# "Water eutrophication: not just a problem in Catalonia but a global one. Studying this process and searching for solutions."


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## Abstract

Water eutrophication is not just a local problem: lakes, rivers and oceans of all around the world are suffering, as a consequence of human activity, a constant supply of phosphor and nitrogen from fertilizers and detergents. We want to stress this remarkable problem on our planet, not only to our ecosystems, but to humans as well. Reducing eutrophication should be a key priority when considering future water policy. Preventive and corrective measures must be studied and considered. In this context, our project is aimed at studing the eutrophication process; its causes, consequences and possible solutions. We hypothesize that the growth of bog plants captures phosphor and nitrogen from the water. Therefore, our investigation will be focused on crafting and monitoring four different eutrophic ponds and studying the purification effect of bog plants (four different species) growing in them.

## Keywords

Eutrophication, bog plants, fertilizers (phosphor and nitrogen).

# 1. Background information

### Origin of eutrophication

This basically begins when water receives a discharge of nutrients, such as agricultural and forestry wastes, favoring excessive growth of organic matter this, causing an accelerated growth of algae[1] and other green plants that cover the water surface and prevents sunlight, from reaching the lower layers[2].

Natural eutrophication: natural eutrophication is a process that occurs slowly in all lakes and reservoirs in the world, all because they receive nutrients from animals and plants and the process of erosion-sedimentation. [1]

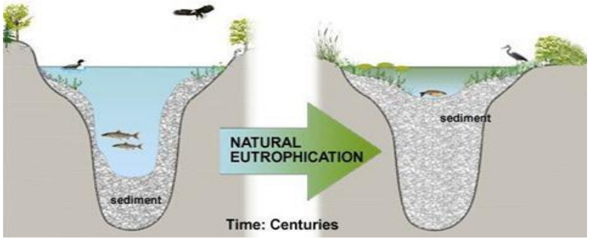


Figure 1: Natural eutrophication process.

Eutrophication is caused by human activity: From urban waste, organic waste and detergent to dumping to livestock farming, which provides fertilizer, organic waste and other waste rich in phosphates and nitrates.


Figure 2: Cultural eutrofication process.

### Consequences

As a result, water becomes cloudy, and decreases the amount of light; there fore the vegetation dies due to being unable to perform photosynthesis[3].

This generates other microorganisms, such as bacteria that feed on dead matter, consuming the oxygen needed by fish and shellfish, while generating toxic algae and pathogenic microorganisms that could cause disease.

*1. The term algae is applied to all single-celled plants living in fresh and marine waters and they were provided with pigments of assimilation.*
*2. Lower stratum.*
*3. The production of organic materials from carbon dioxide and water, using sunlight as energy with the aid of chlorophyll.*

## 2. Introduction

Figure 3: Example of eutrophication in a lake.

Eutrophication (Greek: *eutrophia*—healthy, adequate nutrition, development) or more precisely hypertrophication[4][2], is the ecosystem response to the addition of artificial or natural substances, mainly phosphates, through detergents, fertilizers, or sewage[5], to an aquatic system, which may cause death to aquatic animals.

Generally, most of the companies that work with chemical products dischange these products near rivers. When these rivers empty into lakes, the chemical products (normally rich in nitrogen and phosphorus) accumulate, and when it's full of them, the seaweed starts growing quickly and they fuse all the oxygen in the water, which makes animal life impossible there.

So it is a problem that appears in the water (lakes, rivers, oceans…), produced by the accumulation of nitrogen and phosphorus, thus making water less liveable and choked with aquatic plants and seaweed.

### Percent Saturation (%)

The unit % is a relative measurement in which the dissolved oxygen concentration is expressed as a the percentage of the maximum amount of oxygen that water can hold.

$$\%\, saturation = \left( \frac{actual\ DO\ reading\ in\ \mathrm{mg/L}}{saturated\ DO\ reading\ in\ \mathrm{mg/L}} \right) \times 100 \qquad (1)$$

At standard atmospheric pressure and 25ºC, 100% saturation indicates 8.34 mg/L of oxygen is dissolved in the water. If the concentration were 4.18mg/L for the same sample of water, the water has half the amount of oxygen that it could potentially hold at that temperature, thus the water is only 50% saturated.

The data collector monitor and the DO% sensor took periodic and continuous measurements, and we used those in our study.

*How the vernier optical DO Probe Works.*

The Vernier Optical DO Probe operates on the principle of reversible luminescence quenching of a luminophore[6] by oxygen as it passes through the cap. The cap is coated with a luminescent compound encased in a matrix for protection. Blue light from an LED is transmitted to the cap and excites the luminophore.

A collision of an oxygen molecule with the luminophore in its electronic excited state results in energy transfer from the luminophore to oxygen. As the luminophore relaxes it emits red light. The time from when the blue light is transmitted and the red light is emitted is measured by a photodiode[7]. The more oxygen that is present, the shorter the time it takes for the red light to be emitted.

This time it is measured and correlated to the oxygen concentration. Between the flashes of blue light, a red LED is flashed onto the sensor and used as an internal reference to help validate each measurement. This process is described by the Stern-Volmer equation

$$\tau_0 / \tau = 1 + K_{SV}[DO] \qquad (2)$$

*4. Hipertrophy: excessive growth or accumulation of any kind.*
*5. The waste matter that passes through sewers.*
*6. An atom or functional group in a chemical coound that is responsible for its luminescent properties.*
*7. A semiconductor device that converts light into current.*

Where $\tau_0$ and $\tau$ are the luminescence lifetimes in the absence and presence of oxygen, respectively, DO is the dissolved oxygen concentration, and $K_{SV}$ is the Stern-Volmer quenching constant.

The Stern-Volmer constant ($K_{SV}$) depends directly upon the rate constant for the diffusion of oxygen, the solubility of oxygen, and the natural lifetime of the electronic excited state of the luminophore. Lifetime measurements have an advantage over intensity measurements since they are not usually affected by processes which result in loss of the complex, such as bleaching or photodegradation[8].

*Background Information about Dissolved Oxygen (DO).*

Dissolved oxygen is a vital substance in a healthy body of water. Various aquatic organisms require different levels of dissolved oxygen to survive. Whereas trout require higher levels of dissolved oxygen, fish species like carp and catfish survive in streams with low oxygen concentrations. Water with a high level of dissolved oxygen is generally considered to be a healthy environment that can support many different types of aquatic life. [3]

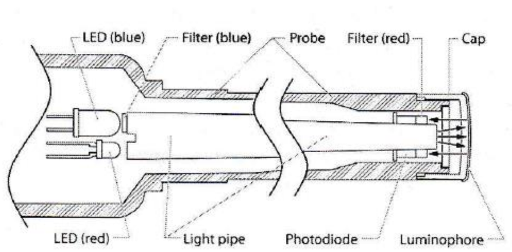


Figure 4: Interior schematic of the Optical DO Probe.

There are many factors that can affect the level of dissolved oxygen in a body of water. Turbulence from waves on a lake or from a fast-moving stream can greatly increase the amount of water exposed to the atmosphere, resulting in higher levels of dissolved oxygen. Water temperature is another factor that can affect dissolved oxygen levels; like other gases, the satured level of dissolved oxygen is less in warm water than in cold water, shown in this figure.

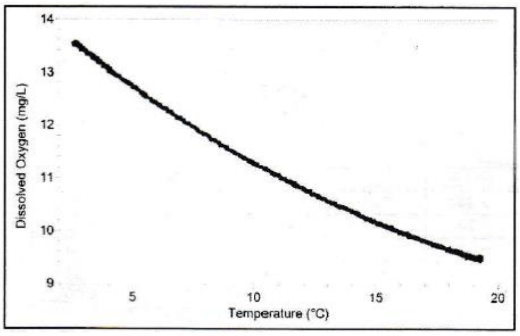


Figure 5: Saturated dissolved oxygen vs. temperature at 760 mmHg.

Photosynthesis cycles also have a large effect on disolved oxygen levels of an aquatic environment. Aquatic plants and photosynthetic microorganisms will cause oxygen gas to be produces during daylight hours from photosynthesis:

$$CO_2 + H_2O \rightarrow C_xH_yO_z + O_2 \qquad (3)$$

Table 1: DO level related to % saturated of DO

| DO level | Percent saturation of DO |
|---|---|
| Supersaturation | >101% |
| Excellent | 90-100% |
| Adequate | 80-89% |
| Acceptable | 60-79% |
| Poor | <60% |

## 3. Content

### 3.1. The purpose of the investigation

**RESEARCH HYPOTHESIS**

When bog plants grow, they may use phosphorus and nitrogen from water as part of their growth, in addition to nutrients. These end up in a water elimination of these nutrients. If that happens, would the eutrophication levels in the water decrease?

*8. Photodegradable: (of substance) capable of being broken down by light.*

Apart from this, we hypothesize that some different species of bog plants have different levels of eutrophic water cleaning properties.

We take this idea from the "Parc de l'Agulla" in Manresa (Barcelona, Spain), where there is a lake with a variety of bog plants used to clean the water using the same system we used in our ponds.

Figure 6: Parc de l'Agulla, Manresa (Barcelona, Spain).

**RESEARCH QUESTION**

Do different species of bog plants decrease the level of eutrophication in the same way?

We studied species of bog plants during a three-month period (January to March).

## 3.2. Our plants

Bog plants have a biochemical and physiological capacity to absorb, retain and degrade pollutants, which is why they are able to clean eutrophicated water.

The systems of aquatic plants consist of two classes based on dominant plant types; the first type uses floating plates, and the second uses submerged plants.

These plants have two functions:

**Phytoextraction**: absorption of metal contaminants using plant roots and their accumulation in shoots and leaves.

**Fitodegradation**: degradation of contaminants through enzymes produced by the plants.

The bog plants we studied were:

- Typha latifolia
- Iris pseudacorus
- Acorus calamus
- Phragmites Communis

**Typha latifolia**

Figure 7: Typha latifolia.

Typha latifolia (bulrush, common bulrush,) is a perennial herbaceous[9] plant in the genus Typha. It is found as a native plant species in North and South America, Europe, Eurasia, and Africa. In Canada, broadleaf cattail occurs in all provinces and also in the Yukon and Northwest Territories, in the United States, Latifolia is an "obligate wetland" specie, meaning that it is always found in or near water. This specie generally grows in flooded areas where the water depth does not exceed 2.6 feet (0.8 meters). The plant is 1.5 to 3 metres (5 to 10 feet) high and it has 2–4 cm (¾ to 1½ inch) broad leaves, and it generally grows out in 0.75 to 1 metre (2 to 3 feet) of water depth. [4]

**Iris pseudacorus**

Figure 8: Iris pseudacorus.

*Iris pseudacorus* (yellow flag, yellow iris, water flag, and lever) is a species in the genus *Iris*, of the family Iridaceae. It is native to Europe, western Asia and northwest Africa.

*9. Of, pertaining to, or characteristic of an herb: herblike. (Of plants or plant parts)*
*· Not woody.*
*· Having the texture, color, etc., of an ordinary foliage leaf.*

Its specific epithet, meaning "false acorus," refers to the similarity of its leaves to those of *Acorus calamus*, as they have a prominently veined mid-rib and sword-like shape.

It is an herbaceous flowering perennial plant, growing to 100–150 centimetres tall, with erect leaves up to 90 centimetres long and 3 centimetres broad. The flowers are bright yellow, 7–10 centimetres across, with the typical iris form. The fruit is a dry capsule 4–7 centimetres long, containing numerous pale brown seeds. Iris pseudacorus grows best in very wet conditions, and is often common in wetlands. The plant spreads quickly, by both rhizome and water-dispersed seed. It fills a similar niche to that of Typha and often grows with it, though usually in shallower water. While it is primarily an aquatic plant, the rhizomes can survive prolonged dry conditions.

It is widely planted in temperate regions as an ornamental plant, with several cultivars selected for bog garden planting.

This plant has been used as a form of water treatment since it has the ability to take up heavy metals through its roots. [5]

**Acorus calamus**

Figure 9: Acorus calamus.

*Acorus calamus the calamus*, it is one of six species of the monotypic genus Acorus family of acoráceas. It is commonly known as "aromatic calamus" (Calamus), "Water quill" or "true ácoro" appears widespread in the northern Hemisphere's temperate zone, being native to Southeast Asia.

This plant lives in wet lowland areas close to lakes, ponds and rivers.

It is an herbaceous perennial small plant that can reach up 75 cm long and 1 m with stem and leaves. Fibrous stems elastic branches present a dark green color and leaves are located in the basal rhizome. They are hairless and have a size of 0.5-2 cm length. [6]

**Phragmites Communis**

Figure 10: Phragmites comunis.

Phragmites, the common reed, is a large perennial grass found in wetlands throughout temperate and tropical regions of the world.

Phragmites is sometimes regarded as the sole species of the genus Phragmites, though some botanists divide Phragmites australis into three or four species. In particular the South Asian Khagra reed – Phragmites karka – is often treated as different specie.

It can be found in Spanish provinces like Alicante, Barcelona, Gerona, Balearic Islands, Tarragona, and Valencia. Its flowering time is in June, July, August, September, October, November and December. [7]

## 3.3. Materials and method of the investigation

**Materials**

In order to build our artificial ponds, we use the following materials:

- Four artificial ponds of 170 l each.
- Fertilizer[10] (sources of Phosporus and Nitrogen)
- String
- Mesh
- Soil
- 4 different types of bog plants (one type per student)

*Construction of the ponds: see in annex 4.2*

In the development of our research, we built artificial ponds (each one of them will be supervised by one of the four members of the team) and we submitted them to an artificial eutrophication process with the purpose to use different species of bog plants to clean them.

The parameter to be measured was:

- D.O. % (dissolved oxygen): percentatge of dissolved oxygen in water.

We monitored these parameters looking at the eutrophication level of the water to determine if there was a recovery process and if it was related to any specific species of bog plant.

The objective was to find the most efficient bog plant species in cleaning eutrophic water.

## Methods

Our eutrophic water was obtained from Llac Petit, Terrassa (Barcelona, Spain) where took 40 liters of water and we deposited it in our control pond.

Figure 11: Llac Petit Terrassa, Barcelona, Spain.

Figure 12: Collecting eutrophicated water from Llac Petit Terrassa, Barcelona, Spain.

At the same time, we took 40 l of clean water and we deposited it in another tank, for the chlorine to evaporate. After 48 hours we put the water from the tank into the pond. Finally, we added fertilitzer to the water. The next day we added 12 liters of this water in each pond and we repeated this operation till the ponds were full of eutrophic water.

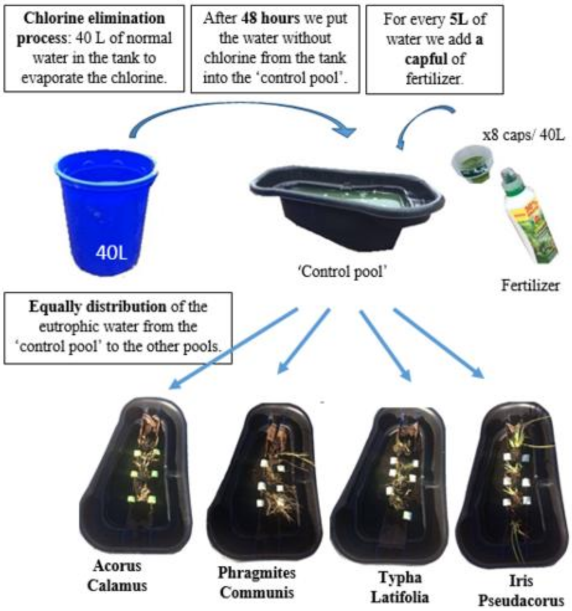


Figure 13: Methodology used on our ponds.

*10. The fertilizer we used during the experiment was Compo, "fertilizante plantas verdes", with K and Fe.*

Figure14: Distributing eutrophicated water to our ponds.

Figure 15: Preparing the ponds for our bog plants.

After the first week we started adding 10 liters of water into each pond instead of the previous 12, because we wanted to keep a reserve quantity of lake water in the the control pond.

Seven weeks after we prepared the ponds with the filters we made, we then replanted our bog plants, but this time in our ponds which then had eutrophicated water.

Figure 16: Making the nets for the ponds.

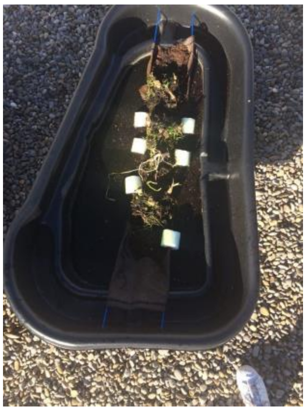

Figure 17: Typha Latifolia.

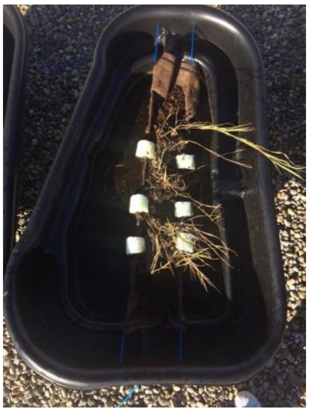

Figure 18: Phragmites comunis.

Figure 19: Acorus calamus.

Figure 20: Iris pseudacorus.

Figure 21: Planting the plants.

To measure the degree of DO we used the labquest Data-monitor collector with the DO% sensor. To set it up, first we plugged the sensor into the labquest and we left it for 10 minutes to warm up. Meanwhile, we took a sample of our eutrophic water from each pond. Afterwards, after 10 minutes, we introduced the DO sensor into the different samples of water. At first the % of DO increased and after a minute it stabilized. We then noted down the DO% in our tables, and we repeated this process with the four ponds. After a short period of time the % of DO started to descend because the sensor has burnt off all the oxygen.

Figure 22: Collecting data about the level of Oxigen dissolved in the water.

# 4. Results

For three months we measured the DO% of our ponds once a week. We have looked at the DO% tendency in a way to better compare the results that we see in the tables and we compared them to the reference line of 100% DO.

The idea was to find out which bog plant could stabilize DO% as close as possible to 100% DO.

The results are:

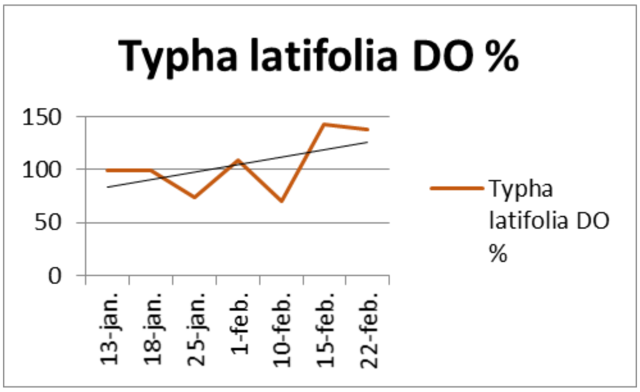


Figure 23: Typha latifolia pond DO% and tendency.

$$y=7.16x + 75.8$$

In this plant we observed that the tendency of the level of DO varied widely around 100%. Tendency starts at 83% and ends at 126%, a difference of 43 points of the DO.

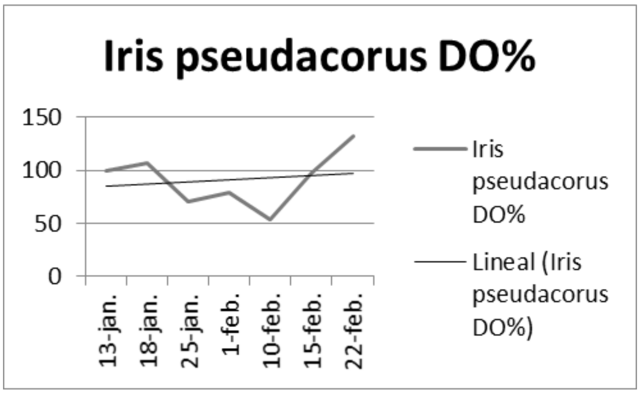


Figure 24: Iris pseaudacorus pond DO% and tendency.

y= 2.12x + 82.7

In this case we can observe a significant difference compared with the previous plant. The average level of DO% varies closely around 100%.

Tendency starts at 84% and ends at 98%, a difference of 14 points in the DO.

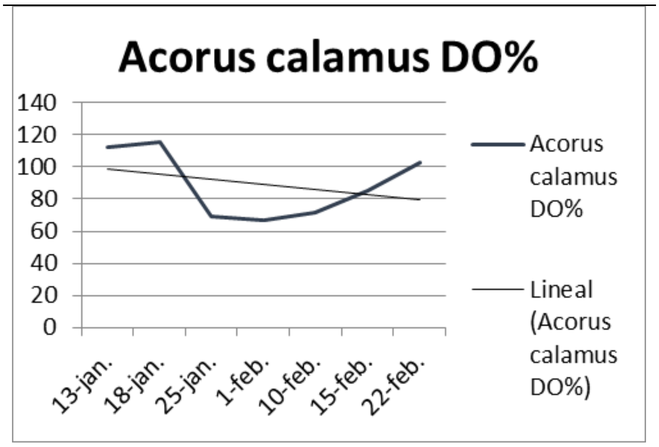


Figure 25: Acorus calamus pond DO% and tendency.

y=-3'1143x + 101,54

In this plant we can observe that tendency of the DO varies widely around 100%. Tendency starts at 98% and ends at 80%, a difference of 18 points of the DO.

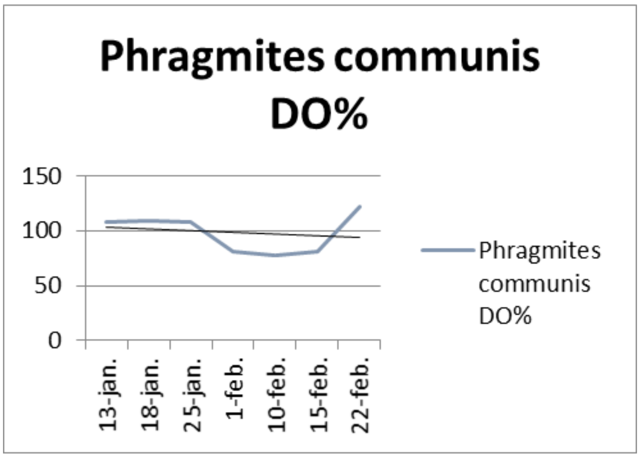


Figure 26: Phragmites comunis pond DO% and tendency.

y=-1.5679x +104.34

In this case we can observe a similarity with I. pseudoacorus because the tendency of the level of DO% does not vary far from 100%.

Tendency starts at 103% and ends at 93%, a difference of 10 points of the DO.

The plants that have oscillated widely around 100 are Typha Latifolia in first place and Acorus Calamus in the second. One hypothesis would be that these plants were the ones with the worst health at the end of the experiment, and that was the reason why there was a low efficiency in cleaning the water.

The Iris Pseudoacorus especially and Phragmites communis have oscillated closely around 100. These plants as opposed to the others, presented better health at the end of the study.

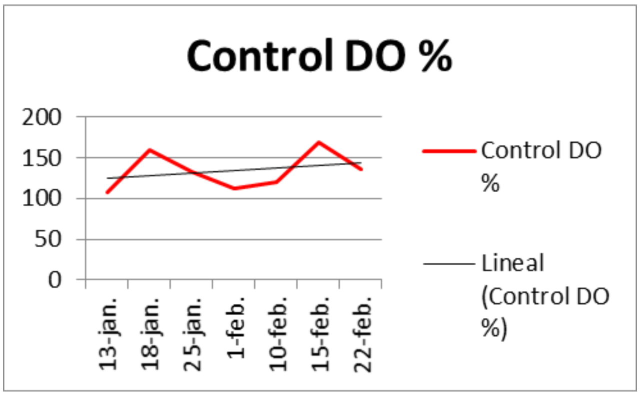


Figure 27: Control pond tendency.

y=3.1107x + 121.11

In our Control pond (the one with no plants) we can observe that the tendency of the level of DO% fluctuates widely around 130%( not like in ponds with plants that oscilates around 100%).

Tendency starts at 124% and ends at 142%, a difference of 18 points of the DO.

We can see that all the ponds start close to 100% of DO, which is considered excellent levels of oxygen, caused by a normal quantity of photosynthesis that algae develop inside the water. After one week all the ponds, except the Control one, decreases its level of DO under 100%, but the Control pond increases its level of the DO to 160%.

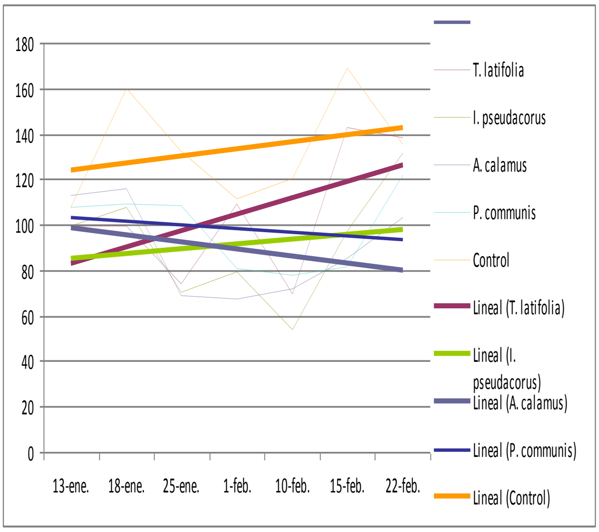

Figure 28: Comparison tendency of all ponds

In this graphic, we compare the average values of the four ponds and the Control pond. We observe that P. communis and I. pseudacorus show a decreasing line, which means that the DO value had been going down to the acceptable percentage of DO. On the other hand, I. pseudocorus, T. latifolia and Control show an increasing line, which means that the value of DO had been going up to a state supersaturation (high level of algae growth).

There is a significant difference among the values of the ponds with plants and the Control pond, which contained no bog plants.

Threfore this indicates that the bog plants have intervened in the water in some way, however insignificant their contribution may have been.

The best results we obtained were from the pond with Phragmites communis, as this was the bog plant that responded best to the eutrophicated water (the one that was best estimulated, absorbing all the N and P in the water), and it was the one that grew stronger and bigger.

## 5. Conclusion

Some differences had been observed between a pond without bog plants (control) and the rest of ponds.

We found a relationship between the good health of the plant and the good DO% tendency; the plants which were healthier during the experiment were Iris Pseudacorus and Phragmites communis.

On the other hand, the plants with the worst DO% tendency were A. Calamus and T. Latifolia. Our hypothesis is that these bad results were caused by the poor health of the plants during the experiment. These two plants have mantained their bulbs during the three months of the experiment.

Ranking the liberating capacity of DO in water:

1. P. Communis
2. I. Pseudacorus
3. A. Calamus
4. T. Latifolia

We think that the health of the plant has been critical for the stabilisation of DO% at 100%, due to the fact that the healthier plants reached best oxygen concentration among all of them.

Further investigations:

- We need to take into account that January to March is not the best time period in the year for doing this experiment because some bog plants are still bulbs at this time. This means that they have not been quite active so they are not able to clean the water as well as they could in spring or summer.
- For a future investigation, it is better to use Spanish bog plants instead of European bog plants to make sure they are adapted to our climate.

The aim of this project is to highlight the role, the importance, and the vulnerability of lakes, rivers, oceans.

Often these have not been taken into consideration by governments and farmers when they spill their waste (fertilizers, dirty water…) into the rivers, lakes and, oceans provoking the eutrophication in them.

Our purpose is to make people aware of this problem, unknown at times, which can become a serious disadvantage for natural living creatures.

We also want to find a natural solution to solve this issue, and hopefully find a solution for the situation found in “Llac Petit” (Terrassa, Spain).

We all need to be aware of the importance of using our natural resources in the right way and water is an essential element to all mankind.

As a conclusion, we would like to say that by keeping our water systems in good health we will have enough water for every use in the region and this policy will represent a huge economic advantage, especially in tough times like the ones we are going through at the moment.

The main objective of our project is to make people aware that water eutrophication is a global problem, not just in lakes, but also in seas and oceans.

In our investigation we used plants from different latitudes and some did not adapt properly to our environment; this is why we believe that in the face of upcoming research we should use plants that we can find in our climate.

What our project wanted was to find a plant that managed to reduce the level of eutrophication of lakes, focusing specifically on the lake of our city, Llac Petit.

After our research, working with four different types of bog plants, we have seen that although some have not met our goal, others have had a good efficiency.

We hope that our research will not be in vain and it can be applied at a large scale.

## Acknowledgments

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[1] http://rmbel.info/lake-eutrophication/

[2] toxics.usgs.gov/definitions/eutrophication.html

[3] http://www2.vernier.com/manuals/labquest2_user_manual.pdf

[4] www.wildflower.org/plants/result.php?id_plant

[5] https://plants.ifas.ufl.edu/plant.../iris-pseudacorus

[6] www.sigmaaldrich.com

[7] http://herbarivirtual.uib.es/cas-ub/especie/4622.html

[8] www.chlamycollection.org/info.html

http://toxics.usgs.gov/definitions/eutrophication.html

http://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466

http://www.scienceclarified.com/El-Ex/Eutrophication.html

https://www.google.com/intl/es_es/drive/

## Links of interest

Departament d'Ecologia a Catalunya

http://www.ecologia.cat/eco/index.php?option=com_content&view=article&id=105&Itemid=127

Agencia catalana de l'aigua:

http://acaweb.gencat.cat/aca/appmanager/aca/aca?_nfpb=true&_pageLabel=P1228354461208201642682

http://www.greenfacts.org/es/glosario/def/eutrofizacion.htm

http://triplenlace.com/2012/09/27/eutrofizacion-causas-y-efectos/

http://water.usgs.gov/ogw/

# APPENDIXES

## APPENDIX I

### The microorganisms of the water

Once a week, during two months (from January to February) we took samples of water from Phragmites communis's pond, and samples of the Control's pond, we put a drop on each slide and observed through a microscope with various degrees of magnification, from 4x to 10x and 40x. We could observe the evolution of the organisms that lived in the water in both ponds, and we found that in both of them were living the same microorganisms, the *Chlamydomonas.* [8]

Figure 29: Watching the microorganisms that lived in our plants.

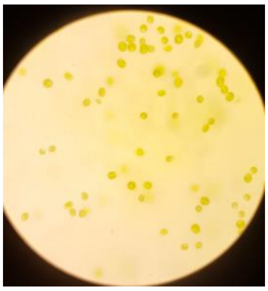

Figure 30: The view of the microorganisms observed from 10x.

Figure 31: The view of the microorganisms from 40x.

Watching them and comparing these photos to other photos that we found on the internet, we discovered that the name of these microorganisms is *Chlamydomonas*, a kind of algae called *Volvocales*, which come from the *Chlorophyceae* type.

We also observed that in the pond that contained the bog plant *Phragmites comunis*, had a bigger concentration of these microorganisms than in Control's pond.

<u>Chlorophyceae</u>

They are the authentic green algae (they are green because they contain chlorophyll), and also the most common in terms of species, forms and adaptations. They range from microscopic flagellated unicellular to highly developed species with a very complex organization.

<u>Volvocales</u>

The Volvocales are unicellular organisms (isolated or colonial), provided naked or cellulosic wall, flagellates and usually autotrophs. They are predominant freshwater planktonic (never saltwater) in all regions of the planet.

<u>Chlamydomonas</u>

Chlamydomonas is a genus of flagellate unicellular green algae. Chlamydomonas is used as a model organism molecular in biology, especially in studies of flagellar mobility, dynamics of chloroplast biogenesis and genetics. One of the most striking features of Chlamydomonas is the existence of directly activated by light, such comocanalrodopsina ion channels. It has a unique chloroplast (organelle responsible for photosynthesis). They can be found in stagnant water and on damp soil, in freshwater, seawater, and even in snow as "snow algae".

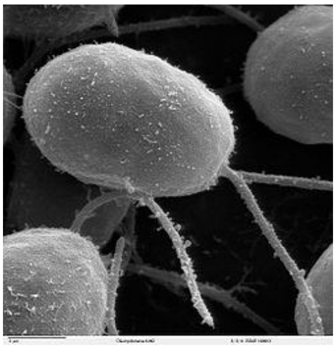

Figure 32: A picture of Chlamydomonas watched in 10000x.

# APPENDIX II

## Construction of the ponds

For the construction of the pools, we took an empty pool, in which we made two holes in two opposite sides in order to be able to thread the strings.

Figure 27: Passing off the strings through the ponds.

Then we attached the net to the rope with staples for a better grip.

Figure 33: Stapling the mesh.

After tying the net, we put a few pieces of a pool float so that the net would not sink and will support the weight of plants.

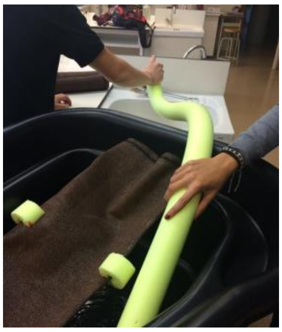

Figure 34: Cutting the pool float.

We tried if this system worked by putting bottles full of water above the net, and we could see that this system was reliable.

Figure 35: Testing the weight that the mesh could support.