# The water quality of the West Lake

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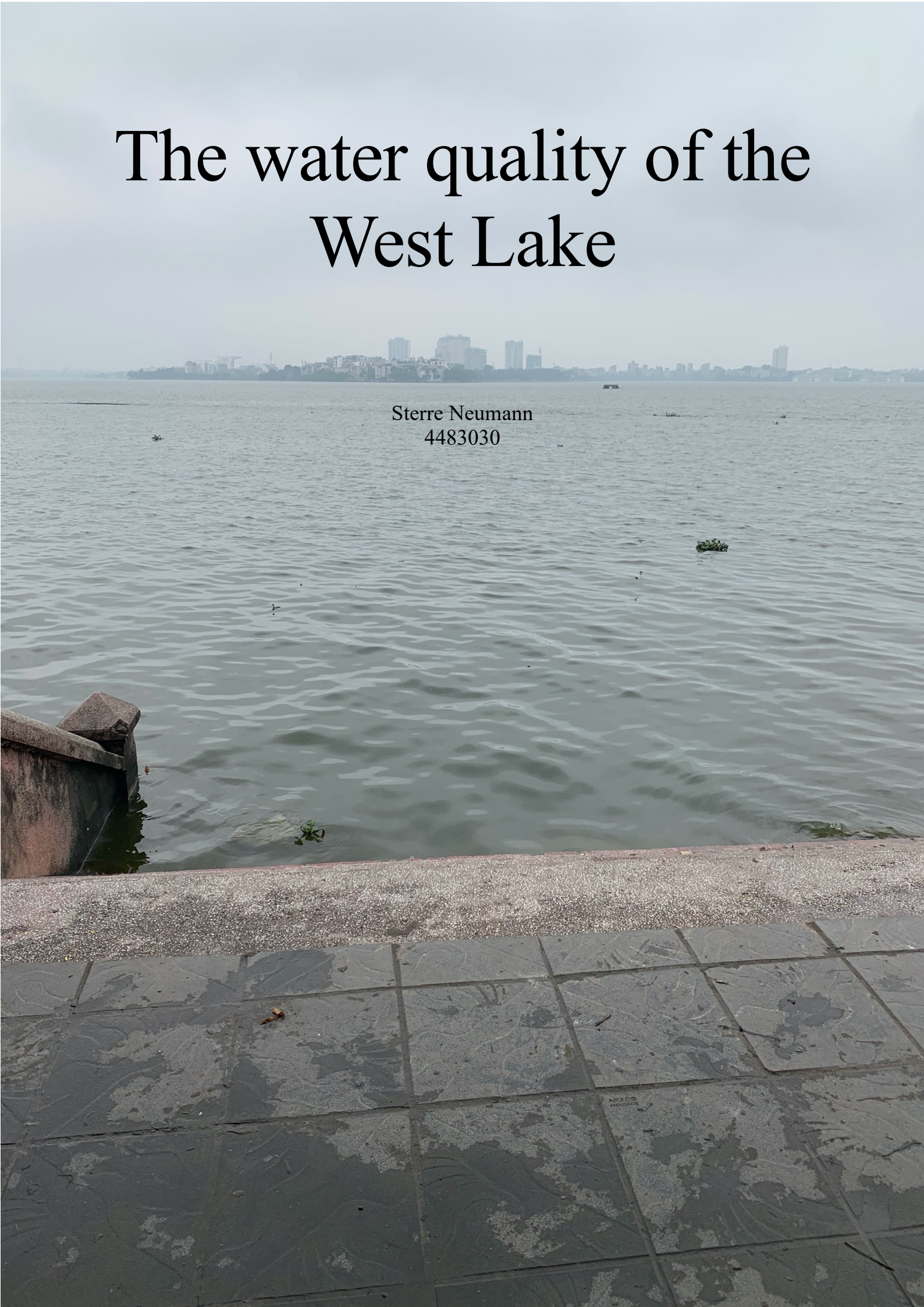

Delft University of Technology and Hanoi University of Natural Resources and Environment

Bachelor Thesis Water Management
CTB3000

# The water quality of the West Lake

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April 6, 2020

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# Preface

This report is a Bachelor Thesis for the study Civil Engineering at the Delft University of Technology. This report contains a research about the water quality of the West Lake. The research has been done at the Hanoi University of Natural Resources and Environment (HUNRE). I went to Hanoi in February and March, with two study friends, Renske den Brave and Florine Speth. Most of the experiments of our three researches we did together.

This research is also part of a bigger project named: Climate Proof Vietnam OKP. This is a cooperation between the Delft University of Technology and Vietnam. The aim of the project is training new generations of engineers who are well prepared to protect their land against the water. There are a lot of challenges in this project and I am glad that I can be a part of it.

I have learned a lot and I would like to thank some people to participate in this project. First, I would like to thank my supervisors, Thom Bogaard and Juliette Eulderink. They helped me a lot with this project and all my questions. Juliette also told me things about Hanoi. At HUNRE, MSc Tran Thuy Chi and Dr. Ta Thi Thoang helped me, they answered my questions and helped me find my way through Vietnam without speaking Vietnamese. I would like to thank Lindsey Schwidder and TU Delft Global as well for the opportunity. And I would like to thank the students of HUNRE, and in special Tran Ha.

I hope you enjoy your reading.

Sterre Neumann

Hanoi, April 6, 2020

# Abstract

For this research I went to Hanoi in February and March. I did research about the water quality of the West Lake. The last couple of years the water quality became worse and organisms died in the lake. In this research the water quality of the lake is tested and analyzed if the area and humans influence the water quality. The research is done at the Hanoi University of Natural Resources and Environment (HUNRE). Another aim of this research is to make students in there enthusiastic about technical studies and work together with the students.

The main research question is: *How is the water quality distributed within the West Lake and the area?*
Therefore, I did all the experiments on 6 different locations on the edge of the West Lake. All the area at the locations have another purpose. So, an area analysis is done for these locations at the West Lake. There are also measured a couple of different parameters around these six locations at the depth of 25 centimeters. At this depth the sun and the rain have much influence on the water. The parameters I measured were temperature, pH, Dissolved Oxygen, Electric Conductivity, turbidity, Nitrate, Nitrite, Total Iron, Phosphate, Biochemical Oxygen Demand and Chemical Oxygen Demand. With these parameters we tested the water quality.

Another sub question is: *Is there a difference in the water quality in wet season and dry season?*
For this research question I compared the data from the wet season, May to October, with the data I collected from the dry season, November to April. Together with the data from the wet season we collected a bigger data set. The university of HUNRE and TU Delft can use this data set and expand the dataset in the future.

During this research I concluded the following things: If we look at the water quality of the entire lake, the pH, the electric conductivity and the nitrate value are in the range of healthy water. But the high phosphate, the high amount of total iron, the stressful level of nitrite, the low amount of dissolved oxygen for some locations, the high value of BOD and COD make not a very good water quality for the lake. Some organisms will not survive in this water. Also, the water is influenced by humans. Location 1 has the lowest conductivity value and the lowest COD value. This is influenced by the rowing boat rentals in the area and the stairs at the location were citizens wash their dogs and stuff. Location 2 has the lowest value of dissolved oxygen, total iron, phosphate, nitrate, nitrite and pH. And the location has the highest water temperature, conductivity and COD. This location is influenced the most by humans. In the area there is a waterpark and agriculture field and they lose their wastewater in the lake. Location 3 has the lowest COD and the highest amount of total iron. At location 3 there are abandoned ships and cafes. Location 4 has the highest nitrate and nitrite level and the lowest value of the water temperature, the turbidity and the COD. This location has a road in the area which crosses the lake and have another part of the West Lake on the other side of the road. Location 5 has the highest amount of phosphate, dissolved oxygen, BOD and COD. Location 5 has restaurants in the water and a couple of shops in the area but mostly the area is used for housing and hotels. Location 6 has the highest value of turbidity, pH and COD. And the lowest amount of BOD. This location has tourist shops in the area, hotels and a hospital. The last conclusion is that the water quality is also influenced by the rain in the wet season, this can be found in the value of the electric conductivity and the amount of phosphate and dissolved oxygen in the water at this season. The water temperature and the pH were higher in the wet season as well.

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# 1. Introduction

The capital of Vietnam is Hanoi, the population of the capital is 7,7 million. Many citizens in one beautiful city. A lot of activities take place around the waters in Hanoi. Hanoi has a lot of water, for example the Red River, the To Lich River and the West Lake. Hanoi has up to 120 lakes, and this has many environmental benefits like their own water supply. The West Lake is in the center of Hanoi; this is one of the reasons the lake is an important part of Hanoi. Around the West Lake, there are many cafés, restaurants and exercises for the citizens and tourist. You can even see a couple fishermen around the lake. However, the last couple of years many fish in the West Lake died. The water quality of the West Lake became increasingly worse, and the Municipal People's Committee thinks that there are a couple of possible reasons for this. With this research the water quality of the lake will be tested, and some reasons will be investigated. The first possible reason is that residents throw their wastewater and trash in the lake and this makes the lake an extension of the city sewers because they are unaware of the impact of doing this. The second possible reason is that residents throw fish in the lake for cultural and traditional reasons. But they also throw some plastics bags with it, this ruined the ecosystem of the lake because there are coming new introduced fishes in the lake. The third possible reason is the higher number of urbanizations, more people are coming to work in the city. All these people also have to live in Hanoi, and they build their houses around the West Lake. This comes with waste. (Justice, Environmental, 2017) But how is the water quality of the West Lake now? This is why there have to come some more data about the quality, different parameters can be used for this.

This research regards measuring the water quality of the West Lake. In the research there will be ten different parameters measured and the measurements will be done at six different location. This are the parameters who define the water quality of the West Lake for this research: pH, Dissolved Oxygen, Electric Conductivity, turbidity, Nitrate, Nitrite, Total Iron, Phosphate, Biochemical Oxygen Demand and Chemical Oxygen Demand. And the six locations are on the edge of the West Lake. This research also analyzes the area around the West Lake, but only on the edge of the West Lake.

Therefore, the main research question is: *How is the water quality distributed within the West Lake and the area?*

The sub questions of this research are:

1. *Is there a relation between the area uses and the water quality parameters?*
2. *Is there a difference in the water quality in wet season and dry season?*

The aim of this research is to collect more data and more awareness for the water quality and the influence the area and citizens has. Other researches can use this data to search for a solution for the water quality problems.
Another aim of this research is a collaboration between the students of the TU Delft and HUNRE. The research will be done with a couple of students of HUNRE and after this research, there will be more data about the water quality of the West Lake available. Hopefully after this research the students want to go further with the researches regarding the West Lake. And maybe in the next couple of years there comes a solution for these water quality problems.

There are other researches done for the water quality of the West Lake. One of this is also from the TU Delft, ‘Feasibility study of flushing To Lich River with Red River water through West Lake’. In this research I will look at their data as well.

The report contains the following chapters: the second chapter is about the materials and parameters that have been used for the research. The third chapter covers the different locations for the measurements and a analyze of the area. The fourth chapter covers the results of all the measurements.  And this chapter is about the results of other similarly researches and the seasonal difference between the results. The fifth and sixth chapter is about the conclusion and discussion of the research.

# 2. Materials and parameters

In this chapter there is an explanation about the different devices I used for this research. There is also an explanation about the parameters. In appendix A, you can find the images of the devices. And in table A.2, you can find the limits of the parameters for healthy lake water. I used the pH-meter, the DO-meter, the EC-meter and the turbidity meter at the West Lake and again in the water lab. The BOD and COD, I used at the environmental lab.

## 2.1 pH-meter

For the pH measurements, we have used the devices from the TU Delft. This is a Greisinger pH-meter. With the pH-meter you can measure if the sample is acidity or basicity water. The pH is a translation for the concentration of the hydrogen ions. This is a really small value therefore the pH is the -log[$H_3O^+$]. The value of the pH is between the 1 and 14. When the value is 7, the sample is neutral. When the value is lower than 7, the sample is acid. If the water is below 6, it will inhibit the growth of the most microorganisms, even bacteria can mortify in this water. Lower than 6.5 the water is acid, soft and corrosive. A lower pH also has more toxic metals in the water. And when the value is above the 7, the sample is base. This don't have to be a problem for the microorganisms, only the activities and growth will be influenced a small bit. But the water above 8 is hard and can cause aesthetic problems. The pH depends on the temperature. For most lakes with living organism, the pH has to be between 6.7 and 8.6. (Oram B. , The pH of water, 2017)

## 2.2 DO-meter

DO is short for dissolved oxygen. We have also used the dissolved oxygen device from the TU Delft. This is a Greisinger DO-meter. The meter measures the amount of oxygen that is dissolved in the water. This is the amount of available oxygen for the living organism in the water. The oxygen is also used for the decomposition of organic materials. The DO-meter also measures the temperature, because the dissolved oxygen is inversely related to the water temperature. Healthy water has a concentration between 6.5 and 8 mg/L. When the DO is to low, the living organism cannot live in the water anymore. But when the DO is to high, this can lead to the gas bubble disease, a lot of organism can die of the disease. The DO depends on the temperature, day and nighttime, location and depth. On the top of the water the sun has the most impact, this also gives dissolved oxygen. (Frondiest environmental learning center, 2016)

## 2.3 HACH EC meter

We used an EC-meter that was already in the HUNRE lab. EC is short for electric conductivity. Electric conductivity is the ability to conduct an electric current. There can be positive and negative ions in the water, and the EC depends on the concentration of these ions. Pure distilled water has a low elective conductivity. There is a relation between electric conductivity and pollution. Fresh water has a conductivity between 100 and 800 µs/cm. (Lenntech, 1998-2020) Surface water has a conductivity around 1106 muS/cm. (Inagro, 2018) The higher the conductivity, the higher the salinity, and not all organism can survive in a really salinity water.

The HACH EC meter also measures the temperature, the resistivity, the salinity and the TDS. The meter measures the temperature because the electric conductivity depends on the water temperature. When the temperature increases, the electric conductivity of the water increases too. The electric conductivity is also related to the TDS, this is because the electric conductivity is directly related to the concentration of dissolved salt (the salinity). TDS is

short for Total Dissolved Solids. And the resistivity is the resistance for an electric current to flow trough the water. The resistivity is the opposite of the conductivity. Pure water has a resistivity of 18.2 Ω * cm. (Lenntech, 1998-2020)

## 2.4 HACH turbidity meter

For measuring the turbidity, we used the HACH Turbidity meter. This device was already at HUNRE. This device can easily measure the turbidity of the water. The turbidity of the water is the cloudy or non-transparence appearance of the water, this is caused by suspended solid particle. Like sediment (clay and silt), fine organic and inorganic materials, algae and other microscopic organisms. Clear water is usually the meter of healthy water. The effects of the turbidity can be harmful. Too much sediment or water plants, like algae, can make it unsuitable for aquatic life and recreation. (Lenntech, 1998-2020)

## 2.5 BOD meter

The BOD meter I used is the HACH BODtrak II meter, it was already at HUNRE. BOD is short for Biochemical Oxygen Demand. BOD is the amount of oxygen what is used by the bacteria and other microorganism while they decompose organic matter under aerobic conditions at a stated temperature. So, it defines the oxygen needed for the depletion of waste in the lake by adding microorganisms and this is why it is called biochemical. The samples are stored at the temperature of 20ºC for five days. Therefore, the name after the incubation time is BOD5. When the BOD is too high, there is less oxygen available for the aquatic live. Therefore, it has the same influences on the water as low dissolved oxygen. The organism in the water can become stressed, suffocate and die. When the BOD is low there is a lot of dissolved oxygen in the water, too much can lead to the gas bubble disease. (EPA, 2012) The BOD value between 1 and 2 mg/L is really good. The BOD between 3 – 5 mg/L is quite clean and between 6 and 9 mg/L, the water is polluted. (USGS, 2016)

## 2.6 COD meter

The COD meter I used is the HACH COD DRB 200 meter, this device is at HUNRE. COD is the Chemical Oxygen Demand. COD is the amount of oxygen required to oxidize soluble and particulate organic matter in water. It is a measure for the reduction of oxygen by chemical reactions. A higher COD value means that the water is more polluted. COD is always higher than BOD. For healthy water the COD level is up to 10 mg/L. The results of the COD test are defined as the mg $O_2$ consumed per liter of sample under the conditions of this procedure. Higher COD levels will reduce the dissolved oxygen levels. And this is harmful for the organism in the water. (Real Tech inc, 2017)

After I used the HACH COD meter I used the following equation to calculate the COD in mg/L:

$$COD\left[\frac{mg}{L}\right] = \frac{(\mathrm{V0} - \mathrm{Vn}) * C * 8000}{\text{Volume sample}} = \frac{(0{,}95 - \mathrm{Vn}) * 0{,}06 * 8000}{2}$$

Equation 2.1: COD

## 2.7 AKVO app

For the parameters, I used the HACH strips and the AKVO app.

### 2.7.1 Nitrate and nitrite

The measuring range of the nitrate and nitrite strips are from 0 to 50 mg/L. Nitrate is $NO_3^-$ and nitrite is $NO_2^-$, so it is composed from nitrogen and oxygen. With oxidization nitrite can become nitrate. A high level of nitrites or nitrates can be toxic for the organism in the water. However, nitrogen is an important component for all the living creatures, because it is a component of protein. Nitrogen consist in many forms and change his forms in the nitrogen cycle. Nitrogen are naturally in the soil, in the decaying plants and animal rests. Then the bacteria convert nitrogen to nitrate. Nitrite come is smaller amounts than nitrate. Nitrate is more stable considering acid water and temperature. There is a limit for healthy water. Nitrite above 0.75 mg/L can be stressful for fish but the limit of nitrite is 1 mg/L. The nitrate limit is 10 mg/L. (Oram B. , Nitrates and nitrites in drinking water, ground water and surface water, 2017)

### 2.7.2 Total iron

The measuring range of the total iron strips are from 0 to 5 mg/L. Total iron is the total amount of ferrous iron ($Fe^{2+}$), ferric iron ($Fe^{3+}$), complexed iron and iron oxides. Iron exist naturally in underground water, lakes and rivers and in rocks. Iron is also in industrial waste and enters the water. But when humans throw waste in the water, the total iron can also be influenced. For organism iron is essential, but a large amount can also be risky. For a lake normally the total iron is 0.15 and 0.30 mg/L. (Lenntech, sd)

### 2.7.3 Phosphate

The measuring range of the phosphate strips are from 0 to 50 mg/L. Phosphate are chemicals that contains the element phosphorous. Phosphate feed the algae, and this creates imbalances because of the growing number of algae. These imbalances can destroy other organisms. With a good amount of phosphate, the plankton will grow which provide more food for the fishes. This can lead to increasing the fish population and this is good for the water quality. However, when there is too much phosphate in the water, the number of algae will grow too much and take a large amount of oxygen. This is bad for the water quality and the fish in the water. The amount of phosphate must be low for a good water quality. But it is necessary. The limits of phosphate in water depends:

- 0.01 – 0.03 mg/L when the level in uncontaminated lakes
- 0.025 – 0.1 mg/L when the level at which plan growth is stimulated
- 0.1 mg/L when the maximum acceptable to avoid accelerated eutrophication
- > 0.1 mg/L when accelerated growth and consequent problems

(Oram M. B., 2017)

# 3. Locations

In this chapter the different locations of the samples are described. When determining the different locations, I looked at the area around the West Lake and where we could take the samples with our stick.

## 3.1 Map of the West Lake

The figure 3.1 shows the map of the West Lake and the places where we took the samples. The locations 1 to 6, I did the measurements 3 times. For the locations 1 to 6 I used the EC-meter, DO-meter, turbidity meter and the pH-meter at the West Lake. I also took 2 bottles of samples for each location; in the water quality lab I did some extra research with the samples. And I used the EC-meter, DO-meter, turbidity meter and the electric conductivity again at the lab. The BOD and COD I used at the environmental lab.

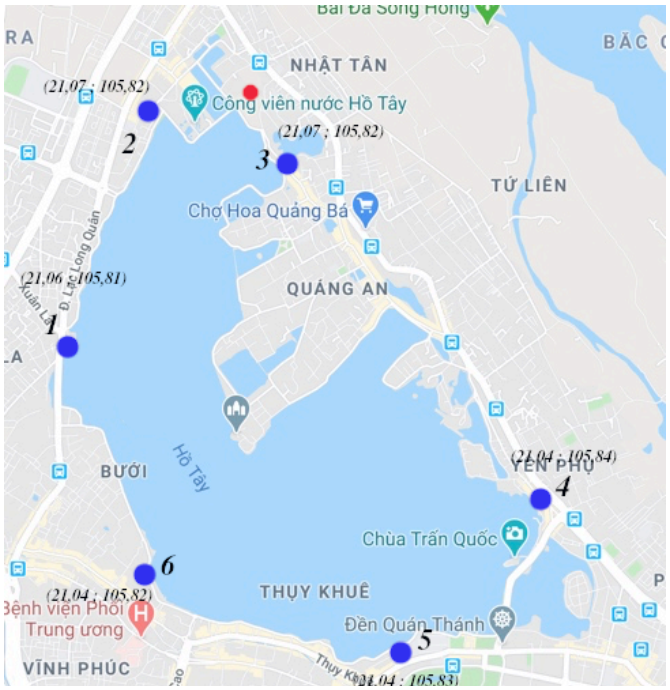
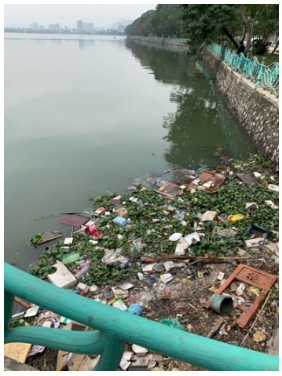


Figure 3.1: Map of the West Lake

In figure 3.2 on the left, you can see at location 1 there are stairs for entering the lake. People wash their dogs, fishnets and other supplies in the water here. Next to the stairs there is a coffeeshop and the seats of the shop are directly on the edge of the lake.

Figure 3.2: Picture of location 1



In figure 3.3 is a picture shown of Location 2. Location 2 has a lot of garbage in the water. There were some dead fish in the water as well. Also, parts of wooden furniture are in the water. You can see a lot of green on the water as well.

Figure 3.3: Picture of location 2

In figure 3.4 is a picture shown of location 3. At location 3 were a couple of ships in the water. Previously a lot of these ships were restaurants and cafes, they threw all their garbage and wastewater in the lake. The police stopped this and demanded they must connect their water pipes to the land system. Not all the people did this but abandoned their ship. Now the ships are outdated, and parts of the ship are floating in the water.

Figure 3.4: Picture of location 3

Figure 3.5 shows pictures of locations 4 and 5. Location 4 and 5 looks like the cleanest locations, but there was also some stuff in the water what does not belong there, like wooden chairs and plastic. At location 5 were many mosquitoes. You cannot enter the water at these locations and there is a road next to the locations. But you could see a couple of fishmen.

Figure 3.5: Picture of location 4 (left) and location 5 (right)

Figure 3.6 shows a picture of location 6. At location 6, the smell was very bad, there were parts dead fish in the water as well.

Figure 3.6: Picture of location 6

## 3.2 Area analysis

In figure 3.7 you can see a categorized map of the function of the area around the West Lake. The legend is on the right side of the figure. The red is for housing and hotels and this is a big part of the area around the West Lake. The brown color is for others, and the brown colors

have letters in the figure. A is for golf center, B is for boat rental, C is for more modern and more beautiful area with big hotels and the waterpark, D is for dragon culture in the water, E is for a small park and F is for rowing boats rental.

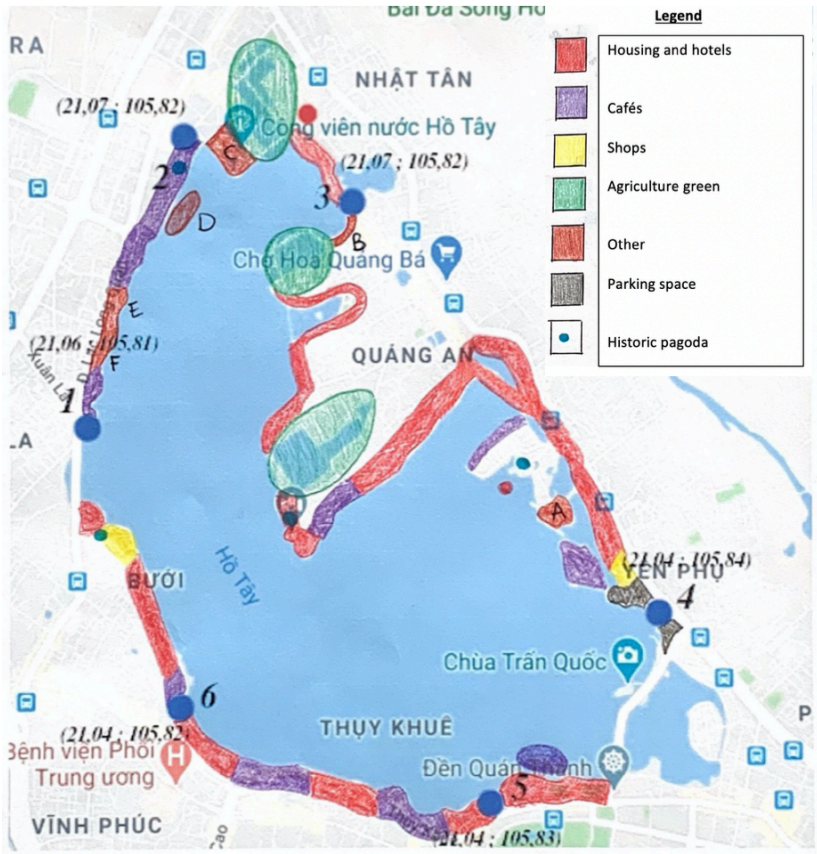


Figure 3.7: Categorized map of the West Lake

You can still see the locations in the map. The area next to the lake at location 1 is mostly used for cars. There is a big road beside the lake at this location. Nearby the location there are rowing boat rentals and people go in the lake there for rowing. There was a small park on the edge of the lake as well. People can walk, sit and sport there. At location 2, the area is used for a water park. Beside the water park, there are a couple of coffee shops nearby. At letter D, there is a dragon statue in the water. Next to the waterpark is a modern street with beautiful building used for residential and there are more touristic coffeehouses like highlands coffee. On the other side of the waterpark there is an agriculture field used for growing crops. At location 3, the area is used for growing some crops and the flower garden is near this area. There is a small boat rental as well. Nearby location 3 is a water treatment that treats wastewater, you can see the location at the red dot in figure 3.1 and 3.7. Between the locations 3 and 4 there is a small road. The area around location 4 is mostly used for housing and hotels. Between location 3 and 4 you can see a little red point in the water, apartments have been built here. In the street of these apartments there are a lot of car and motorbike rentals. At letter A there is a golf range. Next to the location we took samples was a parking space. This area is also close to a road who crosses the water. On the other side of the road is the West Lake as well, but this is used for little swan boats. This is why on that side of the lake are mostly cafes for the tourists. The water can flow under the road, so the parts of the West Lake are connected. In the area of this location is also Tran Quoc Pagoda, this is a cultural symbol of Vietnam. Tourists and citizens are going to this location to see this symbol. The area at location 5 is used for some restaurants and shops but mostly for housing. Next to

the road there are a couple of more expensive restaurants in the lake. And in this area is a high school, the Chu Van A high school. More into the land is the touristic area of Hanoi. Between location 5 and 6 there are cafes and housing alternately. At location 6 there are a couple of tourist spots and cafés. Hotels are there as well. In this area you can see one of the hospitals. Nearby this location is the in- and outflow sluice with the To Lich River.

# 4. Results

In this chapter the results of the water quality of the West Lake are analyzed. The presentation of the results on different dates are in appendix B. And the limits of healthy water can be found in this chapter and an overview in table A.2 in appendix A. The results were taken in February and March. The air temperature was between 20ºC and 28ºC, the temperature varied a lot in this period. There was not much rain, just a couple of days and this was in the third week of measurements. In table B.1 you can find the parameter results and the limits.

## 4.1 Water temperature

Figure 4.1 regards the water temperature; you can see that the water temperatures was around 22 ºC. The water temperature is measured only 25 centimeters in the water. The sun has a big impact on this area of the water temperature. The air temperature these weeks were between 20 ºC and 28 ºC. The lowest water temperature was at location 4 and the highest water temperature was at location 2. Location 2 is located at the water park and there are a couple of cafes around that area. The water park uses a lot of machines to create water stream and golfs. The water park also has roller coasters. So, this location uses many energies, and this can heat up the West Lake around that area. (Hanoi, Travel, 2017) Also has location 2 areas were crops grow, the areas are almost connected to the lake. Water flows from the agriculture field to the water and this is hotter than lake water. Therefore, the water will be hotter on this location. And there are fewer high buildings in this area the sun can reach the water easily and this heated the water on the surface as well. Location 4 had the most shadow of all the locations. This is located in a deeper area and on the east side there were buildings who blocked the sun. The area around location 4 has a lot of residential and housing. This influence the water hardly. Figure B.2 shows the water temperature for the first week was the lowest and the water temperature of the second week was the highest. The second week was the most sun and this influence the surface water temperature. And the third week is in between the two weeks and is almost the same as the mean of the water temperatures of all the weeks. In the third week there was a lot of rain, this affect the water temperature because the sample we took are not very deep in the water.

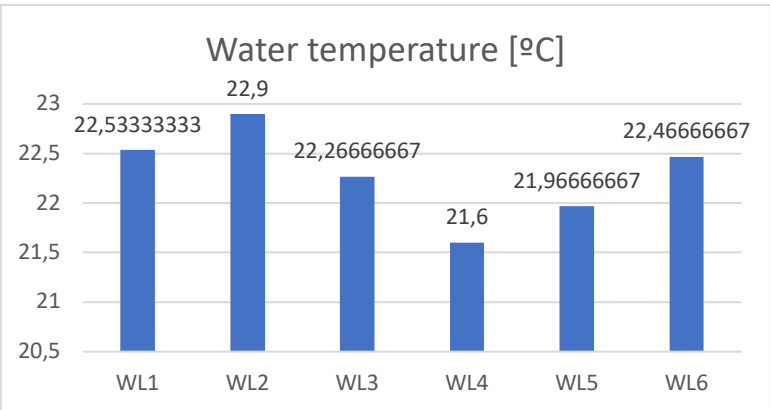



Figure 4.1: Water temperature in ºC

## 4.2 Electric Conductivity

Figure 4.2 is about the electric conductivity; The salinity is almost the same at every point of the West Lake. It is around the 0.20 ‰, this means that there is 0.20‰ dissolved salt in the lake. The electric conductivity is the highest at location 2 and the lowest at location 1. Location 2 is also the location with the highest water temperature. This is caused

by more agriculture water in the lake and it is caused by the water park and more sun reaches the lake water. The high temperature influences the conductivity of the lake. Therefore, you can see the relation between the water temperature and the electrical conductivity. But the electric conductivity does not only depend on the water temperature. There is also in relation to the total dissolved solids. Wastewater has more dissolved parts in it than normal water, the agriculture water also has more dissolved particles and has a higher conductivity. And this is so at location 2. For location 1 there were some dirt in the water, but this led to more pollution but not necessarily to more conductivity because many particles have sunk to the bottom of the water. More water is taken out of the lake at this location. Also the water temperature is lower there. The conductivity of week 1 and week 2 are almost the same. But the third week has a lower conductivity. This is because the conductivity of rainwater is really low, almost 0. And the third week there was a lot of rain. (Inagro, 2018) The data of the different weeks is shown in figure B.3, the conductivity on different dates.

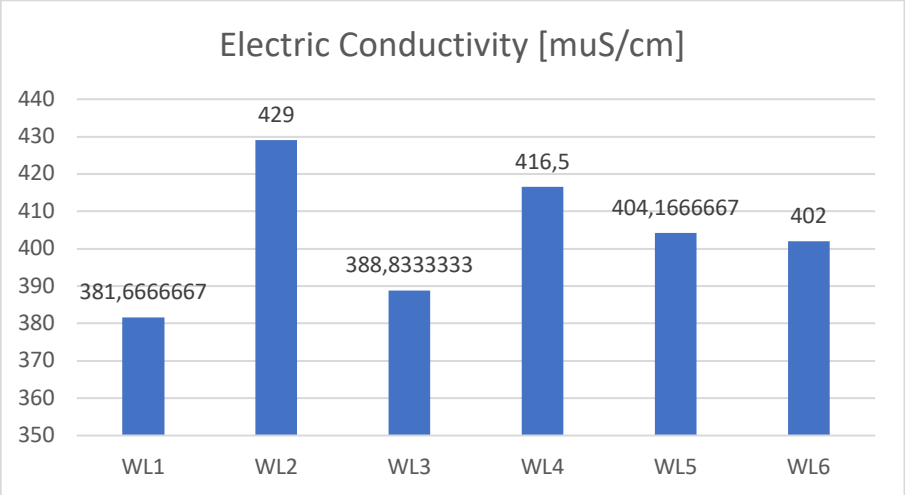


Figure 4.2: Electric Conductivity in muS/cm

## 4.3 Turbidity

The turbidity is shown in figure 4.3. The highest turbidity is at location 6 and the lowest at location 4. Pollution can lead to more turbidity and at location 6 there were parts of dead fish in the water and some garbage. See the picture in chapter 3. At location 6 you can also go in the lake and there are a lot of restaurants and hotels in the area. Also, street food and they can clean their stuff and throw their wastewater in the lake. This led to more pollution in the water. You could see in the water and on the surface many algae, this is probably what causes the turbidity as well. At location 4 there was almost no garbage on the water surface. And the area of location 4 mainly consist of housing, this influences the water hardly. There were also a lot of bricks in the water, this can also affect the turbidity. The turbidity for the different weeks is almost the same, see figure B.4. Only for location 2 there is a significantly different between week 1 and the other weeks. This can be caused by the amount of wastewater in the lake. When the wastewater of the agriculture fields is just before our measurement dumped in the water the measurements will be influenced.

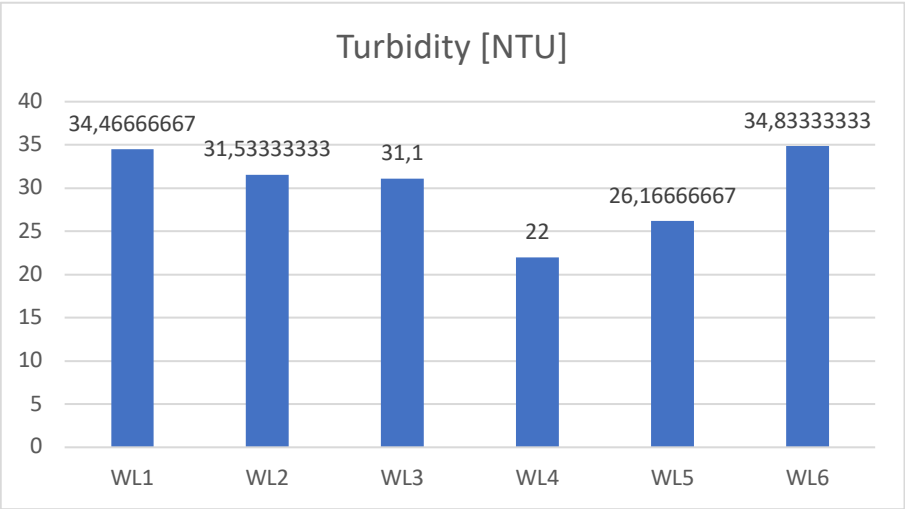


Figure 4.3: Turbidity in NTU

## 4.4 Different parameters

Figure 4.4 shows the different parameters. The nitrite is significantly low at all the locations of the West Lake. The nitrate is a bit higher. The nitrate level is a healthy amount in the lake. The nitrite level is also healthy but for location 4 and 5 the nitrite level can be stressful for the fish in the water, so this is not a really healthy situation. These locations have a road that crosses the water. On the other side of the road there is also the West Lake what is used for smaller boats. This influences the nitrite level. The DO and phosphate are in higher amounts in the West Lake. Dissolved oxygen has a positive impact on the West Lake. But at location 2 the DO is really low; at the field trip we saw a couple of dead fish there in the lake. At location 2 there is agriculture wastewater dumped in the lake and this gives a lower DO. Also, the water park has influence on the water, more people are coming there and throwing waste in the water or on the area. This is not good for the water quality. The total iron is naturally in the water. Iron can be toxic when it is in high doses. Normally the total iron is between 0.15 and 0.30 mg/L, in the West Lake the total amount is between 0.145 and 0.44 mg/L. The highest amount is at location 3 and this is too high. Location 3 has also some agriculture areas nearby; this wastewater will come in the lake. More iron is in this wastewater. Therefore, there is more iron in the water at location 3. The ships in the water at location 3 influences the total iron amount as well. In the earlier days a lot of factory wastewater was thrown in the lake and this has more iron in it. Now the particles of the ships are floating in the water. The phosphate in the lake is really high. And this is not good for the water quality. At some locations in the lake we saw a lot of algae and other sea plants. The highest amount is at location 5, here also come fish to eat the plants, this is why the fishermen are there. But the phosphate is now in a to high amount and can lead in the future to less oxygen. At location 5 the sun reaches the area a couple of hours of the day and this can lead to more photosynthesis and therefore to more phosphate in the water.

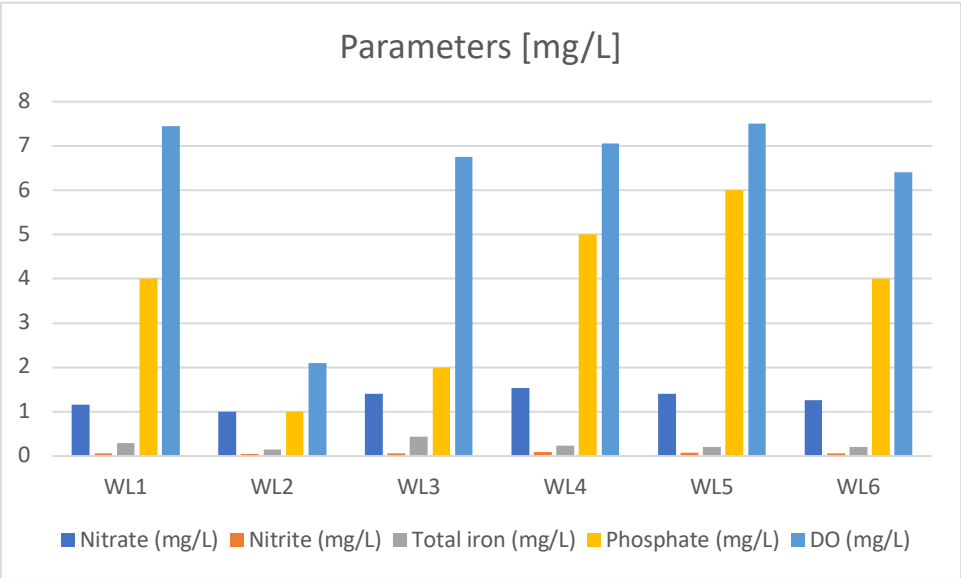


Figure 4.4: Nitrate, Nitrite, Total iron, Phosphate and Dissolved Oxygen in mg/L

## 4.5 pH

The pH values are shown in figure 4.5. All the values are above the 7, this means that the West Lake is a basicity. Therefore, there are more $OH^-$ ions in the lake. The pH can change all the time because of the biological processes. Figure B.5 shows that the pH in the second week is higher than the first week. The temperature of the second week was also higher, this can be a relation between the temperature and the pH. For the fishes to live in the water the pH has to be between 6.7 and 8.6. This also depend on what kind of fish is living in the lake. So, the pH had a good value in the lake. The North-East has a lower pH value than the South-West of the West Lake. The highest values are at the locations 5 and 6. On the South-West side, location 5 and 6, of the West Lake the area directly to the West Lake is more used than on the North-East side of the river. On the South-West side there is a road next to the river and it is often used by cars and motorcycles. More exhaust gasses influence the pH of the lake. And at location 5 and 6 the road is often used and in the rush hour there is some traffic.

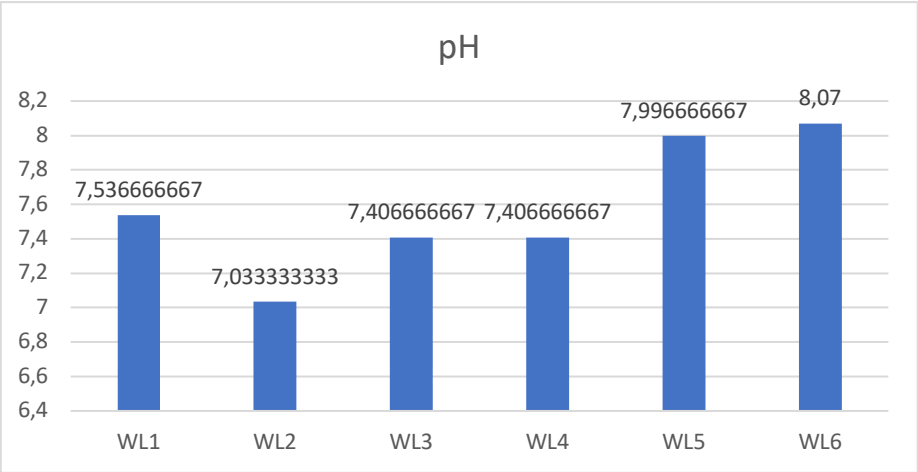


Figure 4.5: pH

## 4.6 BOD

The BOD is between the 2,9 and 90 mg/L. The BOD at location 5 is too high. The water there is polluted and there is a really low amount of dissolved oxygen in the lake. The organism in

the water can die of stressed out. The cars on the road there and the more touristic area have influenced this BOD value. The BOD at location 3 is a value for polluted water as well, this is caused by the wastewater of the agriculture fields. And at location 3 is a boat rental, boats are come and go to this location in the lake and this pollutes the water as well. The BOD value of the other locations is in the range of medium clean water but on the good other conditions it don't have to be on influence on the organism in the water.

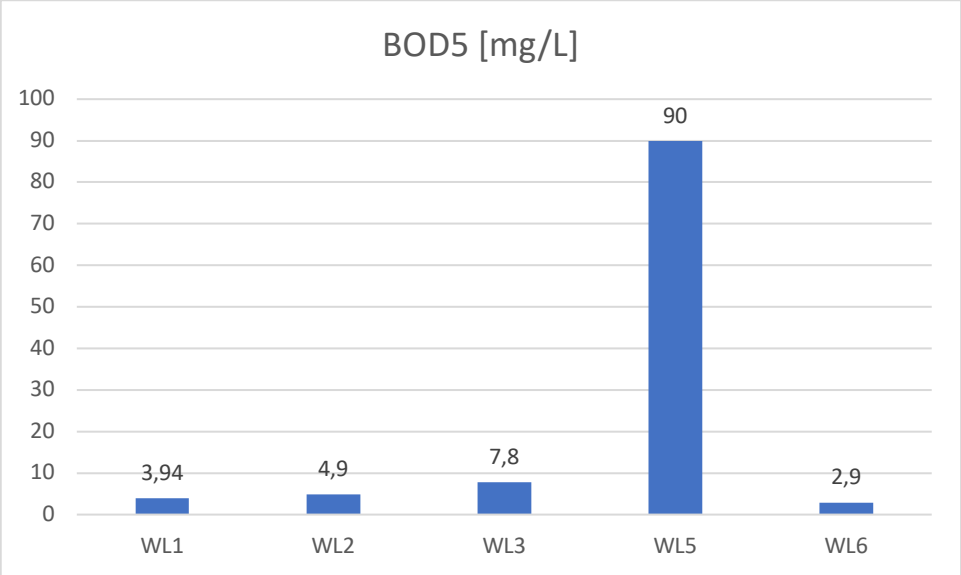


Figure 4.6: BOD after 5 days in mg/L

## 4.7 COD

Most of the COD values are higher than the BOD values. This is always the case but at location 5 it is not true. The value of the COD for all locations is too high. A higher COD value means that the water is more polluted. For location 5 and 6 this is caused by the cars on the road and the cafes. And at location 2 it is caused by the water park and the agriculture fields. For healthy water the COD level is up to 10 mg/L and the COD of the West Lake is between 36 and 48 mg/L. So the water is polluted in the whole lake. Higher COD levels will reduce the dissolved oxygen levels. And this is harmful for the organism in the water. This is why the water is not good for the organisms in the water.

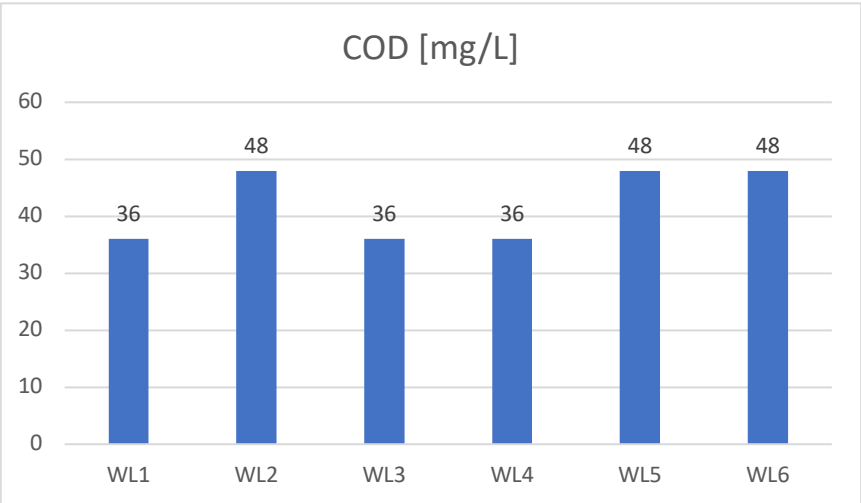


Figure 4.7: COD in mg/L

## 4.8 COD/BOD ratio

In table 4.8 you can see the COD/BOD ratio. This is the ratio for the biodegradability of the wastewater.

| **Location** | **BOD/COD ratio** |
|---|---|
| WL1 | 9.23 |
| WL2 | 9.79 |
| WL3 | 4.62 |
| WL5 | 0.53 |
| WL6 | 16.6 |

Table 4.8: The COD/BOD ratio.

The ratio for reasonably healthy water is between 1.3 and 3.5, for the West Lake there are no locations between this range and has therefore polluted water. This is what I already thought after the COD and BOD values, but this ratio gives a more reliable result.

## 4.9. Seasonal variability

In the previous paragraphs are the results of this research analyzed. Other students have also done some water quality tests in the West Lake; this chapter will analyze the differences of the values. These previous results were taken in September and October 2019. This is done by another group of students as part of their masters. Their results can be seen in appendix C.
In the figures in appendix C are the results shown of the wet season, the wet season in Hanoi is from May to October. And the dry season is from November to April. This paragraph covers the notable features of the figures. Therefore, my results are for the dry season.

The points where they did their measurement are slightly different than mine. But some of the points are almost on the same place. In the table the different points are located. For the description of the locations I will still use my own map and points.

| Previous results | Results |
|---|---|
| Point 1 | Point 2 |
| Point 2 | Point 4 |
| Point 3 | Point 5 |
| Point 4 | Point 1 |
| Point 5 | Point 3 |
| Point 7 | Point 6 |

Table 4.9: Different location point

In figure C.1 is shown the temperature of the wet season. There is almost 4 ºC temperature difference in the West Lake, looking at the different locations in the figure. The difference of the air temperature and the water temperature had a maximum of 2 ºC. At most of the locations the air temperature is higher than the water temperature but there is one exception, this is at location 2. Here the water temperature is 3.2 ºC higher, this can be caused by the agriculture wastewater. The mean of the water temperature is 30.36 ºC and the mean of the air temperature is 30.14 ºC. The water temperature was in the wet season period between 29ºC and almost 33ºC. But the results from now, the dry season, had a water temperature 19 ºC and 28 ºC. Their pH was higher than the pH now. The pH of the West Lake in wet season is all

above 7. The pH is between 8.17 and 9.17, this is a basicity lake. The pH of the locations 4 and 5 are too high and this is not good for the water quality. This can be different because the pH is not a stable measurement. This can depend on the higher water temperature as well. When you take a sample again you can easily find another pH value. The value also changes with the biological processes, the temperature difference between the two measurement is a lot so this can affect the biological processes. There was also more rain in September and October than in February and March. Rain has a pH around 6.

The electric conductivity of the wet season is shown in figure C.2. The electric conductivity of location 3 is also the highest, it is around 680 muS/cm. The water temperature at location 3 was also high, so this can influence the conductivity. The mean of the electric conductivity is 382 muS/cm. But all the locations are in the limit range. The electric conductivity is for most points almost the same in February as in September. Only point 3, there is a high electric conductivity in September but in February there is not. This is possible because the temperature difference between the different times is 10 ºC, and electric conductivity is related to the temperature. Also, location 3 has agriculture fields, when there is more rain more water will flow in the West Lake. In September there was more rain because of the wet season. The other points had a fewer temperature difference. Only point 6 had also around 10 ºC difference, but the electric conductivity data of February is missing from this location. All the other electric conductivities of the wet season are lower than the electric conductivities of the dry season. This is because in the wet season there is more rain, and this had a really low conductivity. Therefore, the conductivity in the wet season will be more influenced and will be lower.

The turbidity of location 5 is the highest. This can be caused by the restaurants in the water at this location. The turbidity can be found in figure C.3. The mean of the turbidity is 65.85 NTU. There is a difference of 75.16 NTU with location 5 and the mean of the locations. The turbidity in September is much higher than the turbidity in February. In September there was more phosphate in the water. Phosphate feeds the algae; more phosphate means more algae. And this is one of the elements what cause the turbidity.

In figure C.4 is shown that the phosphate is the highest parameter. The phosphate of the locations is between 0.5 and 9 mg/L. This is too much and not good for the water quality. There is only a little bit of total iron in the lake. The amount of total iron in the lake is between 0.15 and 0.39 mg/L. The limit of the total iron is 0.30 mg/L, location 3 is over this limit. There is also lower than 1 mg/L of nitrate and nitrite in the lake. All the nitrate and nitrite in the lake is in the range of good quality water. The amount of nitrate, nitrite and total iron are for the two different seasons almost the same. The highest dissolve oxygen is at location 6, this is around 8.8 mg/L. But this is to high. The lowest dissolved oxygen is at location 6, of their map, and has a value of 1.2 mg/L, this is too low. The other locations have also a too low amount of dissolved oxygen. The Dissolved Oxygen in September is lower than in February. It is assumed that the DO levels in the lake drop significantly with the depth due to the low rate of mixing in the lake. (Keunen, et al., 2019) The samples of the two months are not taken at the exact same depth. This is why there can be various results. The Dissolved Oxygen is also related to the water temperature. Cold water holds more Dissolved Oxygen than warmer water. In February the water was colder than in September, this can have influence as well. (USGS, 2010)

# 5. Conclusion

In this chapter are the conclusions of the research described.

First, I have chosen 6 different locations on the edge of the West Lake. All the locations have another area with different functions. I did the measurement on circa 25 centimeters depth in the water. This is the part of the West Lake water were rain and sun have the most effect. I measured a lot of different parameters to look at the water quality of the West Lake. I measured the temperature of the water, the electric conductivity, the turbidity, the dissolved oxygen, the pH, the BOD, the COD, Nitrate, Nitrite and total iron.

If we look at the water quality of the entire lake, the pH, the electric conductivity and the nitrate value are in the range of healthy water. But the really high phosphate, the high amount of total iron, the stressful level of nitrite and at some locations the low amount of dissolved oxygen makes it not a good water quality. For some organisms this is not an environment to live in and this is why fish die in the lake after a couple of years. This is also shown in the amount of BOD and COD the values are too high.

The water of the West Lake is influenced by human activities. Location 1 had some human influences. The part of the abandoned neighborhood and the rowing boats there have influenced the water quality only a little bit and the stairs were people wash their stuff and dogs have influence as well. Nevertheless, almost all the parameters are in a good range for healthy water. But the COD and the phosphate are too high and have a bad influence on the amount of oxygen in the water. Also, the turbidity is not really good, and I could see that on the fieldtrips as well. The second location had a lot of human influences. There is a waterpark nearby and agriculture fields. This had influenced the amount of dissolved oxygen, phosphate, BOD and COD. These parameters were not in the healthy water range for this part of the lake. There were also a couple of dead fish in the water at this location, this is because of the bad water quality. The water temperature was also high at location 2. The turbidity wasn't good either, there were a lot of garbage and furniture in the water there. Location 3 used to have many human influences but now most of the ships there are abandoned but the ships are outdated and in the water there. The agriculture fields influence the water there as well and there is a water treatment place nearby. The amount of total iron and the turbidity is really bad at this location. The phosphate was also too high. Location 4 has a road nearby and another part of the West Lake on the other side of the road, but the water can flow under the road. The area there is mostly used for housing and hotels. The nitrite is at a stressful level there. The phosphate and BOD were not in a good range for healthy water. But the pH, dissolved oxygen, the electric conductivity, the nitrate, the total iron and the turbidity were okay for quite clean water. This makes location 4 the less influenced location. For the fifth location the area is used for some restaurants in the water and shops in the area but mostly for housing. This have influenced the water. The number of phosphates is at this location the highest, the BOD and COD values were also the highest, and the nitrite is on a stressful level. But the pH, the electric conductivity, turbidity, nitrate and total iron were on a good level. The area of location 6 is used for a couple of tourist spots and cafés. Hotels are there as well. In this area you can see one of the hospitals. Nearby this location is the in- and outflow sluice with the To Lich River. This influences the water quality when it is open. The pH is the highest here. The turbidity, phosphate and COD are bad for the water quality and the amount of dissolved oxygen is okay but stressful for organisms in the water there.

Therefore, the functions of the area of the six locations have influenced the water quality of the West Lake. So, the water quality of the West Lake is influenced by humans.

There are also some differences in the parameters for the wet season and the dry season. The wet season in Hanoi is from May to October. And the dry season is from November to April. The water temperature in the wet season was higher than in the dry season. Therefore, the pH of the wet season was also higher than the dry season pH. The pH value changes with the biologically processes and the temperature can influence this. The electric conductivity is for the wet and dry season almost the same but in the wet season the electric conductivity was lower than in the dry season. The conductivity for the wet season is more influenced by the rain which has a really low conductivity. The turbidity of the wet season was much higher than in the dry season. This can also be influenced by the wind. And during the wet season more phosphate was in the water, phosphate feeds the algae, and this is what also caused the turbidity in the water. The dissolved oxygen was lower in the wet season, but this can depend on the depth and daytime or nighttime the measurements are taken. Also, the algae take a lot of oxygen in the water. And the water temperature was higher, and this influences it as well.

# 6. Discussion

This chapter will describe some things that could have influenced the results.

First, we had to leave Hanoi earlier than planned because of the COVID19 virus. Therefore, I did take all the samples of place 1 to 6 three times. But I wanted to do the measurements 5 times to have more accurate data. Also, I wanted to do 8 different places but the places in the middle of the lake I couldn't do anymore.

Second, the HACH strips have a measurement error between 10% and 25%. This in fluence the results. And the HACH Phosphate strips were expired, a couple of them did still work but it can affect the results in a bad way. We tried to order the HACH strips, but the strips would not be on time in Hanoi.

The next point is that all the measurement tools have a measurement error. For most of the tools the error is small, but it influenced the results a little bit. For the DO-meter from Greissinger the error is 1.5%. On the last fieldtrip the DO-meter gave some errors during the measurement, this is why we did not use the DO values of that trip. And I think that the accurate of the results are less than the default error. For the pH-meter from Greissinger the error is 0.03 digits. The pH of the HACH strips has a higher error and this is why I used the results of pH-meter from Greissinger instead of the pH results of the strips. The EC-meter from HACH the error is 0.01 digits. And for the HACH Turbidity meter the error is between 2% and 5%. The BODtrackII meter from HACH has a 95% confidence limit. And the HACH COD meter has a 95% confidence interval as well. The BOD value of the fifth location is not reliable because the COD is lower than the BOD value and this is not possible. The BOD value is so high comparing with the other locations and the COD looks more reliable, this is why I think the BOD value is wrong.

The last part that could have influenced the results is the depth we took the samples. We tried to do all the measurements on the depth of 25 centimeters from the surface into the water. But we did not measure the exact depth of all the taken samples so this could have been more of less than the 25 centimeters.

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# Appendix A: The devices and parameter values

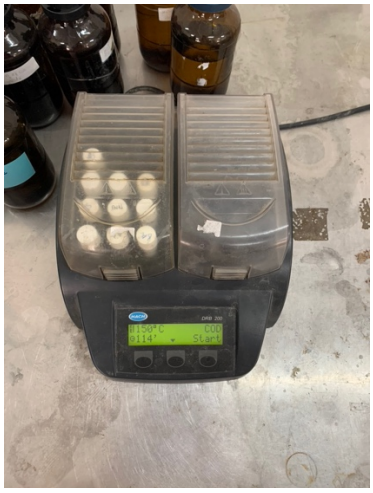

(a): The pH-meter


(b): The DO-meter


(c): The electric conductivity meter

(d): The turbidity meter

(e): The HACH strips


(f): The COD meter


(g): The BOD meter

Figure A.1: The equipment

| **Parameters** | **Limits healthy water** |
|---|---|
| pH | 6.7 - 8.6 |
| DO | 6.5 - 8 mg/L |
| Conductivity | 100 - 800 µs/cm |
| BOD | • 1 - 2 mg/L is really good<br>• 3 – 5 mg/L is quite clean<br>• 6 and 9 mg/L is polluted water |
| COD | 10 mg/L |
| Nitrite and nitrate | • Nitrite above 0.75 mg/L can be stressful for fish<br>• The limit of nitrite is 1 mg/L<br>• The nitrate limit is 10 mg/L |
| Total iron | 0.15 - 0.30 mg/L |
| Phosphate | • 0.01 – 0.03 mg/L when the level in uncontaminated lakes |

| | |
|---|---|
| | • 0.025 – 0.1 mg/L when the level at which plan growth is stimulated<br>• 0.1 mg/L when the maximum acceptable to avoid accelerated eutrophication<br>• > 0.1 mg/L when accelerated growth and consequent problems |

Table A.2: The limits of healthy water

# Appendix B: Results

| **Parameters** | **Limits for healthy water** | **Maximum and minimum measured** |
|---|---|---|
| pH | 6.7 - 8.6 | Lowest: 7.03<br>Highest: 8.07 |
| DO | 6.5 - 8 mg/L | Lowest: 2.1 mg/L<br>Highest: 7,45 mg/L |
| Conductivity | 100 - 800 µs/cm | Lowest: 381,67 µs/cm<br>Highest: 429 µs/cm |
| BOD | • 1 - 2 mg/L is really good<br>• 3 – 5 mg/L is quite clean<br>• 6 and 9 mg/L is polluted water | Lowest: 2.9 mg/L<br>Highest: 90 mg/L |
| COD | 10 mg/L | Lowest: 36 mg/L<br>Highest: 48 mg/L |
| Nitrite and nitrate | • Nitrite above 0.75 mg/L can be stressful for fish<br>• The limit of nitrite is 1 mg/L<br>• The nitrate limit is 10 mg/L | Nitrite<br>Lowest: 0.05 mg/L<br>Highest: 0.095 mg/L<br><br>Nitrate<br>Lowest: 1 mg/L<br>Highest: 1.53 mg/L |
| Total iron | 0.15 - 0.30 mg/L | Lowest: 0.145 mg/L<br>Highest: 0.44 mg/L |
| Phosphate | • 0.01 – 0.03 mg/L when the level in uncontaminated lakes<br>• 0.025 – 0.1 mg/L when the level at which plan growth is stimulated<br>• 0.1 mg/L when the maximum acceptable to avoid accelerated eutrophication<br>• > 0.1 mg/L when accelerated growth and consequent problems | Lowest: 1 mg/L<br>Highest: 6 mg/L |

Table B.1: Parameter values in table

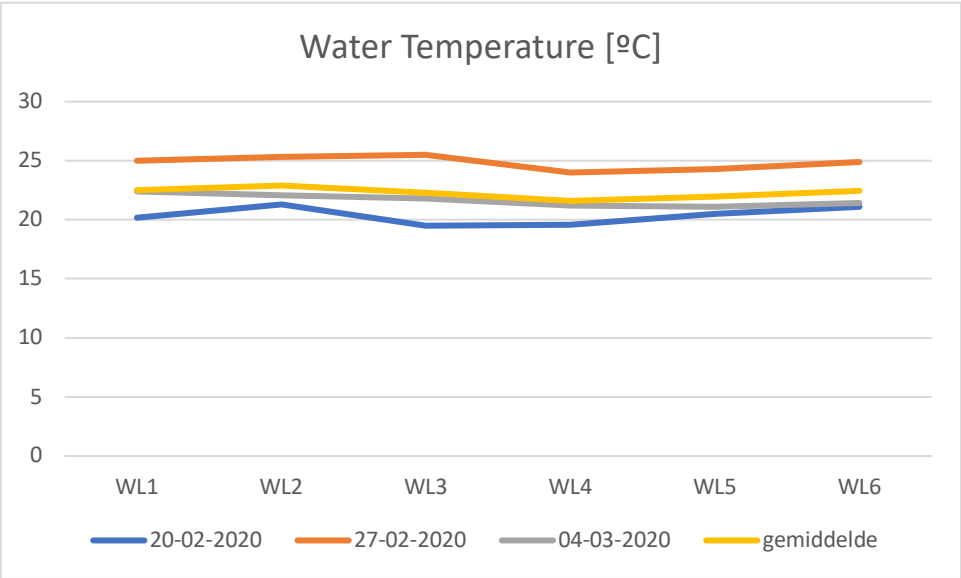


Figure B.2: Water temperature on the different dates

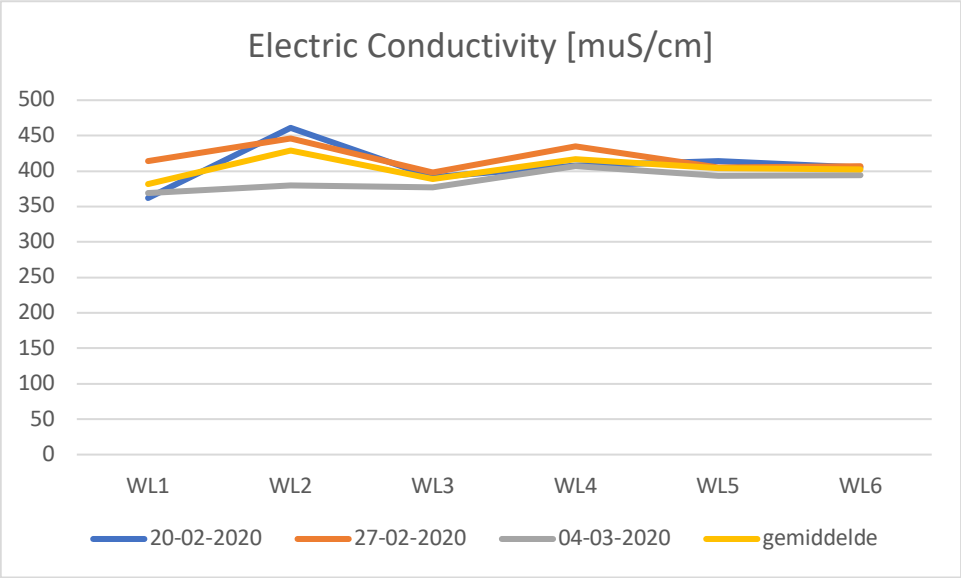


Figure B.3: Conductivity on the different dates

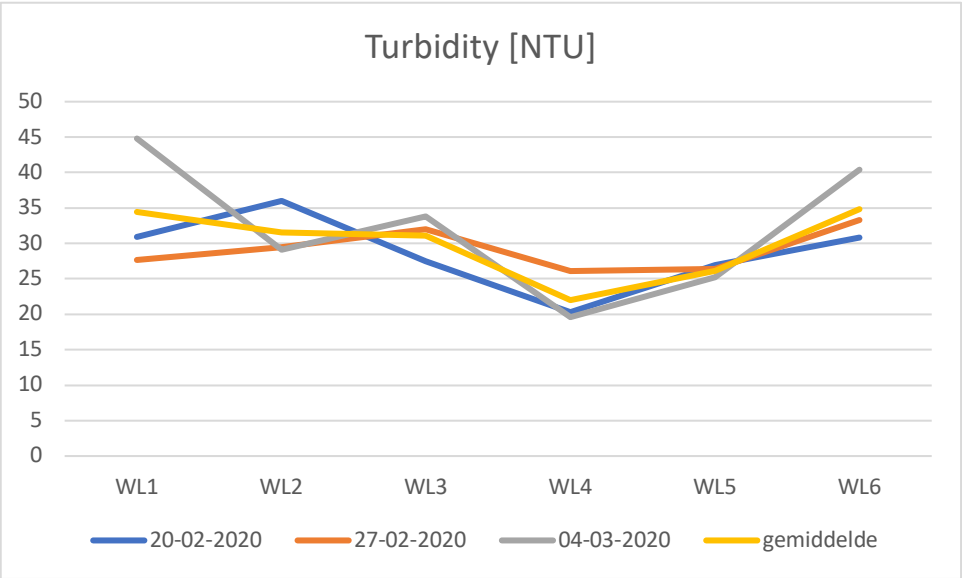


Figure B.4: Turbidity on the different dates

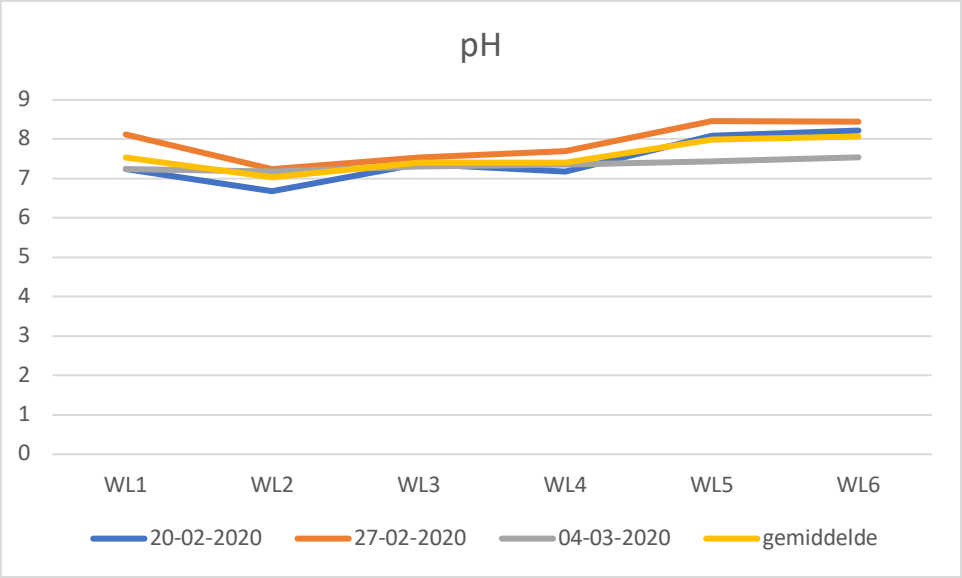


Figure B.5: pH on the different dates

# Appendix C: Wet season results

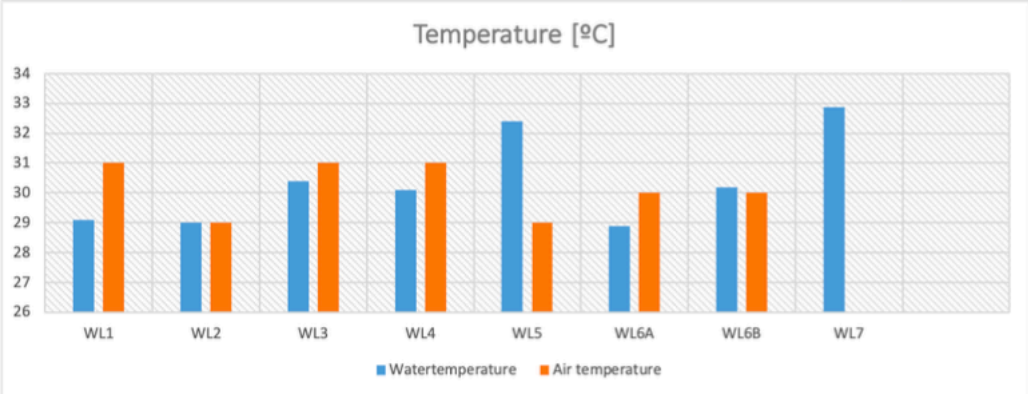



Figure C.1: Temperature (Keunen, et al., 2019)

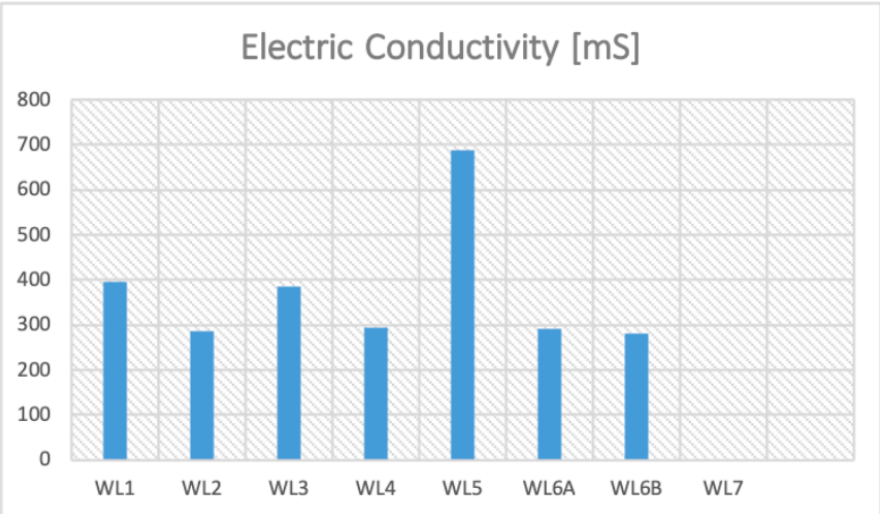



Figure C.2: Electric conductivity [muS/cm] (Keunen, et al., 2019)

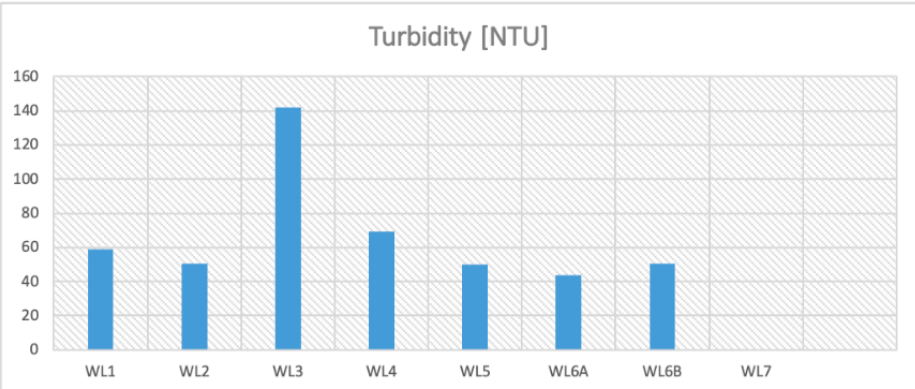



Figure C.3: Turbidity (Keunen, et al., 2019)

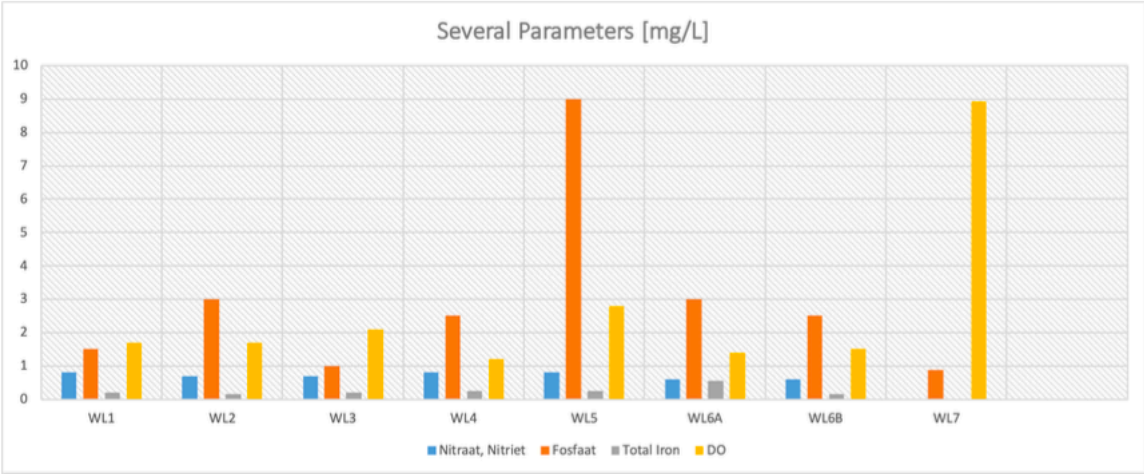



Figure C.4: Phosphate, Nitrite/Nitrate, Total iron, Dissolved oxygen (Keunen, et al., 2019)

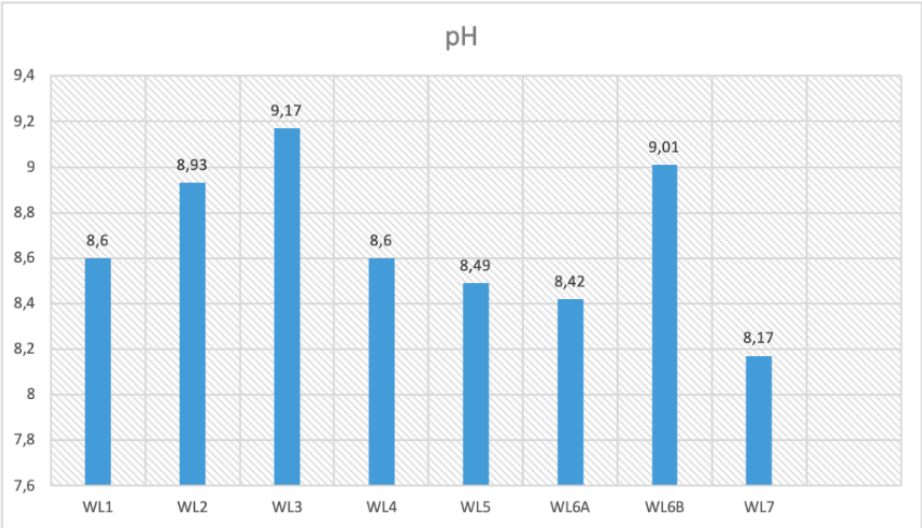



Figure C.5: pH (Keunen, et al., 2019)

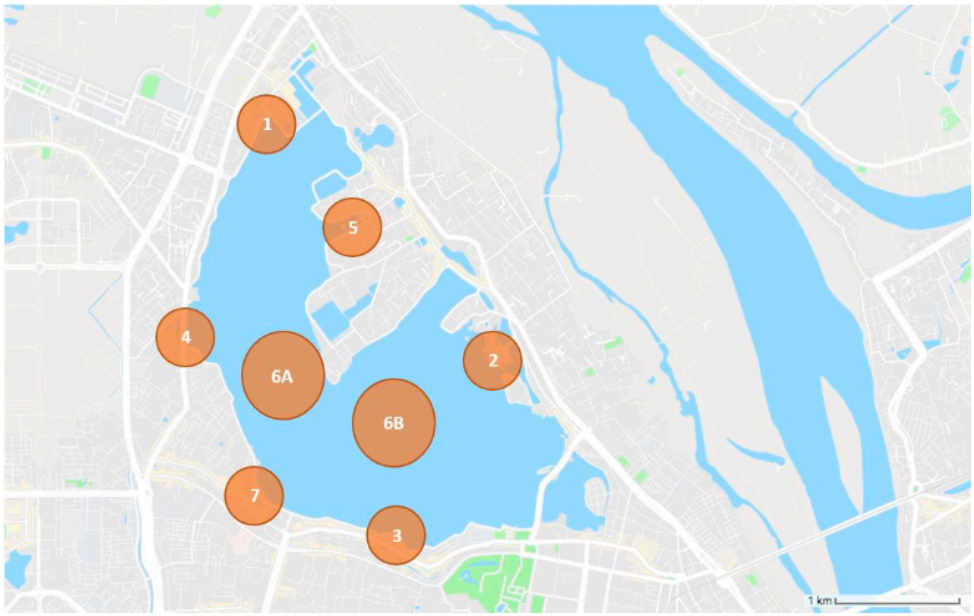



Figure C.6: The locations at the West Lake (Keunen, et al., 2019)