Combined innovative technologies for ensuring water safety in utilities: The city of Thessaloniki case study

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ABSTRACT

Innovative technologies such as monitoring the quality of surface water aquifers with satellite images, applying UAV (Unmanned Aerial Vehicle) and drone technology for a variety of operations, water quality measurements with improved techniques along with IoT (Internet of Things) and ICT (Information and Communication Technologies), can provide sufficient data for enhancing water safety in urban water utilities. Specifically, these data could be an effective tool for improving risk assessment process and management of water supply systems. Nevertheless, till now, there is a relative lack of published works that validate the efficiency of combing these technologies on water safety processes by incorporating most of them with a systematic way and during real working conditions in water utilities. This work aims to present the preliminary design concept of a platform that embraces innovating water safety technologies planned to be applied to Thessaloniki's Water Supply and Sewerage Co. S.A Standard Operating Procedures (SOP).

Keywords

Water safety, satellite images, drones, risk assessment.

INTRODUCTION

As water is a valuable and indispensable ingredient of life, drinking water's safety is extremely important both for ensuring consumers' health and for the proper functioning of communities and the ecosystem. The implementation of new technologies aiming to ensure that water quality and monitoring in water utilities lies in compliance with current EU and national standards, is a very promising tool for enhancing risk assessment processes and management of water supply systems. Some of the most promising technologies are briefly described next:

Tools like satellite imaging can offer valuable data for surface water quality monitoring of large aquifers that are used to supply drinking water in communities. Several studies exemplified how satellite data can be used for water quality monitoring in inland water bodies, particularly for algal bloom monitoring (Flores-Anderson et al. 2020).

The developments in unmanned aerial vehicle (UAV) technology provide new opportunities to collect water samples and to conduct in situ water quality measurements (Koparan, 2020). Compared to traditional water quality monitoring methods, UAVs are relatively inexpensive and they can be used for water quality monitoring in water bodies that are inaccessible with boats or dangerous to field personnel (Koparan et al. 2018).

The recent development of big data processing technology in data analysis, such as deep learning, enables efficient analysis of a large amount of data with given time. A large amount of data collected from in situ field monitoring using sensing technology can be more efficiently used for the management of water quality when it is combined with advanced data analysis techniques, such as deep learning (Park et al. 2020). As Park et al. (2020) notes: "In the future, the integration of ICT into environmental technologies is inevitable and would provide promising solutions for the advanced management and quality monitoring of water resources".

Cost effective sensors combined with Internet of Things brings a paradigm shift for smart water management, supported by artificial intelligence and big data analytics (Jenny et al. 2020). Despite an increased application of numerical tools by water utilities, the digital transformation of the water sector is lagging behind other sectors, such as energy (Park et al. 2020).

Despite the recognized advantages of new technologies in water sector, there is a relevant lack of available works in literature that provide evidence on the benefits or/and the challenges of each one of these technologies during SOP. Furthermore, to the best author's knowledge there is no evidence related to the synergy of the above technologies, e.g. on a basis of a digital platform. Aim of this work is to present the preliminary design parameters of a platform that could be able to embrace innovating water safety technologies as applied on the future Water Safety Plan (WSP) of Thessaloniki's Water Supply and Sewerage Co. S.A (EYATH SA). These technologies are presented at the forthcoming chapter and are expected to be developed, applied and assessed within the next three years under four projects; i.e. aqua3S, PathoCERT and WQeMs (which are co-funded by the European Commission projects) and KILIDA (which is funded and initiated by EYATH SA).

After the completion of the projects described in this work and their implementation into the company's SOP, we expect to enhance the already existing mechanisms for prevention, response and recovery, before, during and after pollution incidents that can potentially pose risk to water safety. Thus we anticipate to strengthen our monitoring tools and procedures and to attain early detection mechanisms for the establishment of effective mitigation strategies towards community resilience.

DESCRIPTION OF TECHNOLOGIES FRAMEWORK

Description of the Case Study

The architecture of the case study where the technologies will be applied, is schematically presented in ***Figure 1***. EYATH SA is the key operator for providing drinking water and sewerage services to the wider area of Thessaloniki, the second largest city of Greece (1,050,000 inhabitants). Water supply resources originate from both surface (Aliakmon River – Polyphytos artificial lake- reservoir) and underground (Aravissos Natural springs and boreholes) water. The case study focuses on monitoring the area that includes Polyphytos Reservoir and the 70 km-long channel that transports water from Aliakmonas River to the Thessaloniki Water Treatment Plant (TWTP). This is an open-flow channel for the first 50 km and then it flows in an underground pipeline towards the TWTP. At present, 60% of the drinking water supply of the city of Thessaloniki originates from Aliakmon River after being treated at the TWTP. However, in the near future, this proportion will increase as a result of the expansion of the capacity of TWTP, possibly leading to the expansion of the company's drinking water network in more suburbs of the city; thus, Aliakmon River will become the main drinking water resource.

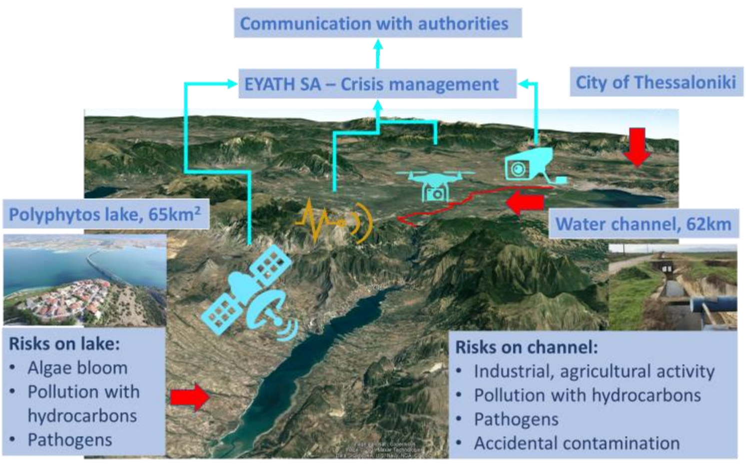

***Figure 1.* Description of the case study indicating the potential risks and the forecasted tools to be used in order to mitigate the risks (i.e. satellite images, network of sensors, drones-UAVs and cameras).**

These resources are situated in an extended area characterized by a wide variety of land uses and development activities (e.g. agriculture, industry, quarry facilities, livestock farms as well as other potential unknown and unauthorized activities) exerting stresses and several potential risks to the water quality/safety of the whole drinking network. Due to that variety of the land uses, an accidental (or deliberate) contamination of the surface water is possible to happen as it has been shown in the past. Thus, it is of utmost importance to be able to employ flexible and effective monitoring tools based on a synergy of innovative technologies that have been proven efficient in confronting water safety related issues by ensuring real-time management of data along with communication tools, to detect such events and timely respond accordingly. Moreover, a rapid decision support system that provides real-time data collection, exploitation and analysis of this information would be of crucial importance to take all the emergency actions and control measures needed to stop further spread of threat.

Description of the Research Projects and their Interrelation Framework

The research projects, the technologies that are related with them and their synergy with the case study architecture are schematically presented in ***Figure 2***. These projects are currently under development, are planned to be completed within the next three years and after their completion they are expected to be incorporated into the company's processes. A brief description of these projects follows:

- ***aqua3S***, an H2020 research project, is expected to provide a digital platform where processed satellite images, cameras on UAVs, Total Organic Carbon (TOC) analyser and other online sensors (Refractive Index sensor, ammonium and turbidity sensors etc.), data sets of anthropogenic uses and company's legacy systems will be appropriately fine-tuned to detect any hazard that could prompt potential risk for the TWTP. Moreover, in case of emergency, a communication standardized protocol will ensure efficient communication and coordination among the responsible Authorities to mitigate the risk. This is the more mature project of all four, approaching at the half of its total duration. Some key user requirements identified by the company to be incorporated in the aqua3S platform are, amongst others: i) the pollution detection from all the above mentioned tools supported by sophisticated data acquisition modules ii) the warnings' generation, iii) a real time visual analytics module that will enable the visualization of all available data and warnings on a dynamic GIS interface, iv) the capacity of modeling of the pollutant diffusion on the water surface, upstream TWTP, v) the development of crisis management scenarios for specific case studies, vi) a crisis classification and decision support tool etc.
- ***KILIDA*** is a project funded and initiated by EYATH that aims to provide an early warning system for the detection of hydrocarbons on the surface of Polyphytos Reservoir. The data are provided by analyzing satellite images with applying deep learning tools. A key requirement for the company is the establishment of an automatic and validated procedure that will detect and analyse available satellite data in early time to detect hydrocarbons' pollution at the reservoir, prior to its appearance at the inlet of the TWTP. This can offer several days of response time to the operators of the treatment plant in order to act and take proper measures according to each potential pollution event.
- ***WQeMS*** is an H2020 research project, which is designed to enhance the experience and technical knowledge of exploiting Copernicus EMS, reinforcing the company's technological assets for safeguarding drinking water treatment and supply. Moreover, ***WQeMS***, is expected to examine several physicochemical parameters (e.g. nitrite, nitrate, total N, color, turbidity and phenomena (e.g. phytoplankton blooms) that affect water quality in Polyphytos Reservoir. The basic requirement of EYATH SA as a user of the WQeMS platform is the satellite monitoring of the occurrence, extent and duration of such events at the reservoir in order to: i) strengthen monitoring efforts of this remote and crucial water resource ii) attain early detection for the establishment of effective mitigation strategies, iii) facilitate decision making in the case of pollution events.
- ***PathoCERT*** is an H2020 research project, that aims to investigate the use of technological tools (i.e. wearable or/and portable sensors under development) as to improve the safety and response capabilities of first responders during a flood incident where the river has been contaminated. In addition, the company will investigate the PathoCERT tools at the case of an extreme weather event that will cause the intrusion of pathogen contaminated water in the city's external water distribution system. The basic key requirement for EYATH is to obtain access to novel, rapid pathogen detection methods that will consist of portable and easy to use sensors which will provide reliable and fast results (within the hour) in order to respond fast and safeguard the quality of drinking water supply.

At the moment the company's SOP to monitor surface water and drinking water quality rely mostly on frequent sampling and daily laboratory analysis of multiple physicochemical parameters and several microbiological parameters, in accordance with the European and National water quality standards according to EU Directive 2015/1787, as well as with the World Health Organization standards and ISO 17025 general requirements for the competence of testing and calibration laboratories. There is also a quality monitoring network of installed sensors (physicochemical and biological) providing in situ measurements, upstream and inside the TWTP as well at the drinking water supply network. Procedures of risk assessment are currently based mostly on these quality monitoring mechanisms. At the case of an alert regarding water pollution event, there are specific procedures of communication with the competent monitoring and respond authorities as well as several control & action procedures which are followed by the operators of the TWTP and of the water supply networks. However, there are yet no standardized respond protocols that are officially established within the company.

After completion, each one of the above research projects is expected to provide tools that will be integrated into the company's ongoing WSP as well as valuable technological knowledge to enhance its daily operational routines. These technological results are expected to also bring the possibility for improvements regarding time and manpower demands during custom operational procedures as well as in emergency events. However, the co-operation among these tools, their validation and integration into the company's SOP would be a real challenging task.

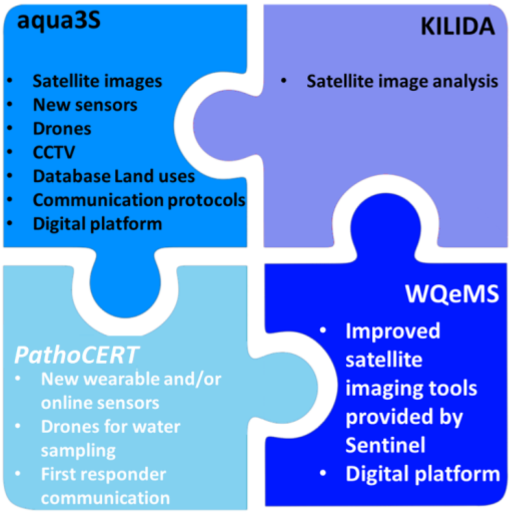

Figure 2. Schematic description of the four projects and their relevant indicative technological tools.

Anticipated Outcome for Company

The technological tools of the so far described projects are expected to be combined with the legacy systems of EYATH SA and to provide necessary data for an integrated risk assessment and an in-depth study to highlight the vulnerabilities in water safety and security. The main reason that the technologies described in this work have not yet been adopted in the company's SOP is the fact that they are relatively new and there is still no experience on water companies' systems integration. There is a high expectation that a series of appropriate mitigation measures and actions will be defined (concerning water resources monitoring methods, communication procedures amongst the first responders, information harvesting methods to exploit social media etc.). This systematic approach will bring out the general rules and procedures to be integrated into a framework of a solid standardized methodology.

Moreover, EYATH SA is currently in the process of developing its Water Safety Plan (WSP), in accordance with the Drinking Water Directive (Commission Directive (EU) 2015/1787 of 6 October 2015 amending Annexes II and III to Council Directive 98/83/EC on the quality of water intended for human consumption, which has been very recently recasted by Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020) with a holistic Risk Based approach within the whole water system it manages. The described projects are anticipated to reinforce these efforts towards the direction of deploying an integrated WSP. To this direction the main "step-wise" objective of EYATH S.A. is to develop and implicate its WSP while being a part of a wider community of European authorities who can standardize safety and security within the Water Sector. ***Figure 3*** schematically presents how the so far described tools could be integrated into the future company's WSP.

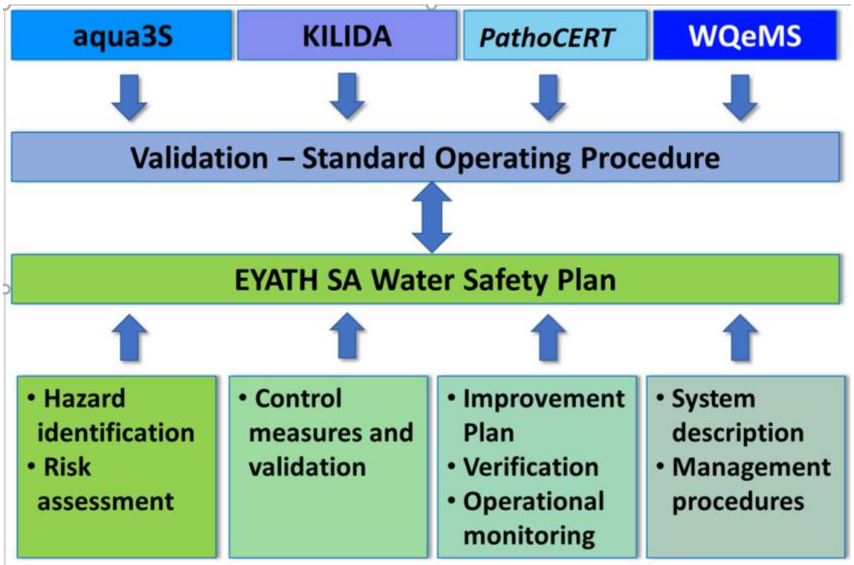

Figure 3. Schematic description presenting how the research projects presented in this work will contribute to company's Water Safety Plan.

The aqua3s project will act complementary and supportively to the forthcoming WSP by providing preliminary yet integrated information concerning the interplay between the company's legacy systems and the new technologies for water quality monitoring in an extended area of our major water source. The PathoCERT project will contribute to the implementation and evaluation of new technologies and practices towards pathogen contamination monitoring and early warning during possible pollution incidents. The role of KILIDA and WQeMS projects is orientated towards the fine tuning of the so-far available satellite tools regarding the surface water quality monitoring of large aquifers.

However, the benefits after the project's completion and integration into company's SOP should be measurable by a quantitative way using benchmarking tools. The measured factors should include parameters such as:

- impact on highlighting the best combination of existing online instrumentation with the new tools
- water resources monitoring methods
- influence of the mitigation measures and actions on company's SOP
- improvement of internal communication in the utility organization, external communication among the stakeholders and communication procedures amongst the first responders
- formatting general rules and procedures to integrate them into a framework of a standardized methodology.

CONCLUSION

The projects described in this work are expected to provide essential data that are needed for an integrated risk assessment and an in-depth study of vulnerabilities in water safety and security. These technological tools developed during the research programs of EYATH SA, taking into consideration both the instrumentation applied and the potential standardization of first response procedures, are expected to contribute to the substantial improvement in safety and security of the drinking water supply of the greater metropolitan area of Thessaloniki. Under this overall risk-based approach, the already complying water supply of the city will become more resilient to unexpected external threats.

ACKNOWLEDGMENTS

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