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iMERMAID

D4.1: Requirements and Design of the Use Cases

Task 4.1: Framework Requirements & Use Case Design

WP4: Pilot Demonstration, Analysis & System Specifications: Background, Requirements, and Materials

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ABSTRACT	This document is a summary of the reports about the preparation of each Use Case following the International Standards of the System Engineering Planning. It considers the required steps for smooth development of the technologies used on specific systems, including the functional and non-functional requirements, constraints, stakeholders' identification, research needs, scenario definition, KPI's, and validation requirements.

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Executive Summary

This document, entitled 'Requirements and design of the Use Cases', corresponds to Task 4.1 'Framework requirements and Use Case design' of the iMERMAID project, and is the reference for the future development of the project.

The document starts with Section 1, which provides a brief introduction of the deliverable. Section 2 is dedicated to outline the pilot studies that will be demonstrated for testing and validating the technologies developed during the project.

Section 3 addresses the specific objectives and expectations that the Use Cases must meet. The objectives are extended with the functional and non-functional requirements as well as the respective key performance indicators. The section is finalised with the constraints that restrict the technology development for further development within the duration of the project.

Section 4 is dedicated to the scenarios of each Use Case. The validation of the scenarios and the alignment with the regulations are also included in the section. Then, Section 5 provides the identification of potential stakeholders of the project's outcomes, while associating them with relevant regulations.

The final section concludes the main findings from the System Engineering Planning preparation of the Use Cases. It also provides the general outcome approach for the implementation of the demonstrations, which is the final task (T4.3) of WP4. Section 6 concludes the preparation processes of the five Use Cases of the iMERMAID project. Part 6.1 summarises the outcome of each Use Case and part 6.2 defines the overall conclusion of the framework for the demonstrations.

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Acronyms

Al	Aluminium
BOD	Biochemical Oxygen Demand
Cd	Cadmium
COD	Chemical Oxygen Demand
CoEC	Contaminants of Emerging Concern
Cu	Copper
D	Deliverable
EC	European Commission
ECs	Electrochemical Sensors
EEZ	Exclusive Economic Zone
EU	European Union
GC-MS	Gas Chromatography-Mass Spectrometry
Hz	Hertz
KPI	Key Performance Indicator
L	Litres
LTP	Leachate Treatment Plant
M	Metres
Mg	Micrograms
MSW	Municipal Solid Waste
NTU	Nephelometric Turbidity Unit
Pb	Lead
PDP	Pulsed Discharge Plasma
PPB	Parts per billion
PV	Photovoltaic
RO	Reverse Osmosis
T	Task
TSS	Total Suspended Solids
UC	Use Case
WP	Work Package
WWTP	Waste Water Treatment Plant
Zn	Zinc

1. Introduction

This deliverable serves the preparation of the iMERMAID's Use Cases for the International Standards of System Engineering Planning. Each Use Case leader has prepared a report for the technologies of their Use Case (see Annexes A-E). Apart from the preparation of the technical objectives for each Use Case, the deliverable considers both the functional and non-functional requirements, the definition of pilot scenarios, and the alignment of the project outcomes with the regulations. This deliverable initiates the identification of potential stakeholders based on each Use Case, which will be further developed in WP5 of the iMERMAID project.

The deliverable refers to Part 4 of ISO/IEC/IEEE 24748 — Systems and software engineering — Life cycle management. This part (ISO/IEC/IEEE 24748-4: Systems engineering planning), which draws on key aspects of the former ISO/IEC 26702 (IEEE 1220), focuses on the processes required for successful planning and management of the project's systems engineering effort. This draws critical attention for the development of a Systems Engineering Management Plan to emphasise or differentiate technical contributions in the processes under discussion. The five parts of ISO/IEC 24748 are intended to facilitate the joint usage of the process content of ISO/IEC/IEEE 15288 and ISO/IEC 12207, to provide unified and consolidated guidance on the life cycle management of systems and software. In this way, ISO/IEC 24748 ensures consistency in system concepts and life cycle concepts, such as models, stages, processes, process application, key points of view, and adaptation.

By the end of the project's first year, the Use Case Leaders prepared a technical report about their corresponding Use Case. The reports provide the means of preparation for the International Standards of the System Engineering Planning, which includes all the required steps for smooth development of the technologies used on specific systems. These steps are summarised in the following sections, where we consider the functional and non-functional requirements, constraints, stakeholders' identification, research needs, scenario definition, KPIs, and validation requirements, among other information.

2. Pilot Overview

iMERMAID pilots are five Use Cases demonstrated in Spain, Tunisia, Italy, Cyprus, and Greece. Each Use Case is led by one local partner from the iMERMAID consortium: SOCAMEX, Opalia Pharma (Opalia), Società Metropolitana Acque Torino (SMAT), Cyprus Marine and Maritime Institute (CMMI), and United Association of Solid Waste Management (ESDAK) in Crete, respectively.

Two of the Use Cases are at Wastewater Treatment Plants, one is at a Leachate Treatment Plant, one is at a Pharmaceutical Industry, and one is at an open-sea moored scientific buoy. The first four Use Cases aim to remove certain pollutants from the water before they are released in nature, which will eventually end up in the sea, and the last Use Case aims to detect and monitor the concentration of certain Contaminants of Emerging Concern (CoEC) already released in the sea.

The Use Cases demonstrate the technologies developed by iMERMAID partners, which are Eden Tech (EDEN), WeeeFiner, Hellenic Centre for Marine Research (HCMR), Biosense Institute (BIOS), IRIS slr (IRIS), Université d'Angers (UA), Università di Firenze (UNIFI), Ecole Nationale d'ingenieurs de Gabes (ENIG), CubexLab (CUB), Zentrix Lab (ZEN), SoftWater srl (Softwater), Fundación Instituto Tecnológico de Castilla y León (ITCL), and National Technical University of Ukraine Igor Sikorsky Kyiv Polytechnic Institute (NTUU KPI).

2.1. Use Case 1

Upstream removal of CoECs from the wastewaters of the Mediterranean Basin

Wastewater treatment plants (WWTPs) receive and treat jointly wastewater coming from different sources, including household and industrial water. Due to the nature of such wastewater, a variety of contaminants are expected to be present due to the recalcitrant behaviour of these compounds to conventional WWTP treatments. In Use Case 1 area, the high importance of the agricultural activities leads to the presence of pesticides in wastewater. In Spain, location of Use Case 1, due to strong water restrictions during drought periods, opportunities to decrease water stress and recycling of treated water are explored.

The main goal of Use Case 1 is to develop a solution for the remediation of agricultural wastewater: to deploy and demonstrate a novel and sustainable monitoring and remediation system based on Electrochemical organic sensor and Pulsed Discharge Plasma (PDP) to monitor and eliminate hazardous pollutants such as pesticides, herbicides, fertilizers, and other chemicals (pharmaceuticals, endocrine disruptors, hormones).

The main approach of Use Case 1 solutions consists of providing practical tools for on-site treatment of wastewater, to address contamination directly at the source, dealing with critical spills close to the point of entry and reduce downstream pollution.

2.2. Use Case 2

Demonstration of innovative solutions for the removal of pharmaceutical contaminants

In this Use Case, a remediation solution will be demonstrated at a Tunisian pharmaceutical industry. The objective of demonstrating the innovative solutions in this Use Case is to effectively mitigate chemical pollution at its origin, preventing its entry into water bodies. This is facilitated by enhancing the removal efficiencies of organic pharmaceutical pollutants using both conventional treatment methods and an innovative microfluidic system. To evaluate the efficiency of this system, the degradation of three representative molecules — Diclofenac, Ibuprofen, and Ketoprofen — will be monitored using an electrochemical sensor box specifically designed for these compounds. Additionally, as a prefiltration to the microfluidic system, a prefiltration system developed by repurposing discarded reverse osmosis membranes will also be demonstrated. The idea is to implement membrane treatments before EDEN remediation process to test the retention rate of molecules using new and used membranes, aiming to reduce the turbidity of wastewater and enhance the system effectiveness.

2.3. Use Case 3

Demonstration of innovative solutions for the removal of heavy metals

This Use Case will be deployed to demonstrate the removal of heavy metals from wastewater. The pilot is a WWTP located in the Metropolitan Area of Turin, designed for a population of 9000 inhabitants.

The WWTP consists of an initial screening of gross solids, skimming of fats, oils and grease. This is followed by a denitrification process in an anoxic environment and a primary oxidation. The process continues with a secondary oxidation and sedimentation. Finally, the disinfectant is dosed into the outlet channel of the secondary sediments.

This WWTP has been selected for Use Case 3 since high concentration of Zinc were sporadically detected at wastewater inlet.

The aim of the pilot is i) to characterise the content of metal in the water entering the WWTP and to eventually detect anomalous discharge above the limits by means of the electrochemical inorganic sensor; ii) to remove heavy metals (Zn, Cu, Al) from wastewater by means of 4D Scavenger technology; iii) to verify the performances of the monitoring system and the treatment technology.

Both the technologies and the monitoring system should be able to deal with wastewater (also by means of proper pre-treatments), that is characterised by high (and variable) concentration of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS).

The data will be made available to the end-user though a dedicated web interface for the remote visualisation of collected data.

2.4. Use Case 4

Monitoring platform on the Mediterranean Sea

This Use Case will be implemented to demonstrate the monitoring of CoEC at the Mediterranean Sea. The Use Case is a moored buoy which serves as a research fixed platform for contributing to marine observation and marine data exchange.

Currently, the facility measures various parameters, including conductivity, salinity, pressure, water temperature, dissolved oxygen, chlorophyll-a, turbidity, fluorescence, dissolved organic matter, pH, nitrates, current speed and direction, acoustic, and meteorological information. Additionally, three technologies will be developed under operational environment (nitrites sensor, heavy-metal sensor, and oil sensor) but only the oil-sensor will be installed in the buoy for being tested under real conditions.

In the Use Case, the iMERMAID consortium will also employ the technology for monitoring water bodies using satellite data. The satellite data will be employed to assimilate the data from in-situ sensors, incorporate innovations and provide a cross-assessment, comparing satellite data recognition with data available from sensors. This assimilation is the combination of in-situ data with all available information from numerical models describing the ocean dynamics, observations, and prior information.

2.5. Use Case 5

Demonstration of innovative solutions for the removal of organic contaminants from landfill leachates

Leachates treatment plant of the Pera Galini Municipal Sanitary landfill located in Crete is the demonstration site of Use Case 5. Sanitary landfill leachate is a strongly polluted wastewater with a variety of components. It is a wastewater type that is characterised by high organic and inorganic pollutant concentrations, and the presence of a wide range of chemicals in municipal solid waste (MSW) landfill leachates is expected and documented.

Currently, the Leachate Treatment Plant (LTP) is monitored monthly through sampling and laboratory analyses of various parameters, which are selected according to the obligations set by the environmental license of the Sanitary landfill (e.g., physicochemical, chemical, biological parameters, etc).

The average raw leachate flow rate entering the plant is 110 m^3/day and the operation of the plant today includes the following three treatment stages:

a) A physical/chemical process including coagulation, flocculation and Dissolved Air Flotation b), a physical/biological treatment based on a Membrane BioReactor and c) a purification process with Reverse Osmosis technology. The effluent after degasification and chlorination can be used for irrigation and/or recirculation to the landfill for enhancing its performance.

Use Case 5 will demonstrate the application of a microfluidic water treatment system in the landfill leachate treatment plant and the Microfluidic water system will be tested for its efficiency in removing micropollutants for the final effluents based on advanced oxidation processes (RO effluent treatment of approximately 1m^3/day in an iterative demonstration for 1 month).

In the same Use Case, the organic micropollutants electrochemical sensor box for monitoring micropollutants and an electrochemical inorganic sensor for monitoring the heavy metals effluents in the effluents will be deployed and its applicability will be demonstrated.

Apart from the chemical/microbiological analyses to be done in the effluents, application of a battery of validated toxicity tests (Microtox, algae growth inhibition, rotifer reproduction, Daphnia immobilisation, zebra fish tests, etc.) for ecotoxicological evaluation of the systems effectiveness will be performed by HCMR.

3. Use Case Objectives

The main objectives of the pilot demonstrations are to validate the proposed methods for detection and monitoring of CoECs, heavy metals, and oil substances, and their effective remediation. These include the remediation of substances from the treatment plants and pharmaceutical industry, and the observation for the pollutant elements in the sea.

The functional requirements of the treatment plant Use Cases are the ability to make real-time measurements of the concentration of the targeted micropollutants before and after the treatment process , and to provide the useful information through a user-friendly monitoring web interface. Similarly, the functional requirements of the pharmaceutical industry Use Case are the detection of molecules concentrations, their degradation, and a user-friendly monitoring web interface. The Use Case of the moored scientific buoy does not aim to remediate any pollutants. Its functional requirements are to be operational in high concentrations of salt (East Mediterranean salty water) and tolerate strong waves, and since the buoy is a remote system, to have uninterruptible operation electrical energy supply (by sufficient battery capacity and PV panels) and reliable data communication (by a 4G plan with sufficient speed and monthly capacity).

The non-functional requirements are set for each Use Case along with their KPIs. For Use Case 1 the Pulsed Discharge Plasma will be assessed with experimental degradation runs on the wastewaters, followed by sampling and characterisation of the treated water, aiming at 95% reduction in agropollutant concentration and 50% reduction in pollutants transfer to the Mediterranean Basin. The levels of concentration measured by the electrochemical sensors should be within the dynamic range of sensitivity adaptation and linear range to the target molecules tested. The response time to detect the selected compounds should be less than 60 seconds.

The aim of Use Case 2 is to achieve at least 95% degradation of pharmaceutical contaminants of emerging concerns from the industrial effluents and 50% reduction more than the conventional techniques of pharmaceutical pollutants at their source to levels that are within EU permissible limits. It requires reliable data transmission with sufficient communication capacity and robust database with satisfactory capacity to store raw data.

For Use Case 3 the monitoring system should be able to detect up to 15 mg/l biochemical oxygen demand and 25 mg/l concentrations of suspended solids of selected metals in wastewater when no pre-treatment is used and above 15 mg/l biochemical oxygen demand and 25 mg/l concentrations of suspended solids with a filtration pre-treatment. The aim is to limit the concentration of Pb, Cd and Cu to not exceed 5 ppb and the concentration of Zn to not exceed 10 ppb. The treatment technology should be able to remove up to 5 mg/l concentrations of suspended solids of selected metals in wastewater when no pre-treatment is used and above 5 mg/l concentrations with a prefiltration setup. In wastewater with more than 0.5 mg/l metals concentration the removal capacity should be more than 95%, but in wastewater with up to 0.5 mg/l metals concentration the removal capacity could be lower but not below 90%. The measurements should be monitored at a user-friendly dashboard with refresh rate of 30 minutes.

The aim of Use Case 4 is to provide reliable monitoring through near real-time in-situ measurements. The non-functional requirements are sufficient communication speed and capacity to connect through 4G network. The meteorological parameters must have a data refresh rate of 15 minutes, for environmental sensors a data refresh rate of 30 minutes, and the communication delays of the Quality Control need to be restricted to less than 60 seconds with stable response time.

For Use Case 5, the assessment of the system aims 95% efficiency of the microfluidic system for the degradation of the targeted micropollutants and more than 50% reduction in the transfer of selected pollutants along the wastewater. It also aims at real-time monitoring of organic chemicals and heavy metals in the wastewater before and after treatment.

The constraints of the Use Cases include the time availability, allocated budget, preparedness, disposal, and maintenance requirements. The time for the validation of the technologies is limited due to the project's duration, the necessary preparation before demonstration, and the operational cost. For the treatment plans, the prefiltration of the samples and proper disposal is also a prerequisite. In some cases, the lag of prefiltration might clog parts of sensors and remediation systems which could require more frequent maintenance. Maintenance is a requirement that all technologies need, although in some Use Cases it is more frequent than others. Frequent maintenance is necessary for the Pulsed Discharge Plasma and the oil sensor, which means higher cost and personnel manhours. The expenses for maintenance and purchasing the consumables, along with the running costs of the demonstrations need to be estimated according to the duration of the validation period. Another constraint is the expenses for transmitting, storing, processing, and managing data, and in conjunction with the time constraint, the delay of the monitoring dashboards' development might cause limitations to the effectiveness of the demonstrations.

4. Demonstrations

The Use Cases of iMERMAID aim to validate the technologies developed during the project under real conditions. The technologies will be validated with the aid of the iWIRE monitoring platform, which is developed by SoftWater, to test the effectiveness of the platform and adjust its functions. For Use Case 4, demonstrated at Sea, the technologies will be examined in nearby ports before they are validated in the real conditions of the Use Case, as tests in operational environment.

4.1. Use Case 1

4.1.1. Scenario development

Scenario 1: An increase in the concentration of the selected compound for continuous monitoring (tentatively, ibuprofen, but not definitive yet) is detected in the inlet water to the WWTP. The peak is quickly detected thanks to the electrochemical sensor implemented by the UA, which is placed in the input to the WWTP. This pollutant is more quickly measurable thanks to this sensor, as it avoids the need to take a sample for the lab and wait for the results (which usually consumes > 1 week). This substantial rise in concentration may have resulted from fluctuations in the area's population, which can increase in specific times of the year (e.g., Christmas, summer holidays).

Scenario 2: The CoECs selected for this Use Case are not found in the inlet water in sufficient concentration as to be quantified in the laboratory. It is possible that the pollutants are present in the wastewater, but in a lower concentration than expected, or it is possible that they are absent owing to a change in the composition of the pool of pollutants which had been previously defined through the screening carried out. Either situation indicates that the research is now not well focused (focus should shifted to a different list of pollutants).

4.1.2. Validation process

Scenario 1 will be validated by continuous measurement of the selected pollutant (tentatively, ibuprofen, but this is not definitive) through the electrochemical sensor provided by UA. This pollutant is used as a model, but the pollutant targeted by the sensor could potentially be any other. The PDP technology will be applied in order to decrease the concentration whenever a peak is detected, and the functioning of the PDP device can be reinforced (e.g., by operating more hours) to tackle this punctual higher amount of pollutant.

Scenario 2 will be validated by periodically measuring concentration of the selected emerging pollutants before and after the PDP technology stage (but mainly before the PDP technology). This will involve taking samples and quantifying them at the laboratory. If concentration is under the quantification limit (and hence cannot be measured), three actuations will take place:

1) The current laboratory in charge of the quantifications will be requested to adjust the method of analysis to increase sensitivity.
2) If the previous point doesn’t deliver an acceptable result, then a new laboratory will be contacted and requested to quantify the pollutants.
3) In parallel with 1) and 2), new screenings will be done in order to detect potential changes in the pool of the CoECs that are present in water. If the composition of pollutants has changed, then the list of pollutants to be monitored will be re-defined.

4.2. Use Case 2

4.2.1. Scenario development

Scenario 1: Regular maintenance will be implemented to prevent any malfunction of the remediation and sensor system due to: Fouling of electrochemical sensors and clogging of the microfluidic networks, which can disrupt the functionality of the system.

Scenario 2: A high concentration of targeted molecules detected by the sensors after advanced treatment: Due to the production of certain pharmaceuticals, the wastewater can have:

- High conductivity, which can cause fouling of the sensors.
- High acidity due to variations in pH ($pH < 6$), which can affect the system's effectiveness.
- High Turbidity (around 150 NTU).

4.2.2. Validation process

Scenario 1: OP plans to conduct daily checks of the systems, as well as regular cleaning of the sensors. Additionally, we will identify a cleaning protocol for the microfluidic system and membrane system to avoid any malfunction of systems.

Scenario 2: A high concentration of targeted molecules detected after advanced treatment by the iWIRE platform: an investigation on site will be necessary to verify the proper functioning of the sensor system.

4.3. Use Case 3

4.3.1. Scenario development

Scenario 1: High concentrations of a heavy metal is detected from the on-line sensor at WWTP inlet. This allows for a fast reaction by the operator and the activation of monitoring both at WWTP outlet and at pilot (4D Scavenger) outlet. The monitoring shows that metals are partially removed from the WWTP plant (near the law limit values for discharge into surface water) and completely removed from the pilot treatment plant. Moreover, thanks to the online sensor it is possible to see that the event is very short in time, and it would be difficult to detect it with periodic analysis. The same event repeats more than once, thus allowing the plant manager to detect anomalous events that won't be possible to detect with a periodic monitoring.

4.3.2. Validation process

Validation Scenario 1: SMAT receives and alerts through the iWIRE software, showing a peak of heavy metals in the water entering the WWTP. SMAT immediately performs laboratory analyses in order to confirm the metal concentration detected from the on-line sensor. Samples are taken both at the inlet and outlet of the WWTP to check whether the discharge complies with legal limits. Samples are also taken at pilot (4D Scavenger) outlet in order to verify the removal capacity of the pilot.

Similar events happen several times, and the same protocol (laboratory analyses of samples from different plant locations in order to confirm the detected concentrations and verify the removal capacity, both of the WWTP and the pilot technology) is applied. This allows the detection of events that wouldn't be possible to detect with a periodic sampling, and to verify the efficiency of the WWTP in removing this contaminant.

If anomalies are detected at WWTP outlet, the use of emergency treatment for heavy metal removal can be considered.

All data is uploaded to the iWIRE platform, thus allowing for a better understanding of the events.

4.4. Use Case 4

4.4.1. Scenario development

Scenario 1: An oil spill incident had occurred due to a maritime accident. The oil sensor promptly detects the high concentration of crude oil derivatives (previously determined). This allowed for quickly informing the relevant authorities and the detainment of the oil at the sea surface. The early warning system provided by the technology developed through the iMERMAID allowed for the elimination of the anticipated environmental impacts while reducing the financial burden associated to an oil spill cleanup protocol.

Scenario 2: A maintenance plan, including anti-fouling of the sensors had been put in place. More frequent actions were planned during summer months, in comparison to winter months due to background knowledge on seasonal fluctuations of water surface temperature, light availability, dissolved oxygen, biodiversity and population of fouling organisms. Due to climate change the sea water temperature was higher than usual during winter months causing the bloom of opportunistic diatoms fouling the sensor. Fouling disrupted the functionality of the oil sensor technology and subsequently the accuracy of the oil concentration readings, therefore activating a false positive alarm.

4.4.2. Validation process

Scenario 1: CMMI, BIOS, and NTUU KPI receive an alert through the iWIRE software that the oil sensor detects values well above the maximum threshold. CMMI immediately check the values of the other sensors installed under the buoy. The latest values of pH and turbidity were also showing unusual changes and rising curves in the graphs of iWIRE. A visit of CMMI to the buoy is immediately planned for physical investigation of the area, and the contractor for oil removal and eradication is informed to be stand-by. At the same time, CMMI examines the seawater current spectrum, and also the wind speeds and directions of the last few hours in the region. Then CMMI sends the information to NTUU KPI. NTUU KPI examines the most recent satellite images around the buoy location, based on the information of water currents and winds. NTUU KPI extracts the latest satellite images and identify the quantities of the oil. CMMI informs the contractor about the expected quantities of oil spilled and ask them to send the most appropriate skimmer vessel(s) to the potential location. As quickly as possible, CMMI boat arrives to the area and communicates with the skimmer vessel to give updated and accurate information. The oil spill is cleaned before reaching the beaches of Limassol and before it sinks to the sea floor.

Scenario 2: CMMI, BIOS, and NTUU KPI receive an alert through the iWIRE software that the oil sensor detects values above the maximum threshold. CMMI immediately checks the values of other sensors installed under the buoy. The values of chlorophyll-a, nitrates, and dissolved oxygen have been showing a gradual change for a few days. The temperature of seawater was also above the normal values. A visit of CMMI to the buoy is planned for physical investigation of the area and inform the contractor for oil removal and eradication to be stand-by. At the same time, CMMI examines the seawater currents and the wind speeds and directions of the last few hours in the region. Then CMMI sends the information to NTUU KPI. NTUU KPI examines the most recent satellite images around the buoy location, based on the information of water currents and winds. NTUU KPI extracts the latest satellite images. The images were not showing any detectable oils on the surface. The CMMI boat arrives at the buoy location and finds no oil around it. A diver inspects the oil sensor and detects heavy fouling by photosynthetic organisms. CMMI schedules immediate maintenance and adjusts the maintenance procedures for cleaning (antifouling) the sensors (and associated equipment) more often (e.g., frequent maintenance all year round).

4.5. Use Case 5

4.5.1. Scenario development

Scenario 1: Assess pollutants qualitatively through the year, in order to discover patterns of pollution production / presence at the site which change dramatically on a seasonal basis due to the seasonal rains and touristic character of the served area.

Scenario 2: Check the information provided by the online sensor against laboratory analyses.

4.5.2. Validation process

Scenario 1 will be validated by performing periodic screenings to samples taken at the influent and effluent of several treatment stages of the LTP (critical points of treatment).

Scenario 2 will be validated by periodical quantification of the selected pollutants (Bisphenol A, Bentazone, Propamocarb and PFOA) by laboratory analysis. The results will be compared to the parameter values detected for the same date by the sensor. Simple statistical tests will be carried out for significant differences between pairs of values.

4.6. Compliance with the Regulations

The Use Cases must comply with the European and National regulations and directives as stated in the project's Grand Agreement.

Since Spain supports the following directives that set out the EU goals, Use Case 1 is obliged with the resulting legislative acts:

Water Framework Directive (2000/60/EC): Ibuprofen and Bisphenol A are observed in this document.

- Marine Strategy Framework Directive (2008/56/EC): General interest for the project's objectives (e.g., bioaccumulation).
- Urban Wastewater Treatment Directive (91/271/EEC): Substances like amisulpride and benzotriazole are mentioned in this directive.
- Directive on the quality of water intended for human consumption (Directive EU 2020/2184): The document imposes limits to certain emerging pollutants, including bisphenol A (2,5 ug/l).
- Directive on environmental quality standards in the field of water policy (Directive 2008/105/EC): The document lists emerging pollutants to observe, including Bisphenol A.

Use Case 2 complies with the Tunisian standard NT. 106.002 relating to effluent discharges into the water environment (Environmental protection). Therefore, the water quality data should be collected and stored for national compliance. iMERMAID is achieving this task through the iWIRE platform, which collects and stores, and also provides monitoring and control capabilities to validate the system.

For Use Case 3, both wastewaters discharged into the sewer and the effluent of a WWTP are subject to legal limits to prevent that at the end of the treatment processes, when treated water is released in the environment, it still has a high concentration of contaminants. In Italy, the transposition of Directive 2000/60 is Legislative Decree 152/06 ("Testo Unico Ambientale"), which contains concentration limits for the wastewater discharge in sewer and the discharge of effluent of the WWTP in water bodies for different contaminants. The concentration limits for heavy metals are the following:

Metal	Concentration Limit (mg/l)	
	Discharge in Sewer	Discharge in water bodies
Al	2,0	1,0
Cd	<	
Cu	0,4	0,1
Pb	0,3	0,2
Zn	1,0	0,5

Moreover, to prevent further risks for Use Case 3, 1) special precautions need to be taken for the hazardous waste from the treatment plan, 2) the implementation of a heating/cooling system in the container that hosts the technologies could mitigate the risk of non-compliance with the environmental conditions required by the technologies, 3) frequent maintenance and recalibration of the aging sensors could mitigate the risk of variability in the analytical response of the measurements, and 4) installation of a pre-filtration system to remove the interferences on 4D Scavenger technology when TSS/BOD is high.

The deployment of stationary structures in the sea, such as the buoy of Use Case 4, requires special permissions from the National Authorities. Adequate national licences have already been acquired by the Cyprus Port Authority, which is the agency responsible for authorising the deployment of a fixed ocean data acquisition system in the specific area of Cyprus' Exclusive economic zone (EEZ). An additional license has been acquired by the Cyprus Department of Fisheries and Marine Research to protect the benthic habitats. The data are collected on the secure AZURE cloud system of CMMI, aiming to become publicly available and in compliance with the FAIR data principles. The AZURE cloud system will be connected to the iWIRE platform. Furthermore, the data will be validated through a Quality Control tool to prevent any data inaccuracy.

Use Case 5 is obliged with the following legislative acts:

- Compliance with the EU Waste Framework Directive (2008/98/EC).
- Compliance with the EU Urban Wastewater Treatment Directive (91/271/EEC).
- Compliance with the EU Marine Framework Directive (2008/56/EC).
- The LTP effluent must comply to the requirements set by the Regional Environmental Authority (environmental licence).

To avoid any unnecessary risks, mitigation measures can be taken into account, such as 1) redundant data storage, 2) frequent maintenance and recalibration of the electrochemical sensors in real samples to avoid inaccurate data due to the matrix or interferences effects, 3) reducing the changes in the leachate quality that could affect the microfluidic remediation treatment efficiency, and 4) pre-filtration system should be installed for removing the interferences and prevent damages of both sensors and remediation system, which might be caused by the variation of the total solids concentrations.

A data management plan, that presents a comprehensive strategy for overseeing the processing of data throughout the entire duration of the iMERMAID project and beyond, has been defined in D7.4 'Data Management Plan' and it is valid for all the use cases.

5. Stakeholder Identification

Section 5 provides the initial association with the potential stakeholders of the project's outcomes. The work of this section will provide the foundations for task T6.3 'Innovation Management, Exploitation and Sustainability', which will be documented in deliverable D6.2 'Exploitation Plan of the project's results and IPR protection'. T6.3 include, among other work of the task, the interaction with the end-users and industry stakeholders to ensure the project's innovation and long-term sustainability, as well as the participation in European technology platforms for strengthening the link toward digitalization-related communities and stakeholders. This work will be further developed in task T5.5 'Multi-stakeholder Web Interface with Showcase Solution', to implement an interactive dashboard addressed to Stakeholders and Decision Makers with predefined and customised data visualisation oriented by users' specific interests and needs for promoting an effective exploration of project outcomes and results.

According to several European (e.g., European Green Deal's Farm to Fork Strategy and Biodiversity Strategy, Water Framework Directive 2000/60/EC) and National Directives (e.g., Legislative Decree 152/06) measures have been taken to meet the quality standards for the additional pollutants, and to make their monitoring data available on a more frequent basis. Also, the Candidate List of substances94 (REACH regulation, EC 1907/2006) have been issued. While not all listed CoEC are regulated yet, it is the expected development in upcoming years that new regulations will be issued. Consequently, industrial ecosystems such as mining, oil, gas, textile, plastic, personal care product, metal coating, agrochemical, or pharmaceutical as well agricultural and aquacultural sector must comply or are in the near future expected to comply with the limits set for manufacturing discharges. Therefore, these industries have a benefit in monitoring or supporting the Research and Development of the remediation technologies of the iMERMAID project. An example of the stakeholder group for Use Cases 1, 3 and 5 are the local agricultural and farmers associations, whose waste is the origin of agropollutants and associations of the pharmaceutical industry for Use Case 2.

The next stakeholder group consists of organisations devoted to guarantee the environmental safety such as the local and national authorities, city councils, regional public administrations for the wastewater sector. Their interest consists off monitoring of heavy metals and CoEC concentration in discharged water, setting limits and recommendations and establishing laws to control compliance with these legal limits. An example of such institution for Use Case 1 is the Instituto Aragonés del Agua. An example of a national authority for Use Case 4 is the Department of Fisheries and Marine Research that deals with the European Marine Strategy Framework Directive (2008/56/EC).

It is important to note that the actual facilities responsible for the water management processes such as wastewater treatment plants, water supply companies, water infrastructure companies, textile factories, hospitals, or technology providers form a separate stakeholder group with the main interest to use and further replicate the technology developed within iMERMAID.

The next two stakeholder groups are the a) NGO and networks and b) the Social innovator groups. Both groups are expected to have lower power as opposed to the previous groups but are highly interested in the CoEC-related topics and may be beneficial especially for the dissemination topics, such as raising awareness and building trust on iMERMAID technologies.

The other end user group for all Use Cases is the general public that is concerned with the water quality in the environment. This includes residents, tourists, other visitors and non-specialized media. Important stakeholders are also the media that can inform the public during an oil spill in a specific area. End users are the divers, fishers, seawater athletes, people enjoying water sports and other recreational activities in the sea.

Finally, the academics, researchers, and environmentalists who study the wastewater and solid waste management and the climate change in the Mediterranean basin, are stakeholders of the iMERMAID project that may provide substantial feedback and recommendations.

6. Conclusion

This section concludes the preparation processes of the five Use Cases of the iMERMAID project. Part 6.1 summarises the outcome of each Use Case and part 6.2 defines the overall conclusion of the framework for the demonstrations.

6.1. Summary of Use Cases' Preparation

Use Case 1 aims at the monitoring and abatement of emerging pollutants which are present at the WWTP outlet and have their origin in the agricultural activity and household wastewaters, together with the industrial activity in the area. PDP technology and the electrochemical sensor are implemented to eliminate emerging pollutants and monitor in real-time selected pollutants, respectively. Unforeseen events will be managed properly for ensuring the achievement of the site's objectives.

Use Case 2 uses a prefiltration system and tertiary treatments as remediation solutions to demonstrate at a pharmaceutical industry. The preparation management ensures the enhancement of the removal efficiencies of pharmaceutical organic pollutants using both conventional treatment methods and an innovative microfluidic system.

Use Case 3 explores the use of innovative technologies for monitoring and remediation of heavy metals in wastewaters under defined conditions. The initial testing of the technologies is at a laboratory scale and will then be installed in an existing WWTP for a pilot study. Tests in an operational environment will allow addressing all the challenges. The three-phase demonstration strategy is tuned for high and variable concentrations of BOD, COD, and TSS, aiming to evaluate the necessity for installing a proper pre-treatment system.

Use Case 4 acts as a testbed for the emerging technologies of sensors to be examined in a relevant environment (within a port), at first, and then to be verified in operational environments (at sea). Examining the technologies in a relevant environment will be reported along with the proposed changes to address the challenges before they are verified in operational environments. The verification of the technologies in the operational environment will also be reported along with the required adjustments to deliver reliable and robust sensors. Then, the technologies will be validated under expected operational conditions. The validation outcomes will be compared with the expected results to either define the baselines or make the required modifications for defining the baselines. Before the actual application is finalised, the technologies will be tested under real conditions for an appropriate duration of time. The evaluation of the testing will then define whether the technologies have met all the required standards or require some additional amendments.

Use Case 5 examines emerging technologies of sensors along with the associated remediation system in a relevant environment to define the potential changes for addressing the challenges before they are verified in operational environments. Verification of technologies in the operational environment will be documented, including necessary adjustments to ensure the reliability of sensors and an efficient remediation system. Subsequently, the technologies will undergo validations under anticipated operational circumstances. The validation results will be compared to expected outcomes to establish baselines or implement modifications as needed. Prior to finalizing the actual deployment, the technologies will undergo testing in real-world conditions for an extended period. Evaluation of the testing phase will determine whether the technologies meet all specified standards or necessitate further enhancements.

6.2. General conclusion

In summary, the validation of technologies in an operational environment requires a systematic and rigorous approach, where all phases of the demonstration are produced during a well-defined verification period. This ensures that the processes are robust, reproducible, and compliant with regulatory requirements, thereby guaranteeing the safety and efficacy of the technologies. The Use Cases for the treatment plans to examine the needs of prefiltration, monitoring capabilities, and remediation processes to regulate the pollutants from entering the Mediterranean Sea.

Use Case 4, the monitoring platform, investigates the maturity of the technologies for monitoring the amount of CoEC in the Mediterranean Sea. In the future, long-term in-situ observations will give us the opportunity to create models for predicting the severity of some parameters and elements to the ocean.

ANNEX A: Use Case 1

Section 1: Introduction

Project Name:

Innovative solutions for Mediterranean Ecosystem Remediation via Monitoring and decontamination from Chemical Pollution

Date:

24 May 2024

Section 2: Use Case Overview

Lead Organisation:

SOCAMEX

Participating Partners:

UA
IRIS

Use Case Title:

Upstream removal of CoECs from the wastewaters of the Mediterranean Basin

Use Case Objective:

Wastewaters treatment plants (WWTPs) receive and treats jointly wastewaters coming from different sources, including household water and water from industries. Derived from wastewaters, a variety of contaminants are expected due to the recalcitrant behaviour of this compounds to WWTP conventional treatments.

The high importance of the agricultural activity in Use Case 1 area favours the presence of pesticides in wastewaters. In Spain, with strong water restriction during drought periods, opportunities to decrease water stress and recycling of treated water need to be explored.

The main goal of Use Case 1 is to develop a solution for the remediation of agricultural wastewater: to deploy a novel and sustainable monitoring and remediation system based on Electrochemical organic sensor and Pulsed Discharge Plasma to monitor and eliminate hazardous pollutants such as pesticides, herbicides, fertilizers and other chemicals (pharmaceuticals, endocrine disruptors, hormones).

The main approach consists of providing practical tools for on-site treatment of wastewaters, to address contamination directly at the source, dealing with critical spills close to the point of entry and avoid affecting polluting waterbodies.

Section 3: Requirements Gathering

Specific objectives:

The main requirement from Use Case 1 implies:
- Effectiveness of the technology in the removal of target CoECs, mainly contaminants derived from agricultural activities, but also coming from household wastewaters.
- Continuous monitoring of selected CoECs using electrochemical sensors.

Functional Requirements:

The **Pulsed Discharge Plasma technology** (PDP) will treat the use case's wastewaters to abate the concentration of selected contaminants of agricultural, as well as industrial and domestic origin. The PDP equipment is composed of a voltage generator that will deliver high voltage, high current pulses:
- 100kV of peak voltage.
- >500A of peak current.
- A discharge rate >6Hz with a pulse energy of 0.5J.

Electrochemical sensors (ECs) should be advantageously used to assist the treatment processes. ECs will be able to measure the concentration of the targeted organic micropollutants before and after the treatment process. For this Use Case, tentatively but still not defined, ibuprofen will be monitored with the possibility to extend the study to bisphenol A. The measurements should be done on site and in real time.

Non-Functional Requirements:

The PDP technology will be assessed with experimental degradation runs on the Use Case 1 wastewaters, followed by sampling and characterization of the treated water by means of Gas Chromatography-Mass Spectrometry (GC-MS).
For the electrochemical sensors, the levels of pollutants concentration measured should be within the dynamic ranges. The measurements taken by the electrochemical sensors in Use Case 1 must be comparable to those obtained for the same samples using validated analytical methods.

Key Performance Indicators (KPIs) for non-functional requirements:

KPIs for **PDP technology**:
- 95% reduction in agropollutants' concentration.
- 50% in pollutants transfer to the Mediterranean Basin.

KPIs for **electrochemical sensor**:
- Response time < 60 sec for detection of selected compounds to be measured.
- Adaptation of sensitivity and linear range to the target molecules tested.

Constraints:

Use Case 1 may involve several potentials constrains:
- Validation period must be adjusted to 12 months + 4 previous months of start-up. Operation of PDP technology will need to stick to the time designed.
- Electrochemical sensor and PDP technology may require maintenance.

- Sampling and analytics from the technology streams may require time to be performed and the results may suffer a lag in comparison with sensor data.

Sampling/analyses plan will need to stick to the available budget for the analytics.
PDP technology upscale (final size) will need to keep within given limits so that effective degradation of pollutants can be guaranteed.
The measurements taken by the sensors must be equivalent to the measurements of the samples analysed by GC-MS. This may require a calibration period for the sensors. Furthermore, the samples could contain amounts of contaminants below the detection limit during certain seasonal periods.

Section 4: Scenarios and Validation

Scenario Descriptions:

Scenario 1:
An increase in the concentration of the selected compound for continuous monitoring (tentatively Ibuprofen, but not definitive yet) is detected in the inlet water to the WWTP. The peak is quickly detected thanks to the electrochemical sensor implemented by the UA, which is placed in the input to the WWTP. The need to take a sample for the lab and wait for the results (which usually consumes > 1 week) is avoided since the pollutant is more quickly measurable thanks to the implantation of the sensor. The peak could be produced by the variation in the population of the area, which can increase in specific times of the year (e.g. Christmas, summer holidays).
Scenario 2:
The CoECs selected for Use Case 1 are not found in the inlet water (water to the PDP technology) in sufficient concentration as to be quantified in the laboratory. It is possible that the pollutants are present in the wastewater, but in a lower concentration than expected. It is also possible that they are absent owing to a change in the composition of the pool of pollutants which had been previously defined. Either situation produces that the research needing to shift towards a different list of contaminants that can be detected by the electrochemical sensor.

Validation Process:

Scenario 1
It will be validated by continuous measurement of the selected pollutant (tentatively ibuprofen, but not definitive yet) through the electrochemical sensor provided by UA. This pollutant is used as a model, but the pollutant targeted by the sensor could be any other one with similar physicochemical characteristics. The PDP technology will be applied to decrease the concentration whenever a peak is detected. Furthermore, the functioning of the PDP device can be reinforced (e.g., by being operated more hours) in order to fight to this punctual higher amount of pollutant.
Scenario 2
It will be validated by periodically measuring the concentration of the selected emerging pollutants, mainly before, but also after the application of PDP technology stage. This will involve taking samples and quantify them at the laboratory. If concentration is under the quantification limit (and hence cannot be measured), three actuations will take place:
1. The current laboratory in charge of the quantifications will be requested to adjust the method of analysis in order to turn it more sensitive.
2. If the previous point doesn't deliver any good result, then a new laboratory will be contacted and requested to quantify the pollutants.

3. In parallel with the previous actions, new screenings will be done in order to detect potential changes in the pool of the CoECs that are present in water. If the composition of pollutants has changed, then the list of pollutants to be monitored will be redefined.

Section 5: Regulatory and Technical Alignment

Compliance:

Water Framework Directive (2000/60/EC): Ibuprofen and Bisphenol A are observed in this document.
Marine Strategy Framework Directive (2008/56/EC): General interest for the project's objectives (e.g. bioaccumulation).
Urban Wastewater treatment directive (91/271/EEC): Substances like amisulpride and benzotriazole are mentioned in this directive.
Directive on the quality of water intended for human consumption (Directive EU 2020/2184): The document imposes limits to certain emerging pollutants, including Bisphenol A (2,5 micrograms / L).
Directive on environmental quality standards in the field of water policy (Directive 2008/105/EC): The document lists emerging pollutants to observe, including Bisphenol A.

Risk Assessment:

In case of **PDP technology** – Risk: unforeseeable changes in wastewater quality could affect the PDP treatment expected efficacy and disruption on the supply chain may delay the delivery of the PDP equipment. Mitigation: develop and implement adaptive treatment protocols that can be adjusted based on real-time monitoring data of wastewater quality. For the disruption on the supply chain, it is necessary to establish contracts with multiple suppliers for PDP equipment to reduce dependency on a single source and to develop a robust contingency plan that includes alternative suppliers and expedited procurement procedures to mitigate potential supply chain disruptions.
In case of **electrochemical sensors** – Risk: inaccuracy of the sensor due to the matrix or interferences effects. Mitigation: calibration and validation of sensor performance in real samples (previous work will be focalized in matrix effect for ECs development dedicated to targeted molecules).
In case of **Use Case 1**: Risk: delays in the development of sensor and/or technology that may cause insufficient duration of the piloting period. Mitigation: definition of system requirements sufficiently in advance to prevent delays. Also in case of Use Case 1: Risk: delays in the start of the demonstration period owing to logistic reasons (transport of pilot, permitting management). Mitigation: planning of the logistic aspects sufficiently in advance to prevent delays.

Data Management:

For PDP technology, data will be stored at IRIS's facilities, project repository and on Zenodo (on confidentiality bases)
For electrochemical sensors, the collected data (concentrations) will be stored on the iMERMAID cloud according to UA policies.
Data derived from laboratory analyses of emerging pollutants will be stored at SOCAMEX's facilities, and/or project repository, and/or Zenodo.

Section 6: Stakeholder Identification

List of Stakeholders:

Local authority – City council.
Instituto Aragonés del Agua – regional public administration (water sector).
Sarga – subcontractor of Instituto Aragonés del Agua.
Agricultural and farmers associations – origin of agropollutants.
Citizens – final users.

Stakeholder Needs:

City council and regional public administration (plus the subcontractor Sarga): owners of the facility and those responsible for providing permits for the installation of the remediation system and collaboration in sample collection. These stakeholders need to know updated information as the innovation activity takes place in facilities by them owned or managed. These stakeholders need to know the data obtained after validation to promote public awareness. Public administrations need to monitor the quality of the water under their responsibility and control the causes that worsen the quality of the treated water and, in those cases, locate those possibly responsible.
Citizens and agricultural associations: Know information about the state of the water bodies, the possibility of obtaining safer treated water, free of contaminants both for irrigation and for possible reuse. Improving the quality of water bodies.

Approvals:

Section 7: Conclusion

Conclusion notes:

Use Case 1 aims at the monitoring and abatement of emerging pollutants which are present at the WWTP outlet and have their origin in the agricultural activity and household wastewaters, together with the industrial activity in the area.
In order to do that: (1) a PDP technology is implemented (provided by IRIS), directed towards the elimination of emerging organic micropollutants; and (2) a electrochemical sensor is tested (provided by UA), aimed at the real-time monitoring of selected pollutants.
The PDP technology will be validated for 1 year and the most relevant stakeholders will be kept up-to-date about the project's advance. The feedback of these stakeholders will serve to improve the way to execute the project.
Unforeseen events will be managed properly, in order to ensure the achievement of the site's objectives.

Section 8: Additional Fields

Resource Allocation:

Engineers for the adaption of the PDP system to the WWTP (interferences planning and execution). Engineers and personnel from the building department of SOCAMEX for the risk prevention and legalisation works. Engineers/personnel of the plant for sample collection.
Financial resources for the plant functioning: energy consumption, materials for sample collection, materials for sample analysis and/or other financial resources for sample analysis (if partly or totally outsourced).
R&D personnel and technical office personnel (engineers) for data analysis and preparation of reports.

User Training and Documentation:

Brief training from IRIS to SOCAMEX and from UA to SOCAMEX will be necessary in order to know how to do the basic operations for the technologies' proper functioning.

Technology Stack:

For electrochemical sensors, the use of the equipment supplier software and/or SoftWater/Cubexlab iMERMAID partners and their platforms for data collection and storage.

Change Management:

- Periodic review of risks: every 4 months. Application of corrective measures if necessary.
- Periodic meetings with the administrations related to the WWTP (Instituto Aragonés del Agua and the subcontractor Sarga): KoM with them celebrated on 23/06/2023 in remote; most recent in-person meeting celebrated on 03/06/2024; next in-person meeting planned for May – June 2025, but continuous feedback by email or Teams is envisaged in the meanwhile. During the meetings, stakeholder feedback is incorporated to the mechanisms for project's execution.
- Periodic evaluation of the costs vs the planned expenditure to date.

Milestones:

1. Performance of 2 screenings for the selection of target pollutants.
2. Installation of the PDP technology.
3. Start of the validation of PDP technology in Use Case 1.
4. Installation of electrochemical sensor for continuous monitoring of the selected pollutant.
5. Successful finalisation of the PDP demonstration period.

Timeframe:

The timeframe for Use Case 1:
- Preliminary assays and pollutants characterization – from July 23 to May 24.
- Legalization project and transport / installation technology – January to March 25.
- Technology and sensor start-up – from February 25 to May 25.
- Validation and operation period – from June 25 to May 26.

Sustainability and Long-term Maintenance:

- Apply for additional projects funded by the Horizon Europe or LIFE programmes, where knowledge is built or the PDP technology is upscaled, based on the findings of IMERMAID and specifically on the conclusions of Use Case 1.
- Explore the possibility and / or feasibility to transfer the pilot to a further facility in order to test it in a different environment, once the project is over.

Feedback Loops:

- Regular meetings with stakeholders.

Privacy and Security:

Revision Section/Change History:

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List of Figures:

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List of Tables:

N/A

ANNEX B: Use Case 2

Section 1: Introduction

Project Name:

Innovative solutions for Mediterranean Ecosystem Remediation via Monitoring and decontamination from Chemical Pollution

Date:

10 June 2024

Section 2: Use Case Overview

Lead Organisation:

OP: Opalia Pharma SARL

Participating Partners:

OP – Opalia Pharma
UA – University of Angers
ENIG – National Engineering School of Gabes
EDEN – Eden Tech

Use Case Title:

Demonstration of innovative solutions for the removal of pharmaceutical contaminants

Use Case Objective:

In this use case, a remediation solution will be demonstrated at a pharmaceutical industry.
The objective is to enhance the removal efficiencies of pharmaceutical organic pollutants using both conventional treatment methods and an innovative microfluidic system.

- UA: Development of **electrochemical sensor** box dedicated to three molecules (Diclofenac, Ibuprofen and Ketoprofen) before and after the remediation process to evaluate the system's effectiveness.
- ENIG: The solution is a **prefiltration system** prior to the microfluidic system to enhance the system's effectiveness.
- EDEN: **Microfluidic system** dedicated to tertiary treatments. The system will enhance the efficiency of degradation of organic micropollutants in wastewater.

Section 3: Requirements Gathering

Specific objectives:

Easy navigation.
Well detection of pharmaceuticals with the carbon-based electrochemical sensors.
Well degradation of organic micropollutants after advanced treatment.
Well-developed and specific platform to visualize the required data Information is safeguarded from unauthorized access.

Functional Requirements:

Efficient and adequate degradation of pharmaceutical molecules.
Effective and real-time detection of molecules concentrations (Ibuprofen, Ketoprofen and Diclofenac) by electrochemical sensors.
Control of the sensors and the system effectiveness from the dashboard.

Non-Functional Requirements:

Sufficient communication capacity to offer uninterruptible transmission of Data.
Raw data storage capacity.
Easy maintenance interventions.

Key Performance Indicators (KPIs) for non-functional requirements:

1. Degradation of >95% of pharmaceutical contaminants of emerging concerns from the industrial effluents.
2. Contribution to more than 50% reduction than the conventional techniques of pharmaceutical pollutants at their source to levels that are within EU permissible limits.

Constraints:

1. Clogging of the membrane system due to the sludge produced by the biological treatment.
2. Fouling of electrochemical sensors due to the high salinity of wastewater will affect the system effectiveness.
3. The new technology will require a maintenance budget (to be reviewed).

Section 4: Scenarios and Validation

Scenario Descriptions:

Scenario 1:
Regular maintenance will be implemented to prevent any malfunction of the remediation system due to fouling of electrochemical sensors and clogging of the microfluidic network, which can disrupt the functionality of the system.
Scenario 2:

A high concentration of targeted molecules detected by the sensors after advanced treatment due to the production of certain pharmaceuticals, the wastewater can have:
1. High conductivity, which can cause fouling of the sensors.
2. High acidity due to variations in pH (pH < 6), which can affect the system's effectiveness.
3. High turbidity (around 150 NTU).

Validation Process:

Scenario 1:
OP plans to conduct daily checks of the systems, as well as regular cleaning of the sensors. Additionally, a cleaning protocol for the microfluidic system and membrane system will be identified to avoid any malfunction of systems.
Scenario 2:
A high concentration of targeted molecules detected after advanced treatment by the iWIRE platform would require an investigation on site to verify the proper functioning of the remediation system.

Section 5: Regulatory and Technical Alignment

Compliance:

Tunisian standard NT. 106.002: relating to effluent discharges into the water environment (Environmental protection).

Risk Assessment:

The data will be controlled to validate the system.

Data Management:

Data collection protocols, storage solutions.
The data will be collected on iWIRE platform.

Section 6: Stakeholder Identification

List of Stakeholders:

iMERMAID Project stakeholders, local authorities, Kalâat al-Andalouss citizens, Pharmaceuticals industries.

Stakeholder Needs:

Local authorities will need this data to monitor wastewater compliance and to gain knowledge to guide future legislation and actions.
Citizens of Kalâat al-Andalouss area will have the possibility of obtaining lower levels of contaminants in water nearby.

Pharmaceutical industries that produce or use Ibuprofen, Diclofenac and/or Ketoprofen will have at their disposal new technologies for its monitoring and removal.

Approvals:

End-user to verify the eligibility.

Section 7: Conclusion

Conclusion notes:

In summary, the validation of technologies in an operational environment requires a systematic and rigorous approach, where all concerned molecules are produced during a well-defined verification period. This ensures that the processes are robust, reproducible and compliant with regulatory requirements, thereby guaranteeing the safety and efficacy of the technologies.

Section 8: Additional Fields

Resource Allocation:

Financial resources for travel. Adequate budget for the maintenance and correction for the operation of the system.

User Training and Documentation:

Training schedules, documentation standards and maintenance. Updating the internal water treatment procedure. Training with technology providers.

Technology Stack:

In a next step

Change Management:

N/A

Milestones:

1. Development of an internal (on site) analytical method for molecule analysis. 2. Implementation of the 1st prototype "electrochemical sensors" to test their effectiveness. 3. Implementation of the membrane system and the microfluidic reactor.

Timeframe:

1. Development of an internal (on site) analytical method for molecule analysis (July 2024).
2. Implementation of the 1st prototype 'electrochemical sensors' to test their effectiveness (December 2024).
3. Implementation of the microfluidic reactor (End 2025).
4. The validation of the technologies (2026).

Sustainability and Long-term Maintenance:

Preventive and remedial maintenance in the event of malfunction.
Training and awareness-raising for users and maintenance employees.

Feedback Loops:

User satisfaction surveys.

Privacy and Security:

Data will always be secure, bearing in mind that Opalia's information system is ISO27001 certified.

Revision Section/Change History:

N/A

List of Figures:

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List of Tables:

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ANNEX C: Use Case 3

Section 1: Introduction

Project Name:

Innovative solutions for Mediterranean Ecosystem Remediation via Monitoring and decontamination from Chemical Pollution

Date:

10 June 2024

Section 2: Use Case Overview

Lead Organisation:

SMAT - Società Metropolitana Acque Torino S.p.A.

Participating Partners:

- WF – Weefiner
- UNIFI - Università degli studi di Firenze
- ZEN – Zentrix Lab
- SOFTW - SoftWater srl
- ITCL - Fundación Instituto Tecnológico de Castilla y León
- CUB - CubexLab

Use Case Title:

Demonstration of innovative solutions for the removal of heavy metals

Use Case Objective:

This use case will be deployed to demonstrate the **removal of heavy metals** from wastewater. The pilot is a WWTP (wastewater treatment plant) located in the Metropolitan Area of Turin, designed for a population of 9000 inhabitants.
The WWTP consists of an initial screening of gross solids, skimming of fats, oils and grease. This is followed by a denitrification process in an anoxic environment and a primary oxidation. The process continues with a secondary oxidation and sedimentation. Finally, the disinfectant is dosed into the outlet channel of the secondary sediments.
This WWTP has been selected for use case 3 since high concentration of Zinc where sporadically detected at wastewater inlet.
The aim of the pilot is i) to monitor in real time the heavy metals content in the water entering the WWTP and possibly detect anomalous discharges above the limits, by means of the **inorganic electrochemical sensor** developed by UNIFI; ii) to remove heavy metals (Zn, Cu, Al) from wastewater

by means of WF's **4D Scavenger technology**; iii) to verify the performances of the monitoring system and treatment technology.
Both the technologies should be able to deal with wastewater (also through proper pre-treatments), characterized by high (and variable) of BOD, COD and TSS concentrations.
The data will be made available to the end-user though a dedicated web interface for the remote visualization of collected data.

Section 3: Requirements Gathering

Specific objectives:

1. Removal of heavy metals from wastewater
2. Monitoring of heavy metals in wastewater
3. Providing data from the monitoring system in an easy way

Functional Requirements:

1. Removal of selected metals (Zn, Al, Cu) from wastewater with different characteristics
2. Monitoring of selected metals (Zn, Cd, Pb, Cu) in wastewater with different characteristics
3. Provision of data coming from the sensor through a user-friendly web interface

Non-Functional Requirements:

1.1. The **treatment technology** should be able to remove selected metals in wastewater with TSS < 5 mg/l without any pre-treatment.
1.2. The treatment technology should be able to remove selected metals in wastewater with TSS > 5 mg/l with a filtration pre-treatment.
2.1. The **monitoring system** should be able to detect selected metals in wastewater with BOD < 15 mg/l and TSS < 25 mg/l without any pre-treatment.
2.2. The monitoring system should be able to detect selected metals in wastewater with BOD > 15 mg/l and TSS > 25 mg/l with a filtration pre-treatment.
3. **User-friendly dashboard** available for viewing measurements (expressed as concentration) at the appropriate frequency for wastewater characterization.

Key Performance Indicators (KPIs) for non-functional requirements:

1.1. Metals removal capacity > 95% in wastewater with metals concentration > 0,5 mg/l.
1.2. Metals removal capacity > 90% in wastewater with metals concentration < 0,5 mg/l.
2.1. Limit of detection of metals (Pb, Cd, Cu) ≤ 5 ppb.
2.2. Limit of detection of Zn ≤ 10 ppb.
3.1. Frequency of the measure tunable up to 2 measures/hour.
3.2. Dashboard availability.

Constraints:

- The treatment technology and the sensor need frequent maintenance.

- High cost for the reagents could limit the duration of the pilot.
- Needs of a pre-filtration both for the sensor and the treatment technology.
- Reagents needed for the treatment technology washing and regeneration should be properly disposed.
- The beginning of the pilot phase will depend on the availability of the monitoring sensor, that will be tested in different use cases.
- Need to adapt the 4D Scavenger technology to the characteristics influencing water streams, such as salinity, pH, presence of ions, COD, BOD, TSS and flow rate.

Section 4: Scenarios and Validation

Scenario Descriptions:

Scenario 1:
A high concentration of heavy metal is detected from the on-line sensor at WWTP inlet. This allows for a fast reaction by the operator and the activation of monitoring both at WWTP outlet and at pilot (4D Scavenger) outlet. The monitoring shows that metals are partially removed from the WWTP plant (near to the law limit values for discharge into surface water) and completely removed from the pilot treatment plant. Moreover, thanks to the online sensor it is possible to see that the event is very short in time, and it would be difficult to detect it with periodic analysis. The same event repeats more than once, thus allowing the plant manager to detect anomalous events that won't be possible to detect with a periodic monitoring.

Validation Process:

Scenario 1:
SMAT receives and alert through the iWIRE software showing a peak of heavy metals in the water entering the WWTP. SMAT immediately perform some laboratory analysis in order to confirm the metal concentration detected from the on-line sensor. Samples are taken both at the inlet and outlet of the WWTP to check whether the discharge complies with legal limits. Samples are also taken at pilot (4D Scavenger) outlet in order to verify the removal capacity of the plant.
Similar events happen several times and the same protocol is applied (laboratory analysis in different plant location in order to confirm the detected concentration and verify the removal capacity both of the WWTP and the pilot technology). This allow to detect events that wouldn't be possible to detect with a periodic sampling and to verify the efficiency of the WWTP in removing this contaminant.
If anomalies are detected at WWTP plant outlet, the use of emergency treatment for heavy metal removal can be considered
All data is uploaded to the iWIRE platform, thus allowing a better understanding of the events.

Section 5: Regulatory and Technical Alignment

Compliance:

Both wastewaters discharged into the sewer and the effluent of a WWTP are subject to legal limits to prevent that at the end of the treatment processes, when treated water is released in the environment (e.g., river), it still has a high concentration of contaminants. In Italy, the transposition of Directive 2000/60 is Legislative Decree 152/06 (“Testo Unico Ambientale”), which contains concentration limits for the wastewater discharge in sewer and the discharge of effluent of the WWTP in water bodies for different contaminants. Regarding heavy metals treated in this Use Case 3, concentration limits are the following: Al: 1 mg/l; Cd: 0.02 mg/l; Cu: 0.1 mg/l; Pb: 0.2 mg/l; Zn: 0.5 mg/l.

Risk Assessment:

- Risk of non-compliance with the environmental conditions required by the technologies: in particular, the sensor has a range of working temperature of 20-30°C, while the 4D Scavenger of 5-40°C. Mitigation: implementation of a heating/cooling system in the container that hosts the technologies.
- Risk of variability in the analytical response of the sensor due to the usage or aging of the electrodes. Mitigation: implementation of an alarm for detecting a decrease of measure accuracy and a subsequent sensor maintenance/substitution.
- Both the sensor and the 4D Scavenger technology could not accept water with high TSS/BOD. Mitigation: a pre-filtration system should be installed to remove the interferences.
- Both for the sensor and for the 4D Scavenger technology the use of an acid solution is necessary. Hence, for both technologies there are risks for the environment and for the plant's personnel. Mitigation: the waste should be properly disposed as a hazardous waste (through the realization of a temporary storage and a subsequent disposal) and personnel should be properly trained and equipped with protective items.

Data Management:

A data management plan, that presents a comprehensive strategy for overseeing the processing of data throughout the entire duration of the iMERMAID project and beyond, has been defined in D7.4 'Data Management Plan' and it is valid for all the iMERMAID Use Cases.

Section 6: Stakeholder Identification

List of Stakeholders:

1. All the industries that use metals in their production processes (such as chemical manufacturing and metal coating industries).
2. Local authorities.
3. Companies dealing with the removal of heavy metals.
4. Citizens of Turin metropolitan area.

Stakeholder Needs:

Stakeholders need reliable technologies that can detect concentrations, at least at the level required by law, with sufficient accuracy and precision. They also need a removal technology that can remove contaminants well below law limits, ensuring that the treated water meets legal requirements. Moreover, the removal process must not consume a lot of water or chemicals and should generate as little additional waste (that contains the removed metals) as possible. Finally, the frequency of updating data from the sensor should be high enough so that timely action can be taken if the concentration approaches the legally required levels.

1. All the industries that use metals in their production processes could be interested in both the technologies, since according to Legislative Decree 152/06, they must comply with the limits set for industrial discharges.
2. Local authorities devoted to environmental monitoring might also be interested in using the sensor to verify that metals concentration in discharged water comply with legal limits.
3. The 4D Scavenger technology could be used by companies dealing with the removal of heavy metals contamination from water (e.g. metal-containing runoff water and mining waters).
4. Citizens of Turin metropolitan area will have an environment less contaminated by heavy metals, which can impact the quality of other recreational activities, food, etc.

Approvals:

Section 7: Conclusion

Conclusion notes:

Use Case 3 will demonstrate the application of innovative technologies for monitoring and remediation of heavy metals in wastewaters under defined conditions. The technologies will first be tested at a laboratory scale and then, installed in an existing WWTP for a pilot study. Tests in an operational environment will allow to address all the challenges similar to that a real application should arise.
The WWTP selected for the use case receive wastewater from both, domestic and industrial discharge, that may be contaminated with heavy metals. Both the monitoring system and the treatment technology will have to deal with water having high and variable concentrations of BOD, COD and TSS. This aspect will be considered and, if necessary, proper pre-treatment will be installed.

Section 8: Additional Fields

Resource Allocation:

- Technicians devoted to the installation of the pilot and the maintenance of both the monitoring system and the treatment technology (weekly regeneration of the scavenger, periodic cleaning of the filter, etc.).
- Data analysts acquire, process, disseminate the data and verify the correct operation of the technology.
- Adequate budget for the needed consumables to do any maintenance of the system.
- Laboratory analysts that periodically perform analysis to verify the correct operation of the sensor and the Scavenger.

User Training and Documentation:

- [WF] On-site training and documentation for the use of the 4D Scavenger technology.
- [UNIFI] Management protocol for the monitoring system.

Technology Stack:

Change Management:

Milestones:

- **Preliminary tests** and analysis performed to characterize wastewater quality and assess the possible interference of the matrix with the sensor and the 4D-Scavenger.
- **Pilot plant installation** in the wastewater treatment plant.
- **Validation** of both technologies under real conditions.

Timeframe:

- **Preliminary tests** performed during the first semester of 2024.
- **Pilot plant installation** will start at M20 (February 2024).
- **Validation** of the technologies under real conditions will be performed after the pilot plant installation (M20-M36).

Sustainability and Long-term Maintenance:

- **Scavenger technology**:

The equipment has a lifespan of approximately 5-10 years.
The core 4DS needs replacement annually.
In case of issues, the equipment sends alerts for necessary actions. Ideally, the 4DS can be ground to powder and printed again. Alternatively, in the worst case, the used 4DS will have to be incinerated.

- **Sensor**:

Sensor will have to be replaced after a certain number of measurement cycles.
Sensor regeneration protocol; flow cell cleaning protocol.

Feedback Loops:

- N/A

Privacy and Security:

- N/A

Revision Section/Change History:

- N/A

List of Figures:

- N/A

List of Tables:

- N/A

ANNEX D: Use Case 4

Section 1: Introduction

Project Name:

Innovative solutions for Mediterranean Ecosystem Remediation via Monitoring and decontamination from Chemical Pollution

Date:

1 June 2024

Section 2: Use Case Overview

Lead Organisation:

CMMI – Cyprus Marine and Maritime Institute

Participating Partners:

UA – Université d'Angers
BIOS – Biosense Institute
UNIFI – Università di Firenze
NTUU KPI – National Technical University of Ukraine Igor Sikorsky Kyiv Polytechnic Institute
ZEN – Zentrix Lab

Use Case Title:

Monitoring platform on the Mediterranean Sea

Use Case Objective:

Use Case 4 will be implemented to demonstrate the monitoring of chemical pollutants of emerging concern at Sea. The use case is a **moored buoy** which serves as a research fixed platform for contributing to marine observation and marine data exchange.
It incorporates both the batteries and the electrical panel with the necessary wiring for the installed sensors. The battery capacity, which is recharged by four PV panels, supports an additional electrical load. The electrical panel has been specifically designed to accommodate two additional 12 V sensors and two additional 24 V sensors, which can be placed within the surplus internal space of the buoy.
Therefore, the buoy's floatation, balancing weight and mooring system are also designed to allow the integration of additional equipment. The internal PC of the buoy is connected to the datalogger and additional instruments connection through USB connectors. The buoy's datalogger is designed with more input slots, allowing the integration of additional sensors through network cable pins. Data collected by these sensors are transmitted via 4G cellular communications to the cloud system of

CMMI. This project complies with open source, and FAIR data principles and CMMI offers an online dashboard to present the information.
Currently, the facility measures various parameters, including conductivity, salinity, pressure, water temperature, dissolved oxygen, chlorophyll-a, turbidity, fluorescence, dissolved organic matter, pH, nitrates, current speed and direction, acoustic and meteorological information.
During the iMERMAID project, the involved partners will explore the perspective of **monitoring organic pollutants and heavy metals** within Use Case 4. For this reason, four iMERMAID sensors will be incorporated into the buoy:

- BIOS - Development of an oil sensor for contaminants (e.g., crude oil derivatives and sunscreen oils) as part of pilot testing.
- UA - Organic micropollutants electrochemical sensor box (nitrite molecule well identified in harbour sample in January 2024).
- ZEN - PFAS monitoring platform.
- UNIFI - Heavy metals electrochemical sensor box.
- NTUU KPI - assimilation of in-situ and satellite data.

In the Use Case 4, the iMERMAID consortium will also employ the technology developed by NTUU KPI for **monitoring water bodies using satellite data**. The satellite data will be employed to assimilate the data from in-situ sensors, incorporate innovations and provide a cross-assessment, comparing satellite data recognition with data available from sensors. This assimilation is the combination of in-situ data with all available information from numerical models describing the ocean dynamics, observations, and prior information.

Section 3: Requirements Gathering

Specific objectives:

Detection of CoEC near the MPA of Amathus.
Oil spill identification near the use case and the projection of oil spill recognition in the Mediterranean Sea.
Near real-time monitoring of Limassol Bay.

Functional Requirements:

The equipment should be functional during permanent operation in salty water up to 40 psu.
Since the use case is a platform that swings from the power of the waves, the sensors should be able to withstand a total wave energy of up to 15 kW/m of wave motion. More precisely:

- Frequency ≥ 0.1 Hz.
- Wavelength ≤ 100 m.
- Amplitude ≤ 2 m.
- Wave speed ≤ 10 m/s.

Sufficient battery capacity to support uninterruptable operation of the sensors.
Access of the sensors to telemetry/communication equipment.
The capability of telemetry equipment to communicate through the cellular network.
Remote access to the mini-PC to monitor and control the sensors from the office.

Non-Functional Requirements:

Sufficient communication speed to transmit all the data of the sensors.
Sufficient communication capacity to offer uninterruptible transmission of data.
Quality Control of the acquired data (effectiveness, stability, reliability).
Accessibility for maintaining the equipment easily (easy access to remove the sensors without lifting the buoy).
Availability of the information through user-friendly dashboards (raw data storage capacity, availability of processed information).
Stable response time.

Key Performance Indicators (KPIs) for non-functional requirements:

The meteorological parameters have a data refresh rate of 15 minutes.
The environmental sensors (including oil and electrochemical sensors and seawater currents) have a data refresh rate of 30 minutes.
Communication delays less than 60 seconds.
Measurement accuracy of each sensor as it is mentioned in the Technical Specification task of Deliverable "D4.2. Benchmarking and Analysis of current aspects, requirements, specifications & conceptual architecture".

Constraints:

Since the use case is an outdoor system, the sensors should operate normally under the following conditions:

- Temperatures: 0°C - 40°C.
- Humidity: 5% - 95% RH.

The oil sensor requires frequent maintenance.
Since the buoy is a platform that swings from the power of the sea waves, the oil sensor needs to be able to be turned off remotely during extreme weather. The remote shutdown will be done with some minor modifications to the system. However, a physical presence is required to restart the oil sensor, needing further development to solve this problem.
If the electrochemical sensor (dedicated to nitrites) loses more than 5% of the value obtained after one measurement with a probe molecule, it would need to be replaced/changed after each measurement.
The high salinity of the eastern Mediterranean (where Use Case 4 is located) will cause clogging effect in the flow system of the heavy metal sensor, due to salt crystallisation. This effect can compromise the maintenance frequency and/or the correct functioning of the fluidic system.

Section 4: Scenarios and Validation

Scenario Descriptions:

Scenario 1:
An oil spill incident had occurred due to a maritime accident. The oil sensor detected promptly the high concentration of crude oil derivatives (previously determined). This allowed for the fast information of the relevant authorities and the detainment of the oil at the sea surface. The early warning system provided by the technology developed through the iMERMAID allowed for the

elimination of the anticipated environmental impacts while reducing the financial burden associated to an oil spill cleanup protocol.

Scenario 2:

A maintenance plan, including anti-fouling of the sensors had been in place. More frequent actions were planned during summer months in comparison to winter months, due to background knowledge on seasonal fluctuations of water surface temperature, light availability, dissolved oxygen, biodiversity and population of fouling organisms. Due to climate change the sea water temperature was higher than usual during winter months causing the bloom of opportunistic diatoms fouling the sensor. Fouling disrupted the functionality of the oil sensor technology and hence, the accuracy of the oil concentration readings activating a false positive alarm.

Validation Process:

Scenario 1:

CMMI, BIOS and NTUU KPI receive an alert through the iWIRE software that the oil sensor detects values well above the maximum threshold. CMMI immediately check the values of the other sensors installed under the buoy. The latest values of pH and turbidity were also showing unusual changes and rising curves in the graphs of iWIRE. A visit of CMMI to the buoy is immediately planned for physical investigation of the area and the contractor for oil removal and eradication is informed to be stand-by. At the same time, CMMI examines the seawater current spectrum and also the wind speeds and directions of the last few hours in the region. Then CMMI sends the information to NTUU KPI. NTUU KPI examines the most recent satellite images around the buoy location, based on the information of water currents and winds. NTUU KPI extracts the latest satellite images and identify the quantities of the oil. CMMI informs the contractor about the expected quantities of oil spilled and ask them to send the most appropriate skimmer vessel(s) to the potential location. Minutes later, CMMI boat arrives to the area and communicates with the skimmer vessel to give updated and accurate information. The oil spill is cleaned before reaching the beaches of Limassol and before it sinks to the sea floor.

Scenario 2:

CMMI, BIOS and NTUU KPI receive an alert through the iWIRE software that the oil sensor detects values above the maximum threshold. CMMI immediately checks the values of other sensors installed under the buoy. The values of chlorophyll-a, nitrates and dissolved oxygen have been showing a gradual change for a few days. The temperature of seawater was also above the normal values. A visit of CMMI to the buoy is planned for physical investigation of the area and inform the contractor for oil removal and eradication to be stand-by. At the same time, CMMI examines the seawater currents and the wind speeds and directions of the last few hours in the region. Then CMMI sends the information to NTUU KPI. NTUU KPI examines the most recent satellite images around the buoy location based on the information of water currents and winds. NTUU KPI extracts the latest satellite images. The images were not showing any detectable oils on the surface. The CMMI boat arrives at the buoy location and finds no oil around it. A diver inspects the oil sensor and detects heavy fouling by photosynthetic organisms. CMMI schedules immediate maintenance and adjusts the maintenance procedures for cleaning (antifouling) the sensors (and associated equipment) more often (e.g., frequent maintenance all year round).

Section 5: Regulatory and Technical Alignment

Compliance:

Adequate national licences have already been acquired by the Cyprus Port Authority, which is the agency responsible for authorising the deployment of a fixed ocean data acquisition system in the specific area of Cyprus' EEZ.
An additional license has been acquired by the Cyprus Department of Fisheries and Marine Research to protect the benthic habitats.
Compliance with the FAIR data principles.
Compliance with EU Marine Framework Directive.
Compliance with MSFD.

Data Management:

The data will be collected automatically on the secure AZURE cloud system of CMMI.
Connection to the iWIRE platform.

Risk Assessment:

Data inaccuracy. Mitigation: the data will be validated through a Quality Control tool.
Change in usual water conditions that may lead to inefficient operation situations. Mitigation: periodic review of facilities and evolution of values determining the monitored water quality.

Section 6: Stakeholder Identification

List of Stakeholders:

The National authorities and NGOs that manage the issues of seawater pollution.
Media (including social media).
End users.
Academics, researchers, and environmentalists who study climate change in the Eastern Mediterranean basin.
Oil and gas industry.

Stakeholder Needs:

National authorities and NGOs need an early warning system when the pollution levels exceed acceptable readings, which are the predefined parameters' limits. They need to be informed within minutes from the first measurement that is above the threshold. The results need to be reliable, accurate and contain adequate information.
Media and social media need an accurate forecasting system to inform the public. They need to be informed within minutes of the oil spill detection. The forecast needs to be reliable, accurate, and contain adequate information. They should instantly receive the map with the current status of the oil spill and prediction of the oil flow.
End users could be tourists, athletes and people who fish or do other recreational activities in the sea.

Academics, researchers, and environmentalists need direct access to the raw data through FAIR data principles. The data need to be reliable, accurate, and contain adequate information. Oil and gas industries would be interested in connecting with monitoring systems that detect spills in almost real time to activate their action plans as soon as possible.

Approvals:

Use Case 4 belongs to CMMI and no approvals are required.

Section 7: Conclusion

Conclusion notes:

The Use Case 4 acts as a testbed for the emerging technologies of sensors to be examined in a relevant environment, at first, and then to be verified in operational environments. By deploying a moored buoy equipped with several sensors and robust data transmission systems, it is expected to establish an effective solution for continuous and real-time environmental monitoring. The buoy's comprehensive design, including its power management via photovoltaic panels and the integration capabilities for additional sensors, should ensure adaptability to various monitoring needs. The integration of the iMERMAID sensors, specifically for detecting oil, organic micropollutants, PFAS and heavy metals, is expected to highlight the platform's versatility and effectiveness. The collaboration between in-situ sensor data and satellite monitoring provided by NTUU KPI would enhance the accuracy and reliability of pollutant detection and assessment. This combined approach should enable a thorough understanding of the marine environment, facilitating prompt and informed decision-making in response to pollution incidents. During the validation scenarios, it is expected that the buoy's sensors will effectively detect significant environmental changes, triggering timely alerts and enabling rapid response actions. These scenarios are likely to underscore the importance of routine maintenance and adaptability to environmental variations, such as increased fouling during unexpected temperature rises. The validation outcomes will be compared with the expected results to either define the baselines or make the required modifications for defining the baselines. The evaluation of the testing will then define if the technologies have met all the required standards or require some additional amendments.

Section 8: Additional Fields

Resource Allocation:

Data analysts acquire, process and disseminate the data. They are also responsible for designing and maintaining the pipeline of the data architecture and for connecting the acquired data with the European portals (e.g., EMODnet). Engineers to maintain the overall operation of the buoy. Oceanographers to confirm the correct operation of the sensors (through calibration) and the accuracy of the acquired information (through quality control). Adequate budget for the needed consumables to do any maintenance, corrections, and modifications required for the smooth operation of the system.

User Training and Documentation:

CMMI is experience in ocean data acquisition systems. Many procedures are documented by the Marine Observation Centre of the organisation.

Technology Stack:

Microsoft AZURE. Python scripts.

Change Management:

The software updates are controlled by the PC installed in the buoy.

Milestones:

Preliminary tests of the new sensors in a relevant environment (including the data transmission, storage and projection). Test of sensors under in an **operational environment** (including data ingestion, pre-processing and dashboards). **Validation under real conditions** (including complete data pipeline).

Timeframe:

Preliminary tests will be conducted during the second half of 2024. Tests in an operational environment will be conducted during Q2 of 2026. The validation under real conditions is out of the scope of iMERMAID but the products are expected to be finalised by 2028.

Sustainability and Long-term Maintenance:

Annual maintenance of the buoy and instruments.

Feedback Loops:

The CyMON workshop is an annual event to update all relevant stakeholders about the status of research buoys and near-future plans. The workshop started in 2023 and is dedicated to engaging stakeholders.

Privacy and Security:

Data encryption tool by Microsoft AZURE to prevent cyber attackers from affecting data integrity and communication reliability. Padlocks to secure the sealed panels/doors that physically secure the instruments.

Revision Section/Change History:

N/A

List of Figures:

N/A

List of Tables:

N/A

ANNEX E: Use Case 5

Section 1: Introduction

Project Name:

Innovative solutions for Mediterranean Ecosystem Remediation via Monitoring and decontamination from Chemical Pollution

Date:

4 June 2024

Section 2: Use Case Overview

Lead Organisation:

ENIAIOS SYNDESMOS DIACHEIRISIS APORRIMATON KRITIS (ESDAK)

Participating Partners:

-EDEN Tech (EDEN) -Universite D'Angers (UA) -Hellenic Centre for Marine Research (HCMR) -Università Degli Studi Di Firenze (UNIFI)

Use Case Title:

Demonstration of innovative solutions for the removal of organic contaminants from landfill leachates.

Use Case Objective:

Leachates treatment plant of the Pera Galini Municipal Sanitary landfill located in Crete is the demonstration site of Use Case 5. Sanitary landfill leachate is a strongly polluted wastewater with a variety of components. It is a wastewater type that is characterized by high organic and inorganic pollutant concentrations. The presence of a wide range of chemicals in municipal solid waste (MSW) landfill leachates has been documented and thus, it is expected to be found in the samples to be treated.

Currently, the Leachate Treatment Plant (LTP) is monitored in a monthly basis through sampling and laboratory analyses of various parameters, which are selected according to the obligations set by the environmental license of the Sanitary landfill (e.g., physicochemical, chemical, biological parameters etc). The average raw leachate flow rate entering the plant is 110 m^3/day and the operation of the plant today includes the following three treatment stages:

a) Physical/chemical process including coagulation, flocculation and Dissolved Air Flotation.

b) Physical/biological treatment based on a Membrane BioReactor.

c) Purification process with Reverse Osmosis technology. The effluent after degasification and chlorination can be used for irrigation and/or recirculation to the landfill for enhancing its performance.
Use Case 5 will demonstrate the application of EDEN's **AKVO microfluidic water treatment system** in the landfill leachate treatment plant. The microfluidic water system will be tested for its efficiency in removing micropollutants for the final effluents based on advanced oxidation processes (RO effluent treatment of approximately $1m^3$/day in an iterative demonstration for 1 month).
In the same use case, the **organic micropollutants electrochemical sensor** box by UA for monitoring micropollutants in the effluents and an **electrochemical inorganic sensor for monitoring the heavy metals** effluents will be deployed and its applicability will be demonstrated.
Apart from the chemical/microbiological analyses to be done in the effluents, application of a battery of validated toxicity tests for ecotoxicological evaluation of the systems effectiveness will be performed by HCMR (Microtox, algae growth inhibition, rotifer reproduction, Daphnia immobilisation, zebra fish tests, etc).

Section 3: Requirements Gathering

Specific objectives:

CoEC detection.
Finalization of the CoEC list.
Data monitoring on organic micropollutants and heavy metals.
Remediation system effectiveness.

Functional Requirements:

1. UA sensor: Electrochemical measurements of 4 CoEC: Bisphenol A, Bentazone, Propamocarb and PFOA (final list of targeted molecules).
2. UNIFI sensor: Electrochemical flow system for the measurement of heavy metals, namely Zn (II), Cd(II), Pb(II) and Cu(II).
3. EDEN AKVO technology: The identified micropollutants (Bisphenol A, Bentazone and Propamocarb) will be degraded using advanced photocatalytic oxidation processes within a microfluidic water treatment system.

Non-Functional Requirements:

1. UA sensor: Lifetime of sensors (passivation, biofouling diseases): one solution to this problem is the replacement of the sensor after each analysis. Furthermore, the main work in Crete will be focalized to EDEN remediation evaluation (on site experiments).
2. UNIFI sensor: Heavy metal monitoring will be performed and validated using a calibration curve or the standard addition method. Matrix effect should be evaluated, together with analytical performances of the sensors in real samples. At this purpose, cleaning protocols will be evaluated and optimized.
3. EDEN AKVO technology: The assessment of the system will rely on its efficacy in degrading the micropollutants, which will be determined by comparing the concentrations of the pollutants before and after treatment.

Key Performance Indicators (KPIs) for non-functional requirements:

- Demonstrate up to 95% efficiency of the microfluidic systems developed in the iMERMAID in the degradation of the targeted micropollutants.
- Performance of real-time pollutant sensors framework for monitoring organic chemicals in the wastewater.
- More than 50% reduction in the transfer of the selected pollutants along the wastewater to the water bodies.

Constraints:

1. UA sensor: No specific constrains or limits for the organic pollutant sensor technology related to the Use Case 5.
2. UNIFI sensor: The device for heavy metal detection requires prefiltration to reduce suspended particles and thus, the clogging of the fluidic system.
3. EDEN AKVO technology: The microfluidic system requires prefiltration to reduce the total suspended solids as these might clog the microchannels.

Section 4: Scenarios and Validation

Scenario Descriptions:

Scenario 1:
Assess pollutants qualitatively through the year in order to discover patterns of pollution production and/or presence at the site which change dramatically seasonally, due to the seasonal rains and touristic character of the served area.
Scenario 2:
Check the information provided by the online sensor against that given by the so far used validated quantification methods (laboratory analyses).

Validation Process:

Scenario 1
It will be validated by carrying out periodic screenings to cover different seasonal characteristics. The samples will be taken at the influent and effluent of several treatment stages of the LTP (critical points of treatment).
Scenario 2
It will be validated by periodical quantification of the selected pollutants (Bisphenol A, Bentazone, Propamocarb and PFOA) by laboratory analysis. The results will be compared to the parameter values detected for the same samples from the same day by the sensor. Simple statistical tests will be carried out to detect significant differences between pairs of values.

Section 5: Regulatory and Technical Alignment

Compliance:

- Compliance with the EU Waste Framework Directive (2008/98/EC).
- Compliance with the EU Urban Wastewater Treatment Directive (91/271/EEC).
- Compliance with the EU Marine Framework Directive (2008/56/EC).
- The LTP effluent must comply to the requirements set by the Regional Environmental Authority (environmental licence).

Risk Assessment:

In case of **AKVO microfluidic technology**, unpredictable changes in the leachate quality could affect the microfluidic remediation treatment efficiency. Mitigation: proper prefiltration set up to remove any interferants.
In case of **electrochemical sensors**, inaccuracy of the sensor due to the matrix or interferences effects. Mitigation: calibration and validation of sensor performance in real samples (previous work will be focalized in matrix effect for ECs development dedicated to targeted molecules). Risk of variability in the analytical response of the sensor due to the usage or aging of the electrodes. Mitigation: implementation of an alarm for detecting a decrease of measure accuracy and a subsequent sensor maintenance/substitution.
Due to the likely variation of the total solids concentration, a pre-filtration system should be installed in order to remove the interferences and prevent damages of both sensors and remediation system.

Data Management:

For the AKVO microfluidic remediation technology, data will be stored at EDEN's facilities, project repository and, on ESDAK.
For electrochemical sensors, the collected data (concentrations) will be stored on the iMERMAID cloud according to UA policies.
Data derived from laboratory analyses of emerging pollutants will be stored at EDEN's facilities, and/or project repository, and/or ESDAK.

Section 6: Stakeholder Identification

List of Stakeholders:

The National authorities and NGOs which are responsible for the municipal solid waste (MSW) and the wastewater management.
Academics, researchers and environmentalists.
End users.

Stakeholder Needs:

National authorities and NGOs need new alternatives for the continuous monitoring and treatment of leachates containing contaminants of emerging concern.

Academics, researchers, and environmentalists that study the wastewater and solid waste management of the Mediterranean basin. They can use new techniques for near real-time continuous monitoring and new technologies based on photocatalytic processes and microfluidics for contaminant remediation. These technologies will provide a field of research with great potential for improvement in the short term.
End users: Served population by the Sanitary landfill of Pera Galini: residents, visitors, tourists, etc which will benefit from higher quality water with lower amounts of heavy metals and organic micropollutants.

Approvals:

Modification of the environmental licence of the Pera Galini Landfill, in case of scaling up the microfluidic remediation technology.

Section 7: Conclusion

Conclusion notes:

Use Case 5 aims to provide significant insights into the effectiveness of advanced technologies for treating and monitoring chemical pollutants by integrating EDEN's AKVO microfluidic water treatment system and advanced electrochemical sensors from UA and UNIFI. It is expected to achieve substantial improvements in the detection and remediation of micropollutants and heavy metals.
The sensors should provide accurate and reliable data on the concentrations of key pollutants, such as organic Bisphenol A, Bentazone, Propamocarb, PFOA and inorganic Zn(II), Cd(II), Pb(II) and Cu(II). This real-time data is crucial for understanding the dynamics of pollutant presence and informing timely interventions.
The EDEN AKVO microfluidic water treatment system is anticipated to demonstrate high efficiency in degrading targeted micropollutants using advanced oxidation processes. The validation scenarios are expected to provide valuable data on seasonal variations in pollutant levels and confirm the accuracy of online sensors compared to traditional laboratory analyses. By conducting periodic screenings and comparisons, it is aimed to establish robust patterns of pollution production and validate the performance of the new technologies.
The validation outcomes will be compared with the expected results to either define the baselines or make the required modifications for defining the baselines. Before the actual application is finalised, the technologies will be tested under real conditions for a substantial time.

Section 8: Additional Fields

Resource Allocation:

Data analysts acquire, process and disseminate the data. They are also responsible for designing and maintaining the pipeline of the data architecture.
Engineers to maintain the overall operation of the remediation system and confirm the correct operation of the sensors (through calibration) and the accuracy of the acquired information (through quality control).
Adequate budget for the needed consumables to do any maintenance, laboratory analyses for chemical parameters, corrections, and modifications required for the smooth operation of the system.

R&D personnel and technical office personnel (engineers) for data analysis and preparation of reports.

User Training and Documentation:

A basic training from EDEN, UA and UNIFI will be necessary in order to know how to do the basic operations for the technologies' proper functioning. A brief manual for the operation and maintenance of each technology will also be helpful.

Technology Stack:

For electrochemical sensors, the use of the equipment supplier software and/or SoftWater/iMERMAID partners and their platforms for data collection and storage.

Change Management:

Milestones:

Preliminary tests of the new sensors and remediation system in a relevant environment (including the data transmission, storage, projection).
Test of sensors and remediation system under in an operational environment (including data ingestion, pre-processing, and dashboards).
Validation under real conditions.

Timeframe:

Preliminary assays and pollutants determination will be finished during the second half of 2024.
Operational tests of both sensors and remediation system in Pera Galini Leachate Treatment Plant will be conducted at the end of Q2 of 2026.

Sustainability and Long-term Maintenance:

The remediation system and the sensors will not be available in the leachate treatment plant after the end of their operation period during the project.

Feedback Loops:

N/A

Privacy and Security:

Data encryption tool to prevent cyber attackers from affecting data integrity and communication reliability.

Revision Section/Change History:

N/A

List of Figures:

N/A

List of Tables:

N/A

The Mediterranean Sea and its surrounding regions support a diverse variety of essential socioeconomic activities. It is one of the highly exploited water ways and the influence of anthropogenic activities on its marine habitats and ecosystems has grown significantly since the industrial revolution. Because of this, the Mediterranean Sea basin is very vulnerable to chemical contamination and build-up. To safeguard the Mediterranean Sea basin from contaminants for emerging concerns (CoEC), iMERMAID will integrate, coordinate, and synergize innovative preventive, monitoring, and remediation solutions. iMERMAID will build an evidence-based multidimensional framework that will guide policymaking and transform societal perceptions to reduce CoEC usage, emissions, and pollution. Furthermore, next generation sensor and remediation solutions will be developed within iMERMAID to monitor and remove prioritized chemicals from its source while reducing upstream pollution. iMERMAID builds an ideal interdisciplinary team by bringing together prominent SMEs, researchers, regulators, and innovation professionals who have been essential in improving the knowledge and awareness of CoEC. Beyond state-of-the-art techniques, iMERMAID will strive to strengthen regulations against CoEC, expand economic possibilities and competitiveness, improve the standard of living for EU residents, while preventing the accumulation of chemical pollution in the Mediterranean Sea basin. iMERMAID will empower the efforts to create a zero pollution, contaminant free waters by enabling the Chemical Strategy's goals to become a practical reality.

iMERMAID

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