What is an ORP meter and why is it useful in hydroponics?

Hydroponic growers are used to using pH and EC meters to control their growing conditions but very few use ORP meters in order to learn more about their nutrient solution. An ORP meter can give you very useful information and cheap ORP meters can usually be bought on ebay or amazon for less than 20 dollars each. Today we will talk about ORP meters, what they are, what they are useful for and how you can use them in your hydroponic crop.

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An ORP meter or “Oxidation-Reduction Potential” meter characterizes the electrochemical environment within a solution. An ORP meter has two electrodes, a traditional reference electrode with a known potential and a platinum electrode whose potential changes depending on how hard the solution is pushing either to take electrons from the platinum electron or give it electrons. A solution that has a lot of substances that are willing to give electrons will tend to give a more negative reading and a solution that has more substances willing to take electrons will tend to give a more positive reading. The ORP reading is given in mV.

So how is this useful in hydroponics? It is useful in the sense that we can know exactly how the chemical environment is behaving. The ORP of potable water is generally around 600-700mV, this is because oxidants – substances that are willing to take electrons – are added to solutions in order to kill pathogens. The chemical environment needs to have an ORP of above 600mV to eliminate harmful fungal spores and bacteria. Of course this means that if you want to run a sterile hydroponic environment you'll want to keep the ORP of your solution probably in the 300-500mV range, large enough to prevent any micro-organisms from growing but low enough to prevent any damage from happening to your roots.

In this way you can use things like hypochlorous acid and hydrogen peroxide to increase the "killing power" of your solution while knowing how harsh you're making the chemical environment. The ORP will also give you signs about water oxygenation and biological activity within the water. A reductive environment – ORP below 100mV – will mean that there is a significant number of substances in the solution that want to give electrons and these substances are generally organic acids, bacteria, viruses or other organics molecules, like reductive sugars. If this is the case then it means that oxygen in solution has a short lifetime so you will want to increase your oxygenation significantly or your roots might be starved of this essential nutrient.

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Standard Reduction Potentials at 25°C (298 K) for Many Common Half-Reactions

Half-Reaction	$\mathscr{E}°$ (V)	Half-Reaction	$\mathscr{E}°$ (V)
$F_2 + 2e^- \rightarrow 2F^-$	2.87	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	0.40
$Ag^{2+} + e^- \rightarrow Ag^+$	1.99	$Cu^{2+} + 2e^- \rightarrow Cu$	0.34
$Co^{3-} + e^- \rightarrow Co^{2-}$	1.82	$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	0.27
$H_2O_2 + 2H^- + 2e^- \rightarrow 2H_2O$	1.78	$AgCl + e^- \rightarrow Ag + Cl^-$	0.22
$Ce^{4+} + e^- \rightarrow Ce^{3+}$	1.70	$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O$	0.20
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$	1.69	$Cu^{2+} + e^- \rightarrow Cu^+$	0.16
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$	1.68	$2H^+ + 2e^- \rightarrow H_2$	0.00
$2e^- + 2H^+ + IO_4^- \rightarrow IO_3^- + H_2O$	1.60	$Fe^{3+} + 3e^- \rightarrow Fe$	−0.036
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51	$Pb^{2+} + 2e^- \rightarrow Pb$	−0.13
$Au^{3+} + 3e^- \rightarrow Au$	1.50	$Sn^{2+} + 2e^- \rightarrow Sn$	−0.14
$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	1.46	$Ni^{2+} + 2e^- \rightarrow Ni$	−0.23
$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.36	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	−0.35
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	1.33	$Cd^{2+} + 2e^- \rightarrow Cd$	−0.40
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Fe^{2+} + 2e^- \rightarrow Fe$	−0.44
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.21	$Cr^{3+} + e^- \rightarrow Cr^{2+}$	−0.50
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}I_2 + 3H_2O$	1.20	$Cr^{3+} + 3e^- \rightarrow Cr$	−0.73
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Zn^{2+} + 2e^- \rightarrow Zn$	−0.76
$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	1.00	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	−0.83
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99	$Mn^{2+} + 2e^- \rightarrow Mn$	−1.18
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96	$Al^{3+} + 3e^- \rightarrow Al$	−1.66
$ClO_2 + e^- \rightarrow ClO_2^-$	0.954	$H_2 + 2e^- \rightarrow 2H^-$	−2.23
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91	$Mg^{2+} + 2e^- \rightarrow Mg$	−2.37
$Ag^+ + e^- \rightarrow Ag$	0.80	$La^{3+} + 3e^- \rightarrow La$	−2.37
$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	0.80	$Na^+ + e^- \rightarrow Na$	−2.71
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77	$Ca^{2+} + 2e^- \rightarrow Ca$	−2.76
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.68	$Ba^{2+} + 2e^- \rightarrow Ba$	−2.90
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.56	$K^+ + e^- \rightarrow K$	−2.92
$I_2 + 2e^- \rightarrow 2I^-$	0.54	$Li^+ + e^- \rightarrow Li$	−3.05
$Cu^+ + e^- \rightarrow Cu$	0.52		

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The chemical environment is determined by the sorts of half reactions that can happen in solution and this is also determined by the pH of your solution. The above table shows some of the most common electrochemical half-reactions that can happen in solution. For example in order to reduce molecular oxygen and obtain 4 electrons we need to produce hydroxide ions. This means that oxidation reactions will tend to increase the pH and therefore they are expected to become harder as the pH rises. We also have the opposite case for hydrogen peroxide where a more acidic solution is bound to prevent the oxidation of peroxide to molecular oxygen. It is worth noting that these are half reactions so in reality what always happens is that two half-reactions – for example oxygen reduction and Fe oxidation – are brought together to generate a chemical change in the environment.

In the end the ORP measurement gives you something that pH and EC measurements do not tell you, which is what the chemical environment looks like from an oxidation-reduction perspective. With this information it becomes easier to tell things like whether you're lacking enough oxygenation, whether you’re adding too much hypochlorite or peroxide and whether or not you should be adding more or less microbes to your environment.

Nitrate, Ammonium and pH in hydroponics

The stability and variability of pH in hydroponic solutions has always been a complicated topic to discuss. There are many reasons why pH may change in a hydroponic system, ranging from the media being used, the micro-organisms present and the amount of carbon dioxide in the air. However the most agressive contributing factor in a healthy hydroponic system with no important pH altering media is plant nutrient absorption. Today we are going to talk about this and how the ratio of ammonium to nitrate heavily affects plant nutrient absorption.

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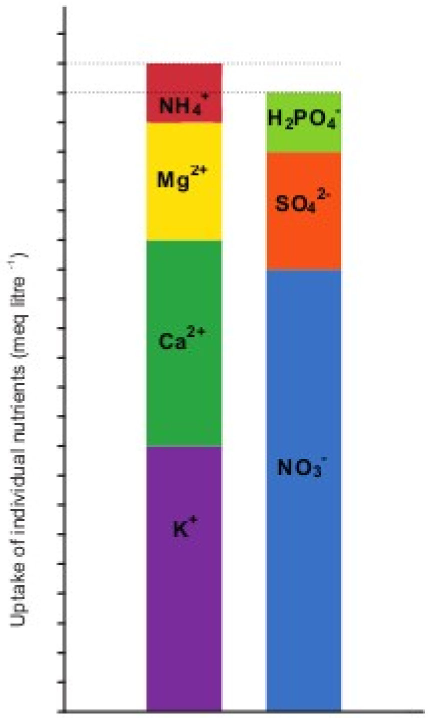
FIGURE 6

Balance between the uptake of cations and anions by plants when the NH_4-N/total-N in the supplied nutrient solution is high, thereby imposing a higher total cation uptake in comparison with that of anions



Under these conditions, the pH in the root zone tends to decrease, because the difference between total cation and anion uptake by the plant is compensated for by release of H+ by the root cells to avoid imbalances of their electrochemical potential.

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As I have discussed in the past in my blog, plants will always compensate ion absorption by releasing a pH altering ion of the same charge. If a plant absorbs nitrate (NO3-) it will release an OH- ion in order to balance the charge. This ion will increase the pH. The same happens when the plant absorbs a cation – like K+ or Ca+2 – as it will release H3O+ ions in order to compensate (one in the case of K+ and two in case of Ca+2). However plants do not absorb all ions equally and therefore if there is more cation than anion absorption pH will decrease while in the opposite case pH will increase.

The image above shows how plants usually distribute their cation/anion absorption. In the case of anions the largest contributing factor is nitrate while in the case of cations the largest contributions come from potassium and calcium. Since adding ammonium to replace nitrate will cause the balance to shift to the cation side we can indeed cause the pH behavior to change significantly by changing the ammonium to nitrate ratio. For many plants – especially fruiting plants like tomatoes or cucumbers – the ideal ammonium to nitrate ratio has been established to be around 2:8 and this usually implies that pH will tend to increase as a function of time since the amount of anions absorbed will be larger. Using larger ammonium to nitrate ratios – like 5:5 – may bring you more pH stability but this may be at the cost of crop productivity. If you want to increase the amount of ammonium in solution ammonium sulfate (shown below) is usually the cheapest source. Adding 0.05g/L (0.18 g/gal) will increase your NH4+ concentration by around 10 ppm.

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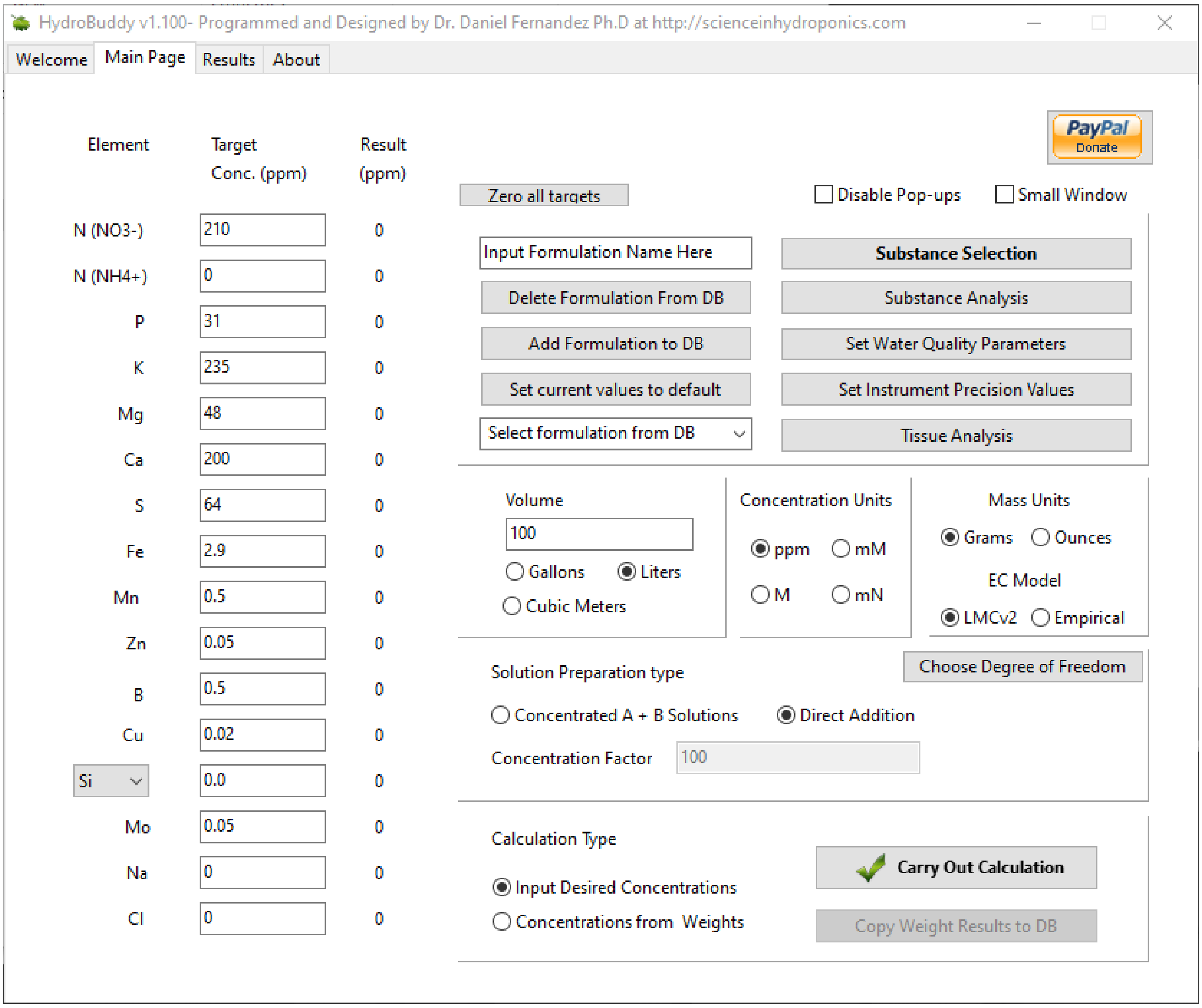
It is also important to note that you cannot easily affect ion absorptions by shifting solution concentrations. Ammonium affects the pH quite directly because adding more ammonium to the solution almost immediately adds that ammonium to the plant’s cation absorption – because it’s taken up very readily – but adding other cations might not increase their absorption because either environmental or plant regulatory mechanisms may stop this from happening. For example increasing potassium may not increase the overall size of the cation absorption column because the plant might simply compensate by reducing calcium absorption. Such a compensatory mechanism does not exist for ammonium, reason why it is so effective in changing the relative size of one column against another.

In the end the nitrate/ammonium ratio is perhaps one of the biggest weapons you have in controlling how your plants change the pH of your nutrient solution. However aiming for the most stable pH – in terms of cation/anion absorption – might not be the best bet since this might reduce your crop's yield. At optimum nitrate to ammonium concentrations most crops tend to experience some moderate pH increases as a function of time. Nonetheless different crops respond to ammonium to nitrate ratios differently so you might want to give different ratios a try to see what works best for you, both in terms of yields and easiest crop management.

HydroBuddy v1.100 : The First Free Open Source Hydroponic Nutrient Calculator Program Available Online

HydroBuddy is a completely free and open source program for the calculation of nutrient solutions for hydroponics and general agriculture built by me – Daniel Fernandez – based on my experience in hydroponics as a professional chemist. This piece of software was coded from the ground up using the Lazarus open source programming suite and implemented using appropriate database solutions as well as a powerful linear equation solving algorithms from AlgLib. HydroBuddy binaries are available for Linux, MacOS and Windows. HydroBuddy is released under the GPL license.



HydroBuddy v1.99 running on Windows

These are some of HydroBuddy's features :

- Calculates the weights of specific substances needed to arrive at specified concentrations of different elements (formulation to salt weights calculation)
- Easily fine tune your salt weights after calculations.
- Contains library with commonly available fertilizer salts (new in v1.7)
- **Leaf tissue database and conversion to concentrations needed in solution based on water use efficiency equations (v1.99)**

- Raw salts in the included DB have links to help new users know where to buy them (accessible by clicking the salt name in the results tab). Please note these are amazon affiliate links that support the development of the software at no extra cost to you. (new in v1.7)
- Includes ability to save and load lists of substances used for calculations. (new in v1.7)
- Empirical model for the prediction of EC (new in v1.8)(read more here)
- Figure out the nutrient contribution from different acids to neutralize different levels of total alkalinity (v1.95)
- Calculate the percent composition of the solid mix used to prepare a given solution (v1.95)
- Program state is completely saved when the application is properly closed (v1.95)
- Calculations in ppm, mmol/L, mol/L and meq/L.
- Calculate liquid additions in mL and add any custom substances as liquids
- Edit the percentage elemental composition of each substance or add new ones to fit your needs
- Powerful open source linear equation solver provided by AlgLib
- Always tries to find the best mathematical fit to a formulation by a given group of substances
- Allows to get the concentration values for the addition of a certain specified amount of substances (salt weights to formulation calculation)
- Easy-to-use interface for the addition, edition and assignation of substances to calculations
- EC prediction module based on limiting molar conductivities, ionic strength and ion charge (new in v1.9)(read more here)
- Use the resulting weights of a formulation calculation to perform a calculation of the opposite nature and vice versa (easily allows you to see the effect of manual modifications)

- Calculations for both direct additions and A+B concentrated solutions
- Use any custom substance as a part of an A+B concentrated solution calculation
- “Substance Analysis” module which allows you to analyze different substance, it can be used to figure out the ppm contributions of commercial fertilizers.
- Water quality module allows you to include water quality analysis within the calculations
- Adequate implementations of instrumental and gross errors with custom instrument precision input
- Proper database implementation allows you to easily save your custom formulations
- Set default water quality and data log data sets that load automatically on program startup
- Save and load formulations using any concentration unit.
- Choose between grams or ounces
- Choose between liters, gallons and cubic meters for volume inputs
- Export calculation results to a CSV file
- Tutorial tabs showing and explaining the main features of the program !

The program allows anyone to easily carry out calculations for the preparation of nutrient solutions, a very cumbersome task that can take a lot of time and effort when done manually. **If you’re having trouble with HydroBuddy and you would like to purchase support please email me by using the contact form with your requirements to receive a quote**. **If you are using HydroBuddy for academic purposes please cite its use as follows:**

Daniel Fernandez Pinto, "HydroBuddy: An open source nutrient calculator for hydroponics and general agriculture", v1.100, url: https://github.com/danielfppps/hydrobuddy*, 2022*

If updating from an old version by replacing only the executable, make sure you delete all the csv and ini files

within the folder to avoid configuration issues.

Versions are numbered sequentially (v1.96, v1.97, v1.98, v1.99, v1.100…). Version v1.100 is the last version available.

You can download the program binaries through the following links:

Get HydroBuddy for Windows

Just unzip the program and run the hydrobuddy.exe file. Binaries provided are 64-bit. For 32-bit binaries please compile from the source on the github page.

Get HydroBuddy for Linux

Unzip, then make sure you execute “chmod +x hydrobuddy” within the folder so that you can execute the program.

Get HydroBuddy for MacOS

Unzip all files into a folder, then run the app file. If you get a permissions error message, go into the hydrobuddy.app/Contents/MacOS folder in a terminal and execute the command “chmod +x hydrobuddy”. If you get an error about the app author, hold the control key while launching the app. Note that you will need to select the HydroBuddy folder each time you start the program. This binary was compiled in MacOS Monterey.

Get HydroBuddy Source

A simplified version of the program with most of its basic functionality is also available on Android. You can get it through the google play store by using the link below:

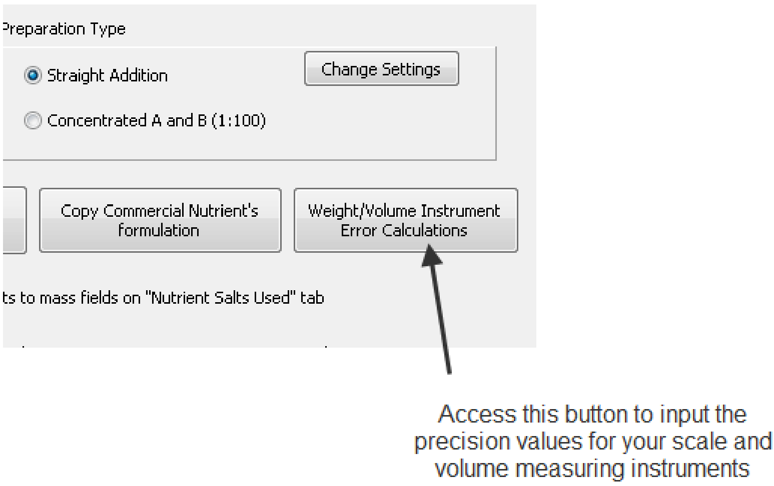
Instrument Precision : Its Importance in the Preparation of Hydroponic Nutrient Solutions

One of the most overlooked aspects when preparing hydroponic nutrient solutions is the actual precision of the instruments used to measure the salt or liquid reagent additions. People who are not familiarized with the preparation of solutions usually underestimate the importance of this aspect of solution making – both concentrated and final – which is absolutely vital for the accurate and reliable preparation of solutions. On today's post I will attempt to explain the concept of instrument precision, the errors caused by this fact and how they are calculated by HydroBuddy to give us an idea of how dependent our calculations are upon our instruments. After reading this article you will be able to know if the instruments you are using for your solution preparation needs are adequate or what you need to do in order to ensure that the preparation of your solutions remains reasonably accurate.

What is instrument precision ? This point is best illustrated by a practical example. Imagine that you are using a ruler to measure the length of a simple pencil. A common ruler (in metric units) generally has large divisions (in centimeters) and smaller divisions (in millimeters), when you measure the pencil you will note that the length of the pencil will be between two of the finest divisions – or very close to one – but you will not be able to determine the measurement beyond this accuracy. For example if the measurement of the pencil is between the 2.3cm and the 2.4 cm line you can say that the pencil measures 2.35 +/- 0.05cm this means that we can be absolutely sure that the pencil has a measurement between 2.3 and 2.4 cm but our instrument does not allow us to “see” any further. In this example the three digits of the measurement are called “significant figures” while the last one is called the “measure of uncertainty” since it is a value we can only be certain about within a certain threshold.

When you measure your hydroponic solutions you need to use instruments to weight your salts or liquid fertilizers and you also need to measure the volume of your solutions (either concentrated or final). When you weight your salts your scale will have some uncertainty (usually represented as the point value of the last digit) so for example if your scale displays a weight for a salt of 5.50g the actual measurement is 5.50+/- 0.01g as – in analogy with the pencil example – the scale cannot determine the latest digit beyond a certain threshold. The problem with this is that if your salt’s weight is in the vicinity of the scales last digit your uncertainty will be a big magnitude of what you want to weight. For example, if you want to weight 0.05g of a salt with the above scale the uncertainty of instrument will be +/- 0.01g so you will effectively have an instrumental error of +/- 20% of the salt’s mass, meaning that your final concentration will probably be VERY deviated from what you intend to measure.

Another important factor is the precision of your volume measuring gear since errors add up as you continue the preparation. If you can measure the volume of your reservoir with a precision of +/- 1L the you need to prepare at least 100L such that the error you get from the measurement of your nutrient solution's volume is not greater than 1%, however if you are preparing a concentrated nutrient solution (for 10L for example) you will need to use a more precise method of measuring volume, an instrument with a precision of at least +/- 0.1L. If you are uncertain of what the precision of your volume instruments are then you need to look at their graduation, the precision of a volume measuring instrument can usually be approximated to half its finest graduation. If you are measuring volume -for a concentrate solution for example – with a cup that has a line every 100mL then your precision is +/- 50mL (or +/- 0.05L).



The above picture shows you where you can change the precision of the instruments used within HydroBuddy so that the program can calculate the error caused by your instruments in your preparation. Some people may have noted that when calculating "direct additions" there is no instrumental error while when calculating concentrated solutions there is, this is associated with the precision in volume since when straight additions are made the amount of volume that needs to be measured is MUCH higher while for concentrated solutions a much more precise volume instrument is required (depending on solution volume) since the volume is lower.

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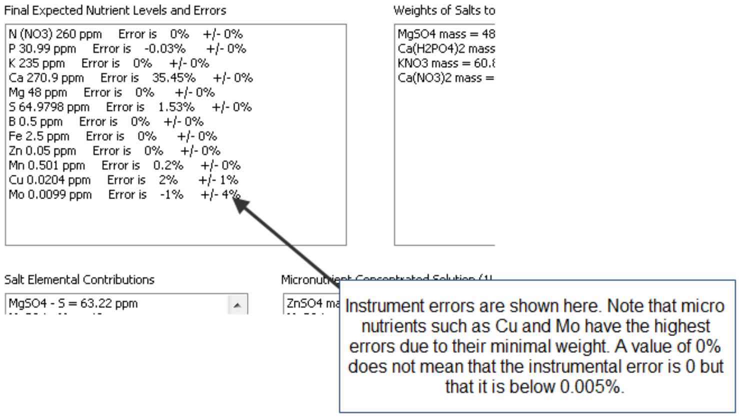


If you get very large instrumental errors (for the calculations you are doing) then there are several things you can do to correct them. The first is to prepare large amounts of concentrated solutions since the amount of salts weight will be much larger. Preparing 20L of a concentrated solution with a 1:200 concentration factor will allow most people to weight their salts in a scale with a 0.01g precision while other solutions -such as using the direct addition methodology with concentrated micro and Fe solutions – are also possible. In the end you need to take very good care of instrumental errors and take them into account since they will determine the final accuracy of your nutrient solutions. For macro nutrients the errors shouldn’t be above 0.05% while for micro nutrients such as Mo and Cu, errors as high as 20% can be tolerated since higher precision would require the use of much higher purity salts since these elements are also possibly contained as impurities within other salts (meaning that salt purity becomes a higher factor than instrumental error below 20%).

Understanding Reagent Purity and Its Importance in Hydroponics

When making hydroponic nutrient solutions one of the most important concepts we need to understand is “reagent purity” and how this affects the overall quality and composition of our hydroponic nutrient solutions. People who have not been academically trained in science usually do not have a very good understanding of this concept and its implications and how they need to take it into account when doing their hydroponic formula calculations. HydroBuddy – my free hydroponic nutrient calculator – allows the user to specify the purity of all the reagents used in the preparation of nutrient solutions so that accurate and adequate calculations are done. What does purity mean ? How do you determine the purity of the reagents you want to use ? What does a 100% purity mean ? Keep reading the following few paragraphs to find out.

What is reagent purity ? Imagine that you have 80g of a pure substance – table salt for example – and you mix it up with 20g of sand. The original salt – which was pure – was 100% table salt while the new resulting mixture is only 80% table salt. This degree of presence of a given “pure substance” with a defined composition within a mixture is what we call the “purity” of a reagent. The objective of purity is to know how much of what you are buying actually fits the chemical composition of what you intend to buy and how much is “other stuff”. The nature of impurities -what is different than what you intend to buy – is different depending on the fabrication process and intent of the reagent you want to use. The nature and amount of these impurities may sometimes be very important while other times it can simply be neglected.

People who are not familiar with this concept generally get confused when people start to talk about the composition ratios of pure substances. For example iron EDDHA is an iron complex which contains about 7% iron. This does not mean that EDDHA is only 7% “pure” but it means that within this pure substance iron accounts for 7% of the weight. The purity of the reagent does not have ANYTHING to do with the composition of the pure substance you intend to get – the iron EDDHA in the above example – but it refers to other things that might be present with what you intend to buy due to the fabrication process. So for example you can can buy Iron EDDHA 7% with a purity of 98% which means that from every 100g, 98g are iron EDDHA with a 7% iron content while 2g are made up of other substances with undetermined composition.

In hydroponics we want to provide our plants with the correct amount of nutrients and for this reason we must make sure that we provide what our formulation demands as a minimum. For this reason when preparing hydroponic nutrient solutions we must always use salts with purity levels above 95% with levels above 98% being better. Salts that are 98% pure aren’t very expensive while the purer grades – used for the biochemical and fine chemical industries – are generally several orders of magnitude more expensive. While you can get a calcium nitrate ammonium double salt with a purity of 98% for just a few dollars per kilogram a single kilogram of this chemical at a 99.999% purity (which is often considered analytical grade) would cost around one thousand dollars. This difference in cost arises because as a salt becomes purer, eliminating the small impurities becomes harder and harder. Salts for which extremely high purity levels are achievable (such as NaCl which can be purified to almost 100%) are known in chemistry as “primary standards” because their composition is known to an extremely high degree.

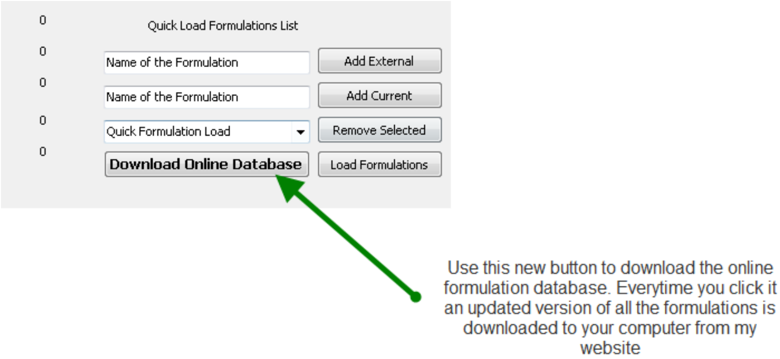
When preparing hydroponic solutions we should not be worried that much about getting very expensive reagents as the impurities we get and the errors we have in our composition are not bound to affect our plants significantly, however we should take them into account so that we know exactly how much of what we know is pure is being added. So even though a reagent may have a purity of 98%, taking into account this will allow us to add enough so that we are certain that at least certain concentration levels are achieved. Of course, using a 100% purity for the reagents is not bound to increase tremendous error if the actual value of the purity of the salts is unknown but making sure that the purity is above 95 or better 98% is always something that should be done to ensure that high quality preparations are being done. You should also understand that the impurities within your salts might actually be insoluble so some small fractions of the salts may remain undissolved when concentrated nutrient solutions are prepared.

HydroBuddy’s Online Hydroponic Formulation

Database

There are certainly thousands of different ways in which a hydroponic nutrient solution can be prepared. You can make a solution schedule to closely follow the environmental and growing conditions of a certain crop – like tomatoes – or you can simply make up a generic formulation to use within all your hydroponic plants. Besides this we also have an incredible amount of commercial formulations you would perhaps like to imitate and a ton of ways in which you can experiment with nutrient ratios to improve things such as the flavor, size and production of your crops. Since there are so many ways in which we can prepare nutrient solutions I have decided to create an Online Nutrient Database we can use to store and easily access all this information.

My hydroponic nutrient calculator – a.k.a HydroBuddy – has the ability to save and load formulations for the creation of almost any hydroponic nutrient solution. Since the calculator has the ability to grab external files and load them into its internal database I saw no reason why we couldn't create an online database in which we could keep a global record of all the formulations we find and develop. The calculator – since v 0.95 – includes a "download online database" button which downloads all the formulations kept within the online database to the grower's HydroBuddy program. This way the user doesn't have to keep on downloading the database manually but simply by pressing a button all the information is automatically re-downloaded and updated. Added to this is the benefit that the users other loaded formulations remain intact as the calculator detects which formulations are downloaded and which ones were created by the local user.



The idea of this online database is to put all the information available about nutrient formulations into one place so that people all around the world can benefit and experiment with different setups. Added to this is the ability to make the imitation of commercial formulations even easier since the formulations can be kept within the online database. So in my mind it is a win-win situation for everyone, we get to have the opportunity to create a unique database filled with information about solutions from both empirical, commercial and academical sources while we retain the flexibility to use them or modify them within HydroBuddy as we please. This also makes the standardization of formulation use much easier since you can easily tell people what HydroBuddy database formulation you are using and they can easily then reproduce what you have or change it slightly to fit the nutrients available in different regions of the world.

How can you contribute to this database ? **In order to add a file to the database you need to send me an email to dfernandezp(at)unal.edu.co** , you need to include the name of the formulation you are adding, its intent and source (what plant or if its an imitation of what commercial fertilizer) and a file created by HydroBuddy with the necessary information. In order to create this file just save the formulation on the “Desired Formulation” tab then send me the file created within HydroBuddy’s directory. After you send me your contribution I will add it to the Online Database so that everybody will be able to download it with the click of a button.**If you want to send many files just put them all within**

a zip files so that they will be easier to download from my email client, include in the body of the email the necessary descriptions for each file as detailed above.

So if you have been waiting for an opportunity to contribute to HydroBuddy feel free to share with me any formulations you might have found or created that you would consider useful for someone. If you have spent a lot of time taking the formulations of commercial nutrients and translating them into HydroBuddy you can now share this knowledge with the rest of the world. I will also do my fair share to add new formulations to the online database, particularly regarding academic sources since most people do not have access to the research databases where the articles detailing them can be found.

If you want to contribute and support HydroBuddy but you do not want to send any formulations feel free to donate using the paypal donate button on the left hand sidebar :o)

Hydroponic Nutrient Availability : What "Pushing Out an Element" Really Means

Plants need a very large variety of elements in order to grow successfully. In hydroponic crops we intend to provide all these elements in their different forms dissolved within our nutrient solutions. However the mechanisms by which plants absorb these elements is complex and there are many different factors that determine which elements are absorbed and which elements are not. On today's post I will write a little bit about the problem of nutrient availability, what factors determine how ions are absorbed and what does it mean to “push an element out” when talking about a hydroponic system. First we will talk about the nature of the elements dissolved in hydroponics solutions followed by the importance of environmental conditions and nutrient interactions that finally determine the actual availability of nutrients for plant growth.

The first important thing we need to understand is that plants can absorb many different forms of the elements we need to provide and that these elements are not absorbed in their pure state but forming ionic entities dissolved within our solutions. For example nitrogen is absorbed by plants as the NO3(-) ion (nitrate) or as the NH4(+) ion (ammonium), both of these ions supply the plant with nitrogen but their overall effect is different and the ratio of their concentration has an important effect on plant growth and development. The second thing we need to understand is that plants can only absorb things that are dissolved in solution and that plants cannot absorb materials that are above a certain size. Although studies have shown that plants can take large particulate aggregates (such as polyoxometalates) it is true that large bulk solid materials of a few microns in diameter are already beyond the cellular absorption capacity of most plants. In order for something to get into a plant it needs to be dissolved in water, it needs to form the ionic entities which are assimilable by the plants.

The third and also probably least understood aspect of nutrient absorption is that the chemistry that leads to the entering of a nutrient within the plant cells must be favorable. What this means is that different conditions must be met so that plants can get their nutrients. There are many things that can cause this process to fail which may not be related with the nutrient itself but with the presence or absence of another nutrient. In plants there is an agonist/antagonist relationship between the different ionic species such that the excess or absence of one specie affects the absorption of another. For example iron is absorbed by plants as either Fe^{2+} or Fe^{3+} while phosphorous is generally absorbed as $H_2PO_4^-$ or HPO_4^{2-}, when there is an excess of phosphate species the formation of iron-phosphate crystals can happen within the plant's nutrient transport system causing what seems to appear as an iron deficiency. The problem is not caused by a lack of iron but by an excess of phosphate that hinders the mechanisms of absorption. Increasing iron concentration when this happens merely makes the problem worse as when phosphate concentrations lower an excessive iron concentration – now causing iron toxicity – is present.

The key to have a healthy plant with adequate absorption of nutrients is therefore to make all the necessary above mentioned conditions adequate. The first thing we need to do is guarantee that the nutrients we provide are in the adequate form (ionic species) and the second is that the conditions are adequate so that these species do not change but instead are absorbed. This leads us to the problem of “nutrient push-out” which is mentioned a lot within the hydroponic community. There are several environmental conditions that can cause the assimilable ionic forms of nutrients to change to something else therefore being “pushed out” of a solution. For example if you have high carbonate ion concentrations within your water the addition of your hydroponic nutrients can cause iron carbonate precipitation. This means that the previously dissolved iron (available as Fe(2+)) now becomes bound to carbonate ions forming a solid (FeCO3). This solid is very stable and hence doesn’t form aqueous ions but instead stays undissolved in the bottom of your nutrient solution. Other things such as an increase in pH (which precipitates metal oxides like Fe(OH)2) can also dramatically affect nutrient availability.

Many people tend to believe that calcium and sulfate precipitate easily but a careful analysis of the solubility behavior of calcium sulfate reveals that you would need a concentration of sulfur as sulfate of more than 400 ppm before any precipitation actually happens. In most cases precipitation can happen if concentrated solutions are mixed too quickly one after another – without adequate dissolution – or if a mix of solid nutrients is added to the reservoir. However this precipitate formed is often later dissolved with time as the aqueous solution reaches equilibrium.

In general when people refer to an element being “pushed out” they talk about the element being made unavailable to the plant through some mechanism generally involving the formation of a stable solid that cannot be used by the plants. The solid “drops out” of the hydroponic solution and therefore the term “pushed out” was born as a way to refer to this phenomena. Nonetheless it is always important to remember that other things can cause elements to become unavailable, such as temperature and the concentration level of other elements. In hydroponics we are dealing with a very complex interaction between ions and plants and our main goal is to keep the different nutrients balanced in such a way that most interactions are beneficial. Keeping an eye on temperature, pH, nutrient ratios and water quality is vital to achieve this desirable outcome.

Preserving Fertilizers and Additives – How to Keep them from Going Bad

When you prepare your own hydroponic nutrient solutions and you are finally happy with the way in which you have been mixing your nutrients and additives you start to notice that something murky is starting to develop from the top of your container. When you open up your nutrients or additives you then find a very happy fungi colony living in perfect harmony with your nutrients, eating away all the useful things you added and filling your solution with possibly toxic substances that will likely affect your plants later on. When microorganisms develop within nutrient solutions you are done, you need to dump them and start over since the living things that lived within them might have damaged, changed or added substances to your solution that you do not want in your reservoir. How do we prevent this problem ? What magic substances can we add to preserve our nutrients and additives ? On today's post I will talk about how nutrient solutions and additives (especially those with sugars) are damaged, why this happens and how you can add some little harmless substances to fight these horrible plagues.

Nutrient solutions are made for plants so you could in fact assume that there is nothing that can grow within them that is not a photosynthetic organism. Most of the time you will be right – especially for solutions with no chelates – since the nutrients are not useful from an energetic standpoint to other organisms such as bacteria and fungi. However one day you open up a concentrated solution and find out a large mass of a gooey substance living within it, what went wrong ? The most common explanation to this problem is that your nutrient solution contains a chelating agent – such as EDDHA, EDTA or DTPA – which are organic molecules that wrap themselves around ions. Since these organic molecules contain carbon-carbon and carbon-hydrogen bonds they are indeed energetically useful for living organisms, especially to some fungi that love to eat chelates and -as a matter of fact – enjoy them better when they are within a soup of highly concentrated iron and other metallic ions.

The second case is even worse which is when you develop an additive that has some very enjoyable food – like some sugar – within it. When you dissolve glucose or other carbohydrates within water you are providing the most useful and delicious meal for any microscopic organism. Fungi, bacteria and protozoa will feed from this solution to the point where it will become filled and vibrant with life. Preparing a sugar additive is like putting a piece of cake next to an ant hill, it would be wishful thinking to believe that it will remain intact. The same thing happens when you develop buffers with organic molecules – such as MES or citric acid – or other types of additives that use amino acids, vitamins, etc. If it has carbon-carbon and carbon-hydrogen bonds some little thing is going to creep inside your bottle and have a feast. Only the air that gets trapped inside the bottle when you prepare the solution already contains a ton of fungi spores, bacteria, etc.

How do we prevent this from happening ? Well thanks to the developments the food industry has had during the past century we are able to add a little of a few substances that will absolutely prevent the development of any of those nasty things within our solutions. These magic substances that make food remain edible after long periods of time – which can also aid you to save your solutions – are called preservatives and they are cheap and harmless substances when used at the right concentrations. The large majority are approved for their use in the food industry – probably they are contained in everything you eat at the supermarket – and therefore they are perfectly safe to use within your hydroponic crops.

To make things simple you can just add a single substance that will prevent – for a long period of time – the development of nasty organisms within your hydroponic concentrated solutions and additives. This substance is used by most commercial hydroponic solution sellers but it is almost never listed as they are not required to do so by law since the substance is considered generally safe and its disclosure is not necessary when the products used are not intended for human consumption. This substance is called sodium benzoate, a substance derived from benzoic acid which has the magic power to keep nasty organisms away from your hydroponic solutions and additives.

How much do you need to add ? Not that much ! Only 100-300 mg/L of sodium benzoate within your concentrated solutions or additives should keep away most fungi and bacteria, allowing you to use your solutions for more extended periods of time without those nasty organisms having a party with your nutrients. However you need to make sure that your concentration remains below 400 mg/L and that your solution uses a 1:100 or higher concentration rate since the concentration of benzoic acid within the final hydroponic solution must remain below 25*10^-6 M in order to prevent phytotoxic effects. Hopefully with this advice you will now be able to prepare many additives and solutions without having to worry about your liquid preparations going bad a few days after you prepare them :o)

Cobalt in Hydroponics : Better or Worse ?

On yesterday’s article we talked about silicon, one of the most beneficial non-essential nutrients you can use in your hydroponic crops. Although Silicon has proved to give marked benefits in peer-reviewed scientific studies, other elements are usually commented on being beneficial without a thorough investigation around current scientific literature. One of this particular cases is Co, with this element being often portrayed as a way to “increase flowering” or “increase fruiting”, something which studies have shown to be false for several different plant species. On today’s article we will talk about cobalt, its potential use in hydroponics, the conclusions of the studies that have been done and the potential danger involved with the use of cobalt in hydroponic solutions.
Cobalt is a transition metal from the same group as Rhodium and Iridium with chemical properties similar -yet quite

different- to these other elements. As a chemist specialized in the area of organometallic chemistry – and especially through my work with this group – I have always enjoyed the chemistry of this element. Cobalt has many uses in pigments, radiotherapy, batteries, etc. Biologically its most important role comes as the metal center of the vitamin B12, cobalamine, which is essential to human life. Vitamin B12 is a large coordination complex in which Cobalt is tightly bound by an organic macrocyle, interestingly enough, this is one of the very few examples of a carbon-metal bond in nature with one of the axial ligands of cobalamin being a methyl organic group (in methylcobalamin at least).
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So now that we know that cobalt is an essential part of a vitamin, it may seem obvious to use it as a minor constituent of our hydroponic formulations. However careful studies have shown that – if cobalt is needed by plants – it is only needed in the most minute quantities with concentrations of only 5 ppm already being markedly detrimental to plant growth (L.Gómez shows this effect in two studies in both lettuce and tomato). Other studies in the lower concentration range (>5 ppm) are contradictory and none show conclusive evidence that the additions of cobalt may be a good idea to increase plant yields in general.
Some people argue that cobalt is essential for some nitrogen fixing bacteria and that plants that rely heavily on these organisms might see improvements with cobalt additions not because of their "personal use" but because of the added benefit of having a healthy microbial population. Although these claims seem to "make sense" to a certain extent there haven't been any studies that confirm that this is true and that a strong and obvious effect exists due to the addition of

cobalt to a nutrient solution. If anything current studies point to the fact that cobalt additions can be detrimental and that -if beneficial- it would only be in the smallest quantities which might already be present in your formulation through mineral impurities.

You have to take into account that most people and companies use fertilizer grade chemicals for the preparation of their hydroponic formulations (otherwise it is not cost effective). These chemicals are most of the time around a purity of 80-98% with most of them being in the 95-98% zone. Since some of these minerals hold cobalt as some of their natural impurities (copper and manganese salts for example) it is not surprising if adequate cobalt levels are already present in your solution through the mere impurities you introduce with your own formulations.

In the end it seems that cobalt additions are unnecessary and the person doing them runs the risk of decreasing their yields and possibly causing a toxic accumulation of this nutrient within the plant’s system that may later be detrimental to the consumer’s health. In this case the no-harm principle should apply, if a given additive is suspected of having detrimental effects then avoiding it is the best possible course of action while conclusive evidence of any positive effect (and the dose in which they are achieved) is revealed. Right now we know plants grow very well without additions of Co and we also know that even low concentrations of Co are not beneficial.

Silicon in Hydroponics : What

Silicon is Good For and How it Should be Used

Certainly if you have been involved with hydroponics for a while or even if you have just started to research this awesome field you might already know that science has only discovered a handful of elements to be necessary for plant growth. From the first 92 elements of the periodic table, plants have only been proved to require C, H, O, N, K, P, S, Mg, Ca, Fe, B, Cu, Mo, Zn and Mn for their adequate growth. However it is certainly true that some other elements have proved to be beneficial – in certain quantities – for the development of several different crops. Such elements include Co, Si and Na. On today's article I am going to introduce you to Si, the way in which plants absorb it, how it should be administrated and the positive effects it is bound to have on your hydroponics plants.

Silicon is definitely one of the most abundant elements on the Earth's crust, forming – with aluminium – a very large portion of the earth's heavier elements. Silicon is mainly present in nature as the silicate ion (SiO_3^{2-}) forming solids with different degrees of polymerization known in the geological world as silicates. From these silicates we have a very large variety of minerals, from the aluminosilicates formed with aluminium to the very fine quartz particles (white sand) making up some of the most beautiful beaches throughout the world.

However when thinking about silicon and our plants we need to think about the way in which plants would be able to absorb this element. The minerals in which silicon is found are quite insoluble at room temperature and for this reason they cannot be absorbed efficiently by plants. If we want our plants to get some silicon we need to provide it in a form which is soluble and readily available for absorption. Such a form is sodium silicate (Na_2SiO_3) usually available as a pure solid or a solution in water called "liquid glass".

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Studies in the field of hydroponics have shown that different types of cultivars such as wheat, tomatoes and cucumbers react positively to a moderate addition of silicate ions. When water glass is applied at a concentration of around 100pm (measured as SiO2), positive effects are found including increased weights of fruits, increased nutritional composition and – most importantly – a very important increase in the resistance to bacterial and fungal diseases. It seems to be that plants use the silicate ions to “line-up” their cell-walls offering a strong additional mineral resistance to any incoming pathogens that would want to get into their cells. Since plants lack and active immunological system, passive measurements like this which increase cell-wall strength are likely to be key to increase disease resistance for many crops.

However most people are quite careless about the way in which they apply this “liquid glass” since they are mostly unaware of the very sensitive equilibrium that takes place to maintain silicate ions in solution. Silicates are by definition very insoluble and the acidic pH in hydroponics is bound to cause some precipitation of different reaction products of this ion with other ionic species present within the hydroponics solution. The silicate ions can also form silicic acid and start to polymerize into complex macromolecular constructs. As a matter of fact, several studies do include information about the problems with drip systems, sprinklers, nozzles, etc, when using silicate ions since they tend to precipitate easily outside the hydroponic solution.

I would suggest – and so I have done with my own systems –

that it is better to apply small quantities of silicate ions every 2-3 days, instead of applying a large amount during the beginning process. Applying a large amount of “liquid glass” (the 100ppm for example) would most likely end in most silicate falling out of solution and only a small part becoming available for plant absorption. I believe that the best thing to do is apply about 5ppm (measured as SiO_2) every 2-3 days until the solution needs to be changed. This provides both higher stability and a better control over the solubility of this tricky ion within the hydroponic solution. Of course this is purely anecdotal evidence and no controlled study has yet shown this to be better. If you want to obtain results as those of the scientific literature available then applying the 100ppm on every reservoir change might be the wisest thing to do.