "too much" CO_2, pH value dropping unnecessarily
If dosing "too little" CO_2, the reactor might not dissolve enough Ca/CO3.

Maintenance: - Check and adjust CO_2-Bubble counter (~ 1 x week)
- Maintenance/spare parts for dosing pump (each 1 – 2 years)

D) Calcium reactor w/o dosing pump, w/o pH-controller

- ***Manually adjusted amount of CO_2 (bubble counter)***
  Regulated variable: Amount of CO2 bubbles per minute
- Adjustment of amount of Ca-carbonised water is done by ***water volume brought into the reactor in a controlled way***

Regulated variable: Rate of flow through reactor
- Type and size of T-connector before reactor intake; Flow rate and pressure of water at this position
- Throttling-valve/ball-valve at reactor's water outlet

This set up is suboptimal because intake and outlet hoses can get glogged up by sediments, algae and especially by Ca-carbonised water of reactor itself. Most reactors need a "milking" of the hoses to keep them clear.

Adjusting your reactor with this set up is more difficult. You need to adjust he amount of CO_2 bubbles with the CO_2 cylinders hand valve, which takes some time. Also amount of CO2 and thus pH within the reactor is changing from time to time (CO_2 bottle getting more and more empty, altering pressure within the reactor).

If dosing "too much" CO_2, pH value dropping unnecessarily
If dosing "too little" CO_2, the reactor might not dissolve enough Ca/CO3.

Maintenance: - Check and adjust CO_2-Bubble counter (~ 1 x week)
- Milking of hoses

5.13 Kalkwasser/CalciumHydroxide

You can mix kalkwasser by adding ***Calciumhydroxid*** ($Ca(OH)_2$) to fresh water *1) by far beyond of its normal maximum solubility.
Due to being highly overdosed, you need to stir up the kalkwasser solution steadily.
Calciumhydroxide is availabale in aquatic stores or chemical supplies.
Eg Aqua Medic - ***Kalkwasserpowder***.

*1) best if RO/purified water is used

Effects:

- Calciumhydroxide raises calcium concentration, alkalinity and pH-value

- Hint: Dosing kalkwasser for a longer time can precipitate phosphates (ticking timebomb). For that reason, some experts don't recommend it anymore.

- Can also be used for a temporary raise of pH-value, but pH drops pretty fast again. If you plan to keep ph high for several days, you need to dose it several times a day.

Rule of thumb:

26g $Ca(OH)_2$ per 100 litre water volume → pH raise by 0.1

example.: water volume: 500 litre; pH-raise by 0.2 pH targeted

→ Dosage = 26g x 500L/100L x 0,2/0.1= 260g $Ca(OH)_2$

- Weigh out calciumhydroxide and add to the water at a position with good current flow (best within your sump, not on sensitive animals/corals).

⚠ Adding lots of calciumhydroxide can lead to precipitations and assembly of Ca at your tank's equipment (flow pumps, overflows, etc)

PART 6 –Filters & methods to reduce nutrients (nitrates, phosphates)

6.1) Advantages and risks of reducing your tank's nutrients

Advantages (reducing nutrients)

Nitrate and phosphate enter our tanks by feeding, excrement and also in form of unwanted contents of chemicals, salt mixtures, ca reactor media, etc.

On the oher hand, nutrients are either removed, absorbed or converted from your tank's circuit:

- skimmers, algae filters, DSB, etc
- Absorbers (eg phosphate absorber)
- Biological and bacterial processes

As long as concentrations are stable and do not become elevated where animals are affected negatively, this is OK. Nitrate concentration of 20-50mg/l and Phosphate 0.2 – 1.0 mg/l have been acceptable concentrations some years ago.

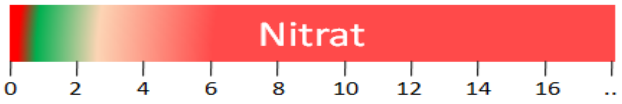
In the meantime, technique, products and know-how has heavily improved. Water parameters as in natural sea water can be achieved quite easily. Besides the required adaptation of Ca, Alk and Mg (see last chapter) ***targeted reduction of nutrients is also of major interest***.

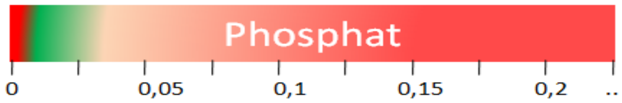
Now it is not only possible to care for sensitive animals like SPS, but also achieve good growth rates and attractive colours.

Risks (of reducing nutrients)

Targeting "low-nutrient conditions" unfortunately holds the risk of ending up without any nutrients. This leads to deficiency symptoms, which can end in coral dying very quickly.

The optimum range for reef tanks with sensible stony corals (***low on nutrients, green area)*** is pretty narrow. The borderline to ***lack of nutrients*** (0 mg/l Nitrates and /or 0mg/l Phosphates) can happen pretty fast and is sometimes recognised too late.





Corals can and will also adapt to higher nutrient levels.
You should avoid changing the nutrient level for the animals too fast

a) corals coming from low-nutrient tanks
→ can generate problems if put into high-nutrient tanks
b) corals coming from tanks with elevated nutrient levels
→ can generate problems if put into low-nutrient tanks

In case your corals suffer from lack of nutrients, they need seperate feeding.

- AminoAcids	(Ultra Amin /Ultra Min S, Aminoacid concentrates…)
- Powdered food mixtures	(CyclopEeze, Ultramin F, …)
- etc.	

There is also another risk, which is unbalanced levels of nitrates vs phosphates. This can also lead to degeneration of corals and should be avoided.

Redfield-relation: N_3 versus PO_4-concentration should be ~10:1.
For most tanks this is automatically taking place and thus OK.

<u>Adjusting unabalanced levels of nitrates vs phosphates</u>

<u>Case-A:</u> Nitrates OK/too many phosphates
→ Use phosphate absorber

<u>Case-B:</u> phosphates OK/too many nitrates (rare)
→ Adding of phosphates artificially

6.2 Wet-dry filters, bio balls, mechanical filters – just a relic from former times?

These were state of the art in saltwater tanks only a few years ago, but things have changed and improved. The idea of these type of mechanical filters is to generate additional aerobic settling area for bacteria to convert toxic ammonia → nitrites → nitrates. Unfortunately the process ends here (generating nitrates) – and having too high nutrients/nitrate concentrations within our tanks is not what we want.

Modern reef tanks do not need any filtering mats, filtering sponges etc. If you need to have them for special/emergency reasons, you should clean them often with saltwater to avoid generating unwanted nitrates.

In general, you shoud avoid any mechanical filters within reef tanks.

In the next chapters you learn about several improved methods that will help you get your tank "crystal clear" and without many nutrients.

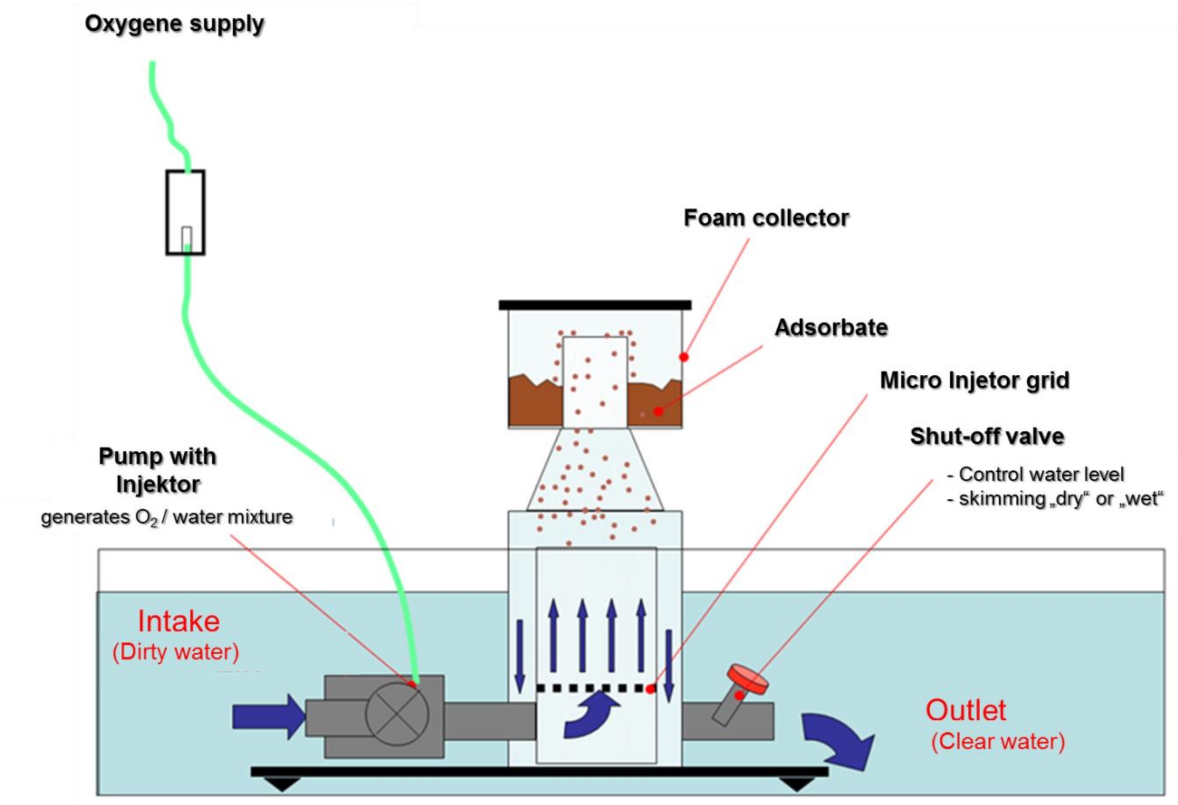
6.3 Skimmers (protein skimmers)

Skimmers are a basic element of nearly every saltwater tank.

Advantages of using a skimmer:

- ☑ Particles/substances/toxins are removed immediately from the tank's water circuit
- ☑ Water is strongly enriched with oxygen

Different to skimmers, mechancial filters just "keep back" particles, excrement, etc. They assemble them over a certain time and still pollute your water before they are finally removed.



Working principle of skimmers: Starting point of each skimmer is forming a huge number of bubbles from air plus tank's water. Nearly all modern skimmers have a ***pump with an air-injector*** doing that job. Water used for forming the bubbles can contain inpurities, toxins, particles etc. (***Intake with "dirty" water***), which attaches directly to the air bubbles, forming a more or less liquid and "dirty foam". Within the skimmer's reactor tube, air bubbles are then wandering upside down. Efficient skimmers use a micro injector grid to canalise the chaotic stream of air bubbles even better. Bubbles coming again and again from the bottom of the skimmer are pressing the other bubbles towards the upper end of the skimmer. Superfluous water is rinsing downwards by gravity. Dirty foam is then being pushed over the edge of the ***foam collector***, where it assembles in the **foam pot/skimmer cup.** Here bubbles are bursting, leaving a dirty liquid. Efficient skimmers allow the user to adjust the height of the water column in the main chamber. The higher the water column, the more liquid is generated. Skimmer shown for this reason uses an adjustable ***shut-off valve***

Skimmers are skimming:

- undissolved surface-active and partially also not surface-active particles
- substances oxidised and soluted in water

Criteria for selection of an effective skimmer:

- Construction and size must fit systems requirements
  several systems available. Choose between a sump or hang-on types

- Skimmer strong enough for tank size/amount of fish
  positive: High amount of air bubbles produced, bubbles as small as possible

- Low power consumption together with high amount of air bubbles
  skimmers are running 24h/day! More expensive models can pay off fast.

- Quiet, no vibrations

- Foam pot should be easy to remove and easy to clean
  Even better: adsorbate can be removed by an extra valve without removing the foam pot

- Good adjustability of adsorbate (liquid or dry)

- No bubbles within water running out of the outlet

- Quality and sustainability of plastic parts and pump

6.4 The "Berlin system"

This is a starting point for all following featured systems for reducing nutrients in your reef tank. Biological filtering is done exclusively by ***live rock***. Coming by high porosity within the stones, already packed with ***millions of useful bacteria***, denitrification is taking place. Different types of bacteria convert ammonia→nitrites→nitrates (later also to escaping nitrogen) and also phosphates. Together with a skimmer, particles and even some toxins are removed from your tank.

Good quality of live rock is decisive:

- The more space for settlement and the more living bacteria stones have, the better reduction of nutrients is working.
- Good quality stones are light weighted and porous
- Best is to get your live rock on the day when it is imported by your dealer (before it might bum around in absence of light and bad current flow situations)
- Good live rock has a healthy appearance

To save some money you can use partially non-live rock. But it is important here to use material from reefs which are very porous. Doing this, the start-up phase of your tank (establishment of bacterial population) will take longer.

What do you need for running a "Berlin system"?

- Top quality live rock
- Skimmer
- No mechanical filters

Running a Berlin system, you can also use in parallel:

- Activated carbon or ozone for filtering out or oxidizing harmful bacteria, toxins and pathogenic germs.
- Your preferred method to supply your tank with Ca, Alk, Mg (eg Balling method, calcium reactors, etc.) and eventually trace elements because these are partially filtered out by your skimmer

6.5 Jaubert System

Target is an improved reduction of nitrates and also phosphates.
The Jaubert System (acc. Prof. Jean Jaubert University Nizza/Monaco) is not very widely spread and just mentioned for completeness. It has a thicker layer of sand and only limited reduction of phosphates.

Functioning principle: A thick layer (>10cm) of a specially constructed sand layer leads to de-nitrification in its anaerobic zones.

Foto: Sabine Mülder

Construction of sand layer (described bottom up):

- Bottom glass plate should have a valve for withdrawal of water
- sheets of plastic that can be streamed through (Plenum)
  (sand-free area with water low on oxygen, 2-3 cm high)
- net with small holes, preventing sand from entering the plenum
  (use non-rotting material!)
- Thick layer of crude coral sand with yet another net in the middle to prevent animals from digging up too much (anaerobic zone, thickness ≥ 10cm, grain size 3.5 mm)
- You should not use too much of the sand area to place your live rock for better de-nitrification

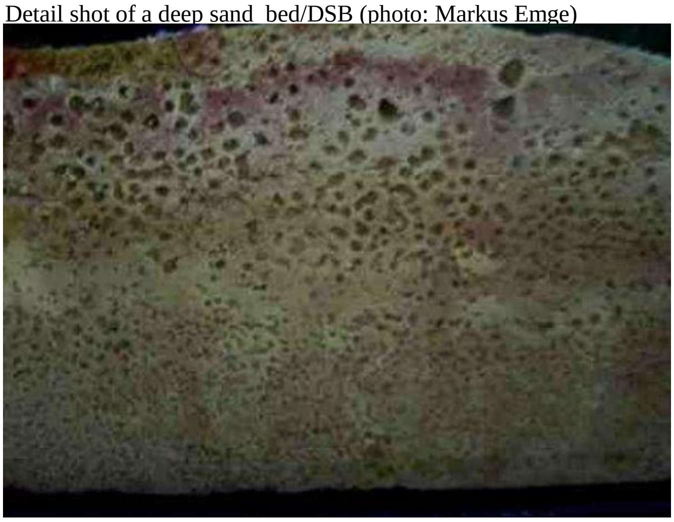
Jaubert systems can run even without skimmers. Take care that enough oxygen can enter your tank.

6.6 Sandbed filters (DSB)

Target: - Improved reduction of nutrients nitrate and phosphate
- Creation of optimal conditions for plankton and small critters
(additional source of food for your animals and also LPS corals)
- A smaller amount of calciumcarbonate is added automatically
(partial adaptation only)

Core of each sand bed filter (**DSB** = **D**eep **S**and **B**ed) is a ***sand layer being 8-15cm thick*** from a mixture of ***very fine white coral or aragonite sand***. Very small granular size especially in bottom zone is generating an optimal area for bacteria and small critters. Nitrate is converted to N3 gas, which escapes the tank especially in the bottom, anerobous zone. Generating good conditions for heterotroph bacteria phosphate is digested and partially converted to biomass, which is removed by the skimmer.

Detail shot of a deep sand bed/DSB (photo: Markus Emge)



What do I need to run a DSB / sand bed filter?

- ***Special sand mixture*** (very fine at the bottom, normal sand at the top)
  incl. denitrifiying bacteria cultures and population of small critters

- Good ***current flow*** (best would be an alternating current, 30-40 x tank volumnia)

- ***Skimmer***

How to set up a DSB (from bottom up)

1.) Form a 6cm layer from **very fine white aragonite sand** (eg Acro Tropic Aragonitsand)
Clean sand with existing saltwater before inserting.

2.) Place a 2-4cm thick layer of ***fine live sand*** to add **bacteria and small critters**
(eg CaribSea AragAlive or Ecoystems Livesand, particle size 0.5 – 1.7mm)

Gently mix part of the live sand with aragonite sand with your fingers.

3.) Form the top layer by more crude ***"real live sand".***
(eg Ecoystems Livesand, granular size 1.0 – 3.5mm)

It is very important to have a ***slight current flow at the top layer.*** Current should steadily clean the top grains, but not totally whirl through or even blow away the sand.

A DSB needs a start-up phase before reducing nutrients in an effcient way. The more real live sand is used the faster the bacteria and critter population will emerge

- ca. 2-6 weeks for full population of bacteria
- up to 12 weeks for small critter to emerge

In most cases, reduction of nitrates starts before reduction of phosphate.

Especially in the DSB's start-up phase, but also later, you should ***avoid animals trenching your sand too heavily and also eating your DSB critters***.
(digging gobies, digging starfish, sanddollars and spotted mandarin fish are not ideal in DSB tanks)

The inner layer of a DSB should be in very slight but steady movement. This comes automatically by bristle worms, small seastars, snails etc digging themselves small caverns.

Running a DSB you should avoid "cleaning your sand" with mull bells or similar.

Risks of using a sand bed filter (DSB)

1.) Rarely DSB users report dying of fish.

High population depth of bacteria and crittera use up lots of oxygen. Especially at night where no photosynthesis can take place, the oxygen supply must be secured. If not, bacteria/critters will use up all oxygen available and fish can suffocate.
A ***powerful skimmer running at minimum all night long*** is a must wthin DSB tanks.

2.) Providing a very efficient reduction of nutrients, there is a chance that, even if plankton is provided by the DSB (small critters), corals can suffer from too little feeding.

In case of any deficiency symptoms of corals, you should provide additional coral food.
(Amino acid like AutraAmino, *UltraMin S/Aminoacid concentrate*, or powder food like *CyclopEeze*, etc.)

3.) In some cases, DSB reduce nitrates very well, but PO_4 levels are still high. This might not be only a DSB problem but can also be caused by PO_4 enrichment within your reef. Due to being suboptimal for your corals, you should avoid this by either

→ using PO_4 absorbers
→ stronger skimming

Frequently asked Questions about sand bed filters/DSB

F: Doesn't a skimmer reduce my DSB source of food, detritus etc?
A: No. Even with skimming a DSB will have plenty of food available.

F: My DSB is reducing phosphates less than nitrates. What should I do?
A: This is not untypical for DSBs. You can correct by stronger skimming and/or using PO_4 adsorbers.

F: Which nutrient levels will I get with a DSB?
A: Stabile, eingelaufene DSB-Systemen liegen meist bei: ***IN GERMAN***

- Nitrate 0.1 .. 5 mg/l
- Phosphate 0.05 .. 0.1 mg/l

F: When is the best starting point for a DSB?
A: In general: As early as possible to allow critter to reproduce without the presence of fish who can decimate a fresh population pretty fast.
Anyway, the start-up phase of your tank should be already over before adding a new DSBs top layer of live sand.

F: The very fine sand is dulling my water. What can I improve?
A: - Add live stones/reef structure before sand
- Use a PVC-tube to let the sand carefully glide through it to the ground.
- Switch of flow pumps when bringing in the sand.

F: Detritus is assembling on my gravel . What can I do?
A: You have to optimise your flow conditions. If you don't, the DSB cannot work.

F: There are collections of detritus within my middle layer of DSB/sand. What can I do?
A: Most likely you used sand with a granular size that was too big.
→ Replace sand. Use smaller granular size.
I do not recommend changing more than one third of sand's volume at one time.

F: Within my DSB/sand there are black, fouly smelling areas. What should I do?
A: Exploitation of detritus by critter is not working well enough.
Possible reasons:
- Not enough critters within your DSB (poor quality real live sand?)
- DSB is stressed too much
(maybe you have too many fish in your tank)
- Too many digging animals within your DSB layers
(digging gobies, digging sea stars, sanddollars) etc.)

Remedy:
- Remove black, fouly sand by sucking up with water
- Reduce stress by too many/big fish
- Add fresh lining of sand to stimulate critter population

F: Do I have to refill sand?
A: Yes. The very fine sand of the bottom layer has to be refilled each 1½ .. 2 years in normal cases. This is required because the sand is from $CaCO_3$ and soluted slowly within the acid milieu within the DSB. This also has the (positive) effect that you might not even need Balling method, calcium reactor etc. (depending on your tank's consumption).

F: I want to remove my old sand. How should I do that?
A: By no means you should remove all sand in one go. Remove old sand in amounts not bigger than one third of the total amount to avoid crashing your bacteria poupluation!

6.7 Algae and mud filters (eg miracle mud)

Targets:
- Improved reduction of nutrients nitrate and phosphate
- Creation of optimal conditions for plankton/small critter (additonal source of food for your animals and also LPS corals)
- Smaller amounts of CalciumCarbonates (within algae filters mud) is added to the tank
- Algae parts can get flushed to the tank and taken up as food

Functioning principle:

- Phosphate in tank water is used to growth some types of algae (caulerpa/macro algae)
  Algae are removed from the algae filter after some weeks, by harvesting by hand and thus directly ***removing phosphates***.

- ***Nitrate*** is converted into gaseous nitrogene (which escapes the filter) within the anerobic zones of the Mud/Filter-substrate by bacteria.

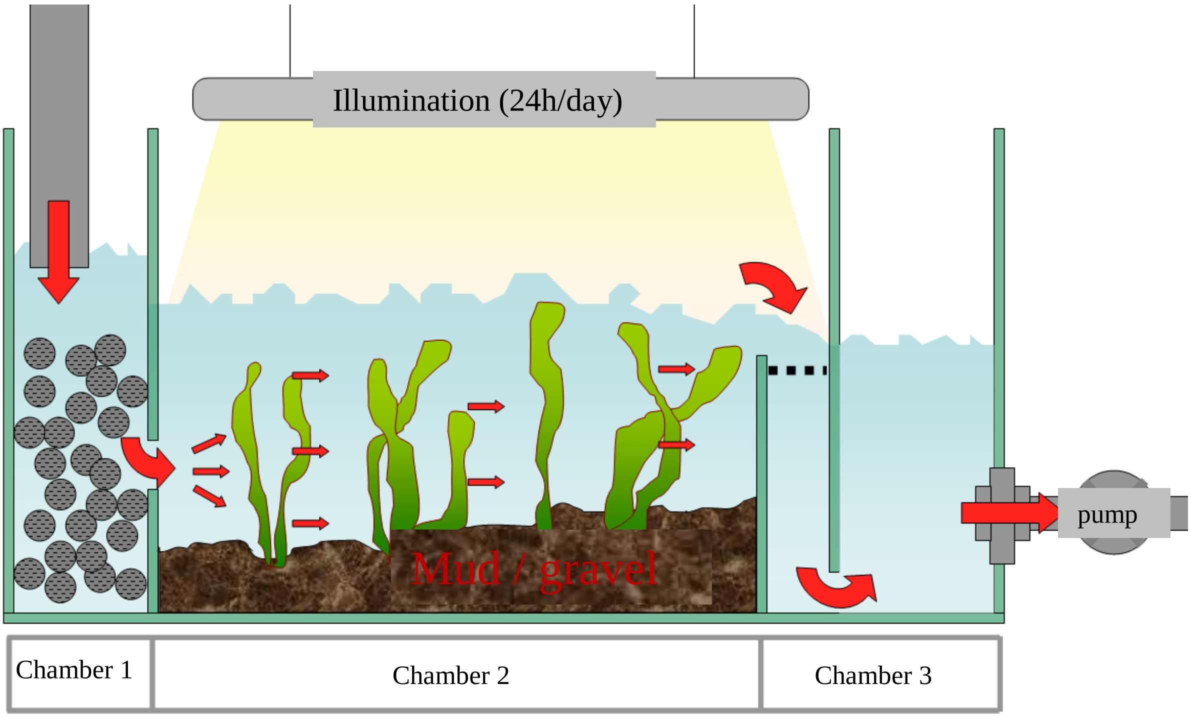
- Photosynthesis taking place all the time the filter's light is on, is supplying your tank with oxygen.

Major advantages:
- Needs only litte maintenance (harvesting algae)
- Trace elements and plankton are to be kept in the tank, if used without additional skimmer. This means excellent food for your corals and fish

Reduction of nitrates and phosphates is only up to a certain limit. For several tanks algae filters work excelent, others have still elevated nutrient levels.

What do I need to run an algae/mud filter?

- Specialised filtering tank or hang-on
- Illumination also for filtering tank
- optimal is using (pretty expensive) live mineral mud
  algae filters with normal gravel are also working
- Macro algae/caulerpa
- Powerful feeding pump (needs very good flow)



- Chambers of the algae filter are streamed in direction 1→2→3 by strong flow

rule of thumb for flow: 6 x tank volume/h
(hint: means pump's actual flow rate, not the maximum value)

- Chamber-1: Pre chamber
  a) Water intake from main tank
  b) Can also hold Bio balls being an area for settlement of aerobe bacteria to
  → convert ammonia to nitrite to nitrate if not done elsewhere within tank itself

- Chamber -2: Main chamber
  a) Anaerobe bacteria within mud or gravel convert nitrate into gaseous nitrogen which will escape the tank
  b) Mud/gravel is a perfect area for settlement for critters.
  Absence of fish allows very good growth.
  c) Caulerpa/macro algae are growing and taking up phosphates from the water.
  Chamber should have an 24h/365 day UV illumination
  Photosynthesis enriches water with oxygen
  d) Spezialised mud (eg miracle mud) contains several minerals/trace elements which are emitted to the wate steadily

- Chamber -3: Pump chamber
  for adding a pump which has to transport water back to the main tank

Miscellaneous

- Harvesting of caulerpa/algae ~ each 1-2 wesks
  Harvesting improves algae grwoth and thus also PO_4 reduction
- Renewal of mineral mud is recommended each 1-2 years by 50% of its amount
- Following macro algae are especially recommended

- I recommend adding a grid between chamber 2 and 3 to prevent algae from coming into the pump/main tank
- Chamber 2 is a perfect settlement area for all types of small critters which are very positive and are also additional food for your animals/fish once they reach the main tank.

Frequently asked questions about algae/mud refugium

F: Do I need a skimmer parallel to an algae/mud refugium?
A: This type of filter also works without skimming.
Tanks with a high fish load should also have a skimmer to prevent fish suffocating, especially during night hours.

F: How do I add mud to a new refugium or if I have to exchange it?
A:
- Fill refugium with salt water
- shut down refugium's pump
- Insert mud slowly/carefully and allow ≥ 1h for settling
  (no panic, water is extremely misted during this time)
- Remove any particles swimming on the surface (net)
- Switch on pump

F: Which type of algae are recommended most?
A: Caulerpa/macro algae such as Profilera, Taxifolia and Racemosa.

F: How should I add algae/caulerpa?
A: 2 possibilities:
- Make a small hole into the mud/gravel → insert algae → close hole
- Insert caulerpa and roughly fix by adding a stone above it.

Hint: in case of established tanks, you should use gloves to prevent contact with bristle worms.

F: How can I remove algae/caulerpa?
A: You can leave your pump switched on.
Simply tear off algae above its root and throw away (trash bin, compost, etc)
Hint: in case of established tanks, you should use gloves to prevent contact with bristle worms.

F: How often should I harvest my algae filter?
A: A typical cycle is each 1-2 weeks. The more often algae is harvested, the faster they will grow and thus remove nutrients.
But you should not harvest algae until they have built up several ramifications.

F: My algae/caulerpa are getting transparent. What should I do?
A: Remove any transparent caulerpa. They might release nutrients/toxins.

F: Can I feed harvested corals to my fish?
A: In general yes. Due to having taken up phospahtes this might be counterproductive

F: Help, my algae refugium is alive! What should I do?
A: Don't panic. This is totally normal and positive for your refugium, tank and especially your animals, which like this source of plankton/food.

F: I have red/green cyano on my caulerpa. What can I do?
A: Remove cyano bacteria from your refugium once you see it. It is best to place a piece of wadding between chamber-2 and chamber-3, then remove cyno, which are cought in the wadding. After that, simply throw away the wadding.
Hint: Cyno bacteria is a problem if flow rate is too low

F: Reduction of nutrients is not working good enough.
Can I use a skimmer together with my refugium?

A: Yes, a high percentage of refugium is used together with a skimmer.
Using a skimmer also reduces the risk of getting low on oxygen.

F: How long do I have to wait for my refugium until it really works?

A: Algae in refugia need some time until caulerpa starts a strong growth and also mud/gravel population with small critters needs some time to establish.
Allow 2-4 weeks for a reduction in nutrients and 1-2 months for full efficiency.

F: Do I have to light my refugium 24h/day?

A: Yes, that is strongly recommended, especially if run without a skimmer.
But it is a must that the refugium's light is on at hours where the tanks lights are off.
a) 24h lightning means more algae growth and thus reduction of nutrients.
b) Photosynthesis at night hours reduces risk of insufficient oxygen supply.

F: Do I need a special lightning?

A: UV lightning is fine.

6.8 Vodka method

Target: Improved reduction of nitrate and phosphate

This method works by feeding the bacteria population, which will make up most of your tank's nitrogen cycle. The growth and cell division rate of bacteria is boosted by adding a source of organic carbon, ie vodka/ethanol.

Vodka method uses 2 parallel running processes:

- ***Optimised denitrification*** from nitrate to gaseous nitrogen
  (which escapes your tank as gas)

- ***Consumption of nitrate/phosphate by building up biomass***
  by generating layers of heterotroph bacteria which:
    - are ***removed partly by skimming***
    - are used partly as ***food for corals***

Once there is no sufficient (heterotroph) bacteria population available, you have to accumulate with bacteria cultures first.

Using the vodka method means only ***little work*** and is ***very reasonable***.
But there is a certain risk if bacteria grows too fast, which then generates problems for your fish.

What do i need?

- Skimmer (as an absolute must)
- Any source of Ethanol being uncoloured and free of harmful substances eg. vodka
- Test kits to determine concentrations of nitrate and phosphate

Risks of the vodka method

1.) Some users report massive loss of fish. Most of the time this happened over night.

Reason is overproportional growth of bacteria population by vodka method ONLY if coming TOGETHER with an insufficient oxygen supply. High population depth of aerobe bacteria is using up lots of oxygen, especially at night where photosynthesis is not taking place. Fish have died by suffocation.
A ***powerful skimmer running 24h/day*** is a must if the vodka method is used.

2.) The vodka method reduces nutrients efficiently. Doing this either too fast or until you reach 0 concentrations of N_3 / PO_4 can lead to problems for your corals by starvation. You should be especially careful not to reduce too fast (see dosing recommendations later on).

Remember, you should target “low nutrients”, but not “nutrient-free conditions”
In case of 0 concentrations you have to feed corals separately
(Amino acids like *UltraAmin, UltraMin S/Amino acid concentrate*, powder food like *CyclopEeze*, usw.)

3.) In rare cases, users report that the vodka method reduces only one of both nutrients (nitrate OR phosphate). Although I see other reasons within your tank being responsible for this (which you should try to resolve in this situation).

Case-A: Nitrate concentration good/low but phosphate concentration too high
→ Use phosphate absorbers parallel to vodka method

Case-B: Phosphate concentration good/low but nitrate concentration too high (happens only very rarely
→ Dosing of Phosphate

4.) In very rare cases, users report a higher sensitivity of fish against pathogenic germs. Increased population depth especially of aerobe bacteria within the water is seen as a possible reason that may have led to a stronger stress for the defence mechansim of fish and thus to an outbreak of illness (starting with dulling of skin, followed by secondary infection with non-bacterial parasites.
But it is not proven that this would not also have happened without dosing vodka.

Dosing recommendation

There is not an exact doing recommendation valid for all tanks, because the biology of tanks are different (amount/assembly of nutrients, available amount for settling of bacteria, type and amount of bacteria being present, etc).
The following recommendation was used by several aquarists in Germany with very positive feedback. It is more on the conservative side (meaning that it starts with moderate dosages)
(Source: Riffaquaristikforum; Thomas Geisel)

Time	Dosing [per 100 litre tank volume]	comment
day 1-4	**0.5ml** vodka /100L	
day 5-6	**0.75ml** vodka /100L	
day 7-14	**1.0ml** vodka /100L	After ~7 days: you should notice more skimmate After ~10-14 days: Reduction of nitrate/phosphate should be measurable with your test kits
day 15 – xx	Evaluate the amount of vodka your tank needs to hold low on nutrient levels for N_3/PO_4 rule of thumb: it **should not be much higher than 1.0ml**/100L	Problem tanks can consume up to 4ml vodka /100L per day (high fish population, not too good flow, not enough settling space for bacteria)
Furthermore (steadily dosing)	Try to reduce amount of vodka used to 20-50% of the amount you evaluated before, based on measuring N_3/PO_4 concentration more often during this time. Target: low on nutrients (but not $N_3/PO_4 = 0$)	

- ***24h/day oxygen supply (eg by skimmer)*** is an absolute must.
  In no way should your tank should stay without additonal oxygen supply overnight.
- Especially within the first 3 weeks using vodka you should ***measure nitrate/phosphate pretty often*** (2-3 times a week). Your specific dosage has to be evaluated according your tank's biological demands.
- Dosing recommendation above is for normal vodka available in super markets (uncoloured, sugarfree, ~40 Vol-% alcohol).

- In case you recognise ***smeary surface layers*** within your tank/glass, this is bacteria films. * reduce amount of vodka dosed

Frequently asked questions about the vodka method

F: Should I pour the vodka directly into my tank?
A: Yes, best if you maesure the amount of vodka you need with a syringe and inject into a position of your tank with good flow

F: Does it matter which vodka I'm using?
A: In general yes. The brand doesn't matter. Should be ~40 Vol%, uncoloured and sugarfree. You could even dose a pure ethanol (dosing recommendation would be different)

F: How can I see that the vodka method is functioning??
A: You will notice a stronger skimming first
Some days later reduced concentrations of nutrients can be measured

F: Slimy white/brownish layers are assembling on my glass, rocks and/or sump. What's that?
A: Most likely this is layers from bacteria. This is indicating that you use too much vodka for feeding → reduce amount of vodka. You can remove this with a toothbrush. Your skimmer will remove them later on.

F: Water surface is getting milky since i use vodka. Is that a problem?
A: Most likely this is died off bacteria (normal). You should improve water movement.

F: My tank's water is getting milky. What's that?
A: Maybe you dosed too much vodka and bacteria are multiplying excessively (bacteria bleed). Reduce vodka dosage and ensure a good oxygen supply/skimming.

Attention: A sub-optimal oxgen supply can be dangerous for your animals/fish

F: Can I use vodka without running a skimmer?
A: No Using vodka without having a secure and strong oxygen back up like a skimmer is not recommended.

F: Can I use a PO_4 absorber running the vodka method?
A: Yes. In case of low nitrate concentrations but still eleavted PO_4 this is recommended.

F: Can I run UV and ozone generators running the vodka method?
A: Yes.

F: Can I run the vodka method parallel to a sandbed filter (DSB)?
A: Normally you won't need 2 systems reducing nutrients. This might even lead to an unfavourable zero-nutrient situation.

F: Can I run the vodka method parallel to an algae/mud refugium?
A: Normally you won't need 2 systems reducing nutrients, but you can reduce more nutrients if running parallel in problematic tanks. Don't forget to use a skimmer if you dose vodka.

F: Can I run vodka method parallel to zeolite?
A: Tanks using zeolite method normally are extremely low on nutrient concentrations. In very problematic tanks you can combine both methods to further reduce nutrients.

6.9 Bio pellets, pellet filters

Functioning principle:

Starting point is small pellets being a mixture of several natural polymers that are biodegradable. They offer a perfect surface for bacteria and also a carbon source for corals, sponges and filtering lifeforms. Thus they are efficient for reducing nutrients.

Allthough you could also place the pellets somewhere in your sump, it is more effective to have them in a filter where they are streamed steadily and from all sides.

Photo: Fauna Marin's NPO redu pellets (NPO redu = **reduce** $\mathbf{N_3}$/$\mathbf{PO_4}$))
within Fauna Marin's pellet filter

6.10 Reducing nutrients by zeolites

This method requires a bunch of measures to be done. The benefit if acting according this labour-intensive and somehow expensive method is, getting very nature like conditions in your tank. Used correctly this will give you ***very good growth and excellent colours especially for sensitive stony corals***.
Colours reached are very distinct and bright (red, pink, blue and green tones). This is the visible effect of reduced building up of lots of brownish zooxanthelle.

You can also use this method for tanks with a very high fish load or strong feeding as common in axo-coral tanks.

Market is offering several systems eg ***UltraLith*** (Fauna Marin – Claude Schumacher), ***ZEOvit*** (Korallenzucht - Pohl). For the following pages I use the wording ***Zeolite-method*** to be as product neutral as possible.

What do I need?

- Effective skimmer
- Zeolite filter
- Zeolites (small rocks, expendable material)
- Specialised bacteria cultures (expendable material)
- Specialised bacteria food (expendable material)
- Specialised coral food (expendable material)

You should use this method only together with all of its components, materials and working steps.

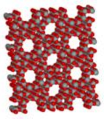
Working principle

Step-1: We want to achieve very low nutrient concentration. Specialised chunks of stones with a very high porosity in specialised filters will do that job for us.

- Zeolith-chunks are ***binding*** a***mmonia*** in a mechanical way**.**
- In parallel we will build up and feed specialised ***bacteria cultures*** (autotroph bacteria).
  Bacteria are ***oxidising ammonia*** with oxygen to ***nitrate***,
  Nitrates are converted to ***harmless (gaseous) nitrogen*** which escapes the water circuit.
- The steadily growing mass of bacteria is also ***binding phosphates***.
  Dying bacteria are swept away and ***removed together with the phosphate*** by the skimmer.

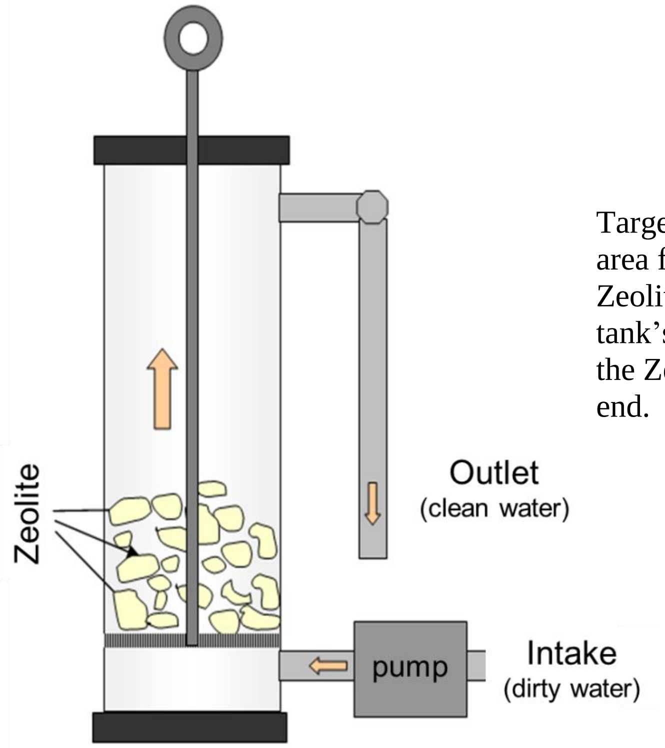
Step-2: Due to the very low nutrient concentration (generated by step-1), ***we have to feed our corals separately*** to avoid starvation. This is done by adding amino acids and other specialised food types.

Zeolites & Zeolite filters



Zeolites are silicate minerals with an extremely porous, sponge like structure and an immense overall surface.
They are used as an ideal area for settling of critters and especially bacteria at its top and also within its structure.

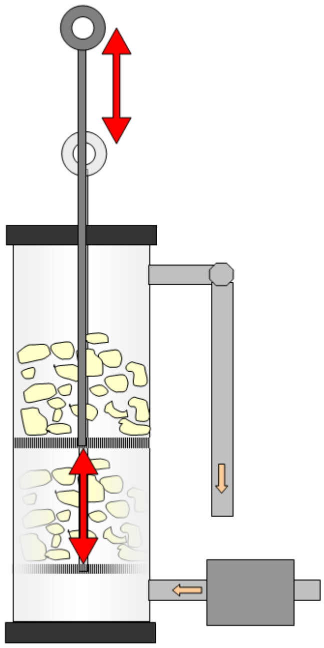
There are ~50 different types of natural zeolites as well as ~150 several artificial ones. Aquarists mostly use a mix from artificial and also natural zeolites (Clinoptilolithes). They have a high absorbing capacity and also an absorbing tendency for amonium.



Target for ***Zeolite filters*** is generating a perfect settling area for de-nitrifying bacteria.
Zeolites within the filter are streamed downside-up with tank's water. Therefore, a pump presses water through the Zeolite chunks, running back from the outlet at the end.

Zeolite chunks have to be cleaned daily from detritus and dying bacteria by flushing them with the water they are in. This is done by pulling up/down the filter basket where the chunks are. This mix from detritus/bacteria is also used for feeding your corals.

There are several good Zeolite filteres available (eg from Fauna Marin, Grotech and Korallenzucht.de). Fauna Marin even offers a model with an automatic cleaning function.



The Zeolite filter should be in the water circuit BEFORE your skimmer.

Alternative to using a zeolite filter, it is also possible (though not as effective) to place zeolite chunks at a position with good current flow within your sump.

The amount of Zeolite chunks used al well as the amount of bacteria, bacteria food and coral food used, should be done according the instructions of the manufacturer of your preferred Zeolite system.

This is only a rule of thumb.
(Recommendations of manufacturers can differ)

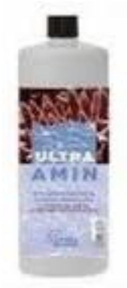
Amount of zeolites	up to 250 gramm zeolite chunks per 100l water volume rinse with purified water before use
Change of zeolites	25% each 6-12 weeks
Current flow	~75litre/h per 100l water volume

Hint: Especially if upgrading to a Zeolite system from a tank being “rich in nutrients”, you should start up a Zeolite filter very carefully. Recommendation: start only with 25-50% of Zeolite chunks and/or use only 40litre/h flow.

Zeolite bacteria and coral food

As described, you need also to dose bacteria, feed them separately and also feed your corals becuase your system will run very close to 0-concentrations.
Depending on your preferred Zeolite system, you should use at least the following **3 main components**:

I) ***Coral food***



UltraAmin (UltraMin S) (Fauna Marin) or
Aminoacid concentrate (Korallenzucht.de)

II) ***Highly concentrated bacteria cultures*** *1)
to optimise nutrient reaction within Zeolite chunks

UltraBio (Fauna Marin) or
ZEObak ***(***Korallenzucht.de)

*1) Even higher concentrated than typical de-nitrifying salt water bacteria cultures

III) ***Bacteria Food***

UltraBak (Fauna Marin) or
ZEOstart ***(***Korallenzucht.de)

Korallenzucht.de also offers ***ZEOfood,*** a combi-product to feed bacteria and corals at the same time

Miscellaneous

- An efficient skimmer is mandatory
- Filtering by activated carbon, best if after the skimmer, is recommended parallel to Zeolite method (reduction xanthochromia and removal of toxins)
- UV-sterilizers/ozone generators should be deactivated for some hours if adding new bacteria cultures
- White, brownish or green layers of bacteria on your tanks glass or rock can be an effect of overdosing bacteria food (over proportional growth of bacteria, maybe even bacteria bleed)
  * reduce your dosage of bacteria food
- Parallel to the Zeolite system, a supply ***calcium, magnesium*** and a***lkalinity*** is required

Risks of the Zeolite method

1.) Major risk is ***starting Zeolite method too fast*** within tanks with ***elevated nutrient levels***. Corals used to higher levels of nutrients cannot adapt as fast as the Zeolites reduce the levels. Be careful in this case: Either use less Zeolite chunks or less strong flow within your filter, to avoid starvation of your corals.

2.) Removing a Zeolite filter too fast can lead to exactly the opposite problem. Due to rising nutrient levels, your stony corals can stop growth and become a brownish color.

3.) Positive effects might not work if you are ***not processing all elements of the Zeolite system***. Eg: if you skip feeding your corals separately, they might die from starvation.

4.) Be careful with some of the chemicals sold together with Zeolite systems. Some of them are expected to use toxic ingredients like heavy metals, just to reach better coral colourisation.

Frequently asked questions about the Zeolite method

F: Which manufacturer has the best Zeolite system?
A: I would select a system from one of the premium sellers. But you should check prices. I would NOT recommend mixing up products from different systems/manufacturers.

F: How do I run a Zeolite-driven tank while on holiday?
A: This should not be too big a problem, because Zeolites do not have to be changed as often.
- Daily cleaning of Zeolite chunks (lifting the basket) can be skipped for a certain period of time
- Feeding bacteria is not an absolute must that it has to be done each day. But be aware that the reduction of nutrients will not be as good anymore in this period.
- You should take care that feeding of your corals is not stopped, once you are on holiday. You can do that by dosing with a dosing pump.

F: Do I really need a skimmer?
A: Yes!

F: Do I really need a specialized Zeolite filter? +++ANSWER NEEDS TRANSLATING+++
A: Nicht unbedingt. Zeolithe können auch an stark durchströmten Stellen im Technikbecken eingesetzt werden.
Die Verwendung spezieller Zeolith-Filters ist jedoch vorteilhaft.

F: Can’t I just use Zeolite chunks as filtering material and skip adding bacteria and bacteria food?
A: No. I doubt there will be a reduction of your nutrient levels. Even if there is, it will not be as significant as if using the complete system.

F: Can I stop the Zeolite method once my nutrient levels have been reduced nearly to 0?
A: This is not recommended. Most likely you will have a yo-yo effect (nutrients being reduced will go up again)
Stopping using Zeolites from one day to the next might even generate the risk of getting a (toxic) ammonia peak.

6.11 Further methods for reducing nutrients

Since 2008, compounds being a combination of bacteria food and absorbing material are offered. The most common is Tropic Marines **REEF-Actif**. It is a powder (called a biopolymer mixture) that is mixed together with tank's water and then added to your tank. There, it will generate a dulling first of all. But after a while the water becomes crystal clear again.

Nutrients and harmful substances (but also some trace elements) are binded to this carrier material first. They can only be used by some type of animals/bacteria. Besides feeding coral's polyps and filtrating lifeforms, this is also bacteria food. Bacteria population is growing and thus reducing nutrients within your tank.

- REEF Actif is said also to improve drive for reproduction of fish and building of coral's polyps.

- Using these types of product, like for other methods for reducing nutrients, you have to take care not to exaggerate. Doing this would lead to counterproductive 0-levels of nutrients and thus starvation/death of corals.

6.10 UV sterilizers

UV-sterilizers kill bacterial (pathogenic) germs and micro algae within water that is streaming through it.
Most bacteria that is positively important for a reef tank are not within the water streaming through the sterilizer, but within gravel, rocks, special filtering media, and thus not affected.

Advantages of using a UV sterilizer:

- ☑ Better vitality of sensitive and/or new fish
- ☑ Reduction in the risk of infection

Part of the tank's water is running slowly through a thick tube. Exactly in the middle of the tube is a strong UV source (fluorescent tube). UV light kills bacteria /algae here.
The sterilizer is covered by a waterproof housing, protecting the electrics within.

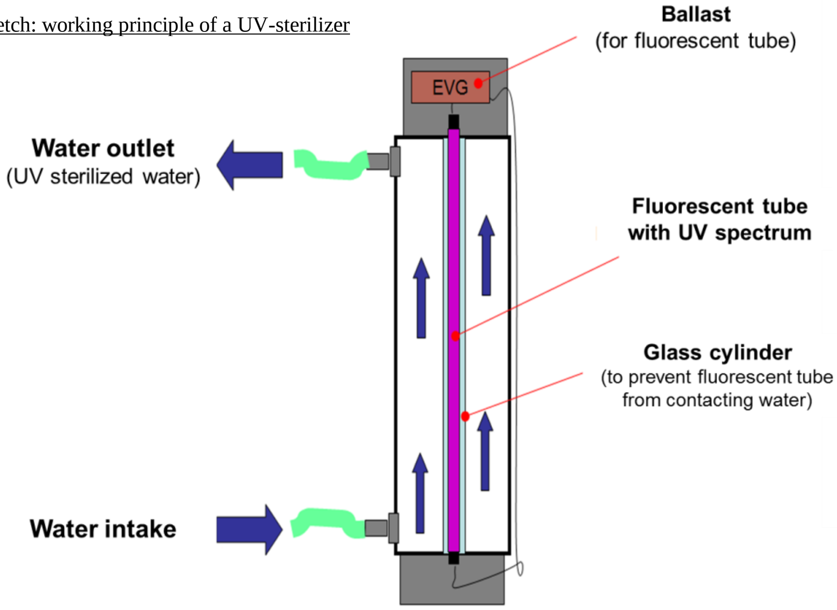
Foto: www.Korallenriff.de – Robert Baur

Longer duration and higher UV intensity for water streaming through improves the degree of sterilization. Select the sterilizer size for your tank (bigger tank, more water to sterilize, stronger source of light/volume flowing through).

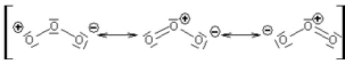
"Overdosing" is impossible. Using bigger sterilizers generates increased safety without any risk, but having higher costs of power consumption (light source, 24h/day).
UV sterilizers should run 24h/day to prevent reproduction of germs in times where light is out.

- Supply the amount of water running through according manufacturer's instructions
- Light bulb within the sterilizer has to be replaced according manufacturer's recommendation (Normally after 1 year).

Sketch: working principle of a UV-sterilizer



6.11 Ozone generators



Ozone (O_3) is an altered, unstable version of oxygen (O_2). It is also gaseous, but different to oxygen it has a typical smell (slightly sharp, known from rooms with copying machines, laser printers). Ozone molecules will resolve and thus are looking for other reaction partners. Thus ozone is a strong oxidiser.

Advantages of using ozone generators:

- ☑ Ozone reduces organical stress by reducing organical dulling material within the water * you get crystal clear water
- ☑ Ozone kills (pathogenic and other) germs and bacteria within the water
  (Most bacteria that is positively important for a reef tank are not within the water streaming by ozone, but within gravel, rocks, special filtereing media, and thus not affected)
- ☑ In salt water ozone is also oxydising parts of ammonia and nitrites to nitrate

You must prevent exaggerating dosing of ozone.
Strong oxidation can lead to negative effects such as acid burns to the gills of your fish

Amount of ozone to be added : ~10 mg ozone per 100 litre water volume

Buying your ozoniser, you should consider a bigger model. Good ozonisers have a power regulator and only very limited power consumption. Ozone is generated with the ozone-tube/element of the ozoniser, by electrostatic discharge.

Ozone is brought to your tank's water either by a separate air hose, or by the air hose connected to your skimmer (standard, preferred method).
If streaming ozone to your skimmer, it is recommended to use activated carbon to convert O_3 back to normal oxygen (O_2) after the skimmer.

Attaching an ozoniser to your tank will increase skimming (at least for some time).

Ozone leads to embrittlement of rubber and plastic parts * Check your parts/hoses frequently.

PART 7 – Some more tips & tricks

7.1 Dosing iodine

There are two affordable methods to dose iodine (both available in drug stores)

a) Lugol's iodine
(0.1%solution: 2 gram potassium iodine + 1 gram iodine + 1 litre Aqua-Dest)

b) PVP iodine/Betaisodonna solution

Rule of thumb for dosing iodine

LUGOL's iodine	2 drops per 100 litre water per day
PVP-Jodide	1 drop per 200-250 litre water per day

7.2 Raising nitrate concentration

a) Standard solution from SodiumNitrate ($NaNO_3$) and RO water

> 137g $NaNO_3$ to be soluted in RO water to a volume of 1L
> (Concentration: 100g nitrate per litre of the standard solution)
> 1ml of this solution per 100L water → raise nitrate by 1mg/l

b) Standard solution from calciumnitrate ($Ca(NO_3)_2$) and RO water

> 132g $Ca(NO_3)_2$ to be soluted in RO water to a volume of 1L
> (Concentration: 100g nitrate per litre of the standard solution)
> 1ml of this solution per 100L water → raise nitrate by 1mg/l

c) Standard solution from amoniumchloride (NH_4Cl) and RO water

> 342g NH_4Cl to be soluted in RO water to a volume of 1L
> (Concentration: 90g nitrate per litre of the standard solution)
> 1.1ml of this solution per 100L water → raise nitrate by 1mg/l

7.3 Raising phosphate concentration

Standard solution from sodiumphosphate (NaH_2PO_4) and RO water

> 12.6g NaH_2PO_4 to be soluted in RO water to a volume of 1L
> (Concentration: 10g phosphate per litre of the standard solution)
> 0.1 ml of this solution per 100L water → raise phosphates by 0.01mg/l

7.4 Evaluate CO_2 concentration within rooms

Measurement tools for evaluation of CO_2 concentrations are pretty expensive.
This method gives you a rough estimation.

What you need is a calibrated pH-sensor, a simple aquatic air pump and a glass with tank water.

- Fill glass with your tank’s water
- Switch on air pump and aerate the glass with water for 15 minutes being outside (fresh air)
- Measure pH oft he water → 1st measurement = reference
  (the CO_2 concentration correlates now to appr. 0.036%, surrounding fresh air)
- Take the glass of water into the room where CO2 concentration is to be measured
  (that can even be your tank’s cabinet) and aerate again for 15 minutes.
  Important: air pump’s air must come also from this room/cabinet
- Measure pH of the water again * 2nd measurement

pH-Value	CO_2 Konzentration im Raum	Bemerkung
Stays the same	0.036%	Optimal ventilated
Drops by 0.1	0.05%	
Drops by 0.35	0.1%	
Drops by 1.0	0.5%	Very bad air (needs better ventilation)

Testing with pH test kits instead of a pH-sensor is not accurate enough, but detecting a “very-bad-air” situation is possible.

SPECIALIST TERMS AND SHORTCUTS

Aerobe	rich on oxygen
Anaerobe	poor on oxygen
Anoxic	very low on oxygen/without any oxygen
Autotrophe	doing photosynthesis: converting anorganical association → organic substance
Azooxanthelle	does not own/use Zooxanthelles, must be fed separately
Caulerpa	macro algae with very good growth rates
Ca	Calcium
$CaCO_3$	CalciumCarbonate
CO_2	CarboDioxide (colour free, non-smelling gas)
Cyclops Eeze	powder food very rich on nutrients
Detritus	sedimentation from excrements, dead critters, algae etc.
Denitrification	Conversion process nitrate to nitrogen
Diatom	brown algae
Density	Weight of a fixed volume of a certain material
Dinoflagellates	type of 1 cellular algae beeing known as a plague in reef tanks
DSB	sand bed filter (DSB= deep sand bed)
Herbivore	eating plants
Heterotroph	NOT doing photosynthesis needs organic nutrients / carbon associations
CaCO3 media	if natural: skeletons from died stony corals, contains lots of CaCO3 other trace elements, but also PO_4
Live Sand	Aragonite sand containg population of Bacteria and critter
LPS	**L**arge **P**olyp **S**tony corals
Mg	Magnesium
Nutrients	Elements that can be taken up as food. Negative if too high concentrated in reef tanks. NH_3 / ammonia is even highly toxic
NH_4^+	Ammonium
NO_2^-	Nitrite
NO_3^-	Nitrate
Nitrification	degradation process from Ammonia/Ammonium ⌧ Nitrite ⌧ Nitrate
Osmosis	streaming of water through very fine membranes
Ozone	oxidising soluted solids, raises Redoxpotenzial and O_2–concentration of water toxic for bacteria, in higher doses also for fish / corals
RO	Reverse osmosis (unit)
Plankton	microscopic organisms living within water
Zooplankton:	Plankton from animals (Brachiones, Copepodes)
Phytoplankton:	Plankton from plants
Buffering capacity	Ability of an element to balance shifts initiated by either acids or bases
Redox potential	can be measured: drops if lots of oxidising organic elements soluted in Water → sign for excessive organical load of water.
Refractometer	measurement tool for determination of salinity (psu) by light refraction
Salinity	Measurement unit for salt concentration of salt water 1 psu (practical salinity unit) = 1 gramm pure salt in 1 liter water
Silicate	Salt from silicone, causes diatoms
SPS	**S**mall **P**olyped **S**tony corals
Substrate	other word for gravel (dead corals, Sand, etc.)
T5 / T8	fluorescent lamp types (∅: T5= 16mm, T8=26mm)
UV-sterilizer	Strong UV lamp streamed by tanks water → kills bacteria and algae
Zooxanthelles	Special type of algae living in symbiosis with corals, sponges, clams get their energy by light/photosynthesis. Provide their symbios partner with nutrients (amino acids, glucose and glycerine)

Salinity Table 1: Density vs. Salinity

measured value: **Density**   value shown in cells: **Salinity [psu]**

Temperature [°C]	Density [g/cm³] 1.0180	1.0185	1.0190	1.0195	1.0200	1.0205	1.0210	1.0215	1.0220	1.0225	1.0230	1.0235	1.0240	1.0245	1.0250	1.0255	1.0260	1.0265	1.0270	1.0275	1.0280
20.0	26.2	26.8	27.5	28.1	28.8	29.5	30.1	30.8	31.4	32.1	32.7	33.4	34.1	34.7	35.4	36.0	36.7	37.3	38.0	38.6	39.3
20.2	26.2	26.9	27.5	28.2	28.9	29.5	30.2	30.8	31.5	32.2	32.8	33.5	34.1	34.8	35.4	36.1	36.7	37.4	38.1	38.7	39.4
20.4	26.3	27.0	27.6	28.3	28.9	29.6	30.2	30.9	31.6	32.2	32.9	33.5	34.2	34.8	35.5	36.2	36.8	37.5	38.1	38.8	39.4
20.6	26.4	27.0	27.7	28.3	29.0	29.7	30.3	31.0	31.6	32.3	32.9	33.6	34.3	34.9	35.6	36.2	36.9	37.5	38.2	38.9	39.5
20.8	26.4	27.1	27.8	28.4	29.1	29.7	30.4	31.0	31.7	32.4	33.0	33.7	34.3	35.0	35.6	36.3	37.0	37.6	38.3	38.9	39.6
21.0	26.5	27.2	27.8	28.5	29.1	29.8	30.5	31.1	31.8	32.4	33.1	33.7	34.4	35.1	35.7	36.4	37.0	37.7	38.3	39.0	39.6
21.2	26.6	27.2	27.9	28.5	29.2	29.9	30.5	31.2	31.8	32.5	33.2	33.8	34.5	35.1	35.8	36.4	37.1	37.8	38.4	39.1	39.7
21.4	26.6	27.3	28.0	28.6	29.3	29.9	30.6	31.3	31.9	32.6	33.2	33.9	34.5	35.2	35.9	36.5	37.2	37.8	38.5	39.1	39.8
21.6	26.7	27.4	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	35.9	36.6	37.2	37.9	38.6	39.2	39.9
21.8	26.8	27.4	28.1	28.8	29.4	30.1	30.7	31.4	32.1	32.7	33.4	34.0	34.7	35.3	36.0	36.7	37.3	38.0	38.6	39.3	39.9
22.0	26.9	27.5	28.2	28.8	29.5	30.2	30.8	31.5	32.1	32.8	33.4	34.1	34.8	35.4	36.1	36.7	37.4	38.1	38.7	39.4	40.0
22.2	26.9	27.6	28.2	28.9	29.6	30.2	30.9	31.5	32.2	32.9	33.5	34.2	34.8	35.5	36.2	36.8	37.5	38.1	38.8	39.4	40.1
22.4	27.0	27.7	28.3	29.0	29.6	30.3	31.0	31.6	32.3	32.9	33.6	34.3	34.9	35.6	36.2	36.9	37.5	38.2	38.9	39.5	40.2
22.6	27.1	27.7	28.4	29.0	29.7	30.4	31.0	31.7	32.4	33.0	33.7	34.3	35.0	35.6	36.3	37.0	37.6	38.3	38.9	39.6	40.2
22.8	27.1	27.8	28.5	29.1	29.8	30.4	31.1	31.8	32.4	33.1	33.7	34.4	35.1	35.7	36.4	37.0	37.7	38.4	39.0	39.7	40.3
23.0	27.2	27.9	28.5	29.2	29.9	30.5	31.2	31.8	32.5	33.2	33.8	34.5	35.1	35.8	36.5	37.1	37.8	38.4	39.1	39.7	40.4
23.2	27.3	27.9	28.6	29.3	29.9	30.6	31.3	31.9	32.6	33.2	33.9	34.6	35.2	35.9	36.5	37.2	37.9	38.5	39.2	39.8	40.5
23.4	27.4	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6
23.6	27.4	28.1	28.8	29.4	30.1	30.7	31.4	32.1	32.7	33.4	34.0	34.7	35.4	36.0	36.7	37.3	38.0	38.7	39.3	40.0	40.6
23.8	27.5	28.2	28.8	29.5	30.2	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.4	36.1	36.8	37.4	38.1	38.7	39.4	40.1	40.7
24.0	27.6	28.2	28.9	29.6	30.2	30.9	31.6	32.2	32.9	33.5	34.2	34.9	35.5	36.2	36.8	37.5	38.2	38.8	39.5	40.1	40.8
24.2	27.7	28.3	29.0	29.6	30.3	31.0	31.6	32.3	33.0	33.6	34.3	34.9	35.6	36.3	36.9	37.6	38.2	38.9	39.6	40.2	40.9
24.4	27.7	28.4	29.1	29.7	30.4	31.1	31.7	32.4	33.0	33.7	34.4	35.0	35.7	36.3	37.0	37.7	38.3	39.0	39.6	40.3	41.0
24.6	27.8	28.5	29.1	29.8	30.5	31.1	31.8	32.5	33.1	33.8	34.4	35.1	35.8	36.4	37.1	37.7	38.4	39.1	39.7	40.4	41.0
24.8	27.9	28.6	29.2	29.9	30.5	31.2	31.9	32.5	33.2	33.9	34.5	35.2	35.8	36.5	37.2	37.8	38.5	39.1	39.8	40.5	41.1
25.0	28.0	28.6	29.3	30.0	30.6	31.3	31.9	32.6	33.3	33.9	34.6	35.3	35.9	36.6	37.2	37.9	38.6	39.2	39.9	40.5	41.2
25.2	28.0	28.7	29.4	30.0	30.7	31.4	32.0	32.7	33.4	34.0	34.7	35.3	36.0	36.7	37.3	38.0	38.6	39.3	40.0	40.6	41.3
25.4	28.1	28.8	29.5	30.1	30.8	31.4	32.1	32.8	33.4	34.1	34.8	35.4	36.1	36.7	37.4	38.1	38.7	39.4	40.0	40.7	41.4
25.6	28.2	28.9	29.5	30.2	30.9	31.5	32.2	32.9	33.5	34.2	34.8	35.5	36.2	36.8	37.5	38.2	38.8	39.5	40.1	40.8	41.5
25.8	28.3	29.0	29.6	30.3	30.9	31.6	32.3	32.9	33.6	34.3	34.9	35.6	36.2	36.9	37.6	38.2	38.9	39.6	40.2	40.9	41.5
26.0	28.4	29.0	29.7	30.4	31.0	31.7	32.4	33.0	33.7	34.3	35.0	35.7	36.3	37.0	37.7	38.3	39.0	39.6	40.3	41.0	41.6
26.2	28.4	29.1	29.8	30.4	31.1	31.8	32.4	33.1	33.8	34.4	35.1	35.8	36.4	37.1	37.7	38.4	39.1	39.7	40.4	41.0	41.7
26.4	28.5	29.2	29.9	30.5	31.2	31.9	32.5	33.2	33.8	34.5	35.2	35.8	36.5	37.2	37.8	38.5	39.1	39.8	40.5	41.1	41.8
26.6	28.6	29.3	29.9	30.6	31.3	31.9	32.6	33.3	33.9	34.6	35.3	35.9	36.6	37.2	37.9	38.6	39.2	39.9	40.6	41.2	41.9
26.8	28.7	29.4	30.0	30.7	31.4	32.0	32.7	33.3	34.0	34.7	35.3	36.0	36.7	37.3	38.0	38.7	39.3	40.0	40.6	41.3	42.0
27.0	28.8	29.4	30.1	30.8	31.4	32.1	32.8	33.4	34.1	34.8	35.4	36.1	36.8	37.4	38.1	38.7	39.4	40.1	40.7	41.4	42.0
27.2	28.9	29.5	30.2	30.9	31.5	32.2	32.9	33.5	34.2	34.8	35.5	36.2	36.8	37.5	38.2	38.8	39.5	40.2	40.8	41.5	42.1
27.4	28.9	29.6	30.3	30.9	31.6	32.3	32.9	33.6	34.3	34.9	35.6	36.3	36.9	37.6	38.2	38.9	39.6	40.2	40.9	41.6	42.2
27.6	29.0	29.7	30.4	31.0	31.7	32.4	33.0	33.7	34.4	35.0	35.7	36.3	37.0	37.7	38.3	39.0	39.7	40.3	41.0	41.6	42.3
27.8	29.1	29.8	30.4	31.1	31.8	32.4	33.1	33.8	34.4	35.1	35.8	36.4	37.1	37.8	38.4	39.1	39.7	40.4	41.1	41.7	42.4
28.0	29.2	29.9	30.5	31.2	31.9	32.5	33.2	33.9	34.5	35.2	35.9	36.5	37.2	37.8	38.5	39.2	39.8	40.5	41.2	41.8	42.5

Salinity Table 2: Relative density (Specific gravity) vs. Salinity

measured value: **relative density / specific gravity** value shown in cells: **Salinity [psu]**

Temperature [°C]	Relative density / specific gravity [-]																				
	1.0210	1.0215	1.0220	1.0225	1.0230	1.0235	1.0240	1.0245	1.0250	1.0255	1.0260	1.0265	1.0270	1.0275	1.0280	1.0285	1.0290	1.0295	1.0300	1.0305	1.0310
20.0	27.8	28.5	29.1	29.8	30.5	31.1	31.8	32.4	33.1	33.7	34.4	35.0	35.7	36.4	37.0	37.7	38.3	39.0	39.6	40.3	40.9
20.2	27.8	28.5	29.2	29.8	30.5	31.1	31.8	32.4	33.1	33.7	34.4	35.1	35.7	36.4	37.0	37.7	38.3	39.0	39.6	40.3	40.9
20.4	27.9	28.5	29.2	29.8	30.5	31.1	31.8	32.5	33.1	33.8	34.4	35.1	35.7	36.4	37.0	37.7	38.3	39.0	39.7	40.3	41.0
20.6	27.9	28.5	29.2	29.8	30.5	31.2	31.8	32.5	33.1	33.8	34.4	35.1	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
20.8	27.9	28.5	29.2	29.9	30.5	31.2	31.8	32.5	33.1	33.8	34.5	35.1	35.8	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
21.0	27.9	28.6	29.2	29.9	30.5	31.2	31.8	32.5	33.2	33.8	34.5	35.1	35.8	36.4	37.1	37.7	38.4	39.1	39.7	40.4	41.0
21.2	27.9	28.5	29.2	29.9	30.5	31.2	31.8	32.5	33.1	33.8	34.5	35.1	35.8	36.4	37.1	37.7	38.4	39.0	39.7	40.4	41.0
21.4	27.9	28.5	29.2	29.9	30.5	31.2	31.8	32.5	33.1	33.8	34.4	35.1	35.8	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
21.6	27.9	28.5	29.2	29.8	30.5	31.2	31.8	32.5	33.1	33.8	34.4	35.1	35.8	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
21.8	27.9	28.5	29.2	29.8	30.5	31.1	31.8	32.5	33.1	33.8	34.4	35.1	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
22.0	27.8	28.5	29.2	29.8	30.5	31.1	31.8	32.5	33.1	33.8	34.4	35.1	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
22.2	27.9	28.5	29.2	29.8	30.5	31.2	31.8	32.5	33.1	33.8	34.4	35.1	35.8	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0
22.4	27.9	28.5	29.2	29.9	30.5	31.2	31.8	32.5	33.2	33.8	34.5	35.1	35.8	36.4	37.1	37.7	38.4	39.1	39.7	40.4	41.0
22.6	27.9	28.6	29.2	29.9	30.5	31.2	31.9	32.5	33.2	33.8	34.5	35.1	35.8	36.5	37.1	37.8	38.4	39.1	39.7	40.4	41.0
22.8	27.9	28.6	29.2	29.9	30.6	31.2	31.9	32.5	33.2	33.8	34.5	35.2	35.8	36.5	37.1	37.8	38.4	39.1	39.8	40.4	41.1
23.0	27.9	28.6	29.3	29.9	30.6	31.2	31.9	32.6	33.2	33.9	34.5	35.2	35.8	36.5	37.2	37.8	38.5	39.1	39.8	40.4	41.1
23.2	28.0	28.6	29.3	29.9	30.6	31.3	31.9	32.6	33.2	33.9	34.6	35.2	35.9	36.5	37.2	37.8	38.5	39.2	39.8	40.5	41.1
23.4	28.0	28.6	29.3	30.0	30.6	31.3	31.9	32.6	33.3	33.9	34.6	35.2	35.9	36.5	37.2	37.9	38.5	39.2	39.8	40.5	41.1
23.6	28.0	28.7	29.3	30.0	30.6	31.3	32.0	32.6	33.3	33.9	34.6	35.3	35.9	36.6	37.2	37.9	38.5	39.2	39.9	40.5	41.2
23.8	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	35.9	36.6	37.3	37.9	38.6	39.2	39.9	40.5	41.2
24.0	28.0	28.7	29.4	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
24.2	28.0	28.7	29.4	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
24.4	28.0	28.7	29.4	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
24.6	28.0	28.7	29.4	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
24.8	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
25.0	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
25.2	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
25.4	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	35.9	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
25.6	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
25.8	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
26.0	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.6	33.3	34.0	34.6	35.3	36.0	36.6	37.3	37.9	38.6	39.2	39.9	40.6	41.2
26.2	28.0	28.7	29.4	30.0	30.7	31.4	32.0	32.7	33.3	34.0	34.7	35.3	36.0	36.6	37.3	38.0	38.6	39.3	39.9	40.6	41.3
26.4	28.1	28.7	29.4	30.1	30.7	31.4	32.0	32.7	33.4	34.0	34.7	35.3	36.0	36.7	37.3	38.0	38.6	39.3	40.0	40.6	41.3
26.6	28.1	28.8	29.4	30.1	30.7	31.4	32.1	32.7	33.4	34.1	34.7	35.4	36.0	36.7	37.4	38.0	38.7	39.3	40.0	40.7	41.3
26.8	28.1	28.8	29.4	30.1	30.8	31.4	32.1	32.8	33.4	34.1	34.7	35.4	36.1	36.7	37.4	38.1	38.7	39.4	40.0	40.7	41.3
27.0	28.1	28.8	29.5	30.1	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.4	36.1	36.8	37.4	38.1	38.7	39.4	40.1	40.7	41.4
27.2	28.1	28.8	29.5	30.1	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.4	36.1	36.8	37.4	38.1	38.7	39.4	40.1	40.7	41.4
27.4	28.2	28.8	29.5	30.1	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.4	36.1	36.8	37.4	38.1	38.8	39.4	40.1	40.7	41.4
27.6	28.2	28.8	29.5	30.1	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.4	36.1	36.8	37.4	38.1	38.8	39.4	40.1	40.7	41.4
27.8	28.2	28.8	29.5	30.1	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.5	36.1	36.8	37.4	38.1	38.8	39.4	40.1	40.7	41.4
28.0	28.2	28.8	29.5	30.2	30.8	31.5	32.1	32.8	33.5	34.1	34.8	35.5	36.1	36.8	37.4	38.1	38.8	39.4	40.1	40.7	41.4

Salinity Table 3: Conductivity vs. Salinity

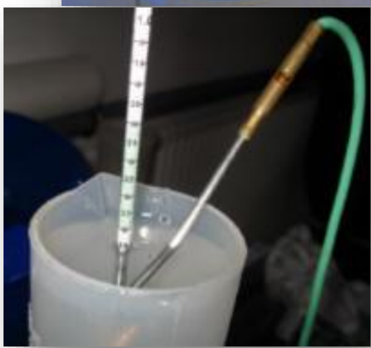
measured value: **Conductivity** value shown in cells: **Salinity [psu]**

Temperature [°C] \ Conductivity [mc/cm]	40.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0	57.0	58.0	59.0	60.0
20.0	28.6	29.4	30.2	31.0	31.8	32.6	33.4	34.3	35.1	35.9	36.7	37.5	38.4	39.2	40.0	40.9	41.7	42.6	43.4	44.3	45.1
20.2	28.5	29.3	30.1	30.9	31.7	32.5	33.3	34.1	34.9	35.7	36.5	37.4	38.2	39.0	39.9	40.7	41.5	42.4	43.2	44.1	44.9
20.4	28.3	29.1	29.9	30.7	31.5	32.3	33.1	33.9	34.7	35.6	36.4	37.2	38.0	38.8	39.7	40.5	41.3	42.2	43.0	43.9	44.7
20.6	28.2	29.0	29.8	30.6	31.4	32.2	33.0	33.8	34.6	35.4	36.2	37.0	37.8	38.7	39.5	40.3	41.1	42.0	42.8	43.6	44.5
20.8	28.1	28.9	29.6	30.4	31.2	32.0	32.8	33.6	34.4	35.2	36.0	36.8	37.7	38.5	39.3	40.1	40.9	41.8	42.6	43.4	44.3
21.0	27.9	28.7	29.5	30.3	31.1	31.9	32.7	33.5	34.3	35.1	35.9	36.7	37.5	38.3	39.1	39.9	40.7	41.6	42.4	43.2	44.1
21.2	27.8	28.6	29.4	30.1	30.9	31.7	32.5	33.3	34.1	34.9	35.7	36.5	37.3	38.1	38.9	39.7	40.6	41.4	42.2	43.0	43.9
21.4	27.7	28.5	29.2	30.0	30.8	31.6	32.4	33.1	33.9	34.7	35.5	36.3	37.1	37.9	38.7	39.6	40.4	41.2	42.0	42.8	43.7
21.6	27.6	28.3	29.1	29.9	30.6	31.4	32.2	33.0	33.8	34.6	35.4	36.2	37.0	37.8	38.6	39.4	40.2	41.0	41.8	42.6	43.4
21.8	27.4	28.2	29.0	29.7	30.5	31.3	32.1	32.8	33.6	34.4	35.2	36.0	36.8	37.6	38.4	39.2	40.0	40.8	41.6	42.4	43.2
22.0	27.3	28.1	28.8	29.6	30.4	31.1	31.9	32.7	33.5	34.2	35.0	35.8	36.6	37.4	38.2	39.0	39.8	40.6	41.4	42.2	43.0
22.2	27.2	27.9	28.7	29.5	30.2	31.0	31.8	32.5	33.3	34.1	34.9	35.7	36.4	37.2	38.0	38.8	39.6	40.4	41.2	42.0	42.8
22.4	27.1	27.8	28.6	29.3	30.1	30.8	31.6	32.4	33.2	33.9	34.7	35.5	36.3	37.1	37.9	38.6	39.4	40.2	41.0	41.8	42.6
22.6	26.9	27.7	28.4	29.2	29.9	30.7	31.5	32.2	33.0	33.8	34.6	35.3	36.1	36.9	37.7	38.5	39.3	40.1	40.9	41.6	42.5
22.8	26.8	27.6	28.3	29.1	29.8	30.6	31.3	32.1	32.9	33.6	34.4	35.2	35.9	36.7	37.5	38.3	39.1	39.9	40.7	41.5	42.3
23.0	26.7	27.4	28.2	28.9	29.7	30.4	31.2	31.9	32.7	33.5	34.2	35.0	35.8	36.6	37.3	38.1	38.9	39.7	40.5	41.3	42.1
23.2	26.6	27.3	28.0	28.8	29.5	30.3	31.0	31.8	32.6	33.3	34.1	34.9	35.6	36.4	37.2	37.9	38.7	39.5	40.3	41.1	41.9
23.4	26.4	27.2	27.9	28.7	29.4	30.2	30.9	31.7	32.4	33.2	33.9	34.7	35.5	36.2	37.0	37.8	38.5	39.3	40.1	40.9	41.7
23.6	26.3	27.1	27.8	28.5	29.3	30.0	30.8	31.5	32.3	33.0	33.8	34.5	35.3	36.1	36.8	37.6	38.4	39.1	39.9	40.7	41.5
23.8	26.2	26.9	27.7	28.4	29.1	29.9	30.6	31.4	32.1	32.9	33.6	34.4	35.1	35.9	36.7	37.4	38.2	39.0	39.7	40.5	41.3
24.0	26.1	26.8	27.5	28.3	29.0	29.8	30.5	31.2	32.0	32.7	33.5	34.2	35.0	35.7	36.5	37.3	38.0	38.8	39.6	40.3	41.1
24.2	26.0	26.7	27.4	28.2	28.9	29.6	30.4	31.1	31.8	32.6	33.3	34.1	34.8	35.6	36.3	37.1	37.9	38.6	39.4	40.2	40.9
24.4	25.9	26.6	27.3	28.0	28.8	29.5	30.2	31.0	31.7	32.4	33.2	33.9	34.7	35.4	36.2	36.9	37.7	38.5	39.2	40.0	40.7
24.6	25.7	26.5	27.2	27.9	28.6	29.4	30.1	30.8	31.6	32.3	33.0	33.8	34.5	35.3	36.0	36.8	37.5	38.3	39.0	39.8	40.6
24.8	25.6	26.3	27.1	27.8	28.5	29.2	30.0	30.7	31.4	32.1	32.9	33.6	34.4	35.1	35.9	36.6	37.4	38.1	38.9	39.6	40.4
25.0	25.5	26.2	26.9	27.7	28.4	29.1	29.8	30.5	31.3	32.0	32.7	33.5	34.2	35.0	35.7	36.4	37.2	37.9	38.7	39.4	40.2
25.2	25.4	26.1	26.8	27.5	28.3	29.0	29.7	30.4	31.1	31.9	32.6	33.3	34.1	34.8	35.5	36.3	37.0	37.8	38.5	39.3	40.0
25.4	25.3	26.0	26.7	27.4	28.1	28.8	29.6	30.3	31.0	31.7	32.4	33.2	33.9	34.6	35.4	36.1	36.9	37.6	38.4	39.1	39.9
25.6	25.2	25.9	26.6	27.3	28.0	28.7	29.4	30.1	30.9	31.6	32.3	33.0	33.8	34.5	35.2	36.0	36.7	37.4	38.2	38.9	39.7
25.8	25.1	25.8	26.5	27.2	27.9	28.6	29.3	30.0	30.7	31.4	32.2	32.9	33.6	34.3	35.1	35.8	36.5	37.3	38.0	38.8	39.5
26.0	25.0	25.7	26.4	27.1	27.8	28.5	29.2	29.9	30.6	31.3	32.0	32.7	33.5	34.2	34.9	35.6	36.4	37.1	37.8	38.6	39.3
26.2	24.9	25.6	26.2	26.9	27.6	28.3	29.0	29.8	30.5	31.2	31.9	32.6	33.3	34.0	34.8	35.5	36.2	37.0	37.7	38.4	39.2
26.4	24.8	25.4	26.1	26.8	27.5	28.2	28.9	29.6	30.3	31.0	31.7	32.5	33.2	33.9	34.6	35.3	36.1	36.8	37.5	38.3	39.0
26.6	24.6	25.3	26.0	26.7	27.4	28.1	28.8	29.5	30.2	30.9	31.6	32.3	33.0	33.7	34.5	35.2	35.9	36.6	37.4	38.1	38.8
26.8	24.5	25.2	25.9	26.6	27.3	28.0	28.7	29.4	30.1	30.8	31.5	32.2	32.9	33.6	34.3	35.0	35.8	36.5	37.2	37.9	38.6
27.0	24.4	25.1	25.8	26.5	27.2	27.9	28.6	29.2	29.9	30.6	31.3	32.0	32.8	33.5	34.2	34.9	35.6	36.3	37.0	37.8	38.5
27.2	24.3	25.0	25.7	26.4	27.1	27.7	28.4	29.1	29.8	30.5	31.2	31.9	32.6	33.3	34.0	34.7	35.4	36.2	36.9	37.6	38.3
27.4	24.2	24.9	25.6	26.3	26.9	27.6	28.3	29.0	29.7	30.4	31.1	31.8	32.5	33.2	33.9	34.6	35.3	36.0	36.7	37.4	38.2
27.6	24.1	24.8	25.5	26.1	26.8	27.5	28.2	28.9	29.6	30.3	30.9	31.6	32.3	33.0	33.7	34.4	35.1	35.9	36.6	37.3	38.0
27.8	24.0	24.7	25.4	26.0	26.7	27.4	28.1	28.8	29.4	30.1	30.8	31.5	32.2	32.9	33.6	34.3	35.0	35.7	36.4	37.1	37.8
28.0	23.9	24.6	25.3	25.9	26.6	27.3	28.0	28.6	29.3	30.0	30.7	31.4	32.1	32.8	33.4	34.1	34.8	35.5	36.3	37.0	37.7

Method used for evaluating salt mixtures data

<u>Step-1:</u> Production of purified water by RO unit with ultra clear water filter (mixed-bed resin) at the end of the unit. Prior to the first tests, all components of the unit have been renewed and new mixed-bed resin was added. Flushing of the unit for 30 minutes.

<u>step-2:</u> Producing salt water
- Amount of water for testing: 8L or. 4L.
  measured by Duran 1000ml Lab glas measuring cylinder
  (NS45/40, deviation ±7.5ml,. 60ml at 8 l → 0.75%),
- Water temperature at beginning 25-26°C.
- Predefined amount of salt for mixing 320g (8L) or 160 g (4L)
- Only "fresh" salt mixtures used. Most of them from still unopened packages
  (salt mixtures had no option to pick up humidity before)
- Weigh: Mettler Toledeo lab weigh, calibrated
- Mixing of salt water: Within 10L bucket also at ~26°C (heater used)
  and 20 min circulation by pump (Aquabee 3000l/h).
- After mixing: Allow salt water ≥ 5 minutes to settle before measuring.



<u>step-3:</u> Determination of salt concentration reached
(* Efficiency of salt mixture)

Fill 450ml of the salt water to a 500ml measuring cylinder (Duran).
Measuring of density (TM Precision-Aräometer, calibrated to density) together with measuring of actual water temperature by lab temperature measuring tool
(Almemo 2090-1, NiCr-temp.sensor, calibrated).

Conversion of measured values density/temperature into salt concentration in psu by "AquaCalculator" (Conversion according UNESCO "Equation State of sea water").

Efficiency factor = salinity reached at test/theoretically reachable salinity
theor. reachable salinity = used amount of salt water volume (320g / 8000ml * 40g/1000ml * 40 psu)

i In reality, all salt mixtures efficiency factor is smaller than 1.0.
That's because salt mixtures do not contain 100% pure salt, but also trace elements and a certain amount of water coming from the production process.
The higher the efficiency factor, the less of the specific salt mixture is needed to reach a certain salinity.

<u>step-4:</u> Determination of concentrations of Ca and Mg and Alkalinity

a) Calibration of test kits by reference solutions.
(Correction shift used depending on values of standard solutions measured with the resp. test kits)
Test kits used: Ca and Mg: Salifert Profi Test kits Alkalinity: Tropic Marine KH-Test

b) Measure salt water's concentrations at the salinity reached at step 3

c) Convert measured results from "b)" to a norm salinity of 34.8 psu (for better comparison)

Contact / Imprint

Author:	Martin Kuhn, Germany, 82110 Germering, Lohengrinstr. 64
email:	martin.kuhn@aquacalculator.com
Homepage	www.aquacalculator.com

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