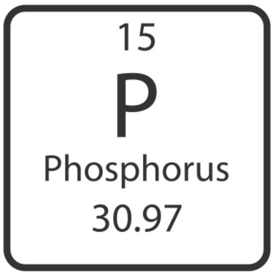
Pharmers



ABSTRACT

Our innovative project addresses the critical issue of agricultural wastewater treatment by focusing on phosphorus extraction and recycling. Through advanced detection techniques combined with the ATTRACT technologies, we capture phosphorus from wastewater and transform it into valuable fertilizer for local farmers. This circular approach not only mitigates water pollution but also fosters economic benefits, creating a sustainable agricultural ecosystem. By monitoring and analyzing data throughout the process, we enhance our ability to predict and manage phosphorus pollution effectively. This initiative not only champions environmental health but also bolsters the agricultural productivity of the region.

A circular Phosphorus solution

From residue to resource

Table of Contents

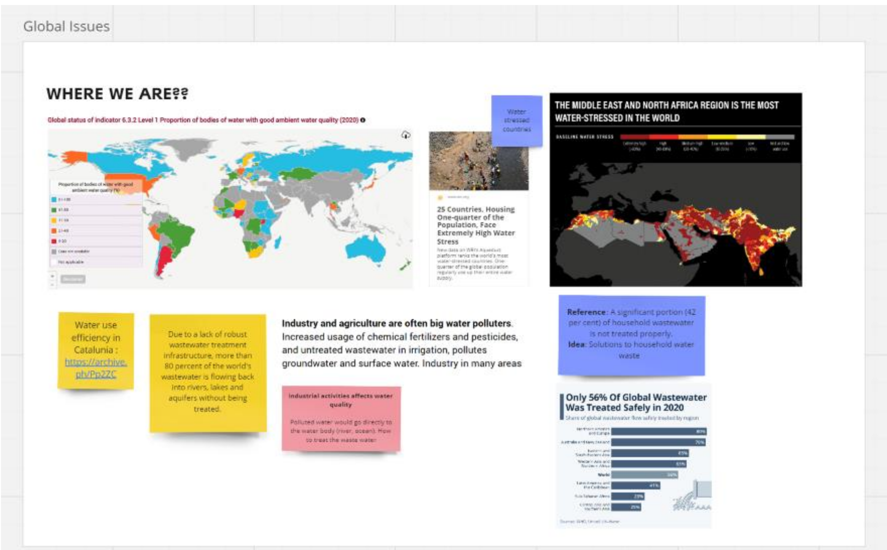
INTRODUCTION

The chosen SDG is Target 6.3: Improve water quality, wastewater treatment and safe reuse. By 2030 improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

The problem at hand

Water is essential for life, yet millions of people around the world lack access to clean and safe water. The rapid industrialization, urbanization, and population growth have led to severe water pollution issues. Untreated wastewater from households, industries, and agricultural runoff is contaminating freshwater resources, making them unsafe for human consumption and harmful to ecosystems. The release of hazardous chemicals and materials into water bodies has further exacerbated the problem, posing significant health risks to humans and wildlife. The situation is dire, as many developing countries lack adequate infrastructure for wastewater treatment, resulting in a high proportion of untreated wastewater being discharged directly into the environment. This not only threatens public health but also hinders sustainable development and environmental conservation.

Global context



Water pollution is a global issue affecting both developed and developing nations. According to the United Nations, over 80% of the world's wastewater is released into the environment without adequate treatment. This alarming statistic highlights the urgent need for improved wastewater management systems worldwide. In low-income countries, this figure can be as high as 95%, indicating a severe lack of infrastructure and resources to address the issue.

The consequences of untreated wastewater are far-reaching. Contaminated water sources lead to waterborne diseases such as cholera, dysentery, and typhoid, which disproportionately affect vulnerable populations, including children and the elderly. Additionally, polluted water bodies impact agriculture by contaminating crops and soil, reducing food security and economic stability in many regions.

Efforts to improve water quality and wastewater treatment are integral to achieving Sustainable Development Goal (SDG) 6.3. This target aims to halve the proportion of untreated wastewater and significantly increase recycling and safe reuse of water by 2030. Achieving this goal requires a coordinated global effort to invest in infrastructure, implement effective policies and regulations, and promote innovative technologies for wastewater treatment and water recycling.

International cooperation and support are crucial in helping developing countries build and maintain the necessary infrastructure for wastewater management. This includes financial aid, technical assistance, and knowledge transfer from countries with advanced wastewater treatment systems. Furthermore, raising public awareness about the importance of water conservation and pollution prevention can drive community-level actions and behaviors that contribute to achieving SDG 6.3.

Addressing water pollution and improving wastewater treatment is not only a matter of public health but also a critical component of sustainable development. By ensuring access to clean and safe water, we can protect ecosystems, promote economic growth, and enhance the quality of life for people worldwide.

1. RESEARCH

1.1 Preliminary Study

A thorough desk research was conducted to analyze the current problems related to the chosen SDG.

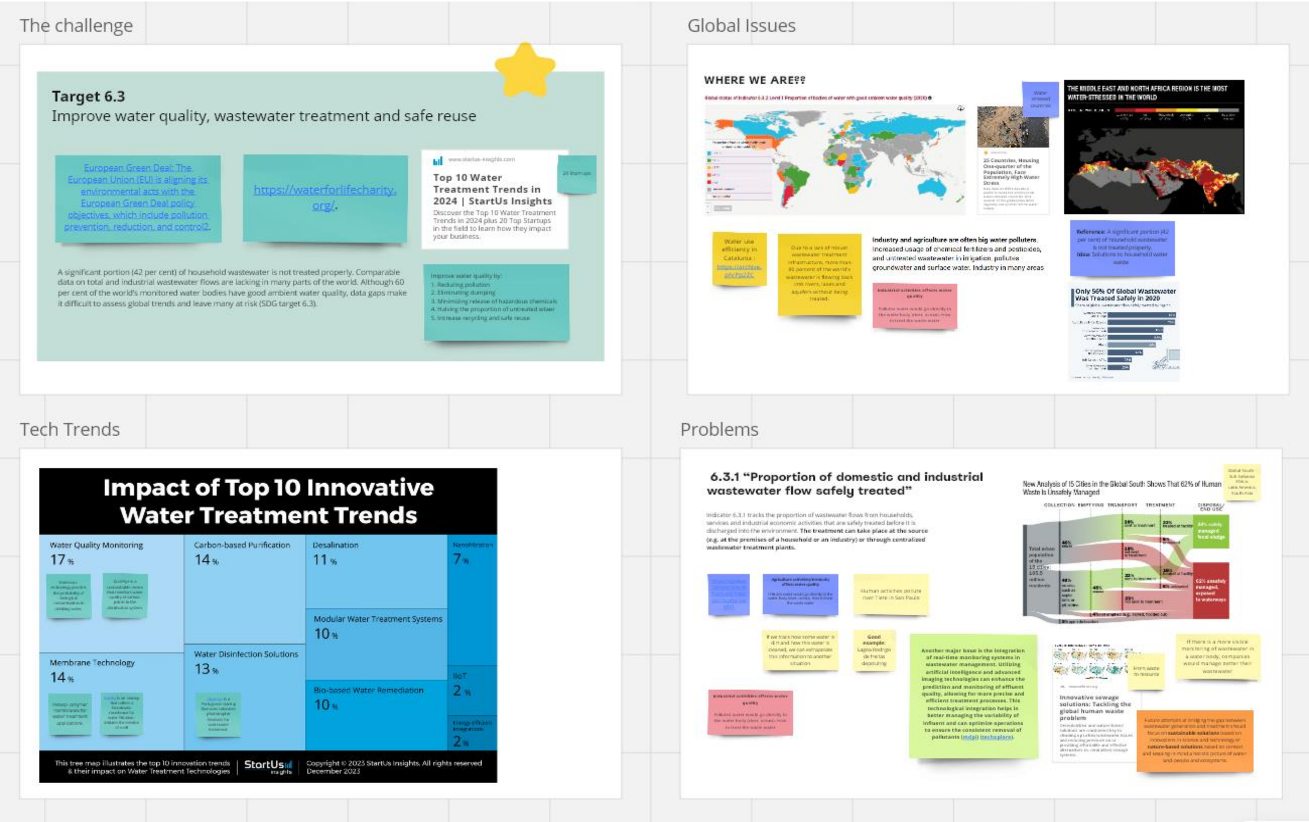


Image 1: Desktop Research-Group Miro

Technologies available in the current market and future trends were analyzed to get a clear understanding of existing solutions

1.2 Narrowing the scope

- Agricultural wastewater pollution

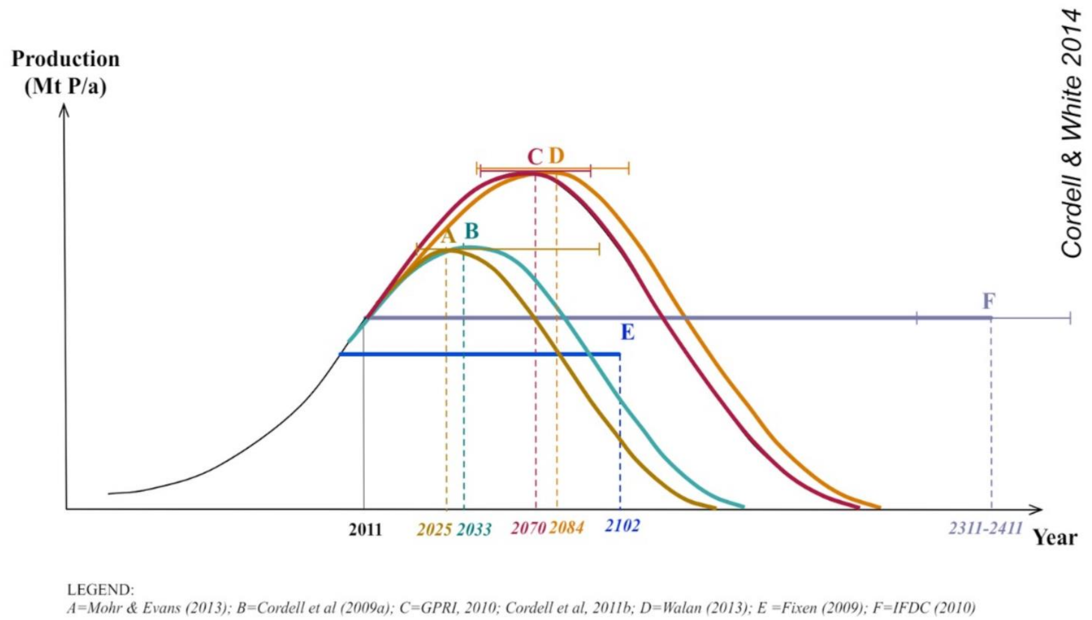
Agricultural wastewater pollution is the No.1 source of water contamination, arising from the runoff of fertilizers, pesticides, and other chemicals used in farming. This type of pollution has widespread environmental and health impacts. It leads to the degradation of water quality in rivers, lakes, and groundwater, affecting ecosystems and human communities that rely on these water sources for drinking, irrigation, and other uses. The excessive use of chemical inputs in agriculture results in nutrient-rich runoff, which contributes significantly to the pollution of water bodies.

- Eutrophication

Eutrophication is a critical environmental issue caused by the enrichment of water bodies with nutrients, particularly phosphorus and nitrogen. This nutrient overload stimulates the excessive growth of algae and aquatic plants, leading to harmful algal blooms. These blooms can severely deplete oxygen levels in the water, creating dead zones where aquatic life cannot survive. The resulting ecological imbalance disrupts aquatic ecosystems, affects fisheries, and diminishes water quality for recreational and potable uses. Agricultural runoff is a major contributor to eutrophication, underlining the importance of managing nutrient inputs in farming practices.

- Phosphorus Scarcity

Phosphorus is an essential nutrient for plant growth and a vital component of agricultural fertilizers. However, phosphorus is a non-renewable resource, and its reserves are being depleted at an alarming rate. The scarcity of phosphorus poses a significant challenge to the sustainability of agricultural production. Over-reliance on phosphorus fertilizers not only leads to environmental problems like eutrophication but also threatens future agricultural productivity. Recycling phosphorus from wastewater offers a dual benefit: it reduces environmental pollution and addresses the issue of phosphorus scarcity. By recovering and reusing phosphorus, we can move towards a more sustainable and circular agricultural system.



1.3 Problem statement - How might we

After narrowing the scope by identifying the common problems related to agricultural wastewater and phosphorus pollution in water bodies, we narrowed down our problem statement into a closer reality: Municipalities and rural areas in Spain.

Problem Statement:

"Municipalities need to reduce wastewater pollution from Spanish farms in order to protect the environment and ensure the wellbeing of its citizens"

Agricultural wastewater pollution poses a threat to the environment and jeopardizes the wellbeing of citizens. The challenge lies in finding an effective solution to mitigate pollution while safeguarding water quality, public health and incentivizing farmers to contribute to reducing this wastewater pollution.

How Might We:

"How might we clean wastewater while extracting valuable resources from it?"

- Our goal was to develop a circular system for wastewater treatment that not only removes pollutants but also recovers a valuable resource, such as phosphorus.
- By doing so, we can create a sustainable approach to water management, benefiting both the municipalities wastewater management, the environment and farmers communities.

1.4 Interviews

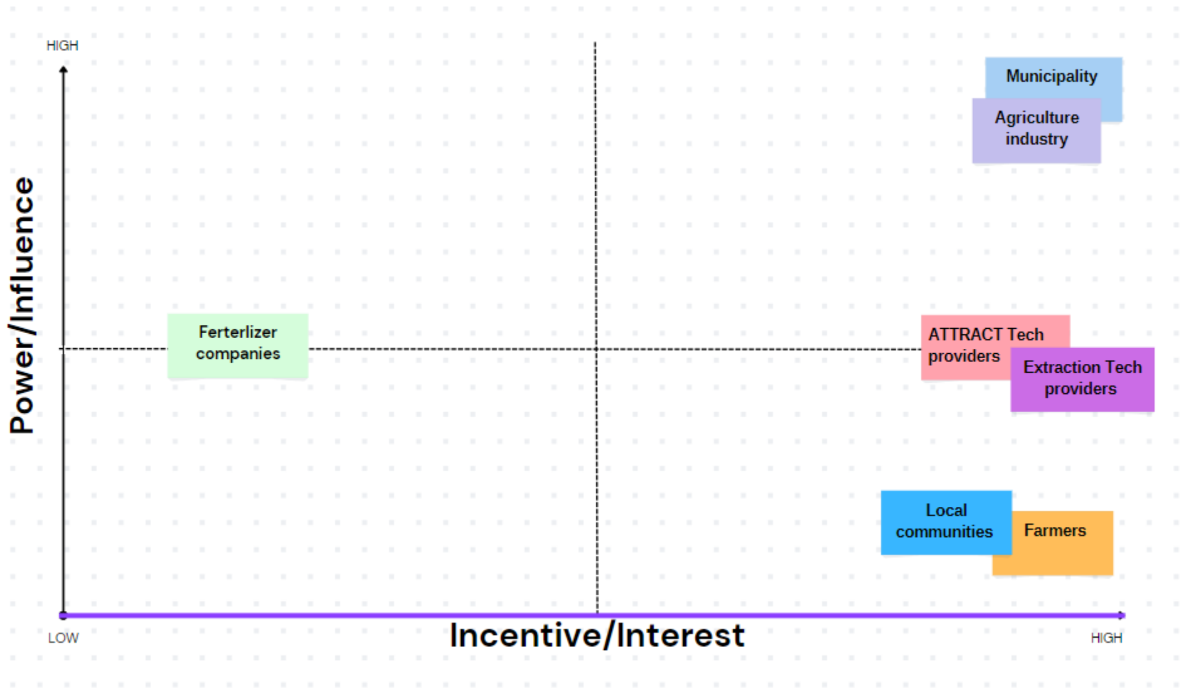
As we were trying to formulate our solution to the problems highlighted above, we wanted to talk to the stakeholders that would be directly impacted by our project. It was necessary to validate the existing problems and understand exactly the practical applications of the technology and feasibility of the solution. The identified stakeholders were:

- Farmers
- Local Municipality - Water treatment plant
- Technology experts

We proceeded to create a moderation guide for the interviews based on a framework outlining

- Key objectives
- Understanding current scenario
- Pain points
- Goals and expectations

for the different stakeholders.



All the interviews were carried out with a previous objective in mind, and their content can be seen briefly below. The entire interview can be consulted in the appendix

1.4.1 Municipality Interview - Interview with Eric Monné Mesalles

Interviewee information

- ***Position:*** *Vocal de la Comissió Informativa de Medi Ambient, Territori i Sostenibilitat de l'Ajuntament de Torres de Segre.*
- ***Contact information:*** emonne97@gmail.com
- ***More information:*** https://www.segria.cat

Objectives

- *To understand the journey of agricultural wastewater through the public infrastructure*
- *Understanding the challenges related to wastewater treatment*
- *Awareness of polluting the ecosystem*
- *Would the municipality infrastructure benefit from our solution*

Previous context

Torres de Segre is a municipality in the comarca of Segrià, in the province of Lleida, Spain and has a population of 2285 inhabitants.

Interview summary

Torres de Segre is supplied with water from the Seròs canal. There is a direct connection between the canal and the water used in the municipality, both for domestic and agricultural purposes. The water is treated in municipal little plan.

Image 2: Municipal Torres de Segre plant

- The domestic water is treated with a plant provided by the municipality council from the water coming from the canal.
- The irrigation water is the water from the canal itself that is used without being cleaned.

Irrigation water comes from the canal but does not return directly to it. It is absorbed by the soil and, through filtration, returns to the canal.

The permission and the irrigation quotas of the farmers is not governed by the municipality but by the irrigation community, which is also a public entity.

- The fields collect untreated water, apply phytosanitary products inject fertilizers, and then they water the fields.

The Municipality just controls the drinking water. The farmer has the pipes connected to the watering system. There are also farm regulations to measure which products they use and in which quantity.

The interviewee provided the following suggestions

- Sometimes, in summer, the use of tap water has been restricted due to the high concentration of chemicals in the canal and the lack of capacity to use the urban treatment plant to treat such highly polluted water.

- He thinks that it should be a super nice tool to try to detect when the water is starting to get polluted, because sometimes, they cut the water once it is super polluted, but it does not mean it was clean before the cut. **Daily detection would help to prevent domestic use of polluted water.**

1.4.2 Technical Interview - Estel Rueda Hernandez

Interviewee information

- ***Position:*** *Ceit Researcher, Environmental Engineer and Ph.D.*
- ***Contact information:*** *estel.rueda@upc.edu*
- ***More information:*** *https://apren.upc.edu*

Objectives

- *To know existing techs*
- *Cost and complexity*
- *How is this being developed-optimized for the future*

Interview summary

Thanks to the interview, we have discovered that there are two main technologies for phosphorus extraction:

- **Struvite Precipitation:**
    - Struvite precipitation is a process where **magnesium**, **ammonia**, and **phosphate (Po4) (phosphorus derivate)** combine in water to form struvite crystals

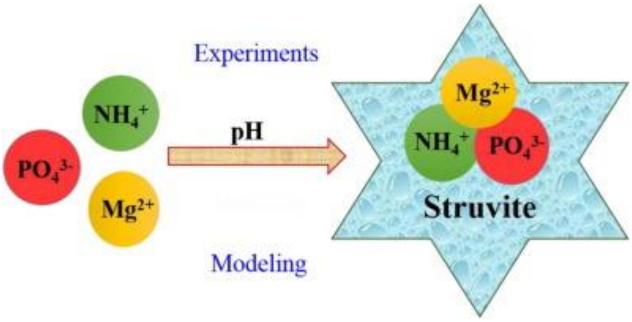


Image 3: Struvite Technology

- To adjust the components of the system (magnesium and ammonia), the **amount of phosphorus must be detected**.
- To detect Phosphorus, we must use **chromatography techniques** and **spectrometers** (no detection using microscope or X-ray)

- **Phosphorus Absorption:**
  - Technique to recover phosphorus agricultural runoff

Image 4: Agricultural Runoff

- Phosphorus is retained inside a material (normally iron or calcium, steel production residues) and then the water is cleaned.
- However, the result is not phosphorus by itself, is the absorbing material:
  - To separate phosphorus to the material, some acids.
  - The absorbing material could be used as a fertilizer (in process). It is being developed and must be checked.
  -
- **Phosphorus in runoffs is less concentrated than in human wastewater (0.5-2mg/l phosphorus in agricultural runoff) but** is not a problem. However, using the absorption technique in human wastewater may be a problem, as we would need a lot of material to absorb all the phosphorus

- As lower concentration, more material is needed (bigger must be the solution).

- Both technologies are not super expensive and are evolving during the years. The technology size is proportional to the water corpus.

- **The main problem in phosphorus extraction, it is legal frame (at least, in Spain because we are stupid)! As the phosphorus is treated as a residue, it is subjected to more restrictions to be applied to the lands and to be commercialized.**

1.5 Context of the project

Torres de Segre, a municipality in the comarca of Segrià, Lleida, Spain, covers an area of approximately 20 square kilometers and has a population of around 15,000 people. The primary water source for this region is the Seròs canal, which is essential for both domestic and agricultural purposes.

Water Supply and Treatment

The water infrastructure in Torres de Segre is divided into two main categories:

- Domestic Water: The municipal plant treats domestic water sourced from the canal through various stages, including sedimentation, carbon filtration, and chlorination, ensuring it is safe for consumption. However, during the summer, high chemical concentrations in the canal water occasionally exceed the plant's capacity, leading to temporary restrictions on tap water use.
- Agricultural Water: For irrigation, untreated water is directly sourced from the canal. This water is used in the fields, where it is absorbed by the soil and eventually returns to the canal through natural filtration.

Image 5: Torres de Segre Canal System

Irrigation and Regulatory Framework

Irrigation practices are managed by the irrigation community, a public entity that oversees water quotas and permissions for farmers. The municipality controls only the regulation of drinking water. Farmers follow strict regulations regarding the types and quantities of phytosanitary products and fertilizers they apply to their fields, which helps control pollution levels in the canal.

Phosphorus Collection

The agricultural runoff in Torres de Segre contains significant levels of phosphorus, which can be collected and repurposed. Using advanced extraction techniques phosphorus can be effectively recovered from the irrigation water. This recovered phosphorus can then be transformed into valuable fertilizer, providing both environmental and economic benefits.

2. IDEATION AND DEVELOPMENT

Our first step towards ideating our solution was to get all the ideas out of our heads by following the crazy 8 exercise.

The project, Pharmers, was conceived to tackle the dual challenges of agricultural waste management and phosphorus pollution in water bodies. Our ideation process involved identifying a critical issue in modern agriculture: the inefficient handling of wastewater rich in phosphorus. This element, while vital for plant growth, contributes to significant water pollution when present in excess. The project aims to create a circular system where phosphorus is not merely discarded but repurposed as a valuable resource.

To develop our concept, we explored several key areas:

Environmental Impact: Recognizing the ecological damage caused by phosphorus runoff, we aimed to create a solution that could significantly reduce water pollution.

Economic Viability: We sought to transform phosphorus extraction into an economically sustainable activity by converting waste into fertilizer, which can be sold back to farmers.

Technological Feasibility: We investigated existing technologies for phosphorus detection and extraction, ensuring that our approach would be both innovative and practical.

Data Utilization: Leveraging data analytics, we planned to monitor and predict phosphorus levels, enhancing the efficiency of our system and providing valuable insights for agricultural management.

Our brainstorming sessions and initial research led us to the idea of a circular economy model, where the waste product from agriculture becomes a resource, thereby closing the loop and fostering sustainability.

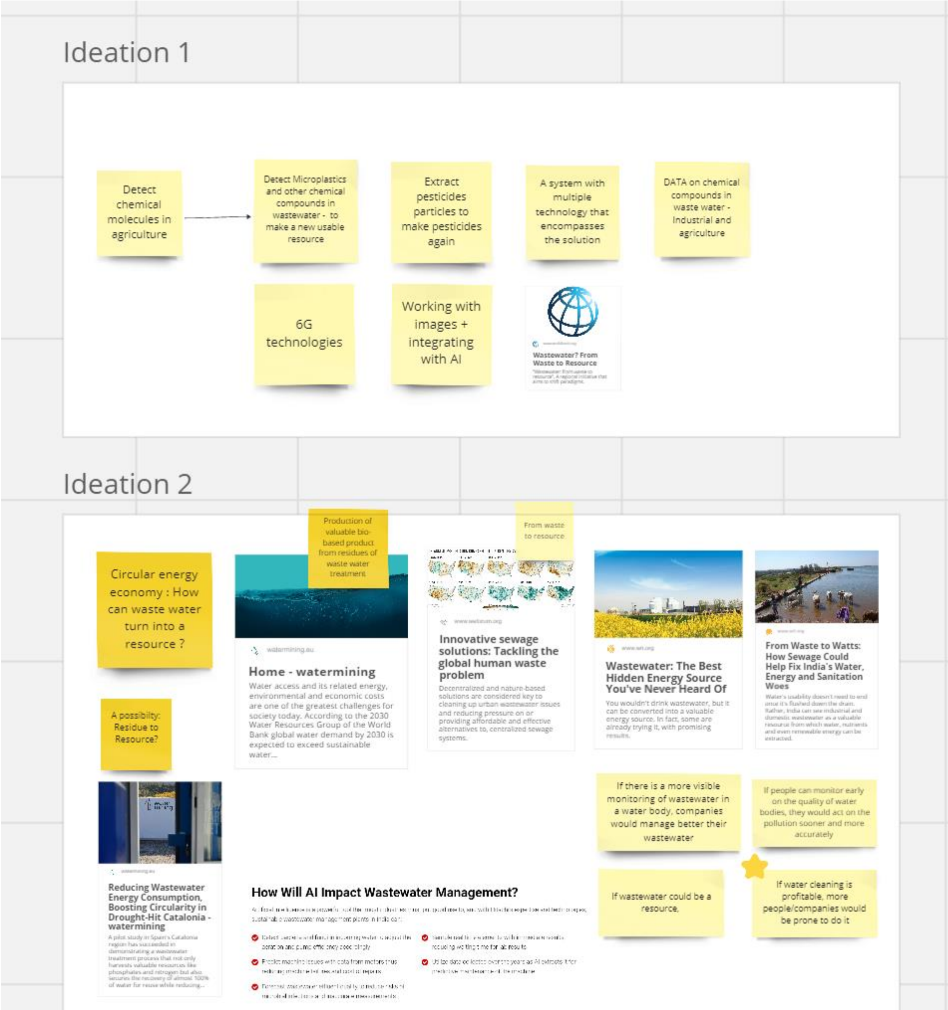

Ideation 1
Detect chemical molecules in agriculture
Detect Microplastics and other chemical compounds in wastewater - to make a new usable resource
Extract pesticides particles to make pesticides again
A system with multiple technology that encompasses the solution
DATA on chemical compounds in waste water - Industrial and agriculture
6G technologies
Working with images + integrating with AI
Wastewater? From Waste to Resource
Ideation 2
Circular energy economy : How can waste water turn into a resource ?
Production of valuable bio-based product from residues of waste water treatment
Home - watermining
Water access and its related energy, environmental and economic costs are one of the greatest challenges for society today. According to the 2030 Water Resources Group of the World Bank global water demand by 2030 is expected to exceed sustainable water...
From waste to resource
Innovative sewage solutions: Tackling the global human waste problem
Decentralized and nature-based solutions are considered key to cleaning up urban wastewater issues and reducing pressure on or providing affordable and effective alternatives to, centralized sewage systems.
Wastewater: The Best Hidden Energy Source You've Never Heard Of
You wouldn't drink wastewater, but it can be converted into a valuable energy source. In fact, some are already trying it, with promising results.
From Waste to Watts: How Sewage Could Help Fix India's Water, Energy and Sanitation Woes
A possibility: Residue to Resource?
Reducing Wastewater Energy Consumption, Boosting Circularity in Drought-Hit Catalonia - watermining
How Will AI Impact Wastewater Management?
If there is a more visible monitoring of wastewater in a water body, companies would manage better their wastewater
If people can monitor early on the quality of water bodies, they would act on the pollution sooner and more accurately
If wastewater could be a resource,
If water cleaning is profitable, more people/companies would be prone to do it

Image 6: Prototype ideas for solution

2.1 Alternatives Discarded

We discarded many options; at the beginning of the project, we had 3 main options:

- Chemicals / Fertilizers and pesticides for reuse.
- Methane for create Graphene.
- Microplastics for recycling.

Chemicals / Fertilizers and pesticides

1 - What are the fertilizers made of ?

The main chemical elements contained in chemical fertilizers are **nitrogen (N)**, **phosphorus (P2O5)** and **potassium (K2O)**.

1-a - Are these components a pollute agent in water?

- **Nitrogen (N): Yes**

Excess nitrogen in the water can cause a rapid increase in the population of toxic algae. It deteriorates water quality, food and habitats, and reduces the oxygen that fish and other aquatic species need to live.

- **Phosphorus (P): YES**

This can lead to eutrophication, a process in which excessive algae growth consumes oxygen in the water and generates large amounts of organic matter.

- **Potassium (K2O): NO**

The presence of potassium in water generally comes from natural sources such as mineral weathering and agricultural fertilization, and is not considered a contaminant unless it is present in extremely high concentrations that could adversely affect water quality.

2 - What are the pesticides made of ?

- **Fungicides**: may contain compounds such as **metalaxyl** ($C_{15}H_{21}NO_4$), **captan** ($C_9H_8Cl_3NO_2S$) or **triadimefon** ($C_{14}H_{16}ClN_3O_2$).
- **Insecticides**: may contain compounds such as **DDT** ($C_{14}H_9Cl_5$), **lindane** ($C_6H_6Cl_6$) or **pirimicarb** ($C_{11}H_{18}N_4O_2$).
- **Herbicides:** they may contain compounds such as **glyphosate** ($C_3H_8NO_5P$) or **2,4-D** ($C_8H_6Cl_2O_3$)

2.a - Are pesticides a pollute agent in water?

Of course yes!

2.c - Can be one of these elements reused to create new fertilizers/pesticides?

Yes, as they are simpler chemicals

2.d - How can be these elements extracted?

- **Nitrogen:**
  - **Possible elimination (but not extraction):** Nitrification and denitrification, where bacteria convert nitrogen into gaseous forms that are released to the atmosphere. Advanced technologies such as Anammox and membrane bioreactors (MBR) allow for more efficient nitrogen removal.
- **Phosphorus: Possible and economically viable**
  - RecoPhos Tech impulsed by EU (https://cordis.europa.eu/article/id/157584-extracting-phosphorus-from-sewage-sludge/es)
  - https://theconversation.com/como-convertir-las-aguas-residuales-en-una-mina-de-fosforo-160799
- **Potassium**
  - Not founded evidences

Although theoretically it would be possible to extract nitrogen from water for use in the creation of fertilizers, in practice, nitrogen used in the manufacture of fertilizers is obtained from **more concentrated and economically viable sources.**

Phosphorus may be our winner!

Example from Denmark

https://www.sciencedirect.com/science/article/pii/S0921344916301227#bib0225

Refer for framework and processes

PERPLEXITY.AI THREAT WITH ALL THE REFERENCES: https://www.perplexity.ai/search/de-que-estan-WNdgz_l2R_KP1rc8rw.3lg

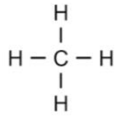
watermining.eu

Home - watermining

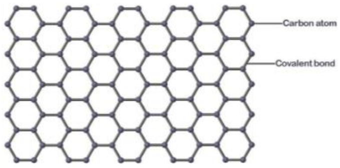
Water access and its related energy, environmental and economic costs are one of the greatest challenges for society today. According to the 2030 Water Resources Group of the World Bank global water demand by 2030 is expected to exceed sustainable water...

5 resources recovered
Phosphorus
Cellulose fibers
Biopolymers
Bioplastics

1- What is Methane (CH4) ?
Chemical compound with the chemical formula **CH4**

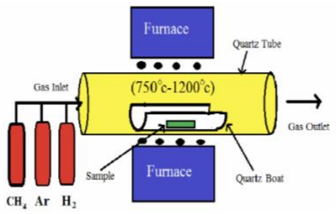


2 - What is graphene?
Substance composed of pure carbon, with atoms arranged in a regular hexagonal pattern, similar to graphite.



3 - How is graphene created?
Several ways to create graphene (Mechanical or chemical exfoliation, or **CVD - Chemical vapour deposition**)

CH4 can be used to create Graphene



https://www.researchgate.net/publication/281642958_Graphene_Potential_material_for_nanoelectronics_applications

4 - Can CH4 be extracted from the water?

- **Vacuum extraction - vacuum pressure swing adsorption (VPSA)**: Good separating CH4 from N2, but not CH4 from water
- **Aeration/air stripping** (more promising): Aeration/air stripping is a process used to remove volatile organic compounds (VOCs) from water by introducing air into the water to facilitate the release of dissolved gases.

PROBS: Maybe Aeration is just for REMOVING (and not to collect), but I'm quite sure it would be possible

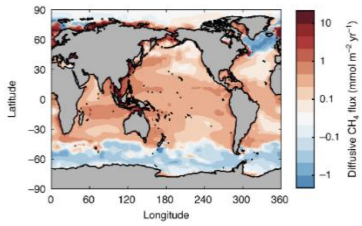
Removing Methane from Drinking Water Through Aerator Reverse Osmosis System
Methane (CH4), often called marsh gas, is the primary component of natural gas. Venting the casing and/or the cap of the well will reduce the problem of methane in the water, but may not completely eliminate it.

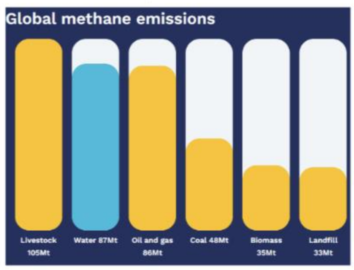
METHANE AERATOR SYSTEM – Water Refining Company, Inc.

Getting Methane out of Water
We hear a lot about methane in well water, especially as a side effect of the gas recovery process known as hydraulic fracturing. We hear a lot less about how to get rid of it. Atmospheric aeration is essentially the only treatment for methane in well w...

5 - Is there enough CH4 in water?

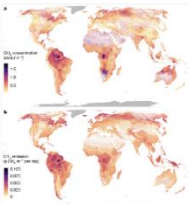
- Quite sure yes: 6 to 12 terragrams (Tg) CH4





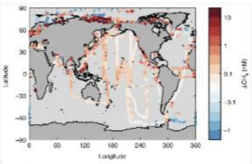
www.bluemethane.com

Methane in water - Bluemethane
Stopping methane from escaping from reservoirs, rice paddies, and wastewater could be one of the most powerful instruments to quickly slow global warming. Bluemethane is developing technology to measure and capture methane emissions from water.



www.nature.com

Global methane emissions from rivers and streams - Nature
A spatially explicit global estimate reveals that land-water connections are important for regulating methane supply to running waters, and that these connections are vulnerable to both climate change and direct human modifications of the land.



www.geomar.de

How much methane is released by the ocean?
25 October 2019/Kiel. Methane (CH4) is a strong greenhouse gas that has both anthropogenic and natural sources. The ocean also plays an important role. A new study published in the journal Nature Communications by American and German scientists, involvi...

6- Existing techs?

cordis.europa.eu

Un método nuevo para obtener grafeno de fuentes renovables

El grafeno se considera un supermaterial con una potencial extraordinario, pero su producción industrial aún no se ha logrado. Una...

A: I promise it is a coincidence that this company is placed in Lleida!!

www.linkedin.com

LinkedIn Login, Sign in | LinkedIn

Login to LinkedIn to keep in touch with people you know, share ideas, and build your career.

Microplastics

1 - What are microplastics made of ?
Microplastics are composed of mixtures of **polymers** (primary components of plastics) and functional additives.

2 - What are the polymers ?
Polymers are macromolecules formed by joining simpler molecules called monomers through chemical bonds.

3 - What are the most popular polymers in microplastics ?
The most popular polymers in microplastics are polyester, polyethylene and polypropylene.

Poliéster

Fibra

Product	Description
Biogas	Biogas is a mixture of CH_4 and CO_2 that can be used to produce green gas and CO_2 and/or electricity and heat using combined heat and power technology.
Cellulose	Cellulose is the polysaccharide of which the fibers in toilet paper consist. The fibers can be used to produce building materials or paper products, but it can also be used to make bioplastic.
Bioplastic	Polyhydroxyalkanoates (PHAs), a type of bioplastic, can be produced from sludge.
Phosphorus	Phosphorus is a necessary nutrient for plant and human growth that can be recovered from wastewater.

Bioplastic was chosen as polyhydroxyalkanoate (PHA) production from wastewater by microbial enrichment cultures and mixed microbial cultures is a promising option for biopolymer production.

Cellulose fibers
Biopolymers
Bioplastics

Phosphorus techs VS Methane Techs

DETECTION

1.a - Can be Phosphorus detected with a microscope?

Yes, Phosphorus can be detected with a microscope. Various methods, such as Scanning Transmission Electron Microscopy (STEM) and Optical Microscopy, have been used to detect and localize Phosphorus in biological samples and materials like black phosphorus flakes

1.b - Can be Phosphorus detected in a general way in water?

Yes.

- Orthophosphate analyzers

EXTRACTION

1.c - How can be Phosphorus EXTRACT from the water?

- Chemical precipitation, biological uptake, physical filtration, thermal treatment, and chemical extraction
- SALTS PRECIPITATON

2.a - Can be methane detected by a microscope?
Methane can be detected using microscopic techniques, but not directly.

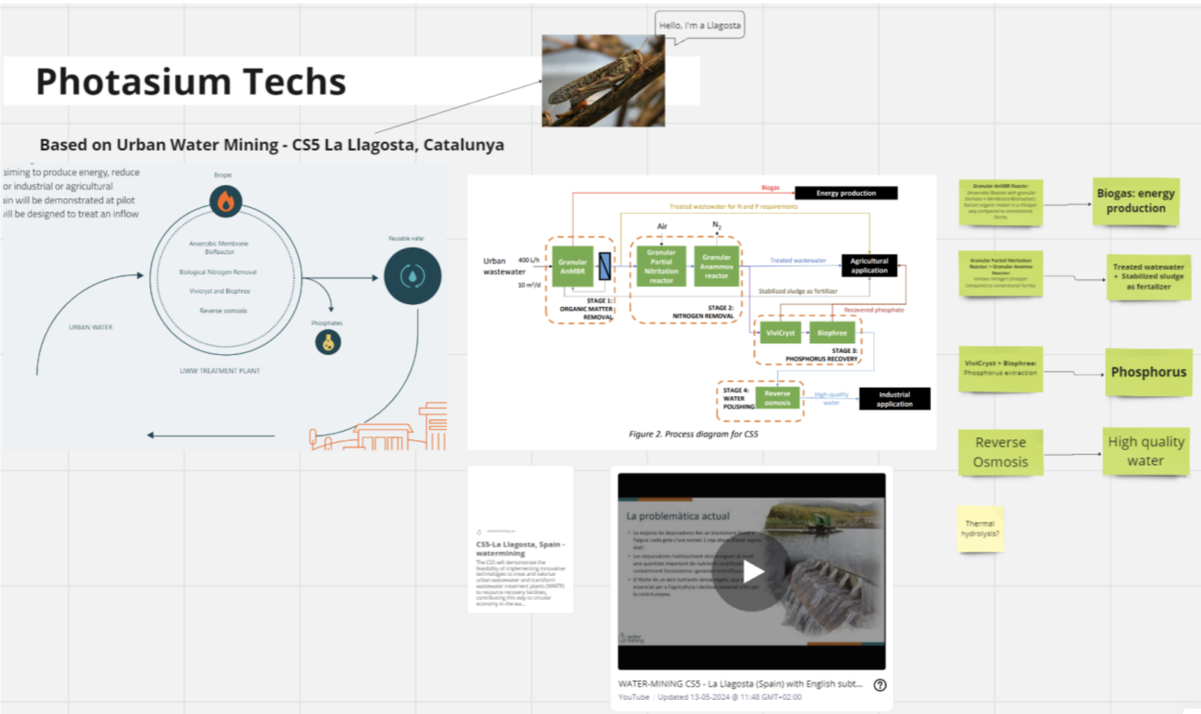
2.b - Can be Methane detected in a general way in water?

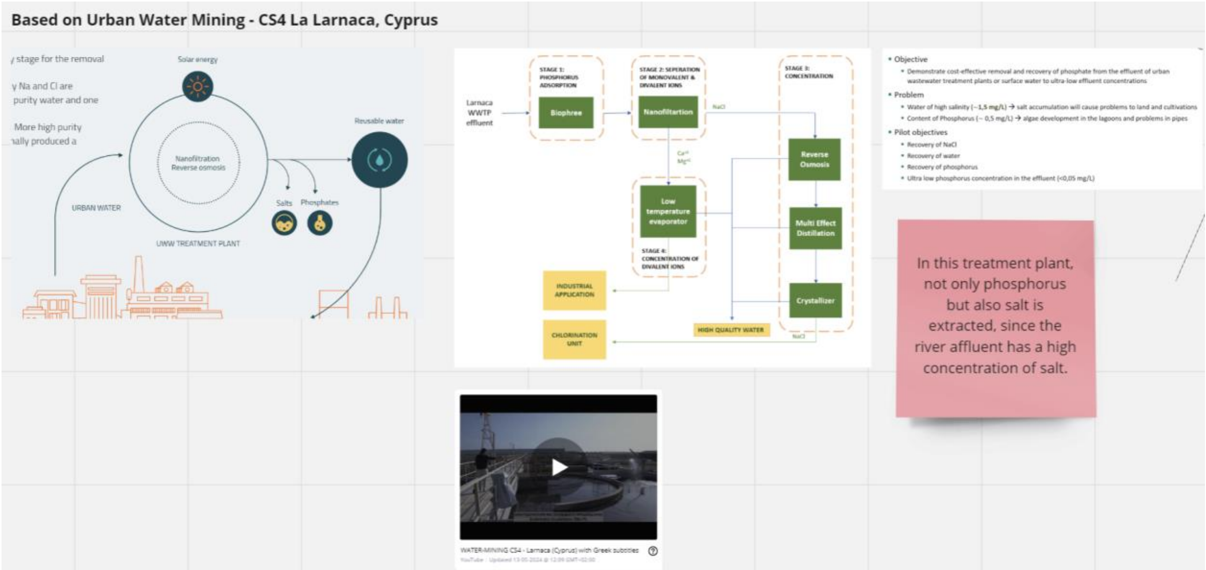
Yes.

- Gas Sensor Systems, Methane-Gas Air Sensor/Monitor, Water Testing Kits, Headspace Analysis
- https://patents.google.com/patent/US7628919B2/en

2.c - How can be methan EXTRACT from the water?

- Depressurization, Water Circulation, Injection Method, Aeration





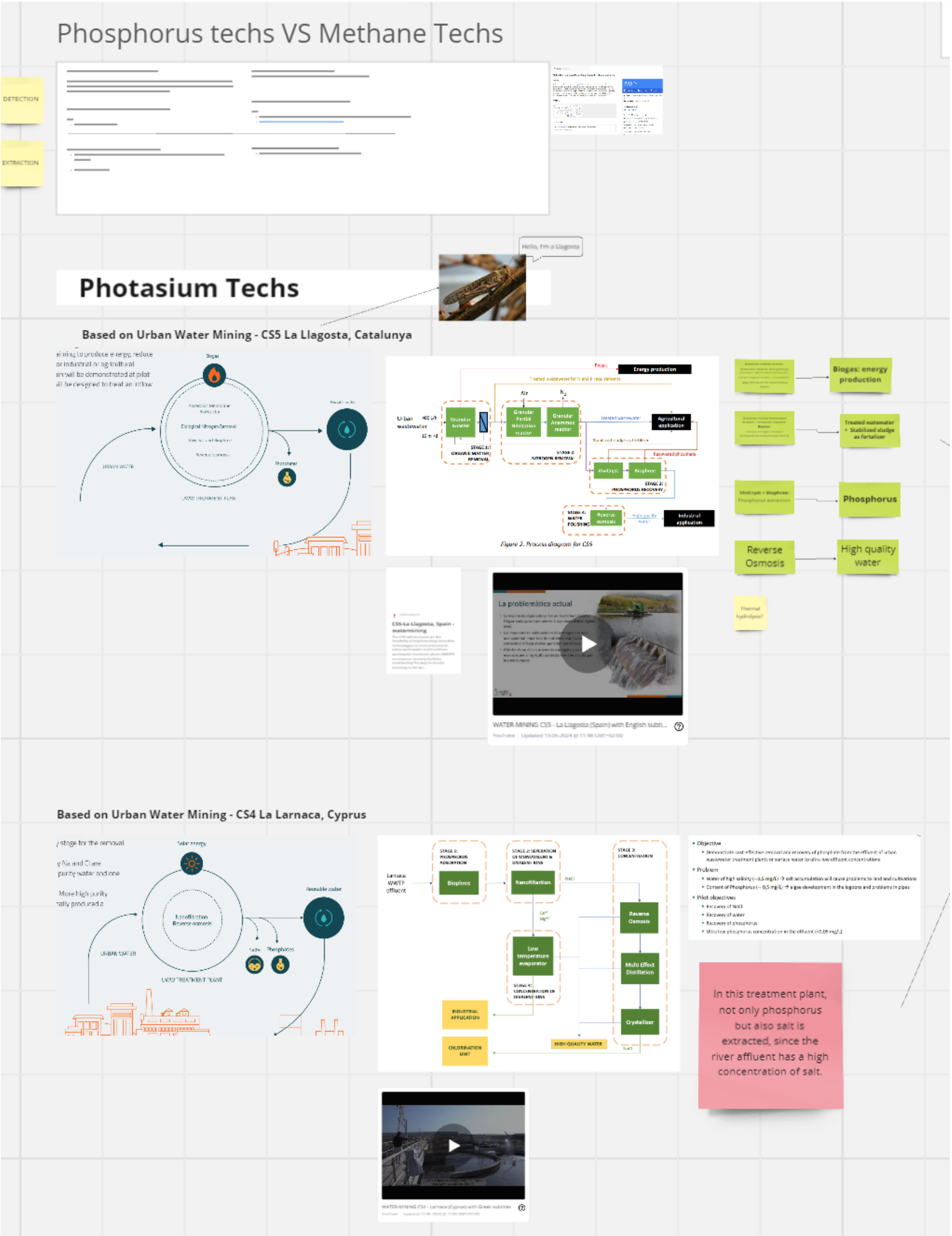
Marco 1

BioPhree Tech

BiOPhree® has been recognized as a promising ecotechnology for phosphorus removal and recovery

- The core principle of BiOPhree® lies in its ability to **capture dissolved phosphorus in water** through a process of absorption using a **hybrid ion exchange resin impregnated with iron oxide**. This absorption material captures phosphorus until saturation, which can take several weeks to months, and can be regenerated by desorbing phosphorus into a cleaning solution for reuse, promoting a circular approach to phosphorus removal

- Key resource: hybrid ion exchange resin impregnated with iron oxide


Phosphorus techs VS Methane Techs
DETECTION
EXTRACTION
Hello, I'm a Llagosta
Photasium Techs
Based on Urban Water Mining - CS5 La Llagosta, Catalunya
Energy production
Figure 2. Process diagram for CS5
Biogas: energy production
Treated wastewater + Stabilized sludge as fertilizer
Phosphorus
Reverse Osmosis
High quality water
La problemàtica actual
WATER-MINING CS5 - La Llagosta (Spain) with English subti...
Based on Urban Water Mining - CS4 La Larnaca, Cyprus
Larnaca WWTP effluent
Biophree
Nanofiltration
Low temperature evaporator
Reverse Osmosis
Multi Effect Distillation
Crystallizer
INDUSTRIAL APPLICATION
CHLORINATION UNIT
HIGH QUALITY WATER
In this treatment plant, not only phosphorus but also salt is extracted, since the river affluent has a high concentration of salt.

Data Map Region with detectors for sell data:

This alternative involves the implementation of a comprehensive network of phosphorus detection devices to monitor the levels in irrigation canals. The collected data can be sold to relevant stakeholders, including environmental agencies, agricultural managers, and research institutions. This real-time monitoring system not only helps in managing phosphorus levels but also aids in predicting and preventing potential ecological disasters.

The scalability potential of this system is significant, as it can be expanded to include various water bodies worldwide. By integrating data related to the chemical composition of the water and other materials, the system can evolve into a global network providing real-time status updates on water quality. This network will enhance citizenship awareness and support government regulations by offering accurate and timely data.

Additionally, the system can employ AI algorithms to analyze the data, identify pollution sources, and make predictions about future water quality issues. This capability will enable proactive measures to protect water resources and ensure sustainable management practices.

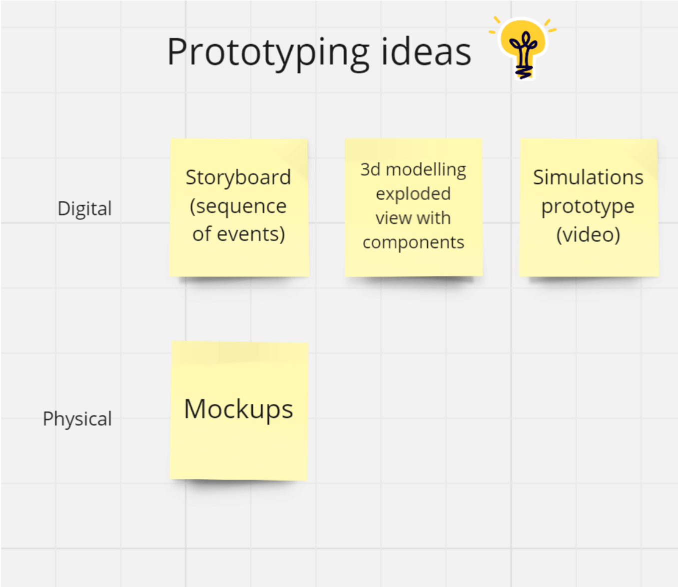
However, we have decided to discard this project due to a lack of feasibility at this moment. The required infrastructure, technological advancements, and investment necessary to implement and maintain such a comprehensive system are currently beyond our reach.

3. PROTOTYPE

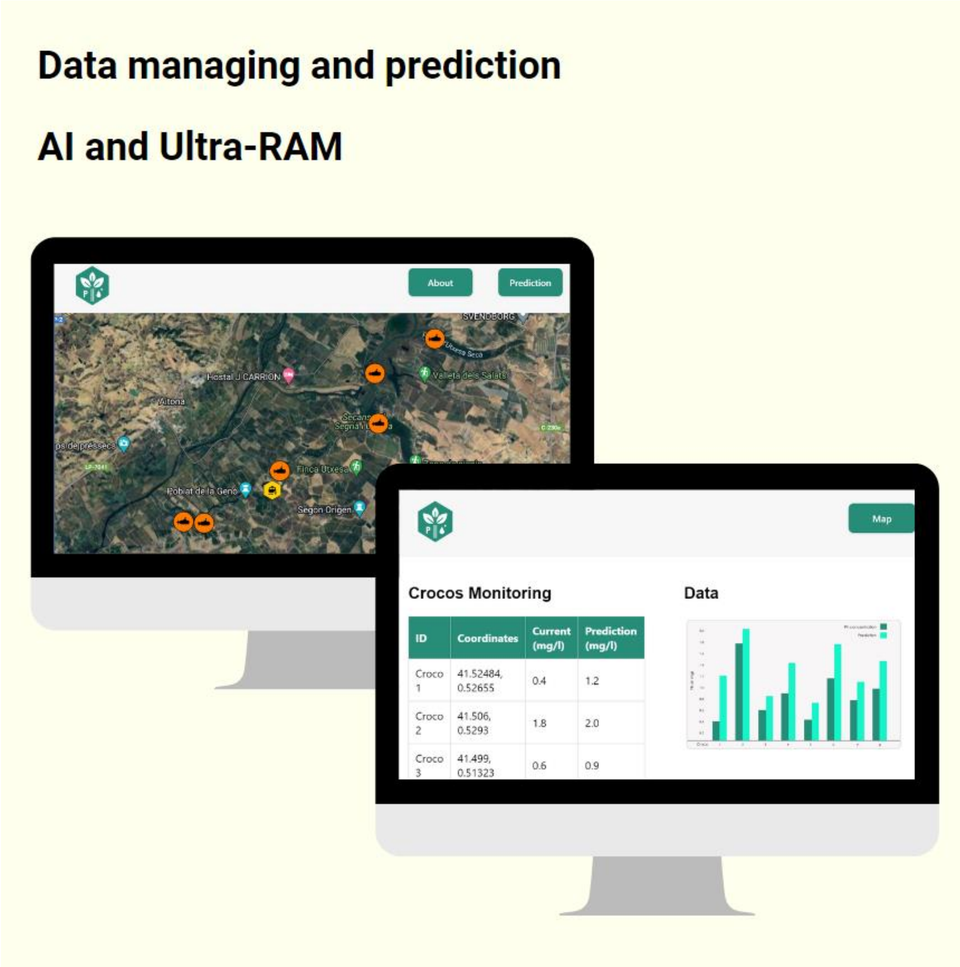
To effectively demonstrate the feasibility and benefits of the Pharmers project, we have developed a comprehensive video prototype that showcases the entire process, from phosphorus detection in agricultural wastewater to its extraction and conversion into fertilizer. This video serves as both a proof of concept and an educational tool to illustrate the practical implementation of our system.

1. Detection System: The video begins by showing the advanced sensors used for real-time monitoring of phosphorus levels in agricultural wastewater. These sensors, connected to a central database, continuously log and analyze data to ensure accurate monitoring.
2. Extraction Mechanism: Next, the video demonstrates our pilot-scale extraction unit. This segment includes footage of the chemical and physical processes involved in precipitating phosphorus from the wastewater, highlighting the efficiency and effectiveness of the extraction mechanism.
3. Data Analytics Platform: The video then transitions to our data analytics platform, showcasing how the collected data is processed using machine learning algorithms to predict phosphorus levels and optimize the extraction process. This part emphasizes the technological sophistication and predictive capabilities of our system.
4. Fertilizer Production: Following the extraction process, the video shows the conversion of isolated phosphorus into a high-quality fertilizer. This includes testing different formulations to ensure the product meets agricultural standards and provides optimal nutrient value for crops.
5. Pilot Testing in Torre de Segre: The final part of the video features our pilot testing phase in Torre de Segre, Spain. It includes real-world footage of our system in action, demonstrating its impact on local agriculture and water quality. This segment also captures user feedback and highlights the potential for scalability and broader implementation.

By providing a visual and detailed walkthrough of the entire process, the video prototype effectively communicates the innovative approach and practical benefits of the Pharmers project. This method not only validates our concept but also serves as a powerful tool for engaging stakeholders, investors, and the agricultural community.


Prototyping ideas
Digital
Storyboard (sequence of events)
3d modelling exploded view with components
Simulations prototype (video)
Physical
Mockups


The Croco



3.1 The Technologies

Having exposed our solution to the problem posed, in this section we will focus on exposing the technologies used for the implementation of this solution.

As mentioned above, our proposed solution has two main focuses

- To extract the phosphorus from the irrigation canal to reuse it in the fertilization of the fields.
- Monitoring the state of the canal to prevent future ecological disasters. Those could collapse the canal and the treatment plants of the municipality, which, as mentioned above, would lead to the cutting off drinking water to the inhabitants of the villages.

Therefore, the technical solution is proposed following these two focuses:

- A network of detectors will be created to monitor the channel, and a barge associated with them will navigate the channel detecting and extracting, respectively, the phosphorus from it.

- At the same time, the data extracted by the detectors will be compiled to train a neural network that will allow the prediction of the presence of phosphorus in the channel in the future.

3.1.1 The Croco - Phosphorus detector

The device in charge of traveling through the channel collecting data on the amount of phosphorus present in the channel will be the Croco.

The Croco is a small autonomous submarine that, by means of a battery, navigates inside the channel to detect the presence of phosphorus in it. To do so, it makes use of an electrochemical sensor.

Image 7: The Croco

The sensor with which the Croco is equipped is based on the electrochemical sensor developed by researchers from KTH Royal Institute of Technology of Sweden and from Universidad Católica San Antonio de Murcia, Spain [1].

This device is intended to be a portable detector to detect dissolved inorganic phosphorus in seawater. The system consists of an electrochemical actuator-sensor that uses an electrochemical reaction to detect phosphorus ions and operates according to the following principles:

1. **Electrochemical Reaction:** The system uses an electrochemical reaction between a phosphorus-selective membrane and a platinum electrode to detect phosphorus ions. The reaction involves the oxidation of phosphorus ions at the platinum electrode, which generates an electric current proportional to the concentration of phosphorus ions.

2. **Electrode Design:** The platinum electrode is designed to have a high surface area and is coated with a phosphorus-selective membrane that selectively allows phosphorus ions to pass through. This ensures that only phosphorus ions are detected, reducing interference from other ions.

3. **Actuator Function:** The system also includes an actuator function that uses an electrochemical reaction to control the flow of water through the sensor. This allows for continuous monitoring of phosphorus levels without the need for manual sampling.

4. **Signal Processing:** The electric current generated by the electrochemical reaction is measured and processed using a signal processing system. This system converts the raw signal into a quantifiable measurement of phosphorus concentration.

5. **Portability and Automation:** The system is designed to be portable and automated, allowing for easy deployment and continuous monitoring of phosphorus levels in seawater. This makes it suitable for long-term monitoring applications.

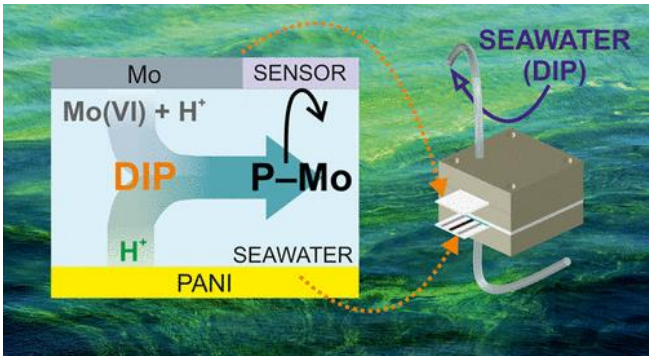


Image 8: Electrochemical sensor schema

Although this sensor is designed for the detection of phosphorus in salt water, it is estimated that soon it could be used in any type of aquatic body. We have chosen to use this sensor because it does not require external actuation (usually phosphorus tends to be measured by laboratory techniques that involve the manipulation of professionals) and because it is extremely portable and autonomous.

It should be noted that the Croco is autonomous thanks to a battery that can be charged at the main station, the Pharmer.

Once the phosphorus has been measured, the system will send the information to the barge via satellite signal. This information will be collected and processed by ULTRARAM.

- ULTRARAM [2] is a revolutionary memory technology developed by Lancaster University that combines the advantages of dynamic random-access memory (DRAM) and NAND flash memory. It uses a patented triple-barrier resonant tunneling structure to achieve fast, non-volatile, and high-endurance memory storage. This technology has the potential to outperform both DRAM and NAND flash in terms of speed, non-volatility, and energy efficiency. ULTRARAM is designed to be highly efficient, with a switching energy per unit area that is 100 times lower than DRAM and 1,000 times lower than flash

3.1.2 The Pharmer - Phosphorus extractor

The device in charge of extracting the phosphorus from the channel will be called Pharmer. The Pharmer consists of a mobile barge driven by motors that are powered by the solar panels installed on the surface of the Pharmer (which are also used to charge the Crocuses, as mentioned above).

Image 9: The Pharmer

To extract the phosphorus, the Pharmer will have 3 removable drawers filled with Polonite, an absorbent material capable of capturing the phosphorus through filtration.

- Polonite is a commercialized form of calcinated opoka, a type of silica-calcite sedimentary rock. It is used as a phosphate sorbent material (PSM) to remove phosphate from water. Polonite has been tested in various experiments, including lab-scale and pilot-scale column tests, and has shown high phosphate removal efficiencies, often exceeding 95% [1].

The following paper [3], written by UPC researchers, evaluates the effectiveness of fine grain size Polonite as a sorbent material for removing phosphorus from wastewater. The study uses column experiments to test the sorption capacity of Polonite for phosphorus, and the results are compared to those of other materials such as granular activated carbon (GAC).

Image 10: Polonite

This phosphorus extraction technology was chosen for two reasons:

- First, this technology can be used on a **small scale**, which is the first one in our project, since the Polonite must fit inside the Pharmer's drawers.
- Many of the other phosphorus sorption techniques required post-processing prior to use. In our case, **phosphorus enriched Polonite itself can be used as fertilizer and compost**.

It should be noted that the changes of Polonite filters is the only point of our system that is not 100% automatic and must be performed by an operator. However, the system is designed to be easy and intuitive to use.

3.1.3 Disaster prevention using LSTM model

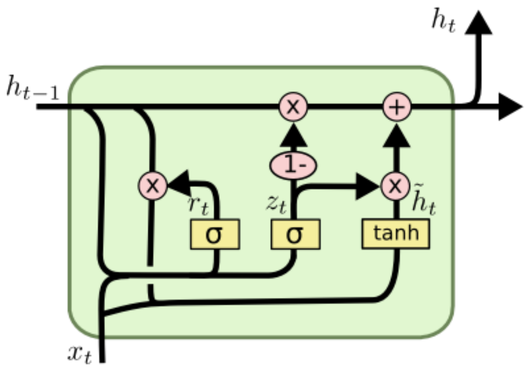
As mentioned above, thanks to the channel monitoring performed by the Crocos, we will be able to have a very clear and accurate view of the channel status. From our interviews with municipal entities, we know that this monitoring of the canal is essential for a better municipal water management. Therefore, we will make use of this collected data not only to inform the administration but also to build a neural network model to predict the concentration of phosphorus in the water, thus making a predictive mapping of the canal.

The neural network selected to perform this forecasting is an LSTM. LSTMs (Long Short-Term Memory) are a type of recurrent neural network (RNN) that are particularly well-suited for time series forecasting tasks. They are useful for several reasons:

1. **Long-Term Memory: LSTMs** can learn long-term dependencies in sequential data, which is essential for capturing trends and patterns in time series data. This is achieved using memory cells and gates that allow the model to selectively retain or forget information over time.
2. **Handling Vanishing Gradients:** LSTMs overcome the vanishing gradient problem common in traditional RNNs, which can lead to a loss of information during

backpropagation. This is achieved using the forget gate, which helps to control the flow of information through the network.

3. **Capturing Seasonalities and Events:** LSTMs can effectively capture both long-term and short-term seasonalities in data, as well as the impact of events on demand patterns. This makes them useful for tasks such as demand forecasting, where understanding these patterns is crucial for accurate predictions.



$$z_t = \sigma\left(W_z \cdot [h_{t-1}, x_t]\right)$$
$$r_t = \sigma\left(W_r \cdot [h_{t-1}, x_t]\right)$$
$$\tilde{h}_t = \tanh\left(W \cdot [r_t * h_{t-1}, x_t]\right)$$
$$h_t = (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t$$

Image X: LSTM cell and its gate equations

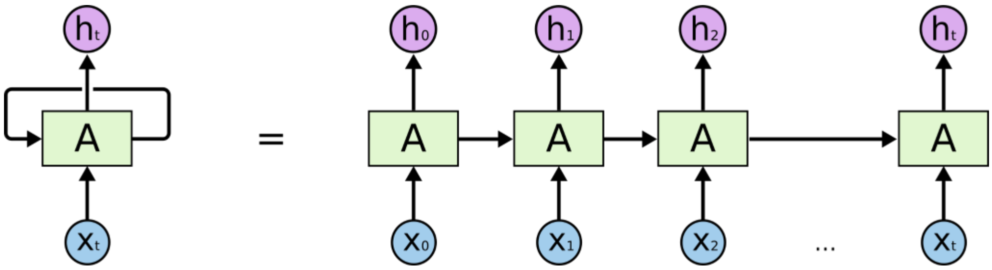


Image 11: LSTM recurrent Architecture

The whole process derived from the use of this neural network will be managed by the ULTRARAM.

3.1.4 System monitoring via web page

Finally, all this information collected, and all the predictions made by our system must be displayed in an accessible and practical way to the end user. For this reason, a web page has been created that will allow access to:

- The real-time position of the Crocos and the Pharmer.
- The status of these
- The data collected by the Crocos
- The predictions of the channel made based on these data
- The status of the Pharmer as well as its filters

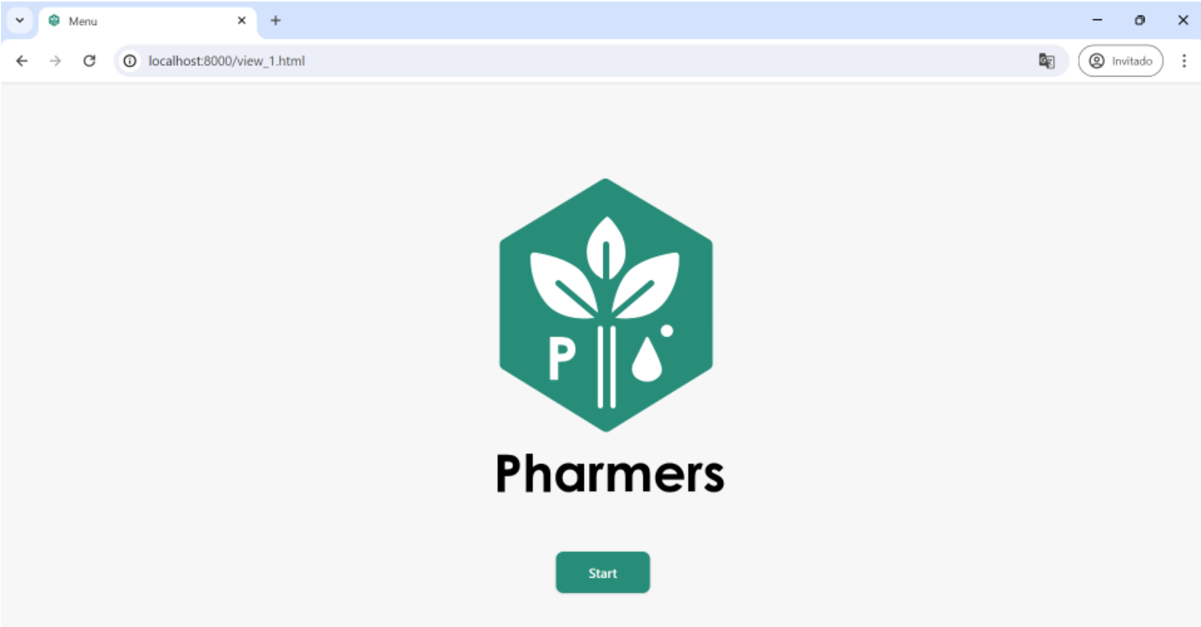


Image 12: Initial Page Overview

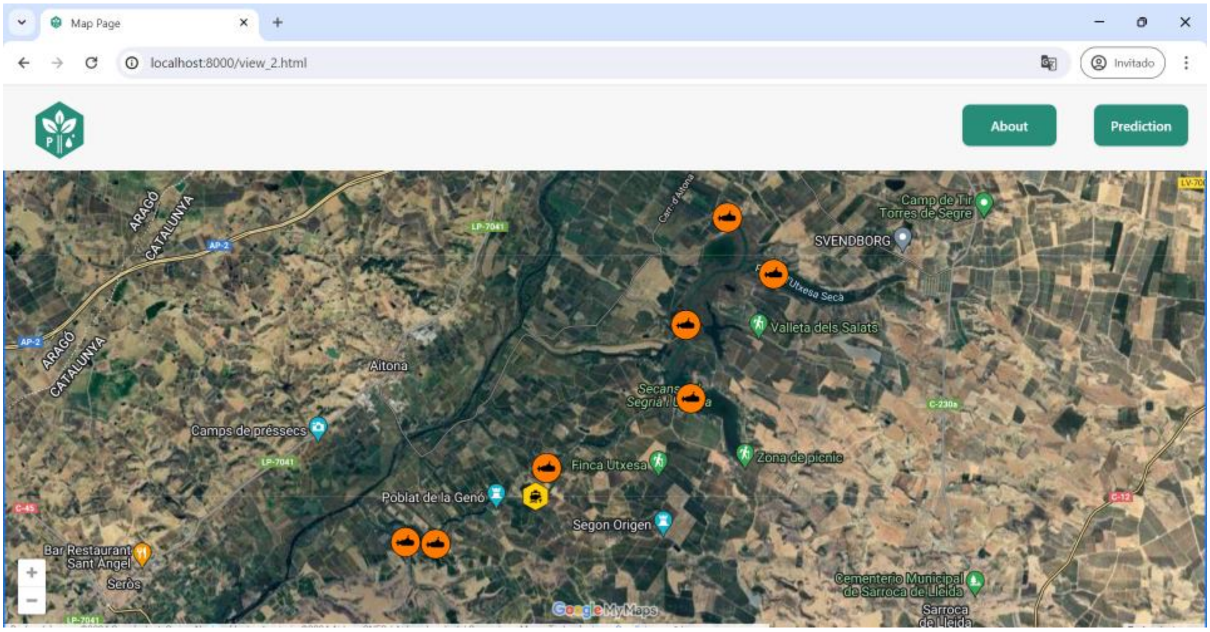


Image 13: Map monitorization Page

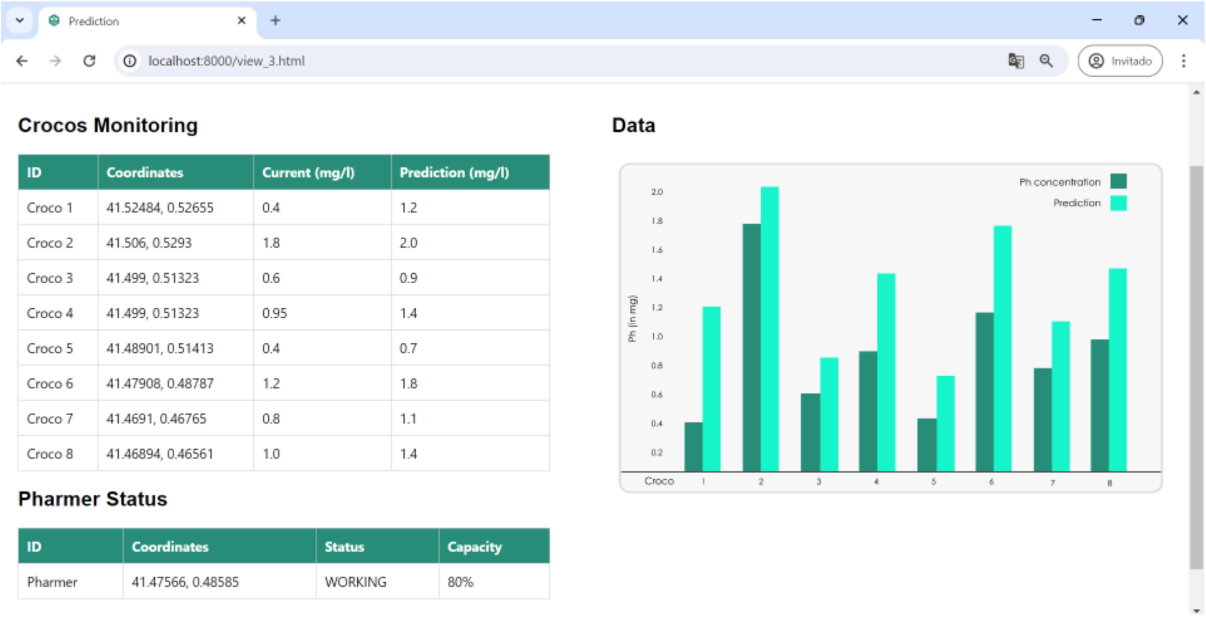


Image 14: Status and prediction page

The full webpage code can be found in the following GitHub repository

https://github.com/annafalpi27/Pharmers/tree/main

3.2 Business model

Our solution provides two main value propositions:

- The extraction of phosphorus to be reused in the farms as a fertilizer.
- The prevention of ecological disaster using the LSTM model.

Both solutions derive from the infrastructure described before.

The cost structure associated with the development of the project is:

Deployment Costs	**Cost**	**Details and Explanation**
Central Extractor Unit (Polonite System)	€ 500,000	Includes advanced technology for phosphorus recovery with Polonite.
Detection Devices (12 units)	€ 120,000	Each device costs €10,000, necessary for monitoring phosphorus levels.
Data Centralization System	€ 50,000	Infrastructure for data collection and analysis, integrate UltraRam infrastructure.
Licenses and Permits	€ 100,000	Costs for obtaining regulatory permits and compliance.
Infrastructure Modifications	€ 100,000	Construction and installation to integrate new technology into existing facilities.
Total Deployment Costs	€ 870,000	
Annual Operating Costs		
Maintenance	€ 67,000	Annual upkeep for the central unit, data centralization system and detection devices.
Labor	€ 40,000	Salaries for personnel to operate the system.
Consumables (Polonite)	€ 21,545	Polonite needed for extraction. Price in the market rounding €1.3/kg.
Licenses Renewals and Compliance	€ 50,000	Annual fees for maintaining compliance and renewing licenses.
Total Annual Costs	€ 178,545	

The revenue streams for the project are:

Annual Revenue	Cost	Details and Explanation
Recovered Phosphorus Sales	€ 8,353	Phosphorus recovered. Price in the market rounding €4.2/kg.
Environmental Credits and Subsidies	€ 100,000	Potential government incentives for reducing pollution and promoting sustainability.
Data Recollected for Disaster Prevention	€ 250,000	Value of disaster prevention valued in €1M.
Total Annual Revenue	€ 358,353	

Financial analysis:

Total Deployment Costs	€ 870,000
Total Annual Costs	€ 178,545
Total Annual Revenue	€ 358,353
Total Annual Earnings (C-R)	€ 179,808
Payback Period (TDC/TAE years)	4.8

The calculations were made with the following assumptions regarding quantities and prices:

Device Capacity:

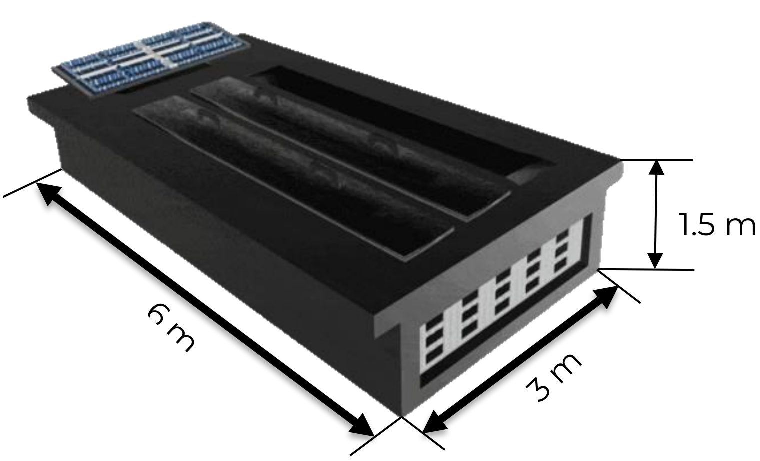


Image 14: Pharmer size

Volume: 3m x 6m x 1.5m = 27.0 m^3.

Water capacity (70%): 27.0 m^3 x 70% = 18.9 m^3.

Water Processing time (Polonite extraction): 10 min -> 144 times per day.

Processed water per day: 144 times/day x 18.9 m^3 = 2,721.6 m^3 = **2,721,600 L/day.**

Phosphorus Recovery Calculation:

Concentration of Phosphorus in river: Up to 2mg/L.

Polonite efficiency: 91% of Phosphorus extraction.

Annual recovery: 2 mg/L x 91% x 2,721,600 L/day x 365 days = **1,988.75 kg/year.**

Sales market price (4.2 €/kg) = 1,986.77 kg/year x 4.2 €/kg = **8,352.77 €/year.**

Consumables (Polonite):

Polonite needed for processing: 0.12 kg P <> 1 kg Polonite

➔ 1,986.77 kg/year / 0.12 P/Polonite = **16,572.96 kg/year.**

Cost market price (1.3 €/kg) = 16,556.40 kg/year x 1.3 €/kg = **21,544.84 €/year.**

Central Extractor Unit (Polonite System):

Estimation of 500,000 € for prototypes and final product development.

Detection Devices (12 units):

Estimation of 10,000 € per detector and 12 units for cover the main affluents to the river.

Data Centralization System:

Estimation of 50,000 € for the device that contains the UltraRam.

Maintenance:

Calculated as a 10% of fixed assets: (500,000 +120,000 + 50,000) x 10% = 67,000 €.

Avoided Emergency Costs:

For a village of 15,000 people in a 20km^2 with and water cut of 14 days due to water collapse.

Emergency Water Supply	€ 420,000	Water needed for population.
Infrastructure Repairs and Clean	€ 300,000	Expenses incurred for municipality.
Business Revenue Loss	€ 200,000	Losses for companies and farms in the area.
Health and Sanitation	€ 80,000	Movilization of resources for the community.
Total Avoided Costs	€ 1,000,000	

Emergency water supply:

2 €/day/people x 15,000 people x 14 days = 420,000 €

Data Recollected for Disaster Prevention Value:

According to the interviews, the ecological disaster occurs almost every year in summer. Giving a conservative point of view, we assume a value of the prevention and cleaning process of 50% of the emergency costs. The cleaning procedures done by the municipality can be assumed up to 250,000 €. The value considered each year for the Data generated in the system is 250,000 €.

3.3 Social impact

The project brings substantial social benefits through its approach to agricultural wastewater treatment and phosphorus recycling. The primary impact is on environmental health. By extracting phosphorus from wastewater, the project reduces the risk of eutrophication, which helps maintain healthy aquatic ecosystems essential for biodiversity and the well-being of local communities. Additionally, the recycled phosphorus is transformed into valuable fertilizer, promoting sustainable agricultural practices and reducing the reliance on synthetic fertilizers, which often have negative environmental consequences.

Economically, the project provides significant cost savings for farmers by offering a locally sourced, recycled phosphorus fertilizer. This reduction in input costs makes agriculture more economically viable. The project also creates job opportunities through the operation and maintenance of the Croco detectors, the Pharmer extractor, and the overall monitoring system, thereby contributing to local economic development.

The project enhances community engagement and education by involving local communities in understanding the importance of wastewater treatment and resource recycling. Educational programs and community initiatives raise awareness about environmental stewardship and sustainable practices. Additionally, the project empowers local farmers by providing them with access to advanced technologies and sustainable farming inputs, enabling them to adopt more sustainable and profitable farming methods.

Moreover, the project fosters technological innovation by utilizing advanced technologies such as electrochemical sensors, autonomous submarines, and LSTM neural networks. This commitment to innovation can inspire further research and development in environmental technology. The project also promotes collaboration between researchers, local governments, and communities, ensuring that diverse perspectives are considered and leading to more effective and sustainable solutions.

The Pharmers project demonstrates significant impact through measurable outcomes. It can extract 91% of phosphorus from wastewater, accumulating up to 2 tons of phosphorus annually. This initiative is projected to prevent disaster-related losses amounting to 1 million euros each year. The benefits of this project extend to 15,000 people, enhancing both environmental and economic conditions in the region.

Overall, the Pharmers project not only enhances environmental health but also creates a sustainable and prosperous future for the local agricultural community and beyond.

Phosphorus used by farms:

Farms use Phosphorus through P2O5 as a fertilizer, 40kg per year. Mass of P in P2O5 is the 43%. Actual market price for P2O5 is 1,800 €/ton <> 1.8 €/kg.

P per Hectare per year: 40kg x 43% = 17.2 kg

Total cost of P2O5 per year: 40kg x 1.8 €/kg = 72 €

Market price for P: 72 € / 17.2kg = 4.2 €/kg

A farm in Catalunya has in average 100 Hectare, and the area covered by the project of 20km2.

20km2 <> 2,000 Hectare <> 20 farms

Phosphorus needs in a farm per year: 100 Hectare x 17.2 kg/Hectare = 1,720 kg/year

Phosphorus needs in the area per year: 2000 Hectare x 17.2 kg/Hectare = 34,400 kg/year

The project produces 1,988.75 kg/year (116% one farm P), that covers 5.8% of the demand of the area.

4. CONCLUSIONS

Finally, to conclude this report on our work, we will make a series of conclusions to summarize the development of the project, our solution and everything we have learned.

Pharmers started from a very ambitious and a bit of dreamy goal, in which we wanted to promote water cleanliness effectively, making it attractive for companies. We believe that this approach was ambitious but realistic, since for us, it was very important not to base and rely on water waste cleaning, a problem that, as we have seen, affects our lives a lot, in the hands of altruism and public administration. Although we believe that in a utopian world, the whole population should collaborate to take the maximum possible care of the environment, we know that money moves the world, and we wanted to promote our project of circular economy in this approach.

We are very proud to have identified phosphorus as a valuable yet problematic resource in our waters. This choice was made after extensive scientific research, during which we also considered alternatives like methane and microplastics.

One of the major challenges of the project was selecting a specific case study to address the questions that arose during our creative process. We chose Torres de Segre, a village in the Segrià region, near a team member's hometown. With this context defined, we conducted crucial interviews to find the solution.

We are especially grateful for the interviews we conducted, as they provided crucial information essential to the development of our project. Speaking with the town hall of Torres de Segre helped us validate the irrigation water cycle, understand the canal infrastructure, and identify additional needs our project could address. Through these discussions, we discovered the significant importance of disaster prevention, which has become a central pillar in the economic development and AI usage in of our project.

Talking to the technical expert gave us confidence in the technologies we planned to use. While we knew the project didn’t need to be 100% viable today, we wanted the technologies to be existing, studied, and stabilized, with ongoing investment to ensure the project's future success. The technical interview also revealed that the primary challenge with phosphorus extraction is the legislation classifying it as a waste product, making it unattractive for companies. However, we found that this issue is specific to the Spanish region. This presents an opportunity for us to help reframe phosphorus as the vital and essential resource it truly is.

The Pharmers project has developed a system that we believe can revolutionize phosphorus extraction and disaster detection. We are confident in the significant impact it can have. Pharmers is a project by the people, for the people, aimed at improving the lives of our communities and maintaining a healthy ecosystem.

Finally, we would like to emphasize that our technology, while focused on phosphorus extraction, can be adapted to other valuable resources, enhancing the crucial recycling system for our water.

For all these reasons, we are fully convinced that Pharmers—a project born from the hard work and dedication of five developers from various disciplines and parts of the world—will revolutionize water treatment.

4.1. Final Reflections

In closing, we would like to make a small reflection on the development of the project.

All the members of the team are very proud of both the process and the outcome of the project, and we are certain that, thanks to it, we have learned a lot about great disciplines such as the design process, social impact, artificial intelligence and the development of innovative technologies.

For all this we are very grateful for the opportunity we have been given by our universities, ESADE, European Design Institute (IED) and Universitat Politècnica de Catalunya, (UPC), and we would like to extend our heartfelt thanks to the project management team and all the teachers and mentors who have helped and guided us throughout this process.

ANNEX

Eric Monné Interview

Questions

Section 01: Current Behavior

(Understand the journey of wastewater from the farms to water bodies)

1. Could you elaborate on how wastewater from the farms reaches the public infrastructure system?

   Wastewater from irrigation seepage into the canal.

2. Do they pass through a wastewater treatment system before releasing into the waterbodies?

   ***Water is treated only for drinking purposes**. The treatment plant of the municipality contains tanks, one for dirty water, 2 carbon, one for sand and silex and one for chlorine.*

   The water used for irrigation is in no case treated.

3. How many treatment plants are there in an area? What are the factors used to decide where to place the plant?

   Depending on the village, there are one or more irrigation plants. ***All the villages in the region have one or more water treatment plants.***

4. Do all the wastewaters manage to reach the local treatment plant?

   Just a part of the wastewater treated and is the one destined to human consumption

5. What are the current measures taken to solve wastewater pollution?

   No, since there is no direct collection of water used for irrigation. This water is returned to the canal through filtration

Section 02: Pain points

(Challenges faced in water treatment plants)

1. What are the limitations of the existing treatment plants?

   The irradiation water is not treated.

   However, there are limitation on drinking water treatment, as if there are a lot of chemicals are used, and, due to lack of investment, some water treatment plans get collapsed.

2. Where does the untreated waste go?

   In the case of the Seròs Canal, it unravels in the river Segre.

Section 03: Future expectations

(To understand Govt. initiatives and plans/investments)

1. Are there any future projects/initiatives regarding wastewater treatment?

   The actual investment is focused on water saving, but not important its treatment treat it

   There is also a new drinking water legislation with an annual plan to test the quality of common use water.

2. What is your take on a circular wastewater system? Can it be achieved? If so how.

   It is possible and would be very positive

Estel Rueda Interview

Questions

Section 01: Current Behavior

1. What are the technologies you use currently?

   Struvite precipitation from wastewater sludge. Not complex problem. You need to add magnesium (not big amounts in wastewater)

2. Explain in detail how it works - water treatment process

   Due to the solubility of the mineral, when you add Ammonia phosphorus and magnesium.

3. What do you do with the data detected?

   Concentration of phosphorus should be measured in order adjust the extraction process. *Detection process can be done with a sensor.*

   Phosphorus cannot be detected by a microscope either X-ray. Ion ***chromatography*** *or chemical adding + reaction (change of color) +* ***Spectrophotometer****.*

4. What are the costs involved?

   Not that expensive (must be checked). Expert to design the units, operation is quite easy.

5. What do you do with the extracted waste?

   Biogas production from sludge & compose form the sludge. Transforming sludge to fuel (by burning).

   Cellulose has also been investigated, bioplastics (more complex), nitrogen, metals (complicated because they are in small concentration).

   Changing the water treatment plants using microalgae that produce products as pigments, natural colorants, bioplastics, proteins (animal feed), stimulants (for the plans)

6. Phosphorus - Why it is not extracted?

   Main problem is legal! Applicability of the phosphorus, which is a residue. More restrictions to apply residue to the lands.

7. Precipitation technology size?

   The size is proportional to the water corpus.

Section 02: Pain points

(Challenges faced in water treatment plants)

1. What are the limitations of the existing treatment plants?

   The limitation is in the legislation, not in the technologies.

2. How could your process be optimized in the future?

Phosphorus Absorption in some determine material (iron, residues form steel production, calcium). Recover phosphorus ***agricultural runoff.*** *Phosphorus in wastewater is much more concentrated than in agricultural runoff.*

Phosphorus is retained inside the material and the water is cleaned. To separate phosphorus to the material, some acids. The material could be used as a fertilizer (in process) Must be check.

As lower concentration, more material is needed. (0.5-2mg/l phosphorus in agricultural runoff)

Section 03: Future expectations

(To understand Govt. initiatives and plans/investments)

1. Are there any companies who are improving the existing tech?

   Absorption is research, so no companies. Struvite Precipitation should be companies

2. How do you think these techs will evolve in the future? (cheaper, smaller etc.)

   Yes

3. What is your take on a circular wastewater system? Can it be achieved? If so how

   From a technological point of view could be achieved. Maybe in an economical point of view, maybe not. The main problems are legal and social. There should be a change of mind.

REFERENCES

- [1] Chen, C., Wiorek, A., Gomis-Berenguer, A., Crespo, G. A., & Cuartero, M. (2023). Portable All-in-One Electrochemical Actuator-Sensor System for the Detection of Dissolved Inorganic Phosphorus in Seawater. *Analytical Chemistry*, *95*(5), 4180-4189. https://doi.org/10.1021/acs.analchem.2c05307
- [2] ATTRACT Phase 2. (n.d.). ULTRARAM: Ultralow-power, Non-volatile, Random-Access Memory Arrays for Datacentres and Space Applications. ATTRACT. Retrieved June 2, 2024, from https://phase2.attract-eu.com/projects/ultraram/
- [3] Beatriz Altamira-Algarra, Jaume Puigagut, John W. Day, William J. Mitsch, Jan Vymazal, Rachael G. Hunterf, Joan García (2022). *A review of technologies for closing the P loop in agriculture runoff: Contributing to the transition towards a circular economy*. Universitat Politècnica de Catalunya. https://upcommons.upc.edu
- [4] Food and Agriculture Organization of the United Nations. (n.d.). Open Knowledge Repository. Retrieved May 2024, from https://openknowledge.fao.org/home
- [5] European Environment Agency. (n.d.). Topics. Retrieved May 2024, from https://www.eea.europa.eu/en/topics
- [6] Hammond, P., Suttie, M., Lewis, V. T., & Singer, A. C. (2021). Detection of untreated sewage discharges to watercourses using machine learning. npj Clean Water, 4, 27. https://doi.org/10.1038/s41545-021-00116-3
- [7] IWA Publishing. (n.d.). Phosphorus recovery from wastewater needs. Retrieved May 2024, from https://iwaponline.com/wst/article-abstract/59/6/1069/15572/Phosphorus-recovery-from-wastewater-needs?redirectedFrom=fulltext
- [8] MDPI. (2021). Membranes for Phosphorus Recovery from Wastewater. Membranes, 12(2), 210. https://www.mdpi.com/2077-0375/12/2/210
- [9] Royal Society of Chemistry. (2021). Recent advances in phosphorus recovery technologies. Chemical Society Reviews. https://pubs.rsc.org/en/content/articlehtml/2021/cs/d0cs01150a
- [10] TechXplore. (2023, July). Recover vital resources from wastewater sludge. Retrieved May 2024, from https://techxplore.com/news/2023-07-recover-vital-resources-wastewater-sludge.html
- [11] Phys.org. (2023, June). Zapping municipal wastewater to recover valuable phosphorus. Retrieved May 2024, from https://phys.org/news/2023-06-zapping-municipal-recover-valuable-phosphorus.html
- [12] RMS. (2022, September). Fertiliser comparisons. Retrieved May 2024, from https://www.rmsag.com.au/articles/2022/09/fertiliser-comparisons

- [13] USDA. (n.d.). Chart Gallery: Phosphorus use in agriculture. Retrieved May 2024, from https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=108828
- [14] Polonite. (n.d.). About Polonite. Retrieved May 2024, from https://polonite.se/about-polonite/
- [15] Frontiers. (2018). Phosphorus recovery technologies. Frontiers in Environmental Science. https://www.frontiersin.org/articles/10.3389/fenvs.2018.00008/full
- [16] Beatriz Altamira-Algarra, Jaume Puigagut, John W. Day, William J. Mitsch, Jan Vymazal, Rachael G. Hunterf, Joan García. (2022). A review of technologies for closing the P loop in agriculture runoff: Contributing to the transition towards a circular economy. Universitat Politècnica de Catalunya. https://upcommons.upc.edu/bitstream/handle/2117/363974/31788159.pdf?sequence=1
- [17] Our World in Data. (n.d.). Fertilizer use per hectare. Retrieved May 2024, from https://ourworldindata.org/grapher/fertilizer-per-hectare
- [18] FarmDocDaily. (n.d.). Agricultural Data and Analysis. Retrieved May 2024, from https://farmdocdaily.illinois.edu/
- [19] European Environment Agency. (n.d.). Fertilizer input per hectare of agricultural land. Retrieved May 2024, from https://www.eea.europa.eu/data-and-maps/figures/fertiliser-input-per-hectare-of-agricultural-land
- [20] Frontiers. (2018). Phosphorus recovery from wastewater. Frontiers in Environmental Science. https://www.frontiersin.org/articles/10.3389/fenvs.2018.00008/full