Water Safety Plans by Utilities: A Review of Research on Implementation

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ABSTRACT

Water supply is essential to public health, quality of life, environmental protection, economic activity, and sustainable development. In this context, it is imperative to assure the continuous improvement of all processes and practices conducive to guarantee water quality and safety. Water Safety Plans (WSPs) by water utilities are an important public policy tool to accomplish these goals. This manuscript reviews the international evidence of the adoption and implementation of water safety planning and reports the current situation in Portugal, as part of the necessary adjustment of the national legal framework to the publication of the Directive (EU) 2015/1787, October 6th, on water quality for human consumption. The aim is to draw lessons from several successful WSP experiments around the world and extract lessons from these cases when drafting new legislation in Portugal and elsewhere. Findings suggest there are four critical dimensions and key elements of success in developing and implementing WSPs: leadership commitment, technical knowledge, governance, and interagency collaboration.

Key Words – Drinking Water Quality; Risk Assessment; Water Safety Plans; Water Utilities

1. Introduction

Water supply is essential to public health, quality of life, environmental protection, economic activity, and sustainable development. Typically, water supply is a service provided by natural monopolies regulated by states to conform to several principles, namely universality, continuity, efficiency, equity in pricing, and adequacy in quantity and quality (ERSAR, 2017).

In this context, it is imperative to design and implement all water safety requirements and use the most efficient and effective methods to achieve the continuous improvement of water quality. The development of technical knowledge and growing concerns about public health and the environment have combined and contributed to positive recent developments in the water sector in many countries (WHO, 2011).

Water Safety Plans (WSPs) are an important public policy tool in this scenario, as it is possible to observe the existence of successful experiments documented in several case studies around the world. This review aims to contribute to a better understanding of this tool in the context of the water policy sector by discussing the methodology proposed by the World Health Organization (WHO) for the development and implementation of WSPs. We draw on the lessons learned from case studies in the literature to suggest four common dimensions: 1) the systematic identification of risks and the definition and formalization of procedures and activities to minimize/mitigate them; 2) a focus on monitoring and reporting, improved document management and increased technical understanding of the water supply system as a whole; 3) external communication, translated into an increase in stakeholder satisfaction, especially end users, as well as the improvement of internal communication in the utility organization; and, 4) the involvement of working teams, commitment of management bodies and interagency collaboration. All these aspects are to be considered when drafting new legislation concerning water safety.

In this paper, we review the international experience with water safety planning, and investigate and report the case of the Portuguese water sector. Following the transposition of the Directive (EU) 2015/1787, October 6th, on water quality for human consumption into the national legal framework, the expectation is that the legislation will require the mandatory implementation of WSPs and/or risk assessment procedures by all Portuguese water utilities. The description of the case is preceded by the characterization of the water sector and water policy in Portugal. This case description contributes to an improved understanding of the national circumstances and the country's standing in this new paradigm of risk management in water supply. The strategic approach to the implementation of water safety planning at the national level should allow policymakers, and especially water utility management bodies, to develop a more effective risk assessment process and management of water supply systems.

The lessons learned and the recommendations gathered from this study, will surely be of use to other countries that, like Portugal, are still in the process of implementing this risk assessment methodology. This methodology is expected to constitute a future mandatory requirement for all water utilities, in Europe and worldwide.

The paper proceeds as follows. The second section provides an historical background of the water safety policy problem. Next, we review the empirical literature on water safety planning by separately focusing on developed and developing countries and identifying the main factors affecting implementation. The fourth section presents a description of the water sector in Portugal and provides an illustration of the introduction of WSPs as the initial response of water utilities to European and national level legislation. Section five proposes a set of recommendations and section six concludes and suggests avenues for future research.

2. Background

Ensuring the quality of drinking water from a public water supply system is an essential component of public health policies (Vieira and Morais, 2005), as well as of a wide range of environmental policies.

Until the early twentieth century, drinking water quality was assessed primarily through its organoleptic characteristics. However, due to the inherent unreliability of this process, parametric rules were implemented to secure water intended for human consumption. It is in this context that technical and legal means have been developed to ensure the disinfection of water in public supply systems. The control of diseases caused by microbiological contamination transmitted by water was improved in a large scale (Vieira and Morais, 2005).

In 1958 the WHO publishes the first International Standards for Drinking Water, specifically dedicated to the quality of water for human consumption. Subsequent revisions were published in the 1980s, namely the three volumes of the first edition of the Guidelines for Drinking Water Quality (GDWQ): Vol 1 – Recommendations; Vol. 2 - Health criteria and other supporting information; and Vol. 3 - Surveillance and control of community supplies.

This approach was a breakthrough in public health protection, providing an assessment of health risks originated in microorganisms, chemicals, and radionuclides. Furthermore, this methodology was the basis for setting public policies and regulatory procedures in many countries, and it remains, in most of them, the basis for quality control of water for human consumption.

In the European Union, the first Directive focusing on this subject was published in 1980 (Directive 80/778/EEC of the Council, July 15th). Subsequently, Directive 98/83/EC of the Council, November 3rd, incorporated the technical and scientific advances at the time, focusing on the obligation of compliance with key quality parameters. In Portugal, Law-Decree No. 243/2001, September 5th, transposed into national law the Directive 98/83/EC, and established that water quality for public supply should rely on the detection of microbiological, physical, chemical and radiological undesirable constituents, potentially dangerous to human health. This is accomplished through the analysis of the compliance of results with the standard parametric values established by law. However, this "end of the line" approach had many serious limitations, and the evidence supported the conclusion that there was no certainty regarding the quality of water supplied to the final consumer (Vieira and Morais, 2005).

These limitations justified the introduction of technical management methodologies based on risk assessment and risk control at critical points of the supply system. The application of principles of risk assessment and risk management in the production and distribution of water for human consumption complements “end of the line” compliance monitoring, enhancing water quality assurance and public health protection (Fewtrell and Bartram, 2001). The provision of safe water for human consumption requires concerted action and structured control throughout the supply system, from the source of raw water to the consumer's tap (Vieira and Morais, 2005).

Despite the overall positive results achieved over the past years, several issues were raised and became the foundation for legislative changes, namely the repeal of Law-Decree No. 243/2001, September 5th, and the publication of Law-Decree No. 306/2007, August 27th. This legal change reformulated the framework of water quality for human consumption based on diagnosed improvement needs and the experience of the previous framework.

However, the recent amendment to Directive 98/83/EC – Directive (EU) 2015/1787, of October 6th, introduced significant changes and generated a critical reflection by the Administration and the scientific community regarding water quality and the strategies to promote concerted control and structured action throughout the water supply system.

In fact, while risk assessment was already included in the previously Directive, it is the 2015 Directive that explicitly mentions WSPs for the first time. The concept of a WSP appears in 2004 following the Berlin Conference on Water Resources Law. It is part of the

WHO recommendations for drinking water quality, specifically in the GDWQ publication, introducing a new approach to risk management of water supply for human consumption. Similarly to what happened in the past with other WHO recommendations, there is a gradual trend to incorporate this methodology in national and international legal norms addressing safe drinking water supply.

In the international framework, standards EN 15975-1:2011+A1:2015 (E) and standard EN 15975-2:2013 are fundamental building blocks in the preparation of water supply policies, particularly in terms of water safety. These standards incorporate key elements of the WHO approach concerning water safety planning. Since WSPs are based on a risk management approach, they help to avoid potential damage to supply levels. The aim is to support water utilities in actively addressing security issues in the context of routine management and operation of the water supply system.

Lastly, the Hazard Analysis and Critical Control Points (HACCP) is an internationally recognized methodology that helps the food and beverage industry to identify risks and legal compliance. The principles and guidelines for the implementation of HACCP were adopted by the *Codex Alimentarius Commission* and became the scientific basis for identifying specific hazards and measures to control them in order to ensure water safety. In fact, as stated by Hamilton (2006), the majority of WSPs published are based on adapted HACCP procedure forms.

3. Risk Management and Water Safety Plans

Risk management is a key activity in utility sectors. The effort to understand and evaluate risk and to design and enforce preventive measures to improve risk control is a fundamental requirement (Pollard *et al*., cited by Hrudey *et al*., 2006). If the goal of risk management in the water supply sector is to ensure water safety, then it becomes crucial to understand the concept of water safety in relation to the goals underlying water safety planning. The first subsection addresses these concepts and goals, the second and third review existing literature in developed and developing countries, respectively, and the fourth discusses the key factors affecting the adoption and implementation of WSPs.

3.1. Water safety: concepts and goals

Hrudey *et al*. (2006) introduced the concept of safety as “a level of risk so negligible that a reasonable, well-informed individual need not be concerned about it, nor find any rational basis to change his/her behavior to avoid such a small, but non-zero risk.” (p. 949). In practice, water safety means that it does not represent a risk to human consumption in the form of death or serious illness. While affluent nations already have reached the highest standards in this regard, the achievement of such goals in developing countries still represents a significant challenge (Hrudey et al., 2006)

From the perspective of drinking water, and given our current capability for reducing risk, this notion of safe drinking water should mean that we do not expect to die or become seriously ill from drinking or using it. Assuring that drinking water is essentially free (to negligible levels) from the risk of infectious disease has been achieved for most public water supplies in affluent nations. The challenge for drinking water risk management is to maintain and extend that remarkable achievement as widely as possible (Hrudey *et al*., 2006).

Since 2004, the WHO recommends the implementation of preventive management measures through the adoption of WSPs. An increasing number of water utilities worldwide are now using this procedure (Gunnarsdottir, 2012).

According to Vieira (2011), a WSP for Human Consumption, as recommended by the GDWQ, is a document that identifies and prioritizes risks that could occur in supply systems, from the raw water source to the consumer's tap (see also Carneiro *et al.*, 2015). The WSP also establishes control measures to reduce or eliminate problems and designs processes to verify the efficiency of the operation of control systems and the quality of the water produced.

The main objective of a WSP is to ensure water quality for human consumption through the use of good practices in water supply systems. These include the minimization of contamination in water sources, the reduction or removal of contamination during the treatment processes, and the prevention of post contamination during storage and distribution. Thus, a WSP reflects an organized operating system of water quality management in which three basic stages can be identified:

• System Evaluation – process analysis and risk assessment encompassing the entire supply system, from the water source to the consumers' taps;

• Operational Monitoring – identifying and monitoring critical control points in order to mitigate the identified risks;

• Management Plans – development of effective management control systems as well as operational plans to meet routine and exceptional operating conditions.

Management control systems should also include a definition of responsibilities, a record of adopted procedures, and a training plan to ensure appropriate skills to personnel related to system operations.

According to Vieira and Morais (2005), the steps to be considered in the development and application of a WSP can be organized as depicted in Figure 1.

Figure 1 – Framework for the development and application of a WSP.

Water Safety Plan
(WSP)

PRELIMINARY STAGE
1. Constitution of the working team
2. Description of the supply system
3. Construction and validation of the flow diagram

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SYSTEM EVALUATION
4. Hazards identification
5. Hazards characterization
6. Identifications and evaluation of control measures

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OPERATIONAL MONITORING
7. Establishment of critical limits
8. Establishment of monitoring procedures
9. Establishment of corrective actions

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MANAGEMENT PLANS
10. Establishment of procedures for routine management
11. Establishment of procedures for management under exceptional conditions
12. Establishment of documentation and communication protocols

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VALIDATION AND VERIFICATION
13. Evaluation of the functioning of the WSP

Source: Vieira and Morais (2005)

3.2. Water Safety Plans: The State of the Art in Developed Countries

After a brief description of the method for preparing and implementing a WSP, we now turn the attention to the empirical studies present in the literature addressing the adoption and implementation of water safety planning. The extent of planning is still unknown. By 2011, the WHO estimated that there were pilot studies in 17 countries and that WSPs were implemented effectively in water utilities of 28 countries (Chang, 2011). In some cases, WSPs are mandatory, as in Australia, Iceland, New Zealand, Serbia, Switzerland, Uganda, and the United Kingdom (Gunnarsdottir *et al*., 2015). By 2016, the number of countries with WSPs had increased to close to 90 (String and Lantagne, 2016).

According to Gunnarsdottir and Gissurarson (2008), Icelandic waterworks adopted HACCP as a preventive approach for water safety management in 1997. A preliminary assessment of the results obtained indicates a significant increase in compliance with water quality regulations. The transposition of the Directive 98/83/EC to Iceland's national law in 2001 represented significant progress, and Iceland presents itself as an interesting case study of the mandatory adoption of water safety planning[1]. Several water utilities adopted WSPs, covering 81% of the population. Out of 49 water utilities, each supplying more than 500 inhabitants, 31 have adopted and implemented WSPs (Gunnarsdottir *et al*., 2015; Gunnarsdottir *et al*., 2012a).

The evaluation of the implementation of this methodology suggests a positive impact on the culture of public service, improved regulatory compliance, and enhanced public health (Gunnarsdottir *et al*., 2012a). A mandatory audit process by the regulatory authority and the demand for greater communication with the users of the water supply system have reinforced the goals associated with water safety planning. Ultimately, the mandatory adoption of WSPs in Iceland proved to be beneficial (Gunnarsdottir *et al.*, 2015; Gunnarsdottir *et al.*, 2012) and an important instrument for improving water quality and minimizing illnesses (Gunnarsdottir *et al.*, 2012).

Australia has legal requirements for water safety planning. This issue has gained relevance after 1998. At the time, the city of Sydney detected microbiological contamination in water supply, which highlighted the uncertainties and limitations associated with analytical results as a response to public health concerns. According to Hamilton *et al*. (2006), water utilities recognized the limitations of safe water quality based only on the monitoring of the final product and adopted preventive strategies by undertaking risk assessment proactively. This led to the development of water safety planning as a procedure to manage the risks in water supply systems. There is a consensus that a preventive management approach to risk as embodied by planning is the most reliable way to protect public health. A key component is

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[1] Even though Iceland is not part of the European Union, it is forced to implement European Directives due to its membership in the European Economic Area through the European Free Trade Association.

the inclusion of specific procedures about when to issue warnings to users, and how these warnings should be communicated (Byleveld *et al*., 2008).

Another case study was presented by Jayaratne (2008), describing the procedures adopted by the *Yarra Valley Water* (Melbourne's largest retail water utility) to develop its risk management plan regarding water quality for human consumption. It incorporates HACCP systems and quality management standard, NP EN ISO 9001. According to the author, the fact that Australia began adopting water safety procedures in the 1990s led the system to sustain these standards, regardless of the introduction of the WHO methodology. The study also highlights the successful implementation of the HACCP methodology, its full integration into the water management system, and its implementation as standard practice. One important aspect to highlight in the *Yarra Valley Water* case is the finding that the planning lacks strong commitment from senior executives. The presence of a fulltime manager to coordinate and actively manage the WSP, to develop of a long-term Improvement Action Plan, and to improve performance monitoring and commitment to a culture change within the organization would move the organization to a more accountable, proactive, risk-averse, and rapidly responsive work environment (Jayaratne, 2008).

Good governance is of paramount importance and mentioned by several authors. Viljoen (2010) presented a case study of South Africa, referring to documentation and guidance from WHO as “a useful guideline document, logical in design and relatively easy to follow and adapt to specific requirements.” (p.179). Senior management commitment, skilled and fully focused resources, and in-depth knowledge of relevant issues of water quality throughout the supply chain are crucial for water safety governance. Implemented in 2003, the WSP by *Rand Water* proved to be much more important than any another integrated quality system.

In 2011, the province of Alberta, Canada, became the first North American jurisdiction to require water safety planning (Perrier *et al*., 2014). This study recognizes a set of barriers related to institutional relations between policy makers, regulators and management bodies, which were determinant for the success or failure of water safety planning, particularly in villages. The study also shows that the implementation of this process influences interagency relationships by establishing bridges between stakeholders, facilitating communication, and providing support to manage the relationships among them. The methodology is adaptable to the context of a particular community without compromising the integrity of the approach or the defined goals, and can provide improved water supply, health, and welfare to communities of all sizes. However, management bodies, regulators, and policymakers should support water safety planning and encourage the necessary actions to ensure the quality of water supply.

Without such support, the plans offer very little to communities and may be seen as a top-down bureaucratic exercise (Perrier *et al*., 2014).

Following the Alberta example, Lane *et al.* (2017) reviewed water management policies in Arctic countries: Iceland, Alaska (USA), Denmark (Greenland), Norway, Sweden, Finland, Russia, and Canada (Yukon, Nunavut, Northwest Territories and the provinces of Manitoba, Quebec, and Newfoundland and Labrador). Focusing on Nunavut, the authors find that community size, remoteness (access to resources), and understanding a trucked water distribution system are all critical factors in the development of a water management strategy. Current regulatory practices based on the establishment of water quality parameters may not be the most effective method for the small communities in Nunavut because of methods of treatment and distribution. The authors recommend the adoption of WSP to face the unique challenges raised by these communities. Ultimately, water safety planning seems like a better approach to protecting public health through hazard identification and monitoring, and accommodating the unique distribution systems and household storage practices in Nunavut communities.

In the United States, federal regulations set drinking water quality standards for all public water supply systems. Baum *et al.* (2015) assessed the potential added value of a preventive management approach to risk relying on water safety planning and finds that WSPs can complement drinking water quality regulations. Planning places more emphasis on management procedures, internal risk assessment and prioritization of actions, and teamwork and training. The comparative analysis contrasts the tailored approach of WSP and the uniform nature of US regulations to ensure safe drinking water and finds that water safety planning has the potential to provides a better sense of the major risks to each water system and help them prioritize risk prevention measures.

In Europe, water safety planning is reported in several countries, including Belgium, Switzerland, the Netherlands, and Germany. The German case was presented by Malzer *et al*. (2010). By 2010, this approach had been implemented in 11 water treatment plants for public supply, with 4 more in progress. The sector was already aware of the risks and given that control was largely established through monitoring and problem management procedures, it was easier to recognize that water safety planning allowed a better understanding of the overall process. As a result, there was an improvement in operational management, mainly related to the corrections of faults in routine procedures. The study reports findings vis-a-vis improved internal communication, the systematic identification of risks and necessary actions to be undertaken, as well as the definition of clear and specific documentation leading to better risk control and better external communication.

Setty *et al.* (2017) recently evaluated the outcomes of water safety planning in large drinking water systems in France and Spain. The authors matched water quality and compliance indicators for the 2003-2015 period with data from a study of acute gastroenteritis incidence before and after water safety planning at five locations. The results indicated that WSPs improved water quality and compliance in most locations, allowing earlier identification of adverse effects and adding to prior evidence that WSPs offer operational performance benefits.

3.3. Water Safety Plans: The State of the Art in Developing Countries

Chang (2011) presented six cases in countries located in the western Pacific region: Australia, Laos Democratic Republic, Democratic Republic of Palau, Vietnam, and two cases in the Philippines. This study consisted of a cost-benefit analysis of water safety planning. The results point to an overall improvement in water safety, translated into a better identification and prioritization of control measures and an increased understanding of the supply system as a whole.

Dating from 2007, national requirements for water quality in Nigeria demand that all management bodies adopt a WSP. The main goal is to minimize the contamination of the public water supply system from the source by reducing or removing the contamination throughout the treatment process, storage, and distribution cycle. The study by Ezenwaji *et al*. (2014) investigated the different levels of implementation of WSP in six selected urban areas of Nigeria. The results show that only two cases had some degree of success. In the case of a county where most health problems of urban residents can be attributed to waterborne diseases, the study concludes that all efforts should be dedicated to implementing the methodology effectively. One of the problems is the lack of human resources, particularly by virtue of their migration to areas where health conditions are not so disastrous, which leads to a vicious cycle at the local level.

Ye et al. (2015) conducted a study in two rural areas in Beijing, China, to assess water safety planning principles and applications. The goal was to develop a methodological guide to allow replication in other rural water systems. The authors concluded that the main risk factors affecting water safety stem from water sources, water processes, and disinfection systems. The study recommends the adoption of control measures for strengthening water sources protection, monitoring water treatment processes, establishing emergency mechanisms, improving chemical input, and operating system management". (p.510). The results showed that water quality improved after the implementation of the plans, not only in terms of technical parameters, but also in terms of the satisfaction of end users. Thus, WSP can be an important tool to improve water quality in rural areas, reducing the occurrence of waterborne diseases and enhancing public health (Ye *et al*., 2015).

Mahmud *et al*. (2007) reported a study of water safety planning in small community-managed systems in Bangladesh for pilot projects led by three non-governmental organizations. The aim was to facilitate water safety planning through simplified and accessible tools for communities to use. The results confirm the relevance of the projects for improving water quality and health conditions, particularly in terms of hygiene behaviors in households. An additional important aspect concerns the involvement of communities, primarily through the establishment of monitoring committees to ensure the continued application of good practices after the completion of the projects.

Omar *et al.* (2016) investigated cultural influences on water safety planning using case studies from WSP pilots in India, Uganda, and Jamaica. Findings on organizational cultures show that "whilst some themes relate closely to governance structures specific to low and middle-income countries, many have parallels in higher income countries; for example, the tensions between water supply and water quality; the influence of professional subcultures (engineers and water quality scientists) on risk management initiatives; the essential role of active leadership; and the critical importance of assembling and managing system knowledge during WSP development." (p.905). In sum, the authors conclude that proactive leadership, stakeholder advocacy, and commitment to knowledge management are critical to WSP success.

3.4. Key dimensions of water safety planning

Organizational culture is defined as the attitudes, experiences, norms, beliefs, and values shared by the members of an organization (Schein, 2004). The organizational culture operates to either facilitate or hinder the adoption of new practices, such as WSP, because it influences the organization's ability to manage knowledge and stakeholder engagement, two key aspects of successful WSP implementation (Summerill *et al*., 2010). More generally, the literature highlights four key dimensions of water safety planning: leadership commitment, technical knowledge, governance, and interagency collaboration.

Several empirical studies underline the need for a strong leadership commitment by utility management bodies. This argument is key in Summerill *et al*. (2010a) article, which focuses on the importance of senior management involvement and engagement in the process to ensure the success of WSP implementation. Illustrated by two case studies, the article discusses the influence of organizational culture and concludes that, despite an internal commitment to risk management, some aspects of the organizational culture constitute weaknesses that prevent the achievement of full potential. Some cultural characteristics support the process, including camaraderie, proactive leadership, customer service mentality, transparency, accountability, competent human resources, and a culture of continuous improvement. Other cultural traits are obstacles to the process, including miscommunication, lack of flexibility, lack of knowledge, interest or reward, and coercion. The authors conclude that, concerning public water supply, it is necessary to consider the influence of organizational culture on the success and sustainability of the adoption of WSPs. In turn, an effective leadership can shape the culture to support such implementation (Summerill *et al*., 2010a).

Summerill *et al*. (2010) also cite a study by Kostova and Roth (2002) on multinational companies. The study noted that institutional environments of subsidiary host countries might affect the internalization and implementation of practices developed by headquarters. As a result, success is dependent on trust, dependence and identification with the headquarters. Internally, barriers between management and unionized workers led to a breakdown in communication and relationships and directly influenced the success of the WSP project. Thus, gaps in project implementation appear when human resources fail to believe in their usefulness and value, resulting in a low level of internalization of WSP. If a regulator expects WSP to be implemented, the internalization management commitment is vital to impact the team positively.

Based on five case studies from the United States of America, Thiel (2015) concluded that the internal dynamics of an organization shape the form of water governance. According to Schlager and Blomquist (2008), institutional arrangements are created and modified by people over time in response to changing awareness and understanding of the issues and to changes in the set of tools available to deal with them, shaping public attitudes and preferences. A strong political component is, therefore, associated with water safety planning, particularly in countries where their character is not (yet) binding.

The introduction of change in a political system or the implementation of innovative policies always contains a level of risk of failure. Also, governments are often risk-averse, opting for the status quo rather than implementing something that could cause them to be held accountable for failing. The risk aversion described by Howlett (2014) in the case of climate change, can be extended to other domains, such as the binding application of WSP. National governments may prefer to deny the need for substantive action rather than addressing the issue proactively.

In addressing the various case studies, one aspect highlighted by several authors is the issue of external communication, understood primarily in terms of end-users. External communication is not just between the management bodies and end users of drinking water. Instead, it covers a wide range of stakeholders or agencies whose relationship is also the subject of study (Ferrero *et al.* 2018). Along these lines, Kot et al. (2015) argue that community readiness translated in terms of leadership, resources, and widespread knowledge and awareness about safe drinking water is a precondition for the successful adoption of WSP.

The WSP approach is both an opportunity and a challenge for water utilities, particularly in terms of interagency collaboration, as most of the process depends on effective collaboration (Jalba *et al.*, 2010, citing Bartram *et al*., 2009 and Jalba *et al*., 2009). In their review of drinking water and health incidents in developed countries, Jalba et al. (2010) propose an emergency management structure based on evidence of cooperation between agencies in the area of public water supply and public health, as part of the overall risk management culture in public services. The authors develop qualitative research to assess the causes of success and failure in effective interagency relationships. Six critical aspects of institutional relations were identified, including creativity, communication, training, exchange of experience, confidence, and regulation. All six components shown are required for optimal institutional relations. Failure in one component might contribute negatively to a future event. For example, failing to share experiences can delay incident investigation and potentially compromise the solution (Jalba 2010).

Improvements in water governance are ways to secure the quality of water supply for human consumption. Access to clean water can be enhanced if certain governance challenges are addressed: interagency collaboration among ministries and countries that deal with drinking water services, monitoring and enforcement of water quality regulations and technical capacity to improve water services management at the local level (Kayser *et al*., 2015).

If viewed more broadly, the four critical components are present in other utility sectors. In the energy sector, Finneveden *et al.* (2013) show how a Strategic Environmental Assessment

(SEA) framework integrates a diversity of analytical tools, such as Life Cycle Assessment, Risk Assessment, Economic Valuation and Multi-Attribute Approaches. This diversity is capable of accommodating differences in the values and worldviews of different stakeholders and, therefore, stimulate consultation and understanding to promote credibility and relevance in environmental assessment exercises. Clearly, commitment, technical knowledge, governance and interagency collaboration are also among the recommendations of the SEA tool.

Planning in the energy sector should improve transparency and accountability along the entire chain and their implementation depends on the full cooperation and participation of Member States and other stakeholders. One of the most important lessons learned from the Fukushima Daiichi accident concerns communication of nuclear safety issues to the public (Langlois, 2013). Thus, good governance and effective communication are key aspects to take into account in energy safety plans, just as they are in WSP.

Finally, Jung *et al.* (2016) conducted a study aimed to review, validate, specify, and prioritize strategic policies for pedestrian safety enhancement in the Republic of Korea. They concluded that road safety facility, law enforcement, and education policies are required for successful strategic policies for pedestrian safety. For these safety plans, along with technical knowledge, governance and communication are essential, just as we saw in the case of WSP.

These examples point to similar recommendations present in safety plans from other utility sectors and serve to further stress how WSP research findings may be of significant interest to other government officials and practitioners.

In sum, several ideas can be extracted from the analysis of the case studies on water safety planning around the world. These ideas are summarized in Table 1 and will be taken into consideration when presenting our recommendations for the implementation of a risk assessment methodology (or WSP) at the end of this article.

Table 1 – Dimensions of Water Safety Planning Extracted from the Literature

Main conclusions	Author
Leadership commitment: WSP implementation improves internal communication in the organization and facilitates external communication, translated into an increase in stakeholders' involvement and satisfaction, especially end-users.	Byleveld *et al.* (2008) Ferrero *et al.* (2018) Gunnarsdottir *et al.* (2012) Gunnarsdottir *et al.* (2012a) Gunnarsdottir *et al.* (2015) Kot *et al.* (2015) Mahmud *et al.* (2007)

	Malzer *et al.* (2010) Omar *et al.* (2016) Perrier *et al.* (2014)
Leadership commitment: WSP implementation requires a strong involvement of working teams and a serious commitment of management bodies.	Jayaratne (2008) Summerill *et al.* (2010) Summerill *et al* (2010a) Viljoen (2010)
Technical knowledge: WSP implementation ensures the supply of safe water, enhancing security on water quality assurance and public health protection.	Chang (2011) Fewtrell and Bartram (2001) Gunnarsdottir *et al.* (2012) Gunnarsdottir *et al.* (2012a) Hamilton *et al.* (2006) Mahmud *et al.* (2007) Perrier *et al.* (2014) Setty *et al.* (2017) Ye (2015)
Technical knowledge: WSP implementation requires sufficient technical capacity to attain in-depth knowledge of the supply chain	Amjad *et al.* (2016) Chang (2011) Ezenwaji (2014) Kayser *et al.* (2015) Malzer *et al.* (2010) Omar *et al.* (2016) Perrier *et al.* (2014) Petterson and Ashbolt (2016) Staben *et al.* (2015) Vieira (2011) Viljoen (2010)
Technical knowledge: WSP implementation allows the systematic identification of risks and the definition and formalization of procedures and activities for their prioritization and minimization/mitigation.	Amjad *et al.* (2016) Baum *et al.* (2015) Carneiro *et al.* (2015) Chang (2011) Malzer *et al.* (2010) Setty *et al.* (2017) Staben *et al.* (2015) Ye (2015)
Governance: WSP implementation improves document management.	Chang (2011)
Governance: WSP complement regulations on water quality and final product compliance monitoring and reporting.	Baum *et al.* (2015) Chang (2011) Fewtrell and Bartram (2001) Gunnarsdottir and Gissurarson (2008) Gunnarsdottir *et al.* (2012a)
Governance: WSP implementation requires enforcement of water quality regulations	Kayser *et al.* (2015) Perrier *et al.* (2014) Vieira (2011)
Interagency collaboration: WSP implementation requires effective interagency collaboration and engagement.	Bartram *et al.* (2009) Howlett (2014) Jalba *et al.* (2010) Jayaratne (2008) Kayser *et al.* (2015) Omar *et al.* (2016) Perrier *et al.* (2014) Summerill *et al* (2010) Thiel (2015) Vieira (2011) Viljoen (2010)

4. Water Safety Planning in Portugal

This section discusses the introduction of WSP in the context of the water policy sector in Portugal. However, before presenting existing data concerning the Portuguese case, it is important to briefly describe the research context, namely the Portuguese water sector.

4.1. Water Utility Sector in Portugal

Water sector operators are classified according to the designations of *upstream* systems and *downstream* systems, depending on the activities carried out by the water utilities. This classification, which is now widely used since the publication of Law-Decree No. 379/93, November 5th, contributed to the establishment of multi-municipal systems. Each of these organizations is responsible for providing services to several municipalities, which serve as shareholders in the company managing "upstream" systems and provide water and sanitation services directly to the population through municipal systems ("downstream") (ERSAR, 2017).

The legal framework defining the management and operation of multi-municipal and municipal systems has been gradually set up. Multi-municipal companies are state-owned systems serving at least two municipalities and involving the intervention of the State according to a rationale of protection of the national interest. Municipal systems are run by the municipalities themselves, by municipal associations, or by the municipalities in partnerships with the State.

Corporatization of the water sector began in the 1990s. The first generation of this movement targeted systems located in coastal, more densely populated areas, while the second generation targeted the rest of the country. Currently, all water utilities that supply wholesale water services are of a corporate nature and the concession management model dominates the sector. By December 31st, 2015, in mainland Portugal, these utilities represented about 72% of the population and 79% of the number of municipalities.

Multi-municipal concessions are the predominant management sub-model in the wholesale sector, covering a total of 174 municipalities and more than 5.1 million inhabitants. State delegations also have some weight in the sector. Although with only one water utility (EPAL), the large concentration of existing population in its area of intervention makes it the most relevant sub-model in the wholesale sector, with 25 municipalities and a population of approximately 1.8 million. In another set of municipalities, the supply service is vertically integrated with water utilities encompassing the entire value chain embedded in its operations, performing water collection and treatment as well as distribution to the end-users. In mainland Portugal, this organizational model covers a universe of 120 municipalities and a total of three million inhabitants (out of ten million), mainly in the north and center of the country. Partnerships between the State and the municipalities provide water services to approximately 250,000 inhabitants, covering about 21% of the territory of continental Portugal in low population density areas (16 inhabitants per km^2). The remaining sub-models have a negligible representation.

Downstream water supply services are characterized by significant fragmentation evident in the high number of management entities (301), mostly with an intervention area equal to, or less than the area of the municipality (Rodrigues and Tavares 2017). The direct management model stands out, covering 70% of all municipalities and approximately 52% of the population of mainland Portugal. The other management models are predominant on the coastal areas or in large urban centers. Municipal services are the sub-model management with greater representation, with 183 municipalities covering 2.9 million inhabitants adopting direct service provision. This regime is prevalent in rural areas with lower population density (along with the joint community/user associations). This is the sub-model with lower population density, at about 47 inhabitants per km^2. This characteristic can be confirmed as it is observed that most of the municipal services arrangements are located in rural areas. In contrast, the only state delegation, with a population density of 5.5 thousand inhabitants per km^2, which is characterized by providing the service in an urban, densely populated area (Lisbon). Municipal utilities, municipal or inter-municipal companies, and municipal or inter-municipal services are also management sub-models in the retail water supply sector, covering 2 million, 1.8 million, and 2.3 million inhabitants, respectively.

The water supply sector is highly fragmented into a large number of utilities, a fact which is partly explained by the majority of service being provided by municipal in-house bureaucracies, but also due to the existence of a high number (43) of small water utilities (covering a population of just 34,000 inhabitants) owned by civil parish associations or consumer associations.

As already mentioned, water utilities under the direct management model dominate *downstream* water supply. However, the last decade witnessed a trend of increasing corporatization of the sector. In the early 2000s, the concession management and delegated models represented only 20% of the population served, whereas today they represent almost half (48%).

As measured by key indicators, service quality in water supply has evolved positively over the last couple of decades as a result of significant investment efforts, sustained by a consistent legal framework and co-financing by European Union funds (ERSAR, 2017). As a result of these investments, national coverage of water supply services which was about 80% in the early 1990s and has increased continuously, reaching 95% in 2011, thus fulfilling the objective defined in the national strategy PEAASAR II (2007-2013) to serve about 95% of the country's total population. Despite having achieved the target set for the coverage of water supply services, effective contracting of the public service calculated using the indicator "physical accessibility of the service" still has potential for improvement, registering 85.8% in 2015, which reflects the persistence of the use of alternative water sources.

In 2015, Portugal reached 99.93% of coverage in water quality analyses, which is a remarkable evolution when compared to 2000, when the value was about 80%. The percentage of controlled water of good quality is about 99%, indicating that water at the consumer's tap consistently presents high quality levels.

The system for evaluating service quality in water utilities was developed by the Regulatory Authority of Water and Waste Services with the technical support of the National Civil Engineering Laboratory and is based on the use of service-quality indicators. The use of these indicators aims at developing quantitative measures of the efficiency and effectiveness of the various features of the services provided by water utilities.

Selected service quality indicators reflect the most relevant aspects of service quality. The presentation of each indicator facilitates the assessment of goal accomplishment and the analysis of progress over time, representing a significant contribution to the quantification of service quality, in a given area and during a specific time period. In 2015, the results show a positive overall quality of service that has resulted in: 1) 53% of retail water utilities having good or satisfactory ratings, 30% receive unsatisfactory ratings, and 16% have not been evaluated; and 2) 69% of wholesale water supply utilities received good and satisfactory ratings and 30% unsatisfactory ratings.

The characterization of water services in mainland Portugal indicates a positive evolution, as well as a gradual convergence towards national objectives. Current water policies were adopted two decades ago and have been adjusted over time, allowing a significant breakthrough and the extension of water services to all population. This success has been recognized nationally and internationally, so it is important to value and consolidate this experience with a clear awareness of the efforts still required (ERSAR, 2017).

4.2. Water Safety Plans in Portugal

In Portugal, one of the most important documents in the water supply sector is the Strategic Plan for Water Supply and Sanitation of Waste Water 2014-2020 (PENSAAR). Given the diagnostic of the water sector in Portugal, the document offers a new paradigm, a strategy less focused on the construction of infrastructures to increase coverage and more in line with asset management, daily operations, and quality of services aiming at comprehensive sustainability. The choice of the motto "A strategy to service the population: quality services at a sustainable price" by the PENSAAR is intended to strengthen the acceptance of the strategy by users and citizens in general, recognizing good performance, service quality, and fair price, and ensuring the continuity of the strategy beyond 2020.

The Strategic Plan also underlines that the next European legislative initiatives related to water quality will require the mandatory extension of this methodology of prevention and risk management to all public water supply systems. In recent years, following the WHO recommendations, there has been significant progress with water safety planning by multi-municipal water utilities. This entails the need for investments in research and acquisitions, as well as infrastructural interventions that prove essential to prevent and manage the risks identified, incrementing water safety and the protection of human health. Accordingly, the PENSAAR explicitly includes the development and implementation of WSP under its operational objective 5.4 *Climate change, natural disasters, risks – Reduction, adaptation*, in its Measure 5.4.3 *Improvement of procedures for prevention and risk management in Water Utilities*, Action 5.4.3.1: *Implementation of Water Safety Plans*.

Since the PENSAAR is a new strategic tool for the water sector, several water utilities have been developing and implementing the structured methodology voluntarily, in accordance with WHO and International Water Association recommendations. However, this has been done haphazardly, as the national legislative framework on the supply of water for human consumption fails to include any reference to this methodology (PENSAAR 2020, 2015).

According to 2014 data provided by the national regulatory agency, 104 municipalities in mainland Portugal had adopted an evaluation and risk management approach in municipal and multi-municipal systems. In the case of municipal systems, 132 of the existing supply areas had applied this approach. Finally, it is estimated that about three million residents were drinking water with quality assessed by a risk evaluation methodology.

According to Vieira (2011), the systematic process of hazard identification and effective management control introduced by the WSP leads to effective risk assessment and risk management in public drinking water systems. The positive results of WSP adoption and implementation in a small number of Portuguese water utilities reported by Vieira (2011) suggest that a nationwide strategic approach is justified to disseminate this methodology. However, the absence of a specific legislative framework and the lack of appropriate monitoring tools constitute obstacles to the establishment of strategic frameworks for systematic and organic scaling-up of implementation at a national level. Additionally, some clarification of the role to be played by national authorities responsible for health and environmental regulations is also required to promote the necessary policy adjustments.

Vieira (2011) reports a successful case, beginning in 2003, of a multi-municipal company of Águas de Portugal, Águas do Cávado SA. The Regulatory Authority recommended the extension of the company's risk management methodology to other water utilities. This initiative also sparked the launching of a pilot project (between 2008 and 2010) in ten water utilities of different sizes and organizational structures. This project aimed to promote the implementation of the WSP methodology and to provide the technical support (training and development of operational tools) to water utilities of different dimensions and complexities, geographically distributed across the country, and taking into account local conditions, including stocked water volumes, number of inhabitants, raw water characteristics, applied treatment processes, and human, technical and financial resources of the organization (Alexandre, 2008). Data on the results of this project were not published and, despite the information about the number of utilities that have implemented WSP, systematic data describing the outcomes of WSP are not available yet.

5. Observations and Conclusions

Based on the results of the empirical studies about WSP implementation around the world presented in section 3.5. and the lessons learned from the Portuguese case, it is possible to draw implications and propose recommendations for other countries facing similar challenges. These lessons provide us with a better understanding of the benefits and constrains of applying a risk assessment methodology to water utilities.

The need for a decisive commitment of utility management bodies and the strong involvement of working teams are key requisites to assure the successful implementation of

WSP (Jayaratne, 2008; Summerill *et al*., 2010; Summerill *et al*., 2010a; Viljoen, 2010). Sufficient technical capacity to attain in-depth knowledge of the supply chain is also crucial when starting a project of this scale (Ezenwaji, 2014; Kayser *et al*., 2015; Perrier *et al*., 2014; Petterson and Ashbolt, 2016; Vieira, 2011; Viljoen 2010),

Some authors regard water safety planning as requiring strong enforcement of water quality legislation (Kayser *et al.*, 2015; Perrier *et al.* 2014; Vieira, 2011; Viljoen, 2010) and recommend serious political commitment and effective stakeholder collaboration and interagency partnerships in order to accomplish the strategic goals of WSP (Bartram *et al*., 2009; Ferrero *et al.*, 2016; Howlett, 2014; Jalba *et al*., 2010; Jayaratne, 2008; Kayser *et al*., 2015; Perrier *et al.,* 2014; Summerill *et al*., 2010; Thiel, 2015; Vieira, 2011; Viljoen, 2010).

In summary, there are many challenges associated with implementing a risk assessment methodology such as a WSP, not only regarding the operational perspective and technical options, but also in terms of governance issues. This study identifies four critical components in developing and implementing WSP: commitment, technical knowledge, governance, and collaboration.

The strategic approach to the adoption of WSPs is decisive for the water sector, allowing policymakers and utility management bodies to accomplish a better implementation of a phased process of effective risk assessment and management in water supply systems for human consumption. In turn, this has positive repercussions for public-health and environmental protection, as well as for the governance of the water sector.

The necessary rearrangement of the national legal framework prompted by Directive (EU) 2015/1787, October 6th, on water quality for human consumption is likely to trigger the mandatory adoption of a risk assessment methodology in all water utilities in Portugal. Water safety plans are expected to play a critical role in water policies. As a result, the conclusions extracted from all international case studies are lessons of major importance when drafting national legislation. Existing research shows that successful implementation of WSP has led to effective preventive strategies of risk assessment, increases in compliance with water quality regulations, and improved public health. To achieve these positive effects on water quality for human consumption, successful water safety planning has relied on four common dimensions: a strong commitment from senior leaders, an organizational culture committed to public service, the presence of technical knowledge, interagency collaboration and governance in order to pursuit active management of WSP. In other words, besides technical aspects, good governance is a crucial element to capture all the benefits promised by this water policy tool.

Data limitations on WSP implementation by Portuguese water utilities prevents us from analyzing additional information regarding the profile of the early adopters. Future research should focus on gathering relevant information about the current status of water safety planning in Portugal through survey methodology, which will allow us to investigate the determinants of their adoption by water utilities.

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