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D.T.2.3.1. Validation of implemented Improved Water Safety Plans (IWSPs) and implemented measures in PAs

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Contents

1. Introduction

The deliverable 2.3.1 represents a Validation of implemented Improved Water Safety Plans (IWSPs) and implemented measures in PAs.

It is an overall evaluation of the efficiency and effectiveness of implemented IWSPs and measures performed in PAs within the MUHA project. The deliverable will compare the planned results to be delivered under AF and T2.2 to the achieved results.

Based on the developed guidelines all PA partners gave the input data summarized in this report.

2. MUHA measures/actions adopted in the PA

2.1. Italy (PP10+LP)

The Italian pilot is the water supply system intended for human consumption connected to the Ridracoli reservoir (Emilia-Romagna region) and managed by Romagna Acque – Società delle Fonti.

Specific activities have been carried out by CNR, supported by the DPC, to provide tools aiming at improving the development of WSP on the four hazards considered within the MUHA framework:

- **Flooding**: analysis and verification of the lamination of the historical flood events affecting the Ridracoli dam. The LAMINA model (Castorani and Moramarco, 1995) is used to describe the lamination of historic flood events incoming into the reservoir. This model can be used both for the dimensioning of the bottom outlets and the spillways and for the verification of their operation, with the aim of identify for each historical observed flood event the maximum initial lake level that could be allowed in order to assure a maximum discharge released downstream not exceeding 50 m^3/s.
- **Accidental pollution**: exploring the use of innovative parameters for the real-time monitoring of water microbial quality to complement the current assessments of microbiological contamination. We hypothesized that varying treatment and supply schemes will result in different microbial removal performances following the quality of the influent raw water and the efficacy of water filtration steps.
- **Earthquake**: developing and testing of a modelling approach based on the graph-theory in the Ridracoli pilot area to provide a straightforward analysis of the main features of a water supply system, specifically focusing on its resilience and on the impact that a single pipe failure (due to external causes) may cause on the overall system operation.
- **Drought**: developing and testing of a tool called INOPIA^{QGIS}, a flexible and parsimonious user-friendly approach supporting Water Supply Systems (WSS) monthly mass balance considering climate variability, infrastructures and multiple allocation options. Once implemented the WSS, it provides *hindcast* simulation (reproducing the past decades) for evaluation and “what if” management scenarios, stochastic simulation for robust drought index estimation and early

warning decision support and climate scenarios simulation for impact and adaptation studies, together with build-in plotting and export tools .

2.2. Croatia 1 (PP4)

The pilot activities carried out to define the measures that need to be adopted to reduce the potential risk were to: determine hydrogeological characteristics of the Golubinka spring catchment area as the basis for the water safety plans. This includes groundwater origin, dynamic, amount of water in the aquifer, water quality, and defining the zone of fresh and saltwater mixing (seawater intrusion).

Description of the key activities that were implemented on the pilot site Golubinka during the project implementation:

Hydrogeological mapping was conducted by field investigations occurred prior to other analyses and during each field research. As such, it provided a basis for further research and interpretation.

Hydrochemical characterisation that includes systematic monitoring established at several springs in the investigated catchment area. Monitoring began in June 2020 and is still ongoing. It comprises of monthly sampling at specific locations and in-situ physicochemical parameter measurements. The following hydrochemical variables are analyzed: major anions $(HCO_3{}^-, Cl^-, SO_4^{2-}, CO_3^{2}{}^-)$ and cations $(Ca^+, Mg^{2+}, Na^+, K^+)$, stable isotopes ($\delta^{18}O$ and δD), trace metals (Ni, Co, Cu, Zn, Cd, Pb), TOC and TIC.

Dataloggers (continuous data): loggers were set up, and measurements were performed (water level, temperature, electrical conductivity - EC). Sampling sites: springs - Golubinka, Vruljica, and wells - Boljkovac, Oko, Bokanjac (B4), and Jezerce.

Geophysical research - Geoelectrical tomography, profiles with a length of 950 meters (depth 165 meters) and two transverse profiles of 950 meters (depth 170 meters) and 315 meters (affected depth 40 meters) were performed.

2.3. Croatia 2 (PP5)

The pilot activities involved the acquisition of computer equipment and hydraulic modelling software as well the development of hydraulic model of IVB WSS and Water safety plan.

The Pilot Action focused on the development of a mathematical (hydraulic) model of the water supply system, which was used for simulating the various hazardous scenarios, their impact on the water distribution as well the simulation of the optimal measures to be taken, all based on the proposals for harmonizing Civil Protection Mechanisms to Water Safety Plans defined in WP1.

2.4. Slovenia (PP6+PP2)

All the activities were performed with an overall objective to improve some aspects of the risk management of the Kamnik water supply system and provide testing platform for the development of the overall framework for the implementation of the water safety plans.

The pilot activities adopted in the PA:

- Development of improved coping capacity, with specific focus on the equipment for the civil protection headquarters of the Kamnik Civil protection.
- Development of the hydraulic model for the Kamnik Water supply system.
- Measurements of discharges on the Kamnik Water supply system (as a sub-measure for the calibration of the hydraulic model).
- Development of the reporting system for the improved understanding of the probabilities of critical events on WSS.

2.5. Montenegro (PP8+PP3)

In the pilot area, several activities were carried out aimed at reducing the risk of hazardous events, especially Drought and Accidental pollution. The main goal of the activities we carried out through the MUHA project was the development of the Vidrovan Source Geological Research Project, as well as the Study on Hydrogeological Research, Engineering-Geological Characteristics and Geophysical Research. The purpose of the research of the subject terrain is the possibility of obtaining additional quantities of drinking water on the territory of the municipality of Nikšić, as well as the protection and securing of buildings from earthquakes.

After the conducted research, it was concluded that an additional 30 l / s of water can be obtained at the source D. Vidrovan. 10 l / s from new wells and 20 l / s with rehabilitation of buildings.

Additionally, in previous time we also activated another source (“Blace”), which have two wells, and could give to the system an additional amount of 40 l / s.

Work is underway on the implementation of a chlorine neutralization system at the D. Vidrovan spring, which also increases the system's resilience to potential accident situations.

2.6. Greece (PP11+PP7)

The pilot action of DEYAL involves the development and operation of an integrated information system for the improvement of the Water Safety Planning Mechanism for the water supply system of DEYAL.

The main pilot action goals are:

- report the problems faced during water safety plan (WSP) development and implementation and the measures taken to face them, providing guidance towards the improved multi-hazard management of the water supply system;

- provide the utility’s experience to implement the water safety plan, from theory to practice;

- provide lessons learnt to other water utilities of how to implement an improved water safety plan, to avoid any gaps or weaknesses.

Specific targets of the pilot activity include the following:

- Address all hazards taking into consideration historical data;

- Monitor water quality parameters at water sources, water supply and distribution networks and at water consumption points;

- Hazard identification at water sources, water supply and distribution networks, and water consumption points;

- Assessment of risks and hazards using a risk-hazard assessment matrix;

- Examination of the measures already applied and suggestion of additional measures to ensure good water quality and safety.

The pilot action consists of:

- the development of the WSP for the water supply system of DEYAL,

- the adoption of an information system which supports the WSP development and implementation.

The Water Safety Plan is being developed according to the World Health Organization guidelines and the guidelines provided by the General Secretariat for Natural Environment and Water (former Special Secretariat for Water) from the Greek Ministry of Environment and Energy. It includes 3 phases:

- Phase I: registration of the existing status and preparation of the implementation guide. Duration: 1 month.
- Phase II: application of the WSP. Duration: 10 months.
- Phase III: WSP evaluation. Duration: 2 months.

The specific steps for the development of the WSP are the following:

- Establishment of the WSP team;
- Description of all the stages of the water supply system of DEYAL;
- Identification of all possible hazards for water safety at any stage of the water supply and assessment of the risk;
- Identification and assessment of the existing control measures for the confrontation of the risks;
- Development and implementation of an improved WSP including: (a) critical control points and (b) critical limit values;
- Operational monitoring – Design the monitoring of control measures including: (a) monitoring at the critical control points and (b) corrective actions at the critical control points;
- Assessment of the efficiency of the WSP including: (a) external and internal control of the operational activities – Review of the WSP, (b) Verification of the WSP, and (c) Consumers' satisfaction;
- Preparation of the managerial activities;
- Development of supporting activities;
- Planning periodic revisions of the WSP – Review;
- Review of the WSP after an emergency event.

The information system supports the WSP implementation during all phases. It is used by the contractor with the support of the staff recruited for the project.

3. PA specific IWSP components/hazards

3.1. Italy (PP10+LP)

The analysis developed for flooding hazard assessment and management for the Italian pilot basically concerns the **artificial reservoir of Ridracoli** (Emilia-Romagna region). The study developed in the context of the project activities allowed to: 1) reconstruct the historical flood events entering into the reservoir during the last decade (these floods cannot be directly recorded and need to be estimated); 2) investigate possible management scenario for the identified historical flood waves and the flood characterized by a return period equal to 100 years.

In particular, the second step of the study was addressed to verify: the loss of water resources (i.e. the water volume released through overflow process that is the only release that cannot be directly managed by the authority in charge of the dam management) identifying the initial reservoir condition that allows to minimize the loss; the magnitude of discharge released downstream.

Earthquake

The analysis developed for the earthquake hazard assessment and management for the Italian pilot is focused on the water supply infrastructure managed by Romagna Acque, identified as the water supply system (WSS) connected (among the others) to the Ridracoli dam. In principle, the developed methodological approach can be used for all WSS or Water Distribution Networks (WDN), and to characterize the response of the system to multiple hazards. More specifically, the study developed in the context of the project activities allowed to: 1) identify and compute a set of relevant topological measures for a WSS, providing a basic characterization of the network under 'normal' conditions, and 2) perform a network degradation analysis with respect to random failures induced by earthquakes through the selective removal of either nodes or links (which may represent respectively e.g. tanks/reservoirs and pipes); 3) aggregate and summarize the results using a Bayesian Network as a means to define a pipe ranking which aims to reflect the individual pipe contribution to WDN resilience to single pipe failure after earthquake-induced failure.

The method has been developed with the aim of analyzing the impacts of earthquakes, although it can be used to preliminarily analyze the potential impacts of any 'physical' hazard on the drinking WSS.

Drought

The drinking water supply system connected to the Ridracoli reservoir is a complex system that can be represented as a multi-users (the 7 different delivery areas) – multi-resources (the Ridracoli reservoir, the local sources and the treatment plant *NIP2*). In case of drought events, it is necessary to carefully address the water needs of each delivery area to the existing water resources, suitably balancing the supply from the reservoir and the several local resources.

The decision support system *INOPIA*^{QGIS}, developed by the Water Research Institute with the support of the Civil Protection Department of Italy, allows to assess the vulnerability of a complex WSS to drought events and consequent potential water shortage conditions taking into account different management options (i.e. different schemes for addressing the water needs to the existing resources and consequent supplying from the resources). From this perspective, the tool is able to perform a risk analysis on the system as a whole, but also on the local components of the system (local inability of a given resource to supply the required water and/or local water needs not met)

Accidental pollution

The hazard assessment and management on accidental pollution was developed to target the artificial reservoir of Ridracoli, and three treatment plants, showing a different potabilization scheme, operated by Romagna Acque. The activity was intended to demonstrate the use of innovative parameters for the real-time monitoring of water microbial quality, possibly implementing prediction models and local IWSPs. The quality of Ridracoli waters, differently feeding the potabilization plants, was related to the treatment performances and the overall microbial removal efficiency following the potabilization steps.

3.2. Croatia 1 (PP4)

The specific measures of the pilot site Golubinka which were measured and applicable were related to the seawater intrusions during the adverse weather conditions. During the summer periods and hydrological minimum, the impact of droughts is becoming more intense, and the need for drinking water is increasing due to agriculture production and tourist season. In some parts of this coastal area, the need for water is growing. Pumping large amounts of water for the drinking water supply reduces the amount of the groundwater, which facilitates the penetration of seawater into the aquifer.

3.3. Croatia 2 (PP5)

The conclusions and suggestions which resulted from the hazardous scenarios hydraulic modelling were implemented in the WSP based on the severity of the consequences.

The modelling confirmed the presumed critical WSS components and simulated the consequences in case of their failure.

The four water sources that IVB use, were confirmed as components which all four MUHA hazards impacts severely, and in the model the simulation showed the timeline

of water shortage occurrence. Based on these simulations the adequate measures were defined (water distribution with cisterns) and implemented in the IWSP.
For several other components, when a MUHA hazard occur, the IWSP suggest as a measure for hydraulic model scenario simulation as DSS measure which will optimize the water distribution.

3.4. Slovenia (PP6+PP2)

The specific measures implemented at the PA Kamnik are connected to all components of the water supply system, addressing all hazards as well.

Hazards, specifically addressed in the PA Kamnik are: earthquake, flood, and accidental pollution. They were selected on the basis of historical events in the area and identified vulnerability.

Management of all three addressed hazards benefited from hydraulic model and improved coping capacity. Evaluation of pilot activities aims to propose recommendations relative to the improvement of water safety plans, developed with a support of the MUHA Toolbox, recognizing the connection between the measures implemented within the MUHA project and the Water Safety Plan.

3.5. Montenegro (PP8+PP3)

The measures implemented in PA Nikšić are mostly related to Drought and Accidental pollution, but the provision of water source construction facilities will also affect the increased resilience of the system to earthquakes.

3.6. Greece (PP11+PP7)

The water supply system of DEYAL faces several hazards, namely drought, floods, accidental or intentional pollution, earthquakes, etc. The hazards addressed in the context of MUHA project are included. Conducting the WSP each hazard is examined and assessed for each water supply zone (i.e., zone with the same water quality). One of the most important aspects of the IWSP is that it assesses extreme events, emergency risks and natural disasters. Hazards from the anthropogenic and the physical environment are also assessed.

4. Impact of implemented measures on risk reduction

4.1. Italy (PP10+LP)

Floods

The outcomes of the analysis developed for the Ridracoli dam can allow the manager authority to know which is the initial the water level in the reservoir that would not produce overflow from spillways for the different historical floods and even for the flood wave characterized by a return period equal to 100 years. Moreover, also the initial lake level that would allow a controlled discharge released downstream lower than an identified threshold (assumed equal to 50 m^3/s for the developed analysis) is provided assuring, at the same time, to not cause problems downstream and to contain the loss of water.

The effect of the provided results is assuring maximum water resources volume stored in the reservoir and, at the same time, guaranteeing a safe condition for the downstream territory where no negative impacts are produced by a released discharge lower than 50 m^3/s, as indicated by the data provided by Romagna Acque referring to the discharges released during the historical flood events. The analysis was carried out by considering the middle and bottom outlets closed, no water derived to the drinking water plant and the discharge released only by the free surface spillway, which cannot be measured and controlled directly.

Earthquake

The outcomes of the analysis developed for the Ridracoli WSS can help the water utility better understanding the behaviour of the investigated distribution network when one (or more) elements are damaged by an earthquake event. It can be also used to understand the potential effectiveness of resilience-enhancing measures. It can be therefore used both to support risk management activities, and to support decisions at strategic/planning level. The analysis can be developed irrespective of the hazard characteristics (e.g. magnitude of the earthquake) although it would be more relevant taking into account the seismicity of the investigated site and local issues (e.g. active faults). The expected outcomes and improvements of the adopted approach are:

- To provide quick and synthetic network degradation analysis based on the GT and expert judgement (with the contribution of experts such as researchers and water managers);
- To identify potential vulnerabilities, pipe prioritization and definition of potential resilience-enhancing strategies, mainly with respect to pipe failure as a consequence of natural hazards
  Potential improvements might be related to: i) the inclusion of hazard-related information; ii) the inclusion of hydraulic information (if available); iii) the coupling with hydraulic models; iv) the extension of the approach to water quality issues; v) network degradation analysis with multiple failures.

Drought

INOPIA^{QGIS} is able to simulate different “what if” management scenarios under different precipitation regimes (observed or simulated) for robust risk index estimation and early warning decision support. Moreover, it is possible to test the vulnerability of the WSS to climate scenarios aiming at impact and adaptation studies.

In general the implementation of *INOPIA^{QGIS}* to a generic water supply system is able to:

• Estimating the vulnerability of a WSS to drought events by statistically analysing the occurrence of deficit in relation to the most common meteorological drought indexes (i.e. Standardized Precipitation Index). This allows focusing on the occurrence and intensity of the impacts instead of the hazardous event (rainfall deficit), strongly improving the risk assessment for drought

- As it is possible through *INOPIA*^{QGIS} to simulate different management scenarios (in terms of addressing of the different water user needs to the available resources), the most suitable measures to cope with drought events can be tested in advance
- Using climate scenarios as input allows also to take into account possible future changes of the precipitation and hydrological regime, thus to estimate possible changes in the occurrence, intensity and duration of water shortage events.
- Finally, the user-friendly approach of *INOPIA*^{QGIS} allows to be shared among different stakeholders. This is very important in case of joint exploitation of the same water resource(s) by different types of users (i.e. drinking water, irrigation, hydropower production, environmental needs, etc.). It is worth stressing that although the water safety plans are in charge to the water utilities, the quantitative management of water, in both ordinary and emergency conditions, necessarily involves several actors (both private and institutional) that needs the adoption of shared tools for risk analysis.

Accidental pollution

The near real-time data provided by advanced technologies for microbial community characterization applied to water quality monitoring can allow to promptly assess local and time-series contamination anomalies which may naturally occur at the reservoir and in the raw water, owing to e.g., accidental microbiological contamination episodes, occurrence of microbial hotspots/aggregates, algal blooms, and the spread of potential pathogenic/harmful microbial elements (e.g., fecal indicators, water-borne pathogens, invasive species, antibiotic resistance genes). The manager authority can identify and adapt the location and time for the water withdrawal, thus improving the efficiency of downstream potabilization treatment and reducing the health risks associated with natural contamination sources. Similarly, the advanced microbial characterization can help identifying malfunctioning at each step of the potabilization treatment and the water supply system, thus allowing a targeted technical intervention with a reaction time much shorter than that required by the current cultivation-based microbiological assessments.

4.2. Croatia 1 (PP4)

The implemented measures in the pilot area will lead to improving knowledge in defining the zone of the fresh and saltwater mixing in the catchment area of the Golubinka spring. The determining hydrogeological dynamics of the aquifer as the basis for the water safety plans. In order to define the zone of fresh and salt water mixing in the immediate hinterland of the Golubinka spring, geophysical surveys were carried out by geoelectric tomography on profiles with a length of 950 meters (depth 165 meters) and two transverse profiles 950 meters (depth 170 meters) and 315 meters (affected depth 40 meters). The interpretation of the aquifer in the Golubinka spring catchment area will be contributed by aerial images made by an unmanned aerial vehicle equipped with a thermal camera on the basis of which the discharge zones of underground freshwater sources will be determined. In addition to monthly monitoring of all physico-chemical parameters, trace metal concentrations are also observed on the pilot Golubinka. Accordingly, the obtained monitoring data and dataloggers, the seawater intrusions were recorded.

4.3. Croatia 2 (PP5)

The hydraulic scenario modelling defined the WSS parts which are mostly affected in case of occurrence of one of the MUHA hazard. A set of priority measures where than defined, and several existing protocols were connected so that the maximize the hazardous situation coping efficiency.
In this way it was possible to define which settlements will be without water and in what time. Beside the repairs on the affected WSS component, the modelling gave the answer for an optimal alternative water distribution along with the water distribution with the water cisterns.

4.4. Slovenia (PP6+PP2)

Development of improved coping capacity, with specific focus on the equipment for the civil protection headquarters of the Kamnik Civil protection.

Improved coping capacity of the Kamnik Civil protection was achieved with the upgrade of the communication equipment and headquarters support equipment for the Kamnik Civil protection. This is directly related to the crisis management procedures (which is directly addressed by the standard EN 15975 Part 1 Crisis management (06/2011). The measure is also in line with the module 8 of Water safety plan manual (WHO, 2009), where the water utility is instructed to prepare management procedures, including emergency response plans. Improvement of coping capacity cooperation leads to proper and timely response in case of all hazards anticipated for the water supply. The measure is indirectly also improving an overall structure of the response (internal – water utility, and external – civil protection) by the improvement of operational and communication procedures during the potential water emergency.

Development of the hydraulic model for the Kamnik Water supply system and measurements of discharges in the Water supply system.

Development of the hydraulic model increases the knowledge of the adaptive capacity of the system in case of all hazards. It is also possible to assess the failure scenarios, important for the evaluation of consequences on the service in the case of different failures (critical events).

Measured discharges on the mains of the water supply system are crucial for the calibration of the hydraulic model as well as for the identification of consequences of the incurred risks on the Kamnik water supply system as they are defined by the Improved Water Safety Plan (final stage of the evaluation in the MUHA toolbox - consequences).

Development of the reporting system for the improved understanding of the probabilities of critical events on WSS.

Based upon the analysis of the existing reporting mechanisms and tools (internal, municipality, state), the upgrade of reporting and the analysis of the reported data is part of the MUHA project. With the upgraded reporting and analysis, it is expected that overall understanding of existing risks, as well as their early recognition could be possible. The reporting component is essential as any reported incident, accident or near-miss is also a learning mechanism enabling avoidance of similar incidents in similar realities elsewhere. The reporting framework follows comparable approaches in other infrastructural systems. Significant limitation, relative to the use of the reporting system was also recognized during the MUHA project activities – the legal status of the reported information should be very clear. It should be clearly understood that the information should be primarily used for the identification of probabilities and as a learning tool, avoiding its use for the potential repercussions against water utility.

4.5. Montenegro (PP8+PP3)

By carrying out activities in PA Nikšić, additional quantities of water were obtained. With new quantities of water and additional monitoring of yields at springs, we have improved the capacity of the water supply system and thus increased its resistance to drought.

Only during dry summers, which do not occur each year, the WSS Nikšić water demands exceed the source's capacities. After the inclusion of Blace wells, and possible additional amount of water at Vidrovan source, situation regarding water scarcity will be significantly improved. Therefore, the city is relatively secure in that respect. The main issues affecting this WSS are related to high levels of NRW, and an inadequate WSS concept. The main reason for this situation has been, and still is, a high and uneven pressure regime in the water distribution network. Therefore, a concept alteration has been proposed. WSS Nikšić concept alteration, which will allow lower pressures in all parts of the system, with good zoning, and thus better water loss management in the WSS. In addition, the springs will be used in an optimal way (lower electricity consumption), gravity will be established as the dominant mode of flow in the WSS (followed by a stable pressure regime), tank space will be activated, and the reasons for shortages in any part of the WSS will be removed.

By obtaining additional quantities of water at the springs, the possibility of including alternative sources in the system in case of accidental pollution was created, and in this way, we improved the capacity of the system. With the planned installation of a chlorine neutralization system, we have reduced the possibility of an accident.

With the interventions on the construction facilities of the water source that we have planned in the near future, we will reduce the risks of damage due to potential earthquakes.

Other described measures, which decrease possibilities of certain hazard events, will take place in the future in line with available funds, and as well made priorities by WUC Nikšić.

4.6. Greece (PP11+PP7)

The IWSP includes measures that have to be taken in order to reduce the risks in the identified critical control points.

Initially, the development of the WSP is based on the identification of the water supply zones, zones where the water quality can be assumed the same. Water supply zones can be large or not. For example, there are 11 water supply zones in the pilot area. One of them supply with water the whole city of Larissa and some municipal districts (WSZ1). The other supply zones supply with water municipal districts and are considered as small water zones (Table 1).

Table 1. Water volume supplied for each water supply zone

Water Supply Zone (WSZ)	Water volume supplied (m^3/day)
WSZ1	29,306.2
WSZ2	398.4
WSZ3	878.6
WSZ4	1,577.0
WSZ5	797.4
WSZ6	124.8
WSZ7	496.0
WSZ8	73.8
WSZ9	67.2
WSZ10	66.4
WSZ11	102.4

The components of the water supply system of DEYAL are: water supply from groundwater bodies, water treatment facilities, water storage and distribution/consumption. To assess the risks in each water supply system component, the necessary data are:

- At the water supply source: the geological background, meteorological data, land use, hydrological data (quantity and quality of the groundwater, flood risk zones), water quality data
- During water treatment: accidental problems (e.g., power supply interruptions, disinfection failure), flood risks, lack of protection, sabotage, fire/explosion
- Storage: status of the infrastructure, lack of protection/access, earthquake
- Distribution and consumption: water quality (physicochemical and microbiological parameters and radioactivity), flood risk, earthquake, intentional contamination.

For the elaboration of the WSP and in order to collect all data, procedures and documents are designed and developed. Specifically, the procedures include:

- Procedure for the documents' management of the WSP: The purpose of the procedure is to ensure that all documents and data used during the implementation of the WSP are issued, approved, reviewed, and kept in a controlled manner
- Procedure for the files' management of the WSP: The purpose of the procedure is to determine the method followed for the identification, collection, classification, archiving, storage, access, preservation, and destruction of WSP files.
- Procedure for the water samplings: The purpose of the procedure is to determine the method followed for water sampling, in order to perform laboratory tests.

- Procedure for the calibration of measuring instruments: The purpose of the procedure is to determine the method of calibration of the measuring instruments so that they have constant stability in their performance and accuracy.
- Procedure for cleaning: The purpose of procedure is to determine the method for cleaning the surfaces in contact with water and the installation in general, in order to avoid contamination of drinking water for distribution.

The documents include:

- WSP documents
- Documents for the production of water
- Documents for instruments and tools
- Documents for each water supply phase.

After the risk assessment phase, the critical control points are identified. In these points further measures are proposed, including monitoring points, monitoring parameters, and frequency of monitoring. The whole process results in the reduction or all risks, as proactive measures are taken.

However, it is crucial to investigate all proposed measures in order to verify their economic performance and their viability. In this way there will be no waste of financial, human and other resources. It is also crucial to make sure that the new measures which will be adopted and introduced will not cause any additional hazards to the water supply system.

The use of the integrated information system results in the improvement of the Water Safety Planning Mechanism in the pilot area. In detail, the information system includes the infrastructure (water sources, treatment plants, distribution and water supply networks) for each water supply zone, providing also their coordinates. At each zone, data related to hydrology, hydrogeology, climatic characteristics, and human activities are identified and registered. The hazards are identified and a risk analysis is elaborated based on the hazard probability of occurrence and the severity of consequences, following a risk assessment matrix. All measures to cope with each identified hazard are identified. The information system supports the determination of a monitoring system in the critical control points (identified in a previous step) along with the monitoring parameters. The information system has the ability to present all the points affected by a potential hazard, allowing the user to choose the appropriate measure. The user identifies the roles of each person involved in the development of the IWSP. Thus, using the information system the responsibilities of everyone involved are assigned, for example the person who is responsible for the sampling and analysis of water, the frequency of the sampling process, etc. The system uses alerts for this purpose and at the same time the supervisor checks the progress.

The operational characteristics of the information tool are presented below:

- Description of the water production and distribution system
  - Water sources – maps – geological data
  - Water treatment systems – disinfection
  - Distribution system (tanks, pumping stations, network)
- Identification of hazards and risks assessment
  - Identification of hazards
  - Identification of hazardous events
  - Risks assessment

- Identification of control and mitigation measures
  - Identification of the procedures for the minimization of hazards
  - Actions for the reduction of risks
- Monitoring
  - Identification of monitoring parameters
  - Determination of allowable limits
  - Drafting elaboration plan
- Management procedures
  - Identification of corrective actions to address the incidents
  - Identification of emergency actions (natural disasters, public health incidents)
- Supporting programs
  - Staff training, maintenance program, standards
- Documentation
- Verification, validation, improvement
  - Measurement of the efficiency of the plan
  - Review of control measures and chemical and microbiological tests

5. Self-validation of the applied measure related to the IWSP.

5.1. Italy (PP10+LP)

Floods

The result of the study can give information to set the optimal initial condition of lake level when the weather forecasts indicate that a significant event is coming to affect the reservoir. Clearly, the expected input (provided by models) is affected by uncertainty that should be estimated and used in the evaluation of dam management actions, i.e. to assess the possible impacts of the initial lake level.

Two main targets are of interest: safe water volume and control discharge released downstream to not cause adverse impacts. The value assumed for the maximum discharge that can be released downstream, 50 m3/s, was derived from the data provided by Romagna Acque referring to the discharges released during the historical flood events. Actually, a flood risk study downstream the dam is currently in progress and the results could modify the maximum reference discharge. This is a key information to be used for the dam outlet systems management in real-time (i.e during the occurrence of the flood event).

Earthquake

The proposed methodology can give valuable information to better understand WSS resilience (mainly with respect to earthquakes) before the occurrence of an event, ultimately helping to identify key elements for system operation, estimating the potential impacts of pipe/node removal and the impact of different resilience-enhancing measures. It could be also used for a very basic assessment of the response of the WSS to stress in the emergency management phase.

Clearly, the proposed methodology aims to be as simple as possible, and does not require detailed network information (e.g. pipe materials or age) as well as data on hydraulic operating conditions (and flow characteristics under stress). This is both a strength of the approach (as it can be run based only on topological information) and a weak point, as the changes in the hydraulic regime cannot be fully described based on topological properties.

Validation of the model is being performed based on expert knowledge. The availability of hydraulic models could significantly improve the quality of model validation and calibration, based on scenario analysis.

Drought

INOPIA^{QGIS} has been customized to the water supply system of Ridracoli and the hindcast run showed the ability to reproduce the observations in terms of time series of reservoir's level and past periods of water shortages. However, it is worth stressing that the pilot of Ridracoli has been used as benchmark for the development of *INOPIA^{QGIS}*, as Romagna Acque already has a specific and very detailed model provided by the University of Bologna able to support the management of the whole system. This implied that the management options numerically tested through INOPIA, are actually implemented in the reality during drought events. On the other hand, the main goal of INOPIA is to provide a general tool easily customizable to a given water supply system.

Finally, it is worth noting that through the proposed tool is possible to test also different topological schemes, for example simulating a not existing connection to resources or water supply system currently not connected. In fact, one of the most effective long term measures to cope with drought and water scarcity is the diversification of the water resources both in number (several sources supplying the same user) and in typology (i.e. surface and ground water, springs, treatment plants, etc.)

Accidental pollution

The proposed approach for assessing the occurrence and consequences of accidental pollution events can provide water quality data nearly in real-time, through the use of harmonized analytical protocols available in the current scientific literature. The procedural workflows of the technologies herein applied for water microbial monitoring comprise major steps and provide different types of results. The overall time-to-results can vary from minutes to days, largely relying on user-dependent manual operations and technological solutions for automation.

However, the standardization process of cultivation-independent methods is in progress and a careful analytical effort is still required to cross-validate the results from early-warning techniques with those obtained by the consolidated cultivation-based approaches included in current water quality regulations. The use of alternate water quality data to implement the IWSP will be also critically dependent on the local availability of suitable technologies and personnel to be specifically dedicated to the validation process.

5.2. Croatia 1 (PP4)

Applied measures on the pilot site will improve the better understanding of the catchment area and will lead to the successful implementation of the improved water safety plans. In order for the validation to be more successful, a certain period is needed. The self-validation of the applied measures will be improved with the finalization version of the toolkit and a lot of time will be saved in the process of implementing the improved water safety plans.

5.3. Croatia 2 (PP5)

The applied PA measures resulted in better risk management analysis (based on the exact hydraulic modelling and past experiences) which made possible to develop the IWSP and integrate all the risk reduction measures.

The hydraulic model itself gives the possibility to continuously adopt and check new risk management measures and if necessary to change the WSP.

Although the validation need some time, at this moment it can be concluded that the taken measures fulfilled the PA goals.

The WSP is not fully integrated, as there is a legislative procedure where the WSP has to be approved by the Croatian Public Health Institute, but it is expected that the process will finish by September 2022.

5.4. Slovenia (PP6+PP2)

All implemented activities are important step to preparation of improved water safety plan.

Improved coping capacity cooperation can always be further improved as it was recognized also in the table top exercise held in Kamnik. With the developed procedures based upon the standard ICS (NIMS Incident Command System) protocols overall improved response in the case of any hazard could be expected. Further improvement would also be connected with user-friendly tools for managing the different headquarters and daily reports.

Hydraulic model increases the knowledge of the adaptive capacity of the system in case of all hazards, but the model can always be upgraded and improved with availability of new data (especially measured data of the system SCADA). This also means that some information regarding the adaptive capacity could change significantly.

The motivation of developed reporting system for the improved understanding of the probabilities of critical events on WSS is (1) to early identify the causes of the event and the causes of it and (2) to take measures to prevent the event from recurring under comparable conditions (systematic learning at events).

This is also the basis for probabilistic event analysis and risk analysis. The purpose of reporting and probabilistic evaluation is not punishment of water supply system operators, but significantly improved risk management process. We recognize a need to establish national incident and disaster systems, to transpose Directive 2019/1937 and to establish an international exchange of probability data on events occurring on the water supply systems. Unfortunately, the standards defining the risk management and asset management are not supported in a way that would enable the collaborative exchange of the probability statistics of incidents, accidents and near-misses, while on the other hand EU is addressing the importance of similar reporting also by the EU Whistleblower protection directive (2019/1937). We recognize this gap and necessity to systematically address it.

5.5. Montenegro (PP8+PP3)

All measures taken are aimed at better risk management. WSP has not yet been implemented in the water supply system of Nikšić, so the validation of measures has not been performed.

5.6. Greece (PP11+PP7)

The development of the IWSP for the pilot case showed that cooperation among the various departments of the water utility is necessary to elaborate the WSP, namely the networks' management department, the environmental department, etc. It is apparent that a common registry to gather all the data for the water supply and distribution system is necessary and it has to be shared among all departments in the water utility. Continuous funding is necessary for the implementation of the proposed measures, and human resources are needed for the monitoring of the WSP. The dedication of the water utility managers and staff is a prerequisite for implementing the WSP continuously.

6. Recommendations and recognized limitations

6.1. Italy (PP10+LP)

Floods

The methodology used for the flooding impact investigation for Ridracoli pilot is transferable and potentially applicable for all artificial reservoirs once the required data and information are available. One key information is the maximum discharge that can be released downstream. This is strictly required to optimize the management of the outlet systems. Moreover, the effect of the implementation of indications derived from the method application in real-time is actually dependent on the availability of: 1) recording of incoming flows; 2) recording of lake level variation. While the second data is usually available, the first one is not typically provided requiring the use of hydrological methods that provide uncertain estimates.

Earthquake

The main advantage of the methodology used is the need for very basic information about the WSS under investigation. It can be therefore easily transferred and replicated to other WSS, provided that the required data and information are available. The availability of additional information (e.g. pipe diameters and length) and hydraulic data can be also taken into account and improve the quality of model results.

The information provided is mainly meant to be used for a simplified scenario analysis and for general assessment of WDN resilience and strategic planning of interventions. More detailed hydraulic models would be needed for a final analysis of WDN response to extreme events and for the assessment of measures effectiveness, ultimately supporting the decision-making processes.

Drought

The tool *INOPIA^{QGIS}* is still in testing phase (although almost finalized) and it is not easy to give recommendations and indicate possible limitations. Generally speaking the following comments can be done:

- A risk analysis for drought events firstly aims at assessing the link between the precipitation regime (represented by indexes of rainfall deficit and/or temperature anomaly) and impacts, that is periods during which all or part of the water needs are not or hardly met. In a water safety plan such a link (possibly through quantitative analysis) has to be carefully assessed, in order to identify in advance the most suitable management options in both ordinary and emergency conditions. As a consequence, it is very important to adopt modelling approaches able to account for the entire chain of involved processes, from climate (precipitation) to users through the withdrawals and distribution infrastructure. It is worth stressing that the same precipitation deficit (possibly represented by standardized indexes) can result in very different impacts (i.e. ability of the system to meet the connected water needs) depending on several factors.
- Some water supply systems are multi-purposes (i.e. human consumption, irrigation, industries, hydropower production, etc.), resulting in case of drought events in a conflicting use of the shared resources. In these contexts, it is very important that all the potentially involved actors share:
  - Common dataset representing the climate regime over the same reference period; data should be also represented through common and recognized indexes;
  - Common dataset representing the water needs of each user (possibly at monthly scale)
  - Common indexes representing the current and future status of the available water resources
  - Common tools to assess the impact of precipitation deficit on the ability of the system to meet the connected water needs

The tool necessitates of several years (20-30) of both precipitation and discharge data (i.e. to calibrate the inflow-outflow model named SPI-Q, or to calibrate the spring module). Such a depth of time series (especially for discharge) is not always available and can constitute a strong limitation for the use of *INOPIA*^{QGIS}

Accidental pollution

The proposed methodological approach is suitable beyond the settings herein tested for different locations and plant schemes. However, the newly generated data cannot be directly used for risk assessment and evaluations associated with the identification of accidental pollution events. A key issue in view of implementing predictive models and IWSPs will be the availability of historical data for a solid evaluation of the variation patterns observed either for short or long-term periods. This will necessarily include the cross-calibration of newly-generated data with those obtained by the traditional methodological approach, as applied locally.

6.2. Croatia 1 (PP4)

The planned investigations have been done during the project implementation. It is important to note that the time component is important and needs to be taken into consideration.

6.3. Croatia 2 (PP5)

Based on our experience we think that a hydraulic model as one of the crucial measures/tools which leads toward developing of a reliable WSP, especially in the context of analysing the consequences of catastrophic hazard situation like MUHA hazards, but as well other situations that impacts the water distribution. The hydraulic scenario is probably the best starting point for developing optimal measures and decisions in order to reduce the risk.
The transferability of the model itself is not possible to other WU but as a general approach in the making of the IWSP we think that a hydraulic model of the WSS is a necessity.

6.4. Slovenia (PP6+PP2)

Improved coping capacity cooperation based upon the standard ICS protocols (or similar protocols) could be recognized as transferable to any WSS, but with limitation if the national protocols in specific country are not compliant to them.

Development of hydraulic model of WSS could be recognized as transferable to any WSS, if there is no existing hydraulic model. Development of a WSS hydraulic model is recognized in many countries also as a first step in the risk reduction process, strongly supporting also the NRW (non-rewenue water) reduction and water loss reduction processes.

The MUHA project developed reporting system for the improved understanding of the probabilities of critical events on WSS would be of great help to all WSS, but unfortunately there is no existing national incident and disaster systems, which would enable an (international) exchange of probability data on events occurring on the water supply systems. This component of the MUHA project is recognized as one of the important developments, which will be also endorsed in the strategic framing of the conclusions of the MUHA project.

6.5. Montenegro (PP8+PP3)

In Montenegro, there are no developed systems at the state level for monitoring, identification and collection of data on the occurrence of dangerous events that affect the water supply system.

The development of a hydraulic model of a water supply system can be a good basis for the process of identification and risk reduction. Doo "Vodovod I kanalizacija" Nikšić, in cooperation with the Institute for Water Management "Jaroslav Černi" PP 3, developed a hydraulic model of the water supply system for the purpose of NRV management and system optimization.

Generally, water scarcity occurs due to the low water source capacities when water demand surpasses it. However, water shortages also occur when water source capacities exceed water demands, due to the high levels of losses in the net, or an inadequate water supply system concept. By the way, in the case of WSS Nikšić, these are the main reasons.

Measures against the permanent Accidental pollution should be applied whenever is possible. Measures against the potential Accidental pollution should be applied whenever they are cheap. For those more expensive potential AP, certain technoeconomic calculation should be done before the measure is applied.

6.6. Greece (PP11+PP7)

It is evident from the data available in D.T3.2.1 that there is an increasing interest in elaborating WSPs in Greece, reflecting the increase concern of water operators in water safety issues. The water operators get more familiar to the legislative requirements (such as the New Drinking Water Directive 2020/2184) and use available financial tools to get funding under the National Strategic Reference Framework and state funds, such as the Programme "Philodimos II", priority axis: Local development and protection of the environment and Regional Operational Programmes. Out of the 43 water utilities which have already elaborated their WSP, or they are elaborating it currently, only 2 have used own financial resources. The remaining 41 water utilities received funding from the above-mentioned programmes.

During the preparation of the WSP, many data is required concerning many sub-sectors of the utility. Depending on the size of the water utility, data availability is a major concern.

One common problem is the continuous implementation and monitoring of the WSP after the completion of the study. To achieve this, the WSP should be integrated into the daily operation of the utility and become an integral part of it. This presupposes the cooperation of all water managers from different sectors of the utility. Elaborating the WSP is a complex process, requiring many parameters. Thus, an extensive analysis is required, both for the status of the water supply zones but also for the practices applied at national level. This creates difficulties, requiring combined work and data from many sub-sectors of the utility.

For a successful WSP, good cooperation of all stakeholders in combination with the establishment of a fully trained and flexible WSP team is required. Also, the development of a fully organized set of procedures is necessary.

In addition, as WSP is a dynamic system, it must always be fully relevant to the hazards threatening water, the technological developments related to the equipment, the current legislation, as well as potential hazards that may cause threat to public health.

Adequate funding for the elaboration and monitoring WSPs is an important parameter of its success but also of its difficulty, a fact that must be considered during the meetings of the WSP teams.

It is of great importance the continuous education / training of the members of the WSP team, but also in general, of the staff of the water utility, both in WSP issues and in drinking water safety, as well as in general issues of awareness of proper use of drinking water.

In case the existing staff of the utility is limited and is not sufficient for the satisfactory staffing of the WSP team, it is necessary to seek external partners, to ensure the correct and effective implementation of the WSP.

Finally, it is recommended that internal and external auditing will ensure the successful implementation of WSPs.