AquaCalculator reef aquarium compendium – Part 1

Perfect water parameters in your reef aquarium

Marine aquariums, and reef aquariums, inspire aquarists all over the world.

In this compendium you will learn everything you need to know,
to create the best possible conditions for your animals and
to get a dream aquarium yourself.

We wish you much success with your marine aquarium.
(Martin Kuhn and the AquaCalculator team)

Last updated: 18th September 2022

Liability exclusion

The information and recommendations made in this compendium
represent the state of knowledge at the time of the author of the last update.
No guarantee can be given for
the topicality and correctness of the contents!
Any liability resulting from correct or incorrect application is rejected.

Symbolism

	INFORMATION	Important notice
	WARNING	Things that are particularly often done/understood incorrectly
	AVOID	You should definitely NOT do that.
	COMPLEX TOPIC	For advanced learners - allow time to read through.

About us

We are a team of 3 software developers and have been striving since 2005 to support reef aquarists worldwide in their hobby in the best possible way. We are enthusiastic reef aquarists ourselves, not dealers or manufacturers of aquarium products.


Martin Kuhn

Michel Mohrmann

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We finance our expenses through income from our computer programme **AquaCalculator**, which is specially designed for marine aquarists.
The licence fee is less than 10€ per year. You can then use AquaCalculator on as many of your own devices as you like. Each licence is linked to one of the four different operating systems for which we create and maintain separate versions.

Windows Mac iOS Android

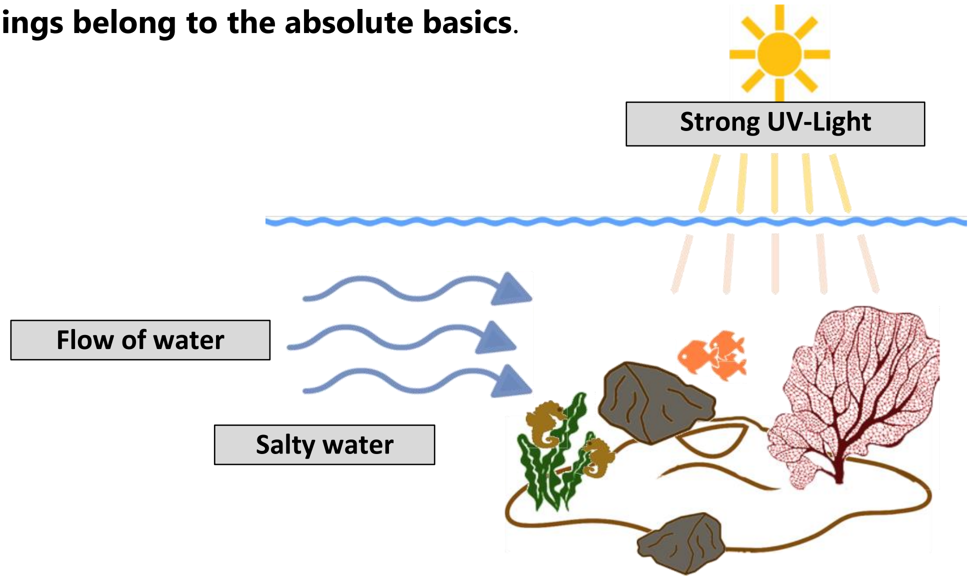
Several thousand aquarists already use our programme and have successfully improved the water values of their aquariums. Complicated calculations, e.g. for the dosage of salts or additional chemicals, are done for you by our software. Water values, aquarium occupants and maintenance work can also be perfectly documented.
In this compendium, we deliberately show you screenshots in some places that show how AquaCalculator can make your life as an aquarist easier.

Please support and appreciate our development work licensing AquaCalculator!

Content

Introduction - Basics

Coral reefs and their inhabitants have adapted and become accustomed to the conditions in nature for thousands of years. Fish, corals and other creatures that we want to keep in our aquariums therefore thrive best and stress-free in exactly this ambience.
If we can create conditions in our aquariums like those in coral reefs, we have the best prerequisites for bringing a piece of nature home permanently!
These 3 things belong to the absolute basics.



Condition-1: **Strong UV light**
The specialist aquarium trade leaves practically nothing to be desired. There is now the perfect lighting for practically every aquarium. Without going into detail here and paying attention to costs and design, I would recommend the following things to create perfect conditions for hard corals as well

- Lamp with a UV-light spectrum similar to nature.
  On request: light colours that emphasise the colouration of corals or luminance effects.
- Choose a lamp that is large enough and a type that provides light over a wide area. (spotlights are less good). This will ensure that corals get light from as many sides as possible and that there is no "shadowing".
- Also pay attention to the power consumption of the lighting. Cost factor!

Condition-2: **Flow**
Marine aquariums absolutely need suitable current for various reasons:
feeding of food particles - swirling up of mulm - mixing of the water - etc.
The importance of flow is underestimated, especially by newcomers, and corrections afterwards are time-consuming and expensive.
We show you how to equip your aquarium so that it offers good flow conditions.

Condition-3: **Saline water with certain ingredients**
The art of well-run reef aquariums is to keep your water parameters constant and as similar as possible to those in real reefs. There are several things to consider here. Available technology, almost perfect products/chemicals, good measuring instruments and the information in this compendium will help you to keep your water values in the aquarium under control.

PART 1 - Important processes in the reef aquarium

1.1 Flow

Often underestimated, but the most important factor for stable marine aquariums
is the flow adapted to the aquarium and
an aquarium design that is geared towards optimal flow.

The current has no direct influence on the water parameters usually considered, BUT...
it strongly influences many things in our aquariums.
There are many good reasons to attach great importance to a clean flow from the very beginning ...

- The right current swirls up suspended particles and transports them.
  It mixes the aquarium water and flushes out places where accumulations could otherwise form. This also applies to areas that cannot be seen directly (drainage shafts, areas behind the reef structure, etc).
  → This is very valuable and necessary to get the nutrient values permanently under control.

- Suitable current is a basic condition for keeping sensitive invertebrates/stone corals.
  - Too weak a current/stream shadow:
  👎 Lack of microbial/food supply
  👎 Failure to clean filigree coral branches

  - too strong a current:
  👎 May cause mechanical damage to animals

- The right flow leads to good surface movement
  👍 Oxygen exchange
  👍 Improvement of the desired temperature dissipation during ventilation
  👍 Visually attractive (curling effect)

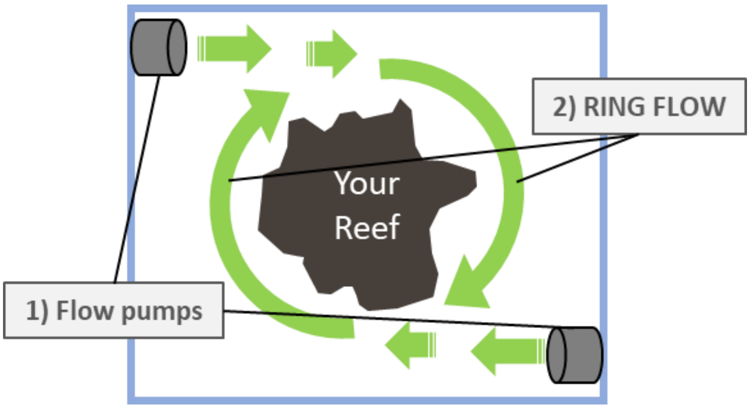
- A suitable current is a prerequisite for clean substrate
  - too weak a current/stream shadow:
  👎 Sediment accumulates.
  → 👎 Cakes w/substrate and can lead to undesirable bacterial or algae accumulation

  - Too strong or unsuitable current:
  👎 Whirling up of sand or formation of "sand piles

Main parameters for optimal flow

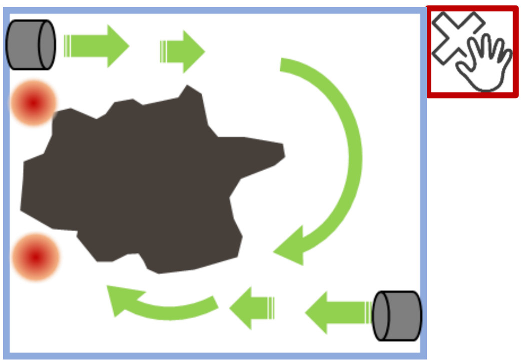
- Geometry of the aquarium
- Geometry of the **reef structure** or other **static aquarium equipment** (note: this includes corals).
- Arrangement, strength and number of **flow pumps**

The optimal flow is a so-called "**ring flow**" in which the flowing water reaches all parts of the aquarium (see sketch in light green).

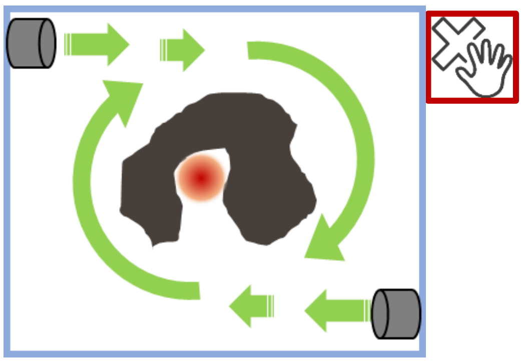


In the following examples, proper flow is prevented (red)

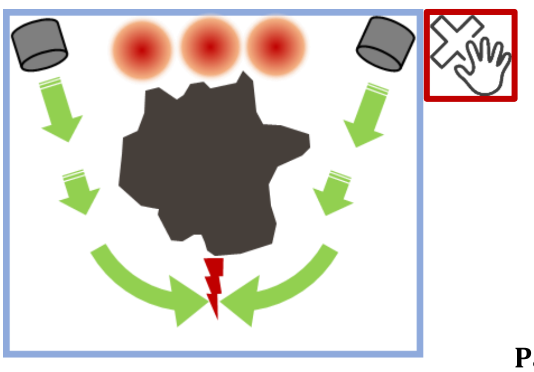
Ex.1: Low-flow locations due to **interruption of the flow**



Ex.2: "**Dead end**" despite ring flow



Ex.3: Low-flow locations due to **opposing flow eliminating themselves**



These are only simple examples for better understanding. The combination of aquarium dimensions, reef construction*1) and combination/arrangement/strength of flow pumps/outlets
can be complex and is up to you or the designer of your aquarium.
*1) incl. further static parts of the aquarium

Plan the size of the aquarium, the reef structure and the flow before planning the details of your aquarium.

Draw a roughly scaled sketch to estimate whether the planned flow pattern can work.

The following tools are available for the optimal "flow strategy:

- ✓ Pumps with "rather punctual" or "wide-ranging flow".
- ✓ "Adjustable pumps" also allow amplification/attenuation of the flow afterwards
- ✓ Pumps "rotatable in several axes" (ball joint) facilitate adjustment
- ✓ Pumps can be used "in several levels" of your aquarium (top/centre/bottom)
- ✓ Disturbing optics? → Cover with reef ceramics or hide in the reef structure
- ✓ Flow (invisible) reef current into "hard to flow" areas
- ✓ In the sea, the direction of the current changes in many places due to the ebb and flow of the tide. This means that water flows over the animals from several sides and with varying intensity.
  → So-called wave simulators (e.g. Wavebox) or pumps with reciprocating outlets (e.g. OsciMotion) offer similar possibilities.

A few more tips:

- ➢ Pay attention to the (actual) electricity consumption of the pumps, because running 24/7. High-quality pumps with good efficiency are more expensive, but they might pay off when you take the electricity costs into account.
- ➢ "Pure flow pumps" have significantly lower power consumption than "feed pumps".

You lack the necessary experience or intuition. Seek advice from experienced aquarists or "real specialists" especially here!

Saving on the flow is saving in the wrong place and often takes revenge later.

1.2 Fresh aquariums: Start-up phase!

You have set up the technical equipment for your new aquarium and set everything up. There is already salt water in the aquarium and the pumps are running.
Now just put in the fish and corals and off you go... right?

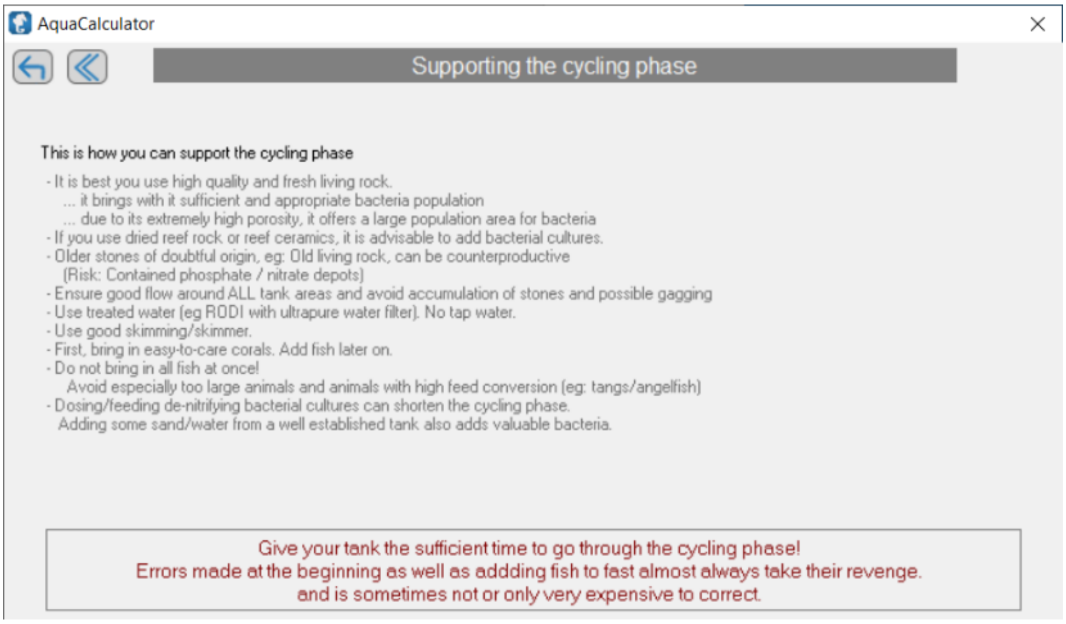
Unfortunately, it's not that simple, because reef aquariums are a living biotope. It first has to get used to various things. If we change too many things too quickly, it can go badly wrong and end with a total loss.

We always have to run in new reef aquariums first.

During the start-up phase, 2 things are important
- To establish a suitable bacterial population in the aquarium.
(reduction of toxins, aquarium ready for nutrient breakdown/control)
- Provide a suitable amount of nutrients.
(necessary food for corals/filtrators, etc).

If this is the case, then we can and should carefully and slowly
with the creatures we really want to keep ...... corals, fish and other animals.

You can also find important information like this in AquaCalculator at any time *1)
We show screenshots here to make life easier for us...

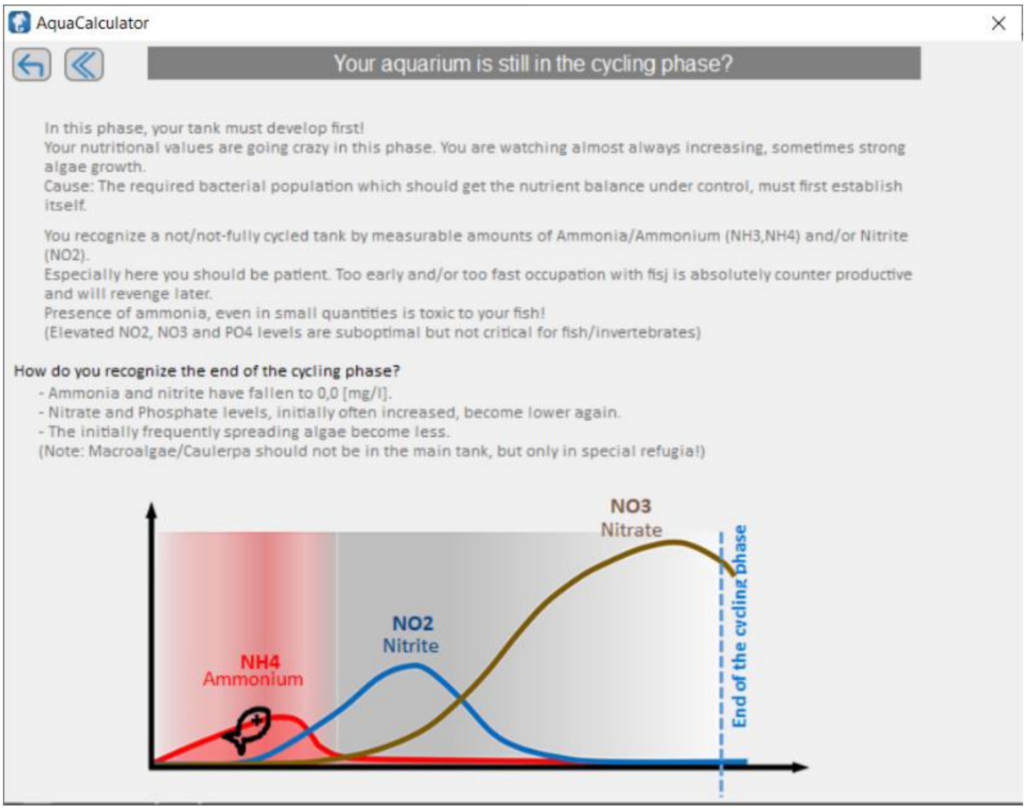


You can do without certain things during the start-up phase, or you should even do so.

`1*) shown: AquaCalculator for Windows

The next question you will ask yourself is:

When can I finally start stocking my aquarium?



1.3 Nutrients

Besides various salts, nutrients (e.g. nitrate and phosphate) are also dissolved in the water. These are produced by excretions and food residues or are introduced into our aquariums via impure chemicals or unclean source water.

On the other hand, nutrients are at least partially converted, adsorbed or removed from the cycle by the technology used (skimmers, algae refugia, etc), adsorbers and biological & bacterial processes.

Nutrients are neither good nor bad ....

- Nutrients are necessary in certain quantities because certain creatures would otherwise starve to death because they may have no other source of energy.

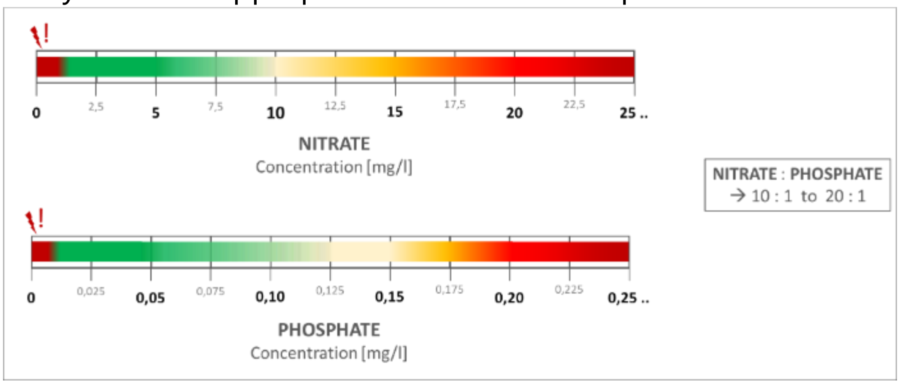
- If the nutrient levels in aquariums increase too much, this can lead to various problems

Keeping an eye on your nutrient levels is very important .... The right balance makes the difference !

For less demanding aquariums it is sufficient if the nutrient values remain within reasonable concentrations.

For sensitive stony corals (SPS), however, specific setting of so-called **NUTRIENT-LOW CONDITIONS** (nitrate/phosphate concentration) is necessary. After all, we do not only want to "keep" these animals, but to achieve good growth and attractive, bright and/or brightly coloured colouration.

NUTRIENT-LOW CONDITIONS in reef aquariums unfortunately also harbour the danger of **NUTRIENT DEFICIENCY**. This is associated with deficiency symptoms, in extreme cases even very rapid death of corals (especially SPS).
The **optimal nutrient-poor range**
for reef aquariums is relatively narrow.
Since **NUTRIENT LEVELS** (= 0.0 mg/l nitrate, phosphate) can have very unpleasant effects, it is important that you understand the interrelationships in order to be able to set up your aquarium correctly and take appropriate measures to keep the nutrient levels in balance.



Here are a few tips

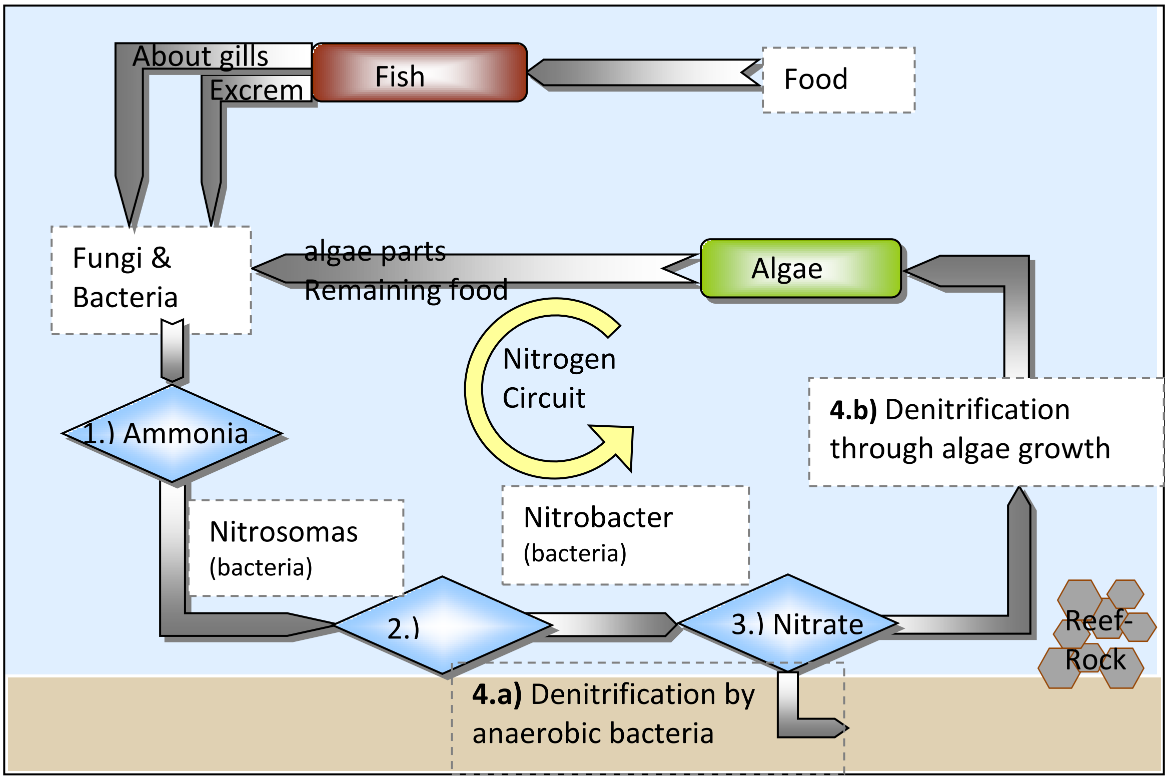
- Measure the nutrient values regularly
- Do not lower your nutrient levels too quickly.
  - PO4 adsorbers should be used only conscious
  - Be careful when dosing highly concentrated bacterial mixtures/bacterial nutrition
- It is better to accept somewhat higher nutrient values, as corals get used to them over time.

In the next 2 chapters (Nitrogen/Phosphorus circle luaf)
we explain 2 basic things you should know.

We recommend that you do not skip this.....
it is important and will help you to get a great functioning aquarium!

1.3.1 The nitrogen cycle
The nitrogen cycle is the most fundamental process of any reef aquarium.

Pollutants are produced by digestion or putrefaction processes and pollute the aquarium. If the nitrogen cycle described and explained below does not function or does not function properly, nutrients will accumulate in the aquarium and pollute the inhabitants.
Therefore, the nitrogen cycle must be established in every aquarium BEFORE it is filled with inhabitants!



1.) At the beginning of the cycle, and in first place in terms of toxicity, **Ammonia/ammonium** is produced by transformations of fish excretions, and putrefaction processes, e.g. by dead animals.

2.) Ammonia is converted into the much less toxic nitrite by ammonifying bacteria.
→ Ammonia concentration decreases, nitrite concentration increases.

3.) Nitrite is converted into the less toxic nitrate by nitrifying bacteria.
→ Nitrite concentration decreases, nitrate concentration increases.

4) a) Nitrate can only be converted into nitrogen by bacteria in oxygen-poor (=anaerobic) areas. It then escapes. This takes place in the substrate and in porous rock.
b) Nitrate (and also ammonia) is converted into growth by algae.
→ Nitrate concentration decreases

→ This process is repeated continuously.
Well-functioning *aquariums*: The amount of pollutants removed is greater than or equal to the amount added. If this is not the case, a aquarium will become "unstable", probably in the long run, which is to be avoided.

Amonium/ammonia is degraded to nitrogen in **2 stages (nitrification / de-nitrification).**

A) Nitrification

The transformation of ammonium into nitrite, and then of nitrite into nitrate is called ***nitrification.***

Nitrosomas

Nitrobacter

Oxidation of ammonium to nitrite $2NH_4+ + 3O_2 \rightarrow 2NO_{2-} + 4H+ + 2H_2O$
(the pH value is lowered by 4 H+ ions being released)

Oxidation of nitrite to nitrate $2NO_2- + O_2 \rightarrow 2NO_{3-}$

In this process, the relatively unstable ammonium/ammonia is "***chemically or biochemically oxidised***" by O2 in the water as the end product of the significantly more stable nitrate. This process usually takes place all by itself. This is why nitrite or ammonium/ammonia is practically never detectable in our aquariums (except immediately during the start-up phase or immediately after the death of larger animals). Nitrate cannot react further with oxygen, as it is already completely oxidised and therefore stable.

This is exactly the reason why ammonium/ammonia and nitrite are not detectable in many aquariums, but people still struggle with nitrate problems!

Ammonium and nitrite are only intermediate stages that are converted.

B) DeNitrification

Nitrate can only be further converted in an anaerobic (oxygen-free) environment.

Pseudomonas aeruginosa

Biochemical degradation of nitrate $5C(H_20) + 4NO_3- + 4H+ 5CO_2 \rightarrow + 2N_2 + 2H_2O$
CO2 produced lowers the pH value,
The elem. Nitrogen N2 escapes from the aquarium as a gas.

For this we need anaerobic zones in our aquariums where bacteria can reside. Like, for example:

- the interior of living stones (porous rock)
- several centimetres thick substrate
- Substitute materials that are porous on the inside (i.e. in places without O_2 supply). Such as zeolite or filter sludge.

The aquarium water is almost always already saturated with N_2 (due to water surface movement, skimming). Newly generated N_2 through denitrification therefore rises in the form of gas bubbles and escapes from the aquarium. This is how we get rid of the constantly accumulating nitrate.

Nitrate can be degraded but not adsorbed.

1.3.2 The phosphorus cycle

Phosphorus is constantly introduced into the aquarium by the aquarium inhabitants and feeding. Of a total of 3 compounds that are formed, two are stable in our aquariums and should be removed: Hydrogen phosphate (HPO_4) and (ortho)phosphate (PO_4).

Phosphate, unlike nitrate, can be precipitated with positively charged metal ions (e.g. iron, aluminium, etc) and alkaline earth metal ions (e.g. calcium).

Depending on where this happens, the precipitating phosphate is deposited:

- in the substrate or in the stone structure or
- in the aquarium water itself or
- on/in the adsorbent material (and can thus be removed)

Phosphates are also incorporated by algae and can be removed by harvesting the algae.

Phosphates dissolved in the water can be absorbed by **algae and corals**.
Phosphates precipitated in water can be absorbed by **bacteria and algae.**

This is also the reason why, despite undetectable phosphate concentration in the water (=dissolved phosphate), algae plagues can occur (precisely due to precipitated phosphates in the stone structure, substrate).

Phosphates can be adsorbed and incorporated into algae/corals, but **not easily degraded.**

1.3 Calcium carbonate and magnesium

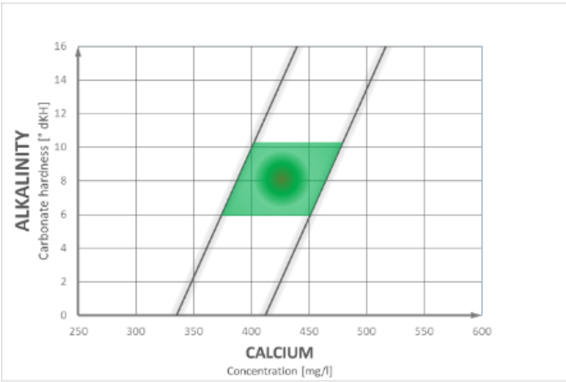
In addition to nutrients/food, many of the inhabitants of our aquariums also need components in the saltwater itself in order to thrive. We are talking about quantities and trace elements here.
In natural reefs, these are replenished again and again in huge quantities by freshly washed up salt water. They are thus available at all times.

In our aquariums it is completely different. Quantities and trace elements are CONSUMED there!
If we do not replenish them, the conditions will change. Animals that depend on them have a corresponding deficiency and will stop growing or degenerate.

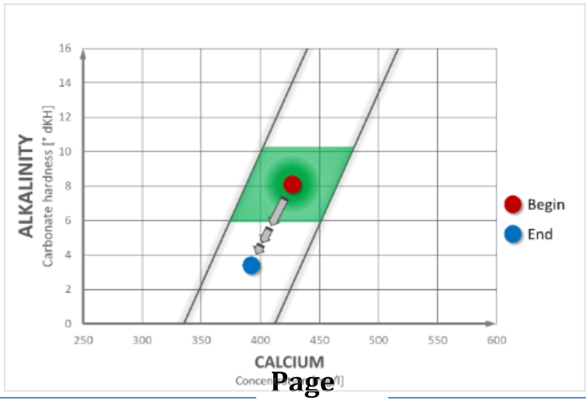
So we have to feed these elements, much like we have to feed fish.

The greatest need is for calcium carbonate. We measure the availability of calcium carbonate with 2 different measurements. The calcium concentration measurement and the alkalinity measurement (for the carbonates). Especially these two values should always occur in a certain ratio to each other. This is why we often speak of ion balance.

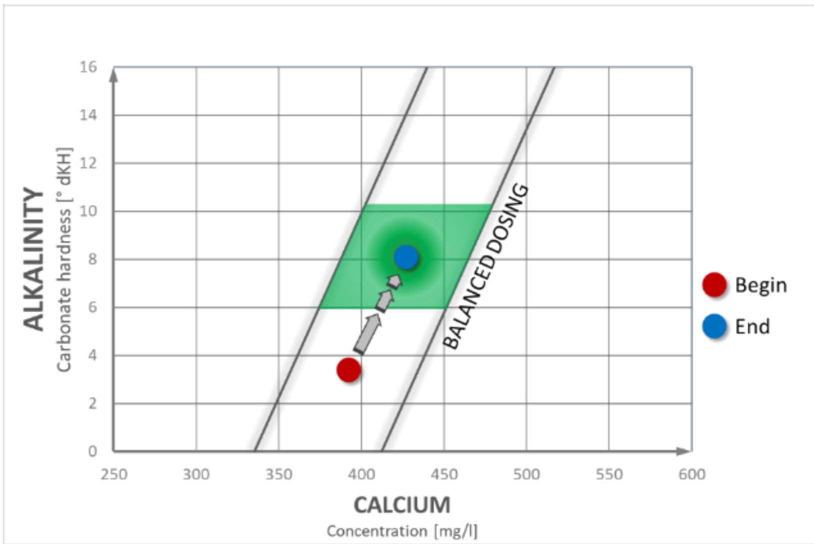
The following illustration shows the optimal range of these two water values. This can be "adjusted" in various ways (more details later).



However, it will not stop there, because calcium carbonate is CONSUMED. The special thing is that calcium and alkalinity are always consumed in the same ratio to each other in the optimal case, as they are in the middle of the optimal range. In the diagram this is represented by the "slope" (=angle) of the arrows. Incidentally, the two sloping auxiliary lines in the diagram show the same gradient. In addition: The speed of consumption depends on the stocking of your aquarium (many stony corals, for example, also mean high consumption).

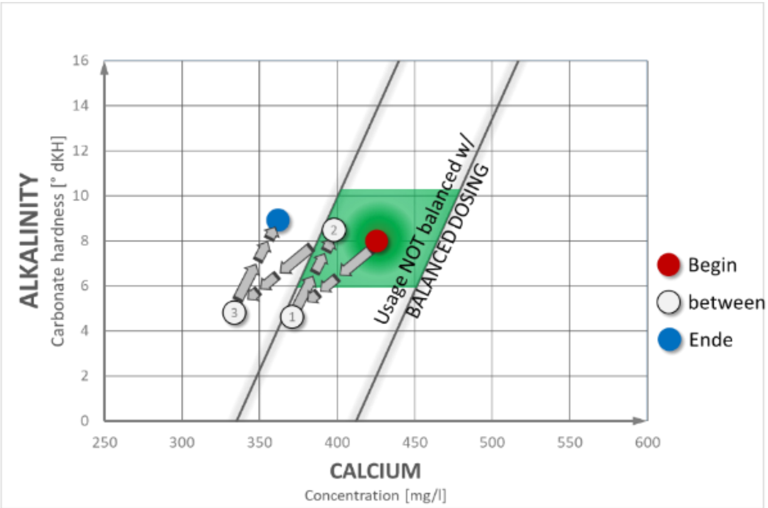


The consequence: We have to add calcium and carbonates again in the same amount. This is consequently called EQUALISING CONSUMPTION.
We should now also "re-supply" calcium and carbonates in the same proportion as they were "consumed" (slope!). Otherwise calcium vs alkalinity "might get out of balance".
The slope of the arrow of the addition should therefore be the same as the slope of the consumption.



So far so good. In reality, in a large number of saltwater aquariums, the consumption is NOT exactly in the predicted ratio! You can determine this by measurements, but you have no influence on the consumption itself.

The logical consequence: aquariums that DO NOT CONSUME Ca/alkalinity in a BALANCED RATIO (=slope of consumption deviates from the auxiliary lines...), you will get an unwanted shift of the ion balance Ca/alkalinity in the long run, if you would DOSE in a BALANCED way.

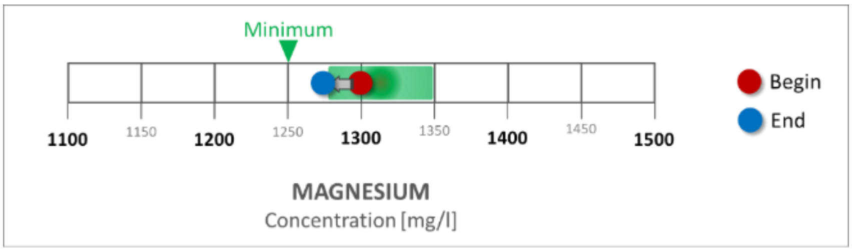


The solution is simple: with a CONSUMPTION-RELATED DOSAGE, you add both elements back in the same ratio in which they are consumed. We will explain how to do this later.

.... there is something else very important ....

To balance your aquarium's consumption of calcium carbonate, a suitable **magnesium concentration** is also required!

Magnesium prevents the precipitation of calcium carbonate in salt water. Calcium/carbonate concentrations as required are only possible at magnesium concentrations of 1250 mg/l and above.
If the Ca/alkalinity values in
your aquarium do not rise as desired despite the addition of large amounts of calcium and chemicals that increase carbonate hardness, it could very well be due to too low a magnesium concentration.



Also consider that magnesium is also consumed in our aquariums, and we have to compensate for this consumption (e.g. by dosing)!

Calcium, carbonate/alkalinity and magnesium are for good reason the Big-THREE of marine aquaristics.

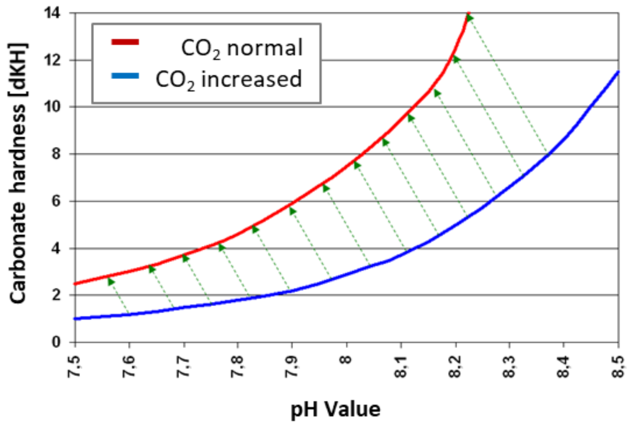
You will have to control these values in your reef aquarium!
For this it is necessary that you can measure these values yourself.

1.4 Relationship between pH value, alkalinity, and CO_2 concentration

This chapter is for those who want to know very precisely.
Skip it if you are in a hurry

There is a direct correlation between alkalinity pH and CO_2 concentration.
pH is a measure of the strength of the acidic or basic effect of a liquid. pH = 7 is called neutral, anything below that is acidic and anything above that is basic.
Alkalinity (or acid buffering capacity or acid binding capacity) is defined as the amount of acid necessary to change the pH to a certain degree. In seawater, mainly carbonate and hydrogen-carbonate alkalinity is relevant and determines >95% of the total alkalinity. Both are significantly influenced by the CO_2 concentration. CO_2 (carbon dioxide) is a colourless & odourless gas that has an acidic effect and therefore depresses the pH value.

The blue curve shows the relationship between pH and alkalinity/carbonate hardness. The CO_2 conce ation has a significant influence on this dependency. With increased CO_2 concentrat



The $C0_2$ concentration in the system fluctuates because there are *$C0_2$-feeding* and *$C0_2$-reducing* mechanisms in the aquarium itself and also in the environment.
This is exactly why the pH value in the aquarium also fluctuates.
In stable systems, the pH fluctuation should be 0,1 to max. 0,5.

<u>a) $C0_2$ supply</u>
The $C0_2$ concentration in the air is normally about 350ppm. However, in rooms and especially in the closed covers above aquariums, this can also increase significantly (~700ppm).
Reasons for this are e.g.:

- Newer buildings with good insulation
- Aquariums closed at the top
- Modern calcium reactors and $C0_2$ which then collects above the water surface

- Many nocturnal creatures and also algae produce CO_2 as a waste product of their metabolism.

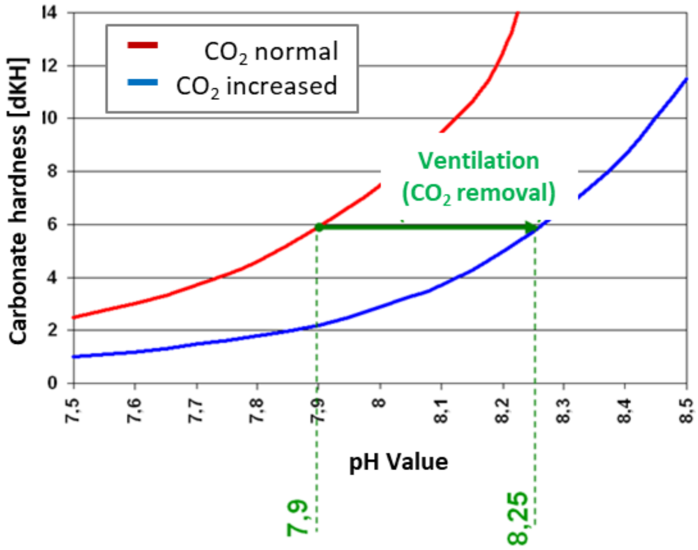
A 100ppm increase in $C0_2$ concentration reduces the pH value in the aquarium by approx. 0,09
A 700 ppm increase decreases pH by 0,25

<u>b) $C0_2$ degradation:</u> takes place during the day in aquaria through photosynthesis as already described. pH value, alkalinity and $C0_2$ concentration are directly related to each other.

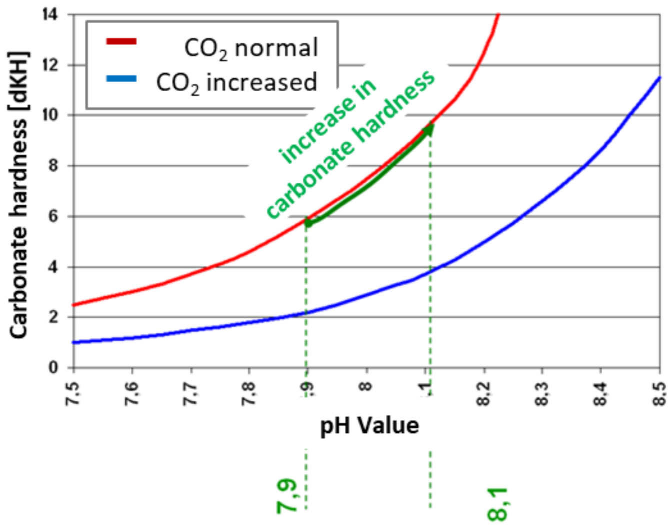
If one of the 3 parameters (alkalinity, CO_2 concentration or pH value) is changed and another is kept constant, this will result in a change of the third parameter. Similarly, changing 2 parameters at the same time could result in a greater change in the 3rd parameter.

Explanation based on a desired change in pH value in 2 ways

a) <u>Diagram: Correction</u> (here increase) of the pH value by reducing the C02 concentration.

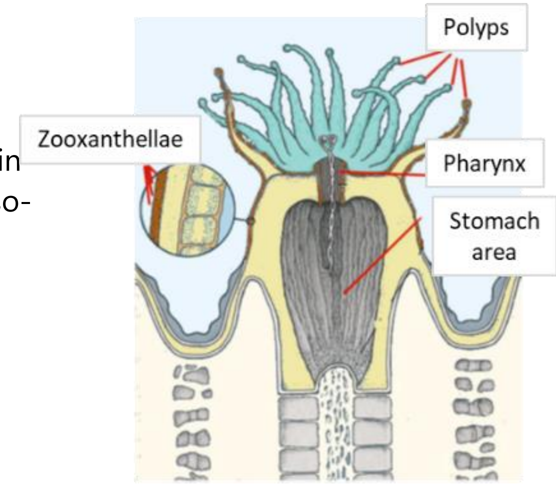


b) <u>Diagram: Correction</u> (here increase) of pH value by increasing alkalinity/carbonate hardness



1.5 Create optimal conditions for SPS

This topic is complex. However, once you have understood it, you are well on the way to taking the right measures to successfully maintain and propagate the "royal class of corals"!



original graphic: planet-wissen.de

Since corals, unlike plants, cannot photosynthesise, they have to take in food. They do this partly by ingesting plankton with tentacles. Most corals kept in the aquarium are also zooxanthell. This means that they let the outer skin of their polyps be colonised by special, unicellular algae, so-called zooxanthellae. The zooxanthellae are washed up (plant plankton). **Corals then live in symbiosis with the zooxanthellae**. However, it can also reject them again if necessary.
Unlike corals, zooxanthellae **absorb nutrients (NO_3, PO_4) in the** water. They use this to carry out **photosynthesis** and produce food in the form of **glucose** (sugar alcohols, fatty acids, amino acids, etc.) that can also be used by corals.

The coral now stimulates the zooxanthellae to release part of the food and feeds on **it itself**. During the recycling process that takes place with oxygen, CO_2 and water are produced, which the zooxanthellae need for their photosynthesis.
The coral can also provide nitrogen (ammonium) through processes of its own food utilisation. In the case of nutrient-poor conditions, the zooxanthellae can be supplied with nitrogen and phosphorus.

Growth (here especially that of the zooxanthellae) requires increased nitrogen to build up new proteins. **Corals can control** (i.e. deliberately reduce) the **growth and cell division of algae** by **limiting nitrogen**. The result is initially reduced growth of the zooxanthellae.
Due to good lighting, and thus good photosynthesis, the zooxanthellae continue to produce a lot of glucose, or "coral usable food". However, they cannot use this at the moment (due to the nitrogen limitation, see above), which is why more usable food is now being released to the coral.
The circle is closed. We have a real symbiosis that is controlled by the coral. By feeding the coral, we automatically feed the zooxanthellae.

When the aquarium water is too rich in nutrients.......
The zooxanthellae are perfectly "fertilised"
→ Reproduction of the zooxanthellae
→ Little or no usable food (glucose) is given to the coral.
→ The coral is "starving" - depending on the type, growth stagnates or the coral dies.

However, high nutrient values do not automatically mean poor growth of SPS. In this case, only the food supply by the zooxanthellae does not function optimally. However, depending on other conditions, e.g. plankton, the corals may still get enough food and show good growth.

Importance of a strong light source
As already described, the zooxanthellae convert light into food that can be used by the coral. The less light a coral has available, the more zooxanthellae it will incorporate in order to be nourished. However, the more zooxanthellae want to be fed, the less food can be delivered to the coral.
Especially with SPS/stone corals, →the brighter the better!

Zooxanthellae and the optics
Zooxanthellae are brownish. Therefore, the more zooxanthellae the polyps have, the darker the coral looks. Tastes differ, but most aquarists like colourful & bright corals better than brownish & dark ones.

Phosphate also has a negative effect on the formation of the calcium skeleton of stony corals. It is incorporated into the coral tissue and disrupts the crystal lattice there (so-called skeletal poison). The more phosphate is incorporated, the more susceptible the corals are to breakage. This can lead to 0-growth.

How do I get strong colours in SPS? The strong colours come from coloured proteins, which the coral can build up itself. However, it only does this if it gets enough food and does not have to spend its energy elsewhere for life support/growth.

For successful maintenance, growth and colourfulness, following parameters are best:

- **- Low nutrient system**
    - functioning symbiosis of coral & zooxanthellae
    - Especially presence of phosphate is critical ("cell poison" for the calcium skeleton)
    - Low nutrient ≠ Nutrient-free!
- Strong lighting
- Maintenance of calcium carbonate and magnesium concentration (separate chapter)
- **Separate food source** in aquarium water (optional, e.g. : plankton, amino acids, ...)

PART 2 - Water values, measuring kits & measuring methodology

The water chemistry in your saltwater aquarium is quite complex and is subject to constant change. You are dealing with a small bitop in which hundreds of processes running side by side (biological, chemical and physical ones).

You will almost certainly reach a point where these processes start to get out of hand. Then it is up to you to recognise this and then to take the right steps with caution (never in a hurry!). You can only do this if you recognise the signals.

Note: The possible loss of living beings is not only a financial aspect, but irresponsible towards the living beings.

Make sure that you are able to measure the most important parameters immediately and independently!

Do not rely exclusively on aquarium dealers measuring for you or doing external analyses like ICP as you will lose time needed for corrections on your aquarium waiting for these results.

2.1 A copy of natural seawater!

Let's first look at the proportions.......

Water quality in coral reefs

- In reefs we have a nearly unlimited amount of salt water.
  1.338.000.000.000.000.000.000 litres, or $1.33 * 10^{21}$ litres
- Vs this huge amount of water ONLY A FEW creatures live here.
- Due to the current, they are constantly supplied with fresh saltwater of the exact of exactly the same consistency.
  Impurities or differences in concentration are balanced out again.

Water quality in reef aquariums

Our aquariums are just an absolute "puddle" compared to the Ocean!
Many creatures live in a small space and ....
- ... pollute the water
- ... consume bulk elements

That's why it's a bit challenging to maintain good water values in our aquariums!
.... but don't worry, we will show you what is important and how it works!

Salinity: physical effect of "density“

In salt water, objects float upwards more easily/faster than in fresh water because the "density" (weight per volume) is higher than in fresh water due to the dissolved salt. Living organisms are used to the higher density and their organs (e.g. swim bladders in fish) are designed for this density.
It is your task to adjust and maintain the (physical) density of your aquariums water to the one of natural seawater.
Attention: A considerable amount of water evaporates in our aquariums every day. However, it is mainly fresh water that evaporates and most of the salt remains in the aquarium. If evaporated water is not refilled, the density increases and at least means stress for the animals. When "quickly refilling with fresh water", this density would be suddenly reduced again. So-called refilling systems immediately replace evaporated water with fresh water and keep the (physical) density constant.

Salt content: quantities + trace elements

The salts dissolved in salt water are important quantity/trace elements for certain living organisms.
(Calcium, carbonates, magnesium, strontium, etc). The higher the salt concentration, the higher the concentration of these elements in the water. By fluctuating the salt concentration, you also
cause fluctuations in the concentration of these trace elements. Another reason to keep the salt concentration as constant as possible!

Element	Name	Konzentration im Ozean	Element	Name	Konzentration im Ozean
		[mg/l]			[mg/l]
Cl	Chlor	19357,2	B	Bor	4,5
Na	Natrium	10782,2	O	Sauerstoff	2,8
Mg	Magnesium	1280,9	Si	Silicium	2,8
S	Schwefel	897,8	F	Fluor	1,3
Ca	Calcium	411,6	Ar	Argon	0,6
K	Kalium	398,8	NO3	Nitrat	0,4
Br	Brom	67,1	Li	Lithium	0,2
C	Kohlenstoff	27,0	Rb	Rubidium	0,1
N	Stickstoff	8,3	P	Phosphor	0,1
Sr	Strontium	7,8	I	Jod	0,1

$$\text{Concentration}_{\text{normalized@34,8psu}} = \text{Concentration}_{\text{measured}} \times \frac{34{,}8\ [\text{psu}]}{\text{Salinity}\ _{\text{measured}}\ [\text{psu}]}$$

Nutrients

In addition to salts, nutrients (e.g. nitrate and phosphate) are also dissolved in water.
These are produced by excretions and food residues, among other things.
Nutrients are urgently needed in small quantities, otherwise certain organisms will starve to death.
If these values increase too much in our aquariums, this can lead to problems. Keeping an eye on your nutrient levels is very important - .... The right balance is what counts!

Toxins (poisons)

Toxins in the water, e.g. heavy metals, should of course generally be avoided or strongly diluted.

2.2 Measuring the salt concentration

As a reef aquarist, you should be able to measure the salt concentration correctly

There are 3 different types of measuring instruments. All are well suited for measurement, but have significant differences in quality, readability and thus also accuracy.

Description	Refractometer	Spindle or pointer instruments (hydrometers)	Conductivity measurement/ Salinity Managers
ca price	 50.- ... 100.- €	  15.- ... 50€	 from €80
Measured variable/unit	**Refraction Fresh/salt water** Indication in [psu] or [‰]	Type-A) **Density** [g/cm³] Type-B) **Relative density** [-]	**Conductivity** (= el. Resistance $^{-1}$) [ms/cm]
Temperature compensation	Yes	No, must be measured separately to determine the correct salt content	Partially, depending on unit
Continuous measurement possible	No	No	Partially, depending on unit
Other - Disadvantage + Advantage	- Beware of cheap refractors from China, they are often inaccurate- refractors often need to be calibrated with reference solutions	- fragile, - Use of an additional vessel for measurement recommended	- Calibrate electrode from time to time - Only expensive devices are really good + Possibility of connection to aquarium computer

The measuring methods provide the results of the salinity in different units, which can only be converted into each other using software.

Definition "Salinity"

In reef aquaristics, a salt concentration (salinity in [psu]) of 34.8 is optimal.
34.8 [psu] is reached when exactly 34.8 grams of "pure salt" are dissolved per 1 kilo of water.

Attention: The amount of salt mixture to be added for [34.8 psu] to 1 litre is higher than 34.8 grams because the salt mixtures also contain other ingredients.

The thing with the water temperature when measuring...
Salinity is the only temperature-independent measured value. Measuring devices that measure density, relative weight/specific density and conductivity are usually temperature-dependent!

Reason: In the range relevant to us (20 ... 30°C), water has a decreasing density with increasing temperature, which is equivalent to slight expansion (increase in volume).

Temperature	Density of water at given temperature [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

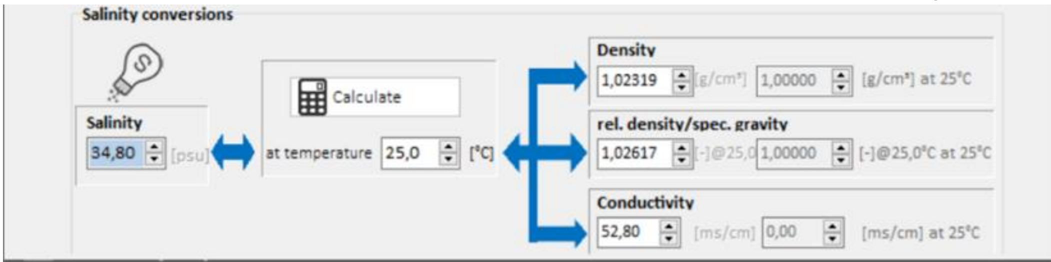
However, the amount of dissolved salts (salt crystals) remains the same.
The result is different displayed readings at different water temperatures.

For all other measurements of salt concentration except salinity in [psu]. You should always take the temperature into account when measuring, as it has a direct influence on the displayed result!

Measured value		at 20°C	at 25°C	at 30°C
Salinity	[psu] or [‰]	34,8	34,8	34,8
Density	[g/cm³]	1,0246	1,0232	1,0216
Specific gravity	[/]	1,0276	1,0262	1,0246
Conductance	[ms/cm]	47,67	52,80	58,05

Recommended: Convert salt concentration to salinity even if measured with instruments other than refractometers.

Tables for conversion to salinity can be found in the appendix:
(DensitySalinity→, Relative Density Salinity→, Conductance Density Salinity→) or in AquaCalculator.



2.2.1 Measuring with refractometers:

a) Use **refractometers calibrated for seawater**,
not those **calibrated** for NaCl (deviation approx. ~1 psu).

b) Refractometers should be regularly **adjusted** with **reference solution** (salt water of a precisely known salinity) in the range in which they are to be displayed/measured later. Adjustment with distilled/RO water to a salinity of 0,0 does not make sense!

c) Read the indicated **salinity in [psu] (**or [‰]).
Do NOT use the density value often given on refractors!
(It is not clear to me why manufacturers continue to print this value - it is misleading).

d) Use only refractors with Automatic Temperature Compensation (ATC).

2.2.2 Measuring with hydrometers:

a) Use **easily readable instruments** with the largest possible labelled measuring range.

b) Measure outside the aquarium. A separate, **transparent and slim vessel for measuring** is optimal (500ml, slim& tall measuring cylinder).

c) Keep the device **free of salt residues.** Otherwise, incorrect values will be displayed.

d) The water temperature during measurement influences the measurement result.

"Density" or "relative/specific density"?

Displayed measured values are different for devices calibrated in "density" and others calibrated in "relative density" (= printed).

	Density measurement	Measurement of specific gravity or relative density
Text/imprint	Density Density	Specific gravity or specific gravity Specific Gravity / SG
Unit	[g/cm³]	[-] Unitless!
Other	Temperature imprint 25/4°C or 25°C only	Temperature imprint 25/25°C These devices are often found in the US

2.2.3 Measuring with conductance meters:

a) Operate the equipment according to the operating instructions

b) Regularly **adjust (calibrate**) the measuring probe with **reference solution** (salt water of a precisely known salinity) in the range in which it is to be displayed/measured .

c) The temperature during measurement influences the measurement result.
High-quality devices offer automatic temperature compensation.

2.3 Measuring water values (concentrations)

As a reef aquarist, you should be able to measure the most important water the most important water values yourself at any time !

In your reef aquarium you will set certain water values. Sometimes you will want to react quickly to problems.

Determined measurement results must be correct / trustworthy!
If you do not put sufficient focus on this, it can happen that you take the wrong measures, that you take the wrong measures
based on incorrectly determined values.

This is especially important if you want to keep stony corals or other demanding animals.

There are good reasons not to blindly trust self-calculated readings.

- Test kit has insufficient quality, insufficient accuracy or a faulty batch was delivered
- Test kit was stored incorrectly
- Shelf life exceeded
- User error: Test not carried out exactly according to instructions
- User error: Test read incorrectly

Conclusion: We learn to measure properly!

2.3.1 Documentation of your water values, progress, disasters

You now know what is important, how you should measure and in what range your water values should be. Great!
You should note down the results of the measurements to be able to draw conclusions from them.

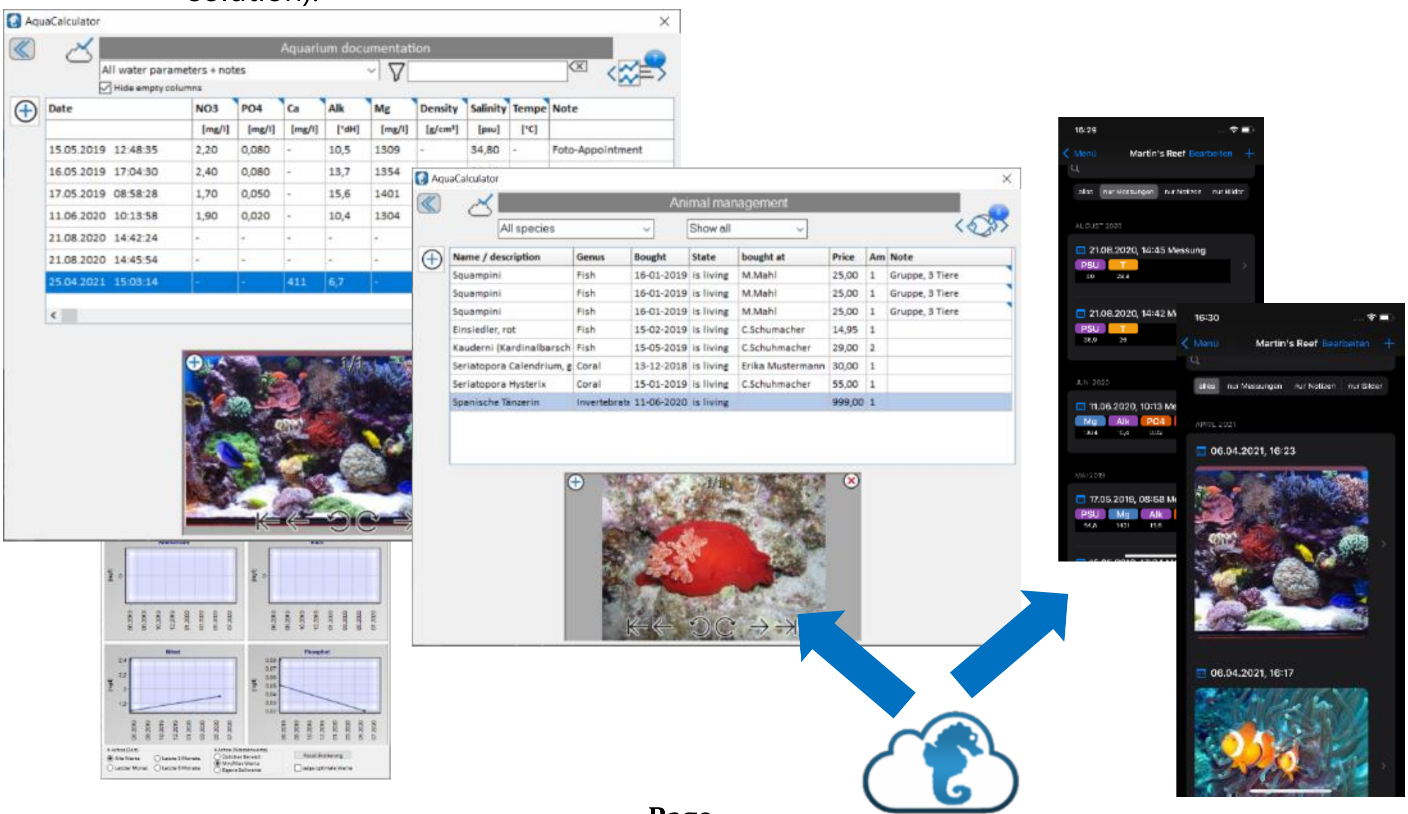
How did your values improve or worsen over time?
What made something better / worse?

- New chemicals or change in dosage)
- Water changes carried out?
- Conversions or maintenance measures carried out?
- New technology installed?
- Technical failures?
- Have you introduced any new fish or corals?

On the way to your dream aquarium
it is advantageous to have documentation
about your aquarium and ideally also about your animals.

Whether and how you do this is of course up to you.

The screenshots shown are of **AquaCalculator**'s aquarium documentation and animal management for **Windows** and **iOS** (synchronised via its own aCloud solution).



2.3.2 Reference solutions are just great!

> First, we calibrate "your own way of measuring" and the "test kits".
> With these you can achieve sufficiently accurate measuring results
> even with tests for home use (e.g.: droplet tests)!
> to achieve sufficiently accurate measuring results!

BEFORE using a (new) droplet test for the first time, you should check it on a so-called **reference solution.** A reference solution is a deliberately adjusted water sample whose values you can rely on.
It is supplied with high-quality test kits or you can buy it separately.

The set values of this water sample are usually at the optimal level of this water value (Ca, Mg, alkalinity), or at a favourable value to be able to check measured nutrient values (N3, PO4, Si).

FM Multi-Reference for testing the accuracy of several measurands (salinity, nitrate, phosphate, calcium, magnesium, carbonate hardness, potassium, strontium, ...)

Easy calibration of water test with reference solutions

1. With each of your water test kits, first measure a sample of the reference solution (not the aquarium water!).

2. a) If the measured value is identical to the value indicated for the stock solution
   → everything is fine.

   b) If this is not the case
   → determine the correction factor (CF) between stock solution /indicated value.

Ex:	indicated value Mg stock solution	1350 mg/l
	Measured value of stock solution	1300 mg/l
	→ CF = indicated value / measured value	(1350mg/l / 1300 mg/L = **1.038**)

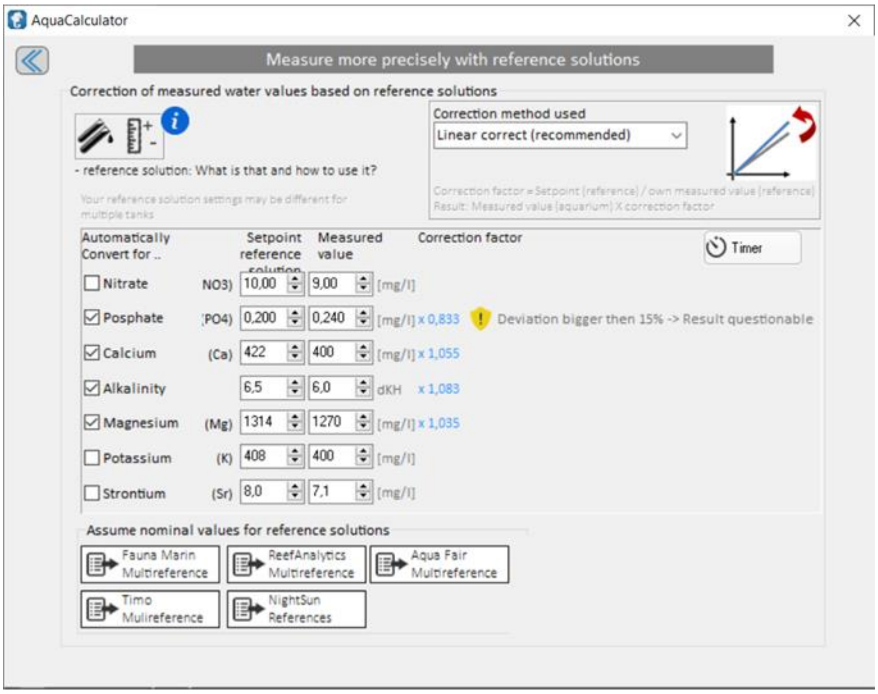
   Note the correction factor, preferably directly on the packaging or operating instructions of the water test. Now take this into account for each subsequent measurement of the aquarium water.

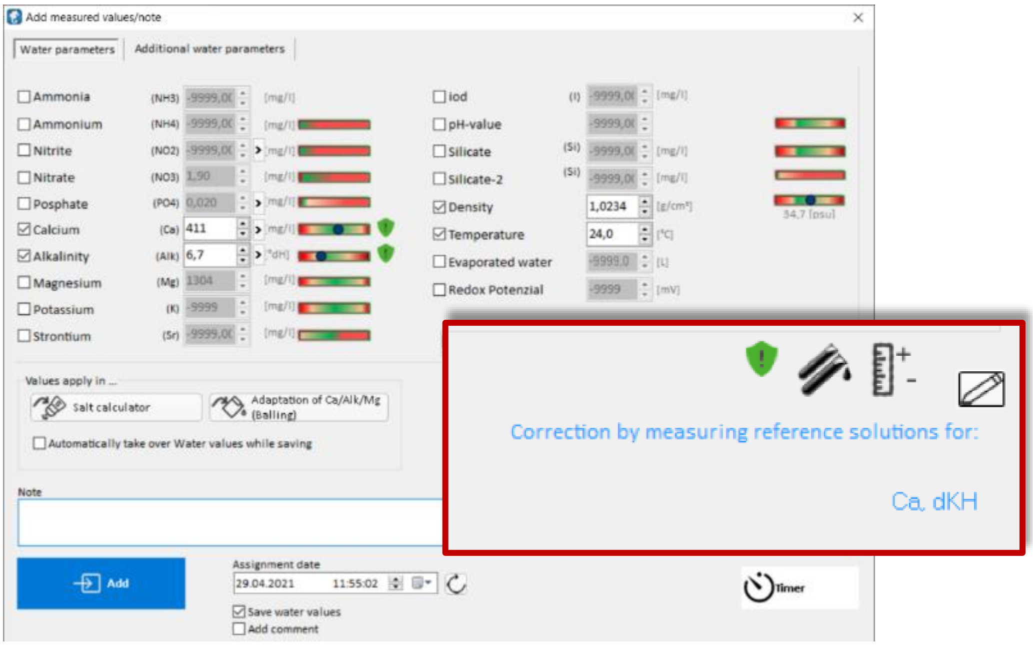
New measured value of aquarium water	1180 mg/l
Correction factor already determined	1,038
Corrected value aquarium water	1180 x 1.038 →1225 mg/l

3. If you use your test kits for a long time, you should repeat the calibration process.

Note: The method given here assumes that the test is able to check the selected water value at all and that the deviation is not too extreme. Similarly, non-linearity of the results is not taken into account. A good rule of thumb is to stop using the droplet test if the deviation is > 20% (warranty claim!).

If you document your water parameters with AquaCalculator,
the software will do the necessary conversion of your measured values with the correction factors. When saving the values, the "corrected" value is saved.





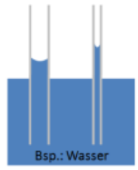
2.3.3 Checklist for measuring water values

- Do not use NoName tests
- Observe the manufacturer's instructions and the expiry date of the tests (some tests should be kept refrigerated).
- Only deliberately use tests suitable for salt water
- Measurements should always be taken at the same time of day, at the same water temperature and not shortly after feeding (the time of day is especially important for pH measurements!).
- Water to be tested should be clean and always taken from the same place in the aquarium
- Concentration measurements of elements dissolved in seawater (Ca/Mg/...) are only comparable if they were measured at the same salinity.
- Read off the amount of water to be taken from the syringe (not the vial/cuvette), as this is more accurate.
- Clean and dry syringes, cuvettes, measuring spoons and lids after use. Do not interchange between different measuring sets, otherwise chemicals may be carried over and measurement errors may occur. Good test sets therefore have different coloured syringes.
- Draw up chemicals and water sample without bubbles.
- In tests where an exact amount of reagent to be added (up to the colour change) must be determined using a small syringe, make sure that nothing sticks to the wall of the cuvette (falsification of the result).
- To avoid unintentional dripping from the dosage vial, either:
  a) Turn the vial away from the measuring vessel with neck downwards and let it drip out
  b) Open the vial upwards, press briefly on the vial (air escapes), release the pressure again when turning the vial (opening downwards).
- Work cleanly, no chemicals on fingers, etc.
  Also observe safety aspects (some reagents are *alkaline* or *acids*).
- Colour comparisons should ideally be made under natural light, but without direct sunlight. When taking measurements in the room, always use the same light source, ideally with as white a light spectrum as possible (twinkling incandescent light, for example, is not optimal).
  Always measure at the same time of day (daylight intensity) and when you are rested.
- Regularly determine the values of your source water (fresh water).
  This also applies to the use of any water treatment technology, as this could be defective or worn out.
- In general, no kind of iron should be added to the aquarium. Also no stainless steel, because even this corrodes in seawater. If possible, measuring electrodes should not be made of steel. Under no circumstances should they be made of copper or brass. Temperature sensors can be covered with foil or plastic, for example.

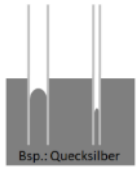
2.3.4 Tips for measuring with syringes, cuvettes and hydrometers

The surface tension of liquids causes the liquid level in smaller vessels or tubes to rise or fall. This "capillary effect" must be taken into account in some measuring procedures, e.g. when filling syringes, cuvettes, etc.

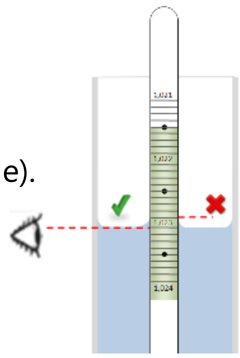
Capillary effect: When a thin tube (capillary) open at the top and bottom is immersed, the water level in it sinks OR rises. The thinner the capillary, the greater the effect.



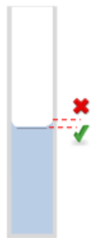
With normal liquids that wet the wall (water on glass or water on plastic), the liquid level in the tube rises and a downward curved surface is formed.
With liquids that do
not wet the surface (water on greased glass, mercury on glass, etc.) the exact opposite occurs. The liquid level drops and the surface curves upwards.



Reverse capillary effect: If you place an object in a liquid, exactly the opposite effect takes place. The surface of the liquid curves upwards around the object. This is exactly what one observes, for example, when inserting a hydrometer.

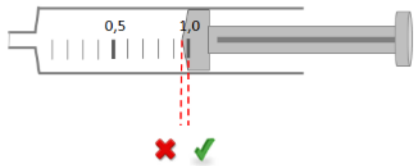


Reading hydrometers
Read the value at the water level, not the one at the top of the meniscus (bulge).
To do this, start your gaze from below and bring it closer to the water level.
When the base area, which at first appears elliptical, becomes a line
you read off the value.
Do not forget: Temperature measurement parallel to the reading is absolutely necessary



Cuvette reading
Proceed as with hydrometers, reading from below

Reading the filling quantity of a syringe
If the syringe is slightly arrow-shaped, read off the edge of the plunger.
This is not the case with all syringes. If in doubt, check the operating instructions of the test kit again.



Syringes with an attachment
The top of the syringe is used to empty the contents slowly.
It is normal that an air cushion is created inside the syringe when drawing up.
(Attachment was filled with air, which is then drawn into the syringe).
Always hold the syringe with the tip down. This causes the air to remain/collect at the top of the plunger. When the syringe is then emptied, the air cushion also empties again at the end.

2.3.5 Recommended test kits (home range)

There are many good water test kits available. We recommend the products of well-known manufacturers.

Recommended droplet tests

Water test for	Formula	Product/Manufacturer
Ammonia/ammonium	NH_3 NH_4^+	Tropic-Marin, RedSea
Nitrite	NO_2^-	Fauna Marin, Tropic-Marin, Salifert, RedSea, Sera, Tetra, JBL
Nitrate	NO_3^-	Fauna Marin, Tropic-Marin, Salifert, Visocolor Eco Machery Nagel
Phosphate	PO_4^{3-}	Fauna Marin, Row ,Red Sea, Salifert, Tropic-Marin,
Calcium	Ca	Salifert, Fauna Marin, Tropic-Marin, RedSea
Carbonate hardness	-	Fauna Marin, Tropic-Marin, RedSea
Magnesium	Mg	Salifert, Fauna Marin, Tropic-Marin
Potassium	K	Fauna Marin, Tropic Marin, Salifert
pH value	-	- All well-known manufacturers supply good test kits - do not use strip tests, as they are inaccurate.
Silicate	Si/SiO_2	Salifert, Tropic-Marin

Values in blue = test currently preferred by myself

My criteria for good water tests:

- Accuracy (Prio-1: Reproducibility, Prio-2: Deviation).
- Good readability
- Easy handling
- Price/performance ratio

2.4 Water tests from the laboratory (ICP-OES and IC-analyses)

Various major suppliers of seawater products are currently investing heavily in saltwater analytics and the corresponding laboratories/measuring equipment.

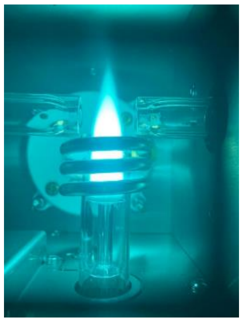
Aquarists thus have the advantage that practically ALL conceivable water parameters are determined. The measured values are given with the utmost precision, although the providers are currently still in the learning phase of evaluating the results.
Various providers offer a consulting package. Depending on the results, you will also receive a **specific detailed analysis with a recommendation of which parameters you should optimise and how this can be done**.
For aquarists who want to keep even the most difficult types of stony corals, this is a worthwhile service.

Brand new on the market since 09/2022: Using artificial intelligence, multiple available ICP results are evaluated **and possible diatom, cyano, dinoflagellate, filamentous algae, RTN, STN and parasite infestations are predicted in advance**.

This is how an ICP analysis works

1. Purchase of **ICP-OES test kit** (approx. 40€) or **ICP-OES +IC laboratory test kit** (approx. 100€ incl. advice). Included: Sample cups/tubes & plastic syringes for water sampling.
2. Taking a **water sample** from your own aquarium **Packing→+ shipping** to laboratory
3. Wait for analysis. Results and possible advice can be obtained by e-mail or web access.

Measuring method: [ICP-OES]



2.5 Important water parameters and frequency of measurements

Water value	Formula	Frequency of measurement
Water temperature		- Constant (exclude heating/cooling error)
Salt concentration		- When refilling - Before/after each water change - For control 2x / month
Ammonia (ammonium)	NH_3 (NH_{4+})	- to determine that the start-up phase is over - in the case of abnormalities in the aquarium, especially with fish
Nitrite	NO_{2-}	- to determine that the running-in phase is finished
Nitrate	NO_{3-}	- Initially 1x/week - 1x/month with stable running aquariums
Phosphate	$PO4_{3-}$	- Initially 1 x /week - 2 x month with stable running aquariums
Calcium	Ca	- initially 1 x /week - less frequently with known Ca consumption in the aquarium
Carbonate hardness/ Alkalinity	-	- initially 1 x /week - less frequently with known Ca consumption in the aquarium
Magnesium	Mg	- approx. 1x /month - less often if Mg consumption in the aquarium is known
pH value	-	Initially 1 x /week if aquarium stable, less frequently
Silicate	Si/SiO_2	- approx. 1 x /month, check the fresh water used before preparing salt water or refilling system

Notes:
Valid for aquariums with demanding animals/corals.

Depending on the stocking of the aquarium, not all values need to be checked and the measuring intervals may be less frequent. E.G.: For fish-only aquariums or insensitive soft corals.

For newly started aquariums, especially if you are still in the start-up phase, the water values are not yet meaningful. However, they should be checked and considered OK before adding fish and corals.

2.6 Recommended water values for reef aquariums

	Description /Formula	In reef aquariums - Recommended range - Optimum value	In natural seawater	Unit /Comment
General values	Water temperature	23,5 - 28,3 **24,0 – 26,0**	Depending on the area/season 23 .. 29	[°C]
	Salinity a) Salinity	33,0 - 36,0 **34,5 – 35,0**	34	[psu]
	b) Density @25°C	1,021 - 1,024 **1,0233**	1,0225 - 1,024	[g/cm³]
	c) specific gravity @25°C	1,024 - 1,027 **1,0263**	1,0255 - 1,027	[]
	d) Conductance @25°C	50,4 - 54,5 **53**	51,7 - 54,5	[ms/cm]
	Silicate Si	0,0 - 0,3 **0,0**	Open sea: 0 - 10 Coral reefs: 0,1 - 0,2	[mg/l]
	pH value	7,7 - 8,5 8,0	8,2	Max. Change day/night: 0.5
Nutrients	Ammonium NH4	0 - 0,1 **0**	0,0 - 0,1	[mg/l]
	Nitrite NO2	0 - 0,10 **0**	0,0001	[mg/l]
	Nitrate NO3	1 - 20 **1 – 8 (≠ 0 !)**	0,01 - 0,5	[mg/l]
	Phosphate PO4	0,05 - 0,5 **0,01 – 0,10 (≠ 0 !)**	0,001 - 0,1	[mg/l]
Set elements	Alkalinity @34.8 psu a) in carbonate hardness	5 - 10 **6-8**	6,5	[°dH]
	b) in mEq/l	1,8 - 3,6 **2,2-2,9**	2,3	[mEq/l]
	(c) in parts per million	90 - 180 **110-140**	116	[ppm]
	Calcium @34.8 psu Ca	360 - 480 **400 – 450**	420	[mg/l]
	Magnesium @34.8 psuMg	1100 - 1400 **1280 – 1350**	1280-1400	[mg/l]
Else.	**Potassium** @34.8 psu K	330 - 420 **380 (< 460!)**	398	[mg/l]
	Iodine J	Poorly measurable	0,06	[mg/l]
	Strontium @34.8 psu Stro	2 -10	7,8	[mg/l]

Recommended for reef aquariums with mixed stocking (fish, invertebrates, more demanding stony corals, etc). For less demanding animals/fish aquariums only, some parameters are not relevant.

2.8 Water treatment or tapwater?

You should only use tapwater if you are absolutely sure that it is free of any pollutants and will remain so. Investing in a solid water treatment system has already saved many aquarists from unpleasant and possibly more costly consequences.

Most water suppliers have water quality fluctuations depending on the season. Good quality at the moment does not necessarily mean that it will always remain so throughout the year!

If you still plan to use tapwater, it is recommended that you check the following water values available from your water supplier.

<u>Disadvantage:</u>

- Increased nutrient and silicate concentration (nitrate, phosphate and silica/silicate).
- Any heavy metals (iron, copper, lead, etc.), especially in old water pipes.
- High chlorine content, especially in summer months

<u>Harmless:</u>

- Calcium
- Sulphate
- Chloride (converted from chlorine)
- Sodium
- Carbonate hardness

.... Because it is already present in the seawater.

Other values given by the water supplier are of little importance.

Almost all commercially available salt mixtures are also designed to set optimal water parameters in the salt water prepared with them when using **treated water** (not tapwater).
If you use tapwater, the contents will be increased by the dose already contained in the initial water and may therefore be too high.

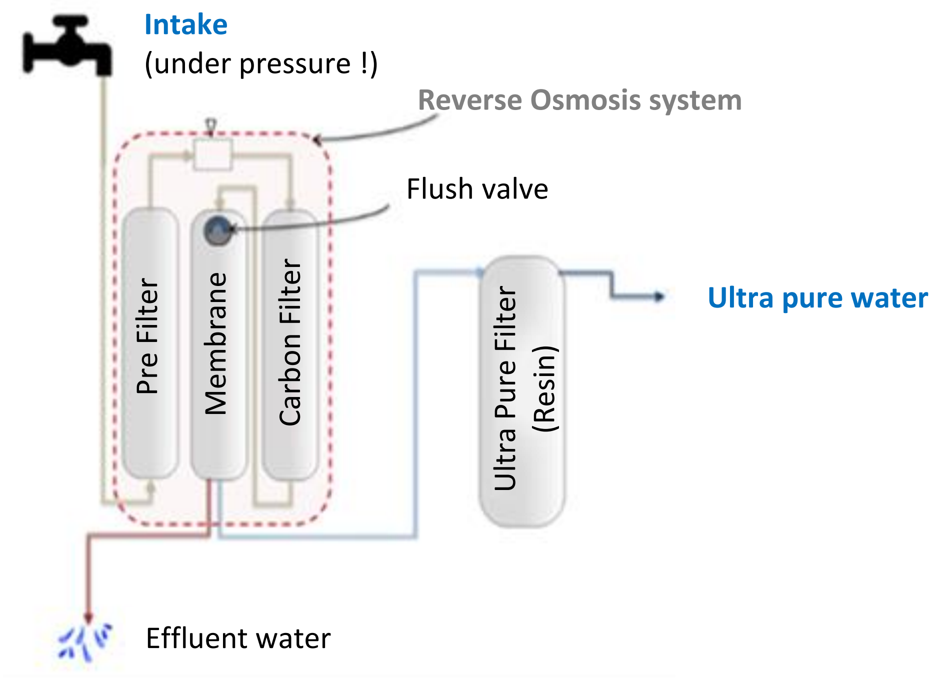
In most cases, the water quality is not sufficient for a clean-running seawater aquarium. The purchase of a suitable water treatment system is therefore actually part of the basic equipment. Only for small aquariums is it advisable to buy clean water instead of preparing it yourself. Acquisition costs and the space required for water treatment are often too high a hurdle. Check with the (aquarium) dealer that it has been produced using one of the suitable water treatment methods described here or buy distilled water from your DIY store.

The right water treatment

For up to medium-sized aquariums, a **reverse osmosis system** (= RO) with a downstream **ultra-pure water filter** is a relatively cost-effective and clean solution in terms of water quality. In addition to substances dissolved in water, heavy metals, etc., this also removes bacteria.

There are no major differences in the quality of osmosis systems. Purchase criteria are:

- Flow rate per day
- Size of the two filter containers (price when replacing vs. filter volume)
- Presence of a flush valve is →not a must, see later.



A reverse osmosis system already removes a large part of the unwanted substances in the source water. Exemplary here table of the retention rate (AquaCare TFC polyamide membrane)

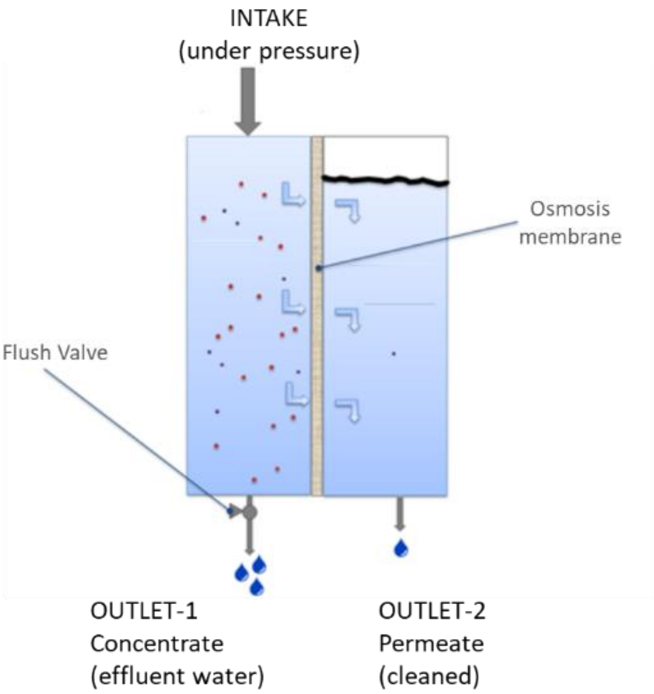
Element	Retention rate [%]	Element	Retention rate [%]	Element	Retention rate [%]
Aluminium	96-98	Cyanide	85-95	Nitrate	90-95
Ammonium	80-90	Iron	96-98	Phosphate	95-98
Bacteria	>99	Fluoride	92-95	Polyphosphate	96-98
Lead	95-98	Total hardness	93-97	o-Phosphate	96-98
Boron	50-70	Potassium	92-96	Mercury	94-97
Borat	30-50	Silica	80-90	Radioactivity (particulate)	93-97

Bromide	80-95	Copper	96-98	Silver	93-96
Cadmium	93-97	Magnesium	93-98	Silicon	92-95
Calcium	93-98	Manganese	96-98	Sulphate	96-98
Chloride	92-95	Sodium	92-89	Thiosulphate	96-98
Chromate	85-95	Nickel	96-98	Zinc	96-98

However, silicate is not removed sufficiently for MARINE aquaristics.

Only in ultrapure water filters silicates are completely bound/removed from the otherwise already very clean water. The water is pressed through a so-called mixed bed resin. The mixed-bed resin is a consumable material and must be disposed of from time to time and replaced by new material, depending on the amount of silicate still present in the water after the UOA.
The use of an ultrapure water filter without an upstream osmosis system is theoretically possible. However, since the resin has to bind not only the silicate but also all the other substances/pollutants in the initial water, it is quickly used up (not very sensible...).

Functional sketch of a reverse osmosis membrane.
In order to have as large a surface area as possible and thus good effectiveness, the membranes are in reality wound spirally around a so-called drain pipe.



- An osmosis membrane is not a sieve or particle filter in the original sense.
  This would not work with substances dissolved in water.
- The outlet water (water inlet) on the left-hand side of the diaphragm must be under pressure. The higher the pressure, the more effectively the system works. The usual line pressure of 3-4 bar is sufficient, but even higher pressures are optimal. If the water pressure is too low, a so-called booster pump can be connected upstream.

- Part of the water migrates, due to the different osmotic pressure (left vs. right chamber) through the membrane into the pressureless right chamber. Water molecules themselves penetrate the membrane very easily. Other, charged ions, however, do not, which creates the actual "filter effect".
  The "purified water" leaves the system (pressureless) as so-called permeate (outlet-1).
- The other part of the water initially remains in the left chamber, as the pressure here must be maintained. However, this water accumulates with dissolved impurities and must therefore be drained off. A valve is used for this purpose, which allows a certain amount of water to drain off without, however, reducing the pressure in this chamber too much.
  The water draining out through this valve now has a higher concentration of dissolved substances and is therefore called concentrate (in this FAQ I refer to it as "waste water" because it is easier to understand) and can either be disposed of or used for other, non-aquaristic purposes (Outlet-2).

Reverse osmosis systems should be cared for and maintained regularly. If you neglect, the permeate quantity will decrease and the concentrate quantity will increase.
You will also notice that the RO takes longer and longer to produce a certain amount of water. The indicated change intervals are only rough reference values, as they strongly depend on the amount of water treated with the RO.

Fine filter/pre-filter: Retains mechanical impurities, can thus become clogged.
The usual replacement interval is approx. every 2 years.

Active carbon filter: Replacement is recommended together with replacement of the fine filter.
The usual replacement interval is approx. every 2 years.
The carbon cartridge does usually not wear out.
If the water contains a lot of chlorine, this can damage the osmosis membrane.
Chlorine is also toxic to fish. The activated carbon filter converts chlorine into harmless chloride. However, the carbon filter can only do this for a a certain amount of chlorine before this function is exhausted.
→ frequent change intervals if there is "a lot of chlorine in the water".

Osmosis membrane: As a rule, this does not wear out! Some aquarists recommend "rinsing" every 2 weeks for about 5 minutes. The increased flow of water past the membrane is supposed to particles are washed away. I do not think this is necessary.
If, however, the function of the pre-filter (fine filter, carbon) was insufficient, the membrane can also be so heavily clogged or abraded that it no longer functions cleanly. (poor retention rate or poor concentrate to permeate ratio) and must then be replaced.

This is how you check the function of an osmosis system:

- Conductance of the permeate ≤ 5% vs conductance of the tap water

- KH test of the permeate test has very low values (0 - max 2 °dH)

- The pH value is not influenced by the osmosis system.
  It should be around 6.5 to 7.

- Silicate concentration may still be present after RO, but after passing through ultrapure water filter, it should be 0 mg/L

PART 3 - Effects of the ingredients of seawater

3.1 Salt concentration

Most animals adapt well to the salt concentration, which is why the recommended range covers a relatively wide range. Seawater aquariums can be successfully operated at both the upper and lower end of the recommendation. There are large differences in salinity between areas of origin such as the Pacific (salinity = 34) and the Red Sea (salinity=41).
Some aquarists keep fish and reef aquariums at deliberately low salinity levels as this reduces germs and pathogens. For the animals, however, this is an unnatural condition, which means stress.
More critical than too high/low salinity are strong fluctuations. These can occur in several ways:

- Relocating or repositioning of inhabitants from other aquariums
- Evaporated water is not balanced out
- too much evaporated water is added (e.g. in case of defective level control)

Various types of shrimp, but also anemones and other lower animals, are particularly susceptible to stronger fluctuations.

When the salt content changes, the quantities and trace elements (also salts) contained in the salts are automatically affected.

Larger deviations should not be corrected too quickly (~1psu distributed over 1 day).

3.2 Water temperature

If the temperature of a MARINE aquarium is not in the correct range, this will initially have the following effects:

- With increasing temperature, the basal metabolic rate of the animals increases.
  As a consequence, they consume more oxygen, CO_2, nutrients, calcium and alkalinity.
  This often increases the speed of growth but also the amount of excretions.

- Temperature has an influence on the solubility of some gases.
  Oxygen and CO_2, for example, dissolve more poorly at high temperatures than at low temperatures.

- Fish and corals, as in nature, are not very sensitive to temperature fluctuations. For anemones, however, the temperature should be adjusted slowly.

The recommended temperatures are in a range that should be relatively easy to maintain. An average temperature of approx. 24.0-26.0°C is to be aimed for. This has the advantage that, in the event of a power failure, the aquarium will not get *too* cold too quickly in winter and will not overheat too quickly in summer.

3.3 pH value

The pH value indicates how "acidic" or "alkaline" the water is. It is therefore one of the most important values for the well-being of our aquarium inhabitants. It should be kept in mind and checked more frequently as it can be an indicator of developing problems.
For this reason, new animals should be acclimatised to the aquarium slowly. Negative effects of a deviating pH value are stress or poorer general condition.

3.4 Calcium carbonate

Many corals need calcium carbonates to build their skeletons. They use bicarbonates which they convert into carbonate. The provision of a suitable calcium carbonate concentration in the water is also one of the most important parameters for the successful keeping of Tridacna mussels and calcareous algae.
A good indicator for a correct calcium carbonate concentration is therefore also the growth of calcareous red algae.

Due to the constant consumption of corals and other organisms, the calcium carbonate concentration decreases and must therefore be artificially adjusted.

Alkalinity
Alkalinity (or carbonate hardness) in saltwater is the amount of acid necessary to reach a pH value of 4.3. The higher the alkalinity, the higher the acid binding capacity, which ensures a more stable pH value.
Too high alkalinity, however, leads to calcium precipitation due to abiotic precipitation of calcium carbonate. These build up in the aquarium and especially on various objects (flow pumps, heating, glass, ...) and also waste calcium, which we also have to supply to the aquarium.

Calcium
A sufficiently high calcium concentration is needed for the formation of calcium carbonate. However, the reverse conclusion "the more calcium the better" does not apply under any circumstances, as this would otherwise precipitate in our aquariums in the form of unwanted deposits.

3.5 Magnesium

The amount of calcium and carbonates dissolved in salt water is so high that it would normally precipitate it, i.e. form solid lime. Magnesium prevents this. It effectively blocks the surface of calcium carbonate crystals so that they cannot continue to grow.

Soft corals and calcareous algae consume magnesium by incorporating it into their skeletons or spicules. To maintain the balance described above, it is therefore sometimes necessary to keep magnesium at a constant level through appropriate dosing.
If too much magnesium is added, it precipitates as magnesium calcium.

Attention: Some methods neglect the magnesium concentration (e.g. lime water supply, lime reactor). In this case, you should maintain Mg by dosing.

3.6 Potassium

K

Potassium is the sixth most abundant element in natural seawater (~400mg/l). However, it is toxic to sensitive animals even at low overdoses (> 460 mg/l)!

The tests available in aquarium specialist shops did not necessarily
run with sufficient measuring accuracy (comparison with reference solutions and routine required!). As the positive effects of additional potassium dosing are not very strong, additional dosing is only recommended for advanced fishers and only under constant control of the water values.

3.7 Strontium

Sr

Strontium consumers are mainly stony corals. However, it is still not clear whether strontium is only incorporated into the coral skeleton because it happens to fit well into the aragonite crystal, the basic material of the coral skeleton, or whether strontium actually has a positive effect on coral growth.

3.8 Iodine

Iodine occurs in natural seawater in many organic and inorganic forms. Interactions and concentration cycles have not yet been conclusively researched.

Consumers of iodine are micro- and macroalgae. Iodine also has a positive effect on the well-being of some invertebrates such as sea urchins and xenia, as well as on the moulting behaviour of crustaceans.

In aquaria, the dosage of iodine used to be rather controversial, but is now advocated. However, iodine is volatile and must be constantly replenished.

3.9 Ammonia

The toxic ammonia is in a dynamic equilibrium with the non-toxic
non-toxic ammonium (NH_4^+). The higher the pH value, the more ammonium is converted into ammonia. Ammonia (NH_3) is constantly excreted by most living organisms in the Marine aquarium during the metabolic process.

Amonia is highly toxic for most living organisms (animals > 0.2 mg/l, plant plankton >0.1mg/l). In fish, respiration and other vital functions are blocked.

Other organisms such as macroalgae (e.g.: various Caulerpa species) and special bacteria fortunately have ammonia on their menu.

In well-worn aquariums there are always enough bacteria (ammonificants) to convert ammonia into nitrite. Nitrite is far less toxic to fish than ammonia.

Increased ammonia concentrations should only occur if:

a) The aquarium is in the run-in phase.
b) New live rock is being added
c) A particularly effective filter technique, e.g. zeolites, is settled too quickly.
d) Additional live sand is added freshly.

3.10 Nitrite

Nitrite is much less toxic for fish in a Marine aquarium than ammonia and healthy inhabitants usually survive even high nitrite concentrations without harm.
Signs of excessive nitrite levels in fish are *rapid breathing*, *hanging on the water surface despite sufficient aquarium aeration,* and even *orientation problems* (animals swaying in the water, turning on their own axis).

Attention: with increased nitrite concentration there is a risk that the even more toxic ammonia is also present in the aquarium.

It is important to measure nitrite during the start-up phase of the aquarium: as the ammonium-degrading bacteria first multiply and then the nitrite-degrading bacteria, an increased nitrite value (nitrite peak) occurs first. The subsequent reduction of the nitrite value, which falls to 0.1 mg/L or below, indicates that enough nitrite-degrading bacteria have formed. At this point at the earliest, you should carefully begin to introduce the first animals.

In well established aquariums there are always enough other bacteria (nitrificants) to convert accumulated nitrite into nitrate (for details see nitrogen cycle).

3.11 Nitrate

An increased nitrate concentration is not toxic for fish, but leads to increased susceptibility to diseases. Increased nitrate concentration leads to:

- -increased algae growth
- -significantly increased proliferation of zooxanthellae
  (sometimes to an extent that stony corals reduce other growth as a result)
- - Increased likelihood of dinoflagellates occurring or other Marine aquarium diseases.

Many aquarists swear by a nitrate concentration just above the detection limit. The aim is better growth of some corals. Short polyp stony corals (SPS) also get a much brighter colouration, which makes some colour varieties more attractive. However, aquariums without any nitrate at all are not the optimum either.

3.12 Phosphate

The phosphate concentration should not be too high, but optimally not too low either.
> 0 mg/l but still < 0.05 mg/l. This is due to the following two principles of action:

Too high a phosphate concentration: The build-up of lime is chemically inhibited (partially prevented). This in turn can lead to restricted growth of all organisms that build calcium into their skeletons. Excessive phosphate concentrations have an inhibitory effect on the growth of stony corals and calcareous algae. Stony corals produce more zooxanthellae, which consume a large proportion of the nutrients. The coral itself thus receives fewer nutrients and "starves". In addition, the brown colouring (zooxanthellae are usually brown) is usually perceived as unattractive.
Corals can be surprisingly flexible. Many species get used to increased phosphate levels.

Too low phosphate concentration: The growth of normal algae as well as symbiotic algae of corals (but not calcareous algae) is disturbed by insufficient concentration of this nu
Below a concentration of 0.03 (<0.03 mg/l), the formation of many types of plant pl
disturbed (phytoplankton).

It is even more **important that the PO4** concentration does not **change too quickly.**
Stony corals (SPS) in particular react extremely sensitively to too rapid a lowering with almost lightning-like death of their zooxanthellae/polyps (RTN = rapid tissue necrosis).
Phosphate can enter the aquarium in several ways. For example, through traces of phosphate in food (especially in frozen food), tapwater, added additives or, to some extent, in seawater salts. Phosphate is also produced by dead organic material such as algae, dead animals and food remains. However, unsuitable activated carbon and unsuitable coral rubble from a calcium reactor can also be a possible source of PO4.
If no measures are taken to reduce phosphate, the phosphate concentration in aquariums usually increases. This occurs due to deposits on the substrate, reef construction, etc.

3.13 Silicate

Silicate is usually introduced into the aquarium through refill water and accumulates in substrate, stones, etc. This is exactly the main problem, because difficulties often only occur with a time lag and are not initially attributed to the slowly increasing silicate content.

Increased silicate content leads to the appearance of the undesirable and unsightly diatoms. Other pests often spread in this environment.

Since the consequences can be unpleasant and annoying, i recommend to keep the source water used for the aquarium completely silicate-free.
Keep an eye on the silicate concentration in the aquarium (measure or watch for the appearance of diatoms) and optimise your water treatment if necessary.

3.14 Other important elements?

Congratulations: If you have these values under control up to here, you can maintain aquariums that represent top condition for 99% of aquarists!

Especially for the care of a few VERY demanding species of stony corals, it is advisable to go one step further and also pay specific attention to other trace elements. It is also important to "bring certain conditions into an optimal range".
For this, however, you are dependent on regular ICP analyses as you cannot measure the concentrations of these elements yourself.

We refer to the extensive knowledge database of

PART 4 – Adjusting the salt concentration

4.1 Sea salt mixtures for aquariums

<u>Marine aquarium salt mixtures</u>
The concentrations of the quantity/trace elements are usually very close to those of natural salt water. These mixtures are suitable for all aquariums where the quantity elements (Ca, Alk and Mg) and possibly also trace elements are balanced anyway by dosing or another method, or for fish-only aquariums.

<u>Special reef aquarium salt mixtures are</u>
somewhat more expensive salt mixtures and have an increased concentration of quantities/trace elements. These can be an option for regular water changes and less demanding aquariums (few/no stony corals) to have to "dose" less to noth

There are also "complete saltwater" or "saltwater concentrates that still need to be mixed with water". The costs are usually excessive due to high transport costs.

All these salt mixtures are very suitable for marine aquariums. Use those that come as close as possible to the water values you are aiming for. The main difference between more expensive products and cheaper ones is that they are less polluted.

In any case, use special seawater aquarium salt mixtures,
Never use table salt, road salt or similar.

The amount of salt required depends on various factors

a. The salt concentration you want
b. The total water volume of your aquarium or
the desired amount to be changed during a water change
c. The amount of salt/litre required to achieve a certain salt concentration,
depending on the sea salt mixture used.

As a guideline, a salinity of approx. 34.8 [psu] should be set and maintained. This corresponds to the salt concentration in many tropical reefs.

The amount of salt you need to add to 1 litre to get 34.8 [psu] salinity varies from manufacturer to manufacturer and the type of salt!

It is usually **between 38 and 41 grams of salt per litre of fresh water.**
This is more than the target 34.8 [psu] would suggest. The reason for this is that all salts contain certain additional components that reduce the pure salt concentration.

5.3 Salt quantity calculation

Various manufacturers recommend: "first add a certain amount of salt", then "measure the salt concentration" and depending on the measured value "add more salt".
Of course, this is not very practical/simple.
Likewise, the concentrations of Ca, Alk, and Mg contained in the salt mixtures are often not related to a certain salinity and are therefore difficult to compare.

The most convenient and safest way to adjust the salt concentration is to use **AquaCalculator** and an accurate **household scale** to measure the required amount of sea salt mixture. You will also get an overview of the most important parameters of the salt mixtures such as Ca, Alk and Mg concentrations.

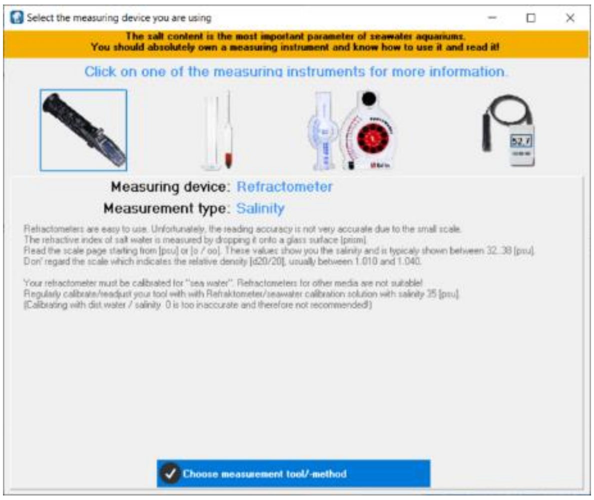
Simply select the sea salt mixture you use and what you want to do.
The programme calculates the exact dosage you need using integrated measurement data of practically all salt mixtures available on the market and tells you how to proceed. (We have been procuring/measuring samples of all available sea salt mixtures for several years).

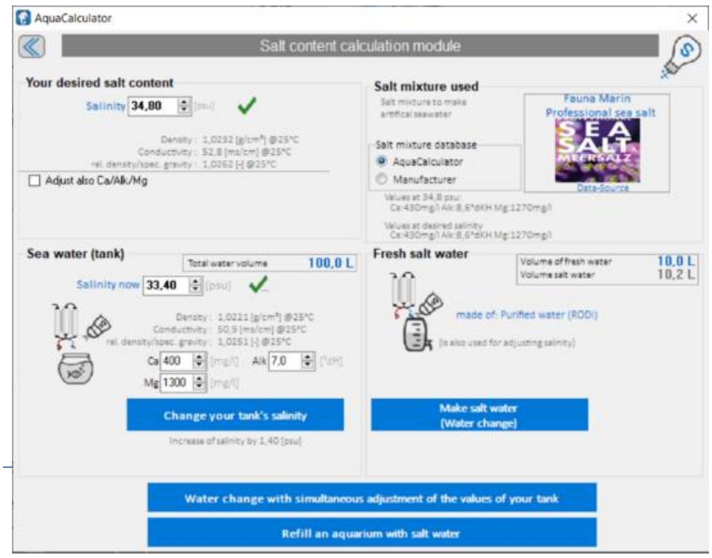
.... No matter which brass instrument you use for the salt concentration

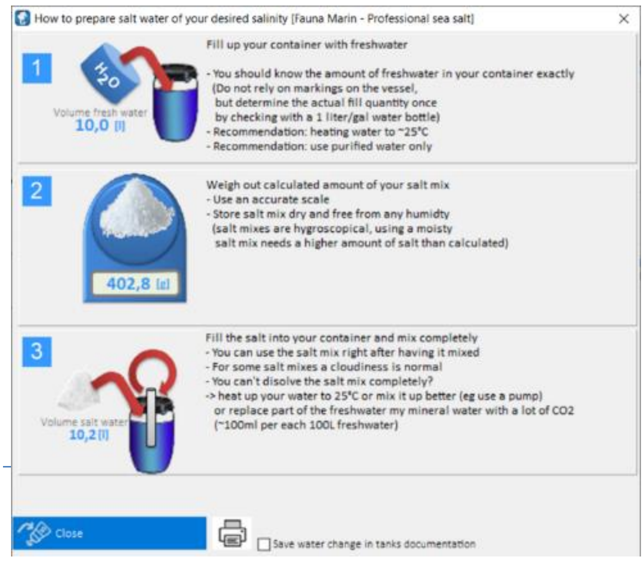
....whether you want to mix fresh salt water or check your salinity in the aquarium.

.... Accurate results by simply weighing the salt
.... on request incl. Ca, Alk and Mg adjustment

.... Explained simply and understandably







5.4 Water changes: The remedy of choice for all cases?

A water change is the replacement of a certain amount of "aquarium water" with "fresh salt water which has been prepared, for example, from a sea salt mixture.

There are various good reasons for carrying out water changes in reef aquariums:

- **Supply of** depleted **minerals, nutrients or trace elements**
- **Diluting pollutants or toxins** that have either been accidentally introduced into the system or are caused by processes or animals in the aquarium.
- **Suctioning** off dirt, algae, food remains or other undesirable things in the aquarium.
- Correcting too low/high **salt concentration** during WW

However, water changes only make sense if the **newly supplied water corresponds better to** the **optimum condition than the replaced water**! The following must therefore be observed

- The source water used should not contain any impurities.
  (Use of treated water is recommended)
- Use salt mixtures that come as close as possible to the desired state of the water values, especially the quantity elements calcium, magnesium and alkalinity.
- Check the actual salt concentration of the change water before addition
- In emergencies, water changes of >30% are also possible and make sense
  (e.g. in cases of poisoning).

How often/extensively should WW be done?

The reasons for water changes are different for each system. A generally valid answer to questions about "WHEN? ", "HOW OFTEN? " and "HOW MUCH? " does not exist.

In the following we will give you some hints on how to find out the "best fitting" water change strategy for your aquarium and needs.

5.4.a Water change for dilution of toxins/pollutants

Now and then toxins or other pollutants are accidentally introduced into the aquarium. These should be removed as quickly as possible, but also in a way that is compatible with the aquarium inhabitants, and possibly completely.

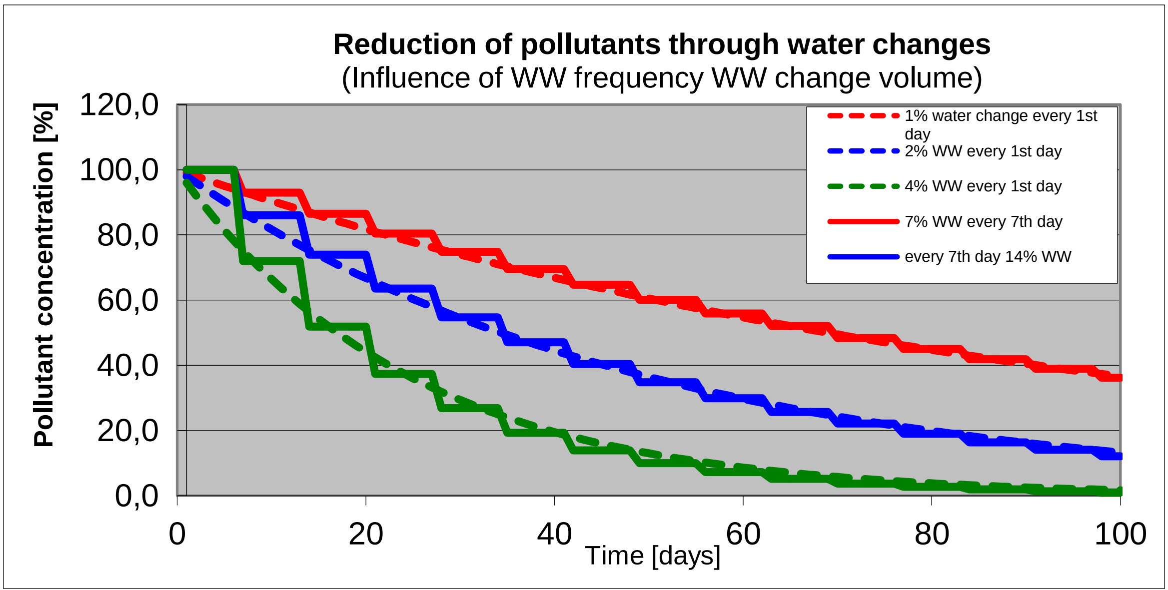
Depending on the costs, you should decide whether you want to remove the pollutants through filters or adsorbers or whether you want to do this through water changes.

The following graph shows the following relationship:

- One-time introduction of a pollutant (which is not subsequently introduced further). At that time, the pollutant has a concentration "X" which is indicated as 100%.
- Water changes with rather low (red), medium (blue) as well as high change quantity (green).
  Solid lines: "weekly", dashed lines: "daily" water changes
  1% per day corresponds to the same volume as 7% per week; 2% per day -> 14% per week

Result:

- The higher the exchange rate, the faster the pollutant is degraded.
  ... logical (red, blue, green)
- The concentration of pollutants is reduced relatively quickly at the beginning and then more and more slowly. Cause: An increasingly larger part of the fresh water is removed again after the second wash.
- Fewer but frequent water changes are somewhat more effective



5.4.b Water changes to reduce nutrients

(e.g.: with constant nutrient input)

In contrast to before, nutrients are usually continuously produced in the aquarium and are not sufficiently are not sufficiently degraded by the aquarium biology and filtration. A typical example
example of this would be a aquarium with a large fish population, large amounts of food and under- oror incorrectly dimensioned filtration. Such systems produce more nutrients than are degraded. The result is a constant increase in nutrients, which can lead to the stress of the aquarium inhabitants and even to the death of animals.

Generally, in this case, one should first look for the causes and try to eliminate them or counteract them with improved technology.
But you can also get a grip on this by changing the water. One advantage of water changes is that you can react very quickly. However, consider the effort and the costs.

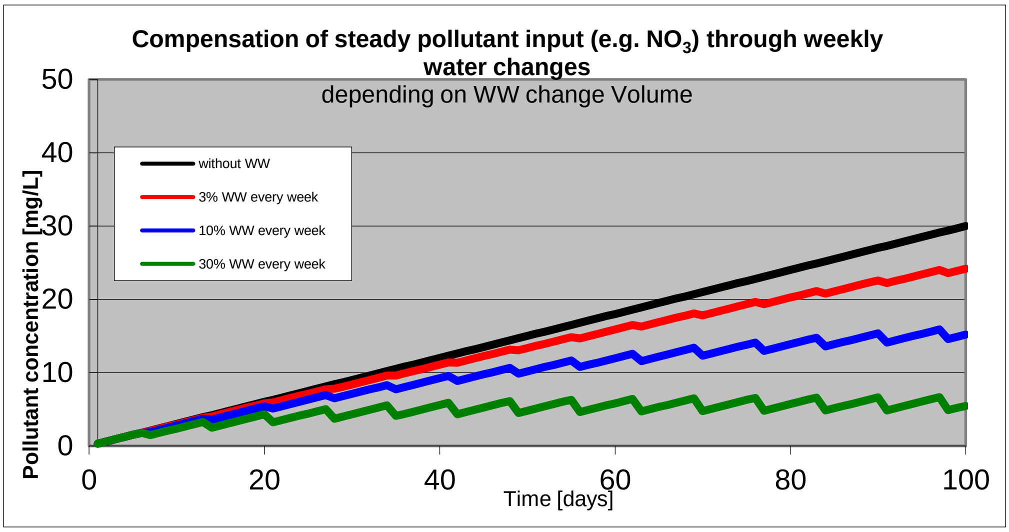
The following graph shows the interaction between pollutant input and reduction through WW:

- Continuous introduction of a pollutant (here No3)
  The NO_3 concentration increases in the given example: by 0.3 mg/l per day.

- The graph again shows WW with low, medium and high change (red, green, blue)
  and in comparison what happens when there is no WW (black line).

Result: Depending on the level of pollutant input, this can only be regulated by massive WW!

- green: ok, settles at 5mg/L
- blue: settles in the already borderline range
- red: too little reduction, concentration of pollutants is constantly increasing at a slightly slower rate.



Ca A Mg Tr

5.4.c Water changes to increase the concentration of bulk/trace elements

Something completely different is the deliberate increase in concentration of bulk elements through WW such as Ca, Mg and alkalinity (KH) as well as other desired trace elements, because these should be deliberately added to the system again and again.

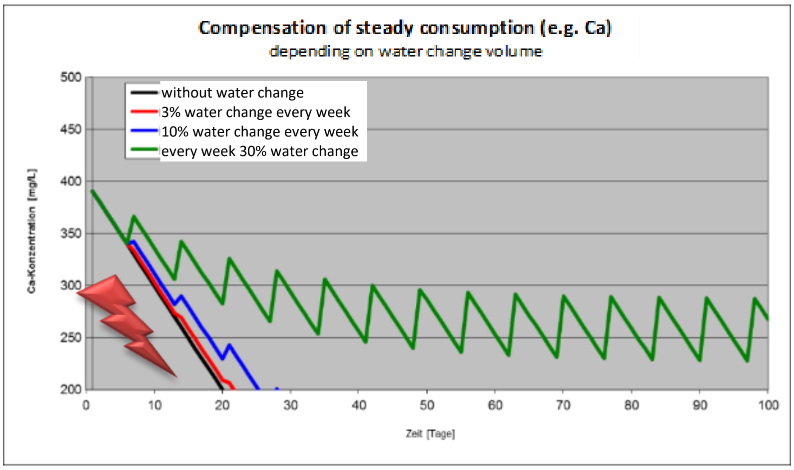
Consumption varies greatly depending on the aquarium set-up and stocking. Consumption can also change. Rock coral aquariums, for example, have a much higher consumption and also demands than predominantly fish aquariums.

The main influencing parameters from which you can recognise whether water changes are a suitable strategy for you to adjust the quantity elements are:

Brought concentration of bulk elements by sea salt mixture
Levels of bulk elements you are aiming for
Determined "consumption" (Ca, Alk, Mg) and size of your aquarium

If the concentration of the quantity elements (Ca, Alk, Mg) of a salt solution is below your target value, WW is even counterproductive, as it reduces the target concentration!

The following diagram shows the course of Ca during water changes and simultaneous consumption. Attention: The diagram is purely hypothetical. In reality, no Ca consumption to 0.0 mg/l would take place in any aquarium, because the Ca-consuming organisms would die or at least the consumption would come to a standstill.



Balancing the Ca, alkalinity consumption by changing the water
is only possible in aquariums with low consumption.
If you have a lot of stony corals, you should use an alternative method!

PART 5 - Alkalinity, Ca, Magnesium and Trace Elements

Every functioning seawater aquarium CONSUMES above all the bulk elements calcium, alkalinity and additionally some magnesium.... the "Big-Three". In addition, our aquariums also consume other elements that occur in lower concentrations in natural seawater/trace elements.
Besides the possibility to adjust the Big Three by water changes, there are 3 different systems to adjust Ca, Alk and Mg and to balance the consumption of our aquariums.
You are spoilt for choice as to which system you use.... Possibly even a combination of several systems. Over time, the systems have developed in the following order.

- **Lime water**
  A solution of a simple chemical + water is added to the aquarium and provides calcium carbonate. Unfortunately, however, only in small quantities as the solution cannot be highly concentrated.

- **Calcium Reactor**
  Coral fragments consisting of calcium carbonate are dissolved
  in the acidic environment of a calcium reactor and then added to the aquarium.

- **Dosing (also called balling method)**
  Several different chemicals, each suitable for adjusting a single water value, are added to the aquarium in dry or liquid form.

Function	Lime water	Lime reactor	Dosage (Balling M.)
Add calcium carbonate in any quantity	Yes Smaller/medium quantities	Yes Yes	Yes Yes
Add calcium/carbonate separately- To correct deviations- in case of unbalanced consumption	-	-	Yes
Add magnesium	-	Conditional	Yes
Correct magnesium value quickly	-	-	Yes
Add other trace elements	Conditional	-	Yes
Can be automated	Conditional (via refill system)	Yes	Yes
Change the dosage if the consumption of the aquarium changes.	-	Difficult to adjust	Easy to adjust

This table shows why **dosing (balling)** is a flexible and very good choice, or that you will still "dose" if you decide to use a different method.

Don't be put off by the fact that "dosing" seems complex at first. Also don't be put off by the fact that you have to measure water values... with all other systems you have to do that too!

5.1 Dosing (Balling Method)

5.1a Adding chemicals to the aquarium

The possibilities range from manual dosing (simply adding powders) to fully automatic dosing of liquid stock solutions from storage containers. A general recommendation cannot be made. The optimal solution for each individual depends on:

- Number, type of chemicals to be added
- Dosing frequency
- Available space for metering equipment
- Existing budget

Consider the following points:

- The basis for correct dosing are credible measured values of your aquarium water. Use high-quality tests or measuring devices and make sure that the measured values were determined at the correct salinity [*1)] and are related to normal salinity (~34.8 psu).

- The weighing of the chemicals must be done with sufficiently precise scales. Pay attention not only to the number of decimal places displayed, but also to the measuring accuracy of the scale (a scale that displays 0.01 grams can display 10 grams incorrectly). In general, the smaller the aquarium (or the smaller the dosing quantities), the more accurate the scale should be.

- Observe preferred dosing times of some chemicals (preferably in the morning, in the evening
- Watch out for incompatibilities of individual chemicals (do not dose *calcium chloride* and *sodium (di/hydrogen) carbonate at* the same time!)

- The more evenly and slowly the dosage, the gentler it is for your animals. Never apply undiluted chemicals to sensitive corals.

- Discharge of chemicals should always take place in places with sufficiently good flow. (avoidance of accumulation of concentrations)

- Containers used to store stock solutions should not release contaminants and should be remixed from time to time.

Calculating dosing quantities yourself (theory)

Skip this chapter if you do not intend to calculate your dosing quantities yourself!

Step-1: First determine the dosing quantity of a certain chemical that is necessary to achieve a given increase in concentration.

If an adjustment/increase is to be made, the following information is necessary:

a) ***Which concentration*** should be increased (calicium&alkalinity and/or magnesium)?
b) By ***how much*** should the value be increased. E.g. by xx [mg/l].
c) Which ***water volume*** *1) should be adjusted?

1) This refers to the water present in the entire aquarium circuit (aquarium volume, minus stones & sand, etc.) but plus the water volume in your sump, pipework, etc.

First calculate the current total deficit of this substance in the aquarium.

$$\boxed{\text{ConcentrationDeficit} = \text{TargetValue} - \text{ActualValue}}$$

$$\boxed{\text{TotalDefizit} = \frac{\text{ConzentrationDeficit} \times \text{WaterVolume}}{1000}}$$

ConcentrationDeficit, TargetValue, Actual value	in	[mg/litre]
Water volume	in	[litre]
Total deficit	in [g]	

Example: We have a aquarium with 100 litres water volume.
Magnesium should be increased from 1280 mg/l to 1320.

- Mg deficit 1320 - 1280 = 40 mg/l
- Total deficit 40mg/l x 100l /1000 = 4,0 g

Result: 4g of pure magnesium should be added to the aquarium.

However, you can do little with this result at first,
because you cannot dose "pure magnesium" into your aquarium!

Step 2:

The desired/mean amount of chemicals (total deficit) cannot be added to the aquarium "just like that", as already mentioned. Instead, commercially available salts, so-called Balling salts, are used. These are chemical compounds and contain other ions in addition to the desired components (Ca, Mg, etc). There are also salts containing water of crystallisation and also water-free salts.

The amount to be added must therefore take into account that part of the balling salt does NOT increase the desired deficit of Ca/alkalinity/Mg! More of the salt must be added accordingly. The exact quantities for this are determined on the basis of the molar masses. The calculations are chemically simple, but cannot be given in a formula and will be described in more detail later.

http://de.wikipedia.org/wiki/Molgewicht

The **molar mass of a compound** (not only that of an element) is determined from the molecular formula of the compound. Add the molar **masses of the individual elements** (sometimes several times, depending on how often the individual elements occur in the compound).

Some formulations are also mixtures of these salts. The aim is to adjust the overall formulation so that it resembles seawater as closely as possible.

The dosage is calculated according to the following formula

$$\boxed{\mathrm{DosingAmount} = \frac{\mathrm{TotalDeficit} \times \mathrm{MolarMassChemicalCompound}}{MolarMassChemicalElement}}$$

Dosing quantity and total deficit in [g], molar masses in [g/mol].

Example: see above (100 litres water volume. Magnesium should be increased from 1280 mg/l to 1320).

How much Balling salt of the compound MgCl2 x 6H2O must now be added?	
Calculate *) the molar mass of MgCl2 x 6H2O and get	203.3021 g/mol
the molar mass of Mg alone (without the rest of the compound) is	24.305 g/mol
we have already calculated the total deficit above	4,00 g

In our example: 4.00g x 203.3021g/mol / 24.305g/mol →**33.4 g**

33.4 grams of MgCl2 x 6H2O are needed to increase Mg in 100 l water by 40mg/l.

With this basic knowledge, you can understand all the formulations used by means of the chemical formulae.

Your specific dosing quantities "in a more comfortable way"

Here's how to do it with less calculation effort

The following table shows the dosage amounts of the various available balling salts. Convert them to your personally required dosage based on your requirements in the aquarium.

$$\text{DosingAmount} = \frac{\text{YourDeficit} \times \text{YourWaterVolume}}{\text{StandardDefixitValue x 100}}$$

YourDeficit, StandardDeficitValue in [mg/L] or [dKH].
YourWaterVolume in [litres]

Required dosing quantities to increase Ca, alkalinity and magnesium

Molecular formula Chemical	Designation	Std. deficit value Value: at	**Quantity required** for 100 L water volume in [Gram]
$CaCl_2 * 2H_2O$	Calcium chloride dihydrate	Ca: +10 [mg/L]	3,67
$CaCl_2$	Calcium chloride (anhydrous)	Ca: +10 [mg/L]	2,77
$NaHCO_3$	Sodium hydrogen carbonate	KH: +1.0 [dKH]	2,99
Na_2CO_3	Sodium carbonate	KH: +1.0 [dKH	1,89
$MgCl_2 * 6 H_2O$	Magnesium chloride hexahydrate	Mg: +10 [mg/L]	8,36
$MgCl_2$	Magnesium chloride (anhydrous)	Mg: +10 [mg/L]	3,92
$MgSO_4 * 7H_2O$	Magnesium sulphate heptahydrate	Mg: +10 [mg/L]	10,10
$MgSO_4$	Magnesium sulphate (anhydrous)	Mg: +10 [mg/L]	4,95

Stock solutions !

Stock solutions are liquids mixed together from osmosis water and balling salts. Compared to dry salts, they are easier to measure (e.g.: draw up with a syringe marked with a ml scale) and, above all, they can be dosed automatically with so-called dosing systems, making your life easier.
With the possibility of small but frequent doses spread throughout the day, they stabilise the chemical system better than one-off doses.
For each stock solution, the "concentration" used is extremely Important. It indicates "how many grams of balling salt" were mixed into a "standardised volume of stock solution" (1L).

- Only if the concentration of the stock solution and its ingredients are known, you are able to calculate "how much you need to add" to increase your water parameters accordingly.

- When mixing the stock solutions, a "maximum feasible concentration" must be taken into account. Mixing more than the maximum soluble salt amaount into water will result in precipitation.

Recommended and maximum soluble amounts of balling salts

Molecular formula Chemical	Designation		Max. solvable to 1 litre at 20°C [grams]
CaCl2 * 2H2O	Calcium chloride dihydrate	Link	986,5 g
CaCl2	Calcium chloride (anhydrous)		740 g
NaHCO3	Sodium bicarbonate (Sodium hydrogen carbonate)	Link	96 g
Na2CO3	Sodium carbonate	Link	217 g
MgCl2 * 6 H2O	Magnesium chloride hexahydrate	Link	2350 g
MgCl2	Magnesium chloride (anhydrous)	Link	542 g
MgSo4 * 7 H2O	Magnesium sulphate heptahydrate	Link	710 g
MgSO4	Magnesium sulphate (anhydrous)		300 g
-	NaCl free salt (mineral salt)		25 g

Another advantage of stock solutions: You can also mix other ingredients of natural seawater into them. So-called trace elements such as potassium, strontium, boron, iodine, etc. can be added.
By dosing the stock solutions appropriately, which are already adapted to your personal aquarium consumption of Ca, Alk and Mg, the trace elements that are "probably consumed to a similar extent" are also dosed.

Dosing of stock solutions... now it's getting a bit complicated

Stock solutions are almost perfectly suited for our marine/reef aquariums (specifically adapted to our aquariums, fully automatable, harmless and even relatively inexpensive).

Due to many possible parameters ....

- Different consumption of the various elements in our aquariums
- Different amount of water to be adjusted
- Different products/chemicals used
- Concentration of the stock solutions from rather weak (for more precise dosing in smaller aquariums) to high-dosage products.
- Stock solutions with/without integrated trace elements

...it is, however, not so easy to determine the "exactly right dosage for your aquarium" yourself!

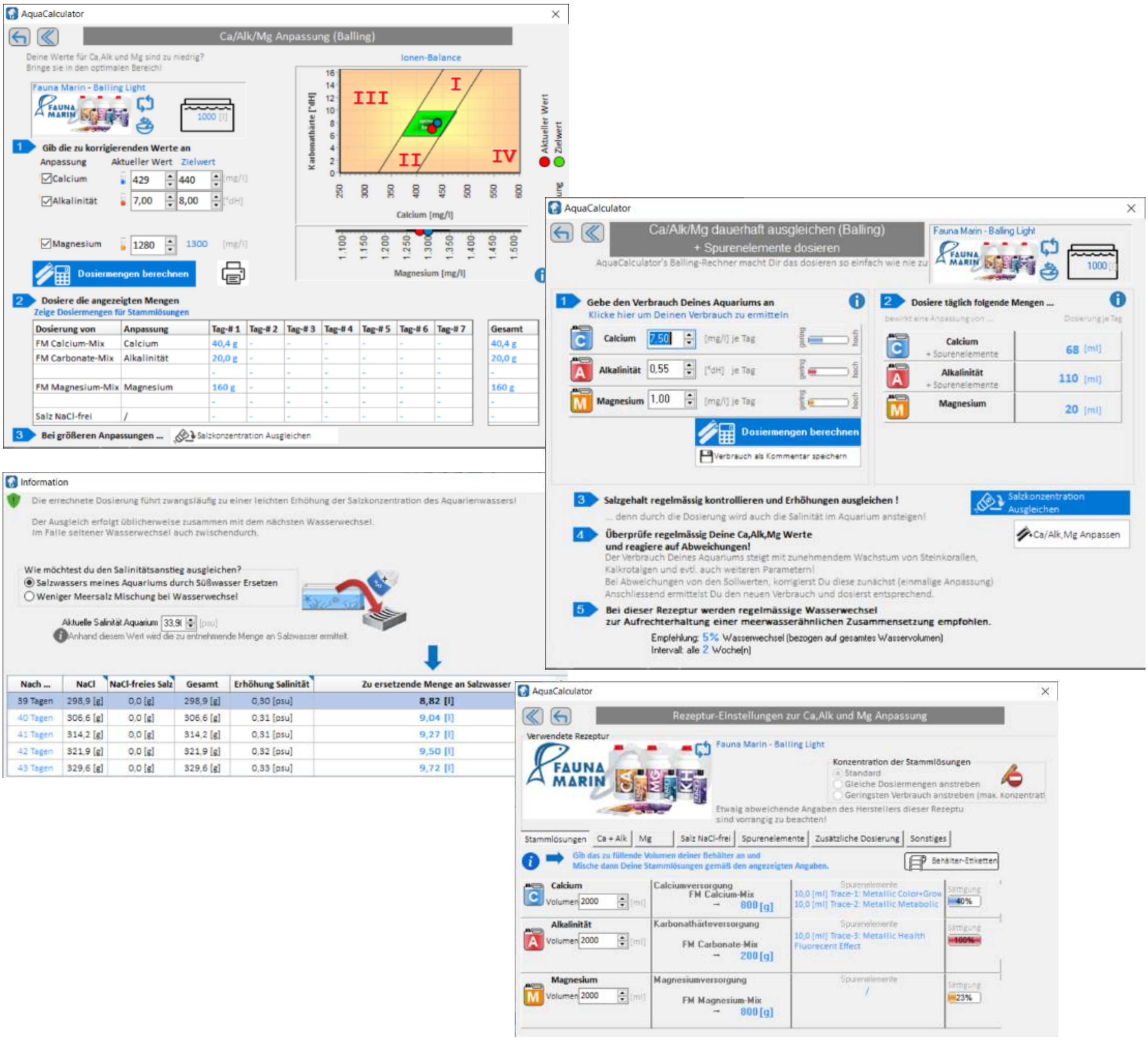
Manufacturers who want to make it easier for their customers publish dosage instructions for their products that can be converted into their personal dosage amounts using several 3-sentence calculations.

Example: 20ml of this product will increase the calcium value of your marine aquarium by 10 mg/l per 100L water volume.

Unfortunately, many manufacturers do not do this and leave the aquarist without information about their products.

The complete software solution especially for dosing (balling method) is **AquaCalculator.**

- Super-simple operation paired with high flexibility
- More than 100 different recipes of practically all manufacturers integrated. with/without integrated trace elements.
  Option to define your own recipees.
- 2 calculation modes: "correction of deviating values" or "permanent compensation
- Instructions for mixing the stock solutions
- Instructions on how to carry out the dosage



Find even more details on dosing/balling method here:
[Dosing of Major and Trace Elements in Reef Aquariums (Balling Method)]

5.2 Calcium reactors

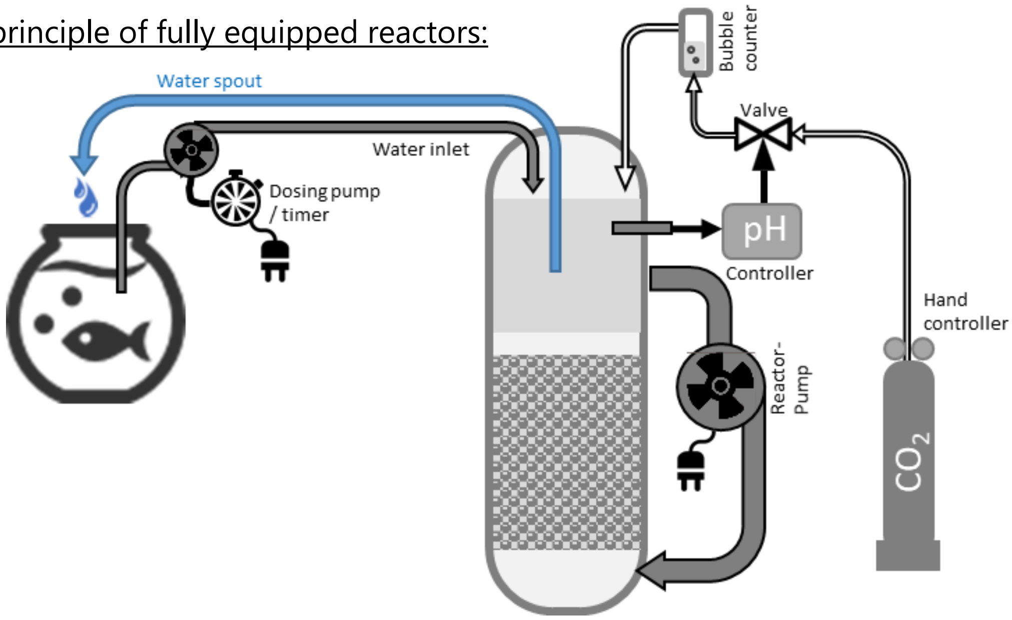
A filling introduced into the reactor chamber of the calciumreactor (coral break) is dissolved by carbon dioxide (CO_2) and then fed into the aquarium. The filling consists of natural coral rubble or artificially produced granulate, which has similar properties.

Reaction equation Ca:

$$CaCO_3 \quad \rightarrow \quad Ca^{++} + CO_3^{--} \rightarrow \quad Ca^{++} + 2\ HCO_3^{-}$$

Wit cial filling material you can also add magnesium.

<u>Functional principle of fully equipped reactors:</u>



- Coral break inside the reactor is constantly flushed with salt water. A feed pump connected in the circuit (blue circuit) is used for this purpose.
- An acidic environment must be present so that the coral fragments can be dissolved. A pH value of 6.2 is optimal (too high a pH means→poor solubility). For this reason, CO_2 is added to the reactor in the so-called injector (red circuit). This gas should constantly flow through the reactor chamber from bottom to top. Modern, particularly efficient reactors collect the CO_2 at the top of the reactor chamber and feed it back via a so-called CO_2/gas recirculation in the diffuser.
  The amount of CO_2 supplied is important for the pH in the reactor. A bubble counter is used to make the discharge quantity from the CO_2 bottle visible. CO_2 first passes through a water column and can thus be "counted in bubbles".
  pH control: To prevent over-acidification in the reactor (not efficient for the reactor and bad for the main aquarium), the CO_2 supply can be stopped when the pH value in the reactor is already optimal. To do this, the pH is measured with a probe in the reactor. When it reaches the optimal value, the CO_2 supply is interrupted by means of a solenoid valve.
- The water that has been lime-treated in the reactor now only has to be removed and fed into the aquarium. For this purpose, aquarium water is pressed into the reactor. The same amount of limed water is then fed back into the aquarium (inflow quantity = outflow quantity, green circuit).

Adjustment of Calcium reactors

Depending on the configuration, the adjustment can be more comfortable or more complicated. There are many users for whom reactors with minimal equipment (i.e. without CO_2 -control and without dosing pump) function excellently. Others complain about poor adjustability and the reactor disadjusting during operation when there is no control and no forced flow through the flow pump.

Decision-making aid

CO2 controller (ph control)	Dosing pump	Setting accuracy	Stability in operation	Maintenance costs	CostsAcquisition
√	√	very high	very high	Very low	High
√	-	very high	Medium	Medium	Medium
-	√	High	High	Very low	Medium
-	-	Medium	Low - Medium	Medium	Low

<u>Calcium reactor with pH control and dosing pump</u>
Dosing quantity mainly set by the volume of water fed in a controlled manner
Controlled variable: Flow rate of the dosing pump
(assuming a controllable dosing pump) Control
Controlled variable: Dosing intervals and duration of the dosing pump.
- pH value in the reactor is automatically regulated by pH controller.
Only the approximate CO_2 addition rate needs to be set.
Maintenance: - Recalibration of pH probe approx. every 6 -12 weeks
- Maintenance of the dosing/hose pump (approx. every 1-2 years)

<u>Calcium reactor with pH control (without dosing pump)</u>
Dosing quantity mainly set by the volume of water fed in a not really controlled manner
Controlled variable: Flow rate of the water through the lime reactor
Adjustment options: Throttle valve at the outlet of the lime reactor
pH value in the reactor is automatically regulated by the pH controller.
Only the approximate CO_2 addition rate must be set.
Set-up is suboptimal, as the cross-section of the inlet/outlet hose is often reduced/clogged by the heavily calcified water. A higher inflow/outflow speed and "milking" the hoses improves the chances that this will still work well!

Maintenance effort: - Recalibration of pH probe approx. every 6-12 weeks
- Depending on the condition, "milk" the hoses every few days

Calcium reactor with dosing pump (without pH control)
Dosing quantity is set as a combination of fixed quantity of added CO_2 (bubble counter) and the volume of water fed into the reactor in a controlled manner
Controlled variables: -Number of CO2 bubbles/minute
- Flow rate of the dosing pump
- Dosing intervals as well as dosing duration in intermittent operation of the dosing pump.

The adjustment of the reactor, in this set-up, is somewhat more complicated.
Reason: The fine adjustment of the pressure regulator on the CO_2 bottle is usually awkward. Likewise, the number of bubbles is adjusted in the long run as the CO_2 bottle is increasingly emptied.

If "too much" CO_2 is dosed, the pH value in the aquarium drops unnecessarily. If "too little" CO_2 is dosed, the solution in the reactor functions worse.

Maintenance effort: - Maintenance of the dosing/hose pump (approx. every 1-2 years)
- Check CO_2 bubble counter, readjust if necessary.

Calcium reactor (without pH control and without dosing pump)
Dosing quantity is set as a combination of Fixed quantity of added CO_2 (bubble counter) and volume of water fed into the reactor
Controlled variables - Number of CO2 bubbles/minute
- Throttle valve at the outlet of the lime reactor

This setup is suboptimal, as the cross-section of the inlet/outlet hose is often reduced by the heavily calcified water and may even become completely clogged.
A higher flow rate of the inlet/outlet and "milking" the hoses improves the chances that this will still work well! The adjustment of the reactor, in this set-up, is also somewhat more complicated.
Reason: The fine adjustment of the pressure regulator on the CO2 bottle is usually awkward. Likewise, the number of bubbles is adjusted in the long run as the CO2 bottle is increasingly emptied.

If "too much" CO_2 is dosed, the pH value in the aquarium drops unnecessarily.
If "too little" CO_2 is dosed, the solution of calcium carbonate functions worse.

Maintenance effort: - depending on the condition, "milk" the hoses every few days.
- Check CO_2 bubble counter, readjust if necessary.

5.3 Lime water/Calciumhydroxide

Purchase calciumhydroxide in aquarium shops or at chemical wholesalers.

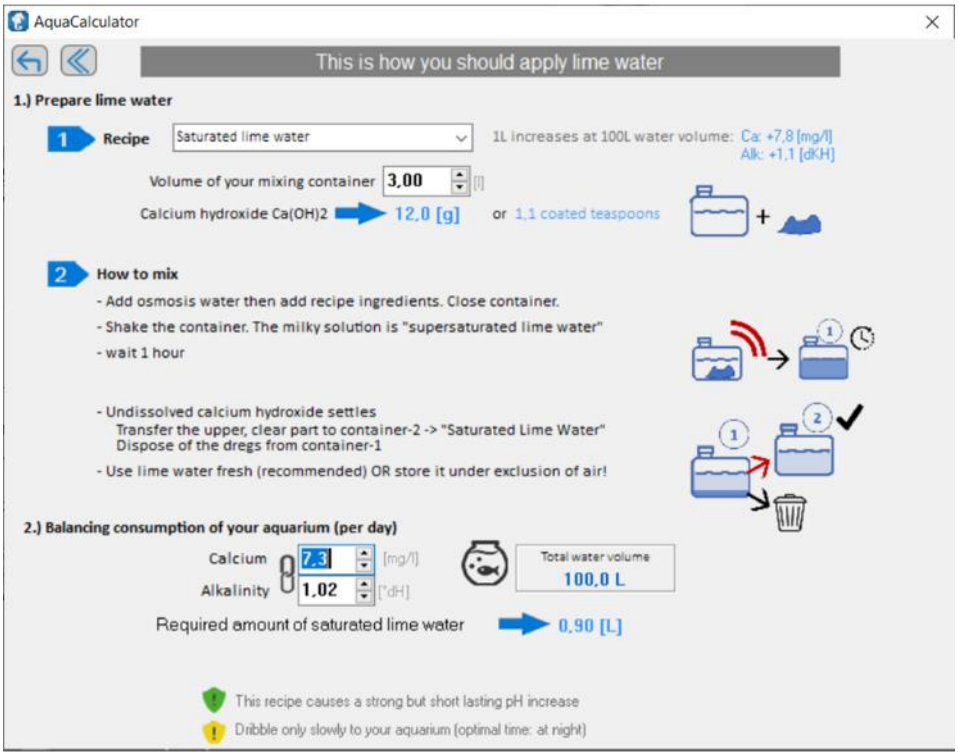
Mixing instructions:	Mix 40g $Ca(OH)_2$ with fresh water to a total of 10 litres. (does not dissolve completely!)		
Dosage:	872 ml increases	Alkalinity Ca	by 1.0 [dKH] and by 7.1 [mg/l]

As you can see...... you need a relatively large amount of lime water to balance your calcium carbonate consumption. If the demand for lime water is greater than the water evaporated every day in your aquarium (SPS aquariums), you cannot completely cover your demand. If you would, you would "overfill" your aquarium.

One more thing ....: Phosphates can precipitate in the aquarium if dosed intensively for a longer period of time. I therefore do not recommend lime water for demanding aquariums.

If you want to use lime water, but mixing/calculation etc are too challening for you ... AquaCalculator will help you here too.

Also included: A special recipe with vinegar, dosed approx. 2x higher.



5.4 Trace elements

You managed to get the Big Three (Ca, Alk, Mg) under control? At least half of the saltwater aquarists are probably well served with this. But it's even better if you also take the "trace elements" into account.

Trace elements are salts that occur naturally in seawater
except "pure table salt" and
except "the big-three calcium, carbonate and magnesium".

The closer our aquarium water comes to natural seawater, the better for the animals. Accordingly, the trace element concentration in our aquariums should also be suitable. However, it is not quite easy to ensure a perfect copy of seawater here because

- Trace elements are also "consumed" in our aquariums similar to the Big-Three
- It is very time-consuming to measure trace element concentrations (ICP measurement required).

The good news first: Even for the maintenance of really great reef aquariums, it is not necessary to constantly recreate a perfect copy of seawater.

There are 3 ways to add trace elements to our aquariums.

- Adding fresh salt water / doing water changes
- Dosing trace element mixtures
- Dosing individual trace elements

5.4.1 Trace elements in salt mixtures

Practically all known salt mixtures contain trace elements in suitable concentrations.
With each water change you introduce trace elements back into the aquarium *1),
and you also dilute possible over-concentrations of trace elements in your aquarium *1).

1*) Admittedly, only in small doses because of the mixing with the water already in the aquarium. The more water is changed, the stronger.

This is one of the main reasons why many reputable manufacturers recommend additional water changes in parallel to other things such as: Dosage/Balling method recommend additional water changes.




5.4.2 Trace element analyses integrated into stock solutions

There are 2 categories of products here

5.4.2.1 "NaCl free salts" or "mineral salts".

These are special dry salt mixtures containing various salts (=trace elements). These are usually mixed in low concentrations in osmosis water (max. 25g/L) and then dosed as a stock solution.
All of these products also contain magnesium salt, which is simply added here. The original Balling method presented by Hans-Werner Balling, uses this method of dosing trace elements.

5.4.2.2 Liquid trace element mixtures

A solution with which you can achieve very good results with little effort is to "integrate" trace elements directly into the stock solutions for calcium and carbonates (alkalinity).
On the one hand, this is super practical because nothing has to be dosed separately, on the other hand, the additional dosing of trace elements is "coupled" to the additional dosing of the most consumed elements (Ca, Alk).

These mixtures usually do not include a magnesium salt. Magnesium is dosed in a separate stock solution, which makes much more sense in my opinion.


My recommendation are liquid trace element mixtures
from well-known manufacturers.
Here, the chances are greatest that these mixtures have been tested and tested and further developed in various aquariums.

5.4.3 Full supply systems

The hottest of the hottest and close to perfection is to adjust all trace elements individually. This allows perfect colouring and care of even the most demanding stony coral species.

However, the effort and costs involved are higher and regular ICP-analyses are necessary to "measure the trace element concentration". This determines which elements are deficient. Then you add the missing elements as needed. Exact dosage instructions are usually provided by the supplier.

Some manufacturers claim that they can do even without any water changes.

FaunaMarin Elementals series (22 products in total)

Triton complete supply system

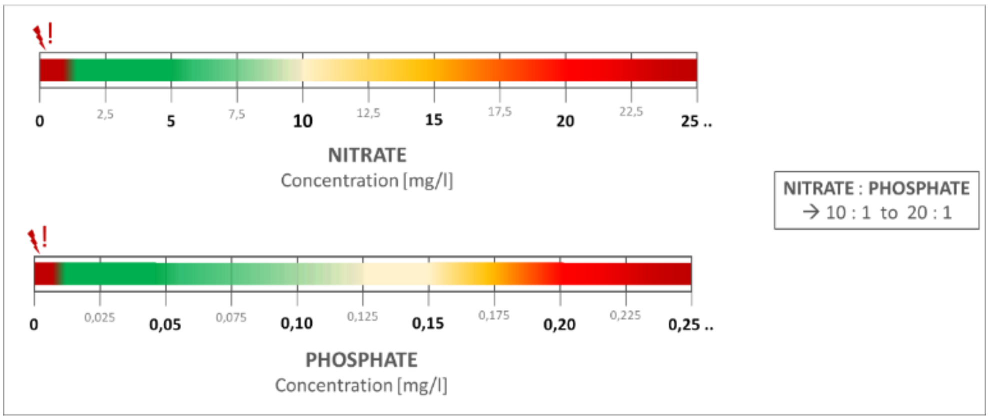
Dutch Synthetic Reef "Full DSR Metho

PART 6 - Control nutrient values

6.1 Be careful applying ultra low nutrient conditions

As already mentioned, it is important to keep an eye on the nutrient levels.
Experienced aquarists recognise deviations by abnormalities in the aquarium (e.g. algae formation) or by sensitive animals such as stony corals.
It cannot be mentioned often enough: Nutrient limitation can occur quickly under certain conditions and the effects can be dramatic.

> We recommend keeping a close eye on nutrient concentrations.
> A reduction of nutrient levels should always be done SLOWLY.



Your values have nevertheless reached 0 (limitation)?

- Supplementary feeding" as quickly as possible with amino acids suitable for MARINE aquaristics or
- Addition of phosphate and nitrate (Link)

In the following, the most common methods are described with which either
- Harmful nutrients removed/transformed (ammonia, nitrite) and/or
- Standard nutrients in reef aquariums (nitrate/phosphate) can be reduced

6.2 Trickle filters, bioballs, rapid filters - relics from a time long ago?

Just a few years ago, so-called trickle filters were state of the art in MARINE aquariums. Many aquariums still run with these or other mechanical filters, including bioballs, filter mats or rapid filters based on similar mechanisms.

The basic idea is to provide bacteria with a settlement area in order to produce nitrite→from toxic ammonium and nitrate→from it. This nitrate, however, is not broken down any further, which turns these systems into nitrate slingshots when used for a longer period of time, which is what we want to avoid in nutrient-poor systems.

In modern aquariums, in my opinion, only rapid filter mats or filter sponges have any justification at all. And this only if they are cleaned regularly every few days. It is important to clean them in salt water so as not to kill bacteria and thus burden the system.

In marine aquaria it is uncommon to "filter out" nitrate/phosphate with conventional/ mechanical filters.

6.3 Tissue roll filters

However, a good option for removing suspended particles are automatic fleece roll filters (e.g. Theiling Rollermat) where the already soiled filter mat is removed from the watercircuit by a motor.

6.4 The "Berlin System"

It has become the standard and is the starting point of other nutrient reduction systems.

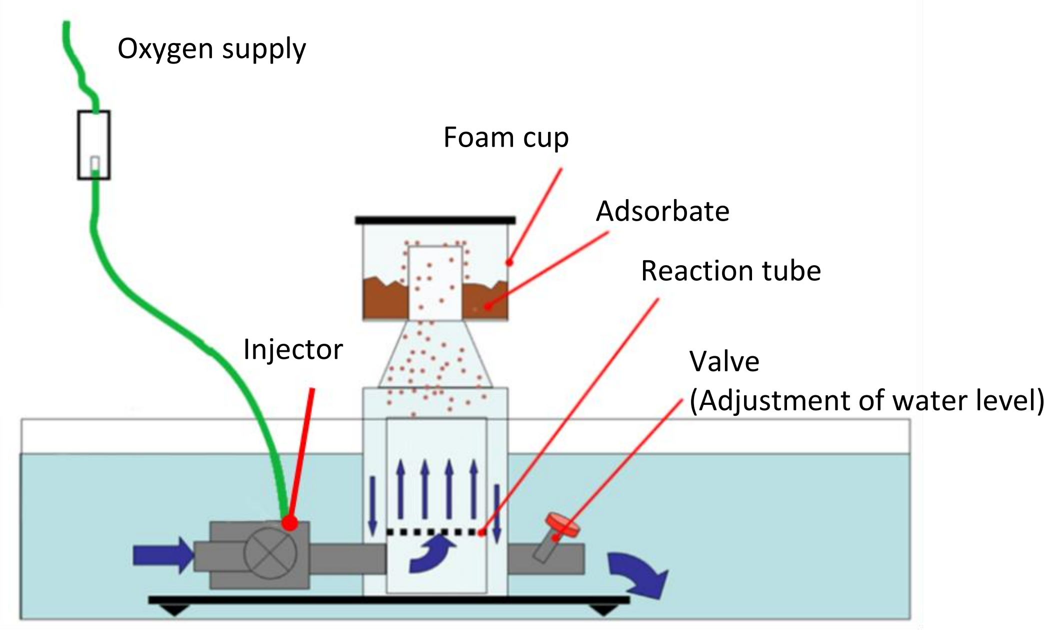
a) **Living reef rock** is used. The more rock, the larger the bacteria population and colonisation area already present there. An aquarium with a high proportion of live rock will start to run accordingly quickly.

Quality and quantity of live rock is crucial:

- The more settlement area and the more living bacteria there are on the stones, the better for nutrient decomposition.
- Good stones are light and porous
- We recommend to get the stones directly from the dealer on the day of importation (before they are left to rot in unlit containers with little flow)
- Good stones do not look rotten and smell "fresh" of the sea.

For reasons of cost or appearance, dead reef rock can also be used in some cases. Stones should be just as highly porous (settlement area for bacteria population). However, it takes longer for the bacteria population to establish itself than on live rock.

b) **Protein skimmers** remove nutrients and also suspended particles in the circulation. They also ensure a high oxygenation of the water and partially remove substances/toxins from the aquarium circulation.



Function: A large quantity of air bubbles, which should be as small as possible, is generated from air and your aquarium water. In modern skimmers this is done by a ***pump with an injector***. The water from the intake might contain impurities, toxins, etc. These stick to the air bubbles or are incorporated into them, resulting in a more or less dirty foam. In the so-called reaction tube of the skimmer, the air bubbles rise from the bottom to the top. In the newer, more efficient skimmers, an injection pan distributes the previously somewhat chaotic flow more evenly. As new air bubbles come in from below, those higher up are pushed higher and higher. Superfluous adhering water flows back down by gravity. At the upper end, in the ***foam cup,*** the bubbles escape and then run down the side of the reaction tube and are collected there. In the foam cup, the bubbles burst and become the liquid ***adsorbate***. This adsorbate then contains, besides some aquarium water, all the skimmed substances and particles. The height of the accumulated water/bubble mixture is adjustable. The higher the water level in the skimmer, the more and more liquid adsorbate is produced. How this setting is realised differs for some skimmer types, shown here by the **valve at the outlet.**

Skimmed off:

- Undissolved surface-active and partly also non-surface-active particles
- Substances dissolved and oxidised in water

How to find the right skimmer

- **Design/size of the skimmer** should fit the conditions of the own system
  There are different systems
  - skimmers that are "attached" to the aquarium and others that are "placed in a separte refugium/aquarium "
- Good **skimming performance** adapted to the aquarium.
  Criterion: Large air volume, bubbles as small as possible
- **Low power consumption**
  Skimmers may run 24 hours a day! electricity costs are not negligible
  Models that are more expensive to buy may pay for themselves after a few months.
- **Low noise level** during operation. Little/no **vibrations**
- **Foam cup can be easily dismantled and cleaned.**
  - must be done regularly
  - is it even possible to drain the adorbate without dismantling the foam cup?
- **Good adjustability of** the adsorbate - moist or rather dry-
  water at the outlet of the skimmer contains little to no air bubbles
- **Quality/longevity of** the components

Systems formerly also used in MARINE aquariums (Jaubert, DeepSandBed) have been deliberately removed from this compendium. They are considered outdated and have no real advantages over the "Berlin System".

6.5 Reproduction of the bacterial population

The higher the population of suitable bacteria, the better the reduction of the nutrient concentration nitrate/phosphate.

Maintaining a suitable and high bacterial population is natural and effective. It is the nutrient reduction method par excellence.

There are generally 2 ways to increase the bacteria population

- **Introduction of special bacterial strains** for "inoculation" or "re-inoculation". (if too few suitable heterotrophic bacteria are present)

- **Targeted feeding of** the bacterial population present in the aquarium by providing a carbon source as bacterial food. (Growth and cell division rate of the bacteria stimulated).

- You will first notice a functioning nutrient reduction by increased skimming. After a slight delay, the nitrate/phosphate concentrations drop.
- The appearance of slimy whitish or brownish deposits on panes, stones and in the technical aquarium indicate an overpopulation (bacterial bloom). Reduce the dosage. Coatings can be brushed off and are then skimmed off.
- A cloudy water surface indicates dead bacteria that are not being removed due to a lack of surface flow/suction.
- If the nitrate concentration is low but the PO4 concentration is high, it makes sense to use a PO4 adsorber at the same time.
- UV clarifier, ozone, activated carbon can be used in parallel

When the reproduction rate is high, bacteria metabolise a lot of oxygen.
Avoid a possible **oxygen deficiency for your animals**!
Always use a skimmer that constantly supplies fresh oxygen to your aquarium.

Aquarists repeatedly reported massive fish deaths within a very short time, mostly overnight. The cause very often is lack of oxygen available for fish due to previous oxygen deprivation by (too many) bacteria.

Why: Aerobic bacteria, like fish, extract oxygen from the aquarium.
Due to a strong increase in the number of bacteria, the total oxygen demand quickly rises. If the oxygen saturation is not constantly raised again in parallel, the fish will literally “suffocate". The risk of this is significantly higher at night, as no oxygen is produced by corals and algae due to the interruption of photosynthesis. A constant supply of oxygen, especially at night, is an absolute prerequisite.

There are various products to keep nutrients in the perfect range through bacteria.

A) Do-It-Yourself products

- This is practically always only **bacteria food**.
  You feed your bacteria with it so that they multiply quickly.
  The best-known representatives are alcohol (e.g. vodka) or vinegar.

B) Purchasable products

- **A) Special bacterial strains** (mostly concentrated bacterial mixtures)
  When buying, pay attention to what the different strains do!
  There are usually 2 types:

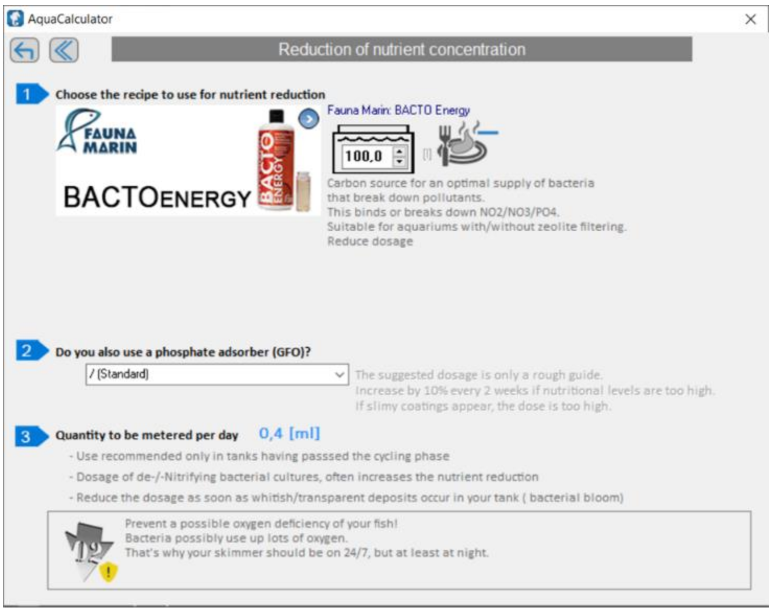
  a) Bacteria that break down nutrients in the water, or

  b) Bacteria that break down solid nutrients such as mulm and detritus

- **B) Bacteria food**
  With this you feed your bacteria so that they multiply quickly.
  (Usually a combination of alcohol and vinegar).

Aqua-Calculator simplifies the mixing process and the calculation of dosing quantities.
(almost 20 integrated recipes, incl. variants you can mix yourself from material available in the supermarket)



Simple and efficient: Vodka dosing

There is no generally valid dosage amount, as the biology of each aquarium behaves somewhat differently. Here is a relatively conservative dosage suggestion (i.e. with low dosage amounts) that has proven positive in practice with various aquarists.

Time	**Dosing quantity** [per 100 litres aquarium 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: Increased skimming performance should be observable. After ~10-14 days: Reduction of nitrate/phosphate should be measurable.
Day 15 - xx	Determine the required dosage, if possible **not significantly more than 1.0 ml** / 100L.	However, there are also aquariums where up to 4ml of vodka is necessary for sufficient nutrient reduction.
Ongoing	Reduce the vodka dosage to an optimum of 20-50% of the maximum dosage previously required.	Select the dosage amount as low as possible in order to still maintain the targeted nutrient limitation.

- Especially in the first 3 weeks, **frequent monitoring of the nitrate/phosphate concentration is necessary** (2-3 times/week). Based on the measured values, the required dosage, which differs for the respective aquarium, is determined.
- The indicated dosage refers to commercially available, uncoloured and unsweetened vodka with usual alcohol content (~40%).
- If smeary deposits (bacterial film) appear, reduce the vodka dose.

6.6 MAXimum bacterial population: Zeolite method

The method described below consists of a sum of measures, which are somewhat complex to implement and not entirely cheap. On the other hand, aquariums in which this method is used currently represent the optimum in terms of proximity to natural seawater.

Correctly applied, the method leads to near-natural aquarium conditions.
Stony corals thrive with good growth and particularly distinct colouration.
The colour variations achieved in the corals are clear, bright and pastel. Clear reds, pinks, blues, greens, etc. emerge. The colouration comes mainly from reduced formation of zooxanthellae with brown colouration.

The method can also be used for nutrient reduction/control in aquariums where heavy feeding leads to water pollution.

Several systems/products are offered on the market for this purpose. The product names of the zeolite systems of the two largest German manufacturers are **ZEOvit** (Korallenzucht - Pohl) and **ZEO Light** (Fauna Marin). The following description is as product-neutral as possible and is **referred to** here as the **zeolite method**.

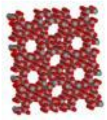
Needs:	- Skimmer with good skimming capacity	
	- Zeolite filter	
	- Zeolites	(small rocks, consumables)
	- Special bacteria cultures	(consumables)
	- Special bacteria food	(consumables)
	- Special coral food	(consumables)

Important: Use the complete method, including all necessary steps and remedies!

How it works

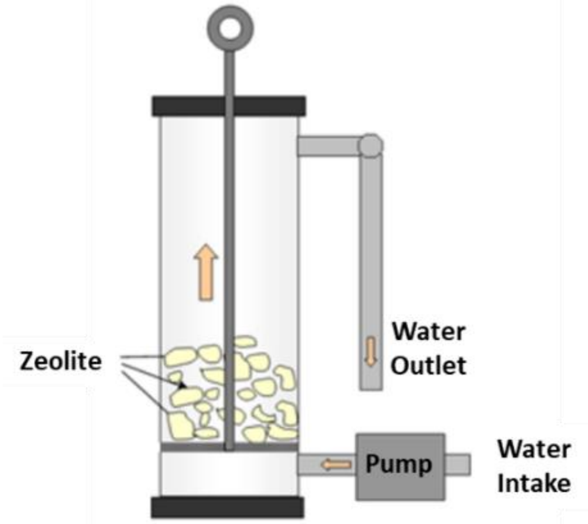
<u>Step-1:</u> First, a very nutrient-poor environment is created in the aquarium. This is done by using so-called zeolites in special zeolite filters. First, **ammonium** is mechanically **bound in the zeolite**
blocks. In parallel, a highly potent **bacterial culture is built up which stimulates the nitrogen cycle**. The mass of bacteria, which is constantly increased by feeding, **also binds phosphate**. Mechanical aeration of the zeolites removes the dead bacteria from the zeolites. These are then removed from the aquarium water via a skimmer, including phosphates.

<u>Step 2:</u> As step 1 forces a very nutrient-poor environment, some **corals have** to be **fed separately to** avoid starvation. This is done by adding amino acids, special feed preparations and specific trace elements.

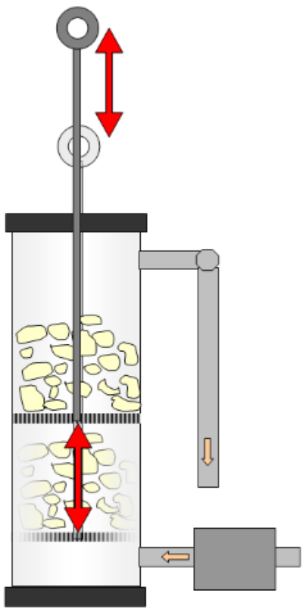



Zeolites are inert silicate minerals with a highly porous, sponge-like structure and a correspondingly **large surface area**. They thus form optimal settlement areas for microorganisms, such as bacteria, on the surface and also inside.

Zeolites occur naturally (approx. 50 different species), but can also be produced synthetically (approx. 150 different species). In aquaristics, mixtures of natural zeolites (clinoptilolites) are usually used. This takes advantage of the fact that they have a very high adsorption capacity and adsorption tendency for ammonium.



The task of a **zeolite filter** is to provide a perfect habitat for nitrogen-degrading bacteria. The zeolites in the filter are optimally flown through from the bottom to the top. A pump is used to pump the water in at the bottom. At the top, the water flows back out of the outlet. Zeolites should be cleaned daily by rinsing them in their own water. This causes a cleaning of detritus and other dirt accumulations, and is done by repeatedly pulling up/draining a filter basket on which the zeolite chunks lie. The mulm/bacteria mixture washed out in the process also serves as food for the corals.



Well-functioning zeolite filters are available from Fauna Marin, Grotech and Korallenzucht.de, for example.

Zeolite filters are best used before your skimmer!
Alternatively and instead of a zeolite filter, the use of zeolites is also recommended in a well and evenly flowing position in a filter aquarium.

For the filling quantity of the zeolite filter, the dosage of bacteria and food, it is best to follow the instructions of the respective supplier.

Rough guide value for zeolite application:

Filling quantity	up to 250 grams of zeolite per 100L aquarium content rinse well with tap or osmosis water beforehand	
Exchange zeolites	replace approx. 25%	every 6-12 weeks
Flow rate	~75Litre/h per 100L aquarium content	

As already described, the addition of special bacteria, feed preparations and amino acids is necessary. Depending on the system/product used, several ***components*** are used:

I) **Highly concentrated bacterial strains**
to optimise nutrient reduction in or on the zeolite

Bacto Blend (Fauna Marin)
ZEObak (Coral Breeding Pohl)

II-a) Combination products Basic (nutrient) solution for corals / bacterial

MIN S, CORAL vitality (Fauna Marin)
ZEOFOOD (Coral Breeding Pohl)

II-b) Amino acids *basic (nutrient) solution for corals*

AMIN (Fauna Marin)
AMINOacid (Coral Breeding Pohl)

III) Trace elements for maximum colour expression of the cora

COLOR ELEMENTS (Fauna Marin)
ZEO spur2 (Pohl Coral Breeding)

More information on the application of the zeolite method

- Use of a sufficiently powerful **skimmer** is a basic prerequisite
- Activated carbon filtration parallel to the zeolite method is recommended to remove any yellowing as well as nettle or other toxic substances from the water.
- Maintenance of constant/natural concentrations of **magnesium, calcium** and **alkalinity** is required regardless of the zeolite method.
- UV clarification as well as the use of ozone are generally less advisable with zeolite application
  (possibility of destroying special bacterial cultures and additives).
  These should be deactivated until a few hours after the addition of new bacterial strains.
- The appearance of white or green **coatings** on decorations and glass panes is often the result of overdosing the bacteria feed → Reduce dosage.
- Especially in the case of initially nutrient-rich aquariums, it is strongly recommended not to start with the full amount of zeolites, but only with 25%-50% of them.
  Another way to gently reduce nutrients is to reduce the zeolite flow rate.

Risks

1.) The main risk is **starting the method** too **quickly in aquarium**s with a **high nutrient content**. The corals are switched too quickly from an accustomed (possibly too high) nutrient content to very few nutrients. In extreme cases, this leads to tissue detachment and even complete death of corals.

2.) **Discontinuing the method too quickly** leads to exactly the opposite. The consequence of increasing nutrient concentrations (nitrate/phosphate) is that any brightening of the colours that has occurred is reversed (darker, brown colouring of the corals again due to increased zooxanthell density).

3.) If the **method** is **not fully applied**,
some of the positive aspects will be lost. Insufficient feeding of the corals in combination with extremely low nutrient content may even lead to starvation of corals.

6.7 Algae refugia (mud filters)

Algae refuges are a good and natural option to breakdown nutrients if the necessary space is available.

This is how it works: **Nitrate** in the aquarium **promotes algae growth**, as algae use this as an "energy source". Phosphate is also absorbed and "incorporated" by the algae. By regularly harvesting and disposing of the algae, **phosphate** is **also permanently removed**. The photosynthesis that takes place in the algae also provides an additional oxygen supply to the aquarium.

- Macro algae should be cultivated in a separate sump.
  It is also possible to introduce algae into the main aquarium/reef structure, but this is not recommended (atypical appearance, possible shading of corals, algae may branch in such a way that it is difficult to remove them).
- Harvest approx. every 1-2 weeks. Frequent harvesting increases growth/phosphate discharge.
- Glassy algae are on the verge of dissolving and would release absorbed pollutants before→removing them from the aquarium.
- Refugium collects various microorganisms and microorganisms that are good for the aquarium biology and also serve as a food supplement for fish.
- Do not feed too much harvested algae to fish (source of phosphate).
- 24-hour lighting in refugia is recommended→improved algae growth.
- The following cauler pairs are particularly suitable because of strong growth.

6.8 Phosphate adsorbers (silicate adsorbers)

Adsorber granulates (e.g. on an iron hydroxide base) remove phosphates and silicates from our aquariums by "binding" them on the surface of the granulate.

Dosage instructions is depend on the product you use.
Stronger and weaker granulates are available.

I would personally recommend the use of **phosphatasdorber** if....

- **Other measures to reduce nutrients in** your aquarium **do not work,** or
- **Phosphate** is **clearly excessive** compared to nitrate

Other options like "optimising the flow" as well as "increasing the bacterial population" are of a more practical and permanent nature than phosphate adsorbers.

Risks

Risk of nutrient limitation if used excessively.
Risk of reducing too quickly

Adsorber granulate should be well flowed around and through. Multifilters are a good choice. The adsorber material is filled into these from the top, the filter is closed and then flowed through with aquarium water.
The "flow of the granulate" with water takes place from the bottom to the top. This prevents excessive channelling and settling of suspended particles.

PART 7 - Other Tips & Tricks

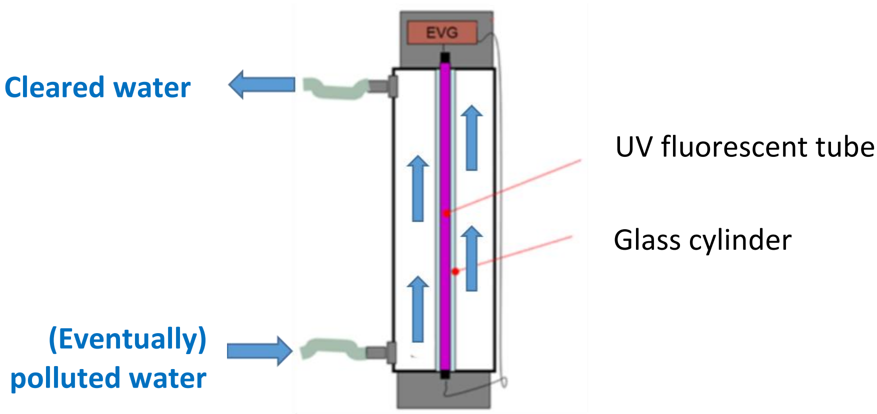
7.1 UV clarifiers

UV clarifiers destroy bacterial pathogens and micro-algae or floating algae in the open water. Many of the important bacteria in MARINE aquariums do not live in the open water, but in the substrate, rocks etc. These are NOT killed by UV clarifiers. This is extremely important because otherwise no aquarium biology with the vital nitrifying bacteria could develop.

Advantages

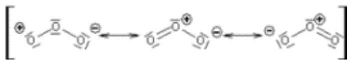
- Reduction of the risk of infection
- better health status of sensitive or newly introduced fish.

Part of the water in the aquarium circuit is led past a special fluorescent tube with UV spectrum in a thicker tube. The tube itself is installed in a watertight dry area in the centre of the UV clarifier.
The longer the dwell time of the water in the strong UV radiation, the higher the UV dose and thus the degree of disinfection. The same applies to the strength of the UV light source. There are different luminous intensities for smaller and larger aquariums.



Overdosing is not possible. However, larger UV clarifiers are more expensive and have a higher power consumption. UV clarifiers should be in operation 24 hours a day. Otherwise, the bacterial population will multiply again each time during the downtimes.
As the luminous spectrum of the tubes decreases over time, the fluorescent tubes should be replaced at certain intervals.

7.2 Ozone



The use of ozone reduces the organic load by removing organic turbidity and ensures clearer water.

It kills pathogens and bacteria strains floating in the open water. Bacteria in living stones and in the substrate remain unaffected.

In MARINE aquariums, ozone also oxidises ammonium to nitrite to nitrate to a small extent.

Risks

- The dosage of ozone must not be exaggerated.
  Otherwise there are negative side effects due to the strong oxidation, especially for fish (burns of the gill covers, ...).
- Use of ozone leads to embrittlement of plastic/rubber parts → Check more frequently!

Ozone quantity to be added: ~10 mg of ozone per 100 litres of aquarium water, 24/7 use

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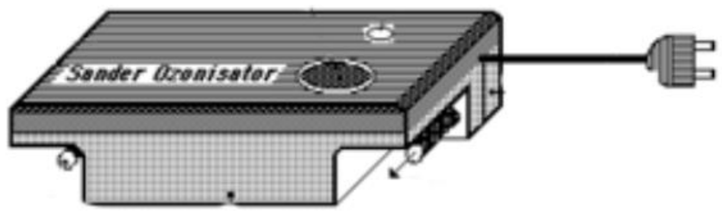
When buying an ozoniser, plan a certain reserve. Good ozonisers have an adjustable output.

When using an ozoniser on a skimmer, it is recommended to convert the ozone introduced into the water back to normal oxygen by permanent activated carbon filtration.

The ozone is produced within the ozone tube/zone element inside the ozoniser by electrical discharge. Ozonisers are the size of cigarette packets and have a very low electrical power consumption. The ozone is usually introduced into the aquarium via the suction hose of the protein skimmer (recommended).



7.3 Adding iodine

Adding iodine is beneficial for some animals and also SPS. The dosage should be held constant, as it "precipitates" again relatively quickly in the aquarium.

There are 2 inexpensive options, both available in pharmacies

a) Lugol's solution with 0.1%.
(0.1% solution: 2 grams potassium iodide + 1 gram iodine in 1 litre Aqua-Dest)

b) PVP iodine is available as a so-called Betaisodonna solution.

Rule of thumb: ***Iodine addition***

LUGOLs solution	2 drops per 100 litres of aquarium water per day
PVP iodine	1 drop per 200-250 litres of aquarium water per day

7.4 Lime water to raise the pH

Lime water powder is also suitable for increasing the pH value, although the pH value often decreases again relatively quickly. If the pH value is to be increased for several days, dosing several times a day is necessary. Keep in mind that Ca and alkalinity are also increased.

26g $Ca(OH)_2$ per 100 litres of water volume increase→the pH value by 0.1 pH

- Weigh out the calciumhydroxide and add it to the aquarium at a place with a strong flow (ideally in the technical aquarium, never on sensitive animals).
- Strong lime supply can lead to precipitation in the aquarium and to deposits on objects (flow pumps, pump impellers, overflows, etc.).

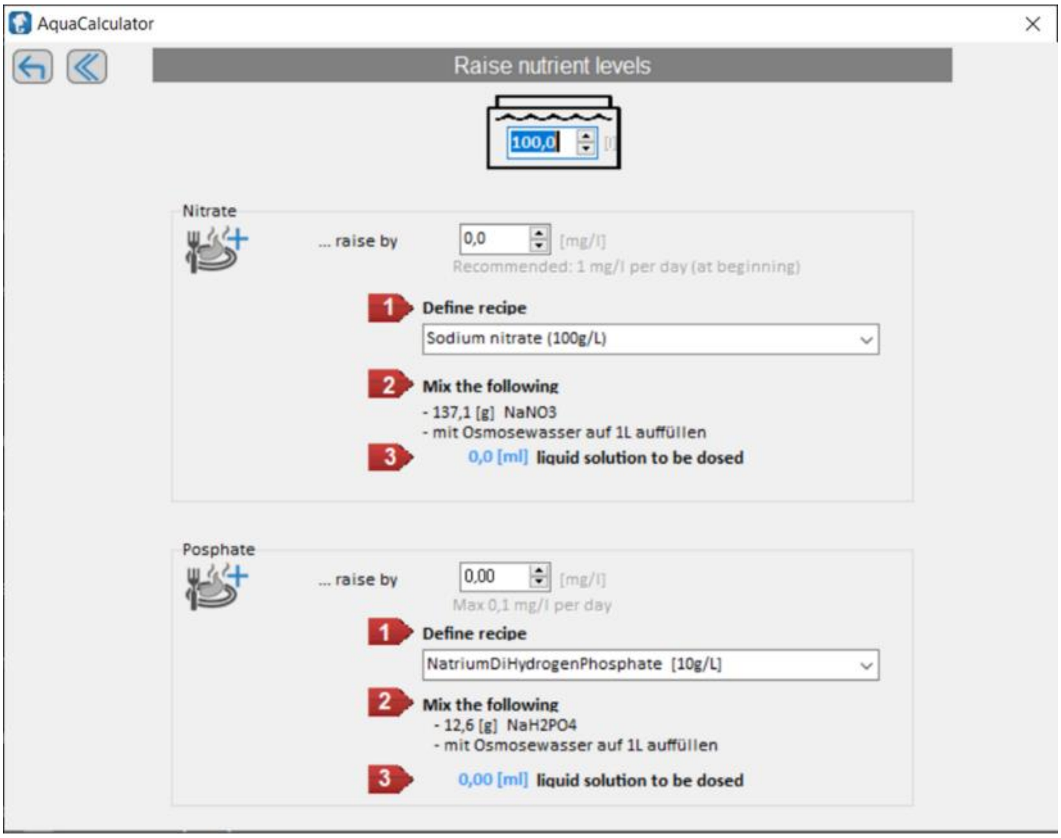
7.5 Increase phosphate (nitrate) concentration

If your aquarium is nutrient-limited...... ordering a phosphate-increasing product from an aquarium shop would take too long and you find a friendly pharmacist, you may be able to help yourself with this homemade phosphate solution of potassium dihydrogen phosphate (KH2PO4).

Recipe:	Dissolve 14.3g KH_2PO_4 in osmosis water to a total volume of 1.0 L.
concentration:	Contains 10g PO_4/litre. Highly concentrated !!!
Dosage:	0.1 ml of the solution per 100L water increase PO_4 by 0.01 mg/l

Preparation of this solution must be done carefully due to the high concentration.

If your aquarium degrades nutrients so efficiently that you have to regularly add phosphate/nitrate, AquaCalculator can support you with several integrated recipes. This may save you from buying expensive special products with the same ingredients.



7.6 Simple method for estimating the CO_2 concentration in rooms

Measuring instruments for determining the CO_2 concentration are relatively expensive and therefore rare. The following relatively simple measuring method provides at least a rough estimate.

Required: A pH meter and a aquarium air pump

- Fill a vessel with aquarium water
- Switch on the air pump and aerate the vessel outdoors for approx. 15 minutes
- Measure the pH value → 1st measurement/reference
  (the CO_2 concentration now corresponds to approx. 0.036%, ambient air)
- Aerate the same water sample for at least the same time in the room to be checked. This can also be in a cupboard. The intake air should come from this room.
- Measure pH value → 2nd measurement

pH value	CO_2 concentration in the room	Comment
remains the same	0,036%	Optimally ventilated
decreases by 0.1	0,05%	
decreases by 0.35	0,1%	
decreases by 1.0	0,5%	Strongly under ventilated

Testing without a pH meter is possible to a limited extent due to the inaccuracy of other pH tests (e.g. droplet tests). Serious under-aeration should, however, also be measurable in this way.

TECHNICAL TERMS AND ABBREVIATIONS

Aerobic	oxygen-rich
Anaerobic	low in oxygen
Anoxic	Oxygen deficiency up to complete absence of O_2
Assimilation	Conversion of substance foreign to the organism into its own substance.
Autotroph	with photosynthesis: transformation of anorg. compound. org. Substance
Azooxanthell	does not have zooxanthellae, must be fed additionally
Caulerpas	Multicellular algae (macro algae) with very good growth
Ca	Calcium
$CaCO_3$	Calcium carbonate
CO_2	Carbon dioxide (colour/odourless gas)
Detritus	Deposits of faeces, dead microorganisms, algae, etc.
Denitrification	Degradation process of nitrate nitrogen→
Diatoms	Diatoms
Density	Weight of a specified volume of a substance
Dinoflagellate	algae (unicellular organisms, shellfish), specific species are fierce pests of aquarists
DSB	Sand bed filter (DSB= deep sand bed)
ICPHigh-precision	analysis method for water parameters
Herbivore	herbivorous
Heterotrophic	does not photosynthesise, needs organic nutrients/carbon compounds
Coral quarry	Skeletons of dead corals of different sizes
	high content of $CaCO_3$ and trace elements, but also PO_4
Living Sand (Live Sand)	Aragonite sand with population of bacteria / microorganisms
LPS	Large Polyp Stonecorals (LPS)
Mg	Magnesium
Nutrients	Substances that can be ingested as food
NH_4^+	Ammonium
NO_2^-	Nitrite
NO_3^-	Nitrate
Nitrification	Degradation process of ammonia/ammonium Nitrite Nitrate
Osmosis	Flowing water through fine membranes for filtration
Ozone	Oxidises dissolved solids, increases redox potential and O_2 content of the water,
	Toxic to bacteria and in higher concentrations also to fish/corals.
UOA	Reverse Osmosis Unit
Plankton	microscopic organisms living in water
	- Zooplankton: Animal plankton (brachions, copepods)
	- Phytoplankton: plant plankton
Buffer capacity	Ability of a substance to compensate for shifts caused by the addition of acids/bases.
	to compensate for shifts
Redox potential	Measured variable, decreases when many oxidising organic substances are dissolved in
the water.	thus shows an increased organic load in the water.
Refractometer	Measuring device for determining salinity by light refraction
Salinity	Measured quantity for the salt content of seawater,
	1 psu (practical salinity unit) = 1 gram of pure salt/litre of water
Silicate	Salt of silicon/silicic acid, causes diatoms.
SPS	Small Polyp Stonecorals (SPS)
Substrate	Designation for substrate (coral/shellgrass, sand, gravel)
T5 / T8	Designation for fluorescent tubes (∅ : T5= 16mm, T8=26mm)
UV steriliser	Powerful UV tube surrounded by aquarium water →Kills bacteria
Zooxanthellae	Algae that live in symbiosis with corals, sponges, giant clams
	Nutrition through light/photosynthesis.
	Provide host with food (amino acids, glucose, glycerine).

Salinity table: Density

Meßwert: **Dichte**

Dargestellter Wert: **Salinität [psu]**

Temperatur [°C]	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
	Dichte [g/cm³]																				
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
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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: Relative density

Meßwert: **relative Dichte** Dargestellter Wert: **Salinität [psu]**

Temperatur [°C]	Dichte [g/cm³] 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: Conductance

Meßwert: **Leitwert** Dargestellter Wert: **Salinität [psu]**

Temperatur [°C]	Leitwert [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

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Sources & personal data

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