AQUAPRED Sudoe Project: Control and prevention system for contaminants in mineral-medicinal waters through Artificial Intelligence.

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Abstract

AQUAPRED SUDOE is a multi-territorial, multidisciplinary, and interdisciplinary project involving physics, medicine, pharmacy, chemistry, biology, and computer science. It focuses on the monitoring and control of thermal/mineral-medicinal water in spas and the prediction of contaminants based on the real-time digitization of key mineral-medicinal water parameters.

The project will determine the fundamental parameters of thermal/mineral-medicinal waters, as well as their fluctuation ranges within a thermal facility. It will also study their influence on therapeutic safety and water quality and explore potential relationship models.

Additionally, the project will establish a hydrobiome model of the thermal/mineral-medicinal waters and associate it with their therapeutic properties.

For the project's implementation, pilot systems for real-time data acquisition will be developed and installed in thermal spring spas in the SUDOE region. These

systems will monitor parameters using specially designed devices for this purpose, followed by digitization and analysis. During this process, an intelligent system will be developed that, based on this data, will allow for monitoring of water treatment elements (disinfectants, etc.) and a machine learning model will be implemented to predict the likelihood of contaminants (microorganisms) appearing in the water.

Energy efficiency models will also be applied, based on the collected data, to optimize consumption and reduce demand.

Introduction

Research into advanced technologies and their application in the SUDOE region, focusing on the economically and socially relevant topic of Thermalism, and supporting sparsely populated areas through innovation centers and strengthening networks already established in previous projects like TERMARED, forms the basis of the AQUAPRED project.

The project's challenges are as follows:

- Lack of synergies between research centers and the private sector in the field of balneotherapy, resulting in unmet business needs and research without practical application.

- Limited connection between research centers and business needs, reflected in a weak tradition of innovation within the balneotherapy sector.

- A sector with a limited tradition of innovation and digitalization, and even less so in the application of advanced technologies and automation to internal spa processes.

- Low investment in R&D&I by companies and public administrations in the SUDOE region, below the European average.

- Lack of research on improving water quality using physical methods and advanced technologies such as sensors, the Internet of Things, big data, and artificial intelligence.

- Insufficient research in the field of therapeutic treatments.

- Increasing global competition, exacerbated by the peripheral location of the SUDOE region within the EU.

- Given the rural nature of most thermal spring spas in the SUDOE region, the shortage of highly skilled technical personnel makes access to advanced technologies more difficult.

- Limited use of residual energy from thermal/mineral-medicinal water compared to the high cost of energy.

The combined experience of the project team and the diverse specializations and areas in which they operate necessitate a transnational approach to address the problem.

Consortium

The consortium is made up of partners from the three countries who provide the project with the necessary technological and scientific tools for its success, with each partner covering the gaps in the others and complementing their capabilities. In Portugal, the Polytechnic Institute of Bragança and the Water Technology Valorization and Transfer Center (AQUAVALOR) in Chaves are experts in the analysis of thermal waters and their recreational use; in Spain, the University of Vigo's Department of Applied Physics has extensive experience in the analysis and valorization of thermal waters and medicinal muds, and in promoting their pharmacological use; the Department of Systems Engineering and Automation also participates, as well as researchers from the Ourense Water Campus; the Complutense University of Madrid, with its School of Medical Hydrology, has broad experience in the evaluation of waters and their medicinal effects; and the University of Bordeaux, with its Institute of Thermalism, has invested in understanding thermal waters, their behavior, and developing testing environments. The University of Pau, with its Thermal, Energy and Processes Laboratory, which specializes in the study of energy systems, chemical engineering, and water composition; the University of A Coruña, with its Research and Development Laboratory in Artificial Intelligence, which specializes in the application of Artificial Intelligence and Big Data techniques; AQUI O Thermes, a thermal cluster in the Nouvelle-Aquitaine region; Hervideros de Cofrentes, a thermal spring spa located in the province of Valencia; and the El Raposo Thermal Spring Spa in the province of Badajoz. Other associated partners in the project include the Galician Tourism Agency, the municipality of Chaves, the Viseu Intermunicipal Community, and the Iberik Thermal Spring Spa hotel chain. Figure 1 shows the logos of the participating partners and associated partners.

Figure 1. Logos of participating partners and associated partners.

Project objective

The objective of the project is the joint development of automated water monitoring tools to improve quality control processes in thermal spring spas, with the potential for extension to the EU. Figure 2 shows a diagram of the Project.
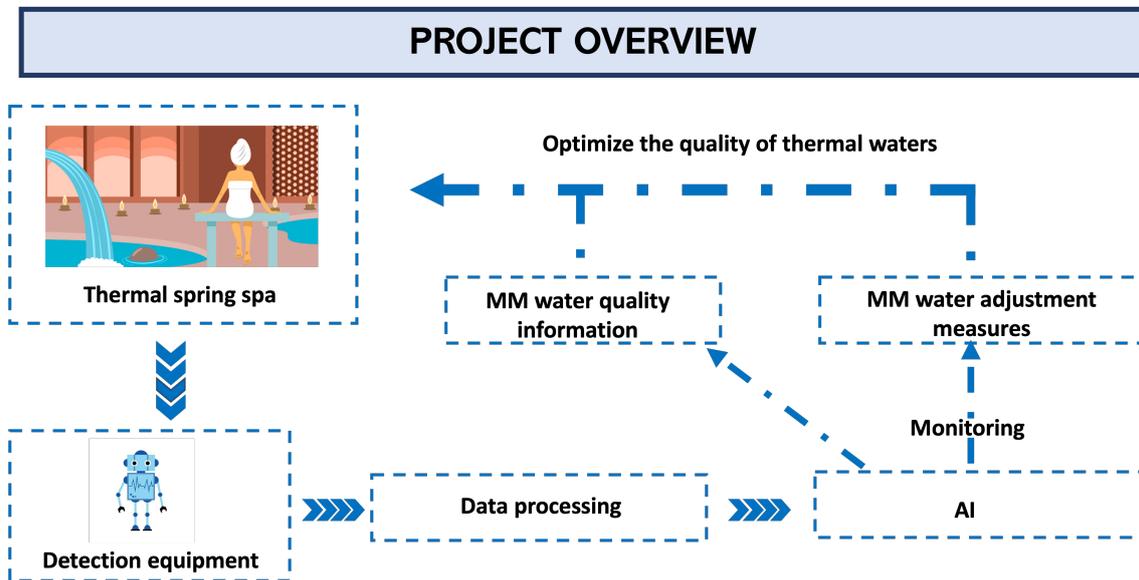
Figure 2. AQUAPRED SUDOE Project Outline.

Project development and phases

The project is developed in three stages:

1- Improving knowledge and use of innovation to strengthen the thermal sector of the SUDOE region.

2- Deployment of the monitoring and measurement system for thermal water parameters.

3- Improving health safety and increasing the quality and confidence in the thermal product of the SUDOE region.

The first stage focuses on improving knowledge and using innovation to strengthen the thermal sector of the SUDOE region (especially its health aspect), through the development and testing of a monitoring and measurement system for thermal water parameters. This will increase regional expertise in thermal innovation and research, foster co-innovation and transnational cooperation, and reinforce the cohesion and balance of the thermal territories within the SUDOE area.

The following activities are carried out in this first stage:

a) Design of the data capture and sensor system.

b) Development of a scale model and initial data acquisition.

c) Development of a control and predictive model.

d) Modeling and characterization of the hydrobiome.

e) Development of energy utilization models.

Six pilot prototypes will be installed for data acquisition at: Laias Thermal Spring Spa in Ourense (Spain), Dax Thermal Institute (France), Chaves Thermal Spring Spa (Portugal), El Raposo Thermal Spring Spa in Badajoz (Spain), Saubusse Thermal Center (France), and Cofrentes Thermal Spring Spa in Valencia (Spain). Figure 3 shows the installation sites for the pilots.

Figure 3. Pilot installation centers.

The second phase aims to foster local innovation and strengthen the triple helix of the thermal sector in the SUDOE region through collaborative work between universities, companies, and government agencies. This will involve deploying a system for monitoring and measuring thermal water parameters, promoting the transfer of innovation, technology, and knowledge among these stakeholders and across the project territories. The activities of the second stage are:

a) Development of a joint strategy for the management and control of thermal water quality.

b) Deployment of the monitoring system in real-world environments.

c) Real-time data capture and analysis.

d) Evaluation of the predictive model and improvement of its performance.

The third and final stage will focus on improving health safety and increasing the quality and reliability of the thermal product in the SUDOE region. This will be achieved through the co-innovation and technology transfer process of the project, resulting in a predictive contamination prevention system.

The following activities are proposed for this third stage:

a) Definition of the possible value ranges for the parameters and the rules of action.

b) Evaluation of data within the framework of the thermal/mineral-medicinal water quality control strategy.

c) Integration of the predictive system into the water quality control strategy.

In all stages, a communication strategy will be developed to disseminate the knowledge acquired during the project.

Expected results

The expected results of the project are as follows:

- Real-time data capture to feed a monitoring system for the quality of mineral-medicinal waters in the SUDOE region. This system will enable and improve quality models, feed a dataset that complements the characterization of the hydrobiome and energy efficiency models, providing a holistic view of the quality management of mineral-medicinal waters in the SUDOE territory.

- Adoption of thermal water quality control strategies in the SUDOE territory, promoting the use of automated water quality monitoring and control systems.

- A solution developed and validated within the project, supported by a strategy in the SUDOE territory that will be adopted as a benchmark for automated mineral-medicinal water quality control systems.

Conclusions

The AQUAPRED project aims to develop and enhance research and innovation capabilities and facilitate the adoption of advanced technologies by the thermal sector in the SUDOE region. It aligns with the EU's research and technological development policy by promoting applied research and innovation activities with demonstrators of their results (six pilot projects involving collaboration between universities/research and technology centers and the private sector, under the supervision and monitoring of the administration). This will also help minimize energy consumption by maximizing the circularity of energy from natural sources.

Another important contribution of the project is the modeling and characterization of the hydrobiome of spas in the SUDOE project area, as this is essential for understanding biodiversity and aquatic ecology in these thermal environments.

Finally, EU water protection and management policies will benefit, as the project will generate and test tools aimed at protecting and managing a specific type of water: thermal water. In this context, the project's contribution will verify, through the valorization of thermal/mineral-medicinal waters, their use as a medicinal resource while improving the control exercised over these waters to reduce their environmental impact once used and maximize their value.

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