LEADER

Europeiska jordbruksfonden för landsbygdsutveckling. Europa investerar i landsbygdsområden

UCV
Utvecklingscentrum för vatten
EN DEL AV CAMPUS ROSLAGEN AB

ANALYSIS OF THE AQUAPONICS DEMO SYSTEM AT UCV

Sammanfattning

The document analyses the equilibrium of an aquaponics demo by assessing different water parameters

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Inledning

Detta dokument har genomförts inom ramen för det LEADER-finansierade projektet ”Akvaponi i Roslagen” Projektet är finansierat av LEADER Stockholmsbygd samt Jordbruksverket. Roslagens sparbanksstiftelse har finansierat bygget av en akvaponisk demoanläggning på Utvecklingscentrum för vatten/Campus Roslagen i Norrtälje. Huvudsakligt syfte är kunskapsspridning kring akvaponi, ett recirkulerande odlingssystem som möjliggör förlängd odlingssäsong, ökad konkurrenskraft hos företag, mer lokalproducerade livsmedel, samt tekniska system som gör minsta möjliga påverkan på miljön.

Sveriges nationella livsmedelsstrategis övergripande målsättning är en konkurrenskraftig livsmedelskedja där livsmedelsproduktionen ökar, samtidigt som nationella miljömål uppnås. Detta för att bidra till en hållbar utveckling i hela landet. Strategin nämner en ökad livsmedelsproduktion som svarar mot konsumenternas efterfrågan. På detta sätt når man en högre självförsörjningsgrad av livsmedel och sårbarheten i livsmedelskedjan bör minska.

Livsmedelsstrategin har utpekat tre strategiska mål för att nå målen

1. Regler och villkor
2. Konsument och marknad
3. Kunskap och innovation.

Projektet Akvaponi i Roslagen har huvudfokus utifrån strategimål 3 i livsmedelsstrategin.

Introduction:

The objective of this paper is to design a plan to improve the efficiency of the demonstration system that I will call D-system for more easiness. The first part is to design a sampling plan to give a picture of the system and understand the system and the potential concentration problem it can have. An analysis of the data already taken will be done, and comment on each variable will be given. If there are concentration problems in the system, eventual changes will be presented in order to handle those problems. The last part is an analysis of the system element by element.

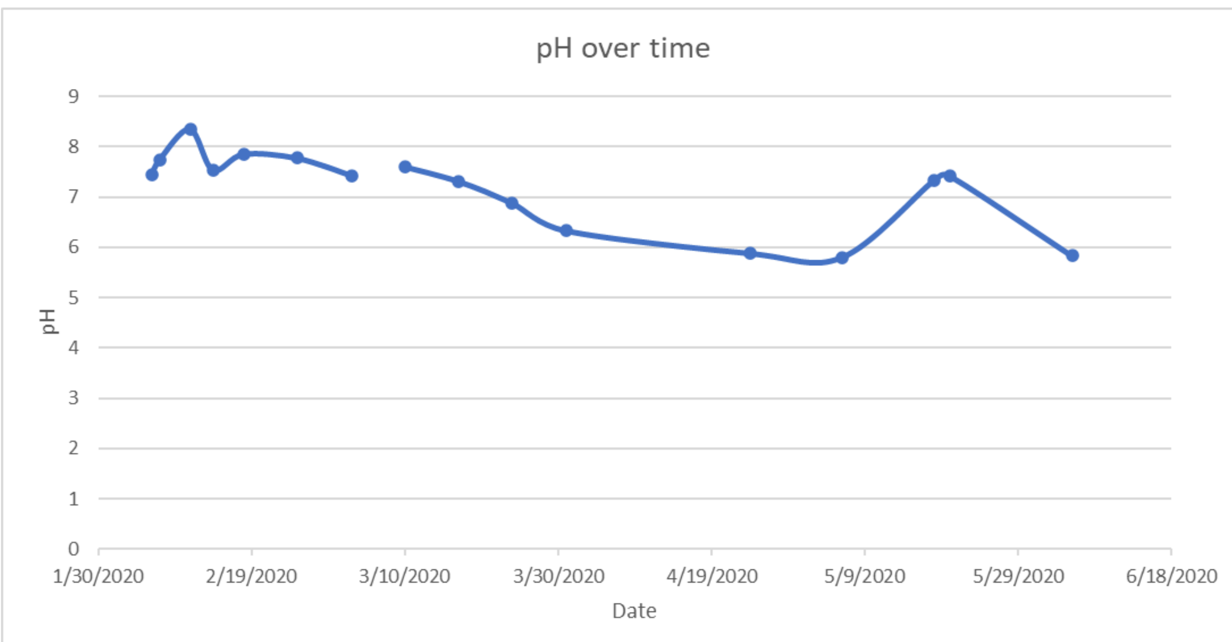
Sampling plan

The first step of the sampling plan will be to examine the analyses already done from the start of the D-system. The second step will be the design of a sampling plan.

Analysis of the samples:

As the number of samples is limited, it is hard to view any trend. Assumptions will still be made knowing that uncertainty is high.

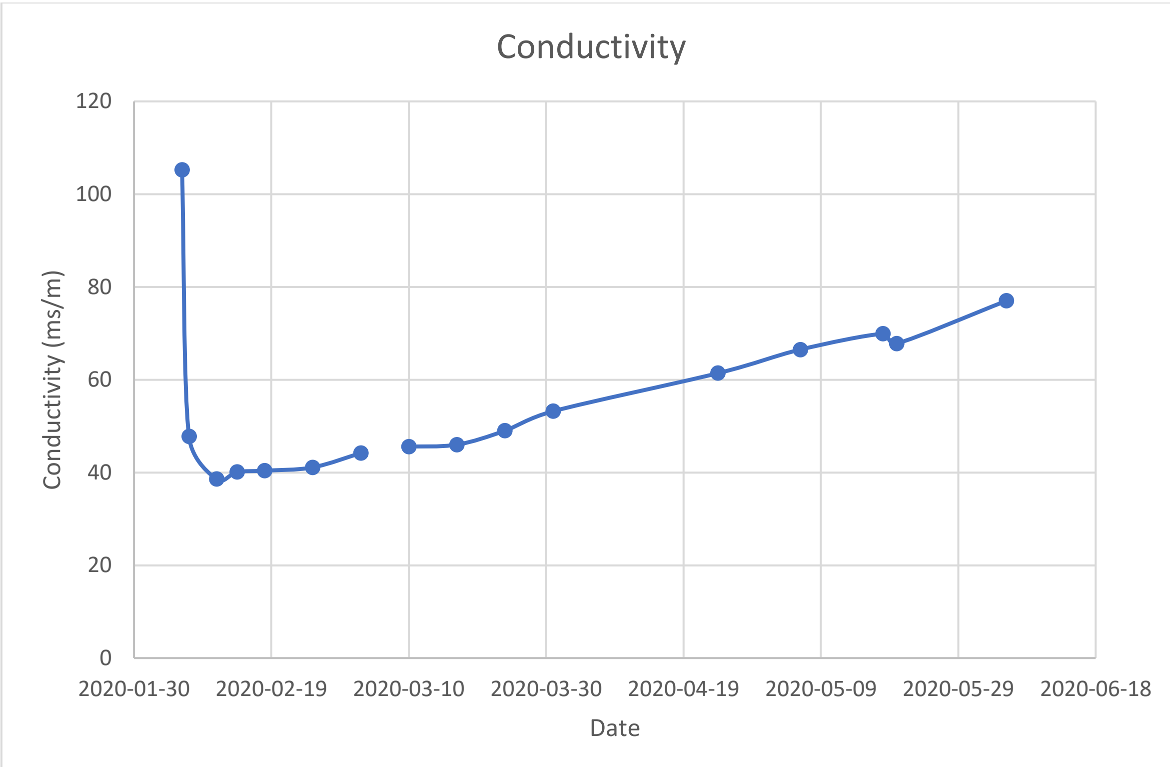
pH:



It is possible to see that the pH was high at the start of the sampling. There was a pH spike at 8.35. That level of pH is too high for an aquaponics system. The pH has since then slowly decreased to reach a pH of 5,8 in 5/6/2020. There was a drastic increase in pH the 2020/05/18 and the 2020/05/20. This increase in pH disappears at the last measure. The increase could be due to manipulation in the system. The last measure shows a pH lower than the optimal (6-7). pH should be carefully monitored. This is mainly due to the decrease of pH due to the conversion of ammonium in nitrate (Brookside Laboratories. (n.d.)).

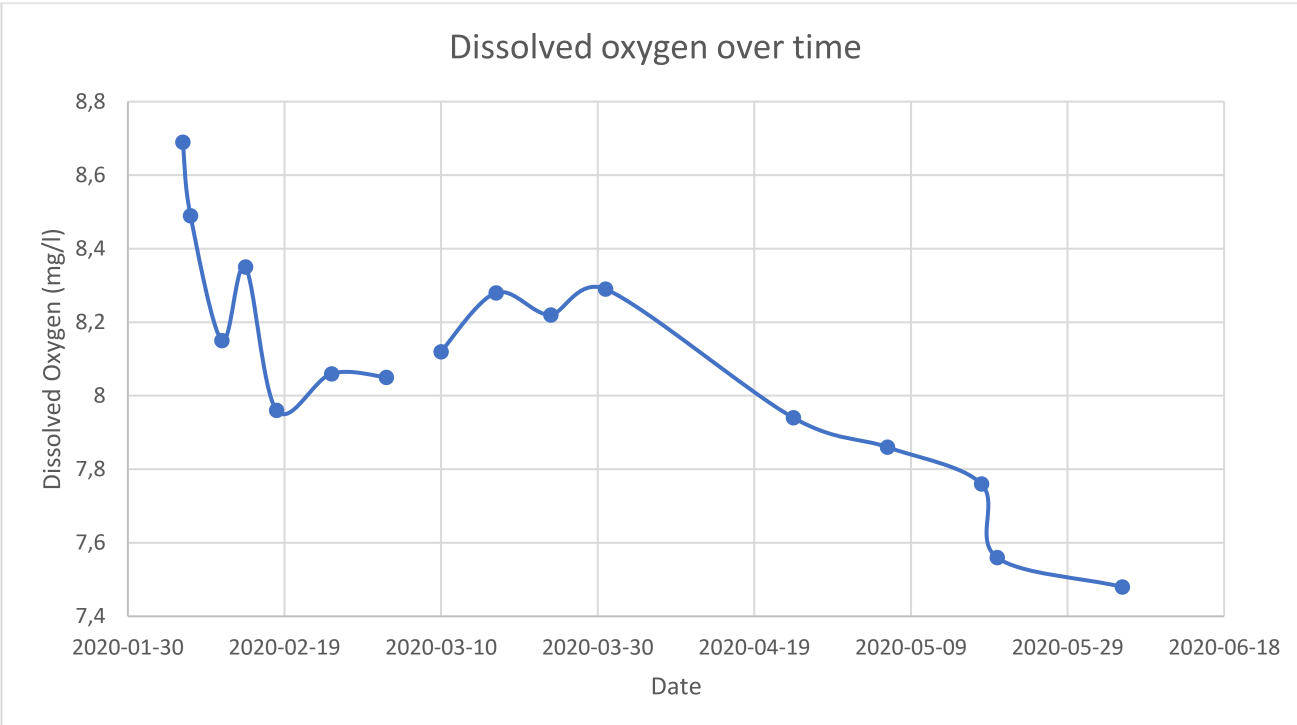
Conductivity:

"Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge)." (EPA, 2012).



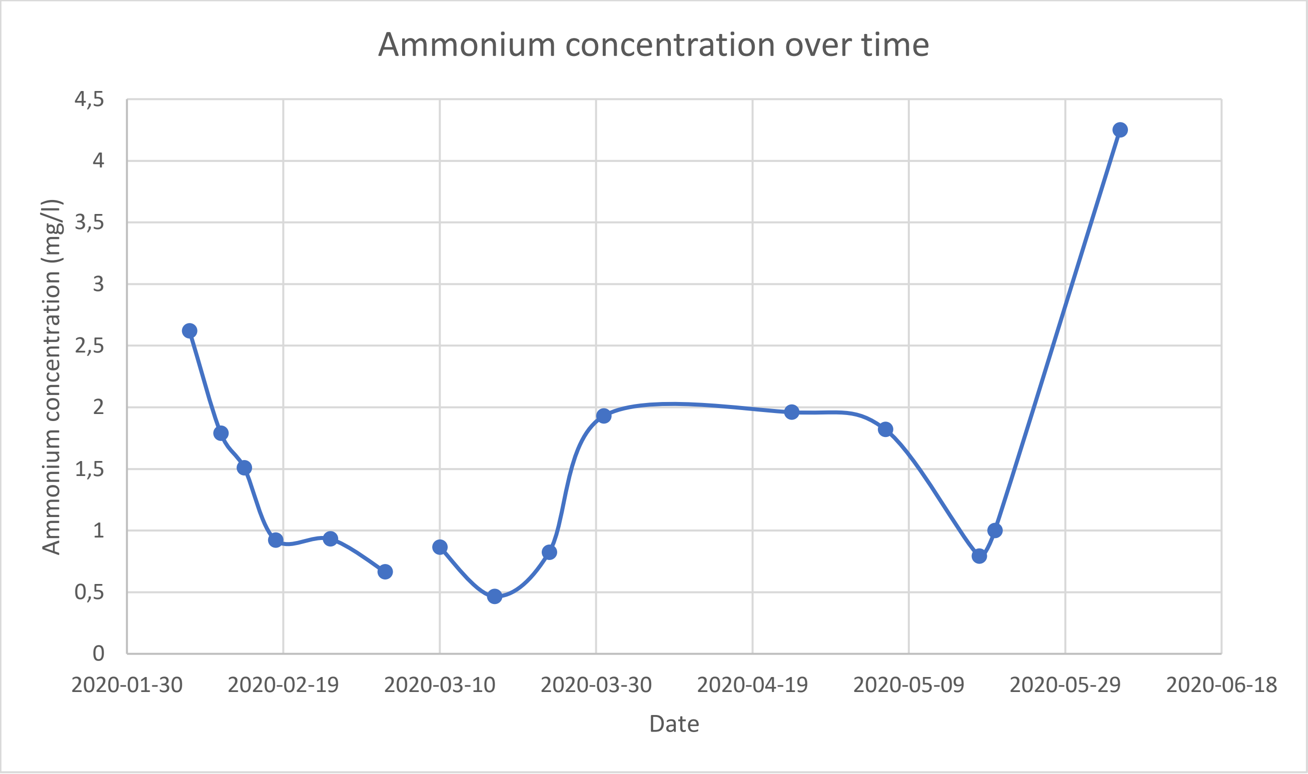
The conductivity has drastically dropped from the first to the second readings. Since then the conductivity has increased steadily. Conductivity change in an aquaponics system seems normal. As the conductivity is a representation of the number of ions present in the system. In an aquaponics system, the higher the conductivity, the more present are the nutrients. This general rule needs some precision. Indeed, it is not because a system increases its conductivity that there cannot be deficiencies. The Electrical Conductivity (EC) does not differentiate between the different type of nutrients, which means that EC can only give a rough estimation of the nutrients present in the system. Moreover, an increase in conductivity can also be due to an increase in salt concentration in the system, which can be problematic. Unfortunately, the simple readings of EC cannot specify if it is an increase in nutrient or in salinity (Lennard, 2012). The observed results are most likely due to a constant increase in nutrient, logical when a system is reaching an equilibrium and maturity. Nutrient in the organic form will not have an influence on the conductivity. This means that the mineralization of the organic compounds needs to be done to influence the conductivity (Lennard, 2012). The ideal conductivity level for an aquaponics system should be lower than 1.500 us/cm (Somerville, 2014). To correspond to the data of the graphic, the data have to be multiplied by 10. It is possible to conclude that the conductivity is at a normal level.

Dissolved oxygen:



The dissolved oxygen (DO) is essential for the fish and the plant. This is why it is important to have good aeration in the system but also to monitor this variable closely. An adequate oxygen level should be within a range of 6–8 mg/litre (Somerville, 2014). The graphic shows that the level of oxygen is very good and in the adequate boundary. However, we can also see that since a few months the DO is decreasing steadily. It will be important to monitor the level never to reach a level below 6 mg/l. The objective is to find an equilibrium.

Ammonium:



The first point has been for clarity (the level was very high compared to the other data)

The optimal level of ammonium in water should be below 1 mg/l. Tilapia can have symptoms of ammonia poisoning at a level as low as 1 mg/l (Somerville, 2014).

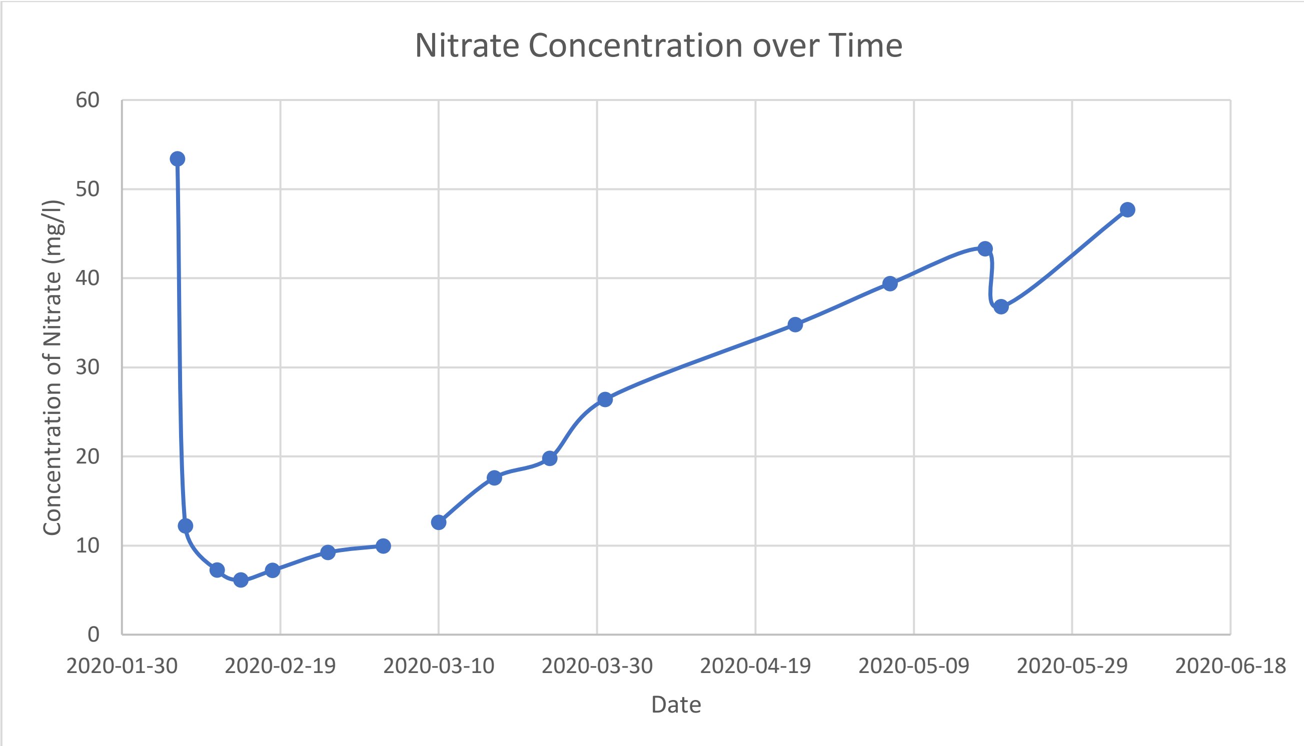
We can see that the level of ammonium in water is problematic and should be corrected as soon as possible to avoid too much adverse effect on the fish in particular. The last value is particularly worrying.

Several reasons can cause a level of ammonium that high: Not efficient enough biofilter, too much fish, bad food amount.

Test before and after the biofilter should be done to be able to see how effective is the biofilter.

The last data is most likely an error as the fish are still alive and healthy. However, a new method to measure the amount of ammonium should be found.

Nitrate:

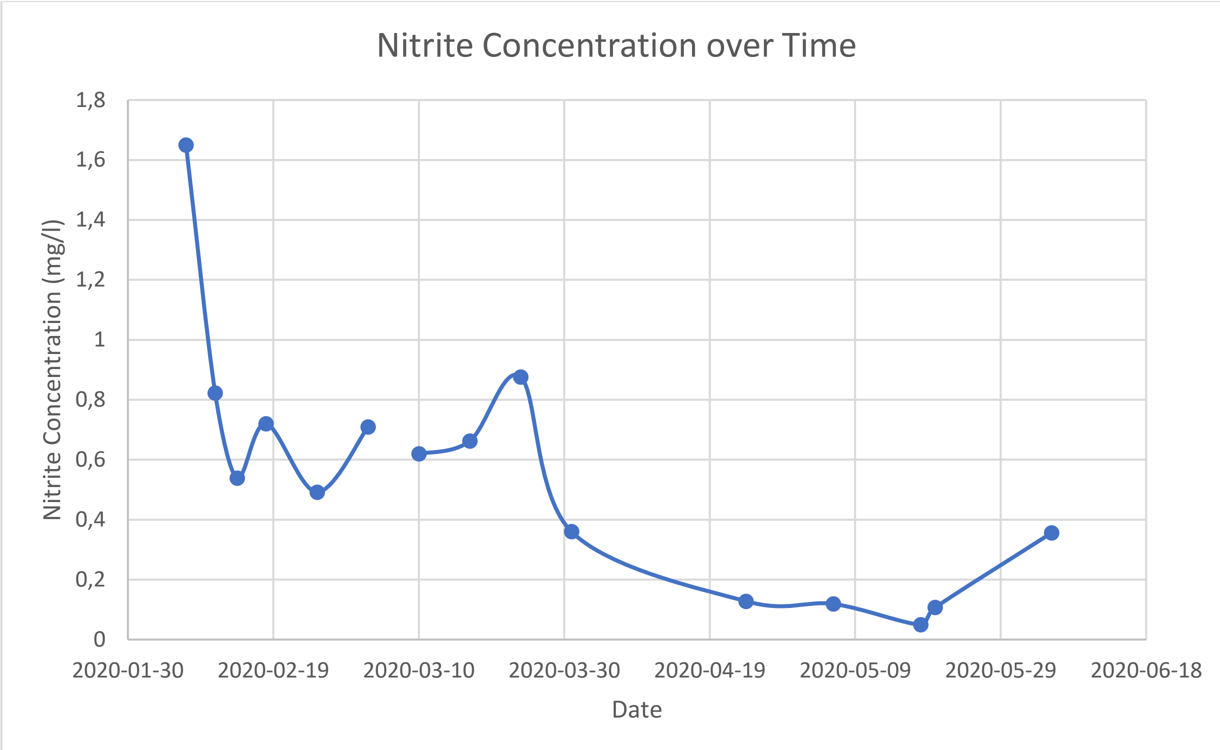


The first readings should be ignored as it does not correspond to normal trends.

Nitrate level is one of the most important variables. Nitrate is the main nutrient for the vegetable. Therefore, it is really important that there is enough nitrate in the system. The adequate level of nitrate concentration should be between 5-150 mg/l (Somerville, 2014). It is possible to observe that the concentration is in the proper boundary. It is also possible to see a steady increase since the start of the sampling.

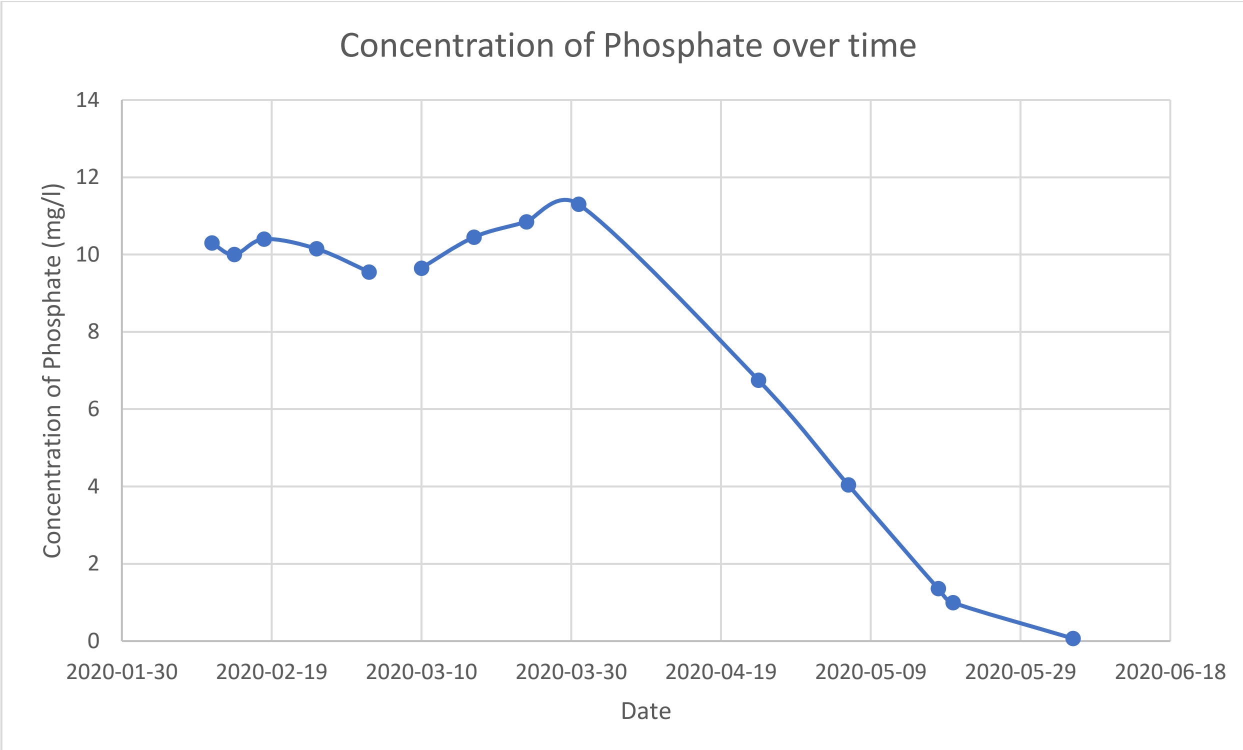
These levels are very encouraging because they show that the system is working well. New, more demanding vegetable, could probably be considered as the concentration of nitrate is high. The objective of an aquaponics system is to manage to reach an equilibrium between the different variables.

Nitrite:



As the ammonium, the nitrite is toxic for the fish, and the concentration of nitrite should stay as low as possible. The adequate level is 0 mg/l. There can be consequences for fish with concentration as low as 0,25 mg/l (Somerville, 2014). It is possible to observe that the concentration of nitrite was too high at the start of the sampling. However, it has been decreasing steadily since then. The last four readings, excluding the last one, were giving good result below 0,2 mg/l. The last reading is too high. Another reading should be done to see if the concentration is still too high or not.

Phosphate:



Phosphate is also an important nutrient for the vegetable. The graphic shows a drastic decline in phosphate level the past 2-3 months. This indicates that there is now a deficiency of phosphate in the system. This is something that was already suspected due to the colouring of tomatoes leaves.

Alkalinity:

The graphic on alkalinity level does not give a lot of information as for the past few months the value has been below 30,5 HCO3 mg/l. the level decrease since the start and is now below 30,5 HCO3 mg/l since a few months.

Last data from the 22/06:

		ms/m	mg/l	mg/l	mg/l	mg/l	HCO3 mg/l	mg/l	mg/l
	pH	**Konduktivitet**	**löst syre**	**Ammonium**	**Nitrat**	**Nitrit**	**Alkalinitet**	**Fosfat**	**annat**
22.06.2020 AP	7.81	93.9	7.77	13.8	72.2	0.323	<30,5	0.772	
22.06.2020 AP2, odling	6.96	93.6	7.67	14.5	74	0.325	<30,5	0.715	
22.06.2020 AP 2 fisk	6.38	93.9	7.15	14.9	75.6	0.304	<30,5	0.761	

The last data taken are interesting to be analyses by themselves as they show a worrying trend. The three data have been taken at three different places of the system to observe the difference among a single system.

For the pH, we can see that the level is perfectly into the recommendation. It is also possible to observe a real difference between the fish tank (6.38) and the biofilter (7.81). The oxygen level is also good as well as the level of nitrate. The level of nitrate is quite high, which indicate that the system is working well and that more demanding plant could be used. The level of nitrite is slightly too high. The level of phosphate is still very low.

The ammonium level is probably a readings error. Indeed, at this level, fish would quickly die, and the system would probably fail.

Sampling plan:

It is possible to observe with the different data at different locations in the system that the system is in equilibrium. There are no major dissimilarities of the amount of a compound in the system. The three noticeable features are the difference of pH among the system, the high level of ammonium and the level of nitrate that is higher in the fish tank than at the end of the DWC system (should be equal or lower).

Recommendations:

- There is a need to confirm the level of ammonium. The level of ammonium is clearly not correct in the last readings. An external laboratory should analyze the water sample to provide the correct ammonium level.
- As errors in the analysis are possible, I would advise getting a water aquaponics kit. In the case of a problem like the one occurring right now, it would be possible to do a quick analysis of the water and to have an idea of the veracity of the sample readings. This would decrease the time between the confirmation of an abnormal level of a compound and the measures that need to be taken if the problem is confirmed.

Optimization of the system:

As a first comment, it is important to understand that an aquaponics system is an evolving system. The system evolves in time, and adaptation needs to be done in consequence. Optimizations are therefore complicated especially in a system that didn't reach maturity. Variables are still changing on a regular basis.

Every part of the system could be optimized as this system was more construct as an educative tool than a production tool.

The system is working correctly right now and could be left as it is as long as the level of ammonium is reasonable. Nevertheless, some optimization tools will be presented to show the improvement that could be done.

Fish tank:

The size of the fish tank seems adequate for the room. The number of fish could be increased but aeration will then be necessary. This is something possible, but if cost efficiency is an aim, fish should just be allowed to grow by themselves. "The recommended fish density is based on a maximum stocking density of 20 kg per 1 000 litres" (Somerville, 2014, p126)

The feeding could also probably be increased (to 2% by day), but the ammonium level needs to be controlled much closer. If this is done, a new or more efficient biofilter should probably be installed.

Other species of fish could be considered, but Tilapia seems the most adequate for the condition of the system. The high temperature of the demo room makes it ideal for a tropical species like Tilapia. As a reminder, the ideal temperature range for the growth of Tilapia is 27°C to 30°C (Somerville, 2014, p109).

Biofilter:

Numerous types of biofilter exist. It is also difficult to know if the filter of the D-system is efficient enough as the data for ammonium is probably false. The size of the biofilter should be around 10-30% of the size of the tank (Somerville, 2014).

The design of the biofilter in the D-system is quite common, and its efficiency should be sufficient. If another type of biofilter needs to be installed, I would advise a moving bed technology. This is a technology that is used in wastewater treatment, and that is known to be very efficient in term of space and efficiency of transformation. The only issue of this biofilter is that it needs aeration, which can sometimes be avoided.

Other biofilters could be considered, but there is a need for more accurate data to be able to evaluate what is needed.

In term of cost, as long as the biofilter can maintain an adequate level of ammonium, nitrite and nitrate in the water, there is no reason to change it. In case the biofilter does not have the capacity to handle bigger fish, then I would advise moving bed technology. The transition of one biofilter to another could be problematic as the biofilter are usually not directly operational. They usually need time to get to their full potential. The solution would be to create a second closed system with only the biofilter and a water tank. The operator would have to add ammonia regularly in the system for 3 to 5 weeks (Somerville, 2014, p79). Once the biofilter is ready, and the bacteria are developed enough, the new biofilter can replace the old one.

Vegetable Tank:

The vegetable tank could be improved if the phosphate deficiency is handled. Indeed, the nitrogen concentration increases, which means the density or the amount of high demanding vegetable could be increased. However, right now, the phosphate level is too low and creates problems for the plants. One of the most common ways to handle phosphate problem is to add phosphate rock in the system. It is important when adding phosphate into the system to be careful about the increase in algae that have high affinity with phosphate (AquaponicsExposed, 2017).

In terms of design, there is not much that can be improved in the structure. The structure is working well, and the place limitation makes it difficult to do any change. The parameters that can be changed are the type of vegetable and the density of vegetable.

I would advice to first handle the problem of phosphate. Once the level of phosphate reaches an acceptable level, I would change the type of vegetable to more nutrients demanding vegetables (tomatoes, cucumber, …). This process should be progressive and drastic change should be avoided to limit the impact on the system. The level of nutrient should be analysed more often during the transition period. Once the new level is reached, the system should not be modified in order for the nutrient to reach equilibrium. If a high level of nutrients is still observed after the modification, the density of the vegetable could maybe be increased.

Aquaponics tries to mimic an ecosystem in miniature. This means that change will impact the whole system and that the system is evolving in time. The most important thing to do then is to adapt to the situation. Old systems regulate themselves and do not need as much attention as young systems. This is, for example, the case for the installation of Bjorn Oliviusson. He mentions that the monitoring of the water quality was less necessary as his system reached an equilibrium.

Light and heating:

As there is no real data about the light and the consumption of energy, it is complicated to give optimization advice. In the actual situation, the lamps are normal lamp (not LED) and the heat produced by them are used for heating of the room. A choice could be made to replace old lamps by lamps that only produces light ray relevant for photosynthesis. This would probably decrease the heat of the room, and a heating device (radiator, …) should most likely be added to compensate. This solution would probably increase the photosynthesis potential of the plant. Without knowing the amount of heat necessary to heat the room and the heat the new lamp will produce, it is impossible to say if it will be more energetically efficient or not.

I am not conformable making any recommendation for the lamp and heating with the little amount of information available. However, specific lamps that only produces light relevant for the plant exist.

Conclusion:

I would not advise changing the system right away except if exceptional conditions demand it. The level of ammonium needs to be verified, and an accurate method should be found to be able to monitor its level. Ammonium level is one of the most important compounds to monitor. Same can be said for the level of nitrite. Even if the level remains very low, it should be at least inferior to 0,2 mg/L. Moreover, the level of phosphate is too low right now and demands correction.

My recommendations are as follow and it this order:

- Analyze the level of ammonium in an independent laboratory.
- Find an accurate method to monitor the level of ammonium in a weekly based.
- Analyze the level of ammonium every week for a month to test the accuracy of the new/corrected method. Ideally, those same samples should be sent to the same independent laboratory to corroborate the result of the new/corrected method.
- Correct the level of phosphate by using a chosen method, for example, by adding phosphate rocks.
- Wait until all the parameters (ammonium, nitrite and phosphate) are at an acceptable level. If the ammonium is still at a high level, replacing part of the water from the tank should be considered. This would influence the amount of nitrate available in the water, but it is necessary for the health of the fish.
- Replace progressively less demanding vegetable (lettuce, basil, …) to more demanding plant. The level of nitrate should be monitor carefully during this period. It might be necessary to wait for a

rotation between each modification to be sure the fish produce enough nutrient for the vegetable tank.
- If the nitrate level is still high, an increase in the density of plants could be considered.

All these recommendations have for purpose to be cheap and need low modification of the entire system. A completely new system could be designed but this does not enter into the objective of this report.

It is recommended to wait after changes and monitor the important variables (ammonium, nitrate, …) carefully. The change should be progressive, and adaptation is the key for an efficient and reliable system.

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