Accurately preparing large quantities of concentrated hydroponic nutrients

When preparing concentrated solutions for hydroponics it is important to have a reproducible process that always generates the exact same results. If this is not done, you'll obtain different nutrient concentrations between different batches and the concentrated nutrient additions to create the final nutrient solutions will yield inconsistent results. To address the potential variability of the concentrated solution manufacturing process we need to understand the different sources of error present and come up with ways to modify the process to generate more reproducible results. In this blog post I will talk about the largest source of error when preparing larger batches of concentrated nutrient solutions and how this error can be greatly reduced in order to obtain both more precise and accurate results.

Picture of a type A 250mL volumetric flask.

The process of preparing hydroponic concentrated solutions involves two steps. First, you dissolve raw fertilizer salts into some volume of distilled or RO water and then you take this volume of solution to a desired final volume of solution using the same source of water. In a small scale setup this process is very simple to carry out, since we can just weight and dissolve all our salts in some fraction of the desired final volume and then use a precise instrument to measure total volume – most typically a volumetric flask – to take our solution to the final desired volume. For example if we desire to prepare 250 mL of concentrated nutrient solution and we use a well calibrated scale with +/- 0.001g of precision and an A grade volumetric flask with a precision of +/- 0.3mL, the error we expect to get from a 500mg salt will be +/- 4.77 ppm with a 99% confidence. Since the concentration of this salt in the concentrated solution is 2000 ppm, we get a final result of 2000 +/- 4.77 ppm. If both instruments are calibrated this is a very precise and accurate result.

When we move to larger amounts of solution we usually get better on the side of mass. This is because we can still get scales that weight with +/-0.1g precision even at weights exceeding 50kg, so our error as a fraction of the total measurement remain in the 0.01% to 1% region pretty easily. However things get way worse in terms of volume. If you are preparing 100 gallons of nutrient solution – around 378 liters – you will be able to weight the salts precisely and accurately but when it comes to measuring final volumes of solution, you are not going to be very lucky. The volume marks in tanks are widely inaccurate and are not even standardized to any level of significant precision or accuracy plus accurately measuring whether water is at a given level in a tank is a very error prone process because of how wide the tank area is.

Although we don’t usually have a way to adequately measure final volume, we do have a way to measure volume going into a

tank in the form of flow meters, which can give us significant accuracy and precision. However, to be able to properly use the flow meter – know how much volume we need to actually get to the final volume we want – we must obtain information from a precise and accurate low scale process. To do this you can carry out the following steps:

- Get a precise and accurate scale (calibrated and at least +/- 0.001g in precision)
- Get a scale that can weight up to 500g that can measure with at least +/- 0.1g precision (if the one above does not).
- Get a 250 mL type A volumetric flask (should be around +/- 0.3 mL in precision).
- Get a 250mL beaker
- Get a plastic lab washing bottle and fill it with distilled water
- Calculate the salts you would need to dissolve to arrive at your desired concentrations at a 250mL final volume of concentrated solution
- Weight those salts and put them in a beaker, take note of all the exact weights added.
- Weight the dry, empty volumetric flask
- Add approximately half the volume of distilled water to the beaker and dissolve the salts
- Transfer to the volumetric flask, use the washing flask to fill the volumetric flask up to the calibration line (bottom of water meniscus is touching the line when viewed at eye level).
- Weight the flask with the solution
- Calculate the weight of water (weight of flask with solution – weight of flask – sum of weight of salts)

If the procedure above was carried out between 10-25C (50-77F) we can approximate the density of water to 1.0g/mL with little error (around 0.003g/mL). This means that we know the volume of water that was required to get to the desired final volume

and we can then transfer this volume to our preparation procedure when we use a large tank. If the volume of water required for the preparation of the 250mL solution was just 230mL, then we can assume that the volume required to prepare 100 gallons will be 92 gallons, as the salts, when proportionately scaled, will take up the same volume and will require the same amount of water proportionately to reach the final desired volume.

When this type of procedure is done and an accurate and precise flowmeter is used, we can usually achieve concentration values at large scales that will be in the 0.1-1.0% error range, which is way better than anything that can be achieved by just using lines in tanks or procedures that use flow meters but ignore what the actual amount of water added needs to be in order to reach the desired concentration (many people achieve the salts take up no volume, which is a mistake). Having low errors in concentrated solutions means there will be less variability in final nutrient solution composition and therefore more reproducibility in crops.

How to prepare pH 4 and 7 buffers from scratch without using a pH meter

I wrote a post in the past about how you could prepare pH buffers in order to calibrate your pH meter if you happen to already have a calibrated pH probe. This can generate decent results if the initial calibration of the probe is excellent and the sensitivity of the probe is high. This however might

not be a possibility for some people – given that their pH probe might not be calibrated to start with – so in today's post I am going to tell you how you can prepare your own pH 4 and 7 buffers without having any other tools but a scale, distilled water and some raw salts. This tutorial will be made assuming you're preparing 500mL of each buffer but feel free to scale this up or down as you wish (these buffers are meant to give you a total 0.1M buffer concentration). *Note that pH depends on temperature, these buffers are meant to give pH values of 4 and 7 at 25C*.

To prepare these buffers you will need the following materials:

- A scale that can weight with a precision of +/- 0.001g
- Potassium citrate (food grade)
- Anhydrous Citric acid (food grade)
- Potassium monobasic phosphate (food grade)
- Potassium dibasic phosphate (food grade)
- Distilled water
- Two clean glass bottles to prepare and store the buffers. (I would recommend these, but any clean glass containers would do)

Follow these steps to prepare the pH 4 buffer:

1. Weight **exactly** 5.259g of potassium citrate and transfer that amount to the glass bottle

2. Weight **exactly** 6.309g of citric acid and transfer the solid to the same glass bottle
3. Fill the bottle to around 250mL using distilled water
4. Mix the solids using a glass rod or any other inert mixing utensil until fully dissolved
5. Fill the bottle to 500mL using distilled water.
6. Label the flask clearly so that you know this is the pH 4 buffer

Follow these steps to prepare the pH 7 buffer:

1. Weight **exactly** 3.369g of potassium dibasic phosphate and transfer that amount to the second glass bottle
2. Weight **exactly** 4.172g of potassium monobasic phosphate and transfer the solid to the same glass bottle
3. Fill the bottle to around 250mL using distilled water
4. Mix the solids using a glass rod or any other inert mixing utensil until fully dissolved
5. Fill the bottle to 500mL using distilled water.
6. Label the flask clearly so that you know this is the pH 7 buffer

The above should provide you with pH 4 and 7 buffer solutions that should be relatively precise. The exact volume of the solution is not critical, as the volume only has a strong effect on the buffering capacity but not on the final pH, especially at relatively high buffering strengths. However, if you want to have more precision use 500mL volumetric flasks to prepare the solutions. The error in these buffers will depend on the purity of the salts used – which is why higher purity food grade salts are recommended above – as well as in the accuracy of the weighting and transferring processes. In order to obtain a higher accuracy you would need to purchase more expensive analytical grade salts and also use volumetric flasks to prepare the solutions, so that you can prepare them at the exact concentration intended.

Another limitation of the above buffers is that they do not

contain any sort of preservative and they are both prepared with food grade substances that can attract fungi and bacteria. For this reason the above buffers will probably not last for a significant amount of time and should probably be discarded within a couple of weeks. However the chemicals used here are very cheap so – with the amounts purchased above – you should be able to prepare as much buffering solution as you might need. Note that the solutions can also be frozen in order to increase their shelf life, although keep in mind that since pH depends on temperature you will need to wait for them to reach room temperature before taking a reading.

It is also worth mentioning that these buffers will both be completely transparent, since they are prepared without any dies in order to give the maximum possible accuracy in the pH. However you can add a very small amount of food coloring to each one to provide a distinct color without causing a significant change in the pH, less than half a drop should be enough to give your solutions a distinct hue.

I would advice you do a pH check with a pH meter calibrated using a normal commercial solution the first time you prepare these solutions. This is just to be sure that you followed the procedure correctly and the resulting buffer is of the intended quality. Once you do this you should be able to create as much buffer as you desire without any problems. *Leave a comment with your experience!*