D.4.1.2 – Implementation/realization of the WQIS in the pilot site

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INDEX

1. INTRODUCTION

The Water Quality Integrated System (WQIS) network was applied and implemented for each study area and focused on urban areas in sewers, riverine and rivers. Our innovative Water Quality Integrated System is based on a thorough knowledge of the magnitude, frequency, and impacts of microbial contamination of bathing water due to high rainfall. The system was developed to protect public health, the environment and the economic activities that rely on tourism. Its proactive approach to coastal water quality management can be applied to a variety of coastal sites characterized by extreme raining events.

The WQIS is based on real-time hydro-meteorological monitoring, a forecast model that simulates pollutant dispersion in bathing water, and a real-time alert tool that predicts potential ecological risks related to the bacterial contamination of bathing water after extreme raining events.

In the D3.1.1 Software Utilities and D3.1.2 WATERCARE WQIS deliverables, design, test and preparation of the WQIS have been described.

After this preparatory phase, the WQIS was implemented in the Fano pilot site as described in the deliverable D.3.3.1 - WATERCARE WQIS implementation and 3.3.2– Sensor data web.

The experience gained in the implementation phase of the WQIS in the pilot site has been transferred to the various partners of the project. In particular, the connection diagrams of the equipment, the sampling strategies and an operating manual regarding the use of the entire WQIS "ecosystem" were shared.

CNR IRBIM provided continuous remote support from the testing phase in the laboratory to the complete installation in the field and subsequent launch of the Watercare site to the production of valid data. During this operational phase CNR IRBIM also updated both the centralized database and the Grafana dashboards designed for data visualization (see deliverable 3.3.1, chapter 3.8 WEB data presentation and sharing)

2. WQIS DEVELOPMENT CYCLE

The WQIS is an IT ecosystem consisting of several interconnected and continuously interacting subsystems (Fig. 1). In the first subsystem (Meteorological, Freshwater, and Seawater monitoring), some activities are automatic and do not require the direct intervention of an operator, whereas other activities, such as seawater sampling and bacteriological and chemical analyses, involve human action. The flow of information stored in the WQIS database is managed by a continuously running software that processes the data by means of a forecast operational model connected to an alert tool.

These tools are the WQIS results and allow generation and delivery of FIB dispersion forecast maps, which are then used by decision makers. Therefore, the system outputs real-time data that updates historical series with new data. The alert tool notifies users of:

- system progress;
- any abnormalities in the environmental parameters;
- any hardware abnormalities detected in real time.

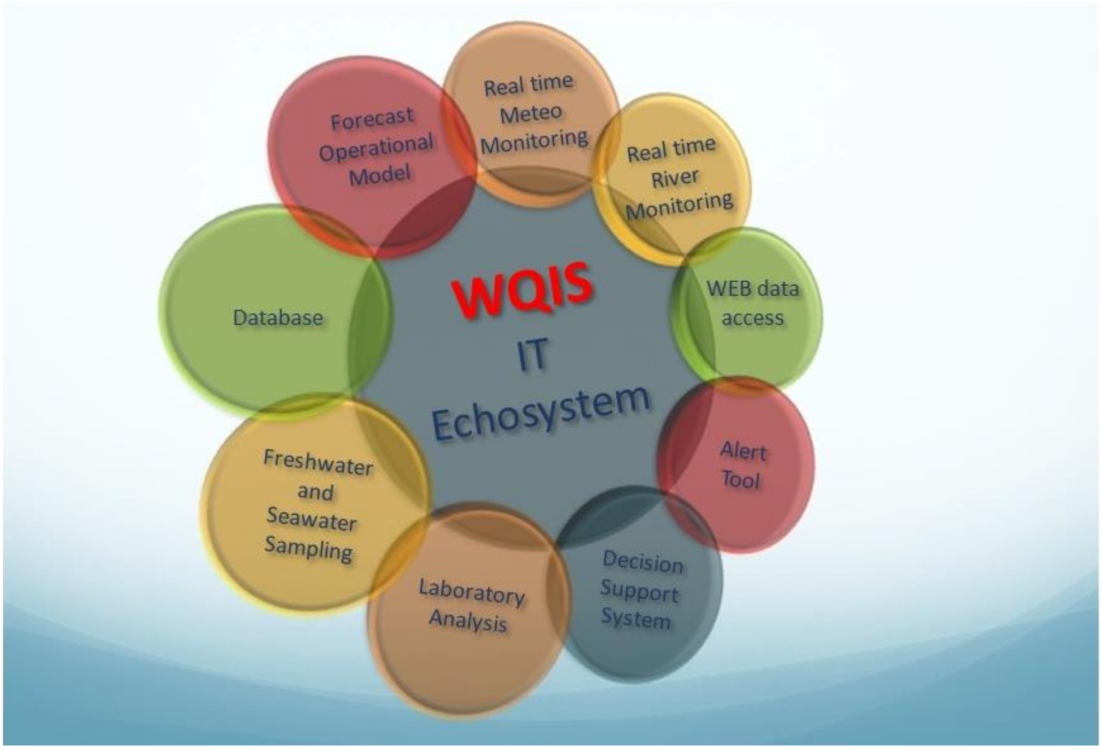

Figure 1. The WQIS IT ecosystem and the integrated subsystem

Regarding software engineering, during the various development phases of the Watercare project, the paradigm called agile software development (ASD) was used. Agile methods are opposed to the waterfall model and other traditional development models, proposing a less structured and focused approach on the objective of delivering functioning and quality software (continuous new verifications), quickly and frequently.

An important practice through which the solution to be delivered evolves from what was only an "idea" (a concept, a proposal, a set of needs) to become a valuable product. Iterative development works through cycles of actions / activities (Fig. 2) that do not change, but which by repeating cyclically lead the 'raw' solution to be refined until it becomes the final product;

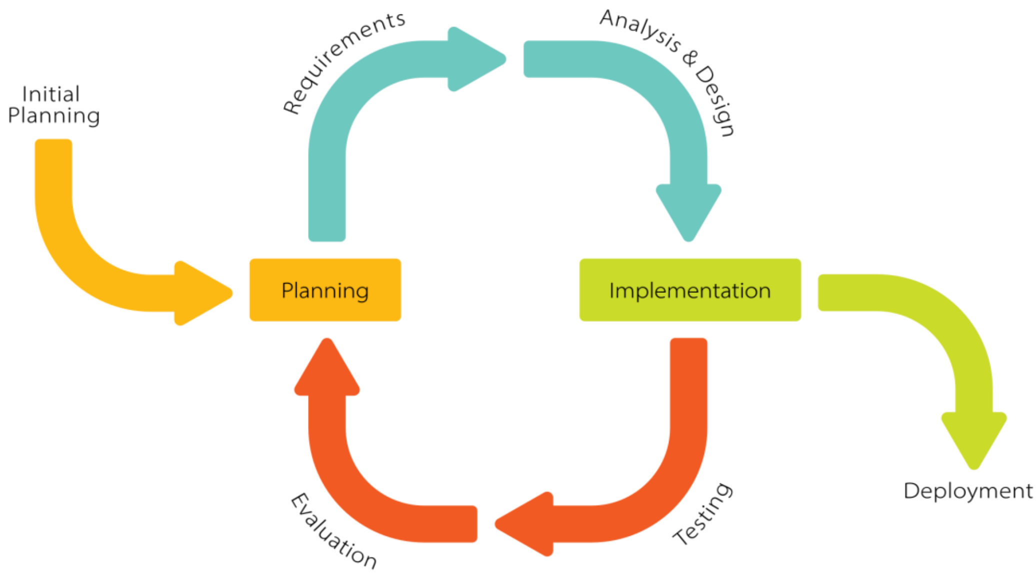

Figure 2 WQIS Iterative development model (modified from Wikipedia, 2021)

Some practical examples of the optimal use of agile methodologies and incremental development during the development of the Watercare project are for example: the integration of river level sensor (Arzilla Outfall-Fano pilot site) and the upgrading of Database, Alert system tool, sample Analysis script and web data presentation after the implementation of each Watercare site.

3. ARZILLA RIVER UPSTREAM STATION (PILOT SITE)

In order to verify the positive impact of tank infrastructure in environmental terms and measure the amount of microbial pathogens released into the environment and not properly treated in the purification plant, 2 monitoring stations were implemented. Monitoring was implemented through the installation of sensors upstream and downstream the tank (Fig. 3) which allow a simultaneous and continuous measuring of the most common water physical-chemical characteristics and with meteorological and hydrological sensors.

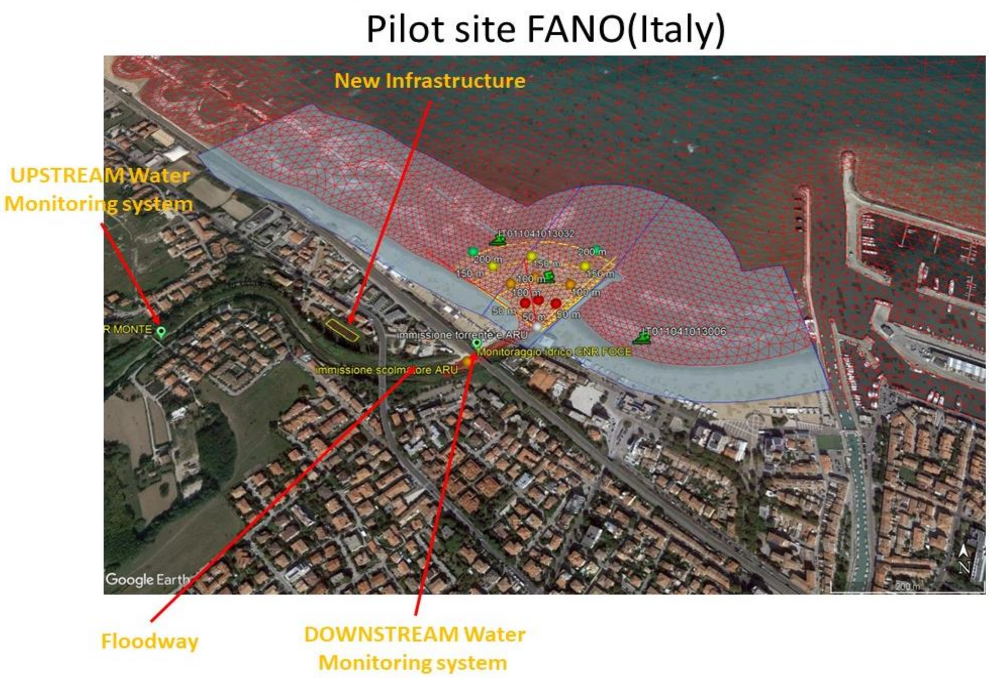

Figure 3. Upstream and outfall stations located in Fano (Pilot site)

The results of microbial pathogens and hydro-meteorological data are useful to the positive impact of tank infrastructure in environmental terms and the diffusion of wastewater into the sea during the extreme rain events due to overflow from the tank.

In this chapter a description of the Arzilla River upstream stations (Fig. 4) is given.

Figure 4. Real-time data acquisition system implemented at Arzilla River upstream (FANO Pilot site).

3.1 Real time data acquisition system

A fundamental step concerning the plan and implementation phase was to study in depth the subsystems and sensors, taking particular care of communication, energy consumption, physical connection, and the format of the data output. During this activity, the most delicate procedure consisted of the implementation and test of the scripts for the management of communication, data reading and data transfer between the datalogger and each sensor.

Subsequently, a complete abstracted firmware and software was implemented: all the source codes produced in the previous step were integrated into subroutines and functions were inserted into a complete reading cycle performed every 30 minutes (the sensor reading routines are performed almost continuously and subsequently processed every 30 minutes).

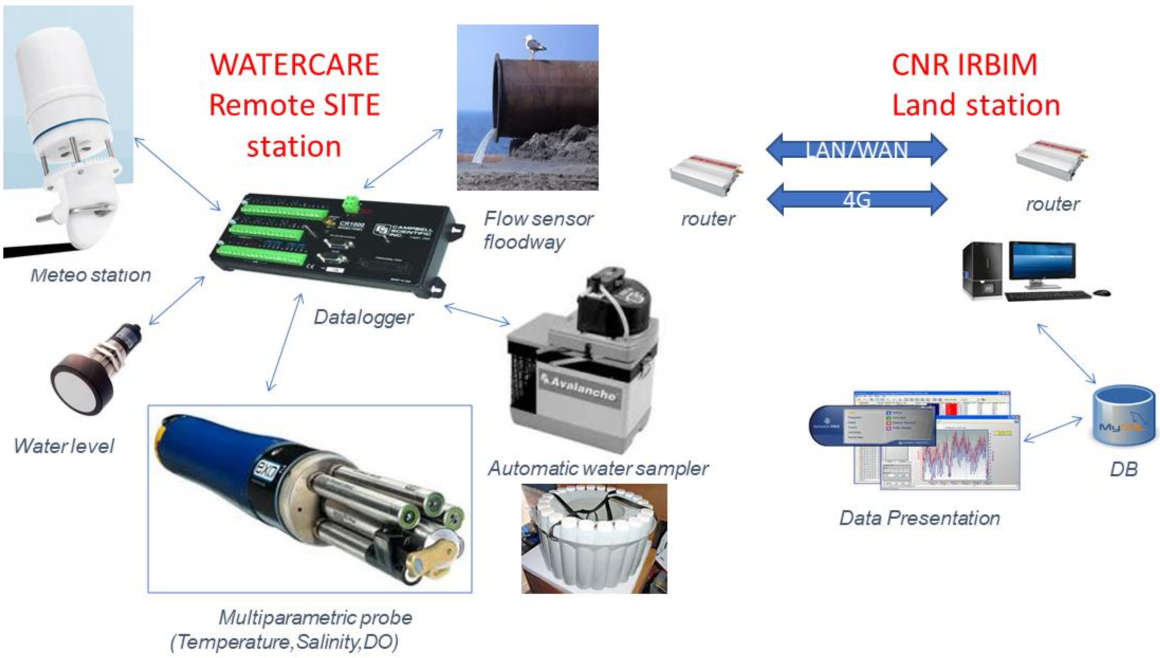

Figure. 5. Block diagram of a WQIS station.

The real-time acquisition system (Fig. 5) includes the following equipment:

- **Campbell Scientific CR1000X** datalogger that manages the interface with sensors/actuators, data collection and remote communications;

- **YSI EXO2 (or EXO3)** multiparametric probe. The sonde allows real-time river water monitoring measuring the following parameters: level, temperature, salinity, conductivity, Optical Dissolved Oxygen (concentration and saturation), turbidity, pH, redox;
- **Teledyne ISCO Avalanche** automatic and refrigerated water sampler which takes samples (14 bottles, 900ml) for laboratory analysis of microbiological parameters of river water.

Nitrate, ammonia (pH, redox Fano only) are measured with a portable multiparametric sonde in water samples collected with ISCO Automatic sampler. (More details about the hardware devices used can be found in deliverable 3.3.1, Annex 1.)

Table S1 summarizes the parameter measured for each Watercare site station and the hardware device used.

HARDWARE SENSORS	PARAMETER	FANO Arzilla Upstream	FANO Arzilla Outfall
Weather Station (ClimaVUE™50)	Wind (speed, direction, gust)	-	x
	Air Temperature	-	x
	Relative Humidity	-	x
	Atmospheric Pressure	-	x
	Solar Radiation	-	x
	Rain Gauges	-	x
	Lightning	-	x
Multiparameter Sonde (YSI EXO2/EXO3)	Water Temperature	x	x
	Salinity	x	x
	Conductivity	x	x
	Optical Dissolved Oxygen (concentration and saturation)	x	x
	Turbidity	x	x
	pH	-	-
	Redox	-	-
Level Sensor (Siemens SITRANS LU240)	River Level	-	x
	River Flow Sensor	-	Estimated by model

3.2 Result analysis data entry

CNR IRBIM staff has developed a web interface, named Sample Analysis (S.A), with the task of acquiring manual monitoring data, such as data from chemical and microbiological analyses performed by the authorized personnel.

See deliverables 3.3.1, chap 3.6

3.3 Centralized database

CNR IRBIM staff has developed a centralized database (WQIS CDB) using the relational database management system (RDBMS) MySQL and it is the heart of the collection project data. (sensors data, analysis results, ancillary data, project partners registers, access information to project websites, geolocation sampling points, etc). The interoperability of data is guaranteed by the use of an internationally recognized vocabulary (British Oceanographic Data Centre-NERC Vocabulary Server) and data format (ODV Ocean Data View).

See deliverables 3.3.1, chap 3.7

3.4 Arzilla river upstream Web Data Presentation and sharing

The data acquired and collected according to the procedure explained in section 3.1, are analysed and visualized using Grafana (Grafana Labs, 2020) open source software installed on a dedicated web server at the CNR-IRBIM (Figure 6).

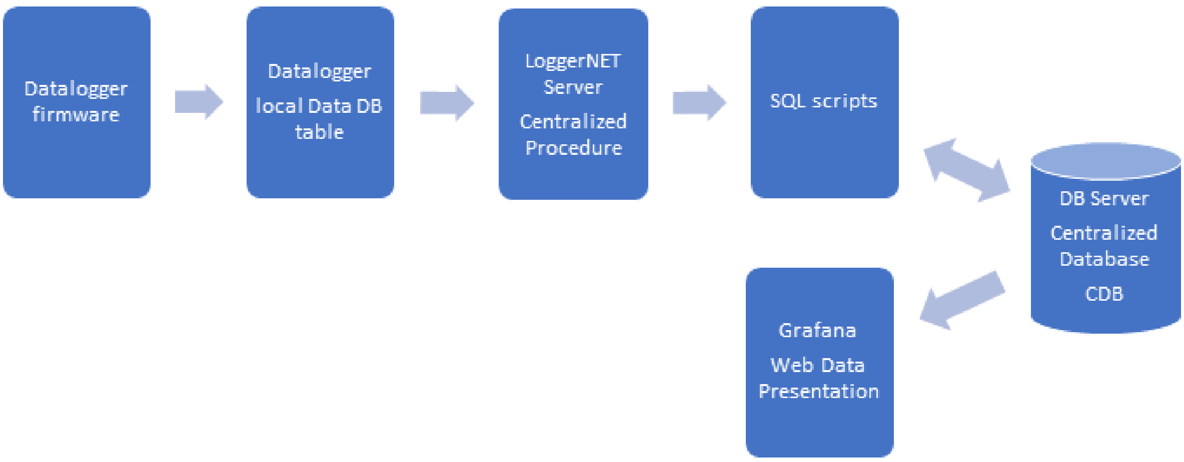

Figure 6. Block Diagram showing the procedure for acquiring, storing and displaying data.

CNR IRBIM staff has developed a dashboard for each project site to display graphs and statistics of all parameters analyzed (air, water, chemical, physical and microbiological). The dashboard of each Watercare site is characterized by a set of panels (the basic data visualization building block). Each panel allows one or more physical parameters to be plotted and correlated versus time. Furthermore, through the grafana web interface it is possible to access the site management pages.

The web interface is protected and accessible with the credentials that the CNR-IRBIM staff has provided to all partners. Once logged in, the user is redirected to the *Watercare Sites* homepage with a summary map of all the project sites (Figure 7). From the map the user can click on the markdown focused on the site of interest and then open the *Data visualization* link to open the dashboard with site data and information.

Figure 7. Watercare Sites Map.

The *analysis points* panel shows a map with all the sampling points provided for the specific site. The points are georeferenced and are extracted from the database. The user can see the sample id by hovering the mouse over the point (Figure 8).

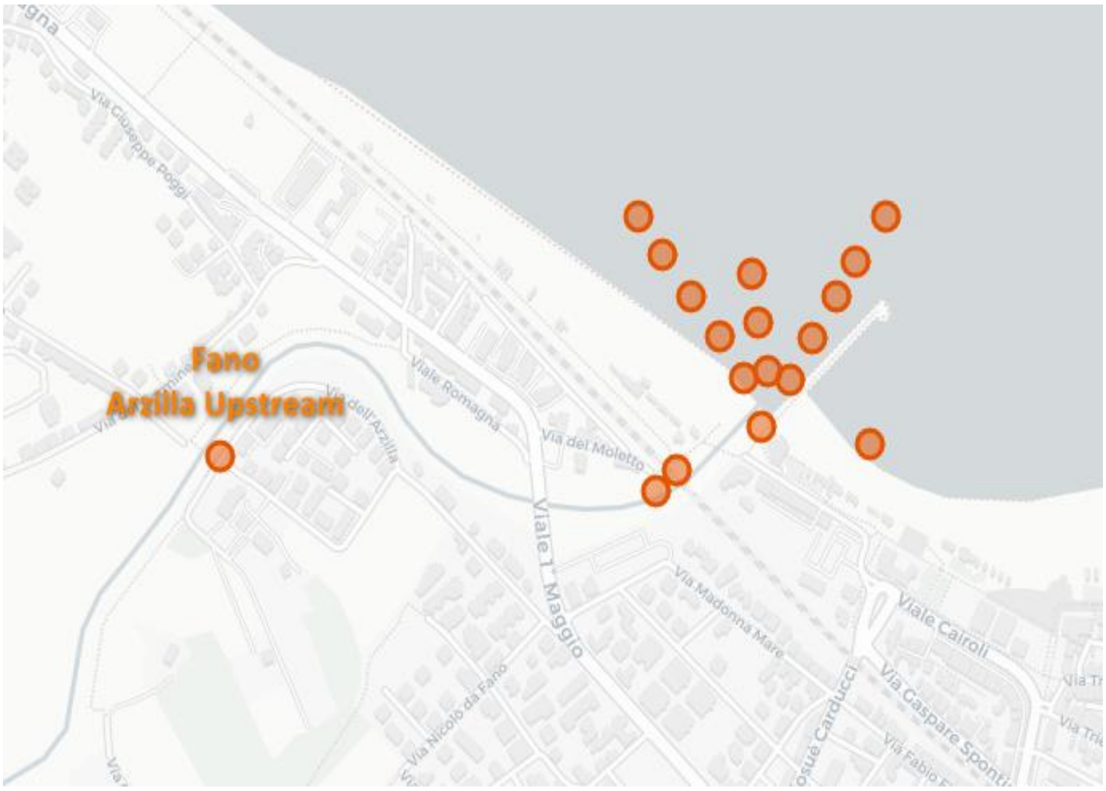

Figure 8. Show the Fano Arzilla Upsteam with the sampling points.

The panels are organized into the following sections:

- FOM - Forecast Operational Model
- Last Observation
- Air
- Water
- Automatic Sampling
- Samples Analysis
- Hardware

Each section can be activated or deactivated by clicking on the > symbol or on the section name.

FOM -Forecast Operational Model shows 3 maps (water temperature, salinity and *E. coli concentration* of the next two-day forecast model.

The *Last Observation* section (Figure 9) contains the air and water information from the latest update. Furthermore, it includes information of the ISCO sampler status. *Last Sample Sampling STATUS* reports the status of the sampler:

- *Ready to Sample* – the sampler is ready and it is possible to start a sampling;
- *Sampling in Progress* – a sampling was started and is still in progress;
- *Waiting for ACK Button* – the sampling is finished, the sampler has collected all the samples. The staff will have to replace the bottle carrier, carry out the required cleaning and then press the ACK button (see section 0).

Figure 9. Example of Last observation (weather information refers to Fano Arzilla Outfall)

Bottle shows the last sampled bottle. Sample Time and Sample Status reports respectively the timestamp of the last sample and the status (sample ok, sample in progress, liquid lost, etc.).

The *AIR* section (Figure 10) includes graph panels with weather information collected by the weather station installed on the monitoring site (data are updated every 30 minutes).

Figure. 10 . Example of the Air section (refers to Fano Arzilla Outfall).The vertical blue lines indicate the time of river automatic sampling. They are shown in all graphs of the site dashboard.

The graph panels inside the *WATER* section (Figure 11) show the measurements made by the CTD probe, water level and everything related to measurements in water. Data is updated every 30 min.

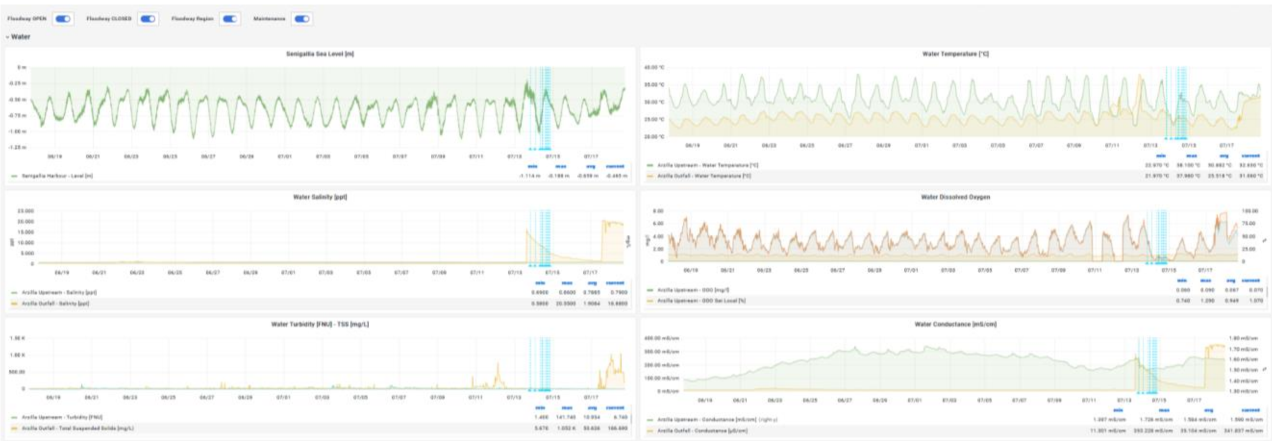

Figure 11. Example of the water section. The vertical blue lines indicate the time of river automatic sampling. They are shown in all graphs of the site dashboard.

The Automatic Sampling section (Figure 12) includes graphs with real-time trends of the sampling status over time (data are updated every 1 minute).

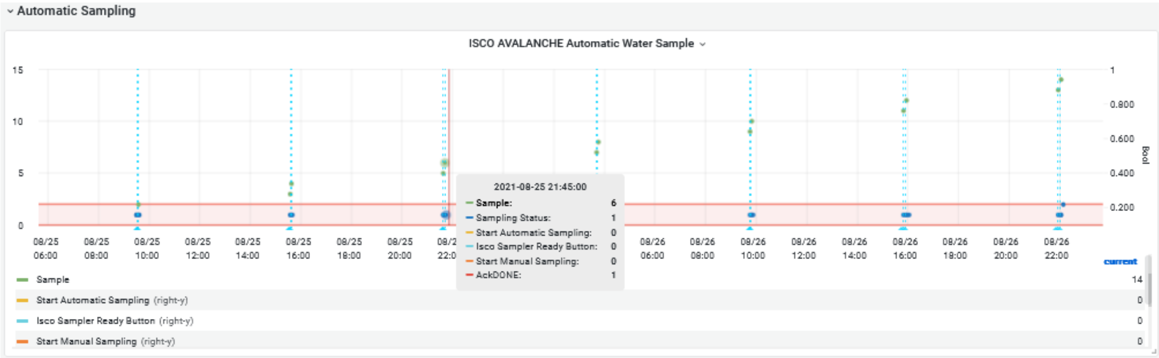

Figure 12. Automatic Sampling section.

The *Sample Analysis* section (Figures 13 - 14) reports the data generated by chemical and microbiological analysis derived from automatic or field sampling at sea (for example, coliform concentration). If provided, it also shows ancillary analysis data. Data is updated every 30 minutes.

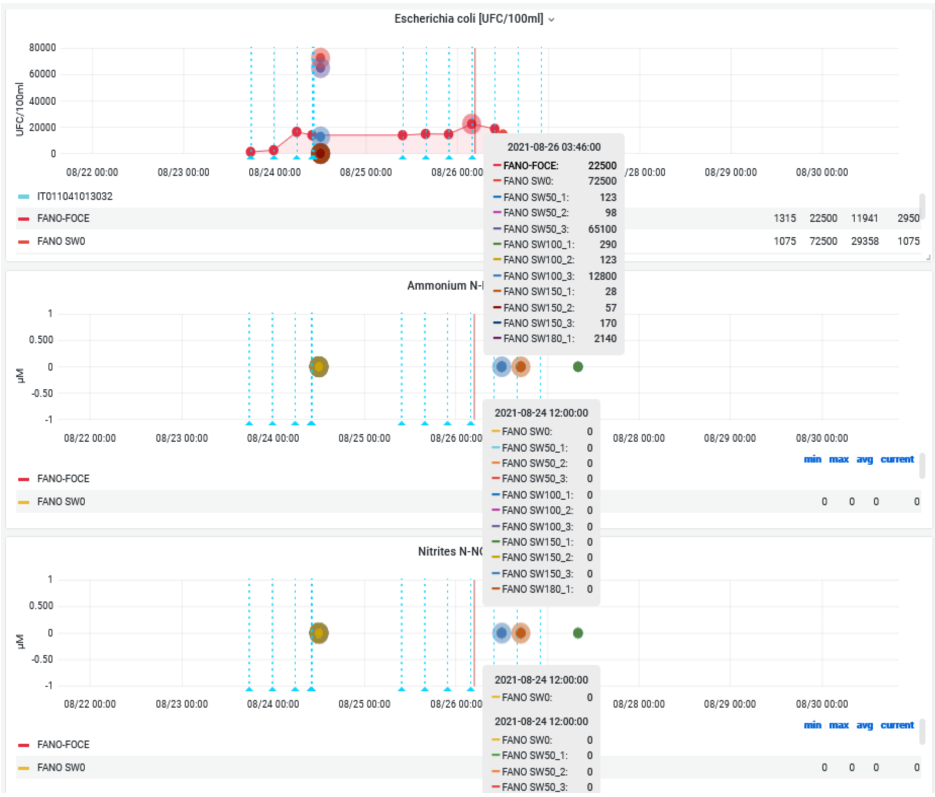

Figure 13. Sample Analysis section, part 1.

Figure 14. Sample Analysis section, part 2.

The *Hardware* section (Figures 15 - 16) includes all important information to analyse the operating status of the systems installed on the monitoring site (data logger temperature and voltage, EXO voltage, ISCO sampler fridge temperature, etc). In the event of anomalies, the system sends an alert to all the technical managers as described in the deliverable 5.2.1.

The data visualization site was updated at the beginning of 2021: Grafana was updated to the latest major release and the dashboards were upgraded with more attractive graphics, cool and easy to be consulted.

Figure 15. Hardware section, part 1.

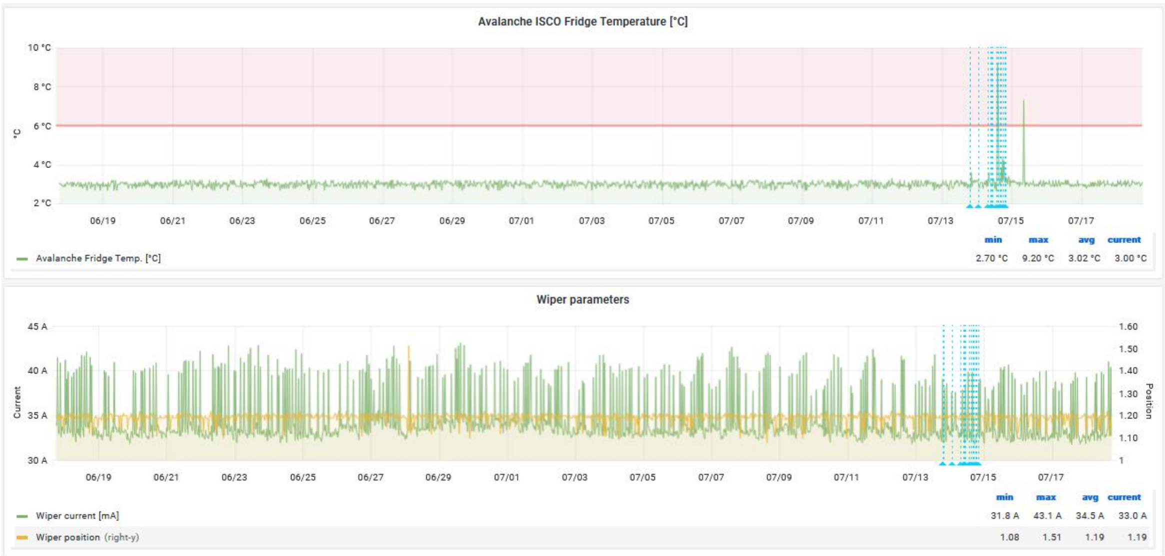

Figure 16. Hardware section, part 2.

3.5 Forecast Operational Model

A finite element hydrodynamic model was applied to five study areas in the Adriatic Sea, which differ for urban, oceanographic and morphological conditions. With the help of transport-diffusion and microbial decay modules, the dispersal of *Escherichia coli* concentration is simulated and forecasted (Ferrarin et al., 2021).

The modelling framework presented here is based on the System of HydrodYnamic Finite Element Modules (SHYFEM, Umgiesser et al., 2014) code, an open-source unstructured ocean model for simulating hydrodynamics and transport processes at very high resolution. The modelling suite consists of:

- a 3D hydrodynamic model, that describes currents and mixing of water mass in the system;
- a transport and dispersion module, that simulates the dispersion of solute and microorganisms through the system;
- a microbial decay module, which defines the decay of microorganisms considering various environmental conditions.

For more details see deliverables 3.3.1, chap 5 Forecast Operational Model and 5.2.2 – Alert Tool final release for more details.

3.6 Alert tool

The alert tool is detailed in the deliverable of the WP5 as follows:

- 5.2.1 – Simulations for the validation of the Alert Tool;
- 5.2.2 –Alert Tool final release.

3.7 Site Management

CNR Staff has developed a web interface (Fig. 17) for the remote management of automatic sampling.

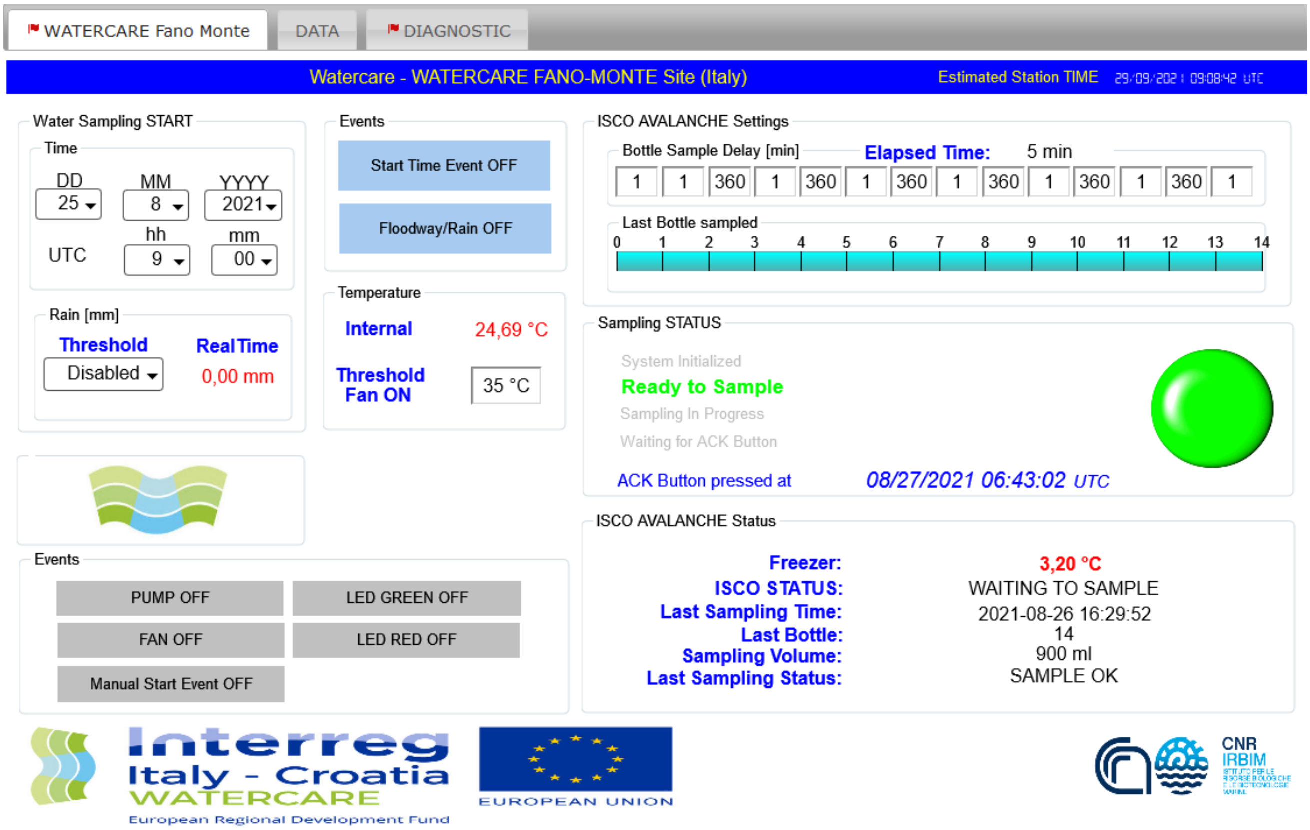

Figure 17. Site Management web interface.

This web tool has been designed to remotely activate the sampling cycle and to have a quick look at the events and the progress of the system. It is reserved to the Scientific site manager, a core actor of the WQIS system planned for each study site.

In collaboration with project staff, the Scientific Site Manager is in charge of consulting the WQIS and seeing the weather-marine forecasts. Then decides the strategy to be applied and is responsible for starting the sampling cycle. It also coordinates all logistic activities related to sample management.

A special function for activating synchronized automatic sampling has been created and implemented in the Arzilla RIver-Fano Pilot Site stations (also applied to Cetina River stations Main upstream and outfall).

In particular, when a trigger event in the Fano outfall station is activated (for example sampling start on a scheduled date or rains above a preset threshold, at the same time the start of the sampling phase in the upstream station is activated.

This synchronization makes it possible to sample water from the river at the same time in both stations. After starting, the Site Manager can setup the other sampling times of the remaining bottles inside the refrigerated autosampler

The Site Management is detailed in the deliverable 3.3.1 – WATERCARE WQIS implementation, chap 4.

3.8 WQIS SAMPLING STRATEGY

Automatic freshwater sampling for microbiological and chemical analyses is activated by a trigger event, e.g. heavy rain detected by the weather station, a rise in the river level, or CSO activation. Seawater sampling starts after CSO closure, its schedule adapted to weather and sea conditions. A time diagram showing the freshwater and seawater sampling phases is reported in the deliverable 3.3.1 – WATERCARE WQIS implementation, chap 5 WQIS SAMPLING STRATEGY.

4 References

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