On the Production of Chlorine Dioxide in a Clamp-Lid Jar

In search of a simple solution to produce high-quality chlorine dioxide solution (CDL) at home

A summary can be found in Chapter 13 on page 20 for readers with limited time.
Anyone who would like to translate this document into other languages is kindly asked to coordinate this with me beforehand.
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Index

1 Introduction

It is my intention to share all of my findings regarding the production of chlorine dioxide solution (CDL) in a clamp-lid jar with interested people. My name is Louis Schneider. Producing CDL at home on a small scale can be a valuable companion on the path toward greater self-empowerment in matters of health, which is why I find CDL so fascinating.
Despite the very simple procedure developed by Andreas Kalcker, a complex process takes place in the background that is influenced by many boundary conditions. In my opinion, the many possible influencing factors have not yet been sufficiently explained, nor have their relationships been fully understood.
Since I personally aim to produce the cleanest possible CDL for myself and my environment in a simple way, I set out on a path to transform knowledge into experience and ultimately into wisdom. To achieve this, I applied the classical scientific method.
In total, I carefully documented 35 production runs in a clamp-lid jar and evaluated them to the best of my ability. For this purpose, I primarily used the so-called “field parameters” known from water analysis. These include electrical conductivity, pH value, and redox potential.
Later, I was able to borrow a MARAQUANTICS device (Mara) to measure the chlorine dioxide concentration. This represented a significant improvement, since the evaluation using test strips only provided very vague results even when preparing four different dilutions of a chlorine dioxide stock solution.
For this reason, I would like to once again express my sincere thanks for the loan of the Mara device.
During the experiments, I tried whenever possible to change only one variable at a time in order to clearly illustrate the relationships.

The basis is, of course, the so-called “pickle jar method” presented by Andreas Kalcker. The video “How to easily make CDS/CDL yourself” can be viewed on Dioxitube at the following link: https://dioxitube.com/w/k4v38RZF7apNKL9nGyUw1m
The term “pickle jar” has become established in German-speaking countries, but in my opinion it does not accurately describe the type of jar that is used. For me, pickle jars are normal jars with a screw cap, and those are not what we use. Rather, it is a preserving jar or clamp-lid jar, which is why in the following text I will refer only to the clamp-lid jar.
In principle, I find the method presented by Andreas very appealing because it is kept very simple and the substances used, especially the 4% hydrochloric acid (HCl), are largely safe to handle. At this point, I would also like to once again express my thanks to Andreas, who even patented the medical use of CDL in 2018 and then selflessly made these methods available to humanity by relinquishing the patents after one year (WO2018185346A1 – Treatment of infectious diseases; WO2018185348A1 – Treatment of poisoning; WO2018185347A1 – Treatment of internal inflammations).

After the first measurements of the conductivity and pH value of the produced chlorine dioxide solutions, I noticed that the conductivity increased significantly compared to the originally used water. At the same time, the pH value dropped into the acidic range to about pH 3 to 4. According to my research, chlorine dioxide is only moderately stable in this range, and decomposition reactions may occur leading to the formation of chlorate, chlorite, chloride, or possibly chlorine gas. For this reason, I aimed to raise the pH value. The exact chemical decomposition reactions are not entirely clear to me. Various reactions can be found in internet research, and I am also not certain which decomposition reactions dominate under which conditions (decomposition to Cl_2 and O_2; hydrolysis to chlorate, chloride, and acid; decomposition to Cl_2 and HCl).
My first experiments therefore involved adding sodium bicarbonate as a buffer to the produced chlorine dioxide solutions and using different acids to activate sodium chlorite ($NaClO_2$). The normal CDL produced from $NaClO_2$ and HCl I attempted…

to buffer it with bicarbonate. I also tried activating $NaClO_2$ with lactic acid. In simple evaporation tests, both approaches showed shorter residence times compared to CDL with an acidic pH ($NaClO_2$ + HCl). This suggested a faster decomposition of chlorine dioxide caused either by bicarbonate or by products formed during activation with lactic acid. Since these experiments were interesting but not particularly productive, they are only mentioned here briefly as an introduction.

The experiments that followed led to much more important findings and are described in detail in the following sections. It was an ongoing experimental series in which I always tried to change only a single variable at a time. Afterwards, I sorted and compared the individual runs so that the results could be presented in a simple and understandable way. The structure of this article therefore emerged only afterward.

The experiments presented here should not be regarded as final or absolute truth. Rather, my intention is to encourage other CDL enthusiasts who are active in this field to examine the simple and powerful method of producing CDL at home in greater depth.

to engage more deeply with the simple and powerful method of producing CDL at home. There are still several open questions, because, as is often the case, each new insight tends to generate many new questions. Further structured comparisons like the results presented below would greatly enrich the exchange of knowledge within the community. Please feel free to take this as an impulse to conduct your own scientific investigations.

At this point, I would like to provide a small insight into the experiments using an image. In this case, chlorine dioxide was produced under indirect light, resulting in a pH value of around 3.

2 Initial situation

After the Mara device became available in Germany in October 2024, many self-produced CDL stock solutions as well as purchased CDL were tested for their chlorine dioxide content. It became apparent that many solutions contained significantly less than 3000 ppm, sometimes even below 1000 ppm. The “great race” to reach 3000 ppm began. There were many discussions about, for example, the correct proportioning of the starting substances $NaClO_2$ and HCl, the influence of altitude differences, or the use of clamp-lid jars in different sizes. It was generally agreed that, with the common method (5 ml + 5 ml for 250 ml), three runs were necessary to achieve 3000 ppm.

An important recommendation for me was that two sealing rings should always be used for the clamp-lid jar, since gas leakage cannot be ruled out. This helped me understand that the CDL smell I occasionally noticed next to my CDL jars (which still had only one sealing ring) was actually caused by outgassing. At that time, I had assumed that clamp-lid jars were completely airtight and I could not logically explain where the smell was coming from.

I immediately adopted the change of using two sealing rings, even though it can sometimes be difficult to fit two rings onto the lid. Clamp-lid jars differ slightly in their lid depth depending on the manufacturer. Personally, I have had the best experience with clamp-lid jars from IKEA. As for the sealing rings, I have not yet found a type that is resistant to the long-term effects of chlorine dioxide. The red rubber seals fade over time and, like the white rubber rings, eventually become brittle and crumbly. The silicone sealing rings that I ordered…

…also eventually became brittle. There are probably significant differences in silicone quality as well. Seals made from PTFE are far too rigid and cannot be stretched over the lid. PTFE is considered extremely stable and is used, for example, as tubing material in generators. If anyone has found sealing rings that still look the same and remain flexible even after 30 production runs, they should share this with the CDL community immediately. At the moment, I simply replace the sealing rings as soon as they start to become brittle and consider them a consumable item.

Otherwise, I continue to use the setup consisting of a clamp-lid jar with a capacity of 500 ml and an inner glass for the activation reaction. I have not conducted experimental series with larger jars, for example using 1-liter jars with a wine glass placed in the center. The process should remain as safe, simple, and reproducible as possible. Anyone who believes that large quantities of CDL can be produced using the clamp-lid jar method should proceed in a manner similar to what is described in this paper. Only then will it be possible to find a way to produce CDL of good quality and with a sufficient chlorine dioxide concentration. In addition, the safety aspect must always be considered. Andreas has occasionally reported accidents involving large containers in South America. As we all know, chlorine dioxide must not be inhaled in high concentrations or large volumes.

3 Measurement Devices Used

At this point, I would like to briefly introduce the devices used, also with the intention that some readers might consider investing in them in order to better understand the underlying relationships.

3.1 Electrical Conductivity

Conductivity, or electrical conductivity, describes the ability of water to conduct electricity. Pure water does not conduct electricity and therefore has a high electrical resistance. As soon as charged particles or ions are present, electricity can pass through the water. The more charged particles there are in the water, the higher the conductivity. Chlorine dioxide is a gas and electrically neutral, so it does not affect conductivity. However, when chlorine dioxide decomposes—for example into chlorate, chlorite, or chloride—these charged particles can cause an increase in conductivity. Acids also increase conductivity through free protons (H^+).

In Germany, conductivity is expressed in µS/cm (microsiemens per centimeter). In the United States, conductivity is often given in ppm, which can be somewhat confusing, especially in the CDL community, since ppm usually refers to the concentration of chlorine dioxide. The units µS/cm and ppm can be converted into one another, but they are not identical.

Conductivity meters can be purchased on eBay for relatively little money and usually do not require calibration. In the lower measurement ranges up to about 300 µS/cm they are quite accurate. Above that range they become somewhat less precise, but considering their price they are still perfectly adequate. Anyone who wants a device that can be calibrated will have to spend a bit more money and could, for example, purchase the Voltcraft LWT-02.

3.2 pH-value

The pH value indicates how many positively charged water molecules are present in an aqueous solution. In everyday language, people usually refer to protons (H^+). In reality, these are oxonium ions (H_3O^+), meaning a water molecule (H_2O) that has accepted a proton.

It is important to note that the pH scale is logarithmic. This means that going from pH 7 to pH 3 does not represent a fourfold increase in H_3O^+ concentration, but rather a ten-thousand-fold increase (10 × 10 × 10 × 10).

In an alkaline environment, hydroxide ions (OH^-) predominate. The derivation of the pH value is based on the autoprotolysis of water (a suitable search term for further independent research).

The pH value of distilled water is practically not measurable, because some ions are always needed to stabilize or “buffer” the pH value. In addition, carbon dioxide from the air dissolves in the water, and especially in water with very low mineral content (e.g., 2–10 µS/cm)…

…is then very quickly acidified by the carbonic acid that forms. Even if a slightly acidic pH value is measured in low-mineral water, for example at 3 µS/cm, only a very small amount of a base such as sodium hydroxide (NaOH) is required to reach a neutral pH value. In practice, these experiments often end with a single drop of NaOH producing a pH of 13, and after adding two more drops of HCl (of the same concentration), the pH value drops back to around 1. For this reason, people often say in everyday language that distilled water has no measurable pH value. The situation is different, for example, with water that has a conductivity of 500 µS/cm and a pH value of 3. In that case, significantly larger amounts of NaOH would have to be added to reach a pH of 7. Inexpensive pH meters from eBay are not recommended, since they must be calibrated before every measurement (calibration powder sachets are usually included). In this case, it is more practical to simply work with pH test strips (litmus paper). This works as well and is illustrated in the photo as an example. Although CDL bleaches the paper at high concentrations, some of the solution still moves up the strip and colors the indicator paper accordingly. Anyone who…

truly wants to measure the pH value needs a device that can be calibrated with a two-point calibration (pH 4 and pH 7). An alkaline calibration solution is not necessary, since the stock solutions are not in a strongly alkaline range. Even pH values around 8 can still be measured reliably. From pH 9 onward, I would recommend an additional calibration solution with pH 10. For example, I use the Voltcraft PHT-02 ACT device. It is important that the probe is stored in a salt solution, as is the case with all high-quality pH probes.

3.3 Redox potential

The redox potential (ORP = oxidation-reduction potential) can be understood as an indication of how many electrons are available in an aqueous solution. The electrons are not present freely in the solution; rather, it is a measure of how quickly electrons are captured by the substances present.
In an oxygen-rich environment, electrons are quickly captured by substances such as oxygen, chlorine dioxide, or hydrogen peroxide and react with compounds that contain many electrons. Even faster at capturing electrons is the frequently mentioned hydroxyl radical (OH•).
In an oxygen-poor environment, such as in a septic tank, the oxygen has already been consumed and one speaks of reducing conditions. In such an environment, electrons are not as strongly competed for.
The value is expressed in mV (millivolts). For normal drinking water, the value is around 400 mV. In an overturned septic tank with rising gases, the value is around -200 mV. The most reducing aqueous solution I have measured so far was hydrogen water from Awake, where the redox value was around -700 mV.
For chlorine dioxide, a value of 940 mV is often cited. However, my results show that high-quality CDL with 3000 ppm has a value of around 860 mV.
Dr. Martín Ramírez (ALK Foundation, Guadalajara, Mexico) once stated that the redox potential cannot be used to measure the chlorine dioxide content, because even very small amounts of CDL already lead to a high redox value, and the value does not change significantly up to 3000 ppm due to the logarithmic relationship.
Therefore, the redox value provides more information about whether only chlorine dioxide is present or whether other substances with a higher redox potential are also present.
I use the Voltcraft ORP-01 measuring device. In general, the values are always referenced to a standard hydrogen electrode. These values are often calculated and also depend on the pH value, which makes the topic rather complex. My approach is therefore simply to measure with the same device and compare the results with one another.

3.4 Performing measurements with the Mara

The measuring device “MARAQUANTICS” (Mara) was developed by Dr. Martín Ramírez and measures the chlorine dioxide content of an aqueous solution through the absorption of light waves. At this point, I would like to describe how I approached the measurements using the Mara.
It is always important to perform a duplicate measurement in order to rule out major errors (for example: a cuvette not properly cleaned, the cuvette inserted at an angle, an air bubble on the glass, or suspended particles in the calibration solution or stock solution that could interfere with the measurement). I always check the cuvettes for cleanliness and suspended particles by holding them against the light. I clean them using a cotton cloth or kitchen paper (cellulose). The duplicate measurement refers both to filling two cuvettes with the same solution and to measuring the same solution twice in a single cuvette. The chlorine dioxide concentrations presented in the following chapters are always average values. Table 1 below shows different ways of performing measurements with the Mara. Initially, I wanted to determine the accuracy of the Mara and therefore measured three cuvettes three times each. However, this procedure is very time-consuming. For that reason, I switched to the method of measuring two cuvettes twice each. In rare cases, when time was limited, I measured a single cuvette twice. Once you see how accurate the Mara is and become more experienced in performing the tests, this approach is, in my opinion, sufficient. Large deviations are usually due to errors in carrying out the test. A slight downward trend during the measurement series is, in my opinion, caused by outgassing. When using the Mara, working cleanly is extremely important. At the university, we always wore cotton gloves during such measurements and cleaned each cuvette with a cotton cloth.

Name	**Chlordioxid [ppm] - individually**									**middle value**	**STD (+/-)**
	cuvette 1			cuvette 2			cuvette 3			[ppm]	[ppm]
Nr. 1 - GeneratCDL p. 6W	1925	1927	1925	1906	1901	1904	1902	1906	1899	1911	11
Nr. 24 - after production	3104	3105		3067	3083					3090	16
Nr. 24 - after bottling	2717	2722								2720	3

Table 1: Examples of measurements using the Mara to determine the chlorine dioxide concentration. Number 1 is generator-produced CDL from an acquaintance. Number 24 is CDL produced in a clamp-lid jar directly after production or after it had been bottled. It can be seen that significant amounts of chlorine dioxide already escape from the solution during bottling. In my case, I had also opened the clamp-lid jar several times to perform measurements. After I noticed the loss, I made an effort to carry out the bottling process as quickly as possible and with as few intermediate containers as possible. the calculated simple standard deviation (STD) is very informative for me, as it confirms that with the Mara we can determine the chlorine dioxide content very accurately (approximately ±20 ppm). In everyday use, the important question is usually whether the solution contains about 3000, 2500, 2000, or for example only 1000 ppm.

4 experimental setup

My experimental setup is very simple. I use clamp-lid jars with a volume of 500 ml containing 250 ml of water. Depending on the experimental setup, the inner glass has a volume of either 40 ml or 100 ml. Die

The temperature was always approximately the same, between 20–22 °C. In the experiments, only $NaClO_2$ from S3 Chemicals was used. The hydrochloric acid also came from S3 Chemicals. I always ordered 9% hydrochloric acid Ph.Eur. and diluted it to obtain a 4% hydrochloric acid solution. I can no longer trace the batch numbers. However, I assume that the acid used was not affected by the recently reported "2% disaster" involving what was supposed to be 4% hydrochloric acid from S3 Chemicals. The experiments were carried out between 2023 and 2025.

As starting water, I had access to well water, tap water, osmosis water, and distilled water. On one occasion, I also used tap water from another region.

5 Influence of Lighting Conditions on Quality

My most important finding is the following:

> ***Is it important to place the clamp-lid jar in the kitchen cupboard (complete darkness), as shown in Andreas's video?***
>
> ***Yes, it is the decisive step toward producing high-quality CDL.***

This is not explicitly stated in Andreas's video, but it is shown. I had interpreted it more as meaning that the jar should simply be placed somewhere out of the way, for example in the kitchen cupboard. Of course, it was also clear to me that it should not be placed in direct sunlight. I had always kept the clamp-lid jars in the kitchen unit, in the shade. The kitchen only has a north-facing window, so direct sunlight is practically impossible. To me, that always seemed "dark enough." However, **Table 2** below clearly shows that even a small amount of daylight can significantly interfere with the reaction between $NaClO_2$ and HCl and can lead to substantially more undesirable side reactions. The occurrence of these side reactions only becomes apparent through changes in the so-called overall parameters (conductivity, pH value, redox value).

Experimental setup:
Mixture: HCl 4% 5 ml // $NaClO_2$ 25% 5 ml
Tap water with 180 µS/cm (pH 8.2) used as the starting water; 250 ml water
Measurement after 2 runs, each approximately 24 hours

production environment	Conductivity [µS/cm]	pH-value	ORP [mV]
in indirect daylight	350 - 790	2,6 - 3,5	900 - 1050
dark in fridge	190 - 220	6,0 - 6,5	850 - 870

Table 2: Influence of daylight on the production of chlorine dioxide in a clamp-lid jar.

The negative effect of "indirect daylight" can be derived both from the increase in conductivity and from the increase in redox potential. The rise in conductivity indicates that more charged particles are being formed, meaning that some hydrochloric acid may be evaporating or chlorine dioxide may be decomposing into substances such as chloride, chlorite, or chlorate.

The redox potential shows that, in addition to chlorine dioxide, other substances are being formed that have a higher redox potential than chlorine dioxide (about 860 mV). These include chlorite, chlorate, and chlorine gas (Cl_2).

I first noticed this relationship when I gradually moved my three clamp-lid jars closer to the window because I needed more space. The conductivity and the redox value kept increasing the closer the jars were placed to the window. Comparative experiments conducted inside the kitchen cupboard then provided the "enlightenment." **The conductivity changes only very slightly during a reaction carried out in darkness, and the redox value remains around 860 mV. I was immediately able to correlate these measurements with my own experience when consuming CDL.**

I was able to relate this to my own experience. CDL produced in a dark environment is noticeably milder and does not cause the same throat irritation as CDL produced under the influence of light. This also suggests that the throat irritation is related to the by-products that are formed. The very acidic pH value observed when production takes place under the influence of light is also a consequence of these unwanted side reactions.
However, it is important to emphasize once again that the pH value of the water used (in this case tap water) is also lowered solely by the activation reaction occurring in the inner glass, even though this is often disputed. From this it can be concluded that the resulting pH value depends on the buffering capacity of the water used and on the amount of acid that is formed. In my case, the pH value of the tap water drops from pH 8 to pH 6 when production takes place in the dark. In my opinion, the solution is then still sufficiently stable for storage. Under the influence of light, a pH value between 2.6 and 3.5 is obtained.

6 Chlorine Dioxide Content Depending on Production Environment and Inner Glass

The next experiment is intended to illustrate how the interaction of several factors can lead to a significantly lower yield of chlorine dioxide. In addition to the lighting conditions, the properties of the inner glass are now also evaluated, as these also have a considerable influence on how quickly the activation reaction takes place.
The reason is that $NaClO_2$ at 25% and HCl at 4% have different densities, which leads to separation or the formation of layers. The density of $NaClO_2$ is higher than that of HCl and therefore sinks to the bottom. This effect can be seen very clearly in the image shown. The narrower the vessel, the… more pronounced this effect becomes. As a result, the two components react only at the interface between the layers, and therefore the reaction proceeds much more slowly.
Since I had always used a jam jar with a capacity of 100 ml as the inner glass, I only noticed this relationship when I once placed a shot glass with a volume of 40 ml inside. Table 3 below shows the overall parameters and the chlorine dioxide concentrations for both experimental series. The 40 ml glass had an inner diameter of about 3 cm, while the 100 ml glass had an inner diameter of about 5 cm.
Experimental setup:

Mixture: HCl 4% 5 ml // $NaClO_2$ 25% 5 ml
Tap water with 180 µS/cm (pH 8.2) used as the starting water; 250 ml water

		CDL after the production		**Chlordioxid [ppm]**		
production environment	**inner Glas**	**LF [µS/cm]**	**pH-Wert**	**Run 1**	**Run 2**	**Run 3**
indirect sunlight	*40 ml Schnaps*	1000	2,6	480	1200	
	100 ml breit	790	2,7	787	1600	
dark in the fridge	*40 ml Schnaps*	171	6,2	820	1589	2200
	100 ml breit	205	6,2	985	2077	3025

One run lasted approximately 24 hours.

Table 3: Influence of the production environment and the volume of the inner glass on the chlorine dioxide content.

The influence of indirect light is illustrated by the conductivity and the pH value, while the slower reaction in the shot glass is reflected in lower chlorine dioxide concentrations. The evaluation in Table 4 shows that up to 40% less chlorine dioxide may be produced when indirect light is present and a shot glass is used. It also becomes clear that indirect light results in about 25% less CDL being formed in the stock solution.

Lower chlorine dioxide yield due to	
daylight instead of darkness	*ca. 25 %*
shot glass instead of a wide glass	*ca. 25 %*
Daylight + shot glass instead of darkness + wide glass	*ca. 40 %*

Table 4: Evaluation of the results from Table 3

The following conclusion can be drawn:

> ****We need the largest possible inner glass. So-called tealight glasses are ideal; these have a volume of about 100 ml, and the liquids lie very shallow in the inner glass, allowing very good mixing.****

The two different variants of the inner glass are shown again in the following **image**.

7 Changing ratios for a higher yield

Next, we examine whether the chosen ratio and the amount of chemicals used are already ideal, or whether it might make sense to reconsider the established 5 ml + 5 ml method over two or three runs. Within the community, there has often been the idea of simply performing one run with 10 ml + 10 ml instead of two runs. There have also been reports suggesting that it works better with twice as much acid.

From a theoretical perspective, the question arises whether the chemical (stoichiometric) equation is balanced and whether other factors must be considered, such as the speed of the reaction. From drinking water disinfection, I know that $NaClO_2$ is activated with a multiple excess of acid (up to 200 times). The reason for this is that no $NaClO_2$ residues should remain, and therefore an extreme excess of acid is used so that the reaction proceeds quickly and the resulting chlorine dioxide can then be added to the drinking water. Since only a small amount is added, the acid ultimately has only a minor effect on the pH value of the drinking water.

If we look at the chemical equation, it becomes clear that with a ratio of 5 ml to 5 ml we are actually using far too little acid to activate all of the sodium chlorite. The exact calculation can be found in Appendix 1. The calculation was done by Anton, who worked it out himself and kindly made it available to everyone. Dr. Ramírez also presented this relationship once in a lecture.

I assume that a misconception has occurred here. In the past, MMS was mixed according to the philosophy that half of the $NaClO_2$ would be activated by the added acid and the remaining portion by stomach acid. This philosophy was maintained when switching from citric acid to hydrochloric acid, and ultimately the same method was likely applied to the “pickle jar method.” A second possible reason is that the activation should not proceed too quickly or too violently for safety reasons. We must remember that this was a new method that first had to be accepted by the community. In addition, devices such as the Mara, which we have today to accurately verify the result, were not yet available.

The fact is that to activate 5 ml of $NaClO_2$ at 25%, we would actually need about 11.2 ml of HCl at 4% or about 5 ml of HCl at 9.3%. Since $NaClO_2$ is the more expensive of the two components, I consider it quite reasonable to use it as completely as possible. However, I generally advise against using 9% hydrochloric acid. The 4% hydrochloric acid is relatively safe to handle. If you try to purchase 10% HCl in a pharmacy, you will receive extensive safety instructions, and safety goggles and gloves are usually provided as well. This shows that 10% hydrochloric acid is quite aggressive (and volatile) and therefore not suitable for general household use. Hydrochloric acid at 9–10% should be reserved for “chemistry professionals” who know what they are doing.

Table 5 shows seven experiments. The first experiment demonstrates that 3000 ppm can be achieved in three runs when using 5 ml + 5 ml. If 10 ml + 10 ml are used, as in the second experiment, only two runs are required, but more chemicals are consumed. The third experiment illustrates that using twice the amount of acid produces much higher chlorine dioxide concentrations per run. Instead of about 1000 ppm in the first run with the 5 ml + 5 ml variant, the 5 ml + 10 ml variant produces between 2000–2500 ppm in the first run. After the second run, the concentration reaches over 4000 ppm. Such high concentrations can develop in the clamp-lid jar because an overpressure forms during the reaction. After bottling at normal pressure, the liquid is naturally supersaturated and tends to outgas quickly. For this reason, I would not recommend producing such high concentrations, unless one wants to prepare a reference bottle to compare the color of other batches.

Experimental setup:
Mixture: HCl 4% + $NaClO_2$ 25% in different ratios
Tap water with 180 µS/cm (pH 8.2) used as the starting water; 250 ml water
One run lasted approximately 24 hours
Production carried out in the kitchen cupboard in darkness
Inner glass with a volume of 100 ml

					Chlordioxid [ppm] per cycle			**CDL after productiom**		
batch Nr.	**HCl**		**$NaClO_2$ 25%**	**Chemicals total.**	**1**	**2**	**3**	**LF [µS/cm]**	**pH-value**	**ORP [mV]**
1 (20)	4%ig	5 ml	5 ml	30 ml	985	2077	3025	205	6,2	863
2 (23)	4%ig	10 ml	10 ml	40 ml	1946	3317	-	177	6,1	866
3 (22)	4%ig	10 ml	5 ml	15 bzw. 30 ml	2467	4250	-	220	6,2	845
4 (33)	4%ig	12 ml	6 ml	18 ml	2543	-	-	-	6	862
5 (24)	4%ig	16 ml	8 ml	24 ml	3089	-	-	208	5,6	860
6 (32)	4%ig	20 ml	10 ml	30 ml	2340	-	-	170	6,04	862
7 (17)	9%ig	5 ml	5 ml	10 ml	2475	-	-	185	5,8	860

Table 5: Comparison of different reaction mixtures for the production of CDL

Let us now look at experiments 4 and 5. I tried increasing the total quantities in order to reach 3000 ppm in a single run. I succeeded once with 16 ml + 8 ml. However, I noticed that with 18 or 24 ml there was already a large amount of reaction liquid in the tealight glass, and the layering effect began to occur. It can be seen that with a larger amount of liquid in the glass, the chlorine dioxide yield does not increase proportionally. This relationship becomes very clear in experiment 6. When using 20 ml + 10 ml, the yield is the same as when using exactly half that amount, namely 10 ml + 5 ml. Also from a safety perspective, I would not use more than about 15 ml of reaction liquid in the inner glass. Finally, in experiment 7 I used 9% hydrochloric acid for comparison. The reaction proceeds much faster than with 4% acid, and the clamp-lid jar must be closed very quickly. However, it was shown that with about 2500 ppm a similar yield is achieved as when simply using twice as much of the 4% hydrochloric acid.

This is a very important finding:

> ***By using twice as much acid, we can achieve a significantly higher chlorine dioxide yield. We save time because fewer runs are required, and we save $NaClO_2$, since it is almost completely activated.***

I would therefore recommend simply activating **10 ml of HCl (4%) with 5 ml of $NaClO_2$ (25%)** in a single run, and then assuming that the resulting CDL has a concentration of about 2000–2500 ppm. The protocols can then be adjusted accordingly. For example, Protocol C10 would no longer be prepared with 10 ml, but with 15 ml per 1 liter in order to obtain 30 ppm. Since the produced CDL is consumed more quickly, long storage times are avoided. This is beneficial, because fresh CDL is always the best CDL.
In all seven experiments, the conductivity changed only slightly compared to the initial value, the pH value was usually above pH 6, and the redox potential was around 860 mV. This demonstrates that all experiments were carried out in complete darkness and that the formation of unwanted by-products during production was kept to a minimum. The most important result is that using more acid does not have a negative effect on the quality of the CDL.

8 Understanding the Activation Reaction

Why does the activation reaction in the inner glass proceed faster when we add more acid? One could say that this is because the chemical ratios are balanced. However, this would only explain why more chlorine dioxide gas is produced in the end. Lactic acid, for example, also reacts more slowly than hydrochloric acid even when the correct ratio is used. Instead, the reaction rate depends on the strength of the acid.

In practice, the decisive factor is therefore the acidic pH value, or the acidic environment, which allows the reaction to proceed quickly. The more acid present in the reaction vessel, the lower the pH value, and the faster and more completely the reaction will occur. This is because the activation of $NaClO_2$ is a relatively slow reaction. If it were a fast reaction, $NaClO_2$ would, for example, be completely converted into chlorine dioxide within about five minutes in an open environment (such as during room disinfection).

If we use different mixtures with (1) 5 ml HCl 4%, (2) 10 ml HCl 4%, or (3) 5 ml HCl 9%, we can measure the pH value in the inner glass after the first run. This provides an indication of whether the activation reaction is still taking place in the inner glass or whether it has already been completed and the yellow color is now caused only by the chlorine dioxide that has formed. The results are shown in Table 6.

Experimental setup:
Tap water with 180 µS/cm (pH 8.2) used as the starting water; 250 ml water
One run lasted approximately 24 hours
Measurement of the reaction residue in the inner glass with a volume of 100 ml

batch	pH-value	remark	activation reaction
(1) HCl 4% 5 ml // NaClO2 25% 5 ml	4,8	slightly acidic	almost completely completed
(2) HCl 4% 10 ml // NaClO2 25% 5 ml	0,27	strongly acidic	still active
(3) HCl 9% 5 ml // NaClO2 25% 5 ml	-0,15	strongly acidic	still active

Table 6: pH value of the activation solution after one run

Sodium chlorite is a salt with basic properties and only dissociates to a very small extent in aqueous solution. In order for it to split, an acid is required. Hydrochloric acid, on the other hand, is an acid that dissociates almost completely. This means it is not present as dissolved HCl molecules but rather as ions of H^+ and Cl^-. I once measured the pH value of a 4% hydrochloric acid solution, which was approximately −0.1. This should not be surprising, since the pH value can also take negative values. This simply indicates that the solution is extremely acidic ($H^+ > 1$ mol/l).

In mixture 1, we see that after 24 hours with 5 ml + 5 ml, the pH value is around pH 5, which is almost neutral. In this mixture, only very little chlorine dioxide gas is still being actively produced. Since sodium chlorite has a basic pH value, some of the acid is neutralized during mixing, the pH rises, and the activation therefore proceeds somewhat more slowly. If we instead use more 4% acid, for example 10 ml, we observe a faster release of chlorine dioxide gas in the clamp-lid jar. We also observe that even after 24 hours the pH value is still in a very acidic range, since the pH value of about 0.3 is below pH 1. With 9% HCl, after 24 hours of reaction we are still in the negative pH range, meaning extremely acidic conditions. This is why the reaction with the more concentrated 9% hydrochloric acid proceeds somewhat faster than in mixture 2 with 10 ml of 4% HCl.

Understanding the chemical background is not absolutely necessary. It is much simpler to perform the experiment yourself and activate two clamp-lid jars, one with 5 ml and one with 10 ml of 4% HCl. It then becomes clear that the driving force behind the activation is the strength of the acid, and this is exactly what we determine through the pH value.

In the **following image**, the activation with 5 ml of 9% acid (right) is compared with the activation using 5 ml of 4% acid (left). After about 30 minutes, it can be seen that with the 9% acid (right) the $NaClO_2$ is activated more quickly, and the surrounding water already contains a higher concentration of chlorine dioxide. The activation reaction with the 4% acid (left) is still in the initial phase, which is why the solution shows a brownish coloration.

9 The Influence of the Starting Water

This point is always discussed very intensively. Is CDL produced with distilled water really the better option? It is often recommended because pure water contains no substances that could consume the chlorine dioxide. However, Andreas once mentioned in a meeting that in Switzerland they had produced very mild CDL directly with spring water from the mountains. So where do the differences lie? First of all, it is important to mention that the following considerations apply only to the clamp-lid jar method and not to generator-produced CDL. In order to understand the following measurement results, we must also know that, in addition to chlorine dioxide gas, a small amount of hydrochloric acid also evaporates. Hydrochloric acid is a volatile substance. Highly concentrated 33% hydrochloric acid is opened in the laboratory only under a fume hood. The amount of acid from the 4% hydrochloric acid that transfers is not large, but it is sufficient to alter the pH value of the starting water. What matters here, of course, is whether the acid is neutralized or buffered in the starting water, for example because basic minerals are present. Pure distilled water contains no minerals (sodium, potassium, calcium, magnesium) or other basic anions such as bicarbonate (HCO_3^-). As already explained, the pH value of pure water is therefore not measurable. Osmosis water usually has a conductivity below 40 µS/cm and is therefore only very lightly mineralized. Its buffering capacity is therefore low. Tap water, on the other hand, varies enormously throughout Germany in terms of composition, mineral content, and overall quality. Its conductivity can reach up to 2500 µS/cm at 20 °C. These are very mineral-rich, or “hard,” waters. In most cases, tap water in Germany is disinfected with chlorine dioxide, and in this case no cross-reactions occur. Only in very few cases is tap water treated with sodium hypochlorite, as is common in some other countries. In such cases, the water smells of “chlorine,” like in a swimming pool. Since hypochlorite reacts with chlorine dioxide, such tap water is of course not suitable.

Table 7 compares distilled water, osmosis water, two different tap waters, and well water. The first tap water from my faucet is surface water originating from a drinking water reservoir in Thuringia. The second tap water I brought back from a vacation. Due to the significantly higher conductivity of 460 µS/cm, it can be assumed that it is…

groundwater. The well water comes from our garden and is shallow groundwater from a floodplain valley. The second tap water and the well water were tested later, which is why the chosen mixtures differ slightly from those in the first round.

<u>Experimental setup:</u>
Different starting waters, each with 250 ml of water
One run lasted approximately 22–30 hours
Production carried out in the kitchen cupboard in darkness
Inner glass with a volume of 100 ml

		Chlordioxid [ppm]	**Start**		**CDL after production**		
batch / Nr.	**Water**	**Run 1**	**LF [µS/cm]**	**pH**	**LF [µS/cm]**	**pH**	**ORP [mV]**
8 ml $NaClO_2$ 25% + 16 ml HCl 4%							
28	Tapwater 1	3005	167	8,2	170	5,85	874
26	Osmose	2893	18	-	136	4,1	910
27	destilliert	2269	0	-	105	3,8	912
5 ml $NaClO_2$ 25% + 10 ml HCl 4%							
34	Tapwater 2	2025	460	7,5	503	6,7	830
35	Well water	2228	700	7,5	814	6,8	820

Table 7: Comparison of different starting waters in CDL production

To understand the results, we begin with distilled water. The conductivity increased from 0 to about 100 µS/cm and the pH value dropped to 3.8. In a control experiment, I was able to demonstrate that this change is almost entirely due to the transfer of hydrochloric acid. Decomposition products of chlorine dioxide play only a minor role here.
In 250 ml of distilled water, I had to add 50 µl of 4% HCl to obtain a conductivity of 100 µS/cm and a pH value of 3.8. This corresponds to approximately one drop of HCl, since 20 drops are roughly equal to 1 ml or 1000 µl.
Here lies the essential difference compared to generator-produced CDL. In the generator, no acid transfers into the stock solution. Based on my experiments and my current knowledge, only the generator method (electrolysis process) can produce pure chlorine dioxide solutions (conductivity of 0–5 µS/cm). With the clamp-lid jar method, a small amount of hydrochloric acid will usually always transfer into the stock solution, and we have to accept this. (With adjustments to the experimental setup, the production of pure CDL in a pickle jar may also be possible; see page 16 “Note”.)
It is interesting that the redox value of about 910 mV is higher with distilled water than when tap water is used (around 860 mV). It must be assumed that some by-products such as chlorite, chlorate, or chlorine gas have already formed. Most likely only in very small amounts, but still measurable. The probable cause is the acidic pH value that develops in the starting water, because the one drop of 4% hydrochloric acid was not buffered. Since pH and redox potential also influence each other, the increase in redox potential may simply be due to the drop in pH value. Taste experiments or the irritation in the throat are the decisive indicators for clearly determining whether by-products have formed.

Osmosis water behaves essentially similar to distilled water. The resulting pH value is also acidic and the conductivity increases significantly, since the transferred acid is not buffered.

The first tap water, however, behaves differently. Here, the conductivity hardly changes at all, since the transferred acid is simply neutralized. This is evident from the decrease in pH value. The pH is slightly below 6 and therefore still within a moderate range. With 16 ml of 4% HCl, we naturally have significantly more acid in the inner glass, which means that more of it evaporates, and the pH value of 5.85 is more acidic than it would be if less acid were used (see Table 5). However, this setup is not preferable, as there is too much liquid in the inner glass (see Chapter 7). The redox value of the tap water is lower than when distilled or osmosis water is used and is closer to the optimal value of around 860 mV that I determined.

The measured chlorine dioxide concentrations should be viewed with caution. Such a large difference between the setups could also be caused by an error, such as a leaking jar. One of the jars I used had two sealing rings, but one of them was made of silicone and was very thin. In this case, duplicate measurements would definitely be necessary to determine the influence of the starting water on the resulting chlorine dioxide concentration with certainty. However, due to the low pH value and the presence of side reactions, it is at least conceivable that chlorine dioxide is consumed when pure or low-mineral water is used as the starting water. If duplicate measurements were carried out for all experiments, the workload would quickly reach that of a full thesis. That was not my goal; rather, the aim is to understand fundamental relationships.

With the second tap water and the well water, we examine changes in the overall parameters in starting water with high mineral content. The pH value decreased only slightly and remained close to neutral, around pH 7. However, the conductivity changed quite significantly. This suggests that reactions are taking place and that the produced chlorine dioxide gas is reacting with a component of the starting water. One example could be the oxidation of dissolved metals. Such reactions would also generate ions, which in turn increase conductivity. Clarifying this in detail is something I leave to a chemist. These reactions could explain why the resulting chlorine dioxide concentrations of 2300 and 2000 ppm are lower than those achieved with tap water No. 1 under the same conditions (2500 ppm, see Table 5). The redox values below 860 mV may be related to the relatively neutral pH value or to the fact that 3000 ppm has not yet been reached. This is another topic for a dedicated chemist to explore.

In summary, water is not simply water, and tap water is not the same everywhere. Maintaining a stable pH above 6 is only possible when using tap water with a conductivity above approximately 180 µS/cm, since low-mineral water cannot sufficiently buffer the transferred hydrochloric acid.

From this, I conclude that it is more practical to use tap water, provided it has not been chlorinated with hypochlorite. It may also be beneficial to dilute very mineral-rich tap water (>1000 µS/cm) with low-mineral water. Tap water is available to everyone, which significantly lowers the barrier to producing CDL at home, especially for beginners.

My experiments have shown that chlorine dioxide concentrations between 2000 and 2500 ppm can be achieved in a single run. If we assume 2000 ppm, then the existing quantities in the protocols simply need to be multiplied by 1.5: for example, from 10 ml per 1 liter to 15 ml per 1 liter for Protocol C10. The advantage is that we then tend to use slightly more chlorine dioxide than specified in the protocol, thereby compensating for chlorine dioxide losses caused by repeatedly opening the bottle and by long storage times.

10 Comparison of Clamp-Lid Jar CDL and Generator CDL

At this point, I would like to once again highlight the difference between the two production methods. In the generator, the chlorine dioxide gas that is produced is introduced via a hose into highly purified water. There appear to be differences between the generators and the ways they are operated. Since I do not own a generator, I can only share second-hand knowledge here. However, I have been told of resulting chlorine dioxide solutions with **3–5 µS/cm and 3000 ppm**. In this case, it is highly purified water containing dissolved chlorine dioxide gas. Measuring the pH value in such a solution does not make much sense, because even CO_2 from the air will slightly acidify the solution, and a single drop of mineral-containing tap water can drastically change the pH value. At such low conductivity, this represents a chlorine dioxide solution of the highest purity, which, in my opinion, is particularly relevant for medical or intravenous applications. In addition, this method can be standardized very well. The quality and purity of the solution can be clearly controlled via the chlorine dioxide concentration, conductivity, and redox potential. However, caution is advised, as I have also heard of generator-produced CDL with higher conductivity values when, for example, strong pumps are used or the chambers are overfilled.

The level of purity that can be achieved with generator-produced CDL cannot be reached with the clamp-lid jar method in my experiments. With the clamp-lid jar setup I used and the selected starting materials, the resulting solution will always have a conductivity above 100 µS/cm. To ensure pH stability and an appropriate redox value, a certain buffering capacity in the starting water is also required, which leads to a conductivity of around 200 µS/cm. Table 8 provides a summary overview of this.

I have never personally tested the also well-known loop method for production, nor have I received CDL produced using this method. Therefore, I cannot make any statements about it.

method of production	**Generator**	**Clamp-Jar**	**Clamp-Jar**
used Water	destilled	destilled	Tapwater with 180 µS/cm
ORP [mV]	850 - 860	900 - 920	850 - 860
Conductivity [µS/cm]	0 - 5	100 - 120	170 - 200
pH	-	2 - 4	5,8 - 6,2

Table 8: Comparison of generator-produced CDL and clamp-lid jar CDL

Note: I shared this document with Anton for proofreading. He used the findings presented here and was able to produce CDL with **5 µS/cm and 2400 ppm** using double-distilled water. However, he used a much larger inner glass, different starting materials, and temperatures below 20 °C. This suggests that it is also possible to produce CDL of the highest quality using the clamp-lid jar method. The key influencing factors are not yet fully understood, and further repeated experiments along with thorough documentation are needed to make the results clearly understandable for the community.

11 The Shelf Life of the Produced Stock Solutions

Of course, the question arises as to how stable the produced CDL is. It is known that CDL has a limited shelf life, as it undergoes a natural decomposition process through hydrolysis (reaction with water). It is therefore often stated that it should not be stored for longer than six months, and that after longer storage, for example, simply twice the amount should be used. I have only limited comparative data on this.

One CDL batch that I produced in 2023 was stored in a 10 ml vial and opened for measurement for the first time 1.5 years later. It still had a concentration of 1600 ppm. I have also heard that generator-produced CDL stored in the dark still had almost the same concentration after six months, with negligible losses. However, I do not have any reports on the shelf life of CDL produced using the clamp-lid jar method.

I filled the respective stock solutions into 100 ml amber glass bottles and stored them in the refrigerator. The initial value available to me is the measurement taken directly after production in the clamp-lid jar. I did not take a comparative measurement from the bottle after one day, as this would have been too time-consuming. For sealing, I have so far always used polypropylene caps. These can be found under the search term “brown screw cap standard PP28 ApoGlass” and are shown in the image in Chapter 14. I chose these caps because, in my experience, they are very chemically resistant to CDL. The topic of caps is discussed in more detail in Chapter 14.

However, based on my latest findings, these caps are not particularly airtight. On airplanes, meaning under reduced pressure in the luggage compartment, some CDL always escapes. On one occasion, it even affected a T-shirt in my travel bag when we were traveling by car. In that case, the temperature had simply changed, and the bottle was not upright as it is in the refrigerator, but lying on its side. The caps are therefore definitely not airtight. This means it is quite possible that some CDL continuously escapes through the cap over time, even in the refrigerator. The observed CDL losses may therefore be higher than they would be with completely airtight caps. Nevertheless, the differences between the test setups remain meaningful, since all stock solutions were stored under the same conditions.

Table 9 shows the results measured after three months. My main interest was to compare CDL produced using different types of starting water. The CDL concentration decreased by between 20% and 55%. Tap water performed better than osmosis water and distilled water. The conductivity increased slightly over time, while the pH value decreased. This indicates ongoing decomposition processes. The redox value of tap water No. 1 remained تقريبately the same, while it decreased slightly in all other cases. For the low-mineral waters (distilled water and osmosis water), I assume that the already low pH value after production promoted decomposition. Tap water No. 1 had a higher pH value after production, so the decomposition reactions were initially somewhat slower.

In fact, I would not overinterpret these results, but rather consider them as a preliminary experiment. For solid conclusions, at least duplicate measurements should be performed for each setup, and the concentration should also be measured again one day after bottling in order to clearly separate losses caused by bottling. Of course, fully airtight caps should also be used.

Experimental setup:

Different starting waters, each with 250 ml of water
One run lasted approximately 22–30 hours
Production carried out in the kitchen cupboard in darkness
Inner glass with a volume of 100 ml

	Chlordioxid [ppm]		**CDL-loss**		**LF [µS/cm]**			**pH-Value**			**ORP [mV]**	
Water	**t=0d**	**t=3m**	**total**	**%**	**Water**	**t=0d**	**t=3m**	**Water**	**t=0d**	**t=3m**	**t=0d**	**t=3m**
Tap 1	3090	2152	938	**30%**	167	167	200	8,2	5,6	3,9	868	870
Tap 1	2637	2073	564	**21%**	175	170	214	8,2	5,9	4,1	874	866
Osmose	2893	1338	1555	**54%**	18	136	156	-	4,1	3,5	911	893
Destilliert	2269	1210	1059	**47%**	0	105	125	-	3,8	3,5	912	888
Tap 2	2025	1262	764	**38%**	460	503	555	7,45	6,7	5,9	830	810
Wellwater	2228	1241	987	**44%**	700	814	817	7,48	6,8	6,25	820	793

Table 9: Shelf life of different CDL batches after 3 months (0d = day 0, 3m = after 3 months)

My personal conclusion is that using tap water is preferable to water without buffering capacity, and that the produced CDL should be consumed as quickly as possible. Since every tap water is different and it is impossible to analyze them all, it is more practical to assume a limited shelf life and to routinely prepare fresh CDL, for example every 6 weeks.

12 How high are the losses due to repeated opening?

We have already established very important relationships, and the remaining question is how much CDL is lost through repeatedly opening the bottles. For this purpose, I also carried out various experiments over a period of about two weeks, repeatedly removing a certain amount, measuring the chlorine dioxide content, and then placing the bottle back in the refrigerator.

In general, it can be stated that there is, of course, some loss. However, if the CDL is consumed quickly, the losses remain small. With longer storage times and a high proportion of air in the bottle, the chlorine dioxide content decreases rapidly. During the experiments, I also found that it is important to shake the bottle well before opening it, as chlorine dioxide present in the air space will dissolve back into the water.

Whether the bottle has a capacity of 100 ml or 330 ml is irrelevant. It also makes no difference whether amber glass or clear glass is used for storage in the refrigerator. I now prefer clear glass, as the color provides a better indication of the approximate concentration and gives a better sense of the active substance, chlorine dioxide. If CDL is always stored in amber glass and consumed according to Protocol C10 in amber bottles, one may not even notice that a 3000 ppm solution has dropped to 1000 ppm, or that a drinking solution prepared according to Protocol C10 has decreased from 30 ppm to only 10 ppm.

There are also nice clear glass bottles from the company Salus (for example, fresh-pressed herbal juice bottles, 200 ml) that can be stored compactly in the refrigerator with a suitable cap (search term: Salus dandelion juice 200 ml).

Table 10 shows the first experiment conducted. After each measurement, 20 ml was removed. Since there were 8 days between the second-to-last and the last measurement, and only 10 ml remained in the bottle (worst-case scenario), the cumulative losses are shown for 6 days and for 14 days. The first shaking test is highlighted in green. Here, the loss was reduced by about 10% compared to experiment A. In other words, the solution contained about 300 ppm more—1080 ppm instead of 770 ppm.

As a rough estimate, I would assume that approximately 2–5% of chlorine dioxide is lost with each opening, provided that the CDL is consumed regularly and long storage times are avoided.

	Brownglas 100 ml			**A**		**B**	
Day	**CDL [ml]**	**Air [ml]**	**withdrawal after mesurement [ml]**	**Chlordioxid [ppm]**	**Reduction per withdrawal**	**Chlordioxid [ppm]**	**Reduction per withdrawal**
0	100	10	20	2764		2637	
2	80	30	20	2741	1%	2681	-2%
3	60	50	20	2617	5%	2542	5%
4	40	70	20	2520	4%	2507	1%
6	20	90	10	2296	9%	2401	4%
14	10	100		773	66%	1076	55%
			total Reduction 6d	**468**	**18%**	**236**	**9%**
			total Reduction 14d	**1992**	**84%**	**1561**	**64%**

Table 10: Loss of chlorine dioxide due to repeated opening, storage in the refrigerator in 100 ml amber glass bottles, duplicate measurements performed (experiments A and B).

Table 11 shows the second experiment, in which 330 ml bottles were used and amber glass was compared with clear glass. I cannot say exactly why the losses were lower than in the first experiment. It may have been due to different threads and better-fitting caps. At some point, I removed relatively large amounts so that the experiment could be completed sooner.

				Clamplid-Jar		**Clearglas**	
Day	**CDL [ml]**	**Air [ml]**	**Withdrawal after Mesurement [ml]**	**Chlordioxid [ppm]**	**Reduction per withdrawal**	**Chlordioxid [ppm]**	**Reduction per withdrawal**
0	330	0	0	2533		2570	
1	330	0	40	2471	2%	2511	2%
2	290	10	40	2446	1%	2495	1%
4	250	50	40	2456	0%	2485	0%
12	210	90	40	2363	4%	2429	2%
13	170	130	120	2379	-1%	2387	2%
15	50	250	50	2327	2%	2256	5%
			total Reduction	**206**	**8%**	**314**	**13%**

Table 11: Loss of Chlorine Dioxide Due to Repeated Opening, Storage in the Refrigerator in 330 ml Amber Glass or Clear Glass

In conclusion, it can be derived that

> **…that long storage times in the refrigerator with a high proportion of air space significantly reduce the chlorine dioxide content. If the bottle is shaken beforehand, the loss can be reduced. It is recommended to use the CDL within 2–3 weeks once the bottle has been opened.**

13 Interim Conclusion and Summary

It is time to summarize what should be considered when producing and using CDL based on the experiments conducted. The detailed explanations are provided in the respective chapters. The summary is presented in tabular and bullet-point form.

Action..	Results in...
Production in darkness	**Much higher yield, CDL is milder, causes less throat irritation, and is more stable**
wide inner glass	**Less layering and therefore a higher chlorine dioxide yield**
higher acid proportion during activation	**Faster production, higher consumption of sodium chlorite, and a higher chlorine dioxide yield**
tap water as starting water	**Mild CDL, minimal change in pH value during production**

From this, the clamp-lid jar method 2.0 can be derived:

- Use a clamp-lid jar with a volume of 500 ml
- Use two sealing rings (rubber/silicone) – only then are the jars airtight
- Replace sealing rings as soon as they become brittle
- Use an inner glass with a capacity of 100 ml and an inner diameter of about 5 cm (e.g. a tealight glass); a shot glass with 40 ml (4 cl) leads to a lower yield
- Use exactly 250 ml of water (mark once for reference) with at least 150 µS/cm (electrical conductivity)
    - Tap water can be used if it has not been chlorinated with hypochlorite (chlorine smell like in a swimming pool)
    - Tap water with a conductivity below 150 µS/cm is very rare
    - The conductivity of tap water can be obtained from the drinking water analysis of the local utility if no measuring device is available
- Production must take place in darkness (kitchen cupboard), otherwise poor quality results
- Single activation using 5 ml $NaClO_2$ (25%) and 10 ml HCl (4%) in the inner glass
- Wait for the color of the inner and outer liquids to equalize (after approx. 12–32 hours)
- The resulting CDL has approx. 2000–2500 ppm and is used directly; no second activation required
- Store in glass bottles in the refrigerator with suitable caps made of PP or HDPE
- Amber glass for transport; for storage in the refrigerator, clear glass is also suitable; bottle size (100 ml, 200 ml, or 300 ml) does not matter
- For common protocols (based on 3000 ppm), multiply the used amount by a factor of 1.5 (e.g. 10 ml → 15 ml, 20 ml → 30 ml)
- CDL is used according to the principle: “fresh CDL is always the best CDL”
- Shake well before opening to reduce chlorine dioxide loss into the headspace
- Once opened, use the bottle within 1–2 weeks
- After 6 weeks, produce a new batch routinely; unused CDL has a lower chlorine dioxide content and is therefore replaced or used for bathing, cleaning, or washing fruits and vegetables. In critical cases, the loss is accounted for by assuming a concentration of 1500 ppm and doubling the calculated dosage (factor 2).

14 Addendum 1: Taste Test as an Indicator of Plastic Stability in Contact with CDL

At this point, I would like to share some additional personal experiences that have helped me better understand the handling of CDL.

It is often emphasized that DMSO has solvent properties. That is correct. When I transfer DMSO and a drop comes into contact with the black plastic of my small scale, the plastic actually becomes somewhat viscous. This is well known, which is why special care is taken to use glass containers whenever possible. Of course, plastic is not all the same—there are significant differences. In diluted form, DMSO is much less reactive and, after proper rinsing, can also be used in plastic syringes. Hartmut Fischer describes this in detail in one of his compiled works.

However, the oxidative power of chlorine dioxide should also not be underestimated. I would like to share a few real-life examples:

1: As an inexperienced beginner, I once ordered 200 ml of CDL in a glass dropper bottle. The description stated in detail that the dropper, made of soft rubber or a plastic alternative, was highly resistant to chemicals and therefore suitable for use with CDL (I no longer remember the exact material or manufacturer). After some initial use, I stored the bottle in the refrigerator. About six months later, I used it as a mouth rinse by adding a few drops to about 100 ml of water. It tasted bitter, penetrated deeply into the gums, and caused pain at the tooth neck. Only later, when I began producing CDL myself, did I realize that properly made CDL is essentially tasteless—and that what I had used back then was likely contaminated with oxidized plastic compounds.

2: An acquaintance once showed me what was supposedly high-quality CDL stored in an amber glass clamp-lid bottle (a former beer bottle, with a PE sealing ring instead of silicone). She had obtained it indirectly and did not know the original producer. The CDL was considered very valuable. However, when diluted at 10 ml per 1 liter of water, it was almost undrinkable due to its sharp, biting taste. I told her that it could only be used for cleaning. Most likely, unsuitable materials had been used during production, leading to significant reactions between plastics and chlorine dioxide.

3: I am a big fan of chlorine dioxide-treated aloe vera gel. I once stored this gel in a dropper bottle made of LDPE and kept it in the refrigerator. I used it only externally on the face and skin. At some point, I had the idea to use it as a mouth rinse (of course diluted in water). The sweet, plastic-like taste seemed familiar. The gel remains stable in the refrigerator for a long time, which means it had ample time to react with the plastic. Since then, I only store it in glass bottles with PP caps.

4: If you have ever carried out the activation of $NaClO_2$ in a reaction vessel made of HDPE (e.g., 50 ml) or in a small plastic syringe, you will notice that even after rinsing the container once, a slightly sharp odor remains. The activation reaction is, of course, even more reactive than the stock solution. Similarly, collecting the reaction residue in a PET or LDPE bottle leads to clearly noticeable odors.

It is therefore possible, even without sophisticated laboratory analysis, to determine whether plastics react with CDL simply through smell and taste. Depending on the type of plastic and the resulting compounds, the odor or taste may be sweet, bitter, or sharp. It reminds me of my experiences in Africa (Ghana), where drinking water…

…was sold on every corner in plastic bags. When it was cold and had not yet been exposed to the sun, it was still drinkable. But as soon as it warmed up and had been sitting in the sun, a slightly bitter aftertaste became clearly noticeable.

Based on these experiences, I have tried to switch entirely to glass. However, conventional pharmacy bottles with ground glass stoppers are far from gas-tight. Even when stored in the refrigerator, you can practically hear the chlorine dioxide gas lifting the stopper and small gas bubbles escaping.

These experiences have also discouraged me from using the clamp-lid jar method in glass-lock systems (glass containers with plastic lids, such as food storage boxes). There is simply too much plastic involved for my comfort. The weak point of the clamp-lid jar at the moment is still the sealing ring, but perhaps one day a sealing ring will be found that can withstand 30–40 runs without degradation.

For drinking solutions, I also prefer glass bottles with separately purchased PP caps, since bottles from supermarkets usually come with metal caps. There are also aesthetically pleasing bottles available that do not make one appear like an “anonymous alcoholic.” Those who prefer amber glass can find suitable options under the search term “juice bottle 750 ml brown.” I also like to use clear glass, making sure it is always kept in the shade. This provides a better sense of what one is actually drinking—a slightly yellowish liquid, i.e., strongly diluted CDL.

Of course, there are tables regarding chemical resistance that recommend materials such as PTFE, silicone, HDPE, and PP for handling highly concentrated chlorine dioxide. However, these are broad material categories. Each manufacturer, for example, adds different plasticizers to PE or PP. If a plastic used produces noticeable odor or taste, alternatives should be sought.

To determine which plastic caps have low reactivity with CDL, I once conducted the following experiment: take several caps of one type, place them in a clamp-lid jar with CDL stock solution, and let them sit for 1–2 days. Then open the jar and allow the chlorine dioxide to slowly evaporate in the refrigerator. Once the liquid becomes clear, remove the caps and check whether they have become brittle or lost color. Then smell the water and taste a small amount to see whether it has a sweet, bitter, sharp, or pungent flavor. It is, of course, necessary to run a control test without plastic caps under the same conditions to ensure that any change in smell or taste is actually caused by the caps.

Based on this experiment, I settled on brown PP caps. I now assume they are very chemically resistant, likely due to a relatively rigid PP formulation. The downside, however, is that they seem to be too rigid and do not form a completely airtight seal with the glass rim, no matter how…

…tightly they are screwed on. While searching for alternatives, I came across black PP caps that are made from a slightly softer formulation. Since they securely seal CDL and aloe vera gel even during air travel without leaking, I assume they are better suited. Both types of caps are **shown in the following image**.

Cap on the left: PP black – “Cap, PP, 28/410, screw-on, black, ribbed”: https://allinpackaging.de/kappe-pp-28-410-schraubbar-schwarz-gerippt-pp

Cap on the right: PP brown – “Brown screw cap standard PP28 ApoGlass”: https://www.glas-shop.com/verschluesse/schraubverschluesse28mmfuerpetmedizinflaschen/schraubverschlussbraun28mmfpetmedflstandard.php

At one point, I tried to compare the brown and black caps directly. I placed two amber glass bottles in the kitchen window for several days. The decrease in chlorine dioxide concentration was relatively small, and there was no noticeable difference between the caps, so I discontinued the experiment. Had I been more patient and placed the bottles in the refrigerator for three months, I might have gained more insight. The outgassing effect is likely very slow and only becomes measurable after several months.
Therefore, I leave it to someone with a Mara device to determine which caps are truly airtight and practical to use. I have also heard that glass bottles with swing-top closures and silicone seals work well and are airtight, but I personally find plastic caps more convenient—especially since many small glass bottles with screw caps can be reused.

15 Addendum 2: Use of very small amounts of DMSO to… to neutralize by-products of CDL production

The mixture of DMSO and chlorine dioxide is known from Protocol K. The goal is that DMSO, acting as a carrier or penetration enhancer, allows chlorine dioxide to penetrate deeper into the tissue. However, it is also repeatedly stated that the mixture should not be stored for long periods, since chlorine dioxide reacts with DMSO over time. This is understandable, as DMSO has a redox potential of approximately 300 mV. The reaction is relatively slow, however, and does not result in the complete disappearance of chlorine dioxide immediately after mixing DMSO with CDL.

A similar experiment has already been described by Hartmut Fischer in his DMSO handbook (page 112, 14th edition). He refers to a Japanese study showing that very small amounts of DMSO can be used to reduce traces of chlorine gas present in chlorite or hypochlorite solutions to chloride.

I wanted to verify this process myself. For this purpose, I used CDL that had been produced under the influence of light, which already resulted in a redox value of about 930 mV and a pH value of 3.4. I then placed it next to a window and waited for daylight (UV light) to cause the decomposition of the chlorine dioxide present. The CDL was stored in a closed glass bottle that was only half filled, allowing gases to slowly escape into the air and surrounding environment. Table 12 presents the full series of measurements. After 14 days, the redox value had risen to about 1160 mV. This indicates that decomposition products of chlorine dioxide had formed that possess a higher oxidative potential. The pH value was 1.9, indicating that the decomposition process is associated with the formation of protons, i.e., acid. The chlorine dioxide content was estimated at around 500 ppm using test strips.

Experimental setup:
CDL production under light exposure
Storage in a closed pharmacy glass bottle (half-filled) for 2 weeks at room temperature by a window (north-facing, without direct sunlight)

Time point[d=day]	**ORP [mV]**	**Difference [mV] to previous measurement**	**pH-value**	**CDL concentration [Teststrips LaMoote]**
immediately after production	930		3,4	
1d bei RT	980	+50		
10d bei RT	1150	+170		
14d bei RT	1166	+16	1,9	ca. 500 ppm
14d bei RT + insg 1 Tr. DMSO	980	**-186**		
14d bei RT + insg 2 Tr. DMSO	973	-7		
14d bei RT + insg 3 Tr. DMSO	967	-6		

Controll

15d in Fridge	930

Table 12: Change in ORP of a CDL under light exposure after the addition of DMSO

The decisive factor is the significant drop in redox potential when a single drop of 100% DMSO is added to this solution. I carried this out after 14 days. The redox potential decreased by approximately 180 mV, from 1160 mV to 980 mV, which is almost the same value as at the beginning of the experiment. After adding more DMSO, the redox value only decreased slightly by about 6–7 mV. This may indicate that the highly oxidizing substances (e.g., chlorine gas) were already neutralized in the first step. With each additional drop, the reaction with the remaining decomposition products (e.g., chlorate) appears to proceed more slowly. It is also possible that DMSO is now reacting with another decomposition product (ORP around 960 mV), which is present in higher quantities and is not yet fully consumed even after two additional drops. Only a further significant drop in redox potential would indicate that this substance has been completely converted.

To fully describe these processes, one would need to know exactly which reaction products are present from decomposition, what their redox potentials are, and how the chlorine dioxide concentration changes after the addition of DMSO. However, this is not my objective. What I have understood is that irritating substances (by-products from production or decomposition products caused by UV light) with an ORP above 1000 mV in CDL can be neutralized by very small amounts of DMSO. I make use of this, for example, by adding a small amount of DMSO to CDL eye drops—significantly less than specified in the protocol. I simply take one drop of a 3% DMSO eye drop solution and add it to the CDL eye drops.

16 Further experiments

These experiments can be continued indefinitely, but this requires a great deal of time and personal motivation. Based on the experiments presented, it is very clear how one can plan and conduct their own comparisons and tests. It is always important to change only one parameter at a time; otherwise, it becomes impossible to determine the cause of observed differences. Anyone whose questions have not yet been fully answered is encouraged to conduct their own experiments. In my opinion, measuring only the chlorine dioxide concentration using the Mara is not sufficient. If done properly, it should also include the use of three additional measuring devices for pH, electrical conductivity, and ORP. Anyone who needs support or guidance is welcome to contact me.

My thirst for knowledge has now been satisfied. I know how to produce my own CDL at home in fairly good quality, which water to use, and what concentration it approximately has. I am also able to give others appropriate recommendations on how to proceed in order to obtain a usable CDL. My derived “clamp-lid jar method 2.0” is, of course, just one of many possible approaches, but it helps prevent errors in production that could cause the applied protocols to not work properly.

Below are some ideas for further experiments:

1. **Comparison of different starting substances available on the market** (both sodium chlorite 25% and hydrochloric acid 4%)
   a. Use the same experimental setup for all tests and change only one component at a time—either sodium chlorite or hydrochloric acid—to determine which chemical is responsible for what effect
   b. Observe how the overall parameters (pH, conductivity, ORP, and chlorine dioxide concentration) change

2. **Use of citric acid instead of hydrochloric acid**
   a. Determine the exact concentration and amount of citric acid needed to fully activate $NaClO_2$
   b. Observe how the overall parameters (pH, conductivity, ORP) change
   c. Check the resulting pH value in the reaction vessel; if it is only weakly acidic, adjust the acid proportion
   d. Test shelf life and compare whether there are differences compared to CDL activated with hydrochloric acid
   e. Check whether self-prepared citric acid solutions remain stable or become contaminated (e.g. by fungal growth) over time

3. **Adjusting the amount of water**
   a. It may be possible to activate a slightly larger volume of water, but there is a risk that water may spill into the reaction vessel when moving the clamp-lid jar. Since the inner glass (tealight glass) is relatively large, the available space in the jar is limited
   b. Alternatively, reduce the water volume to 200 ml and test whether the 5 ml + 10 ml setup yields exactly 3000 ppm; 200 ml would then fit perfectly into a 200 ml bottle

4. **Influence of different temperatures**
   a. Use the same setup and compare one batch stored in the refrigerator with one stored in the kitchen cupboard

5. **Duration of activation**
   a. Test whether it is beneficial to leave the clamp-lid jar with the 5 ml + 10 ml setup for two days to allow more chlorine dioxide to dissolve into the water
   b. For example, prepare three identical setups and measure the chlorine dioxide concentration after 12 hours, 24 hours, and 48 hours

6. **Different types of tap water**
   a. It would be interesting to test various tap waters to generalize recommendations. In Germany, only very few tap waters are chlorinated with hypochlorite and therefore unsuitable
   b. Are there substances present that react with chlorine dioxide and lead to different final concentrations depending on the water source?
   c. Is shelf life similar, and are there correlations between mineral content and storage stability?

7. **Alternatives to tap water if it is unsuitable**
   a. Test different mineral waters from major brands that are available in supermarkets throughout Germany, for example Vilsa Naturell and Gerolsteiner Naturell. Unfortunately, the companies do not always provide the pH value and electrical conductivity, so these would need to be measured independently. The following website may be helpful for research, as it lists many mineral waters along with their anions and cations: https://www.mineralienrechner.de/vergleichstabelle-gerolsteiner-mineralienrechner/wasser-1897/
   b. Gerolsteiner Naturell, with around 800 mg of minerals, has a conductivity of about 890 µS/cm, which is quite high. Vilsa Naturell, however, with a total mineral content of around 200 mg, is likely closer to 200 µS/cm. According to Google, its pH value is 7.7. In my opinion, that points in the right direction. Volvic, at around 160 mg/l, may also be suitable.

8. **Conducting long-term experiments**
   a. Testing different caps
   b. Evaluating the suitability of different tap waters and mineral waters

9. **Influence of methods for energizing or structuring water**
   a. Use different methods to energize or structure water and compare the results with water that has not been energized or structured

17 Interesting questions for an artificial intelligence (AI)

In preparation for my experiments, I once asked Perplexity (an AI from China) several questions regarding the reactions taking place. The answers to these questions can be quite insightful for those interested in chemistry. Therefore, the formulated questions are provided below for copying.

1. I have a reactor in which there is a glass containing 5 ml of 9% hydrochloric acid and 5 ml of 25% sodium chlorite solution reacting with each other. A chlorine dioxide gas is formed, which fills the free air space of the reactor. In this reactor there is a second glass containing 250 ml of distilled water, in which the chlorine dioxide gas present in the air can dissolve. The distilled water turns yellow. This indicates that chlorine dioxide dissolves in water. However, I have also found that after 24 hours, the distilled water in this reactor has a pH of 3.8 and an electrical conductivity of 100 µS/cm. I assume that hydrochloric acid evaporates and changes both the pH and the conductivity. Is that correct, or could there be other reasons as well?

2. Chlorine dioxide diluted in water to 3000 ppm is stable when stored in a closed bottle for several days or weeks, since it cannot evaporate. The water in which the chlorine dioxide is diluted is distilled water. Due to the production process, this water contains a small amount of hydrochloric acid. As a result, the pH value is between 2.5 and 3. The conductivity of the water is 100 µS/cm. The conductivity is assumed to be caused solely by the acid content of the water. Are there chemical reactions that cause a decrease in the amount of chlorine dioxide? Is there a reaction that is promoted by the acidic pH? Would it be advisable to use a buffer in order to achieve a neutral pH?

18 Epilogue

I hope I was able to provide valuable insights into the clamp-lid jar method for those interested in CDL. If this serves as inspiration to conduct your own experiments, I would be very pleased. Because not only the chlorine dioxide content is important, but also the absence of by-products or decomposition products that can cause throat irritation.

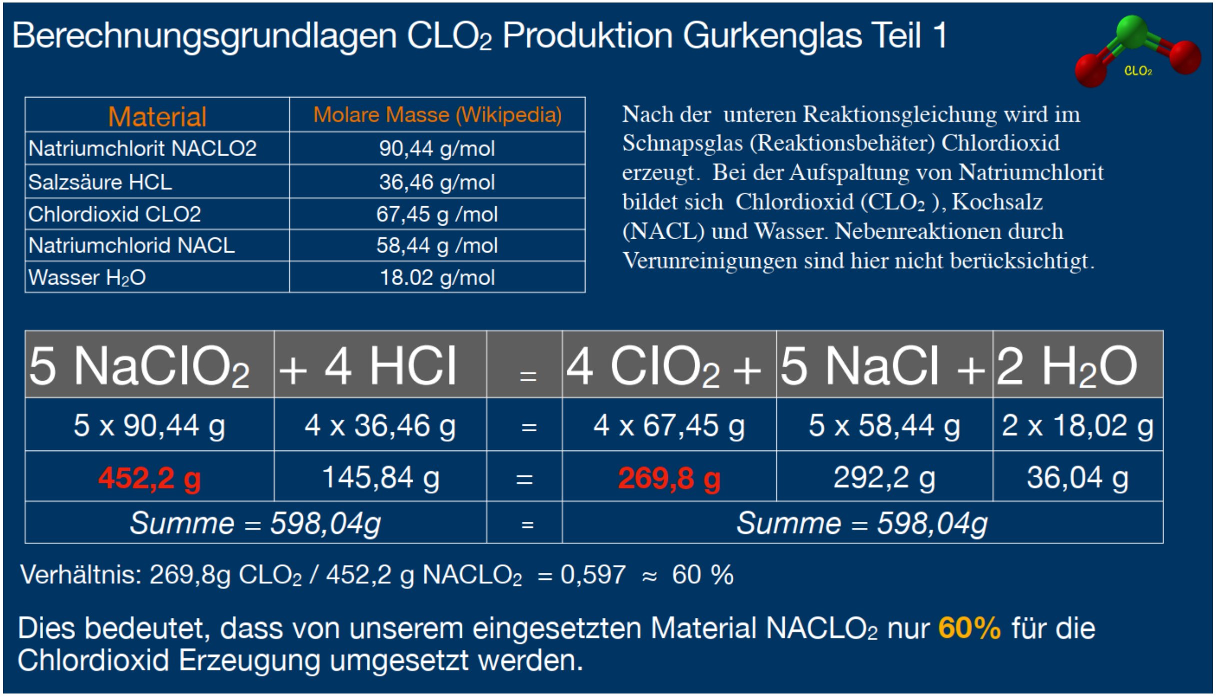
If anyone is interested in translating this document into other languages, please coordinate this with me first. I can also provide the editable files for this purpose. If you find any spelling errors, feel free to share them with me as well.

If you have questions regarding the clarity of this document or would like to provide feedback, you are welcome to contact me via the HUB of the Kalcker Institute, username: louis.s.

19 Appendix 1: Calculation of the reaction taking place

Two slides from an online presentation by Anton from November 2024

According to the reaction equation below, chlorine dioxide is generated in the shot glass (reaction vessel). During the decomposition of sodium chlorite, chlorine dioxide (ClO_2) and water are formed. Side reactions caused by impurities are not taken into account here.



Berechnungsgrundlagen CLO_2 Produktion Gurkenglas Teil 1

Material	Molare Masse (Wikipedia)
Natriumchlorit NACLO2	90,44 g/mol
Salzsäure HCL	36,46 g/mol
Chlordioxid CLO2	67,45 g /mol
Natriumchlorid NACL	58,44 g /mol
Wasser H_2O	18.02 g/mol

Nach der unteren Reaktionsgleichung wird im Schnapsglas (Reaktionsbehäter) Chlordioxid erzeugt. Bei der Aufspaltung von Natriumchlorit bildet sich Chlordioxid (CLO_2), Kochsalz (NACL) und Wasser. Nebenreaktionen durch Verunreinigungen sind hier nicht berücksichtigt.

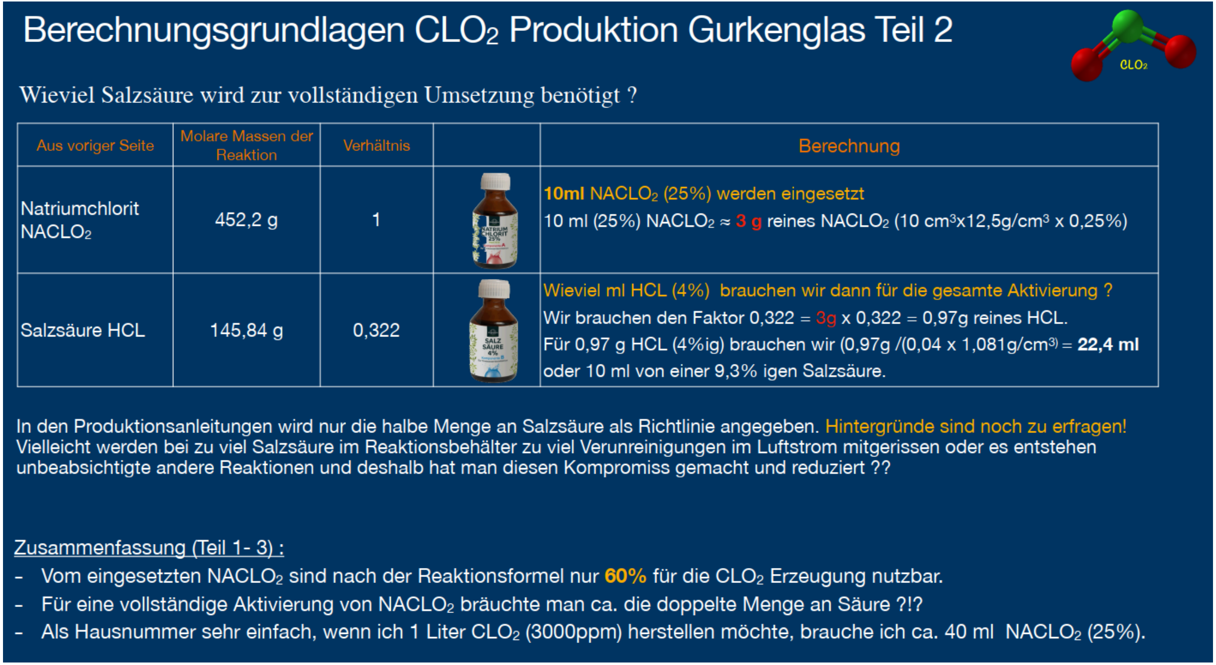
$5\ NaClO_2$	$+\ 4\ HCl$	=	$4\ ClO_2\ +$	$5\ NaCl\ +$	$2\ H_2O$
5 x 90,44 g	4 x 36,46 g	=	4 x 67,45 g	5 x 58,44 g	2 x 18,02 g
452,2 g	145,84 g	=	**269,8 g**	292,2 g	36,04 g
Summe = 598,04g		=	*Summe = 598,04g*		

Verhältnis: 269,8g CLO_2 / 452,2 g $NACLO_2$ = 0,597 ≈ 60 %

Dies bedeutet, dass von unserem eingesetzten Material $NACLO_2$ nur **60%** für die Chlordioxid Erzeugung umgesetzt werden.

This means that from the used Material NACLO² only 60% are used to create Clorinedioxide.

How much hydrochloric acid is required for complete conversion?



Berechnungsgrundlagen CLO_2 Produktion Gurkenglas Teil 2

Wieviel Salzsäure wird zur vollständigen Umsetzung benötigt ?

Aus voriger Seite	Molare Massen der Reaktion	Verhältnis		Berechnung
Natriumchlorit $NACLO_2$	452,2 g	1		**10ml** $NACLO_2$ (25%) werden eingesetzt 10 ml (25%) $NACLO_2$ ≈ **3 g** reines $NACLO_2$ (10 cm^3x12,5g/cm^3 x 0,25%)
Salzsäure HCL	145,84 g	0,322		Wieviel ml HCL (4%) brauchen wir dann für die gesamte Aktivierung ? Wir brauchen den Faktor 0,322 = 3g x 0,322 = 0,97g reines HCL. Für 0,97 g HCL (4%ig) brauchen wir (0,97g /(0,04 x 1,081g/$cm^{3)}$ = **22,4 ml** oder 10 ml von einer 9,3% igen Salzsäure.

In den Produktionsanleitungen wird nur die halbe Menge an Salzsäure als Richtlinie angegeben. Hintergründe sind noch zu erfragen! Vielleicht werden bei zu viel Salzsäure im Reaktionsbehälter zu viel Verunreinigungen im Luftstrom mitgerissen oder es entstehen unbeabsichtigte andere Reaktionen und deshalb hat man diesen Kompromiss gemacht und reduziert ??

Zusammenfassung (Teil 1- 3) :
- Vom eingesetzten $NACLO_2$ sind nach der Reaktionsformel nur **60%** für die CLO_2 Erzeugung nutzbar.
- Für eine vollständige Aktivierung von $NACLO_2$ bräuchte man ca. die doppelte Menge an Säure ?!?
- Als Hausnummer sehr einfach, wenn ich 1 Liter CLO_2 (3000ppm) herstellen möchte, brauche ich ca. 40 ml $NACLO_2$ (25%).

In production guidelines, only about half the amount of hydrochloric acid is specified as a guideline. The reasons for this are still unclear and need to be further investigated. It is possible that using too much hydrochloric acid in the reaction vessel may carry more impurities into the gas stream, or lead to unintended side reactions—therefore a compromise may have been made by reducing the amount.

Conclusion part 1-3:
- Of the $NaClO_2$ used, only 60% is available for ClO_2 generation after the reaction.
- For a complete reaction, approximately twice the amount of acid would be required.
- As a rough estimate: if I want to produce 1 liter of ClO_2 (3000 ppm), I need approximately 40 ml of $NaClO_2$ (25%).

END of the document