PART C

WATER JOINT PROGRAMMING INITIATIVE

WATER CHALLENGES FOR A CHANGING WORLD

2018 JOINT CALL

Closing the Water Cycle Gap

“MANAGED AQUIFER RECHARGE: ADDRESSING THE RISKS OF RECHARGING REGENERATED WATER”

“MARadentro”

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1. EXCELLENCE

1.1. Introduction

Climate change and the expansion of urban areas is a major worldwide threat for sustainable and safe drinking water supplies. Managed Aquifer Recharge (MAR) is generally viewed as a powerful tool for replenishing depleted aquifers and for restoring ecological services of rivers with limited consumption of energy and chemicals[1]. Natural MAR systems based on water filtration during soil passage have proven to retain suspended particles and colloids, including microorganisms, and to favor biodegradation of contaminants, resulting in a significant water quality improvement. However, periodic detection of pathogens in groundwater (GW), some with severe human health impacts[2], has led to strict quality requirements that effectively impede the use of lesser quality water for MAR. This is paradoxical because potable water treatment during the XIX century simply consisted of sand filtering to remove pathogens and caused a life expectancy increase of some 20 years[3]. This paradox is well reflected on the on-going debate about quality requirements for GW recharge. Health protection authorities recommend strict controls on the water used for MAR but at the same time several major cities experience that recharge using wastewater can be safe. As a result, the JRC[4] failed to reach a consensus on MAR water quality recommendations. The situation is unsatisfactory. Prudence demands regulations, while fear hinders actual implementation of MAR. New effective treatment strategies based on MAR can be the solution. The objective of **MARadentro** is to address the risk issue and provide recommendations on how to accomplish efficient MAR to guarantee human health, ecosystems protection and public acceptance on water reuse while increasing the fresh water resources.

1.2. State-of-the-art and relation to the work programme.

Population increase is causing severe shortages in water reserves and leading to aquifers overexploitation. The problem is especially severe in areas where climate change is causing a reduction in rainfall[5]. Lowering aquifer heads causes degradation of ecosystem functioning. For example, the loss of base flow in rivers implies the loss of hyporheic flow exchange, and thus biodiversity and its contaminants degradation services, causing rivers to become canals. Moreover, overexploitation of aquifers impacts society and human well-fare as it directly affects production of food as well as the development of urban areas. Reversing this negative trend requires low footprint technologies that allow the reuse/re-naturalization of water to increase the resilience and adaptability to climate change.

In this context, MAR is an excellent option not only because it increases available water resources, thus increasing water use efficiency, but also because by recovering water levels it contributes to maintain wetlands and hyporheic exchange in rivers. MAR may also be used to prevent seawater intrusion, thus helping in the protection of coastal ecosystems. Water quality improvement during soil passage is well documented since long ago[6]. Specifically, the loads of pathogens, organic matter, and contaminants are reduced[7,8,9,10].

Despite its advantages, the implementation of MAR is still under debate. It was generally believed that pathogens did not move through porous media and that natural degradation processes removed most contaminants. However, outbreaks have shown that pathogens may reach pumping wells[11]. Waterborne pathogens are diverse in size, infection dose, and survival and transport capacities in soils[12]. Therefore, the behavior of different pathogens needs to be examined to reduce health risks in any water reclamation process[4]. Pathogens removal can be enhanced by chemical and biological additives supporting inactivation and adsorption processes[13,14]. However, a better

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understanding of factors influencing transport and fate of microorganisms is urgently needed to assess the risk of microbial contamination of aquifers, and to develop control strategies and treatment approaches.

Anthropogenic pollutants have increased dramatically in all water bodies during recent years and led many countries to impose strict water quality requirements on the source water for MAR. In practice, these requirements are so strict that even rainfall does not qualify due to high levels of suspended solids and low pH. The debate caused the JRC[4] to abstain from producing recommendations for MAR, as they would have made illegal numerous systems that have worked properly in several European cities for more than 50 years.
Moreover, growing pressures on water resources appear continuously, which makes it difficult for water engineers to address them in the framework of an integrated approach to manage the water cycle and to support the circular economy. An attractive alternative is to use MAR as a tertiary treatment to ensure pollutants and pathogens removal by adding a reactive layer. By increasing the reactive surface, allowing diverse microbial communities to develop and creating a range of redox states, reactive layers have proven efficient for contaminants degradation[15,16]. However, experience is limited regarding the optimal design for efficient functionality of these layers.

In addition to the technical aspects not yet resolved on MAR, the great challenge is the "human factor" on water reuse. A positive response from the general public is essential for the smooth implementation of MAR.

1.3. Objectives and overview of the proposal.

The overall aim of **MARadentro** is to lower the pressure on water resources through (i) the evaluation of the risks associated to the use of regenerated water in MAR considering new water challenges and (ii) the identification of proper requirements to ensure adequate human health and environment protection, feasibility and public confidence in the use of reclaimed water in MAR. To meet this objective, the specific goals are:

- Enhance water quality improvement during MAR through advanced tools to stimulate natural pollutants degradation and pathogens retention. These tools include reactive layers based on biotic systems (plants, fungi and microorganisms) to promote degradation and transformation processes in reactive layers and to boost retention by plants, as well as abiotic processes (e.g. enhancing sorption by addition of organic carbon and iron oxide). We will also analyze the effect of reactive layers on (i) improvement of pathogen retention and (ii) enhancement of antimicrobial activity. Quantify water quality improvement during MAR through the determination of pathogens, and pollutants removal. A screening approach will be applied to assess requirements for further chemical analysis by a range of effect-based tools (biomarkers, bioassays) to account for the presence of compounds with similar effects and to limit the number of chemical analyses.
- Resort to reactive transport modelling tools to predict the behavior of pathogens and pollutants. Modeling will emphasize understanding on the relationship among pollutant degradation, pathogen retention and inactivation and microbial communities.
- Address the challenges in upscaling MAR operations from lab tests to a pilot MAR and a real field MAR site.
- Perform an environmental risk assessment by advanced modeling tools to test whether the use of reclaimed water for the proposed MAR system has no adverse effects on the ecosystem.
- Evaluate the economic feasibility of the proposed system in a real field MAR.
- Transfer knowledge gained and provide recommendations to stakeholders for efficient implementation and operation of MAR, and to authorities and policy makers on water to help for an EU regulation on MAR.
- Promote the general public acceptance on water reuse and MAR.

1.4. Research methodology and approach.

MARadentro will achieve the objective by experimental and modelling work. Experimental work will include laboratory, pilot and field scale tests. The performance of diverse reactive layers will be tested in the pilot scale by comparing water quality (pathogens and chemical contaminants) of the influent and effluent water after different residence times. Microbial communities are an important component of reactive layers for degradation of pollutants and for the fate of pathogens entering the reactive layer. Quantitative and mechanistic understanding of microbiome is thus central to the sustainable operation of MAR systems. We will study at the pilot scale the role of biotic and abiotic degradation stimulants (plants, fungi), heterogeneities, and dry/wet cycles in the water quality improvement.

Chemical contaminats will be evaluated by means of powerful analytical techniques based on liquid chromatography and mass spectrometry (LC-MS), including high resolution mas spectrometry (HRMS) for the un-

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target analysis of the metabolites formed mainly through biodegradation by the microorganisms present, but also by the fungi to be added to the pilot/field MAR to enhance natural degradation. Abiotic degradation processes may also produce unknown degradation products that will be investigated, identified and structurally elucidated.

In agreement with the JRC[4], the reactive layers will be tested on selected microbial indicators representing a broad range of pathogens (viruses, bacteria, and protozoa). Combined approaches comprising conventional standardized cultivation methods, immunofluorescence, and flow cytometry will be applied.

Water toxicity will be analysed by respirometry test, Biolog. MT2 microplates and FCM (Flow cytometry)-based metabolic assays that, using fluorescent markers, will allow quantifying the effects of contaminants and treatment options on microbial growth rate inhibition, cell membrane state and detoxifying activity.

We will rely on bacterial 16S rRNA and fungal ITS amplicon analyses to identify microbial populations. This allows analyses of distribution patterns and inferred fate in relation to the design of the reactive layer. Candidates for mediating contaminant attenuation will be identified. Selected samples will also be subjected to shotgun metagenomics to capture overall differences in functionality of the microbiomes. This will entail reconstruction of genomes and pathways and key enzymes involved in contaminant degradation and main metabolic features. Overall, this information will bring clues to microbial pollutant removal and can be used for improving both design of reactive layers and predictive models of MAR functioning. For direct monitoring purposes, we will develop targeted approaches for specific pathogens or pollutant degraders using quantitative PCR.

For the modelling work, **MARadentro** will develop biochemical classes to describe the fate of chemical contaminants as well as pathogens acknowledging the role and dynamics of microbial communities. Furthermore, numerical models will be coupled with toxicological information in order to develop a risk assessment tool which will facilitate making decisions for managers of MAR.

AQUALIA, as an operator of sanitation facilities, will carry out the field scale testing. A bioaugmented/biodynamic reactive layer with organisms (plants, microorganisms and fungi) to enhance the pollutants' removal in a real waste water treatment plant (WWTP) will be designed and built according to the results of the lab and pilot tests.

1.5. Originality and innovative aspects of the research (ambition)

MARadentro is an innovative project by addressing MAR risks/challenges through the following novel approaches:

- Advanced bio-layers. Development of bioaugmented/biologically active reactive layers (plants, microorganisms and fungi) to enhance the pollutant and pathogen removal capacity.
- Up-scaled testing (lab-to-real field site). Developed layers will be adapted to three environments, laboratory, pilot and field MAR, to identify and overcome issues related to flow, aquifer characteristics, climate, etc.
- Determination of the key-points governing the risk of MAR to human health and ecological status through the incorporation of the risk assessment concept in advanced numerical modelling tools.
- Use of the rapid early warning monitoring approaches i.e. flow-cytometry and toxicity assays to monitor MAR depuration efficiency.
- Application of the most powerful analytical techniques for the identification and structural elucidation of the biotic and abiotic transformation products of the chemical contaminants produced during MAR.
- Development and application of enhanced modeling tools for evaluating and upscaling MAR systems.

1.6. Clarity and quality of transfer of knowledge for the development of the consortium partners in light of the proposal objectives.

MARadentro is a truly collaborative project since it is formed by a multidisciplinary consortium, composed by experts in different fields including hydrogeology (CSIC), chemical analysis (CSIC), modelling (UPC), microbiology (CNR, SLU), geochemistry (CNRS) and engineering (AQUALIA). All the partners are experts in water resources (continental water and GW), which act as a backbone guarantying the understanding and knowledge transfer within the consortium.

Lab and pilot MAR experiments will be managed by CNRS and CSIC, respectively, and field MAR by AQUALIA. CNR will contribute with know-how on the level and spread of microbial contamination in MAR. Knowledge, on the use of traditional and alternative indicators and methods for microbiological water quality analysis will also contribute to the definition of optimal monitoring approaches of MAR hygienization efficiency. CNR will benefit from the partners know-how, on pollutant transport in soil and on microbial community composition, gaining a better understanding of the occurrence and flow of non-indigenous microorganisms of human health concern in MAR. UPC will develop the numerical models and the risk assessment in cooperation with CSIC and CNRS.

CSIC will provide its expertise in two fields, i.e. MAR operation and contaminants transport, and emerging contaminants analysis. Part of the team has got a broad experience on characterization of permeable media, reactive transport, artificial recharge, and groundwater pollution and remediation. The other part of the team is internationally recognized in the trace analysis of organic emerging and related contaminants. The group has experience of more than 25 years in the development of analytical methods and the application of chromatography and mass spectrometry techniques to determine contaminants in several matrices, including wastewater and GW. Moreover, the CSIC team has wide experience in the study of the environmental impacts of emerging and wastewater-derived contaminants. CSIC will benefit from the expertise of the rest of consortium partners on the knowledge about contaminants transport and degradation by different microbial communities.

CNRS will provide its expertise in laboratory-scale experiments on reactive transport processes. Part of the CNRS group is well recognized for reactive percolation experiments on porous medium since several years while the other part is mainly expert on the study on emerging organic contaminants including a large number of substances with various physicochemical characteristics. Understanding the behavior of these substances in aquatic environments, particularly those with biological activity (drug residues, endocrine disruptors, etc.), is one of the key developed research at the CNRS group. CNRS and CNR will have close collaboration on the laboratory experimental part to evaluate the role of the microorganisms in contaminants degradation. Moreover, CSIC and CNRS will work together on the modeling part in order to adapt the laboratory scale results to pilot and field scales, which will represent an important benefit to CNRS.

SLU is contributing with expertise in microbial community analysis. The team is recognized for its achievements in functional microbial ecology and development of molecular tools for functional groups. SLU has a track record of working with terrestrial and aquatic environments as well as engineered systems, which fits well with the MAR technology using soil-based reactive layers. SLU and CNR will have a close collaboration regarding the microbiology, with obvious benefits for SLU. SLU will also benefit from the other partners in all experimental work as process performance is the key to interpret the microbial communities and their functional potential.

Thanks to **MARadentro,** the expertise on the analysis of EOCs from CSIC to the AQUALIA will allow to improve the evaluation methods of sanitation treatments. AQUALIA foresee to decrease the economic costs of obtaining GW for potable reuse compared to the actual processes implemented (reverse osmosis or tertiary coagulation/flocculation), both in investment and in operation. Moreover, AQUALIA expects to develop, in collaboration with CSIC and UPC, tools for the design, construction and operation guidelines that will be incorporated based on their technical/economic feasibility to the portfolio of services of the Company. The generated knowledge will serve to have an advanced and cost-competitive solution compared to other companies in the sector.

1.7. Quality of the consortium partners and collaborative arrangements. Capacity of the consortium to reinforce a position of leadership in the proposed research field.

The **MARadentro** consortium consists of 5 leading research partners from Spain, Italy, France and Sweden and 1 private Company from Spain. Research partners are not only internationally renowned in academia, but also in the practical application of their research results to water reclamation projects. The private Company, AQUALIA, has a long record of innovation in the human water cycle sector. Therefore, at least in principle, the consortium has got the reputation needed to achieve the paradigm shift sought by **MARadentro**.

All **MARadentro** partners (and several of the stakeholders) have collaborated successfully in the past. Therefore, we will adopt collaborative arrangements that have already proven appropriate: (1) shared students and students from every partner participating in every type of experiment, thus ensuring a continuous interaction among partners; (2) exchange of researchers among the partners (mostly to perform experiments); and (3) WPs and joint experiments have been designed to maximize synergies between partners, which facilitates collaboration (no one feels “threatened” by a partner, but we need each other). In fact, we view **MARadentro** as a way to consolidate established connections among partners.

The CSIC team involves environmental chemists and hydrologists, who have coordinated and participated in national and international research projects in the field of MAR, water-soil interactions, water resources, water treatment/remediation and reuse, and reactive transport (RASA, ENSAT, ACWAPUR, ENIGMA, ARTDEMO, INNOVA-MED, WASTEWATER CLUSTER, CEMAGUA, SCARCE, GLOBAQUA and ROUSSEAU). The team collaborates regularly with urban water cycle companies (Barcelona, Buenos Aires, Santiago de Chile, Murcia, etc.) and Public Water Agencies (Catalonia, Guadiana, and Guadalquivir in Spain, but also abroad).

The CNRS team in Montpellier is well known for its work on hydro-systems: water pathways and resources, contaminant fate, transformation and fluxes in human-impacted watersheds, metrology and hydro-climatic risks. The group works on water resource management at basin scale, models as a tool for forecasting studies, water preservation, savings and reuse through technological innovation, and on contaminants and human risk assessment, mining pollution and environment-health issues. The CNRS team is in charge of different national (ANR AWARE, ANR IMAP, ANR ANSES, AERMC) and EU projects (SUDOE- 4KET4Reuse, UNESCO-sida).

The CNR Water Research Institute (CNR-IRSA) research activity is devoted to water focusing on water treatment, quality assessment and management. CNR-IRSA is Italian referent for the definition and publication of normative Italian methods for water analysis and has produced >100 publications in the field of water and wastewater treatment. CNR-IRSA has recently coordinated or played a key role in numerous EU projects on biotechnological water reclamation and reuse; focusing on water hygienization efficiency and microbiological quality monitoring in RECLAIMWATER, ACWAPUR, WATER4CROPS, DRINKADRIA, BIOWYSE and ROUTES projects.

The SLU team is renowned for its frontier research on functional microbial ecology. Ongoing research related to **MARadentro** includes a project on aquifer microbiology in Sweden and the EU project ACWAPUR. The team has been involved in a national project on treatment of mining waters, from which a new project “NITREM” on reactive layers developed and recently received 5 M euro from the EIT. SLU is also working on risk assessment of contaminated soils (APPLICERA) and soil biodiversity across Europe (BIODIVERSA Digging Deeper).

UPC research activity is focused on GW resources and MAR is one of the main research lines. UPC has participated in several research projects related to MAR in the international and the national context (MARSOL, GABARDINE, INDEMNE, ACWAPUR, SCARCE). UPC research group produces yearly some 50 publications in peer-reviewed journals.

AQUALIA as the third-largest private water management company in Europe (Global Water Intelligence) and the seventh worldwide is part of the environmental services of the FCC group, present in 4 continents, and employing some 55000 people in 35 countries. AQUALIA covers the whole water cycle, managing water and wastewater services more than 1100 towns and cities, serving more than 23 million people. AQUALIA’s activity comprises 3 major areas among which it creates synergies in knowledge, methodology, research and development, working with local partners and administrations: (i) integral management of public water services, (ii) design/construction of water infrastructures and (iii) global solutions for the use of water in industry. AQUALIA has been certified to confirm the right track developed in different fields: Quality Management System (ISO 9001), Environmental Manag. Syst. (ISO 14001), Corporate Social Responsibility Report, in accordance with G4 Guide of Global Reporting Initiative (GRI), Innovation Manag. Syst. (UNE 166002:2014). Energy Manag. Syst. (UNE-EN ISO 50001), Environmental Manag. of Greenhouse Gases (ISO 14064-1:2006), Information Security Manag. Syst. (ISO / IEC 27001:2013). Six laboratories accredited in Testing Environmental Samples (UNE-EN ISO/IEC 17025) and Family-friendly Responsible Entity (EFR 1000-1 ed. 4).

AQUALIA has its own ITD, in charge of over 16 industrially oriented demo projects, and international activities focusing on Portugal, Italy and the Czech Republic as well as Latin America. Design-Build-Operate Contracts for major water and wastewater infrastructure are currently being executed in Romania, FYR Countries, Algeria, Egypt, Tunisia), Colombia, Chile, Mexico and Panama.

AQUALIA has a solid experience in wastewater treatment and management, aimed at innovative and sustainable solutions to problems arising in the field of water treatment, allowing the design of water treatment facilities with the latest technologies. AQUALIA through pilot programs testing plants has provided necessary knowledge to solve wastewater treatment problems with very different technologies. Over this background, AQUALIA has participated in many research projects on topics related to **MARadentro** (REMEMBRANE, RUN4LIFE, INCOVER, CLEANWATER, ICIRBUS4INDUSTRIES, URBANWATER, and ITACA).

2. IMPACT

2.1. Impact of the proposal

MARadentro will fill a knowledge gap as well as a regulatory gap for MAR technology to contribute to closing the water cycle gap. Specifically, **MARadentro** will develop a knowledge base for understanding, preventing and mitigating the risks associated to MAR implementation, to make MAR a reliable technology for water management adapted to the emerging water challenges. The incorporation of novel reactive layers will ensure MAR as a sound and safe technology, capable to increase fresh water resources as well as to improve ecological status and chemical quality of GW, while ensuring no negative impacts over human health. The knowledge base will include state of the art process understanding (WP2), international experience at various scales (WP3-5; France-Spain), and modelling and risk assessment methodologies (WP6). The economic analysis (WP7) will facilitate the market replication of MAR into the water sector. Key scientific recommendations, validated by the demonstrable data produced, will be formulated and legislative refinement suggested over the basis of scientists and stakeholder's guidance (WP8). General public concerns about MAR will be addressed (WP8) by providing a firm scientific basis. The technological readiness level from several multidisciplinary approaches and applications will be improved, reaching a MAR prototype close to market (WP7-8).

2.2. Expected outputs

MARadentro will **produce** (tangible outputs):

- Publications (some 50 scientific and some 10 for the general public).
- Contributions in Conferences (some 20 oral, 20 poster, 5 invited conferences, 2 session organization).
- Organization of a Webinar.
- Organization of two stakeholders meetings.
- Lectures on MAR in, at least, two Master courses.
- 10 Master and 7 PhD Theses.
- Sofware applications and models.
- Interactive model that can be applied for economic feasibility studies and technical project evaluations
- Monitoring tools for pathogens
- Events at MAR field site for stakeholders, schools, and the public to increase awareness
- A TV documentary about water resources, closing the water cycle gap and MAR technology.
- A protopype of the reactive barrier developed. Pilot plants provision for research, which will be further used for demonstration to stakeholders, schools, and the general public.
- The patent for the prototype of the reactive layer.
- Provide a success case of market ready solution, in order to boost the replication in other regions and transferability to other sectors.
- Provide economic and environmental impact of a full scale indirect potable water reuse scheme with MAR optimized design. Decrease economic costs of obtaining water for reuse compared to current processes.

MARadentro will further **contribute** to (intangible outputs):

- Increase the understanding of water quality improvement processes during MAR, and specifically the conditions for effective removal of pollutants and retention of pathogens, thus contributing to integrated water resources management (IWRM).
- Realize the multidisciplinarity of IWRM and the need to incorporate a broad range of engineers, scientists, stakeholders and water authorities, in order to convey how to perform MAR in a safe way.
- Formalize and demonstrate the benefits of MAR and the requirements on MAR design, construction and operation to guarantee a high quality effluent.
- Evaluate alternative early warning tools for rapid assessment of microbiological water quality ameliorations in MAR.
- Suggest realistic EU recommendations favouring implementation of MAR while avoiding its potential risks.
- Improve chances for economic development of all economic sectors as a result of an increase on water availability and increased resilience to water stress conditions.
- Promote the positive perception to water reuse and MAR by the general public (social acceptance).

2.3. Exploitation and communication activities (measures to maximise impact)

To achieve the general goal of **MARadentro**, the involvement of stakeholders at different levels is crucial. With this aim, we have identified target pools in the society where **MARadentro** should contribute: health experts, policy makers (from different fields) and water users (e.g. irrigation communities, water companies). We have involved a broad range of stakeholders, which are listed in **Table 1** (some support letters are in the Annex file and other are on the way, which will be provided when required). Besides these stakeholders, **MARadentro** includes the Spanish private Company AQUALIA in its consortium, which is the third largest water company in Europe. With this, we will guarantee that all the new knowledge generated by the project will be transferred to the company and, consequently, to the market and society.

Table 1: Stakeholders represented in **MARadentro**.

Target stakeholders	**Institution**
Health experts	**Catalonian Public Health Agency** (Spain)
Policy makers	**Joint Research Center** (JRC, Italy), **Catalonian Water Agency** (ACA, Spain)
Water companies	**Montpellier Metropole** (France), **Norrvatten** (Sweden) and **VERITAS S.p.a** (Italy)

In order, to disseminate the results of **MARadentro** at different levels, we plan the activities displayed in **Table 2.**

Table 2.: Dissemination activities of **MARadentro**.

Receptor	**Dissemination activities**
End-users of MAR	1. Organization of **two meetings** with stakeholders, at the beginning and at the end of the project, in order to create an open discussion about the implementation of MAR and to transfer the achievements of the project. This includes **events at our field scale MAR site.** 2. Development of a **set of "recommendations for regulators"** for the European Parliament. These recommendations will be transferred to the **JRC** (a stakeholder of the project) and to local and regional water administrations (stakeholders of the project). 3. **Development of a guideline to** be disseminated to the water companies and water end-users.
Scientific Community	1. Communication of new developments through **scientific papers** published in Web of Science indexed journals. The **publishing politics** will be **open access, green and gold.** 2. Programming of **lectures in Master courses** in UPC and Montpellier University (MU). 3. Communication of new developments through scientific conferences. **Special sessions** will be organized towards the end of the project at the major scientific meetings in the **fields of geosciences and environmental toxicology and chemistry**, AGU, EGU and SETAC. 4. Communication of project metadata in the webpage of **MARadentro** (data and software).
General public	1. We will develop a **Webpage**, where we will publish all the project results and events. This webpage also will serve as a repository of all the data generated by the project. 2. A **Webinar** will be organized during the second year of the project. It will be open to general public, but stakeholders will be specially invited to attend. 3. **Events at** the project **field scale** MAR site (close to the end of the project). 4. A **TV documentary** will be produced. Especial emphasis on local TVs (at end of the project).

2.4. Market knowledge and economic advantages/return of investment

Overexploitation of water resources and declining GW levels are among the worst threats to sustainability. River quality has improved somewhat thanks to generalized wastewater treatment, but is far from reaching a good status demanded by the EU WFD because the loss hyporheic exchanges and associated environmental services limits the potential for river quality improvement. Reversing this situation requires MAR. Therefore, the market for water reuse technologies providing reclaimed water of good quality can only be expected to increase. Yet, while MAR is used in numerous developed and developing countries, its application has been limited, with the notable exception of Australia. As mentioned in Sections 1.1 and 1.2, one of the main reasons for the paucity of MAR development is the fear that presumed virgin GW resources might get polluted by pathogens and organic contaminants through the recharge water. We contend that the **MARadentro** reactive layer technology will minimize this risk and has the potential to be readily implemented in both existing and future MAR systems.

But there is another barrier to broad MAR implementation: cost. MAR systems need not be expensive ad certainly far cheaper than alternatives yielding similar water quality outflow without the environmental recovery benefit (we estimate a few cents per m^3, but with high uncertainty on operational costs, maintenance of plants and long-term reactivity, hence the need for WP5). Still, the ultimate question is who will pay the cost. The benefits of a healthy river or a good status aquifer are indirect. They do not return to the one who pays for the recovery. In fact, we feel that the main reason behind the success of MAR in Australia is a well-defined water costs system. It seems clear to us that it is the responsibility of the governments to ensure the good status of water bodies (but they lack advanced regulations and they fear pollution).

We envision that getting out of this vicious circle will be a slow process in which water agencies and health authorities will slowly gain confidence in well managed advanced MAR systems (it took almost the full XIXth century for generalizing sand filtration of surface water resources in most European countries, recall the discussion in Section 1.1). We feel that the main contribution of **MARadentro** will be a definitive push along this path. Specifically, the management tools and guidelines that **MARadentro** will provide will expand the water types serving as source water for recharge, and broadening the applicability of the developed MAR technology. In particular, this project will provide success cases of implementation of market ready solutions in order to boost the replication in other regions and transferability to other sectors. Furthermore, consortium partners will cconduct marketing, business and commercial activities to increase the commercialization of the MAR approach developed.

3. IMPLEMENTATION

3.1. Overall coherence and effectiveness of the work plan.

MARadentro comprises eight interlinked WPs according to **Table 3**, whereas the organization and interactions among WPs is represented in **Figure 1**.

Table 3: Description of **MARadentro** WPs.

WP Number	WP Title	Duration (months)	Start Month	End Month	WP Description (see graphs and text below for detailed descriptions)
WP1	Coordination, management	36	1	36	Administrative and financial management.
WP2	Data mining, exper. design	7	1	7	Literature review on MAR data to identify knowledge gaps and to help in the design of MAR at lab, pilot and field scales.
WP3	Lab testing	12	1	12	Column experiments on different reactive layers. Microbiological, toxicity and chemical analyses.
WP4	Pilot testing	24	12	36	From lab to a pilot MAR using waste water as recharge water source. Microbiological, toxicity and chemical analyses.
WP5	Field testing	11	25	36	Up-scaling from the pilot to a field MAR using waste water as recharge water source. Microbiological, toxicity and chemical analyses.
WP6	Transport modeling and risk assessment	30	6	36	Development of models to: (i) verify conceptual models of the lab, pilot and field experiments, (ii) assess the removal performance, and (iii) provide software as a tool of water management able to perform risk assessment of MAR.
WP7	Economic balance	4	28	32	A model will be created, for economic feasibility studies and technical project evaluations under different scenarios. Possible industrial outcomes will be evaluated to reach the market.
WP8	Exploitation-dissemination	36	1	36	Dissemination to scientists, policy makers and public. Exploitation plan for efficient outcomes' transfer and commercialization.

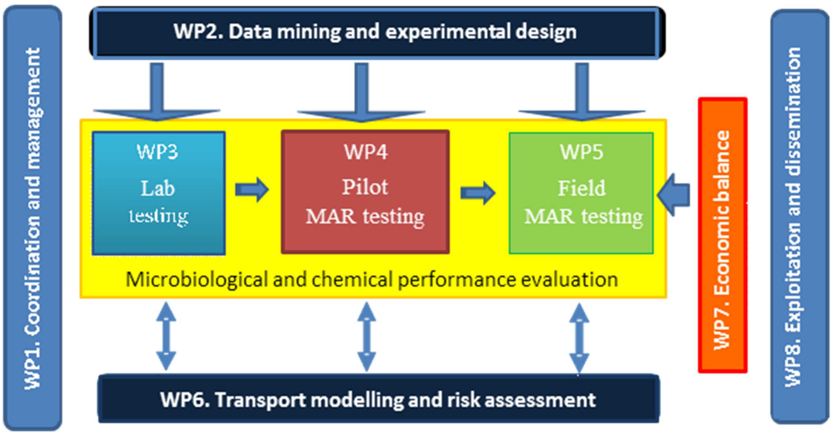

Figure 1: Global flow diagram and interdependence among WPs.

WP1. Coordination and management | Leader CSIC

Provide the necessary administrative and financial management coordination based on JPI accepted rules and guidelines. It will ensure a high standard of supervision, quality control and overall coordination of the activities described, within the planned time and planned budget, for the smooth running of **MARadentro**.

WP1 includes the following **tasks**: acting as contact point between EC and the Consortium. Handle payments from EC and distribution of funds within the consortium. Day-to-day technical management and coordination of administrative duties. Coordinate management of IPR on the project (establishing internal intellectual property agreements for research, surveys and strategy development and other foreseen project results). Organize regular Steering Committee, Advisory Board and project meetings. Monitoring and managing the risks which potentially threaten the successful completion of the project.

WP2. Data mining and experimental design | Leader CNR | Participants: All the rest of partners

Review existing reclaimed water reuse for MAR projects, databases and records to identify gaps in knowledge, methodology and information as well as data needs. This will be discussed at an internal workshop and will serve as a basis for properly developing novel reactive layers and will aid in the design and implementation of MAR at three scales. To this end, the following tasks are planned: **Task 2.1.** To screen the last 5-years available data on microbial populations, fecal contamination indicators and pathogens, in MAR processes and their retention and inactivation. In agreement to JRC[4] three microbial groups (bacteria viruses and protozoa) will be considered to identify gaps of knowledge and data. **Task 2.2**. Literature search of last 5-years published data on occurrence, impacts and transformation processes underwent by emerging contaminants in source water for MAR and GW.

WP3. Lab testing | Leader: CNRS | Participants: All the rest of partners

Column experiments will be carried out to test and calibrate the performance of different layer compositions. Microbiological, toxicity and chemical analyses will be used to evaluate the performance of the tested layers and systems for the removal of pathogens and chemical contaminants. In this WP the following tasks are foreseen:

Task 3.1. column experiments will be performed to evaluate and calibrate the performance of several layer compositions. Varying water quality and boundary conditions will be tested to emulate field conditions.

Task 3.2. Quantitative and mechanistic understanding of microbiome functioning within the layers will be addressed by characterizing microbial communities and their functional attributes using 16S rRNA-based amplicon analyses to identify microbial taxa and shotgun metagenomics to assess metabolic pathways for degradation and transformation of pollutants. Results will help understanding the genetic potential of the reactive layers tested.

Task 3.3. Effects of tested layers on the transport and removal of pathogens will be determined by FCM quantitative monitoring of seeded pathogen indicators in columns. Microbial groups with diverse retention capacities in soil will be considered, and relevant target microorganisms will be selected to fill major gaps of knowledge shown in WP2. Available fluorescent pathogen indicators will be selected and tested for their detection by FCM. FCM will be successively applied for quantification of seeded fluorescent microorganisms in columns providing data for the selection of optimal layer composition.

Task 3.4. The occurrence and fate of organic emerging contaminants of concern (EOCs), such as pharmaceuticals and personal care products (PPCPs), will be determined through advanced analytical methods based on on-line and off-line SPE followed by high performance liquid chromatography attached to tandem mass spectrometry (HPLC-MS/MS). Identification and structural elucidation of degradation/transformation products of organic chemical contaminants will be performed by high resolution mass spectrometry (HRMS) with the help of Orbitrap-MS and QTOF-MS detectors, which provide exact mass for univocal identification and structural characterization.

WP4. Pilot MAR testing	Leader: CSIC	Participants: All the rest of partners

A greater degree of complexity will be achieved in an existing pilot scale MAR located in Palamós WWTP (close to Barcelona). The facility consists of 6 recharge areas (2.4 m^2) connected to 15 m. long sediment tanks that emulate the aquifer (**Figure 2**). The system allows biomass augmentation (fungi, bacteria), addition of organic carbon sources and adsorbing chemical species (iron oxides). The use of real wastewaters in the pilot MAR will allow a realistic understanding of pollutants behaviors, largely influenced by source water physical, chemical and microbiological characteristics, in a complex fluctuating environment. For a more integrated approach, microbiology, toxicity and chemical analyses will be performed to describe the functionality of the reactive layers as well as to evaluate the performance of the pilot MAR for the removal of pathogens and chemical contaminants.

Task 4.1. In order to assess the behavior and possible correlation of the aforementioned parameters at least two sampling campaigns will be carried out jointly all partners during the warm and the cold season.

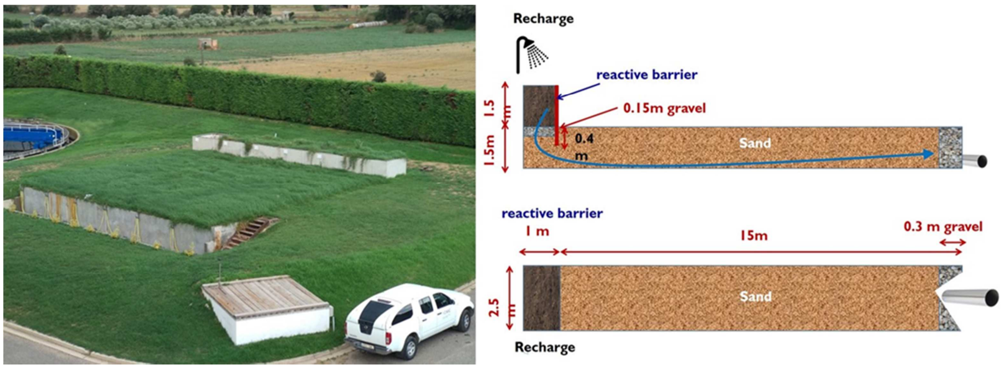

Figure 2: Pilot MAR and scheme (cross section and plant view) of one of the six artificial recharge emulation tanks.

Task 4.2. The microbiological analysis to estimate fate and removal of microorganisms of human health concern will be performed as described for the lab experiments (conventional and advanced methods, and FCM for real time, 20 min. from sampling). Results will be compared with the occurrence of fecal contamination indicators. Relationships among microbial contaminants, their spatial distribution and removal will be defined by GIS. At pilot scale, pathogen indicators level will be monitored in the plant inflow, layers outflow and sediment tanks to evaluate pathogens inactivation and removal and final water microbial quality.

Task 4.3. Fast and cheap tests to assess the toxicity of the water, such as FCM-based metabolic assays and respirometry tests, will be applied to asses water toxicity improvements in the pilot MAR.

Task 4.4. The procedure for EOCs analysis in the inflow, layers outflows and within sediment tanks to assess the performance of the layers for EOCs degradation will be similar to those describe for laboratory tests in WP3.

WP5. Field MAR testing	Leader: AQUALIA	Participants: All the rest of partners

Validate MAR technology at a WWTP where the feasibility of our solution will be assessed under long-term operation. The MAR prototype will be fed with treated domestic wastewater with or without previous tertiary treatment. The design, construction and evaluation will be led by the industrial partner AQUALIA in close collaboration with the other partners.

Two alternative demo sites are proposed since the decision must be made based on the site suitability (Task 5.1): WWTP Borja (Zaragoza, Spain) and WWTP Riera de la Bisbal (El Vendrell, Baix Penedés, Tarragona, Spain). Both WWTPs have secondary and tertiary treatment through conventional filters so that the suitability of the **MARadentro** process can be tested using either secondary or tertiary source water in the two cases, which implies an added value to the validation since the comparison will be able to confirm also at technical level (EOCs and pathogens removal) as well as at economic; amortization of the investment and maintenance costs of both systems.

The two WWTPs treat mainly urban influents of 2.500 and 15.000 m3/day, respectively, and have tertiary treatment for the reuse of part of the effluent in agriculture, industry and golf courses according to R.D. 1620/2007 governing reclaimed water, which stipulates that tertiary treatment and disinfection necessary for these uses.

It should be noted that in the case of the La Riera de la Bisbal WWTP, the total or partial infiltration of part of the water treated in the plant could be validated given that it has tertiary treatment output to the next public channel or it can be sent partially by means of an emissary to by-pass the drinking wells downstream. This entire infrastructure would allow different options for water treatment that could be used by the **MARadentro** project, increasing the added value of the study through scaling /comparison to industrial prototype.

AQUALIA will collaborate also in the analytical work required during the industrial prototype validation.

Task 5.1: Site selection: a preliminary borehole will be drilled with core extraction to verify the suitability of the sediments column and a pumping test will be performed to verify the suitability of the aquifer. We will try first La Riera de la Bisbal WWTP because previous works suggest it is appropriate. Land availability on the surface required to treat some 10-15 m^3/h expected (some 250-400 m^2) also needs to be checked. Permits for recharge and excavation works will be sought.

Task 5.2: Project design and construction. Since lab and pilot tests will only be in their preliminary stages, the preliminary design will be based on current experiences. However, we will leave room for final changes prior to actual construction.

Task 5.3: Operation. Key operation and control parameters will be monitored at the inflow, suction cups beneath the layers and at three monitoring points in the aquifer (one to monitor native GW) to guarantee long-term stability of the process, as well as, to satisfy quality standards to be used in MAR. Microbiological, toxicity and chemical analyses will be performed as previously described for lab and pilot experiments.

Task 5.4: Cost analysis: maintenance costs will be carefully monitored to assess and validate the economic model in WP7, taking into account both the investment and operating costs and considering the advantages in eliminating pollutants from the solutions analyzed.

WP6. Transport modelling and risks assessment | Leader: UPC | Participants: All the rest of partners

Numerical models will be developed to understand and predict the fate of basic ions and minerals, as well as pollutants and pathogens during MAR. These models will be calibrated with data generated during the experiments performed at three scales (WP3-5). AQUALIA will provide technical assistance to develop tools for the design, construction and operation guidance based on the work carried out in the WP5. This work will allow the development of a design and implementation guide of the MAR process developed, which will guarantee its future replicability. As new challenges, complex models incorporating pathogen transport as well as colloid transport will be developed. Furthermore, we will incorporate the degradation of pollutants and its interaction with biogeochemical processes occurring during MAR. In **MARadentro** we will test existing equations and, if needed, we will generate new mathematical formulations to describe the fate of organic pollutants and pathogens. The resulting model will be used to perform a risk assessment aimed at ensuring the no-risk of MAR from and ecological and a human health perspective. According to JRC[4]on risk assessment, the key-points driving the risks of MAR operations (type of layer, type of water, GW velocity, etc.) will be determined. Toxicological data will be incorporated in the existing models for more reliable results. Thus, we will produce a model code which will incorporate the riskier processes of MAR and that will allow us to evaluate the risk of a MAR implementation. Besides this, advanced modeling tools will be developed for upscaling MAR systems. To meet these objectives, the following tasks are planned:

Task 6.1 Development of mathematical formulations for organic pollutant and pathogen transport. We anticipate splitting our current chemical system class into an aqueous and an immobile phase's class.

Task 6.2. Modelling of **MARadentro** experiments using the above codes for design purposes.

Task 6.3. Verify/test models results through the experimental information developed in WP3-5.

Task 6.4. Couple risk assessment toxicological concepts to reactive transport modelling.

Task 6.5. Perform a sensitivity analysis to verity the critical issues in risk assessment applied to MAR.

Task 6.6. Developing advanced models to upscale MAR systems benefitting from the lessons learned.

WP7. Economic balance | Leader:UPC | Participants: All the rest of partners

All partners will provide information to be compiled (background, state-of-the-art and advances in **MARadentro**), and all aspects will come into place, along with a set of technological and environmental elements. Thus, the economic analysis will take a multi-disciplinary approach. A comprehensive and interactive model will be created, which can be applied for economic feasibility studies and technical project evaluations under different scenarios. Possible industrial outcomes will be evaluated to reach the market. Economic impact, market trends and technology positioning will be studied by the consortium: AQUALIA will provide analytical, process and economic data both at the investment and operating levels of the tertiary systems operated by the company for the comparison with the MAR process tested in the WP5 and WP6. Transfer of project results from R&D performers to industrial players will be promoted by all partners. Moreover, key factors such as water quality analysis in terms of basic parameters usually evaluated: intestinal nematodes, *Escherichia coli*, *Legionella*, suspended solids and turbidity completed with emerging contaminants and considerations on the economic costs of the treatments required for the elimination of emerging contaminants of health concern, such as endocrine disruptors, to facilitate political and other decision-makers stakeholders' involvement to implement **MARadentro** technology.

WP8. Exploitation and dissemination	**Leader: SLU**	**Participants: All the rest of partners**

Exploitation and dissemination of the project outcomes will be coordinated and supported by WP8 and will cover all WP activities during the entire duration of the project (see sections "2.2: Expected outputs" and "2.3: Exploitation and communication activities"). A number of **tasks** will be developed: a dissemination and exploitation action plan will be organized to ensure that the results will be efficiently disseminated, exploited and transferred to other research units, the relevant stakeholders and regulatory bodies or commercialized. This plan includes the creation of a project webpage including the main reports, presentations and publications. A TV documentary will be produced to promote the project objectives and results to the scientific and stakeholder communities as well as to the general public. It is also anticipated that **MARadentro** will lead to the development of tools and protocols that could be used by the relevant industrial sector for MAR. This will be handled by the **Exploitation Management Board** (see section 3.2 below).

3.2. Appropriateness of the management structure and procedures, including quality management

There are three key issues for the successful completion of **MARadentro**, namely project management, consortium suitability and resources distribution. Project management will cover financial, administrative, scientific and knowledge management and innovation aspects. **Figure 3** illustrates the management structure in **MARadentro.**

Figure 3: Actors involved and their interactions within the Management structure of the project.

The main aims of the **Management** are (i) the effective monitoring of the project, in administrative, technical and financial terms, to guarantee the adherence of the work to the overall project tasks, available resources and timing, and (ii) to offer the necessary interface to the EU services and external actors.

The **coordination** of **MARadentro** will be carried out through the **Coordinator** (Dr. Silvia Díaz-Cruz, CSIC, Spain) and the **Deputy Coordinator** (Prof. Jesús Carrera, CSIC) along with the **Project Manager** (a qualified person **to be hired**). These three persons constitute the **Coordination Team**, responsible for daily management of the project, who reports to the **Project Steering Committee**, who is the ultimate responsible for project decisions. They are supported by the administrative specialized departments of CSIC (European contracts management, legal and communication services). Specifically, the **Project Coordinator** will be in charge of the global consortium organization. She will carry out the following tasks:

- Coordination of all activities. Financial and administrative matters in the implementation of management' procedures (costs, personnel, facilities and communication).
- Leading of the **Advisory Board** and the **Steering Committee**.
- Monitoring project progress and achievements.
- Communication consortium - EC, including delivery of financial and scientific reports.
- External communication of the consortium.

The Project Steering Committee will be led by the **Project Coordinator,** chaired by the **Deputy Coordinator** and supported by the **Project Manager** with the participation of the **MARadentro WP's Leaders.** The **Steering Committee** is the project executive board that represents the highest level of decision-making, thus responsible for strategic decision-making regarding all key contractual, financial and administrative issues concerning the consortium and the project as a whole, e.g. project reorganization contractual matters (incl. IP), exploitation matters, requests to the EC about contract items, revision of the Consortium Agreement and all issues in which collective responsibility is involved. It is also the responsible of getting the feedback from the **Advisory Board.** *Meetings:* Twice a year (additional ones if needed). The specific duties of the **Steering Committee** will be to:

- Coordinate/monitor the progress of the work and validate the reports to be delivered to the Commission.
- Identify financial/technical risks. Submit, if necessary, proposal of tasks' change and budget allocation.
- Project implementation and evaluation of the objectives.

The **Advisory Board** will be constituted by **Scientists** and **Stakeholders**. Two multidisciplinary quality control bodies, one involving high-level scientists and the other stakeholders in the water area, will be responsible for peer reviewing scientific results, and suggestions to the Project Coordinator on how to improve the quality and applicability of the results and ensure their maximum impact connected to the stakeholder needs. The **Advisory Board** will be confirmed by the **Steering Committee** at the Kick-off meeting and will be purely a consultative body, with no decision. The stakeholder members who have accepted to serve as **MARadentro Advisory Board** members are listed in **Table 1**. Scientific **Advisory Board** members will be proposed at the Kick-off meeting.

The **Exploitation Management Board** will be composed by the Coordination team, beneficiaries more involved on dissemination activities and the WP leaders. This board is needed as an important element in **MARadentro**, since the activities included involve knowledge transfer, dissemination activities, exploitation of results and IPR. *Meetings:* Once a year, additional meetings if needed. This Board will be in charge of community diffusion and protection rules related to IPR; exploitation and enrichment of the acquired know-how; adaptation of the processes to new targets and take-up activities; and development of a prototype of reactive layer as market ready product. The **Exploitation Management Board** will be responsible for:

- Identifying exploitation and end-users of the outcomes and promote contacts with potential customers.
- Regular feedback on the adequacy of research efforts towards the exploitation of related results.
- Assist project beneficiaries in exploitation activities and on IPR and innovation activities.
- Organization of diffusion activities to increase the international visibility of the project results, e.g. by organization of a Webinar, visit to the facilities, etc.
- Addressing potential conflicts of interest between dissemination and exploitation including IPR issues.

3.3. Risk management

Risk management will be a permanent item at the agenda of all Steering Committee meetings. The potential risks to be faced by **MARadentro** are listed in **Table 4**.

Table 4: Potential risks and associated countermeasures.

Potential Risks	Risk Level	Impact Level	Contingency Plan
Project resources, partners and timing			
Key staff member leaves.	Low	Low	Ensure each key member has a deputy. Each partner is part of a research team, ensuring continuity in expertise.
Funding exhausted.	Low	Medium	Proactive management of threats to cost-performance overviewed by WP1.
Ineffective cooperation by the consortium members.	Low	High	**MarAdentro** is structured by integration between WPs. Frequent meetings will address this challenge.
Delays and late deliveries.	Medium	Medium	Perform periodic progress status assessments. Relevant indicators will be used to verify the progress achieved.
Stakeholders unable/unwilling to cooperate/join meetings.	High	Low	Start contacting early. Reimbursement of travel expenses to meetings. Use consortium members to identify alternative contact persons. Offer different formats for collaboration.

Permitting problems for the industrial prototype.	Medium	Low	Two demo sites have been planned and proposed to prevent this situation and a third alternative is available if necessary.
Unforeseen costs.	Medium	Medium	Assume partially extra cost with internal resources.
Technical risks			
Damage of instruments.	Low	Low	Use other equipment or subcontract the analyses.
Damage of microbial targets in sample transfer.	Low	Low	Sampling carefully organized or equipment/personnel will be temporarily transferred for on-site analysis.
The proposed scheme does not reach expected goals.	Low	Medium	Change operating conditions, materials or timing (size).
The proposed scheme is not cost feasible.	Low	Medium	Optimize critical points at early stages of the project.
Delays in development of novel techniques.	Medium	Low	Alternative technologies exist.
Delays in MAR construction at field site.	Medium	Medium	Development of site starts early. The construction is led by one of the partners, which ensures commitment.

3.4. Potential and commitment of the consortium to realise the project.

MARadentro is an ambitious project aimed at enhancing water quality improvement during MAR. Quality here is considered in full, as it includes, apart from inorganic chemistry indicators, the fate of pathogens, biotic systems (fungi and microorganisms), plants, and emerging organic contaminants, at different scales, from the lab to the full facility. Fulfilling this overall goal requires complementary expertise in a number of fields, including microbiology, mathematical modelling, analytical chemistry, and process engineering. The **MARadentro** partners have been carefully selected to meet these overall requirements. **CNR-IRSA** is highly experienced in the spreading of pathogens and antibiotic resistance. **CSIC** has expert knowledge on GW with emphasis on MAR systems, as well as in the occurrence, fate and impact of organic chemical contaminants in the environment, including all types of emerging organic compounds such as pharmaceuticals, personal care products, hormones and biocides, among others. **SLU** has expertise on microbial ecology. **UPC** has expertise in mathematical modelling of contaminant removal in different environments, as well as on risk assessment related to several aspects of MAR. **CNRS** are experts in experimental work at the laboratory scale (batch and columns) for reactive inorganic species and pharmaceutical contaminants. **AQUALIA** is the industrial partner, in charge of economic feasibility and impact, market trends and technology positioning, as well as the transfer to industrial players. **CSIC, UPC, CNR-IRSA,** and **SLU** are presently working together in a project on MAR at the Palamós site and **CSIC** and **SLU** are both involved in a project on treatment of mining waters using reactive layers. **CSIC** (coordinator) has been engaged in numerous EU projects, in many cases as Project Coordinator.

Each **MARadentro** partner has strong contacts with stakeholders, authorities, and policy makers. The active involvement of the end-user's board (Advisory Board) in the project will secure a rapid transfer of the technologies to the market.

GANTT CHART **M:** Milestone**; D:** Deliverable**;** R:responsible

Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
WP1	M	1	2							3									4									5								6	
	D	1																			2																3
WP2	M				1																																
	D							1																													
WP3	M		1	2		3						4		5																							
	D						1			2							3																				
WP4	M													1			2			3		4															
	D																				1						2										
WP5	M					1							2							3											4	5			6		
	D						1							2							3															4	
WP6	M																												1				2				
	D																														1				2	3	
WP7	M																						1												2	3	
	D																							1												2	
WP8	M					1																															
	D					1																													2	3	

WP1 Coordination and management: M1.1. Consortium Agreement; **M1.2.** Kick-off and 1st Steering Committee meeting; **M1.3.** 1st project meeting; **M1.4.** End-users meeting; **M1.5.** 2nd project meeting and Webinar; **M1.6** Developed technologies transferred to end-users and Final project meeting; **D1.1** Consortium agreement signed; **D1.2** Mid-term report**; D1.3** Final report**.** R: CSIC. **WP2 Data mining and exper. design: M2.1.** Literature search; **D2.1.** Report on microbial populations, fecal contamination indicators, pathogens and EOCs in MAR systems. R: CNR**. WP3 Lab testing: M3.1.** Selection of EOCs; **M3.2. C**olumn experimental setup; **M3.3.** Selection of pathogen indicators; **M3.4.** Microbial community analysis and qPCR assays for specific microbes**. M3.5.** Analysis of the selected EOCs and degradation/transformation products identification; **D3.1.** Kd determination of selected EOCs in batch experiments; **D3.2.** Report on reactive layers efficiency; **D3.3.** Report on pathogens, microbes, EOCs behavior in the batch tests, R: CNRS/CNR**. WP4 Pilot MAR: M4.1**. Optimized conditions for FCM-based metabolic and respirometry tests; **M4.2** Toxicity assays in tested layers and sediment tanks; **M4.3**. Analysis of the target EOCs in water; **M4.4**. Microbial community analysis of water and reactive layer. **D4.1** Water microbial community characteristics and fecal contaminants levels variations in layers and sediment tanks, and identification of specific microbes; **D4.2.** Elimination rates of selected EOCs and degradation/transformation products identification. R:CSIC/SLU. **WP5 Field MAR: M5.1**. Site selected; **M5.2.** MAR permits and design; **M5.3** Construction and commissioning; **M5.4** Microbial contaminants level variation in MAR prototype; **M5.5.** Analysis of the target EOCs and degradation/transformation products identification in the influent and GW from the field MAR; **M5.6** Microbial community analysis of water and reactive layer. **D5.1**. Site characterization report; **D5.2.** Project of the industrial prototype to be built; **D5.3.** As-built report; **D5.4** Industrial MAR prototype performance. R:AQUALIA. **WP6 Transport modelling and risks assess.: M6.1**. Code ready; **M6.2.** Coupling of risk assessment concepts to the reactive transport modelling; **D6.1** Mathematical formulation for EOCs/pathogen transport; **D6.2.** Modeling of experiments at different scales; **D6.3** Risk assessment of MAR concerning the fate of EOCs and pathogens and modeling tools to upscale MAR systems. R: UPC**; WP7 Economic balance: M7.1**. Assessment of construction cost and replicability; **M7.2.** Operational risks and costs; **M7.3**. Economic impact, market trends and technology positioning; **D7.1** Construction cost and replicability report**; D7.2** Economic impact, market trends and technology report. R: UPC**. WP8 Exploitation and dissem.: M8.1**. Communication and exploitation plan. R: SLU; **D8.1** Webpage. R: SLU/CSIC; **D8.2.** TV documentary. R: CSIC**; D8.3** Recommendations for decision-makers R: CSIC**.**

4. DESCRIPTION OF THE PARTICIPATING RESEARCHERS

Gender Action in MARadentro

In 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development as the framework for international development. The Agenda, unlike the previous Millennium Development Goals has a stand-alone Goal on gender equality and the empowerment of women. Gender balance is considered within **MARadentro** and will be equilibrated in the participating teams. The Coordinator and most of the IPs and WP-leaders are women (4 out of 6, see **Table 5**). Thus, in the selection processes for the researchers to be hired, the equal balance between genders will be pursued.

Table 5: Major achievements and proven track record of the personnel involved in **MARadentro**.

Partner Number, according to Part A	Research Team Members (for personnel include name, position and affiliation)	General Description
Partner 1 (Coord., CSIC) Silvia Díaz-Cruz	Jesús Carrera, Research Professor, CSIC	Expert in GW, with emphasis on MAR, reactive barriers, experimental and modeling methods.
	To be hired PostDoc researcher, CSIC	Scientific and manager profile. Responsible of the Pilot MAR and sampling. Daily technical and administrative tasks.
	M. Pau Serra-Roig, Technician, CSIC	Expert technician in sample preparation, instrumental analysis and data treatment.
Partner 2 UPC Maarten Saaltink	Xavier Sanchez-Vila, Professor, UPC	PI of several Spanish and EU projects on MAR, in numerical modeling applied to biogeochemical processes, and risk assessment linked to MAR activities.
	To be hired PostDoc researcher, UPC	Scientific profile. Expertise in biogeochemical modeling.
	Lurdes Martínez-Landa Researcher, UPC	Expert in MAR facilities. Has participated in the design, construction, testing, and exploitation of the Palamós MAR site.
Partner 3 AQUALIA Víctor Monsalvo	Pilar Icaran Lopez Project manager, FCC Aqualia	Expert in WWTP processes during 25 years in private companies and 10 years of experience in R+D projects in AQUALIA related to tap and waste water including energy sustainability projects.
	To be hired / Non-permanent staff	Researcher with the expertise required.
Partner 4 CNRS Linda Luquot	Elena Gomez Hernandez, Professor, MU	Characterization of pharmaceutical contaminants and data analysis.
	To be hired PostDoct. researcher, CNRS	Batch and columns experiments, data analysis.
	Frédérique Courant, Assistant professor, MU	Batch experiments and data analysis.
	Patricia Licznar-Fajardo, Assistant professor, MU	Choice and study of antimicrobial resistance genes of human health concern.

Partner Number, according to Part A	Research Team Members (for personnel include name, position and affiliation)	General Description
Partner 5 **CNR** **Caterina Levantesi**	Annamaria Zoppini, Researcher, IRSA-CNR	Expert in aquatic environment and sediments microbial ecology. User of Biolog systems and immunofluorescence methods. Author of more than 25 ISI papers, book chapters and many contributions in relevant international conferences.
	Stefano Amalfitano Researcher, IRSA-CNR	PhD. in Ecology and Evolutionary Biology. Expert in the use of flow cytometry, fluorescence micros-copy and image analysis. Author of more than 25 ISI products and numerous contributions in conferences of international relevance.
	Anna Bruna Petrangeli Technologist, IRSA-CNR	Experience Technologist skilled in GIS environmental analysis: Geodatabase management, cartography, development of GIS customized tools aimed to decision support system implementation and procedure automation.
Partner 6 **SLU** **Sara Hallin**	Jaanis Juhanson, Junior Researcher, SLU	Expertise in microbial ecology, especially community analysis and skills in molecular methods, bioinformatics and biostatistics. Author of 15 ISI publications. Two years' experience from the biotech industry.
	Maria Hellman, Research Engineer, SLU	Experienced senior technician with skills in molecular methods, to some extent also in bioinformatics and biostatistics. Experience from bioreactors with reactive layer, involved in an innovation project on N removal from mining effluents, 6 ISI publications.

5. CAPACITY OF THE CONSORTIUM ORGANISATIONS

Partner Number (Org. Name)		General Description
Partner 1 (Agencia Estatal Consejo Superior de Investigaciones Científicas, **CSIC**)	**Role and main responsibilities in the project**	Coordination of the Project. Provision and operation of the pilot MAR systems. Analysis of emerging organic pollutants at all test levels.
	Key research facilities, infrastructure, equipment	Pilot MAR system, hydrogeochemistry labs. Laboratories equiped with advanced analytical technology for sample preparation and extraction (Automated SPE, turbulent flow chromatography, PLE), and chromatography coupled to Mass Spectrometry (GC-MS/MS, UHPLC-MS, HRMS).
	Relevant publications and/or research/innovation products	Patent P201301011: Procedimiento para la depuración de aguas contaminadas por metales, e instalación correspondiente. Valhondo, et al. 2014. Env. Sci. Pollut. Res. 21 (20), 11832-11843. Valhondo, et al. 2018. STOTEN. 612, 985–994.
Partner 2 (Universidad Politécnica de Cataluña, **UPC**)	**Role and main responsibilities in the project**	Leader of WP6 and WP7. Responsible for the development and maintenance of numerical models for pollutants and pathogens and modelling of experimental results. Risk assessment analyses.
	Key research facilities, infrastructure, equipment	Hydro-geochemistry lab. Field equipment to support field tasks. High Performance Computing system.
	Relevant publications and/or research/innovation products	Rodriguez-Escales et al. (2018) *HESS*, 22. Doi: org/10.5194/hess-22-3213-2018 Carles-Brangari et al. (2017) *Water Resources Research*, 53. Doi: 10.1002/2015WR018517.
Partner 3 (AQUALIA Gestion Integral del Agua SA, **AQUALIA**)	**Role and main responsibilities in the project**	Leader of WP5. Responsible for the field demo-site and collaborating in economic balance of the MAR construction and operation
	Key research facilities, infrastructure, equipment	Partial dedication of technical specialists plus the incorporation of one researcher. It will build the regeneration pond for the MAR field trials in a WWTP in Spain and will perform the start-up and monitoring of its performance.
	Relevant publications and/or research/innovation products	Design of tools for the construction and operation of AR areas for its implementation and replicability
Partner 4 (Centre National de la Recherche Scientifique, CNRS)	**Role and main responsibilities in the project**	Leader of WP3. In charge of the laboratory batch and column experiments. Evaluation of pharmaceutical's efficiency removal.
	Key research facilities, infrastructure, equipment	Column setup, peristaltic pump, CPG-MS, HPLC, LC-MS/MS, GC-MS/MS,
	Relevant publications and/or research/innovation products	Arpin-Pont et al. (2016) *Env. Sc. Poll. Res.* 23, 4978-4991. Héry, M. et al. (2014) *FEMS Microbiol. Ecol*, 90.3, 922-934.

Partner Number (Org. Name)		General Description
Partner 5 (Centre Nationale pour le Recherche **CNR**)	**Role and main responsibilities in the project**	Leader of WP2, and responsible of the evaluation of microbial contamination and toxicity levels and reduction in layer and aquifers at laboratory pilot and field scale WP3-4-5.
	Key research facilities, infrastructure, equipment	Advanced technologies for chemical and microbiological water analysis including instrument and tools for the rapid and specific identification of microorganisms in environamental samples (Flow-cytometer, Biolog, Epifluo-rescence microscope PCR Real-Time PCR, next generation sequencing).
	Relevant publications and/or research/innovation products	CNR-IRSA researchers produced more than 100 ISI publications related to wastewater water treatment and reuse.
Partner 6 (Swedish University of Agricultural Sciences, **SLU**)	**Role and main responsibilities in the project**	Leader of WP8. Responsible for microbial community analysis in WP3-5.
	Key research facilities, infrastructure, equipment	State-of -the -art molecular lab. (PCR, quantitative real-time PCR, NGS). Responsible for the university infrastructure SLU metabarcoding Laboratory. UPPMAX computational cluster in Uppsala and small cluster at the department.
	Relevant publications and/or research/innovation products	Hallin et al. 2015. *Wat Res*, 85:377-383. Iribar et al. 2015. *Ecol. Engin*, 80:101-197. Herbert et al. 2014. *Wat Res*, 66:350-360.