NutriClean





Florian Werner
Design Management
IED

Dhruv Agarwal
MBA
Esade

Karen Robles
MBA
Esade

Francesca Diez
Engineering
UPC

Bernat Olle
Engineering
UPC

NutriClean
Table of Contents

NutriClean
Abstract

NutriClean emerges as a holistic and innovative response to the pervasive issue of Harmful Algal Blooms (HABs) in European water treatment plants (WWTPs). This comprehensive initiative, rooted in thorough research, expert interviews, and diverse analytical tools, addresses the intricate challenges associated with excess nutrient removal. The culmination of these efforts yields NutriClean, an integrated system featuring NutriSense, Algae Turf Scrubber, and Natural Coagulant, collectively transforming wastewater treatment into a sustainable and revenue-generating process.

The abstract encapsulates the meticulous conceptualization process, highlighting the utilization of various models such as the Iceberg Model, People & Connections Map, 5 WHYs, and the Impact Gap Canvas. NutriClean's user journey reflects a commitment to seamless integration, with a focus on training, continuous support, and iterative improvements. From a business perspective, the abstract underscores NutriClean's value proposition, revenue streams, and its alignment with United Nations' Sustainable Development Goal 14.1, emphasizing the reduction of marine pollution.

The project's forward-thinking approach is evident in strategic partnerships, envisioned internal production, and a five-phase roadmap. The abstract emphasizes NutriClean's potential impact on marine pollution reduction, regulatory compliance, and its role in fostering environmental sustainability. Beyond its technological innovation, NutriClean signifies a transformative initiative poised to enhance water quality, ecosystem health, and community well-being.

Research
Context

The Challenge-Based Innovation (CBI) program, a brainchild of CERN, stands at the forefront of converging groundbreaking science and technology with pressing societal challenges. This program is a testament to CERN's commitment to applying its open science, cutting-edge technology, and deep expertise towards tangible societal benefits.

In the 2023-24 academic year, the CBI program strategically aligns with specific Sustainable Development Goals (SDGs) to amplify its impact. These goals include SDG 3.9, focusing on reducing illnesses and deaths from hazardous chemicals and pollution; SDG 11.6, aimed at minimizing the environmental footprint of cities; and SDGs 14.1 and 14.3, which concentrate on mitigating marine pollution and ocean acidification, respectively.

Central to this year's CBI agenda were four pioneering technologies fostered under the EU-ATTRACT program. These technologies include;

H3D VISIOnAI3
PiPe 4.0
SNIFFER DRONE
IALL

Our team, named 'Curietors', is inspired by the legacy of Marie Curie, reflecting our ambition to delve deep into understanding complex systems and emerge as catalysts for positive change. In line with our commitment to the sustainable goals, we chose to explore three critical challenges: wildfires, landfills(3.9), and algae blooms(14.1, 14.3).

Finding our Problem

CBI takes a non-linear, experiential approach to learning and innovation where experimentation, failures, and iteration are expected and encouraged along the way. It brings together design, systems thinking and future thinking methodologies to bring both a top-down and bottom-up view of a particular challenge, in addition to a push against the infrastructures and strong-held assumptions on which our contemporary world and wicked problems are built and sustained.

To understand where we could intervene we decided to create a matrix mapping the various possibilities with the technologies we were offered.

	PiPe 4.0	**SnifferDrone**	**IALL**	**H3D Vision-Air**
3.9 (Mortality from environmental pollution : Reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination)	*Identify harmful gasses in specific areas, linking them to potential issues	*Detect harmful gases in specific areas and correlate/connect it with a specific illness *Detect the impact of a wildfire in the surrounding cities or villages. *Drones monitor air quality in real-time and send localized warnings to residents via mobile apps, suggesting they stay indoors during high pollution times. *Monitor urban environments for potential health hazards, such as the spread of vector-borne diseases or harmful algal blooms in water bodies	*Intelligent cameras for forest fire observation	*Utilize 3D imaging for real-time surveillance of forest fire spread and potential threats
11.6(Reduce the environmental impacts of cities)	*Detect leakages in cities that are heavy polluters *Implement smart pipes throughout cities to monitor wastewater quality and detect any hazardous substances, enabling early identification of industrial pollutants.	*Detect industrial pollution in and around cities *Help first responders to assess the environmental impact of places they need to save. *Drones equipped with AI can identify litter in public spaces and either pick them up or signal to maintenance teams. – landfills in the global south → municipalities (better collection in safer and more efficient way) → garbage pickers health improvement → residents around landfills	*Use spectral imaging to inspect and assess the condition of urban infrastructure, including bridges, roads, and buildings. *Employ spectral imaging to analyze rooftops and building surfaces for solar energy potential. *Monitor urban environments for potential health hazards, such as the spread of vector-borne diseases or harmful algal blooms in water bodies	*Let residents take a virtual tour of underground sewage and pipe systems to understand the importance of reducing waste and pollution. - application?

	PiPe 4.0	SnifferDrone	IALL	H3D VisionAir
14.1(Prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution) 14.3(Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels)	*identify different types of waste and better eliminate *detect types of acidification and what causes more acidification *Install systems that release natural alkaline substances when acidification levels get too high, helping to neutralize the ocean's pH in localized areas. (linked)	*Equip drones with sensors that can detect variations in ocean pH levels, mapping areas of excess nutrients. *Equip drones with specialized sensors to monitor the health of coral reefs, sending alerts when acidification levels become critical		*Understand the effect of micro plastics on fish. *Use 3D visualization to showcase the effects of microplastics on marine life, raising awareness and promoting research.

Research
In Detail

The matrix indicates that our team elected to investigate three predominant issues;

Harmful Algae Blooms
Landfills
Wildfires

To dig deeper into each problem we decided on conducting interviews with people from the industry to explore the causes, effects and solutions that each of the problems have.

Harmful Algal Blooms

Causes: Insights from industry professionals
Our dialogue with wastewater treatment and agritech experts revealed a troubling trend: algae growth has accelerated by 60% in the past two decades. This surge in harmful algae blooms, primarily attributed to nutrient-rich runoff from wastewater treatment facilities and excessive use of fertilizers, poses a significant ecological challenge.

Effects: The environmental impact
These harmful algae blooms (HABs) are more than just an eyesore; they create dead zones in marine environments. By depleting oxygen levels in the water, HABs render these areas uninhabitable for most aquatic life, disrupting the delicate balance of marine ecosystems.

Solutions: Current landscape and innovation gaps
In exploring solutions, we identified companies like LG sonic and BLOOM working in this space. However, there's a noticeable gap in proactive innovation. Current efforts largely focus on managing blooms after they occur, underscoring the need for more preventive approaches in combating this escalating issue.

Landfills

Causes: Insights from urban planning perspectives
Through interviews with city planners, we learned that in developing nations, a staggering 65-80% of municipal solid waste ends up in landfills, with 40-70% of this being organic material. Diverse types of landfills exist, including municipal solid waste, industrial, hazardous, and green waste landfills, each with its own set of challenges.

Effects: Urban and environmental concerns
The mismanagement of landfills poses significant issues for urban areas. In addition to the unpleasant odor, which deteriorates living conditions, developing countries often rely on waste pickers to sort through landfill waste, leading to inhumane working conditions. Environmentally, landfills contribute to methane emissions and leachate, posing risks to both local ecosystems and broader urban environments.

Solution: Advancements in landfill management
In response to landfill challenges, there is a notable, ongoing commitment from various companies to enhance landfill treatment. This includes the deployment of innovative technologies such as Eviave for effective waste segregation, Flux Chambers for gas monitoring, Landfill Gas (LFG) recovery systems to harness energy, and advanced Leachate treatment processes for managing liquid waste. Moreover, the field is characterized by the presence of established waste management companies, leading to a highly competitive and saturated market.

Wildfires

Causes: Insights from fire management experts
Discussions with wildfire experts have highlighted that the primary drivers of increased wildfire activity are rising global temperatures and changing rainfall patterns. This trend is starkly evident in regions like California, where the area impacted by wildfires has doubled in the past three years.

Impacts: Ecological and environmental consequences
The repercussions of wildfires are extensive and include severe deforestation and the endangerment of wildlife. Regions such as Australia, the Amazon, and California are among the most affected, experiencing significant ecological disruption.

Solutions: Addressing a complex global challenge
Finding effective solutions for wildfires is complex, mainly because the issue is intricately linked to global climate change and CO2 emissions. Localized solutions can be challenging to implement due to the global nature of the problem. However, advancements in fire observatories and monitoring tools have shown promise in alerting and evacuating local populations, providing a measure of mitigation against this growing threat.

Research
Interviews

	Karan Shighal	Laura Ramoneda	Maria Gallindo	Gabriella Druz
Topic	Impact of agriculture on marine pollution	Wildfire management	Sustainable Waste Management	Marine pollution
Position	Research analyst	Fire safety inspector	Board of european union of smart cities	Co-founder of the Good ocean
Main outcome	Identified nutrient runoffs from excessive fertilizer use as a key contributor to harmful algae bloom proliferation.	Noted that wildfires with the most significant atmospheric impact require prompt response; ongoing efforts in fire path prediction and rapid intervention strategies, especially in the Pyrenees region.	Emphasized the need for specialized approaches to different landfill types and the promotion of waste diversion and recycling to enable a circular economy. Dumping is common in both dry and wet waste, there is a lack of a circular ecosystem.	Advocated for the exploration of using algae as a bioremediation agent to absorb excess nutrients in water bodies, with potential applications in biomass production.

During our initial coaching session, the team, guided by our coaches, concluded that our efforts would be best directed towards addressing harmful algae blooms. This decision was informed by the recognition that harmful algae blooms represent a niche area in dire need of innovation. Furthermore, our review of planetary boundaries literature underscored the urgency of this issue, revealing that the threshold for biogeochemical flow has been exceeded since 2009, with the situation worsening progressively. This alarming trend highlights the critical need for focused attention and innovative solutions to mitigate the impact of harmful algae blooms on our ecosystems.

Research
Harmful Algal Blooms (HAB)

Our next step was to take a deep dive on the HAB. Trying to map what are the reasons for them and which communities are impacted the most.
The incidence, scale, pervasiveness, and toxicity of harmful algal blooms (HABs) are escalating globally. Yearly, they are emerging in previously unaffected aquatic regions. A driver of these blooms is the escalating levels of nutrient pollution, which is a byproduct of industrial, urban, and agricultural runoff. This influx of nutrients is hastening the eutrophication process in a variety of water bodies, including lakes, rivers, and coastal zones.

The specific timing, quantity, and nutrient ratios play pivotal roles in the proliferation of HABs. An imbalance, particularly in the presence of nutrients, can intensify the toxicity of HABs, especially among dinoflagellates and cyanobacteria.
Nitrogen (N) and phosphorus (P) are the primary nutrients that underpin the health and growth of aquatic ecosystems. While these nutrients are naturally essential for the sustenance of algae and aquatic plants, their overabundance is leading to the unchecked growth of harmful algal blooms.

To further understand how the system of nutrients works we decided to dig deeper into the sources of nutrients.

Agriculture

Fertilizers: In agriculture, there is a recognized link between fertilizer application and crop yield. Yet, the overapplication of fertilizers results in about 70% of these nutrients escaping via runoff into water bodies or wastewater treatment plants (WWTPs)

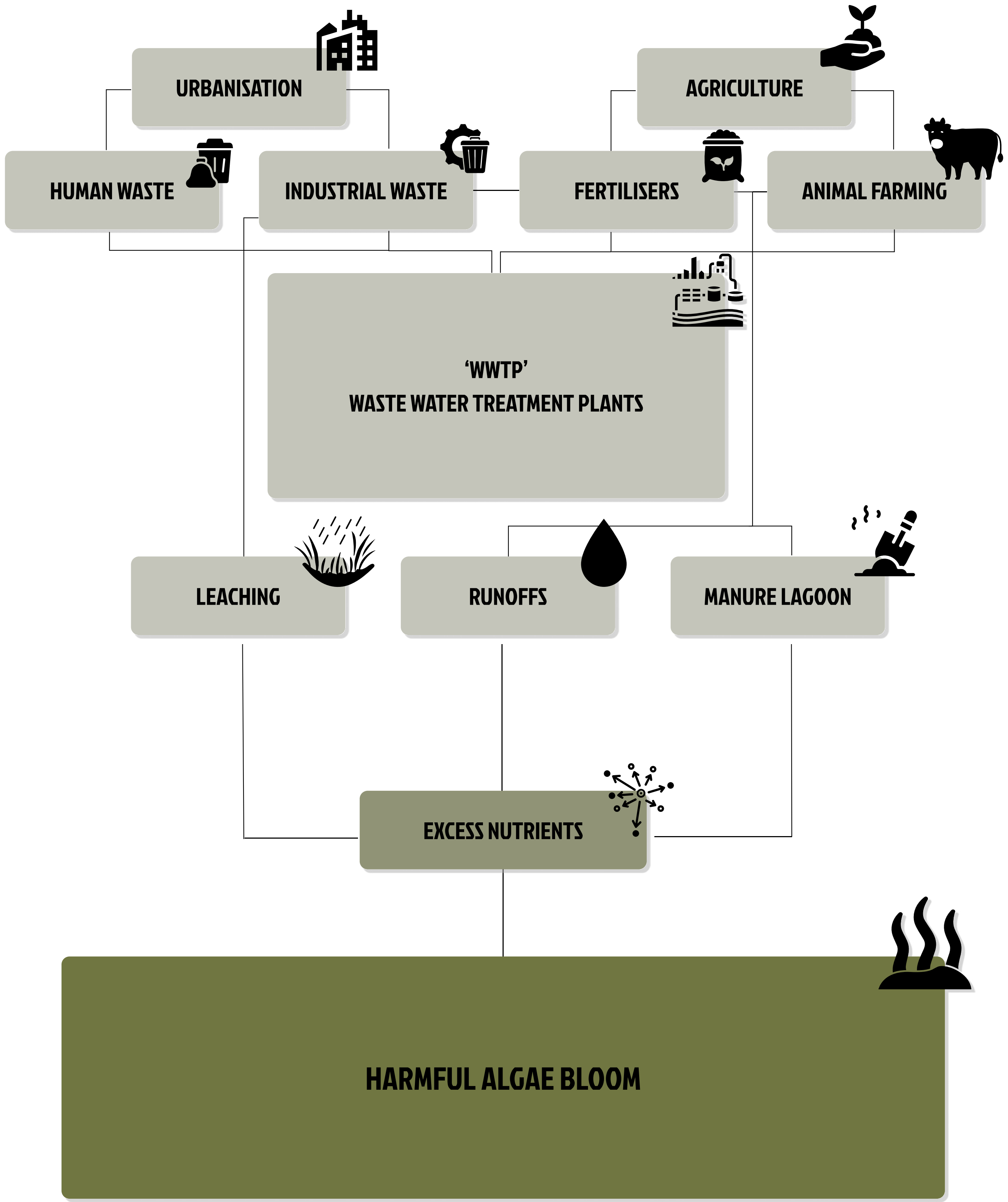
Animal Farming: The practice of animal farming intensifies nutrient pollution as well. Crops cultivated for animal feed are often heavily fertilized, which promotes rapid growth. This over-fertilization, coupled with the disposal of animal waste, leads to substantial nutrient runoff.

Urbanization

Human waste: On an individual level, each person contributes significantly to nutrient loads at WWTPs, with an average adult adding around 6 kilograms of nitrogen and 1 kilogram of phosphorus annually. This input stems from human waste, food remnants, and household chemicals. Urban wastewater is channeled to WWTPs, where it undergoes treatment. If nutrient removal is inadequate, these substances persist in the effluent and are eventually discharged into natural water systems.

Industrial waste: Industries also play a role in nutrient pollution, though to a lesser extent compared to other sources. Industrial processes can lead to nutrient-rich waste, which, if not properly managed, may end up in landfills, contributing to leaching, or is otherwise discharged into WWTPs. Stringent regulations are prompting industries to direct waste towards WWTPs, but the challenge remains in effectively treating and removing these excess nutrients before they reach the marine ecosystem.

Upon delving into the nutrient ecosystem, our team identified that wastewater treatment plants (WWTPs) are hotspots for nutrient concentration. Existing WWTP infrastructure is often inadequate for effective nutrient treatment, constrained by the high costs and complexities of necessary upgrades. In response, we decided to direct our efforts towards developing a solution tailored for WWTPs. Our ambition was to design an affordable and efficient method to enhance their nutrient treatment capabilities, thereby addressing a critical point in the nutrient pollution challenge.



Research
Problem Statement

The presence of excess nutrients, particularly nitrogen and phosphorus, in water treatment plants poses a significant environmental and public health concern. These nutrients, primarily originating from urban and agricultural runoff, can lead to harmful algal blooms that suffocate aquatic bodies and create dead zones in the ecosystem. Thus, there is an urgent need to develop innovative solutions to improve the detection and removal of excess nutrients in wastewater treatment plants.

Nutrient pollution from WWTPs is a global issue but is especially pronounced in densely populated areas or regions with intensive agriculture, as they have a high input of nutrients into the system. Areas with a large number of outdated WWTPs or lacking adequate treatment facilities altogether face significant challenges.
To tackle this problem we decided to use the HMW (how might we) framework to build our research further.

The three HMW were;

How might we assist more efficient wastewater treatment?

How might we intervene in the current infrastructure of wastewater treatment plants?

How might we create an economical and more accessible solution for underfunded communities to improve the detection and removal of excess nutrients in water treatment plans?

Development
Finding a Solution

Upon recognizing that the main source of Harmful Algal Blooms (HABs) is an abundance of nutrients, the team conducted further research and analysis using various tools, literature reviews and expert interviews. This multifaceted approach aimed to deepen the understanding of the problem's scope, its sources, existing solutions, and the gaps within these solutions, providing insights for the team in its conceptualization and ideation stage. Employing the Design Thinking process, we initially delved into the problem space before transitioning to the solution phase. Simultaneously, the team used systems thinking to develop a closed-loop solution.

The following outlines the tools and interviews utilized, the findings and insights gained, and how these inputs contributed to the conceptualization of the final solution.

Development
Desk Research

In both the research and the conceptual development phase, the team used desk research as the initial step. This includes reading scientific papers, news and articles. This allowed us to have an overview of HABs, the effects it has in the marine ecosystem and the main sources of it.

Upon identifying our problem statement, focused on the excess nutrients from WWTPs, we conducted additional research on the intricacies of the WWTP processes. Our research showed that WWTPs typically undergo three distinct stages:

Primary Treatment: In the primary stage, solid waste is separated from water through sedimentation, following the filtration of larger contaminants. The wastewater undergoes tank and filter processes, resulting in “sludge” containing approximately 50% of suspended solids.

Secondary Treatment: In the second stage, oxidation is utilized through three methods: biofiltration, aeration and oxidation ponds. This stage is needed to further purify wastewater.

Tertiary Treatment: The final stage is specifically engineered to filter out nutrients and waste particles that could pose harm to delicate ecosystems. In this phase, wastewater is directed through additional filtering lagoons or tanks to eliminate excess nutrients, providing an additional layer of purification.

This desk research highlighted a key concern in the tertiary treatment phase, which proved to be the main blocker in the removal of excess nutrients. While the European Union currently mandates primary and secondary stages, the tertiary phase is not obligatory. However, by 2045, member states must ensure the adoption of tertiary treatment in larger plants exceeding 150,000 population equivalents (p.e.) and in smaller plants at risk of eutrophication.

Development
More Interviews

To complement the desk research, we also conducted our second round of interviews, engaging with subject experts. The team sought insights into the functionality of the existing solutions, ultimately aiding in the identification of gaps within these solutions. The following lists the experts interviews as part of this process.

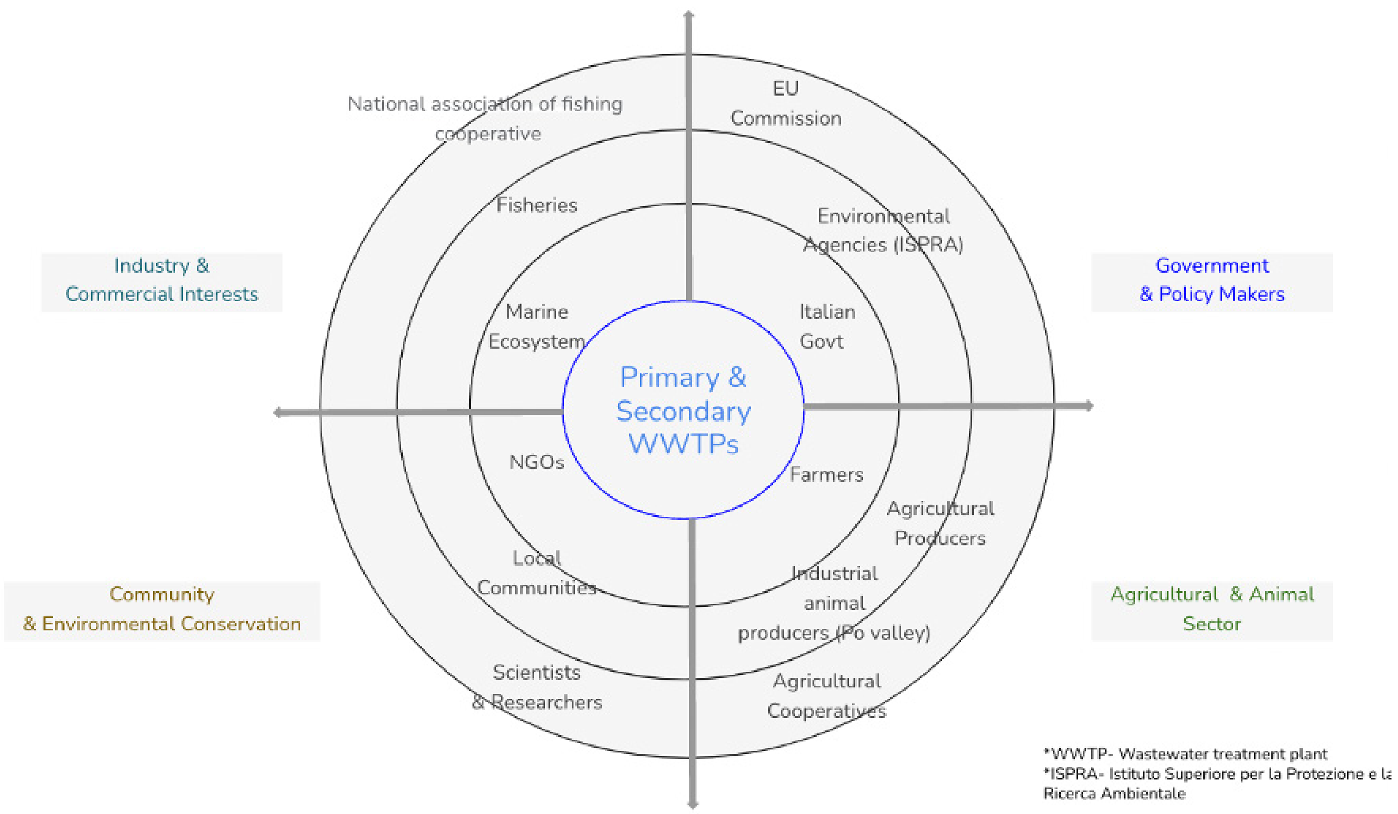
	Arzina Darmayani	**Patricia Gilbert**	**Margarita Fernandez**	**Ruchira Goyal**
Topic	Algae bloom solutions	Algae bloom effects	Algae bloom	Eutrophication
Position	Global Digital Marketer	Professor	Marine economy and taxonomy of HAB	Programme Associate
Main outcome	Successful case studies of LG sonic applications that use ultrasound to eliminate blooms	Learnt the need to focus on geography and better understanding of cyanobacteria	Many technologies already exist in the removal of algae and there are differences in what each solution are solving. At the same time, there are a lot of political situation to consider in solutions and there	Eutrophication and how the excess nutrients are being generated due to over fertilizers usage for animal feed.

Development

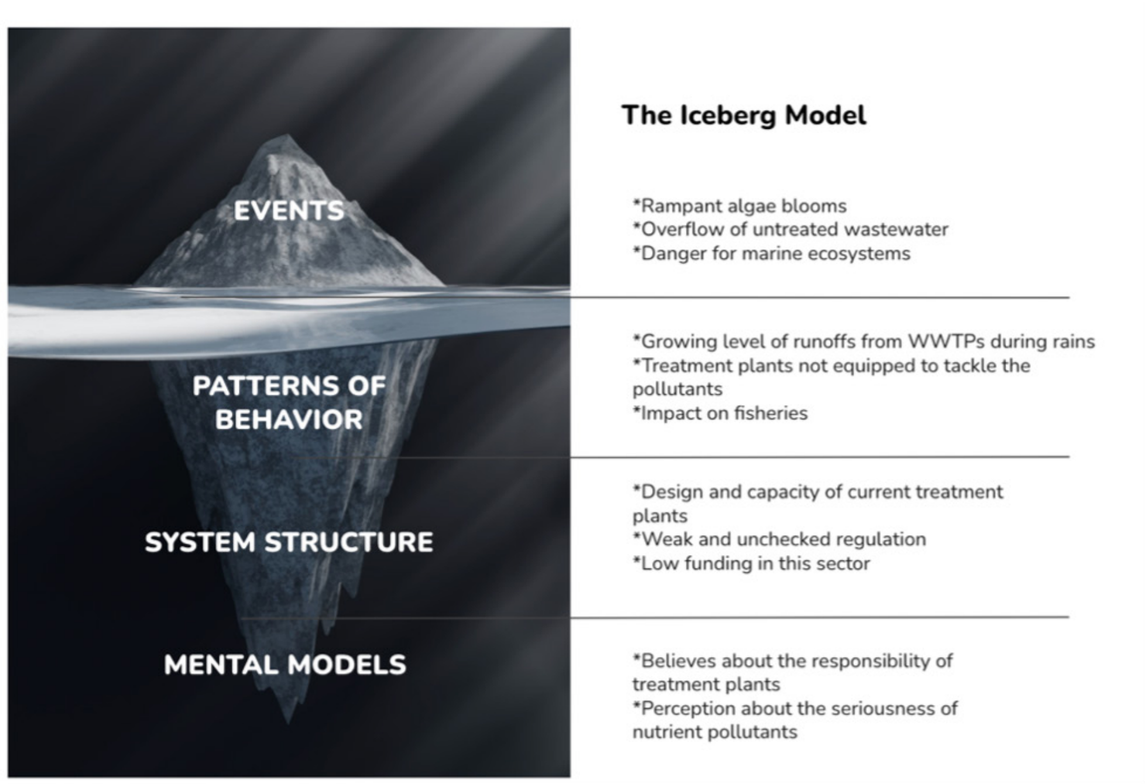
Iceberg Model, People's Connections and 5 Why's

Simultaneously utilizing the Iceberg Model, People & Connections Map and 5 WHYs, proved instrumental for the team in unveiling patterns and root causes related to excess nutrients, HABs and the reluctance of WWTPS to implement tertiary treatment and in understanding of the complex and dynamic relationships within the system.

In the People & Connections Map, we identified the core target audience and the main source of the issue which is the Primary and Secondary WWTPs. From there the team worked towards the outward layers and interconnections. These were categorized into four segments: industry and commercial interests, community and environmental conservation, government and policy makers, and agricultural and animal sectors. A key insight emerged, revealing that these stakeholders operate not in a hierarchical structure but rather as an interconnected web. For instance, government regulations can impact WWTPs methods and scientific research can influence policies.



The Iceberg Model and 5 WHYs mirrored the complexities found in the People & Connections Map, showing the interconnected relationships within the system. In addition, we discovered that a primary factor contributing to the absence of tertiary treatment in WWTPs is the outdated design and limited capacities of existing treatment plant infrastructure. These structures were designed before the need for excess nutrients removal was introduced. The challenge is further heightened by the substantial capital investments required for overhauling current infrastructure, a burden particularly bigger for smaller WWTPs. Moreover, existing regulations lack strong enforcement mechanisms. The leniency in the current EU legislation allows WWTPs more than 20 years without the immediate obligation to comply with the regulation.



5 WHYs Waste water treatment plants (WWTPS)

Why? - Some WWTPs only perform primary or secondary treatment, which may not adequately remove nutrients such as nitrogen and phosphorus.
Why? - Advanced nutrient removal processes (like tertiary treatment) are not always in place because they are more complex and can be more expensive to implement and operate.
Why? - Many WWTPs, especially older ones, were designed before the understanding of the link between nutrient pollution and algal blooms was widespread or before modern nutrient removal technologies were available.
Why? - Retrofitting older plants with advanced nutrient removal technologies requires significant capital investment, which might not be readily available or prioritized.
Why? - There's often a lack of awareness among the public and decision-makers about the role of WWTPs in nutrient pollution, leading to underfunding or delayed upgrades in infrastructure.

Development
The Impact Gap

After using the Iceberg Model, People & Connections Map and 5 WHYs, the team utilized the Impact Gap Canvas. The challenge mapping assisted in refining the broader issue of water pollution, focusing specifically on HABs, and ultimately on excess nutrients coming from WWTPs. In the second checkpoint, the tool directed us to a specific geographical area in Europe: Italy. This focal point enabled a deeper understanding of the challenges faced by WTTPs in the country, their interconnectedness with other WWTPs globally and in mapping existing solutions worldwide. Aligning challenges with solutions and identifying gaps facilitated the team in uncovering white spaces during the concept development phase. Below is the Impact Gap Canvas used in the ideation phase and the findings on each part.

1. Challenge: Within the EU, 82% of sewage undergoes treatment in accordance with EU regulations, but Italy falls below the average with only a 56% treatment rate.

Impact Gap: Cost constraints for Tertiary treatment - WWTPs need high capital investment. At the same time, there's a sharp rise in the marginal cost curve above the secondary treatment stage.

Solution Mapping: WWTPs employ a combination of in-line sensors and periodic laboratory testing to monitor contaminant levels such as nitrogen and phosphorus.

2. Challenge: In Italy, 52.3% of WTTPs exclusively perform primary and secondary treatments, with nearly half not implementing biological treatment involving nitrogen and/or phosphorus removal.

Impact Gap: Estimated cost is €15,310,000 for construction costs and € 361,000/yr for operation and maintenance

Solution Mapping: Biological Nutrient Removal (BNR): - Cultivation of specific bacteria to consume excess nutrients that then get settled out as solid clarifiers.

2. Challenge: Italy allocates 16 euros per citizen annually for the development of new collecting and treatment infrastructure, lagging behind the EU average of 41 euros per citizen per year.

Impact Gap: Many WWTPs were established before the nutrient removal requirements were introduced.

Solution Mapping: Addition of chemicals to react with phosphorus, forming solids for removal

Impact Gap: There's a need for highly skilled personnel to operate and maintain the systems.

Solution Mapping:

Constructed Wetlands - Treated wastewater is passed through constructed wetlands before release. Plants in wetlands absorb nutrients as part of the treatment process. Enhanced Biological Phosphorus Removal: Utilization of bacteria (polypho phate accumulating organisms) in a cyclic anaerobic-aerobic process. These bacteria are then separated from the water in the clarification process and wasted in the form of a sludge.

Tertiary Filters - Final polishing of treated wastewater to remove suspended solids and associated phosphorus.

Nitrification/Denitrification for Nitrogen removal - Nitrification involves the oxidation of ammonia to nitrate by aerobic bacteria. Denitrification reduces nitrate to nitrogen gas under anoxic conditions, releasing it to the atmosphere.

On-farm waste treatment plants, or regional treatment plants handle manure either on-site or through a network of pipelines, contributing to a comprehensive approach to wastewater management.

The solutions work but they are not optimized, and not implemented in all the WWTPs and some of them only remove 80% of the nutrients. For the current microalgae solutions, the process is longer and they create toxins.

Development
Finding white spaces

After utilizing all the models, tools and literary reviews, the team moved to identifying which part of the problem we can come in to create a solution. This involves understanding the existing technology and solutions in three areas: detection, monitoring and removal.

Detection

The detection of excess nutrients in wastewater is a way to prevent and manage HABs. Identifying and controlling the sources of nutrient pollution can contribute to prevent the development of HABs. The team found various solutions related to detection such as:

IoT Water System Solutions: Intuz is a company that enables AI to create software, cloud and IOT solutions. One of their current solutions is IoT in WTTPs, leveraging different sensors for liquid monitoring. It offers the capability to precisely and promptly convey real-time water quality data and development trends. The parameters monitored are temperature, pH level, dissolved oxygen (DO), density of wastewater, ammonia, conductivity, titration, and turbidity. Some of the sensors that are used in the IoT Water Treatment Solution are pH sensor, COD sensor, ORP Sensor, etc. These sensors are crucial in monitoring water quality and accumulating enough data for the WWTPs to take the correct actions.

Hydra-DS Ammonium Analyzer: Electro-Chemical Devices (ECD), a manufacturer of liquid analytical process instrumentation developed the Hydra-DS Ammonium Analyzer which is designed to measure the concentration of dissolved ammonium as nitrogen (NH_4^+-N) in water. Utilizing three electrodes – a specialized Ammonium Ion Electrode, a Potassium Ion Electrode and a pH Electrode – the sensor accurately determines NH_4^+-N concentration directly in the aeration basin of a WWTP.

Monitoring

Monitoring of excess nutrients in bodies of water is a critical aspect of managing and preventing HABs. This could serve as early warning system for HABs development, as nutrient loading assessment from various sources, as identification of specific areas or hotspots where nutrient concentrations are particularly high, and as a way for researchers and scientists to understand the dynamics of eutrophication and its potential consequences for water quality.

LG Sonic PO4 Sensor: LG introduced a PO_4 sensor that allows real-time measurement of PO_4 at various water depths, providing insights into the nutrient levels within natural waters. It offers in situ measurements which delivers both temporal and spatial data resolution.

Imaging Flow Cytobot (IFCBs): IFCBs automated submersible microscopes designed for the continuous monitoring and early detection of HABs. Integrating flow cytometric and video technologies, these devices capture high-resolution images of suspended particles. Employing machine learning, the systems can identify potentially toxic algal species from these images. The Woods Hole Oceanographic Institution (WHOI) was awarded a three year grant to expand the project.

Removal

The removal of excess nutrients in WWTPs is crucial in preventing HABs and maintaining water quality. Removal at the source helps mitigate the risk of the issue, protects ecosystems even before the nutrients reach the body of water and ensures compliance with water quality standards.

Membrane Bioreactors (MBRs): PCI Membrane is one company that employs MBRs, a process that combines microfiltration or ultrafiltration member units with a suspended growth bioreactor. In the MBR process, membranes function as solid-liquid separation devices, retaining biomass within the bioreactor and releasing only treated effluent into the environment. Essentially, MBR replaces conventional activated sludge (CAS) process clarifiers, which is a significant advancement in wastewater treatment.

Algal Turf Scrubber (ATS): Hydromentia, a company that specializes in natural, sustainable, and cost-effective water treatment technologies, focusing on innovative solutions for water pollution control, released an Algal Turf Scrubber. It is a solution that acts as a periphytic algae culture unit, utilizing the prolific nature of these plants to directly remove nitrogen and phosphorus from polluted water. The system features a sloped floway where water is pulsed in waves, cultivating dense mats of algae on the surface. The harvested algal biomass is repurposed into biomass.

LIFE NEWEST Project: This project is a European research project approved by the European Union, developed by Servyeco, which addresses the issue of phosphorus in urban wastewater through the use of natural-based coagulants in tertiary wastewater treatments. It aims to replace the current reliance on toxic and hazardous inorganic coagulants with a safer alternative that enhances the efficiency of phosphorus removal.

Through a thorough understanding and analysis of the existing solutions and leveraging the tools provided to us in the project, our team identified the initial goals for our innovation. Key realizations include:
Existing solutions focus on individual stages of the problem, such as detecting excess nutrients, monitoring the nutrient levels or the actual growth of HABs in a body of water or removing excess nutrients in WWTPs. However, there is a lack of comprehensive solutions that address all three stages simultaneously.

Recognizing that HABs are both a government and public concern, we aim to develop an end-to-end solution that would be advantageous not just for the WWTPs but also, local governments and communities.

Considering the pre-existing nature of many WWTPs, our objective is to create a solution that does not necessitate additional infrastructure. Most WWTPs were constructed before the awareness of the need to remove excess nutrients for HABs, and retrofitting infrastructures would entail substantial capital investments.
A critical aspect of our solutions is to be economical and accessible, catering to a range of WWTP sizes, from small to large, ensuring widespread applicability.

Development
Tech Possibilities & Ideas

Considering our problem statement, the How Might We (HMW) questions we came up with, the existing solutions, and our set goals, the team decided to take a closer look at how we can use the ATTRACT technologies. After further analysis, we picked two technologies, Pipe 4.0 and Snifferdrone, to explore further. The other two, H3D VISIOnAir and IALL, won't work for us because we don't need to focus on imaging in our solution. Listed below are the questions we had about these technologies, how they fit into the project and the ideas we brainstormed and explored.

Pipe 4.0

Questions: How can we make this technology capable of detecting substances inside the water?
Is it capable of detecting and/or absorbing nitrogen and phosphorus?

Idea: Smart Pipe - Using Pipe 4.0, we thought of creating a smart pipe installed in WWTPs. The pipe will integrate algae to absorb nutrients, while simultaneously measuring nutrient levels in the flowing water.

Snifferdrone

Questions: How can we use the e-nose detecting substances in water?
Can it detect nitrogen and phosphorus within or outside of water?

Idea: Boat Sensors - Employing a boat equipped with sensors similar to those in the Snifferdrone, we can monitor nutrient removal performance around WWTP tanks. This approach allows us to track nitrogen and phosphorus levels in the treated water.

After assessing feasibility and consulting with researchers and coaches, the team decided to further develop the boat sensor idea. Pipe 4.0 and the Smart Pipe concept were ruled out for two main reasons:

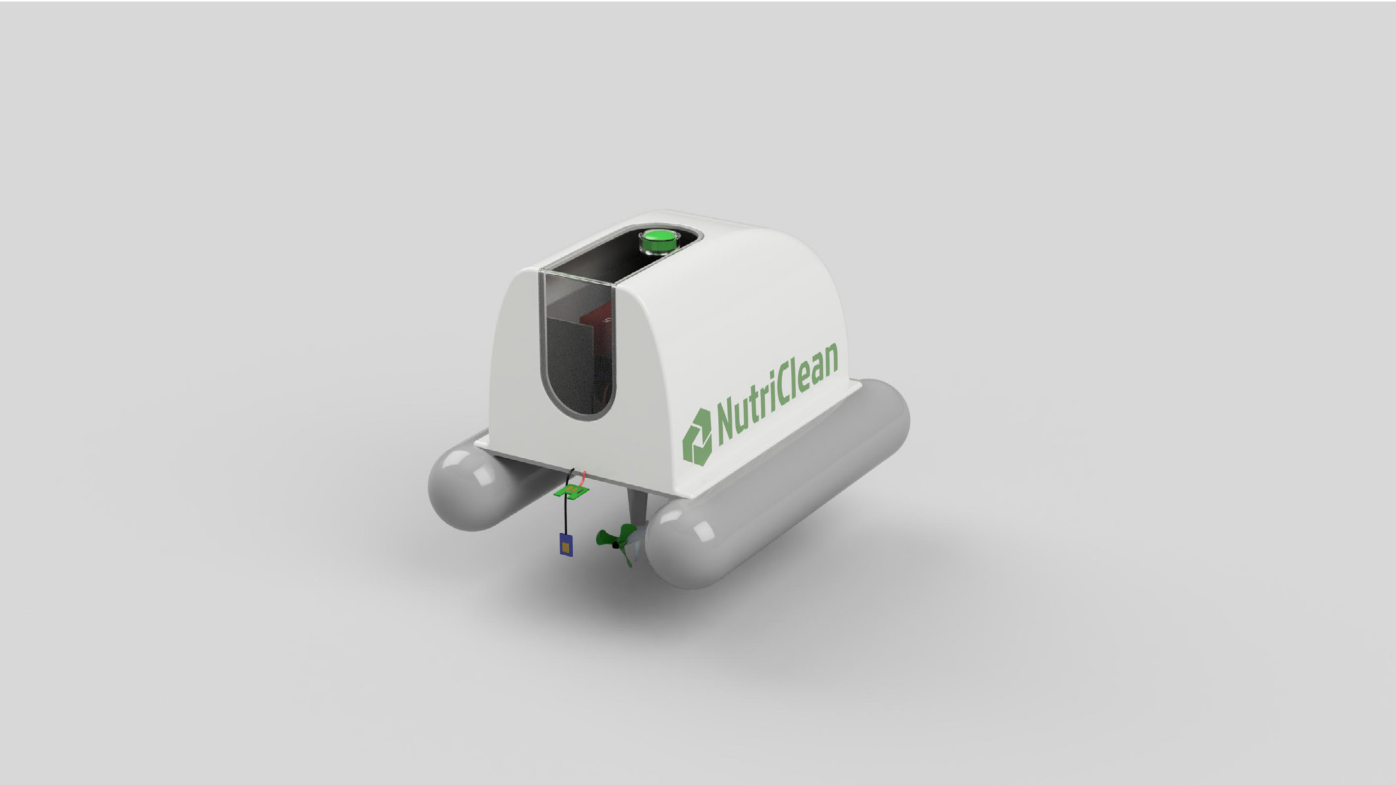
Algae growth in the pipe requires stagnant water for optimal efficiency.
Isolating water in the pipe hinders continuous monitoring of nutrient levels. Pipe 4.0 necessitates water retrieval and testing each time it flows, impeding real-time assessment.

Solution
NutriClean

NutriClean is a groundbreaking initiative aimed at elevating water treatment plants throughout Europe by seamlessly integrating advanced technologies. The solution harmonizes existing water treatment methods with a state-of-the-art monitoring device, guaranteeing optimal plant performance. Our innovative approach focuses on making algae a robust and reliable solution for nutrient removal. NutriClean comprises three key components: NutriSense, Algae Turf Scrubber, and Natural Coagulant, all contributing to the establishment of a circular economy.

NutriSense

Our aquatic device, equipped with eight sensors, provides real-time data on algae performance, offering crucial insights into nitrogen and phosphorus absorption. The prototype incorporates electric components and sensors.



Electric components and sensors: NutriSense comprises multiple components, namely pH, temperature, light, and water turbidity. Each of these components plays a crucial role in assessing the performance of algae serving as purifiers to eliminate nitrogen and phosphorus in water treatment plants. The pH level indicates the acidity or alkalinity of the water, temperature affects biochemical reactions, light is essential for photosynthesis, and water turbidity reflects its clarity. To integrate these sensors, we connected them to an Arduino WiFi Nano 33, following the recommended connections outlined in the datasheet. Additionally, certain connections were soldered to ensure the proper assembly of the prototype.

Here is the detailed list of the sensors that were used for the prototyping:

Temperature	DS18B20 Temperature	(check Datasheet)
pH	SEN0161 Analog pH Sensor	(check Datasheet)
Light	Flora Lux sensor	(check Datasheet)
Turbidity	Turbidity sensor for Arduino v1.0	(check Datasheet)

Ideally, the prototype should also include nitrogen and phosphorus sensors that would be compatible with the prototype. However, these sensors were not incorporated into the final prototype due to their high cost. It is worth noting that they are envisioned to be part of the solution for continuously monitoring the levels of these nutrients in water, ensuring a comprehensive evaluation over time.

Software Implementation

In this section, four distinct software components were developed to enhance the functionality of the prototype.

1. Heatmaps: a code was implemented for pH and temperature heatmaps using Python.
2. Real-time plots: Another Python-based component was dedicated to plotting real-time graphs of pH, temperature, light, and water turbidity.
3. Radial graph: a third code was implemented using Matlab, this last component was implemented to generate a radial percentage graph.
4. Arduino: Arduino code to assemble and communicate the different sensors.

This unique visualization aids in identifying environmental conditions, such as pH, temperature, turbidity, or light, where the algae-based filters may be experiencing shortcomings or underperforming. Each software element contributes to a comprehensive and efficient monitoring process for evaluating the system's performance.

Check the annexes at the end of this report to see the full codes.

Algae Turf Scrubber

Inspired by Hydromentia, our approach involves using periphytic algae to enhance nutrient absorption from wastewater. Deployed as mats over a 2.5-acre area, these scrubbers are continuously monitored using NutriSense to optimize their performance.

Coagulants

Drawing inspiration from the Life Newest project, where the EU developed natural coagulants for nutrient absorption, this component acts as a complement to the algae scrubber. In cases where natural conditions hinder target absorption, the dashboard recommends coagulant usage to meet daily requirements.

Dashboard and monitoring

A user-friendly dashboard is a pivotal aspect of our solution, providing treatment plant managers with precise information from the eight sensors. It offers assistance in optimizing overall scrubber performance and addresses inadequate conditions during operation.

Solution
User Journey

For our target we look at medium to large size WWTPs as our ideal customer. Currently lacking the nutrient removal from its treatment plants, Nutriclean will provide an end-to-end solution that removes excess accurately, reliably and consistently. To visualize how we imagine the process to look like.

1. Field visit by the Nutriclean team (assessment and first evaluation on the treatment required)

2. Economical considerations (the company will ensure that the economical constraints are well understood before recommending the solution)

3. 1 month training with Nutrisense (ensuring the administration is comfortable with the usage)

4. 3 month hand holding with the first bathes of algae (the company will ensure that sale is not completed with the algae but to ensure the treatment plant can utilize the algae scrubbers and Nutriesense)

5. 3 month reviews (ongoing review every 3 months to understand areas to improve and problems that the treatment plants are facing)

Solution
Business Model

Value proposition

Our solution's primary value proposition lies in real-time tracking, ensuring algae's viability for WWTPs. Bridging the impact gap, we aim to unite current solutions with a user-friendly dashboard, easing the challenges faced by treatment plant operators. NutriClean alleviates cost constraints for WWTPs, providing continuous support through our dedicated team of engineers, facilitating knowledge transfer and continuous improvement.

Business impact

Cost Effectiveness
Operational cost -

Assumptions;
Inflow of water - 10000 liters per day
Nutrient inflow - 45 mg per liter
Phosphorous inflow - 3.5 mg per liter

The yearly saving of this effluent is approximately 2,000 euros. Calculated based on a case study by Hydromentia, which compared chemical vs. algae absorption in Korea.

Water treament plant has an inflow of 10000 literes per day		
	Current cost (euro/kg)	Alage scrubber (euro/kg)
Nitrogen (45mg/l)	66	57
Phosphorous (3.5mg/l)	238	154

Assuming the same inflows, the biomass created will be 73,504 kgs with a market price of 250 euros per ton. This generates an additional revenue of 18,376 euros per year, transforming a cost center into a revenue stream.

The team envisions structuring the organization as an impact startup with a dual focus on financial success and environmental impact. The primary objective behind the establishment of NutriClean is to contribute to the realization of the United Nations' Sustainable Development Goal 14.1, specifically targeting the reduction of marine pollution. This goal aims to prevent and significantly decrease marine pollution, encompassing various forms, especially those originating from land-based activities such as marine debris and marine pollution, by the year 2025.

Solution
Impact

In alignment with this goal, the team has used the Five Dimensions of Impact, serving as a framework to analyze the primary and quantitative impacts generated by our project. Additionally, we have compiled a list of qualitative impacts that the project contributes to.

Five Dimensions of Impact

***What** (is the intended outcome)*
- Contribution to UN's SDG 14.1: Reduce Marine Pollution
- Contribution to reduction of Harmful Algal Blooms
- Contribution to purification of waters
- Alignment with EUs' 2045 treatment goals

***Who** (experiences it)*
- Target stakeholder: Wastewater Treatment Plants in Italy
- Other stakeholders: Local Communities, Fisheries and Aquaculture, Marine ecosystem

***How much** (of the outcome is experienced)*
- WWTPS: 1,934 with not tertiary treatment out of 3,696 WWTPs
- 7.6B of water treated out of 46B From 50% to 66% of water treated (16% in addition due to the project) during launch - 38.4% of water treated out of 46B From 66% to 100% of water treated. (34% in addition due to the project)

***Contribution** (of the business to that outcome)*
- The project will assist WWTPs in achieving compliance with the EU's 2045 wastewater treatment directive. Without this initiative, WWTPs would incur higher costs to implement a tertiary treatment stage and rely on existing, more expensive solutions that may not adequately remove the excess nutrients required.

***Risk** (that the impact doesn't happen)*
- Stakeholder participation risk: potential resistance of WWTPs.
- Execution risk: likelihood that the developed product may not function effectively across various WWTPs and face challenges in scaling to other territories.
- Efficiency risk: possibility that the project could incur higher costs and be less efficient compared to existing solutions. to 100% of water treated. (34% in addition due to the project)

Solution
Other long-term impacts

Health

Harmful Algal Blooms have far-reaching consequences, contributing to health issues that may not be immediately apparent. These repercussions include compromised food and drinking water safety, as well as an increased risk of respiratory diseases. A notable example occurred in the Gulf of Mexico, where the toxin produced by one algae brevis become airborne during beach wave breaks, causing considerable respiratory irritation among individuals in the vicinity. The involvement of NutriClean in preventing HABs across different water sources directly translates to a positive impact on the health of the surrounding communities.

Productive activities

The degradation of water quality has the potential to impact various economic activities that rely on water resources, such as agricultural productivity, industrial output, market value of harvested crops, and fisheries and aquaculture. One example is the annual damages caused by HABs, resulting in $2 billion costs to the US economy. These costs primarily stem from increased filtration expenses and declines in fish population. The implementation of our solution holds the potential to mitigate economic losses arising from water degradation, contributing to a more sustainable and resilient economy.

Solution
Revenue Streams

To secure a robust financial foundation during the initial years of our business, we are actively exploring diverse revenue streams.

Grants & fundings: In the initial phase of the project, our fundraising strategy involves seeking support from both public and private grants, particularly those aligned with marine pollution and water purification initiatives. In addition, we intend to secure funding from impact investors and capital funds. The following are the targeted organization and companies that we believe can contribute to the success of our impact start-up.

Horizon Europe: Within the framework of Horizon Europe, the European Commission provides funding for research and innovation that assess the effects of climate change on our land and marine environments, as well as on natural resources, agriculture and food systems.

LIFE Programme: Managed by the European Commission, LIFE is a grant program specifically designed to support projects that contribute to the implementation, updating and development of EU environmental and climate policies.

The EEA and Norway Grants: These grants are designed with dual objectives: to foster greater equality across Europe, both socially and economically, and to enhance and fortify relations between Iceland, Liechtenstein, and Norway, and the 15 Beneficiary States in Europe.

Program for Early-stage Grants Advancing Sustainability Science (PEGASus): A program dedicated to advancing knowledge, fostering innovation, and developing evidence-based solutions for the most complex sustainability challenges globally.
Italian Angels for Growth: Italy's leading seed venture capital firm with an objective to heighten awareness within the venture capital industry about the significance of Environmental, Social and Governance (ESG) considerations.

Ananda Impact Ventures: An impact venture VC fund, with Level 2 certification under the Diversity VC Standard. The fund places emphasis on supporting impact-driven founders dedicated to the principles of the UN's Sustainability Development Goals.
Alter Equity: A French fund that actively engages with founders who are committed to addressing environmental or social challenges.

Oltre Impact: An impact fund company that actively addresses both social and environmental challenges and places particular emphasis on solutions that contribute to fostering healthier individuals, empowering people, and creating a cleaner environment.

European Circular Bioeconomy Fund: A pan-European VC with a foundational commitment to sustainability. It's the first VC impact fund exclusively dedicated to the circular bioeconomy that is focused on supporting founders who drive innovations accelerating the transition from a fossil-based economy to a bio-based one.

Rubio Impact Ventures: A prominent impact investing firm specializing in investments in purpose-driven companies. Their focus is on supporting businesses that actively seek to create positive social and environmental impact.

Operating cash flow & revenue model

Once the project is underway and we have secured funding from grants and impact venture companies, the team will progress to the full-scale production of the technology. Our revenue streams will primarily be generated through the sale of the NutriSense sensor and dashboard to WWTPs. Collaboration with Hydromentia for the Algal Turf Scrubber and Serveyco for the coagulant will involve negotiating advantageous deals to offer WWTPs a more competitive pricing structure.

In the long term, our strategic plan involves the internal production of our own Algal Turf Scrubber and coagulants, allowing us to offer an end-to-end solution. This approach positions us to provide comprehensive solutions to WWTPs and further diversity our revenue streams.

Solution **Costing**

We've calculated the direct costs associated with producing the NutriSense sensors, resulting in an amount of €2,134 per sensory. To streamline the production processes and ensure cost efficiency, we have opted to outsource this manufacturing to a third-party production company. As for the indirect costs and the expenses related to the Hydromentia Algal Turf Scrubber and Serveyco coagulants, these figures will be determined at a later stage following ongoing discussions and negotiations. This approach allows for a more comprehensive understanding of all associated costs before finalizing the costing and budget.

NutriSense Production Cost

Lifeline (in years)	**Items**	**Cost in €**
1	Nitrogen Sensor	1000
5	Phosphorus Sensor	1000
5	Temp Sensor	6
1	pH Sensor	35
5	Turbidity Sensor	10
10	Light Sensor	8
	Motherboard	25
	Shell Manufacturing & Assembly	40
	Battery	10
		Total: € 2,134

Solution
Roadmap

The project is structured into five phases, each with specific objectives and activities:

Phase I (Funding & Research): This phase focuses on engaging stakeholders, venture companies, and potential partners to secure necessary financial support. Efforts are directed towards establishing key partnerships, particularly with collaborators such as Hydromentia and Serveyco. Continuous research is undertaken to ensure ongoing viability throughout this phase.

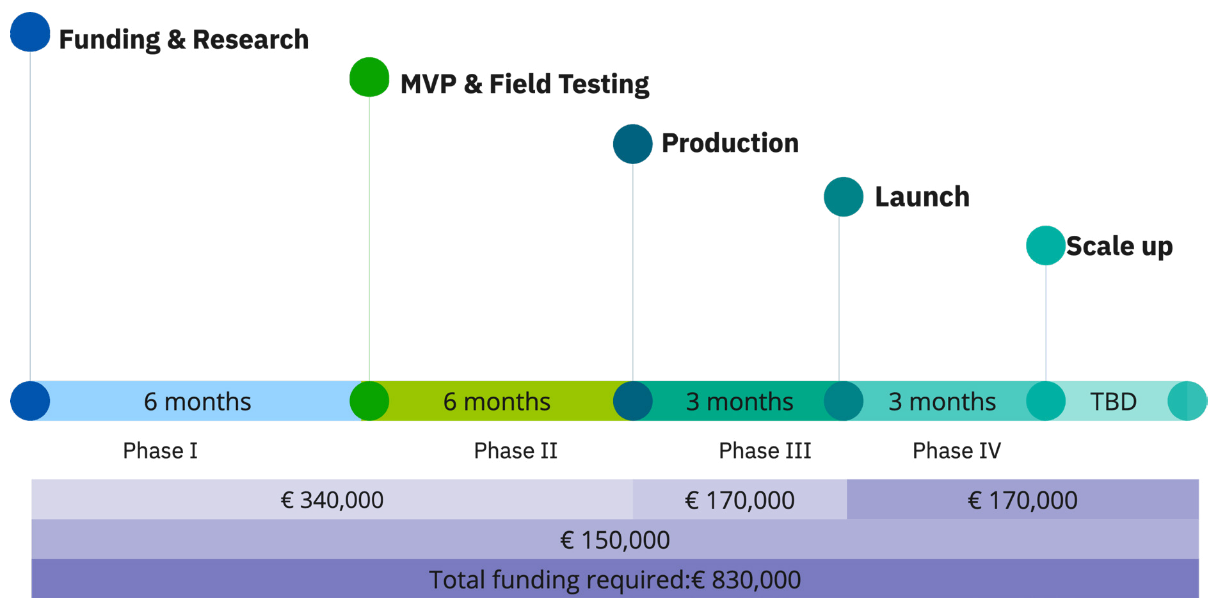
Phase II (MVP Development & Field Testing): In the second stage, the project shifts its focus to the creation of prototypes and the testing of the Minimum Viable Product (MVP). With at least four WTTPs in Italy as testing grounds, data from the initial testing is analyzed to identify areas for technological enhancement.

Phase III: (Iteration & Production): Next phase includes adaptations based on the results obtained from field testing. Simultaneously, the production of the initial 500 units commences, specifically targeting 30% of WWTPs in Italy lacking tertiary treatment. Sales and marketing initiatives are initiated to raise awareness, and the phase starts data collection and impact measurement efforts.

Phase IV (Product Launch in Italy): Our fourth phase signifies the product launch in Italy, where an additional 1,500 units are produced to cater to the remaining WWTPs in the country without tertiary treatment. This stage sustains sales and marketing campaigns, data collection, and impact measurement activities. A post-launch review is conducted to assess the project's alignment with set targets and the satisfaction of WWTPs with the technology.

Phase V (Scale up): The last phase involves expanding the business beyond Italy to other target countries, particularly focusing on Eastern European nations such as Croatia, Poland, and Romania. Simultaneously, research and studies commence for the development of our own Algal Turf Scrubber and coagulants.

The product journey is estimated to require a total investment of 830,000 euros, with a planned duration of 18 months commencing in January 2024. As outlined in the revenue stream strategy above, income generated during Phase 4 from the full-scale production will be strategically utilized to sustain the project's ongoing operations and facilitate its scaling efforts. This approach ensures a self-sustaining model for continued project success.



NutriClean
Conclusion

In conclusion, NutriClean stands as a pioneering solution that addresses the multifaceted challenges associated with Harmful Algal Blooms (HABs) in water treatment plants (WWTPs) across Europe. The initiative's conceptualization, grounded in extensive research, interviews, and analysis, reflects a comprehensive understanding of the complexities involved in excess nutrient removal. The utilization of various tools, models, and methodologies, such as the Iceberg Model, People & Connections Map, 5 WHYs, and the Impact Gap Canvas, played a pivotal role in unraveling root causes and identifying strategic intervention points.

The culmination of these efforts resulted in the development of NutriClean, a three-pronged approach encompassing NutriSense, Algae Turf Scrubber, and Natural Coagulant. This integrated system not only addresses the immediate need for real-time monitoring and nutrient removal but also aligns with the broader goals of creating a circular economy. By leveraging algae's natural potential for nutrient absorption and biomass creation, NutriClean transforms a traditionally challenging aspect of wastewater treatment into a cost-effective and revenue-generating process. The user journey, as outlined, reflects a meticulous onboarding process, ensuring that WWTPs seamlessly integrate NutriClean into their existing operations.

The emphasis on field visits, training, and ongoing reviews underscores a commitment to long-term success and adaptability to the unique needs of each treatment plant. From a business perspective, NutriClean's value proposition, impact metrics, and revenue streams provide a solid foundation for financial sustainability. The emphasis on securing grants and funding in the initial stages aligns with the mission to contribute to the United Nations' Sustainable Development Goal 14.1, emphasizing the reduction of marine pollution. The strategic partnerships with organizations like Hydromentia and Serveyco, along with the envisioned internal production of key components, showcase a forward-thinking business model that aims to evolve with the project's growth.

The product roadmap, delineated across five distinct phases, reflects a nuanced understanding of the project's progression. Starting from funding and research to a gradual scale-up, each phase aligns with tangible goals, impact measurements, and strategic maneuvers. The projected investment, revenue generation, and self-sustaining model during the scale-up phase demonstrate a pragmatic and well-thought-out approach.
In essence, NutriClean is not just a technological solution but a transformative initiative poised to make a significant contribution to environmental sustainability. By targeting the reduction of marine pollution, aligning with regulatory goals, and introducing an

economically viable and circular approach to nutrient removal, NutriClean emerges as a beacon of innovation in the realm of water treatment. As the project moves forward, its success will not only be measured in financial terms but in the tangible improvements it brings to water quality, ecosystem health, and the well-being of communities relying on these vital resources.

Annex
Resources

1. European Parliament. (2023). European Parliament Briefing: Horizon Europe - EU's Key Programme for Research and Innovation (EPRS_BRI(2023)739370_EN).

2. Azevedo, L., Pereira, R., & Menaia, J. (2020). Harmful Algal Blooms: Impacts and Detection Monitoring Strategies. Frontiers in Bioengineering and Biotechnology, 8, 962719.

3. Lg Sonic. (n.d.). LG Sonic PO4 Sensors.

4. PCI Membranes. (n.d.). Membrane Bioreactors (MBR) for Wastewater Treatment

5. NOAA. (n.d.). Transitioning Imaging FlowCytobot.

6. Agua Residuales. (n.d.). Servyeco Desarrolla un Coagulante de Origen Natural Que Elimina el Fósforo de las Aguas Residuales.

7. Servyeco. (n.d.). Home.

8. Roth, V. L., Lomas, M. W., Heidelberg, K. B., Kelly, L., & Nencioli, F. (2022). Rapid Expansion of Industrial Farming in the US Contributes to Increased Pollution and Harmful Algal Blooms. University of Maryland Center for Environmental Science.

9. Water Calculator. (n.d.). The Toxic Algae-Agriculture Connection. Retrieved from link Brand, L. (n.d.). Nutrient Pollution and Algal Blooms: Causes and Solutions

10. He, R., & Jin, X. (2022). Anaerobic Ammonium Oxidation in a Membrane Bioreactor (MBR) Treating Domestic Wastewater. Bioresource Technology, 330, 124979.

11. Wanner, J., Feitz, A., Holliger, C., & Oehmen, A. (2021). Impact of Polyphosphate Accumulation on Biological Nutrient Removal Performance in a Full-scale Membrane Bioreactor. Water Research, 193, 116829.

For the costing references, included are the relevant ones:

1. Han, Y., & Ergas, S. J. (2017). Biomass Production Cost for Algal Turf Scrubber. Journal of Environmental Management, 202, 267-276.

2. CoralVue. (n.d.). IceCap Algae Turf Scrubber

3. Lee, D. S., Cho, S. H., Cho, H. J., Jeong, J. Y., & Kim, H. (2021). Algal Turf Scrubber® as a Nitrogen and Phosphorus Control Measure in South Korea. Water, 13(17), 2406.

All Links

1. https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/739370/EPRS_BRI(2023)739370_EN.pdf
2. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6999062/
3. https://www.lgsonic.com/lgsonic-po4-sensor/
4. https://www.pcimembranes.com/articles/membrane-bioreactors-mbr-for-wastewater-treatment/#:~:text=In%20the%20MBR%20process%2C%20membranes,activated%20sludge%20(CAS)%20process.
5. https://ioos.noaa.gov/project/ott-transitioning-imaging-flowcytobot/
6. https://www.aguasresiduales.info/revista/reportajes/servyeco-desarrolla-un-coagulante-de-origen-natural-que-elimina-el-fosforo-de-las-aguas-residuales
7. https://www.servyeco.com/
8. https://www.frontiersin.org/articles/10.3389/fbioe.2022.962719/full
9. https://www.umces.edu/news/rapid-expansion-of-industrial-farming-in-us-contributes-to-increased-pollution-harmful-algal
10. https://www.watercalculator.org/news/articles/toxic-algae-agriculture-connection/
11. https://www.linkedin.com/pulse/nutrient-pollution-algal-blooms-causes-solutions-lisa-brand/
12. https://www.sciencedirect.com/science/article/abs/pii/S0956053X18307554
13. https://www.sciencedirect.com/science/article/abs/pii/S1464343X21002119
14. https://www.sciencedirect.com/science/article/abs/pii/S2211926416303046
15. https://www.coralvue.com/icecap-algae-turf-scrubber
16. https://www.researchgate.net/publication/368390869_Algal_Turf_ScrubberR_as_a_Nitrogen_and_Phosphorus_Control_Measure_in_South_Korea
17. https://www.noaa.gov/what-is-harmful-algal-bloom
18. https://www.yakimawa.gov/services/wastewater-treatment-plant/operations-maintenance/
19. https://water.europa.eu/freshwater/countries/uwwt/italy
20. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2003WR002037
21. https://wedocs.unep.org/bitstream/handle/20.500.11822/7465/-Economic_Valuation_of_Wastewater_The_Cost_of_Action_and_the_Cost_of_No_Action-2015Wastewa-

ter_Evaluation_Report_Mail.pdf.pdf?sequence=3&isAllowed=y
22. https://cinea.ec.europa.eu/programmes/life_en
23. https://rea.ec.europa.eu/funding-and-grants/horizon-europe-cluster-6-food-bio-economy-natural-resources-agriculture-and-environment/land-oceans-and-water-climate-action_en
24. https://www.italianangels.net/en/news/esg-venture-capital-iag-invests-in-sustainability/
25. https://www.xyzlab.com/post/vc-funds-and-angel-investors-in-italy
26. https://www.vestbee.com/blog/articles/top-impact-investing-vc-funds-from-europe
27. https://eeagrants.org/about-us
28. https://www.renewablenutrients.com/ammonia-recovery
29. https://www.ijabe.org/index.php/ijabe/article/view/2318/pdf
30. https://www.sciencedirect.com/science/article/pii/S2211912413000540
31. https://www.lenntech.com/phosphorous-removal.htm
32. https://www.consilium.europa.eu/en/press/press-releases/2023/10/16/council-adopts-position-on-new-rules-for-a-more-efficient-treatment-of-urban-waste-water/#:~:text=Wastewater%20treatments&text=By%202045%2C%20Member%20states%20will,areas%20at%20risk%20of%20eutrophication
33. https://www.sciencedirect.com/topics/chemical-engineering/biological-nutrient-removal#:~:text=Biological%20nutrient%20removal%20is%20a,during%20wastewater%20treatment%20%5B74%5D.
34. https://www.sciencedirect.com/topics/engineering/chemical-precipitation
35. https://www.sciencedirect.com/science/article/pii/S1319562X12000332
36. https://ecdi.com/two-in-one-sensor-for-nutrient-nitrogen-monitoring-in-waste-water-effluent-and-surface-water-storage
37. https://hydromentia.com/technologies/algal-turf-scrubber/
38. https://environment.ec.europa.eu/topics/water/urban-wastewater_en#wastewater-monitoring
39. https://www.sciencedirect.com/science/article/pii/S0048969722046915?via%3Dihub
40. https://stockholmuniversity.app.box.com/s/sr0nfknm95oydnnsm1zj0c526qzjn1vs/file/1305811057353
41.

Unset
```
 /*

  WiFi UDP Send and Receive String

 This sketch wait an UDP packet on localPort using the WiFi module.

 When a packet is received an Acknowledge packet is sent to the client on port
remotePort

 created 30 December 2012

 by dlf (Metodo2 srl)

 */

#include <SPI.h>
#include <WiFiNINA.h>
#include <WiFiUdp.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_TSL2561_U.h>

Adafruit_TSL2561_Unified tsl = Adafruit_TSL2561_Unified(TSL2561_ADDR_FLOAT,
12345);

void displaySensorDetails(void)
{
  sensor_t sensor;
  tsl.getSensor(&sensor);
  Serial.println("------------------------------------");
  Serial.print  ("Sensor:       "); Serial.println(sensor.name);
  Serial.print  ("Driver Ver:   "); Serial.println(sensor.version);
  Serial.print  ("Unique ID:    "); Serial.println(sensor.sensor_id);
  Serial.print  ("Max Value:    "); Serial.print(sensor.max_value); Serial.println("
lux");
  Serial.print  ("Min Value:    "); Serial.print(sensor.min_value); Serial.println("
lux");
  Serial.print  ("Resolution:   "); Serial.print(sensor.resolution);
Serial.println(" lux");
  Serial.println("------------------------------------");
  Serial.println("");
  delay(500);
}
```

```
void configureSensor(void)
{
 /* You can also manually set the gain or enable auto-gain support */
 // tsl.setGain(TSL2561_GAIN_1X);    /* No gain ... use in bright light to avoid sensor
saturation */
 // tsl.setGain(TSL2561_GAIN_16X);   /* 16x gain ... use in low light to boost
sensitivity */
 tsl.enableAutoRange(true);         /* Auto-gain ... switches automatically between 1x
and 16x */

 /* Changing the integration time gives you better sensor resolution (402ms = 16-bit
data) */
 tsl.setIntegrationTime(TSL2561_INTEGRATIONTIME_13MS);    /* fast but low
resolution */
 // tsl.setIntegrationTime(TSL2561_INTEGRATIONTIME_101MS);  /* medium resolution
and speed  */
 // tsl.setIntegrationTime(TSL2561_INTEGRATIONTIME_402MS);  /* 16-bit data but
slowest conversions */

 /* Update these values depending on what you've set above! */
 Serial.println("------------------------------------");
 Serial.print  ("Gain:     "); Serial.println("Auto");
 Serial.print  ("Timing:    "); Serial.println("13 ms");
 Serial.println("------------------------------------");
}
const int oneWirePin = 3;

OneWire oneWireBus(oneWirePin);
DallasTemperature sensor(&oneWireBus);

int status = WL_IDLE_STATUS;
char ssid[] = "CERN";     // your network SSID (name)

int keyIndex = 0;        // your network key Index number (needed only for WEP)

unsigned int localPort = 2390;    // local port to listen on

char packetBuffer[256]; //buffer to hold incoming packet
char  ReplyBuffer[] = "acknowledged";     // a string to send back

WiFiUDP Udp;
const int buzzer = 9;

unsigned long int avgValue;  //Store the average value of the sensor feedback
```

```
float b;
int buf[10],temp;

void setup() {

 //Initialize serial and wait for port to open:
 sensor.begin();
 Serial.begin(9600);
 Serial.println("Light Sensor Test"); Serial.println("");
 pinMode(buzzer, OUTPUT);
 /* Initialise the sensor */
 //use tsl.begin() to default to Wire,
 //tsl.begin(&Wire2) directs api to use Wire2, etc.
 if(!tsl.begin())
 {
  /* There was a problem detecting the TSL2561 ... check your connections */
  Serial.print("Ooops, no TSL2561 detected ... Check your wiring or I2C ADDR!");
  while(1);
 }
 Serial.println("Hola");
 /* Display some basic information on this sensor */
 displaySensorDetails();

 /* Setup the sensor gain and integration time */
 configureSensor();

 /* We're ready to go! */
 Serial.println("");

 // check for the WiFi module:

 if (WiFi.status() == WL_NO_MODULE) {

  Serial.println("Communication with WiFi module failed!");

  // don't continue

  while (true);

 }

 String fv = WiFi.firmwareVersion();

 if (fv < WIFI_FIRMWARE_LATEST_VERSION) {

  Serial.println("Please upgrade the firmware");
```

```
 }

 // attempt to connect to Wifi network:

 while (status != WL_CONNECTED) {

  Serial.print("Attempting to connect to SSID: ");

  Serial.println(ssid);

  // Connect to WPA/WPA2 network. Change this line if using open or WEP network:

  status = WiFi.begin(ssid);

  // wait 10 seconds for connection:

  delay(10000);

 }

 Serial.println("Connected to wifi");

 printWifiStatus();

 Serial.println("\nStarting connection to server...");

 // if you get a connection, report back via serial:

 Udp.begin(localPort);

}
int light = 0;
float temperatura = 0;
bool alert = false;


void loop() {

 /* Get a new sensor event */
 for(int i=0;i<10;i++)    //Get 10 sample value from the sensor for smooth the value
  {
   buf[i]=analogRead(A1);

   delay(10);
  }
```

```
 avgValue=0;
 for(int i=0;i<10;i++){            //take the average value of 6 center sample
  avgValue+=buf[i];
 }
 float phValue=(float)avgValue*5.0/1024/10; //convert the analog into millivolt
 phValue=3.5*phValue;             //convert the millivolt into pH value

 int sensorValue = analogRead(A0);// read the input on analog pin A0:
 float nitiValue = sensorValue * (3.3 / 1024.0) + 2.2;


 sensors_event_t event;
 tsl.getEvent(&event);

 //LIGHT in lux

 if (event.light)
 {
  light = event.light;
 }
 else
 {
  Serial.println("Sensor overload");
 }


 sensor.requestTemperatures();
 temperatura = sensor.getTempCByIndex(0) + 3;

//Alarm buzzer

 if ((light < 200) || ( phValue < 5 || phValue > 9)  || (temperatura < 20 || temperatura >
30)) {
  alert = true;
  tone(buzzer, 500); // Send 1KHz sound signal...
  delay(2000);    // ...for 1 sec
  noTone(buzzer);
}
else {
  alert = false;
}

 // Send the data via Wifi
```

```
 String resultado = String(temperatura) +"," +
String(light)+","+String(nitiValue)+","+String(phValue)+","+String(alert) ;

 Udp.beginPacket("194.12.147.242", 2390); // Reemplaza con la dirección IP de tu
máquina y el puerto que escucha el script de Python

 Serial.println(resultado);
 Udp.print(resultado);
 Udp.endPacket();
 if (alert == false){
  delay(1000);
 }

 }

void printWifiStatus() {

 // print the SSID of the network you're attached to:

 Serial.print("SSID: ");

 Serial.println(WiFi.SSID());

 // print your board's IP address:

 IPAddress ip = WiFi.localIP();

 Serial.print("IP Address: ");

 Serial.println(ip);

 // print the received signal strength:

 long rssi = WiFi.RSSI();

 Serial.print("signal strength (RSSI):");

 Serial.print(rssi);

 Serial.println(" dBm");
}
```

Python’s Code for heatmaps:

Python

```python
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.colors import LinearSegmentedColormap
import matplotlib.image as mpimg

def gaussian_2d(x, y, x0, y0, xsigma, ysigma, amplitude):
  """
    Define una función gaussiana 2D.
    :param x: Coordenadas x de la malla.
    :param y: Coordenadas y de la malla.
    :param x0: Coordenada x del centro de la gaussiana.
    :param y0: Coordenada y del centro de la gaussiana.
    :param xsigma: Desviación estándar en x.
    :param ysigma: Desviación estándar en y.
    :param amplitude: Amplitud de la gaussiana.
    :return: Matriz 2D gaussiana.
    """
  return amplitude * np.exp(-((x - x0) ** 2 / (2 * xsigma ** 2) + (y - y0) ** 2 / (2 *
ysigma ** 2)))

# Crear la malla
x = np.linspace(0, 10, 500)
y = np.linspace(0, 10, 500)
x, y = np.meshgrid(x, y)

# Configuración inicial
n_focos = 15
x0_list, y0_list, orig_amplitud, orig_sigmas = [], [], [], []
temperatura_mapa = np.full_like(x, 18) # Iniciar con 18 para el fondo

# Crear fuentes de calor iniciales
for _ in range(n_focos):
  x0, y0 = np.random.uniform(0, 10), np.random.uniform(0, 10)
  xsigma, ysigma = np.random.uniform(0.5, 2, 2)
  amplitude = np.random.uniform(0, 1.0)

  x0_list.append(x0)
  y0_list.append(y0)
  orig_amplitud.append(amplitude)
  orig_sigmas.append((xsigma, ysigma))

  temperatura_mapa += gaussian_2d(x, y, x0, y0, xsigma, ysigma, amplitude)

temperatura_mapa = np.clip(temperatura_mapa, 15, 20)
```

```
# Bucle principal
while True:
  temperatura_mapa = np.full_like(x, 18)
  for i in range(n_focos):
    x0 = (x0_list[i] + np.random.uniform(-0.1, 0.1)) % 10
    y0 = (y0_list[i] -0.5) % 10

    if y0 < 0:
      y0 = np.random.uniform(7,10)
      x0= np.random.uniform(0,10)
      xsigma, ysigma = np.random.uniform(0.5, 2, 2)
      amplitude = np.random.uniform(0, 1.0)

    xsigma, ysigma = np.random.uniform(orig_sigmas[i][0] - 0.02, orig_sigmas[i][0] +
0.02), \
            np.random.uniform(orig_sigmas[i][1] - 0.02, orig_sigmas[i][1] + 0.02)
    amplitude = np.random.uniform(orig_amplitud[i] - 0.2, orig_amplitud[i] + 0.2)

    temperatura_mapa += gaussian_2d(x, y, x0, y0, xsigma, ysigma, amplitude)
    x0_list[i], y0_list[i], orig_sigmas[i], orig_amplitud[i] = x0, y0, (xsigma,
ysigma), amplitude

  temperatura_mapa = np.clip(temperatura_mapa, 15, 20)

  # Configuración de colores y visualización
  colors = ['#a86b00cf', '#9c2222']
  cmap = LinearSegmentedColormap.from_list("custom_red_light_to_dark", colors,
N=20)

  plt.figure(figsize=(8, 6))
  img = mpimg.imread('image.png')
  img_rotated = np.rot90(img, 3)
  plt.imshow(img_rotated, extent=[0, 10, 0, 10])
  plt.contourf(x, y, temperatura_mapa, 20, cmap=cmap, alpha=0.5)
  plt.colorbar(label='Temperature (Degrees)')
  plt.xticks([])
  plt.yticks([])
  print(i)
  plt.savefig('mapa_temperatura.png', dpi=300, bbox_inches='tight',
transparent=True)
  plt.close()
  plt.pause(5)

  # Restablecer el mapa de temperatura para la próxima
```

```
```

Python's Code for real time plotting:

```python
import socket
from datetime import datetime
import matplotlib.pyplot as plt
from matplotlib.patheffects import withStroke

# Configuración del servidor
local_ip = '194.12.147.242'
local_port = 2390

# Crear un socket UDP
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
sock.bind((local_ip, local_port))

print(f"Escuchando en {local_ip}:{local_port}")

try:
    v_data_t = []
    v_data_l = []
    v_data_n = []
    v_data_p = []
    v_time = []
    fig, (ax1, ax2, ax3, ax4) = plt.subplots(4, 1, figsize=(12, 10))
    plt.ion()

    # Límite superior inicial para la luz
    upper_limit_l = 10000
    alert_text = None

    while True:
        string_data = ""
        # Mantener solo las últimas 200 muestras
        if len(v_data_l) >= 200:
            v_data_l.pop(0)
            v_data_t.pop(0)
            v_data_n.pop(0)
```

```
        v_data_p.pop(0)
        v_time.pop(0)

      hora_actual = datetime.now()
      v_time.append(hora_actual.strftime("%H:%M:%S"))

  data, addr = sock.recvfrom(1024)
  data_t, data_l, data_n, data_p, alarm = data.decode().split(",")
  print(data.decode())
  v_data_l.append(int(data_l))
  v_data_t.append(float(data_t))
  v_data_n.append(float(data_n))
  v_data_p.append(float(data_p))

  # Ajustar el límite superior si es necesario
  if max(v_data_l) > upper_limit_l:
    upper_limit_l = max(v_data_l)

  ax1.cla()
  ax2.cla()
  ax3.cla()
  ax4.cla()

  ax1.set_ylim([0, upper_limit_l])
  ax2.set_ylim([10, 40])
  ax3.set_ylim([0, 5])
  ax4.set_ylim([0, 9])

  # Definir y establecer ticks y etiquetas para el eje X
  if len(v_time) > 10:
    tick_positions = [i for i in range(len(v_time)) if i % (len(v_time) // 10) == 0]
    tick_labels = [v_time[i] for i in tick_positions]
  else:
    tick_positions = range(len(v_time))
    tick_labels = v_time

  for ax in [ax1, ax2, ax3, ax4]:
    ax.set_xticks(tick_positions)

  ax1.plot(v_time, v_data_l, 'r-')
  ax1.set_title('Light')
  ax1.set_ylabel('lux')
  ax1.set_xticklabels([])

  ax2.plot(v_time, v_data_t, 'b-')
```

```
    ax2.set_title('Temperature')
    ax2.set_ylabel('degrees')
    ax2.set_xticklabels([])


    ax3.plot(v_time, v_data_n, 'g-')
    ax3.set_title('Turbidity')
    ax3.set_ylabel('')
    ax3.set_xticklabels([])

    ax4.plot(v_time, v_data_p, 'y-')
    ax4.set_title('pH')
    ax4.set_xlabel('Time')
    ax4.set_ylabel('')
    ax4.set_xticks(tick_positions)
    ax4.set_xticklabels(tick_labels, rotation=45)

    string_data = "WARNING"

    if int(data_l) < 200:
      print("light")
      string_data += "\nBad Light"

    if float(data_n) < 2:
      string_data += "\nBad Turbidity"

    if float(data_p) < 5 or float(data_p) > 9:
      string_data += "\nBad pH"

    if float(data_t) < 20 or float(data_t) > 30:
      print("temperature")
      string_data += "\nBad Temperature"

    if alarm == '1':
      if alert_text is None:
        alert_text = fig.text(0.5, 0.5, string_data, fontsize=70, color='white',
ha='center', va='center',
                  bbox=dict(boxstyle='round,pad=1', facecolor='red',
edgecolor='black', linewidth=2, alpha=0.7),
                  path_effects=[withStroke(linewidth=5, foreground='black')])
      else:
        alert_text.set_text(string_data) # Actualiza el texto
        alert_text.set_visible(True)
    else:
      if alert_text is not None:
```

```
        alert_text.set_visible(False)


    plt.tight_layout()
    plt.draw()
    plt.pause(1)

except KeyboardInterrupt:
  sock.close()
  print("\nSocket cerrado")
```

Matlab's code for radial percentage graph:

```
% Characteristics's percentage
porcentaje_pH = 50;
porcentaje_temperatura = 80;
porcentaje_luz = 65;
porcentaje_turbidez = 40;

% Normalized percentages
porcentajes = [porcentaje_pH, porcentaje_temperatura, porcentaje_luz,
porcentaje_turbidez] / 100;

% Characteristics'name
caracteristicas = {'pH', 'Temperature', 'Light', 'Turbidity'};

% Color RGB format
color_fondo = [196, 197, 186] / 255;

% New color from dashboard
color_verde_oscuro = [89, 95, 57] / 255;

% Create diagram
figure;

% Draw graph background
polarplot(0:2*pi/100:2*pi, ones(1, 101)*max(porcentajes), 'Color',
color_fondo);
```

```
hold on;

% Draw line division
polarplot(0:pi/2:2*pi, ones(1, 5)*max(porcentajes), '-', 'Color',
color_verde_oscuro, 'LineWidth', 1.5);

% Draw radial points
polarplot(0:2*pi/4:2*pi, [porcentajes, porcentajes(1)], '-o',
'MarkerSize', 8, 'LineWidth', 3, 'Color','r');

% Personalize graph
set(gca, 'ThetaTick', 0:90:360);
set(gca, 'ThetaTickLabel', caracteristicas);
rticklabels({'0%', '25%', '50%', '75%', '100%'});
title('Diagrama Radial de Comparación');
hold off;
```