Universidade do Minho
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PUBLIC POLICIES IN THE WATER SECTOR: WATER SAFETY PLANS AS TOOLS FOR RISK ASSESSMENT

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

PUBLIC POLICIES IN THE WATER SECTOR: WATER SAFETY PLANS AS TOOLS FOR RISK ASSESSMENT

ABSTRACT

Water supply is a structural and irreplaceable service, essential for sustainable development, thus determinant in environmental preservation, the promotion of public health, good pursuit of economic activities and an important indicator of quality of life of populations. It is a service provided under a natural monopoly regime, which must comply with the principles of universality, continuity, efficiency, price equity and adequacy in quantity and quality. In fact, in 2010 the United Nations (UN) General Assembly declared access to safe drinking water and sanitation a human right, essential to the full enjoyment of life and all other human rights. Five years later, in 2015, a collection of 17 global goals was set in the UN 2030 Agenda – the Sustainable Development Goals (SDGs) – leading countries around the world to express strong political will to ensure drinking water is universally safe, as acknowledged in SDG 6 – Clean Water and Sanitation. In this context, it is imperative to safeguard the continuous improvement of all processes and practices performed by water utilities aiming to ensure water quality for all and, for that matter, Water Safety Plans (WSPs) represent an important and strategic tool linked to public policies in the water supply sector. Because of the perspective of its mandatory application and the impact that it may represent on water utilities, namely in terms of governance, this dissertation intends to investigate three major dimensions related to the implementation of this methodology, performed through scientific articles.

First, we reviewed the international evidences of the adoption and implementation of WSPs in water utilities all over the world and the lessons to be learned from those several WSPs experiments documented in empirical studies. This knowledge was relevant when drafting the new legislation in Portugal as part of the necessary adjustment of the national legal framework related to the approval of the Directive (EU) 2015/1787, on water quality for human consumption. There are many challenges associated with implementing a new mandatory risk assessment methodology such as a WSP, not only regarding the operational perspective and all technical options, but also in terms of governance issues and this first study identified four critical components in developing and implementing a WSP: commitment at all levels of the organization, technical knowledge, governance arrangements, and interagency collaboration. These items are critical to the success of WSPs implementation and it was possible to obtain very relevant guidelines for application by national water utilities.

The second study aimed to learn about the factors that influenced the voluntary adoption of WSPs by water utilities in Portugal, prior to the change of the national regulatory framework. EU Directive 2015/1787 mandates the implementation of a risk assessment process for all water utilities and the strategic approach of WSPs is decisive for that purpose. More specifically, the scope meant to explore whether the governance arrangement of water utilities affects the likelihood of adoption of a WSP. The results suggest that water utilities run by in-house bureaucracies are less expected to adopt WSPs, meaning they may have extra difficulties when facing the mandatory implementation of such a methodology and may need additional guidance. The dimension is also a relevant factor as utilities serving above 50 000 residents or 10 000 m^3/d are more prone to adopt WSPs. Moreover, water utilities with quality management systems are more predisposed for the adoption of WSPs. All these findings point to the importance of technical skills and previous experience dealing with formal procedures by water utilities as key determinants in the adoption of WSPs.

In a context of growing external uncertainties arising from changes in the climate and the environment, ensuring water quality for all is a growing concern and studying this issue would allow to learn about the impacts of climate change on water quality modification and the new public policies to deal with the related problems. Adaptive changes are already taking place, and others are expected to be compulsory, namely legal requirements for water quality parameters, the adjustment of treatment processes and the implementation of new approaches, explicitly risk assessment strategies. WSPs are regarded as part of the solution, contributing to minimize climate change impacts on water utilities and, inherently, on water quality. But, are climate change concerns an input considered in updating Water Safety Plans? The third study investigated the adjustments made over time to WSPs of an *upstream* system comprising a pioneer multi-municipal system in the implementation of a risk assessment strategy and of a *downstream* system in Portugal. Results show that the WSPs of both water utilities are being amended in response to new public policies and new regulations are being designed to mitigate climate changes. Even though presenting different strategies, both aim and embody a similar output.

Keywords – Climate Changes; Risk Assessment; Water Public Policies; Water Quality; Water Safety Plans; Water Sector; Water Utilities

POLÍTICAS PÚBLICAS NO SETOR DAS ÁGUAS: PLANOS DE SEGURANÇA DA ÁGUA COMO INSTRUMENTO DE AVALIAÇÃO DE RISCO

RESUMO

O abastecimento de água é um serviço estrutural e insubstituível, essencial para o desenvolvimento sustentável, determinante na preservação ambiental, promoção da saúde pública, boa prossecução de atividades económicas e um indicador da qualidade de vida das populações. Trata-se de um serviço prestado em regime de monopólio natural, que deve cumprir os princípios de universalidade, continuidade, eficiência, equidade de preços e adequação em quantidade e qualidade. De facto, em 2010, a Assembleia Geral das Nações Unidas (ONU) declarou o acesso à água potável e ao saneamento como um direito humano, essencial para o pleno gozo da vida e de todos os outros direitos humanos. Cinco anos depois, em 2015, foi estabelecido um conjunto de 17 objetivos globais na Agenda 2030 da ONU – os Objetivos de Desenvolvimento Sustentável (ODS) – que conduziu os países de todo o mundo a expressarem uma forte vontade política para garantir que a água potável seja universalmente segura, como define o ODS 6 – Água Potável e Saneamento. Nesse contexto, é imprescindível salvaguardar a melhoria contínua de todos os processos e práticas em implementação pelas entidades gestoras de abastecimento de água com o objetivo de garantir a qualidade da água e, para tal, os Planos de Segurança da Água (PSAs) representam uma importante e estratégica ferramenta conexa às políticas públicas no setor de abastecimento de água. Dada a perspetiva da sua aplicação obrigatória, e do impacto que tal pode representar nas entidades gestoras, nomeadamente em termos de governação, esta dissertação pretende investigar três grandes dimensões relacionadas com a implementação desta metodologia.

Em primeiro lugar, investigaram-se as evidências internacionais da adoção e implementação de PSAs em serviços públicos de abastecimento de água em todo o mundo e quais as lições a aprender com as experiências documentadas em estudos empíricos. Este conhecimento foi relevante na elaboração da nova legislação em Portugal como parte do necessário ajustamento do quadro jurídico nacional relacionado com a publicação da Diretiva (UE) 2015/1787 sobre a qualidade da água para consumo humano, a qual impõe a obrigatória implementação de uma metodologia de avaliação de risco, como um PSA. Constituindo tal um desafio no que diz respeito à perspetiva operacional e a todas as opções técnicas, e também em termos de governação, este primeiro estudo identificou quatro componentes críticas no desenvolvimento e implementação de um PSA: compromisso da organização a todos os níveis, conhecimentos técnicos, governação e colaboração interinstitucional. Com a informação obtida foi possível obter orientações relevantes para aplicação pelas entidades gestoras nacionais.

Era ainda objetivo conhecer quais os fatores que influenciaram a adoção voluntária de PSAs em Portugal, antes da mudança no quadro regulatório nacional por força da Diretiva UE 2015/1787. Mais especificamente, o âmbito do trabalho incidiu sobre o estudo da influência da tipologia de governação da entidade gestora e se tal afeta a probabilidade de adoção de um PSA e os resultados indicam que existe relação, sugerindo que os serviços públicos de água administrados por gestão municipal são menos propensos a adotar um PSA, o que significa que podem ter dificuldades adicionais aquando da sua implementação e podem necessitar de orientação complementar. A dimensão da entidade gestora também é um fator relevante, pois os serviços públicos de maior dimensão, que atendem acima de 50 000 habitantes ou 10 000 m^3/d, são mais orientados para a adoção de um PSA. Além disso, os serviços públicos de abastecimento de água com sistemas de gestão de qualidade implementados estão mais predispostos a adotar um PSAs. Estas informações levaram a concluir sobre a importância da capacidade técnica e da experiência anterior em lidar com procedimentos formais por parte dos serviços públicos de água.

Num contexto de crescente incerteza associado ao fenómeno das alterações climáticas, importa perceber os impactos das alterações climáticas na qualidade da água e as novas políticas públicas para lidar com os problemas associados. Estão já em curso várias estratégias adaptativas, e outras serão obrigatórias ao nível dos requisitos legais para parâmetros de qualidade da água, para o ajuste dos processos de tratamento e para a implementação de novas abordagens, explicitamente estratégias de avaliação do risco. Os PSAs são considerados parte da solução, contribuindo para minimizar os impactos das alterações climáticas nas entidades gestoras e, inerentemente, na qualidade da água. Porém, serão as preocupações com as alterações climáticas um *input* considerado na atualização dos PSAs? A investigação teve como objetivo avaliar os ajustamentos realizados ao longo do tempo aos PSAs de um sistema "em alta" e de um sistema "em baixa" e os resultados demonstram que os PSAs de ambos os serviços públicos da água estão a ser ajustados em resposta às novas políticas públicas e regulamentos, contribuindo para a minimização/mitigação das alterações climáticas. E, se bem que apresentando diferentes estratégias, possuem um fim similar.

Palavras-chave – Alterações Climáticas; Avaliação de Riscos; Planos de Segurança da Água; Políticas Públicas no Setor das Águas; Qualidade da Água; Setor das Águas

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ACRONYMS

ERSAR – Entidade Reguladora dos Serviços de Águas e Resíduos (Regulator Agency)

EU – European Union

GDWQ - Guidelines for Drinking Water Quality

IPCC - Intergovernmental Panel on Climate Change

IWA – International Water Association

PSA – Plano de Segurança da Água

UN – United Nations

WSP – Water Safety Plan

WHO – World Health Organization

Water Safety Plans represent an important opportunity to contribute to the realization of the Sustainable Development Goals and to the human right to water, provided that equity is duly considered.

Water Safety Plans, therefore, provide a well-established and widely accepted framework that can be applied to ensure social inclusion in the improvement of drinking-water supplies.

(*WHO, 2019)*

CHAPTER 1

INTRODUCTION

1.1. CONTEXT OF THE STUDY

In 1958, the World Health Organization (WHO) produced the first publication specifically dedicated to the quality of water for human consumption under the title International Standards for Drinking Water (with subsequent revisions in 1963 and 1971), establishing a methodology for verifying the conformity of water characteristics supplied with pre-established numerical values (standards), through "final product" sampling programs. Later, in the 1980s, the three volumes of the first edition of the Guidelines for Drinking Water Quality (GDWQ) were published: Vol. 1 - Recommendations; Vol. 2 - Health criteria and other supporting information; Vol. 3 – Surveillance and control of community supplies. The second edition of the three volumes was published in 1993, 1996 and 1997 respectively (WHO, 1993; WHO, 1996; WHO, 1997), the third edition was published in 2004 (WHO, 2004) and, more recently, in 2011, the fourth edition (WHO, 2011).

This later edition replaces previous editions of the International Guidelines and Standards and develops concepts, approaches, and a wealth of information from previous editions, including the global risk management approach to ensure drinking water quality. Eight points can be highlighted as the most important updates. First, water safety, including minimum procedures and specific values, and how they are intended to be used. Second, approaches used in determining guidance, including benchmarks. Third, microbial hazards, which remain a major concern in both developing and developed countries. The experience has shown the importance of a systematic approach to ensuring microbial safety. The updated edition of the document builds on the prevention principles introduced in the third edition to ensure microbial safety of drinking water, highlighting the importance of water source protection. Fourth, a focus on climate change, which results in changing water and rain temperature patterns, severe and prolonged drought or increased flooding, and its implications for water quality and water scarcity, recognizing the importance of managing these impacts as part of water management strategies. Fifth, chemical contaminants in drinking water, including chemical information not previously considered as pesticides used for control, revisions of existing chemical data sheets, taking into account new scientific data, and, in some cases, reducing the coverage of the Guidelines by taking into account new information suggesting a lower priority. Sixth, major chemicals responsible for large-scale health effects through exposure, including arsenic, fluorine, lead, nitrate, selenium and uranium, providing guidance on identifying local priorities and management. Seventh, the role of the different stakeholders to ensure that water is safe. The fourth edition of the Guidelines promotes the discussion introduced in the third edition regarding the

roles and responsibilities of key stakeholders to ensure safe drinking water. Eighth, guidance for situations other than traditional ways of supplying communities, such as rainwater harvesting and other systems.

The guidelines are accompanied by a number of supporting publications, including examples of risk assessments in international peer-reviewed publications, and other publications explaining the scientific basis for their development and providing guidance on good practice in their application. It also presupposes guidelines for surveillance and control of supply, monitoring, and evaluation of drinking water quality in community sources. The guidelines are directed primarily to water and health regulators, policy makers and their advisers to assist in the development of national standards. It is also relevant to refer that the guidelines are recognized as representing the position of the UN system on drinking water quality and health issues - UN-Water, which coordinates UN agencies and programs concerning water issues.

This approach represented a significant advance in protecting public health around the world, providing an assessment of health risks originating in microorganisms, chemicals and radionuclides. On the other hand, this methodology served as the basis for the definition of public policies and associated legislative procedures in many countries, and, in most of them, was the basis of the entire quality control process for water intended for human consumption.

As mentioned before, in the EU, the first Directive on this subject was published in 1980. This legal document was repealed by Council Directive 98/83/EC of November 3rd, which incorporated the technical and scientific advances at the time, focusing mandatory compliance on essential quality parameters. Portuguese Law-Decree No 243/2001 of September 5th, which transposed Directive 98/83/EC into national law, established that "water intended for human consumption must be characterised by not containing micro-organisms, parasites, or any substances in quantities or concentrations that pose a potential danger to human health (...)." This document also stated that, in order to ensure the quality of water provided to consumers, the water utility responsible for the supply system should "(...) submit to the approval of the competent authority a quality control programme (...), to verify the quality of water aiming at demonstrating its conformity with the water quality standard (...), carrying out sampling corresponding to the conformity assessment, periodically throughout the year, in order to obtain a representative image of the quality of water distributed by the respective systems in that period of time."

At the operational level, ensuring water quality for public supply was based on the detection of undesirable microbiological, physical, chemical and radiological constituents, potentially hazardous to

human health, through the conformity analysis of results obtained in monitoring the quality of water provided to consumers with the parametric values stipulated in the legally established standards. This approach guarantees adequate water quality standards for human consumption, especially in industrialized countries, resulting in high levels of consumer confidence in the quality of the service provided to them (Vieira and Morais, 2005). However, the same authors attest that this quality control methodology presented a set of serious limitations, like the fact that results are only available after the water has been distributed and consumed, and this evidence allowed to conclude that there was no guarantee of the necessary confidence in the water provided to the consumer.

Thus, the evidence justified to evolve into technical management methodologies based on risk analysis and control at critical points of the supply system. The application of risk assessment and management principles in the production and distribution of water for human consumption complements the control carried out by monitoring conformity of the final product, enhancing safety in ensuring water quality and protection of public health (Fewtrell and Bartram, 2001). The safe supply of water for human consumption presumes, therefore, a concerted and structured control action throughout the supply system, from the origin of raw water to the consumer's tap (Vieira and Morais, 2005).

In the meantime, there was a more recent amendment to Directive 98/83/EC through Commission Directive (EU) 2015/1787 aiming to modify two of its annexes. In this context, and as it is imperative to safeguard the continuous improvement of all processes and practices leading to water quality, WSPs became an important and strategic tool linked to public policies in the water sector to achieve these goals. They represent a set of procedures aiming at risk management, which is an essential business requirement, not only in the water sector, but in all processes and service sectors. From incorporating good governance into organisations, to project and asset management, the ability to understand and assess risks and implement preventive measures to improve their control is a main activity (Pollard *et al.,* cited by Hrudey *et al.,* 2006).

According to Vieira (2011), and as recommended by the GDWQ of the WHO, a WSP can be defined as a document that identifies and prioritizes plausible risks that can occur in a supply system, from the origin of raw water to the consumer's tap, establishes control measures to reduce or eliminate them, and establishes processes to verify the efficiency of the management of control systems and the quality of the produced water. Its main objective is to ensure the quality of water for human consumption through the use of good practices in the water supply system, such as: minimizing contamination in water

sources, reducing or removing contamination during the treatment process, and prevention of post contamination during the storage, distribution and handling of water in distribution.

With a WSP, an operational water quality management system can be structured in an organized manner, where three fundamental steps can be identified:

• Evaluation of the system - risk analysis and assessment process, comprising the entire supply system, from source to consumer tap;
• Operational monitoring - identification and monitoring of critical control points in order to reduce the identified risks;
• Management plans – development of effective schemes for the management of systems control, as well as operational plans to meet routine and exceptional operating conditions.

System control management should also include a definition of responsibilities, which is a fundamental step of this method and extremely dependant of internal governance structure. It should also present a record of the procedures adopted and a training plan, ensuring adequate skills for staff related to the operation of the system. The methodology to be applied should be appropriate to the size and complexity of the water supply system. The WSP shall cover all aspects related to the control of the origins, treatment and distribution of water, with the responsibility of its application assigned to the system managing body.

The first stage of the WSP involves the development of the technical bases necessary for process evaluation, in order to identify the hazards and assess the risks associated with it. In many situations, the water utility does not have water management skills in the watershed, and cannot directly control the quality of its origins. However, the WSP should include all aspects related to water sources and their quality control, and in such a case may be a decisive element in order for this entity to involve the competent authorities at the level of the watershed (political good relations are fundamental) in the adoption of measures to protect water quality.

In the second stage, critical limits are defined, and the establishment of monitoring procedures and definition of corrective actions are to be considered throughout the system.

The third stage includes a series of activities aimed at ensuring the applicability of the WSP. To this end, procedures are developed for the management of system control, which include monitoring established control measures and the defined critical limits.

Operational support programmes are also drawn up, which include training of staff involved in the daily basis operation of the system and in the verification of control measures. In addition to these two activities, communication protocols are established, including internal information and communication with external authorities, with the media and with the general public.

To ensure success in the implementation of a WSP, the managing body of the water supply system requires operational conditions and appropriate human resources to implement an effective control. This assumes the formation of a multidisciplinary team with knowledge of the whole system and with competence to make an initial assessment of the system, in relation to its ability to achieve the expected quality objectives:

- Identification of places where contamination may occur and control measures must be applied to prevent, reduce or eliminate contamination.
- Validation of the methods used to control hazards.
- The application of a monitoring system that ensures water quality of the entire supply system, consistent with the legal standards in force.
- Corrective actions to give an immediate response to deviations in the expected quality objectives.

Before the preparation of the WSP itself, it is necessary to establish preliminary steps involving the formation of the responsible team, a general characterization of the system and the construction of the corresponding entire system under evaluation. In these stages, technical structure, organizational inventory and specific conditions of the supply system are designed.

After the plan is operational, it is necessary to validate and verify it. Through validation, it is ensured that the operating system is effective and is composed of barriers that ensure the control of the hazards detected.

Periodically, a check should be carried out to determine whether the WSP is being properly applied and whether it is capable of achieving the previously established quality objectives. In this sense, an assessment of the determining factors, including water quality, facilities, processes and organisation, and proposals for improvements to the system should be carried out.

The entire process of implementing the WSP must be monitored by an independent entity, which in itself constitutes an additional element of external control. This inspection may be carried out through audits of the plan, validation of the proposed control measures and verification of the final product (Vieira and Morais, 2005; Vieira, 2011).

In summary, WSPs implementation represent many challenges, not only from an operational perspective and associated with technical criteria and options, but also, and with a very substantive weight, with regard to the issues of governance.

In Portugal, Vieira (2011) refers specifically to a WSP case study beginning in 2003 in a multi-municipal company that had an enormous success and gathered the recognition of the national regulator (ERSAR), which extended the recommendation of this risk management methodology to other water utilities. This initiative also sparked the launching of a pilot project (2008-2010) in ten water utilities of different sizes and governance arrangements, but the results of this project were never formally published (Roeger and Tavares, 2018).

According to ERSAR (2018), several water utilities in Portugal have been developing and implementing voluntarily the WSP methodology in accordance with the recommendations of the WHO and the IWA. However, this has been done in an uncoordinated manner, since the national legislation on the quality of water for human consumption has only recently included this approach. With the publication of Law-Decree 152/2017, this risk management approach became mandatory (with an implementation deadline of 2020) and it is now based on European and international standards, in particular the structure of the WSP approach promoted by the WHO and EN 15975-2.

This last standard describes the principles of a risk management approach to improve the integrity of the drinking water supply system, involving all entities and stakeholders who share responsibilities in the provision of drinking water throughout the supply chain, from origin to point of use (protection of resources, capture, treatment, storage, transport, distribution and water installations inside buildings). Risk management should be based on a permanently updated description of its drinking water supply system, taking into account the relevant legal requirements and knowledge acquired from the interdisciplinary group that manages that business area.

Hazards can occur at various points in the drinking water supply chain and can be triggered by a wide variety of dangerous events and enhanced by climate change, so the aim is to systematically identify the risks of processes governing normal operation of water supply systems, as well as events that can trigger the occurrence of a dangerous situation. This analysis should be performed for each element of the water supply chain and be guided by the questions “What can go wrong?”, “Where?” and “How?”.

The risk assessment comprises the general risk analysis and risk assessment process, constituting a valuable decision support tool that helps to identify and prioritize any improvement, and update the needs required to achieve the objectives. This will facilitate the efficient comparison of different

types of risk decision-making and support in resource allocation. This process also supports the management body's business planning process and is an important tool to sustain any policy changes in the water sector.

Given the relevant role of water utilities in the protection of public health, control measures should be established to enable a high degree of process safety and operational stability ought to be regarded as vital to risk control. The adequacy of risk control measures has to be validated and its effectiveness controlled in accordance with the specifications and/or procedures established.

1.2. THEORETICAL CONTEXTUALIZATION OF THE STUDY

The complexification of society and the increased pressure on public entities to solve economic and social problems are at the root of the emergence of the discipline of public policy (Tavares, 2006). Public policies are omnipresent in modern societies, exerting a preponderant influence on the daily lives of citizens. Consequently, the field of knowledge of public policies has grown over the most recent decades, due to a number of factors. From the outset, the changes in perspective on the role and actions of the State, coupled with the political development of societies and forms of government that have consolidated over time contributed to this development.

Initially concerned with functions of maintenance of internal public order and security, preservation of private property, and the defence of borders, the State has diversified and expanded its responsibilities and functions, a process marked by the emergence of a new important function – the promotion of social welfare. These new demands required the State to take a new stance in the face of the problems of society and the daily lives of citizens, translated into the emergence of Public Policy as an area of study and knowledge.

Similarly, the need to take more restrictive approach to spending policies led to a growth in their visibility, not only because they have come to dominate the agenda of the vast majority of countries with different administrative traditions, but also because the inherent changes in social and economic policies have had repercussions, and present very significant consequences for society. New ideas concerning the role of governments have been replacing post-war Keynesian policies with policies based on balanced budgets and restrictive State intervention in the economy and social policies (Asensio, 2013).

The analysis of public policies involves the understanding of several concepts, among them a dimension considered as institutional (polity), a procedural dimension (politics) and a material dimension (policy). The first – polity – is related to the institutional order of the political system, outlined by the legal

system, and to the institutional structure of the political-administrative system (Frey, 2000). In politics, the political process, often of a conflictual nature with regard to the imposition of objectives, content and distribution decisions (Frey, 2000), is the term used by Anglo-Saxons to refer to the policy understood as consensus building and struggle for power (Asensio, 2013). Policy is the material dimension and refers to the concrete contents, that is, the configuration of political programs, technical problems and the material content of political decisions (Frey, 2000). According to Asensio (2013), it is the term used to refer to the most concrete governmental activities in specific fields such as environment, health, defence or education. Policy contains the outputs resulting from political activity, that is, the material result of political programs, state resolutions for technical and more immediate problems of society.

Meny and Thoening (1992) refer to public policy as the result of the activity of an authority invested in government and government authority, while Hogwood and Gunn (1984) claim that it is a designed program of values, purposes and practices. It is also important to mention Peters (1986), who considers public policy as the sum of the activities of governments that act directly or through delegation and that influence the lives of citizens (*in* Asensio, 2013).

One of the most widely used and recognized definitions is the one which refers to public policy as who gets what, when and how (Lasswell, 1971). This definition is based on the impact of public action and especially on the groups or people who are affected or benefited by this action. Policy decisions and analysis imply answering the following question: who gets what, why and what difference it makes (Asensio, 2013).

Heclo (1978) states that in the genesis and implementation of a given policy are the interactions of the different institutions and groups, both of the executive and legislative branches, and of society. Policy networks (or issue networks) are of great importance, especially as factors of conflict and coalition processes in political-administrative life. It is possible to demonstrate that, within the political reality of the more consolidated democracies, the members of such policy networks usually rival each other, but end up creating internal bonds of solidarity, which enables them to defend themselves and act against other policy networks considered as competitors (Frey, 2000). However, of course, the networks and arenas of sectoral policies are likely to change in the course of policy-making and implementation processes, and it is therefore essential to take into account the dynamic nature of the political and administrative processes.

Accordingly, the water policy sector addressed in this dissertation is associated with a policy network. This network includes central government officials, local officials, regulatory agencies, private

and public companies, and the citizens/public as customers of the water systems. In this sector, and especially regarding water quality issues, the majority of the current legal framework is the result of EU policies. From the publication of an EU Directive until its practical application by Member States, there is a set of processes involving all the actors mentioned above. The Parliament legislates under the influence of European Directives, the Government implements the legislation, the Regulatory Authority (ERSAR) controls the implementation by the water utilities and the public evaluates the service provided.

The phases of the formulation, implementation and control of the impacts of policies can be found in Frey (2000). The author presents a more accurate distinction: perception and definition of problems, agenda-setting, preparation of programs and decision, implementation of policies and, finally, the evaluation of policies and possible corrections of the action. The policy cycle provides the reference framework for procedural analysis and by assigning specific functions to the various stages of the political-administrative process points to clues regarding the possible causes of deficits in the problem-solving process.

The policy cycle in the water supply sector, particularly in terms of water quality, has allowed the great developments that have occurred in recent years. The perception that the evaluation of the organoleptic characteristics of water for public consumption was insufficient to guarantee its quality, and the awareness of the public health problems that would be at stake, led to the definition of new policies and instruments that allowed a more detailed assessment of water quality, as well as new obligations due to its mandatory compliance. The next phase of the process followed with the implementation of such policies and their subsequent evaluation. Scientific and technological developments led to the correction of existing policies, and, again, a new framework was defined to integrate new measures aiming to improve water quality assurance, namely risk assessment processes.

Frey (2000) refers, however, to neo-institutionalism, which assigns importance to institutional factors in the explanation of concrete political events. The author refers to the limitations of the rationality of the decision-making process not only as a consequence of a lack or an excess of information, but also stresses the existence of general rules and fundamental understandings that prevail in each society and that exert a decisive influence on the interpretations and the very action of people. This means that political and social actors perform not only according to their personal interests, but their identities influence their behaviour in political decision-making processes.

On the other hand, the criticism of the assumption of traditional policy analysis that political processes would be determined mainly by the contents of politics contributed to the strengthening of

institutionalist approaches, highlighting the importance of stable and consolidated institutions (polity) for the success of public policies. At the same time, it has led to the emergence of a research strand that can be designated as an analysis of political styles and which has been dedicating itself more to the aspect of politics, highlighting cultural factors, patterns of political behaviour and even attitudes of singular political actors as essential to better understand the political process, which in turn has repercussions on the quality of political programs and projects elaborated and implemented.

Pressman and Wildavsky (1984) developed the two main theoretical approaches to the study of the implementation of public policies – top-down and bottom-up. According to the bottom-up model, in the implementation of policies it is not possible to fully control the process, since the objectives are, as a rule, ambiguous, vague and contradictory, with conflict and negotiation, which translates almost invariably into policy changes.

In the top-down model, in contrast, it is sought to verify that the mechanisms that lead to implementation are close to the formulation of the policy. In fact, the main aspect of this model is to focus on the implementation of the policy as a mere result of the decision-making process, in a rigid and deferent view to the legislative process, emphasizing above all the role of the central actors of the decision. The feature of enhancement is thus the centralization and its exclusive emphasis on authors as main actors. It is observed that the main concern of the authors is to elaborate a process in which there are no deviations from the objectives formulated, promoting the control of the implementation process and the implementers. According to Matland (1995) and Hill and Hupe (2006), this involves policy making with clear and consistent objectives, simple implementation structures, fewer links in the implementation chain, little margin for change, greater control over actors and little external interference.

This model is therefore considered hierarchical or linear. Hierarchical, because it conceives the implementation as a phase of mere execution of what was formulated, that is, the goals, resources and the time horizon are defined only in the formulation stage. It is linear, as it does not consider the back-feeding effects of the implementation on the formulation and, thus, does not consider the cycle of policy construction as a process (Grindle, 1991).

Magone (2011) describes the top-down approach as particularly evident in the transposition and implementation of European Union directives by Member States, related to various areas, namely at the level of structural funds and environmental policies, such as water policies. Over the last few decades, the Portuguese public administration has absorbed much of this process of Europeanization, even in a reactive and accommodation perspective.

In fact, the national socio-political landscape has been changing with the process of Europeanization and not only in the development and implementation of public policies, but also in terms of public management models, progressively integrating more complex and participated systems and policy implementation and decision-making processes. In a brief retrospective on this subject, it will not be abusive to say that each State model corresponds to a model of public administration, being possible to identify three major State models to which different models of Administration are associated (Araújo, 2013).

The first model is the Liberal State, which accommodates the assumption of an apolitical public service associated with the political-administration dichotomy and the concept of neutral competence within the public service. Bureaucrats implement the decisions made by the Government and politicians and officials carry out their decisions according to the rules of good management. This model was in force at the beginning of the 20th century and was largely influenced by liberal ideas, reducing to a minimum its intervention in the economic path and, above all, in social life.

The second model of state arises after World War II (especially between the 1950s and 1970s), with the development of the Welfare State, characterized by state intervention in economic and social life, as a result of the increase in its functions, especially in the level of support for the most disadvantaged, since there was a sharp productive decline with the inherent increase in unemployment. On the other hand, at the level of health and education, the state's action has also become urgent and strongly conditioned by the exponential increase of the population, with increasing needs for education and health services. These new functions of the State, which thus begins to provide health, education and social assistance/social security services, led to a paradigm shift, which was reflected, of course, in the public administration model, as well as throughout the public policy process.

The management model was transformed in the face of these needs – Professional Administration Model - which was characterized by the increase in the activity of the public administration and by the professionalization and specialization of employees according to the various and distinct areas in which they have their spectrum of intervention, as well as their recruitment to be carried out on the basis of neutral, apolitical competencies. The functions can be characterized by an impersonal nature, guided by rules, in a top-down structure in the relationship between objectives and use of resources, and with the separation between means and ends.

The economic crisis that occurred in the late 1970s placed Western governments under heavy scrutiny to deal with problems and overcome the crisis. The traditional model of organization of the public

administration failed to introduce the innovations necessary to deal with the crisis that existed at the time. Criticism of the size and expenditure of the State from the sectors ideologically identified with the centre-right and with the economists of the Chicago school (of which Friedman is a paradigmatic example) led the Governments of western countries to seek new solutions for public sector reform. These reforms occurred mainly in the United Kingdom in the governments of Margaret Thatcher and in the United States under the Presidency of Ronald Reagan.

The financial problems of governments, the need to slow down the rate of growth in public spending, the maturity of social protection systems, the difficulty in controlling an increasingly spendthrift and inefficient Administration, the discredit in relation to public organizations and citizens' expectations regarding the quality of public services were some factors that have put pressure on reforms at this time (Pollitt *et al.*, 2001; Pollitt and Bouckaert, 2004).

According to Bevir (2003), the welfare state was the cause of three problems. The high level of public spending hurt the economy, leading to high inflation rates. Often these expenses proved inadequate and disrupted the natural balance of the system, causing bigger problems than those they sought to correct. Secondly, the level of spending was exaggerated and unsustainable, which accelerated the demise of the model. It was argued that part of the public expenditure was used to feed an inefficient bureaucratic elite and that this elite could be replaced by the market. Finally, the system was very permissive, with no incentives to the efficient use of resources. Several sectors of society called for a more efficient, faster and responsive public administration that responded to the needs of a dynamic, constantly changing society and the demands of economic agents. At the time, politicians shared the idea that the State is a bad producer because it produces little, poorly and at high costs, and should therefore look to the market for those who produce with the highest quality and lower costs.

The difficulty in dealing with emerging problems has thus led to the search for new forms of governance based on more liberal models. The political class was determined to reduce the size of the state machine through spending-containment policies and the use of privatisation. The control and rigour of public spending arise as widespread concerns on the part of governments to regain citizens' confidence and improve the quality of services provided. The idea was to do less, but to do what the government wanted to do by introducing alternative methods of providing public services (Araújo, 2013), preferably through the private sector. According to Kickert (2010), there is no doubt that the factors that had the most influence on the reform of public management were economic and financial.

The changes seek to introduce incentive system structures that would lead to changes in the functioning of organizations, seeking to promote the values of efficiency, economy and effectiveness.

As Araújo (2013) writes, there were several reform strategies adopted to change the structure and functioning of public administration, from budget cuts, sale of state assets, privatization, contracting of services, introduction of performance indicators, objective management, and other techniques of management of the private sector. These reform measures are part of the management reform model which has been considered to be the solution capable of responding to economic and social problems and, in particular, the solution to introduce greater efficiency and effectiveness in the functioning of public administration. This model, which was progressively accepted by the academic community being referred to as the New Public Management (Hood, 1991), appears as the solution to the problems of public administration, based on the belief that the management of the private sector is superior to management in the public sector. It has translated into a form of government more associated with the provision of service with the objective of greater competitiveness, an economic logic and whose control mechanism is the market.

An OECD text (OECD, 1993) refers that changes, in the 1980s, pushed most western countries towards a focus to make the public sector slimmer and more competitive while at the same time trying to make public administration more accountable to citizens' needs and offer value for money, flexibility of choice and transparency.

This new paradigm has, in fact, gained expression in many countries and can be read in the same text cited by the OECD: "Emphasis on performance management; greater flexibility and autonomy of financial management; greater autonomy in the management of people with increased use of performance-related compensation and personalized contracts; greater responsibility to users and other customers of public services; further decentralization of central government authority and accountability to lower levels of government; increased use of market-like mechanisms such as domestic markets, usage fees, vouchers, franchising and external procurement; and also privatization of market-oriented public enterprises."

The New Public Management focused, therefore, on the use of privatization mechanisms, internal markets, organizational performance and productivity incentive (intraorganizational).

According to Araújo (2013), there were several theories that contributed to this model. On the one hand, managerialism that emphasizes management as the best alternative to improve efficiency and social success, assuming that management is a generic instrumental activity whose principles and

practices can be applied both to the private sector and to the public sector. This approach takes up one of the main ideas developed at the beginning of the 20th century, and which was deeply developed by the Scientific Administration, according to which management is the solution to the problems of inefficiency. In order to obtain results, public administrators must have autonomy and flexibility, that is, discretion. On the other hand, the management model resorted to the rationalism of economic theory applying the concepts and models of the Theory of Public Choice, agency theory and transactional cost economics. This perspective introduces economic rationality in the analysis of public administration problems and in the identification of solutions. Among the various ideas introduced by economic theory, we highlight the favouring of competition through privatisation, the introduction of market mechanisms, consumer choice and the use of procurement.

This new approach consists of seven elements that are interconnected (Hood, 1991):

- The entry of professional managers from the private sector in the public sector, thus seeking the professionalization of management and guidance for management techniques;
- The definition of measures and performance standards with measurable and clearly defined objectives;
- The concern with the control of the results emphasizing the need to insist on the results and not on the processes;
- The disaggregation of public sector units by dividing large structures into smaller units using innovative ways of organizing activities;
- The introduction of factors that promote competition in the public sector, in particular with contracting, seeking to reduce costs and improve the quality-of-service delivery;
- The emphasis on the styles and practices of management of the private sector, introducing models that make management more flexible;
- The concern with discipline and sustained use of resources, seeking greater efficiency in their use of resources and cutting costs.

The experience of reform showed that the influence of the New Public Management had as a consequence the fragmentation of the unitary structure of the public administration. The model that previously operated in an integrated manner with the use of hierarchy and a unified system of civil service gave rise, in various sectors of public administration, to a near-market model (Araújo, 2013).

The traditional hierarchical link between political power and the structures responsible for the production/supply of public goods and services has been significantly reduced, and these relationships are preferably based on contracts. At the same time that the State reduced its direct activities, it

transferred or increased the activities it intended to ensure to the private sector. The use of procurement and other market mechanisms have altered the direct supply of goods by the State with the use of public services and public enterprises, for the provision using private agents of the third sector and the for-profit sector. Many examples can be given, such as waste management, public cleaning, hospital unit management, and more relevant for this thesis, management of water systems, from water supply to drainage and wastewater treatment.

Hence, the new paradigm was established through a balance between market forces and government regulation and it was precisely in this context that occurred the establishment of the national regulatory agency for the water and waste sectors.

The need to have more information and greater control over the operation and costs of services was the origin of the search for alternative ways of providing public services and a way to overcome these difficulties was to separate responsibility for policy development, responsibility for their implementation, transferring greater autonomy to those responsible for management. Thus, autonomous or near-autonomous services were created, giving managers great freedom to decide on the functioning of the services. The traditional form of control has been replaced by a type of control that represents the transition between a command structure and a large market.

In terms of organizational structure, the New Public Management transforms the composition of the public administration. While the State reinforces its decision-making position, administrative structures are no longer multi-objective organizations with a vast field of action and are reorganized into agencies with a perfectly identified core business (Rodrigues, 2005). It is necessary to create excellence in organizations, centred around the customers and specialized in meeting their needs. The idea is not to reduce the size of the State, it is to adapt it to the conjectures and current challenges.

Citizens and users are considered consumers of public services. However, the idea of having consumers instead of participating and involved citizens runs counter the foundation of public administration. When using the concept of customer or consumer, the individual is placed in a market relationship position. In contrast, the concept of citizen describes a member of a political community, which has a vast role that comprises political relations that connect the individual with the State.

There is therefore a new trend – the New Public Service, which results from the humanist democratic tradition and focuses primarily on citizenship and community issues. There are several aspects that characterize this new movement: to serve rather than drive; the public interest is the focus (not the consequence); think strategically and act democratically; serve citizens, not customers;

accountability is not a simple act; valuing people and not just productivity and valuing citizenship and public service above entrepreneurship (Denhardt and Denhardt, 2000).

What is at stake is, thus, the adoption of a new governing posture towards the citizen, with involvement and accountability of the latter, who is more and better informed and whose expectations in public services are greater, with the creation of conditions for citizens to exercise real skills of choice, with positive repercussions in terms of quality and adequacy of the services provided and in the autonomy of people – interorganizational. Consequently, the aim is to continue improving the quality of life of the population from a civil society perspective and networking among the different actors.

This conceptualization of government as networks finds in the context of public policy networks its most common manifestation. A multiplicity of actors interacts and participates in the processes of design and implementation of public policies. Although the interaction between State and society have always involved non-state actors, authors such as Klijn *et al.* (1995) and Rhodes (2002) argue that the nature of this interaction has been undergoing profound changes. The relevance of this perspective is based on the assumption that the actors now have a relative independence and autonomy vis-à-vis the authority of the State.

Although the State remains the main centre of political power, it no longer exercises this power in isolation, increasingly resonating on other social actors to cope with the lack of resources, legitimacy or increasing social complexity (Rodrigues, 2013).

Indeed, the vertical model based on hierarchy and authority has given way to a complex network-like structure. The need to negotiate increases, the interdependence between organizations is greater and, therefore, it has become more difficult to govern the complexity of public organizations responsible for the supply of goods and public services.

The implementation of coordination mechanisms that preserve the coherence of processes and return to political power the ability to manage, plan, conduct and make decisions is therefore at the heart of the emergence of a new model of public administration. The role of the State began to focus on promoting inter-organizational relations, rather than controlling its actions (Araújo, 2013).

This growing need to find and implement coordination mechanisms, according to Christensen and Laegreid (2007), is justified by four distinct and fundamental reasons. Thus, we mention the already referenced effects of the New Public Management, whose fragmentation increased the need for implementation of vertical and horizontal coordination mechanisms, as well as the fact that it is found that its auspicious results have not been possible to achieve as expected. Political will be another reason,

justified by the fact that the political power has perceived itself of its loss of control over the public administration, particularly because of limitations in access to information and influence, while remaining responsible for the actions taken by the agencies. One last element relates to the requirement imposed on states to provide coordination for all actors involved in the resolution of occurrences of various order, such as natural disasters, climate change, terrorist attacks, among others.

Thus, the political power assumes the strategy of coordination and control, with the use of delegation and devolution, seeking a balance between control and autonomy of public organizations, correcting the theoretical and practical limitations of the models that preceded it, namely the bureaucratic model and the New Public Management, covering the current complexity and the reality of governance (Araújo, 2013).

In the Portuguese water sector, all these changes can be clearly observed. In the early 1990s, the legal framework defined a new perspective for management and operation by creating the multi-municipal and municipal water systems and it has been gradually evolving, as all water utilities that supply *upstream* water services are now of a corporate nature and the concession management model dominates the sector. Just a few years later, it was also published the legal model of creation and regulation of municipal companies, and the last two decades witnessed a trend of increasing corporatization of the sector, with the concession management and delegated models supplying now about half of the Portuguese population. Nevertheless, Public Administration has maintained the competence for the approval of all strategic guidelines, as well as has supervisory power and, by means of the regulatory agencies, supervisory competences.

Focusing on social, political and economic complexity as causes of new emerging governance models, Peters (2010) characterizes governance as the combined result of four components: articulating a common set of priorities for society; coherence, consistency and coordination of objectives; orientation or direction of society towards the objectives; accountability.

We are therefore facing a movement that was defined by the OECD, in 2005, as corresponding to the formal arrangements that determine how public decisions are taken and how public actions are conducted, with a view to maintaining the constitutional values of each country in the face of changes in problems, actors and environments.

In The New Public Governance, a 2010 work that hosts articles by various authors, it alludes to Stephen P. Osbourne and his introductory note. According to the author, the New Public Governance is a conceptual tool with the potential to help understanding the complexity of the challenges that arise in

the provision of public services in the 21st century, as well as a reflection of the reality of the work of public managers today. In fact, public managers matter and have a significant influence. For instance, public managers working in politicized administrations and those whose education includes a law degree exhibit lower pro-innovation attitudes (i.e., receptiveness to new ideas and creative solutions and change orientation) (Lapuente and Suzuki, 2020).

Public administration has always played an important role in the elaboration and, mainly, in the implementation of public policies. Coordinating and integrating different policies and public sector organizations is a major challenge for practitioners (Trein *et al.,* 2020). Public management models influence the approach that the government uses to organize resources and transform them into public services and the outputs and outcomes of public policies depend to a large extent on the management model adopted and how this model works.

With regard to this issue, it can be said that the hierarchical model of organisation is the one that best fits the interests of the legislature, as the coordination of activities is done through the administrative order, according to a series of rules through which the government controls the activity of the administrative structure. Centralised nature and its hierarchical structure allow for the control of resources and objectives and how they should be managed. The hierarchy addresses several problems associated with the production and supply of goods and services and its main advantage lies in its ability to manage information flows in a centralized communication system. In addition, its stability ensures the continuity of administrative activity even in situations of political instability.

The first-generation reforms emphasized efficiency and results, paying little attention to outcomes. Many of these reforms were carried out without considering the process of public policy making. The fragmentation of public administration has had, as a consequence, the disarticulation of public policies requiring the search for coordination and integration mechanisms. The implementation of public policies with the use of the market has placed a set of new obligations for the government: it now has to ensure that market mechanisms work effectively and regularly. These tasks go beyond the imposition of regulations or exchange standards. A new set of instruments and structures is needed to verify the contribution of the private sector and the public sector and new institutions to ensure that contracts are met. This type of control has been done through audit and regulatory institutions, which is a new form of accountability. However, institutional fragmentation increased organizational interdependence, making it difficult to guide services. In addition, the autonomy of services has created a "void in policies" that weakens the coordination mechanisms (Rhodes, 2002).

The challenge for the implementation of public policies is therefore to use these tools from a systemic perspective in order to adapt the capacity of the administrative system to respond to the challenges that are posed while maintaining the core values of public services.

While it is true that many of these change efforts have positively altered the functioning of the public administration, the results regarding the connection with citizens, for e.g., is still scarce. Reform programs often fail to understand citizens' wishes to get involved and participate in the governance process. Of course, the process of involving citizens and promoting their participation is complex and a challenge for public administration.

The Government emerges as one of the actors in the political arena and the development process of society, together with other actors. Network structures, particularly in their cooperative and collaborative form, are emerging to increase traditional means of coordination due to the wide dispersion and variety of public services. Despite the strong confidence in networks to deal with complex social issues and the growing interdependence between services, there is still a limited understanding of how networks actually work and how they can be managed in order to maximize results and ensure their sustainability.

The current debate focuses on the political nature of citizenship. As stated by Cruz *et al.,* (2020), the most studied governance challenge, by far, is citizen participation. After a long period of increasing state influence in society we are witnessing the reasserting of the political rights of citizens in their relations with the State, clarifying the concept of citizenship and giving more powers to citizens. But when these are also customers it means that they have the right to choose from different public services or between public and private services and that they have purchasing power in the "public market".

Policies and programs are more effective through collective effort and the collaborative process, in a logic of thinking strategically and acting democratically. Thus, the New Public Service seeks to ensure that the Administration is open, accessible and works to serve citizens and create opportunities for citizenship, paying great attention to how different organizations and actors interact in order to achieve a high level of a desired outcome – the outcome achieved by citizens and stakeholders. The Administration must therefore take into account aspects that are beyond the mere rationality of the market, valuing people, not exclusively productivity (Denhardt and Denhardt, 2000; 2003; 2007).

After decades in which management rationalism has guided reform measures, governments are facing new pressures that require systemic adaptations. Concern for efficiency is being replaced by concern for governance, adaptation, collaboration and understanding of the impact of policies on society.

This requires an integrated approach to governance and management issues, in a logic that aims to drive the full capacity of the public sector to change while maintaining the core values of the public service.

Despite these new trends, the Portuguese water sector is still implementing these governance changes at a very slow pace. Nevertheless, the prospect of the impacts of all the global problems that are emerging, such as climate change, will certainly bring a new perspective and a stronger awareness for citizens to be involved in public decisions and policies.

Revisiting the previous approach regarding Europeanization, some scholars portray it as the institutionalization at the European level of a distinct system of governance with common institutions and the authority to make, implement and enforce European-wide binding policies (Olsen, 2002). This view is illustrated by Risse *et al.* (2001), who define Europeanization as the emergence and development at the European level of distinct structures of governance, that is, of political, legal, and social institutions associated with problem solving that formalize interactions among the actors, and of policy networks specializing in the creation of authoritative European rules.

Kaeding (2006) claims that Europeanization involves the transposition and implementation of European legislation in EU Member States. Whereas EU policy implementation is explicitly recognized as the responsibility of the Member States, the new emphasis on benchmarking recognizes that different implementation strategies can be beneficial, provided the outcome is appropriate.

The process – Europeanization - has had a strong influence in Portuguese public administration, right from the outset because the European Union represents an important external link that has led the country to (partially) overcome the remaining neo-patrimonialism impulses, that is, the centralization of decision-making, the poor allocation of human resources and the low level of qualifications (Magone, 2011). If, on the one hand, this represents a positive influence, it should be noted that the national approach has been reactive and slow to accommodate these pressures, which means that only a low/medium change has been achieved in the Administration (Magone, 2011).

Nevertheless, the integration of Portugal in the European Community/European Union in 1986 led to the much-mentioned process of Europeanization, which is, according to Magone (2011) substantively characterised by the application of standards in a top-down context, guiding decision-making processes at national policy level. Even though Europeanization dynamics strongly influence the direction of *domestication* of EU policy (Thomann and Sager, 2017), this top-down approach is particularly evident in the transposition and implementation of environmental directives, just as is the case of public policies on water quality.

Actually, with the exception of treaty revisions, European decisions are legally binding for the Member States and, hence, do not require ratification at the domestic level. Yet, while regulations are directly applicable, directives must be transposed into national law. Moreover, both regulations and transposed directives have to be practically applied and enforced by national administrations (Börzel, 2000) – effective transposition is the first goal that falls under the Lisbon action plan (European Commission 2005). The Lisbon obligation entails, on the one hand, that Member States transpose legislation on time, as well as, on the other hand, in line with the contents of the EU text and rulings by the European Court of Justice (Kaeding, 2006).

According to Knill and Lehmkuhl (2002), European policies can be very prescriptive and require Member States to take certain measures in order to comply with EU requirements. They may also be limited to promoting opportunities for change in internal structures.

For the first case, which involves, as example, the application of Directives in the area of environment and water quality, EU policy prescribes an institutional model for which the procedures and arrangements of each country have to be adjusted. Thus, Member States have only a limited institutional criterion when deciding on the specific modalities for compliance with European requirements. The mechanism of Europeanization by institutional compliance is particularly, but not exclusively, pronounced in the policies of so-called 'positive integration' (Taylor, 1983, cited by Knill and Lehmkuhl, 2002), including environmental protection, health and safety at work, consumer protection and some social policies. EU policies are explicitly directed at replacing existing national regulatory provisions and entail a genuine reformulation of them (Scharpf, 1999, cited by Knill and Lehmkuhl, 2002).

According to this author, the first Directive on drinking water, published in 1980 (Council Directive 80/778/EEC of 15 July), is a good example of command-and-control regulations. The Directive specifies the quality standards of water intended for human consumption. The provision of binding and legally uniform rules assumes hierarchical structures of intervention and very formal and legalistic standards in the administrative intermediation of interests at internal level. The defined standards are non-negotiable and apply uniformly to all water suppliers (or management entities). In view of these detailed specifications, national regulatory authorities have very limited discretion and flexibility in implementing European legislation. In other words, there is a close link between the content of the policy and the corresponding institutional regime of national compliance.

Thus, in view of the close link between political content and the requirements to be transposed into State Members' policies, European legislation imposes institutional models requiring

rearrangements, or adjustments, at national level of regulation (Knill and Lehmkuhl, 2002) and imposes institutional adaptation. In fact, the EU enforces European institutions to incorporate new norms, rules, practices, and structures of meaning, which are diffused to the Member States. Institutional isomorphism points to four diffusion mechanisms, which can result in domestic change (Olsen, 2002; Knill and Lehmkuhl, 1999 and Radaelli, 2000):

• Coercion: The EU positively prescribes or imposes a model with which the Member States have to comply.
• Mimetic imitation and normative pressure: Member States emulate a model recommended by the EU to avoid uncertainty (mimesis) or has been successfully implemented by other states (normative pressure) as it happened with the introduction of independent regulatory agencies.
• Competitive selection (regulatory competition): while the EU does neither impose nor recommend a model, Member States compete for the most efficient domestic arrangements in order to avoid comparative disadvantages.
• Framing: European actors can behave as 'ideational entrepreneurs', trying to alter the beliefs and expectations of domestic actors by disseminating new ideas and concepts, such as the principle of cooperative governance.

Compliance problems with European policies often arise when public administrators or economic and societal actors are not willing to bear the implementation burden. If the implementation of an EU policy requires considerable legal and administrative changes imposing economic and political costs on the public administration, implementation failure should be expected (Börzel, 2000).

At the same time, the Commission and the European Court of Justice hold Member State governments responsible, if European policies are not properly implemented and complied with. Consequently, Member State governments tend to be rather cost-sensitive in European policy-making (Börzel, 2000).

States may also lack the technical capacity to fulfil obligations because of the lack of technical competence to develop and enforce technical regulations consistent with international commitments. Many developing countries and formerly centrally planned economies have greater difficulties in complying with international obligations than industrialized countries owing to less developed administrative systems and fewer monitoring and financial resources which can be devoted to enforcement. Technical capacity may be less of a factor when a Member State is asked to forgo an activity rather than to halt an ongoing activity (Haas, 1998).

As stated by Börzel (2000), the more a European policy fits the domestic context, the lower the costs of adaptation in the implementation process. In the absence of an elaborate policy structure, misfitting European policies may still inflict significant costs since these structures have to be built-up in the first place.

Some case studies regarding the transposition of environmental policies show that the Northern European 'first-comers' (Denmark, Netherlands, Germany, Sweden, Finland, Austria) have a strong incentive to export their strict environmental standards to the European level to avoid competitive disadvantages for their industries and adaptations of their regulatory structures. They also have the action capacity (resources) to shape actively European policies according to their environmental concerns and economic interests. The Southern European 'late-comers' (Greece, Spain, Portugal, Italy) lack both the policies and the action capacity (money, staff-power, expertise, administrative coordination) to upgrade them to the European level. Since they are policy takers rather than policy makers, the Southern Member States are far more likely to run into serious policy misfit than the Northern pacesetters. The result is a somewhat paradoxical situation where those Member States with the most limited policymaking capacities bear the highest implementation costs since they have to adapt their domestic policies and institutions much more than their Northern counterparts (Börzel, 2003).

Some years before, Lampinen and Uusikyla (1998) presented similar results as the regression analysis supports that stable political culture combined with efficient and flexible institutional politico-administrative design are the best predictors of successful implementation of common European policies. The research hypotheses were tested by analysing a set of data which included the number of unimplemented directives as well as indices reflecting factors that affect countries' capability and willingness to implement EU directives. The Member States were divided by implementation rate into categories: Northern countries are by all measures the best implementors, while Southern Member States have constantly failed in implementing EU legislation.

A more recent case study presents a research on Member State (non-)compliance and points a number of explanatory factors at both the supranational and national levels which contribute to the observed EU compliance patterns (König and Luetgert, 2009). These factors emphasize Member States willingness (or national preferences) and strategic choice, on the one hand, and capacity (or administrative restrictions and resources) or legal complexity and ambiguity, on the other. Non-compliance may result from tight transposition deadlines, the inability of domestic actors to effect and monitor policy change or vagueness in commitments and ambiguities in the body of the directive.

Likewise, Falkner *et al.* (2004) also grants that non-compliance is due to administrative shortcomings, interpretation problems, and issue linkage.

Published in 2015, Directive (EU) 2015/1787, October 6th, mandates Member States to bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 27th October 2017, at the latest, and it is possible to acknowledge that Portugal transposed it to the national legal framework by December 2017. Furthermore, risk assessment analysis – the main issue investigated in this thesis – will be mandatory by January 2022.

1.3. The water sector in Portugal – public policies and organizational topics

Water supply, urban waste water sanitation and urban waste management are structural public services essential to general well-being, public health and collective security of populations, to economic activities and to environmental protection. Those activities must comply with a set of principles, including the universality of access, continuity and quality of service, efficiency and price equity.

A secure system of water supply and waste water sanitation forms the basis of a healthy society and supports economic development (Ye, 2015), contributing significantly to the economic and social progress of a country, both by the capacity to generate economic activities and, consequently, to create jobs and wealth, as well as by the improvement of living conditions of the population. They are generally classified as services of general economic interest and are recognized as essential public services by national law, namely the Essential Public Services Act (Law No. 23/96, July 26th, in its current text).

In 2010, the UN General Assembly declared access to clean water and sanitation an essential human right to the full enjoyment of life and all other human rights. This recognition implies an obligation for States to respect, protect and guarantee the right, but it does not mean the gratuity of services. The implementation of these rights means that everyone must have adequate and safe access to drinking water and sanitation, which can be done through traditional public systems (supply or sanitation networks), simplified public systems (e.g., collective sea stations) or individual installations (e.g., individual sea tanks). Services and facilities must be physically accessible, with adequate capacity, with acceptable quality, economically accessible and culturally adapted. Non-discriminatory access by all, citizens' participation in the decision-making process and monitoring and reporting should be ensured (UN, 2010).

The specificities of this sector, in particular the large number of water utilities, makes challenging the definition and application of a single model capable of responding effectively to its multidisciplinary

and cross-sectoral nature. These are services that function as typical examples of a natural monopoly, and for technological reasons there is a single entity to provide these services in each geographical area, with virtually no choice of alternatives for users, that is, competition is rare (Marques, 2008; Marques and Witte, 2011).

The sector can be divided into two significantly distinct subsectors from the technological perspective: the subsector of water services, in which the urban water cycle encompasses all the phases referred to water supply and wastewater sanitation activities, from water collection to the final rejection of waste water in nature, and the subsector of urban waste management services.

Water and waste services have been classified with the designations *upstream* and *downstream*, according to the activities carried out by the various water utilities. This classification, which became widely used since the publication of Decree-Law No. 379/93, November 5th, was at the heart of the creation of multi-municipal systems, mainly responsible for the *upstream* management, and municipal systems, mainly responsible for *downstream* management, and which correspond respectively to the wholesale and retail activities of the water supply, urban waste water sanitation and urban waste management sectors.

This structuring of the sector is referred to by the Regulatory Authority for Water and Waste Services (ERSAR) as having led to advantages in terms of economies of scale, but, at the same time, implied the loss of process savings. This is in accordance with the conclusions of a study by Marques and Witte (2011), in which the authors allude that research results about the optimal scale and scope economies leads to contrasting viewpoints. Whereas some studies find economies of scale, others do not. And, subsequently, there is also a reference highlighting the inefficient of water utilities in Portugal.

From the point of view of the market structure, the water sector, in particular, is a typical case of a network industry, both at the *upstream* and *downstream* level, what configures the management of these infrastructures situations of natural monopoly. Since it is a market failure, in the sense that it is not competitive, the regulation of the sector, in particular the economic one, appears as a way of reducing the loss of social welfare and consequent inefficiencies resulting from the existence of a natural monopoly. In fact, the measure of inefficiency is crucial in terms of economic regulation (Zamorano, 2004; Fried *et al.*, 2008; Marques and Witte, 2011) and in this sector represents a relevant theme.

As of the resources it absorbs, the water sector is capital-intensive and with prolonged periods of return on investment. This characteristic is justified by the high investment required at an early stage, the return of which occurs only in the long term, with the smoothing of tariffs practiced over the period of

service of the infrastructures. In fact, in order to reduce the period of return on investments made, it would be necessary to substantially increase annual revenues in the first years of infrastructure life, which would have significant impacts on tariffs to be applied to end-users.

The legal framework for the management and operation of multi-municipal and municipal systems has gradually being built through a set of complementary diplomas. State-owned systems serving at least two municipalities and requiring state intervention on grounds of national interest and municipal systems are considered to be all other, for which it is up to municipalities, alone, through associations of municipalities or in partnership with the State, to define the mode of organization and management (also designated as municipal ownership).

The Law of Delimitation of Sectors (Law No. 88-A/97, July 25th, amended by Law No. 35/2013, June 11th) defines the situations in which the access of the private initiative to the management of these services is allowed. Thus, in the case of water supply and wastewater sanitation systems, private operators can only assume a minority position in the capital of the concessionaires of the multi-municipal systems, a restriction that does not exist for municipal system concessionaires.

Following the amendment of the Sector Delimitation Law, which marked a new stage in the water and waste sector, a review of the legal framework of multi-municipal systems began and in Portugal there are still water utilities of a different nature acting within the framework of different management models.

Decree-Law No. 92/2013, July 11th, which repealed Decree-Law No. 379/93, November 5th, continues to allow multi-municipal systems to be managed directly by the State, even if there is currently no example of this.

The direct management of municipal ownership systems is carried out through municipal services, which are governed by the legal regime of operation of municipalities and parishes. However, the last decades witnessed a trend of increasing corporatization of the sector, as Law No. 50/2012, August 31st, that revoked Law No. 53-F/2006, December 29th, and Law No. 5/2011, November 15th, approved the legal regime of local business activity and local participation, clarified the rules of creation, organization/operation and extinction of municipal services.

The delegation of the management of municipal owned services in companies in the local business sector was first enshrined in 1998 in the Local Business Sector Act, which allowed the creation of such companies. The current legal regime for local business activity and local holdings continues to provide that these companies (local companies with municipal, intermunicipal or metropolitan nature) may be in charge of the management of services of general interest, a concept including public water

supply, urban waste water sanitation and urban waste management. This management model presupposes the signing of a management contract that defines the objectives to be pursued by the company and the following pricing policy.

Municipalities can also constitute institutional public-private partnerships, selecting, through public procurement procedures, private partners for the capital of companies in commercial form (maintaining the dominant public influence).

Decree-Law No. 194/2009, August 20th, came to establish the framework of the management models of municipal services. The great innovation in relation to services in direct management is their inclusion within the water utilities regulated by the ERSAR. Since the entry into force of this Decree-Law, and as amended by Law No. 12/2014, March 6th, in addition to the requirements of the local business sector regime, the delegated management contracts to be concluded between municipalities and companies must define objectives, initiatives, investments and tariffs to follow, which are subject to revisions every five years. Where municipalities wish to establish a partnership with private companies, a minimum period of stay of the private partner should be defined, as well as options for buying and selling their shares, with a view to allowing them to leave on their own initiative or by the municipality. The partial grant of the delegated service is expressly permitted.

Decree-Law No. 90/2009, April 9th, institutionalized the possibility for municipalities to establish partnerships with the State for the management of municipal services. The partnership materializes in the conclusion of a partnership contract between the State and the municipalities, followed by a management contract between them and the system management entity, which can be a local or state business sector company. The regulation of this management model is minimalist, which will certainly be a challenge for the success of the partnerships to be established.

Law No. 75/2013, September 12th, which establishes local authorities' competences, continues to allow municipalities, through delegation, to transfer to the parish's tasks inserted within the scope of their duties. This possibility explains the maintenance of a relatively significant number of small water supply subsystems managed by parish councils (although the delegation has not always been properly formalised).

As mentioned, while concessionaires of multi-municipal water supply and wastewater sanitation systems remain subject to the rule of public shareholder control (by the State and/or the municipalities served by the system), the amendment of the Sector Delimitation Law in 2013 also allowed the operation

and management of multi-municipal waste systems to be attributed to companies whose share capital is mostly or fully subscribed by private sector companies.

The regime for the granting of multi-municipal systems, the general principles of which are contained in Decree-Law No. 92/2013, is detailed by Decree-Law No. 294/94, November 16th, Decree-Law No. 319/94, December 24th, and Decree-Law No. 162/96, September 4th, which approved the bases of concessions for multi-municipal municipal waste systems, multi-municipal water systems for public consumption and multi-municipal waste water systems, respectively. Following the opening of multi-municipal concessions for municipal waste services to private capital entities, specific bases for these contracts were approved through Decree-Law No. 96/2014, June 25th.

The creation of the systems and the allocation of their management is done by the State by decree-law, followed by a concession contract, for a period of up to 50 years. The state grantor, represented by the Ministry of the Environment, has powers of supervision, authorization, suspension and approval. With the entry into force of Law No. 10/2014, March 6th, the ERSAR was given increased responsibilities in setting tariffs and supervising the economic and financial aspects of state-owned systems. The bases of the concession contracts of the multi-municipal systems allow the sub-concession and the transfer, provided that authorized by the grantor, to a largely public capital entity. In the first case, the concessionaire retains the rights and obligations resulting from the concession contract and, in the second case, transmits them definitively to the trespasser.

Decree-Law No. 92/2013, already mentioned, also allowed the creation of multi-municipal systems by aggregation of existing systems, which implies the extinction of the latter and the concessions granted to the respective management entities, as well as the extinction of the management entities themselves, transferring the rights and obligations of the non-operational multi-municipal systems to the managing body of the new multi-municipal system.

The concessions of municipal systems were re-established, until the end of 2009, by the provisions of Decree-Law No. 379/93 and also by Decree-Law No. 147/95, June 21st, which allowed a municipality or an association of municipalities to assign the management of their system to an enterprise (of public or private capital) or to an association of users by concession contract, by prior public procurement procedure (which was governed by the provisions of the Public Procurement Code, approved by Decree-Law No. 18/2008, January 29th), dispensed when the concessionaire was an association of users recognized as a public utility. The concession contract sets out the rights and obligations of the concessionaire regarding the provision of the service, defining the formula for annual updating of tariffs,

subject to ratification by the grantor, as well as the conditions under which the concessionaire will be entitled to the replacement of the economic and financial balance, when there is a significant change in the operating conditions, by determination of the grantor or by modification of the legal and regulatory rules in force at the date of the concession. The transmission of municipal systems is not permitted, in whole or in part. Decree-Law No. 194/2009, August 20th, revised the table described above.

The rules on municipal concessions of this law complement the rules of the Public Procurement Code, not only at the level of the contracting procedure but also in the execution of the contract, with the main concern being the clarification of the division of responsibilities and risks between the parties. The maximum period of concessions has been 30 years, unlike the previous provision which allowed for a duration of up to 50 years.

In order to improve the decision-making process, it has now been required that the decision to grant (as required for the establishment of municipal enterprises, partnerships between municipalities and the State and inter-municipal systems) is required to be preceded by a study demonstrating the financial viability of the concession and the increased economic and financial rationality resulting from the development of the activity through this management model, in particular on the basis of expected efficiency gains and transfer to the concessionaire of risks that could be better managed.

Currently, all *upstream* water services are of a corporate nature and the concession management model dominates the sector. By December 31st 2018, in mainland Portugal, these utilities represented about 72% of the population and 79% of the number of municipalities (RASARP, 2019).

Multi-municipal concessions are the predominant management sub-model in the *upstream* 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 119 municipalities and a total of 3 million inhabitants (out of 10 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 (306), as referred in RASARP (2019) and it shows an intervention area equal to, or less than the area of the municipality (Rodrigues and Tavares 2017). The direct management model stands out, with 251 water utilities (including parishes), covering about 69% of all municipalities and approximately 52% of the population of mainland Portugal. Municipal services, or in-house bureaucracies, are the sub-model management with greater representation, with 184 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 *downstream* water supply sector, covering 1.9 million, 1.7 million, and 2.2 million inhabitants, respectively.

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%).

The quality of service in public water supply, urban waste water sanitation and urban waste management in Portugal has evolved greatly in recent decades, the result of a significant investment effort in the framework of a consistent public policy, and co-financing by EU funds has been decisive.

In terms of development, at the beginning of the 1990s, the coverage of the water supply service was about 80%, and this percentage has since increased continuously and significantly, having reached 95% coverage rate in 2011, a value that has been maintained until now, thus meeting the goal set in Strategic Plan for Water Supply and Sanitation of Wastewater II - PEAASAR II (2007-2013) to serve about 95% of the total population of the country with public water supply systems. It should be noted that, despite having reached the goal set for the coverage of the water supply service, calculated through the physical accessibility indicator of the service, it is verified that the value of the service's support still has the potential for improvement, registering a participation rate of about 87% in 2017, thus reflecting situations resulting from the use of alternative water sources (ERSAR, 2019).

Regarding water quality, in 2019 the country maintained the level of 99 % of safe water on the consumer's tap, corresponding to compliance with the regulatory sampling frequency very close to 100 %. This result represents a very significant evolution as in 2000 this figure was about 80%. Regarding compliance with parametric values (VP) set in the legislation in force, the results show a 99% (ERSAR, 2020).

The framework used to evaluate the quality of the service provided by water utilities, which was developed by the ERSAR with technical support from the National Laboratory of Civil Engineering, is an instrument based on the use of service quality indicators. The use of these indicators aims to determine a quantitative measure of the efficiency or effectiveness of the various components of the service provided for utilities users.

As a whole, the selected service quality indicators translate, in a synthetic way, the most relevant aspects of the quality of the service in a way that is intended to be true and balanced. The presentation of each indicator, by contributing to the quantification of the quality of the service from a given point of view, in a given area and during a given period of time, facilitates the evaluation of the achievement of objectives and the analysis of evolution over time.

The indicators chosen are typically expressed by ratios between variables. Each indicator corresponds to a processing rule, specifying the data necessary for the calculation, the unit in which it is to be expressed and its algebraic combination. With a total of 16 indicators for each area of activity, the indicators are grouped into three distinct subsystems:

• Indicators that reflect the protection of users' interests, corresponding to aspects that are directly related to the quality of the service provided to them and felt by them directly.

  • Service accessibility to users:

  AA01 - Physical accessibility of the service (%)

  AA02 - Economic accessibility of the service (%)

  • Quality of service provided to users:

  AA03 - Occurrence of supply failures [no/(1000 extensions.year)] or [no/(delivery point.year)]

  AA04 - Safe water (%)

  AA05 - Response to complaints and suggestions (%)

• Indicators that reflect the sustainability of the Managing Entity, corresponding to aspects related to its economic and financial capacity, infrastructure, operational and human resources, necessary to ensure a regular and continuous service to users.

• Economic sustainability:

AA06 - Coverage of total expenditures (-)

AA07 - Service support (%)

AA08 - Unbilled water (%)

• Infrastructure sustainability:

AA09 - Adequacy of treatment capacity (%)

AA10 - Rehabilitation of ducts (%/year)

AA11 - Occurrence of pipeline breakdowns [no/(100 km.year)]

• Physical productivity of human resources:

AA12 – Adequacy of human resources [no/(1000 extensions.year)] or [no./(106 m3.year)]

• Indicators that reflect environmental sustainability, corresponding to aspects related to the environmental impact of the management entity's activity, in particular in terms of the conservation of natural resources.

• Efficiency in the use of environmental resources:

AA13 - Actual water losses [l/(extension.day)] or [m3/(km.year)]

AA14 - Compliance with the licensing of funding (%)

AA15 - Energy efficiency of lifting installations [kWh/(m3,100 m)]

• Efficiency in pollution prevention:

AA16 - Final destination of sludge treatment (%)

These three subsystems correspond, moreover, to the main objectives of regulation: the protection of users' interests, such as price optimisation *versus* quality of services, safeguarding the viability of water utilities and their legitimate interests and safeguarding environmental aspects.

The characterisation of water services in mainland Portugal shows positive developments as well as a gradual convergence towards national objectives. The current public policies, defined almost three decades ago and adjusted throughout this period, have allowed a huge advance and generalization of these services to almost all the Portuguese population. This success has been recognized nationally and internationally, and it is therefore important to value and consolidate this experience, capitalizing on the added value obtained, with a clear awareness of the effort still needed.

This evolution contributes not only to a strengthening of regulatory activity, becoming more effective, but also to the increasing improvement of the effectiveness and efficiency of water utilities. It is

also important for other players in the sector for the provision of validated information on all management entities, also contributing to the updating of the sector's strategic plans.

The national panorama was led by the continuity of a diverse set of water utilities, with different management models and different scales, in different stages of development and with very differentiated service levels. In some systems, the necessary infrastructure is still being completed to ensure the population's access to services. Other systems are already in a phase of consolidation and performance improvement, with the focus on optimizing service management. This diversity has implications in efficiency and structural efficiency in the provision of services.

1.4. STRATEGIC POLICIES IN THE WATER SECTOR

In the field of public policies in the water sector, there is a whole strategic framework of reference covering documents of international, national and regional scope and also legal reference documents.

One of the most structuring documents at national level is the Strategic Plan for Water Supply and Wastewater Sanitation 2020: "PENSAAR 2020 - A new strategy for the water supply and wastewater sanitation sector", published through Dispatch No. 4385/2015, April 30th.

This document aimed to carry out a balance of PEAASAR II and a diagnosis of the situation (Reference Situation), the definition of the Strategic Framework through the definition of the vision, objectives, indicators, goals and scenarios, the preparation of the Action Plan, involving measures, actions, investments and financial resources, human and legal aspects, and the execution of the Management Plan, including the management, monitoring, updating of the plan and evaluation of its performance.

Taking into account the results of the analysis of the country's diagnosis in the sector, the document proposed a new paradigm based on a strategy less focused on the realization of infrastructures to increase the coverage rate of public systems, focusing more on asset management, their functioning and the quality of services provided with a comprehensive sustainability.

In fact, for the preparation of the Plan, several assumptions have been taken into account to ensure the success of this important strategic document: the identification and clarification of the causes of the problems affecting the sector, consistently and on the basis of concrete data, the definition of strategies based on sustainability objectives in all its aspects – technical, economic, environmental, financial and social – in order to create a context of global acceptance by all stakeholders in the medium

and long term and the aggregation of these medium and long-term strategies in order to create a partnership for all actors, bringing together consensus and broad commitments. Moreover, the document aimed to ensure the good governance of the sector, contributing to the high performance in a context of equity and solidarity in a sector that produces an economic and social good.

PENSAAR 2020 therefore aimed to reinforce the widespread acceptance of the strategy by users and citizens in general, recognising the good performance, quality of service provided and fair price, ensuring the future of the strategy beyond 2020.

From the balance sheet of the PEAASAR II and the diagnosis, five strategic objectives were defined that underpin the vision for the sector, underlying the premise of a sector at the service of the population and the economy of the country, which provides quality and sustainable services in environmental, economic, financial and social terms, developing on the basis of a governance in partnership, supported by the strategy.

Table 1.1. – Strategic and Operational Objectives of PENSAAR 2020.

Strategic Objective 1 Environmental protection and improved quality of water bodies	Strategic Objective 2 Improving the quality of services provided	Strategic Objective 3 Optimization and efficient management of resources	Strategic Objective 4 Economic, financial and social sustainability	Strategic Objective 5 Basic and transversal conditions
OP1.1 Compliance with regulations	OP2.1 Improving the quality of the water supply service	OP3.1 Optimizing the use of installed capacity and increasing service adherence	OP4.1 Sustainable costs recovery	OP5.1 Increased availability of information
OP1.2 Reduction of urban pollution in water bodies	OP2.2 Improving the quality of the wastewater sanitation service	OP3.2 Reduction of water losses	OP4.2 Optimization and / or reduction of operating expenses	OP5.2 Innovation
OP1.3 Increased physical accessibility to the Wastewater Sanitation service		OP 3.3 Control of undue influences	OP4.3 Reduction of water losses	OP5.3 Improvement of the operational, management and service provision framework
		OP3.4 Efficient asset management and increased rehabilitation		Op5.4 Climate change, natural disasters, risk-mitigation and adaptation
		OP3.5 Valorisation of resources and by-products		OP5.5 Externalities, employment, competitiveness and internationalization
		OP3.6 Efficient allocation of water resources		

In terms of water supply *downstream* systems, the document states that in recent years there has been remarkable progress with the implementation of WSP, following the recommendations of the WHO. This prevention methodology and risk management, "which seems to be an obligation under the next EU legislative initiatives related to water quality, should be extended to all water utilities of public water supply systems". Therefore, it will be necessary to invest in studies and acquisitions, as well as in infrastructural interventions that are essential to prevent and manage the risks identified, thus increasing water security and protecting human health.

In this same document, under its operational objective 5.4., *Climate change, natural catastrophes, risks - reduction, adaptation*, in its Measure 5.4.3., *Improvement of the processes related to the prevention and risk management of the Water Utilities, namely at the level of the development and implementation of Water Safety Plans*, Action 5.4.3.1: *Implementation of Water Safety Plans* is explicitly included.

So, it is expected that the implementation of PENSAAR 2020 may increase the guarantee of safe water through the development of risk management and assessment methodologies, namely through the WSPs. It also advocates ensuring water safety and the protection of human health through the promotion of a preventive management policy throughout the operating process, integrating risk management from the source of water, through treatment and distribution, to the consumer's tap. With regard to the guarantee of water security, it is considered that the application of measure 5.4.3: *Improvement of the processes related to the prevention and risk management of the Water Utilities, namely in terms of the development and implementation of Water Safety Plans*, represents a very important contribution in this area, which could benefit from the legal review in the sense of binding legislation for its implementation by water utilities.

As part of the SWOT analysis of the water supply and wastewater sanitation sector presented in the Strategic Environmental Assessment Document of the Plan, within the scope of the Critical Decision Factor for Infrastructures, the strong point is the “proactive role of the Regulatory Entity of the Water and Waste Services in promoting and supporting the implementation of Water Safety Plans”. As a threat, there is the absence of binding legislation for the implementation of risk management methodologies in water supply systems: “In the field of Water Safety Plans, the absence of binding legislation for the implementation of management methodologies risk in water supply systems can compromise the success of the strategy”.

Considering the above, and the fact that this Plan has adopted a strategy that had the current EU and national legal framework as structural basis, the importance that is committed to the WSPs implementation is verified.

The evaluation of the execution of the Strategic Plan for Water Supply and Wastewater Sanitation, *PENSAAR 2020 - A new Strategy for the Water Supply and Wastewater Sanitation Sector*, approved by Order No. 4385/2015, April 30th, demonstrates that significant progress has been achieved in water supply and wastewater sanitation services in mainland Portugal, in particular in terms of population coverage and the quality of the service provided.

However, this assessment also shows that it is necessary to adapt the guidelines for the sector in face of the great challenges that still exist that may call into question the results achieved, within the framework of a strategy that ensures the sustainability of the sector in the long term.

Noting that it is essential to proceed with the elaboration of a new strategic plan, in line with the previous plans, including in its scope not only water supply and wastewater management, but also rainwater management (1); Considering that the future Strategic Plan for Water Supply and Wastewater and Rainwater Management, for the period 2021-2030 (PENSAARP 2030), should constitute the guiding instrument of policies for the urban water cycle and its articulation with the remaining relevant sectoral policies (2); Bearing in mind that these policies must be adapted to the changes that have occurred in the public water supply and wastewater management services, resulting, on the one hand, from the division of multi-municipal systems and, on the other, from the aggregation of municipal systems (3); Bearing in mind that these policies must also respond to the challenges that arise, for example, due to climate change, as well as the need to align the national investment policy with the Portugal 2030 Program, in preparation (4); Considering that PENSAARP 2030 must be subject to strategic environmental assessment (5), the Portuguese Government determined the constitution of a Taskforce (GT) to prepare a draft of the strategic plan for the supply of water and sanitation of residual and rainwater, for the period 2021-2030 (PENSAARP 2030). In fact, the GT PENSAARP 2030's mission is:

- Analyze the current situation in terms of water supply and wastewater and rainwater management, including compliance with the legal regulations applicable to the sector;
- Assess the fulfilment of the goals defined within the scope of PENSAAR 2020;
- Define the lines of intervention for the water supply and wastewater and rainwater management sectors, namely in terms of the legislative framework, institutional framework, service governance, access and quality of service goals, tariff and tax policies , provision and management of financial resources,

construction and renovation of infrastructures, improvement of structural and operational efficiency, training of human resources, promotion of research and development, development of the business fabric, introduction of competition, protection, awareness and participation of users and availability of information;

- Define and specify the actions to be performed;
- Define the investment needs to be made to achieve the established objectives and goals, the renewal of existing infrastructures and compliance with the legal regulations applicable to the sector;
- Define scenarios and sources of financing that enhance investment with the objective of solving the problems still observed in the sector, with a view to mitigating regional disparities and guaranteeing economically and socially viable tariffs;
- To monitor the process of preparing the strategic environmental assessment of the plan and ensure coordination with the respective work for the preparation of PENSAARP 2030;
- Define the model for monitoring and monitoring the execution of the plan;
- Proceed with the preparation of the final version of PENSAARP 2030 after all consultations.

Also relevant in the elaboration of the strategy was the European Commission's view on community support, which is expressed in the document Position of the Commission Services on the development of the partnership agreement and programs in Portugal for the period 2014-2020. In addition to this international document, the important inputs of the Europe 2020 Strategy, the European Strategy for Adaptation to Climate Change (COM (2013) 216), as well as the European Innovation Policy for the Sector can be added. Through a communication from the Commission (COM (2012) 673) to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, a matrix is presented to preserve Europe's water resources - *Blueprint, a safeguard to Europe´s waters*. This document defines actions aimed at better implementation of water legislation and integration of water policy objectives in other policies, and aims to fill existing gaps, especially in terms of efficient water use. The aim is to ensure that there is enough quality water in sufficient quantity to meet the needs of the population, the economy and the environment within the European Union.

Returning to the strategic reference framework with regard to national documents, the National Program for the Efficient Use of Water (PNUEA), the Operational Program for Sustainability and Efficiency in the Use of Resources (PO SEUR), the National Policy on Climate Change (PNAC), the National Strategy for Adaptation to Climate Change (ENAAC) and the National Strategy for Sustainable Development (ENDS 2015). Also, at the regional level, the Hydrographic Region Management Plans (PGRH), the Coastal Management Plans (POOC), and the Regional Action Plans 2014-2020, among several others.

Even though there is no particular relevance, at this point, to better explain the specific contributions of each document to the topic under study, they are, nonetheless, referred to, as in a future development of the present work it may be seen with interest.

Bearing in mind the vast legislative framework relevant to the context under study, and since a brief approach has already been made about the sector's management and organization models, regulation, municipal competences and of the public business sector, due to its relevance to the present work, public policy details on the quality of water for human consumption are now presented.

Water is one of the most heavily regulated areas in the European Union's environmental policies, from the themes of bathing water, groundwater and water for human consumption (Wright and Fritsch, 2011).

In fact, and as mentioned before, in the European Union, the first Directive on drinking water was published in 1980 (Council Directive 80/778 / EEC, July 15th). This legal document was repealed by Directive 98/83 / EC, of the Council of November 3rd, which incorporated the technical and scientific advances recorded in the meantime, concentrating the mandatory compliance on essential quality parameters. Decree-Law No. 243/2001, September 5th, which transposed Directive 98/83/EC into national legislation, established that “water intended for human consumption must be characterized by not containing microorganisms, parasites, nor any substances in quantities or concentrations that pose a potential hazard to human health, as well as meeting the minimum requirements set out in parts A) and B) of Annex I and generally respecting the values of the parameters in Part C) of Annex I”. This document also provided that, in order to guarantee the quality of the water supplied to consumers, the water utility of the supply system should (...) "submit a quality control program to the approval of the competent authority" (...), " carry out the verification of water quality, with a view to demonstrating its compliance with the water quality standard "(...)," carry out sampling corresponding to the conformity assessment, periodically, throughout the year, in order to obtain a representative image of the quality of the water distributed by the respective systems in that period of time ”.

In practice, the guarantee of the quality of water for public supply was based on the detection of undesirable microbiological, physical, chemical and radiological constituents, potentially hazardous to human health, through the analysis of compliance of the results obtained in monitoring the quality of the water supplied to consumers with the parametric values stipulated in the legally established norms. This approach guarantees adequate quality standards for water for human consumption, especially in

industrialized countries, resulting in high levels of consumer confidence in the quality of the service provided to them (Vieira, 2005).

However, this quality control methodology had a number of serious limitations, some of which related to the following aspects:

• There is a limited correlation between pathogenic microorganisms possibly present in the water and the indicator organisms generally adopted in the standards on which the quality control methodology of the final product is based. Recent investigations, carried out in cases of outbreaks of waterborne diseases, have shown their occurrence in the absence of E. coli, for example. In reality, there has been a weak correlation between bacteriological indicators and viruses and pathogenic protozoa, perhaps due to their different disinfection-resistant capacity.

• The analytical methods used in the monitoring of microbiological parameters are, in general, long enough to serve as an element to prevent accidental situations. This type of control only makes it possible to check whether the water was suitable (or unfit) for consumption, after being supplied to consumers.

• The statistical significance of the results of monitoring the final product is limited. On the one hand, the volumes of water submitted to monitoring for compliance with the standards are relatively insignificant when compared to the volumes of water distributed; on the other hand, the sampling frequencies generally adopted in public water distribution systems hardly guarantee an adequate representation, both temporally and spatially (Vieira 2005).

With the evidence of these limitations of the "end-of-line" compliance monitoring, the consumer is not guaranteed, categorically, the necessary confidence in the water supplied. It was therefore justified to evolve towards technical management methodologies based on risk analysis and control at critical points in the supply system. The application of principles of risk assessment and management in the production and distribution of water for human consumption complements the control carried out by monitoring compliance of the final product, reinforcing security in guaranteeing water quality and protecting public health (Fewtrell and Bartram, 2001).

Thus, the safe supply of water for human consumption presupposes a concerted and structured control action throughout the entire supply system, from the source of raw water to the consumer's tap (Vieira, 2005).

Without prejudice to the overall positive results achieved for the quality of water intended for human consumption, it was understood, in fact, as urgent the revision of Decree-Law No. 243/2001, September 5th. Therefore, the publication of Decree-Law no. 306/2007, August 27th, revised the water

quality regime for human consumption based on the experience of applying the previous legislative framework and diagnosed improvement needs.

In this review, and among others, it was essential to define and implement an operational control program, since regular and frequent control of all components of the supply system is essential, in order to optimize the quality of water for the consumer.

On the other hand, the experience resulting from the application of the revised regime supported the need to introduce new parameters in the control of water quality, taking into account the existence, in some areas of the country, of water with high or aggressive hardness, or with frequent appearance of cyanobacterial blooms, reasons why they should be controlled through the analysis of specific parameters. As water for human consumption can be supplied through public or private supply systems, it has also become necessary to proceed with the specificities of the latter.

Relevant to the decision to revise the diploma was also the need to better adapt national legislation on the quality of water for human consumption to Directive 98/83/EC, of the Council, November 3rd (a reference also to the fact that necessary to resolve the pre-litigation problem with the European Commission regarding the transposition of that Directive).

In addition to setting the values applicable to various parameters, under the establishment of quality standards, the Directive provided, in Article 7 (1) - Control - that "Member States shall take all necessary measures to ensure carrying out regular checks on the quality of water intended for human consumption in order to evaluate whether the water made available to consumers meets the requirements of this Directive, in particular the parametric values set in accordance with Article 5. Representative samples of the quality of the water supplied must be taken throughout the year. In addition, Member States shall take all necessary measures to ensure that, whenever disinfection forms part of the treatment scheme or distribution of water for human consumption, the effectiveness of the applied disinfection treatment is verified and that contamination by by-products disinfection is kept as low as possible without compromising disinfection". In point 2. it reads: "In order to comply with the obligations set out in paragraph 1, the competent authorities shall establish adequate control programs for any water intended for human consumption. These programs must meet the minimum requirements set out in Annex II".

Visiting the aforementioned Annex II, it can be seen that, in addition to defining general objectives and monitoring programs for water intended for human consumption, defining parameters and frequencies, and sampling methods and sampling points, a part is provided (Part C) dedicated to risk assessment. It can be read in point 1. "Member States may provide for the possibility to derogate from

the parameters and sampling frequencies in Part B, provided that the risk assessment is carried out in accordance with this Part''. In point 2., “The risk assessment referred to in point 1 must be based on the general principles of risk assessment set out in relation to international standards, namely the EN 15975-2 standard on 'safety in water supply for human consumption, guidelines for risk management and crisis management”. Finally, an allusion to point 6., under which “Member States must ensure that (a) risk assessments are approved by their competent authority; and b) Information is available that demonstrates the performance of a risk assessment, as well as a summary of its results”.

Thus, it appears that the bases have been laid for the elaboration of a risk assessment with regard to the quality of water for human supply, namely under the standard EN 15975-2 on “safety in water supply systems intended for human consumption, guidelines for risk management and crisis management ». This was not, however, transposed into national law through Decree-Law no. 306/2007, of 27 August.

However, and even before addressing this standard, it should be noted that Directive 98/83/EC, of the Council of 3 November, on the quality of water intended for human consumption, has since been amended through Directive (EU) 2015/1787 of the Commission of 6 October 2015, amending its Annexes II and III.

It is therefore important to allude to the terms of this new Directive, which has been transposed into national law in the form of Law-Decree No. 152/2017, December 7th.

Comparing the terms of Annex II of Directive 98/83/EC, of the Council, November 3rd, with the text presented in Directive (EU) 2015/1787, of the Commission, October 6th, it appears that, in its fundamentals, the content regarding the risk assessment and the competences of such accomplishment is maintained. However, the latter diploma expressly contains the following: “Since 2004, the World Health Organization has developed the approach related to the Water Safety Plan, which is based on risk assessment and risk management principles established in its GDWQ. These guidelines, together with the EN 15975-2 standard, on safety in water supply systems for human consumption, are internationally recognized principles on which the production, distribution, control and analysis of water parameters are based. Annex II to Directive 98/83/EC should therefore be aligned with the most recent updates to these principles”. Furthermore, “In order to control risks to human health, control programs must ensure that measures are in place throughout the entire water supply chain and analyse information from bodies of water used to capture water drinking (...)”.

Despite the fact that the subject of risk assessment is already in the Directive previously in force, it is at this stage, with the publication of the new Water Quality Directive, Directive (EU) 2015/1787, that explicitly appears the reference to WSPs.

This concept, which emerged in 2004 following the International Conference - "Water Risk Management Strategies for Human Consumption" (Berlin, 2003), is considered within the scope of the WHO´s recommendations for the quality of water for human consumption, specifically in the publication GDWQ, introducing a new approach to risk assessment and management of water supply services for human consumption.

As previously mentioned, the concern with ensuring the quality control of drinking water is not new, as there is already an example of the methodology of WSPs incorporated in the good operating practices of water supply services, namely through processes certification. However, the implementation of this approach, because it is integrated, and not just focused on compliance with parameters at a given point, because it is open and transparent and because it is based on the concept of continuous review and improvement, will certainly increase capacity system response to situations that may jeopardize the security of supply, as well as the confidence of consumers and all interested parties in the supply process (Vieira, 2005).

Similarly, to what happened in the past with other recommendations of the WHO, there is a progressive trend of incorporating this methodology in public policies regarding water intended for human consumption, embodied in national and international legal regulations. This confirms the relevance that is attributed, in terms of public policies on water for human consumption, to the implementation of a tool that allows risk assessment and the implementation of management measures throughout the process.

Also important is to address the international regulatory framework that directly concerns public policies in the water sector, namely Standard EN 15975-1: 2011 + A1: 2015 (E) and Standard EN 15975-2: 2013, as well as the structuring document of the WHO, the GDWQ, since they constitute basic fundamental elements with regard to the elaboration of public policies in water supply.

Standard EN 15975-1: 2011 + A1: 2015 (E) presents the fundamentals of crisis management, including the relevant recommendations for drinking water providers (Water Utilities), and offers examples from national organizations and authorities that contribute relevantly in crisis and disaster management.

Following the approach of Standard 15975-1: 2011 + A1: 2015, it is also important to briefly introduce Standard 15975-2: 2013, a complement to the first, which focuses on risk management in all

elements of the supply chain of drinking water supply (protection of sources, water abstraction, transport, treatment, storage and distribution).

The standard states that this will contribute to the fulfilment of drinking water requirements by suppliers, or water utilities, in order to guarantee the safety, reliability, sustainable and environmentally friendly and economical operation of their water supply system, the in order to provide drinking water at consumers' taps.

As mentioned earlier, across Europe there are many different ways of organizing water supply. Responsibility for risk management may vary according to the legislation and the nature of the organizations involved (public or private) and national legislation may impose definitions that differ from those contained in the standard. In this case, the necessary adaptations must be made in its application.

This standard incorporates fundamental elements of the WHO's approach to WSPs. As such a Plan is based on risk management, the approach helps to avoid potential damage to the supply. The objective is to support the water utility to actively address security issues in the context of the routine management and operation of the water supply system.

The implementation of a risk management approach is of added value in that it supports the systematic assessment of the installation of the water supply system, the diligent performance of the system management, as well as the identification and prioritization of improvements and updating of needs. In addition, it improves communication between stakeholders, particularly those who share responsibility in the water supply chain.

The general approach to risk management employs the most general principles of value analysis that can be applied in various fields of business activity. This approach helps to reinforce the importance of internalizing risk management in water supply within the water utility.

Thus, this standard describes the principles of a risk management approach to improve the integrity of the drinking water supply system, involving all entities and stakeholders who share responsibility for the provision of safe drinking water throughout the supply chain, from the source to the point of use (protection of resources, collection, treatment, storage, transport, distribution and water installations inside buildings).

A brief parenthesis to allude to HACCP – Hazard Analysis and Critical Control Point, as it constitutes an internationally recognized methodology of structured operation that assists the food and beverage industry in identifying its risks safety and legal compliance. The principles and guidelines for

the implementation of HACCP were adopted by the Codex Alimentarius Commission, having a scientific basis for the identification of specific hazards and measures for their control to guarantee safety, being also applicable to the water product. In fact, and as Hamilton et al. (2006), most of the WSPs published are based on forms adapted from the HACCP procedure.

According to Codex Alimentarius, for the implementation of a HACCP system, the various principles must be considered, from the outset:

• Identify the dangers and preventive measures, that is, identify any dangers that should be avoided, eliminated or reduced to acceptable levels;
• Identify the critical control points, that is, identify the critical control points in the phase or phases in which control is essential to avoid or eliminate a risk or to reduce it to acceptable levels;
• Establish critical limits at critical control points, which separate acceptability from non-acceptability with a view to preventing, eliminating or reducing identified risks;
• Monitor / control each critical control point, that is, establish and apply effective surveillance processes at critical control points;
• Establish corrective measures when surveillance indicates that a critical point is not under control;
• Establish verification procedures to be carried out regularly, to confirm that the measures referred to in the previous principles work effectively;
• Create a registration system for all the controls carried out, through the preparation of documents and records appropriate to the nature and size of the companies, in order to demonstrate the effective application of the measures associated with all other principles.

Out of curiosity, HACCP originates from a theory of microbiologists from the 1930s, having been developed, in the late 1960s, by the American company Pillsbury, in conjunction with NASA - National Aeronautics and Space Administration- and the US Army Laboratories in Natick, for the NASA space program - APOLO project, in order to develop safe techniques for providing food to NASA astronauts.

In the 1970s, it was applied to the American canning industry and, in 1980, the World Health Organization and the Food and Agricultural Organization (FAO) of the United Nations recommended its application to small and medium-sized companies. HACCP was, therefore, a method initially developed by the private sector in order to guarantee product safety.

In 1993, through Directive 93/43/EEC, HACCP became part of European regulations, and in 2006, Regulation (EC) 852/2004, of the European Parliament and of the Council, April 29th 2004, on the hygiene of foodstuffs, and repealing Directive 93/43/EEC, stipulates in its Article 5 that all food sector

operators must create, apply and maintain a permanent process or processes based on the 7 HACCP principles.

A reference also to the NP EN ISO 22000: 2005 standard. This standard, referring to food safety, focuses on the presence of hazards associated with food at the time of consumption (ingestion by the consumer). As the introduction of these hazards can occur at any stage of the food chain, it is essential to have adequate control throughout it. Consequently, food security is ensured through the combined efforts of all parties that make up this chain.

Organizations involved in the food chain range from animal feed producers and primary producers, through food manufacturers and operators and subcontractors in charge of transport and storage, to retail and sales outlets (together with interrelated organizations, such as manufacturers of equipment, packaging material, cleaning agents, additives and ingredients). Service providers are also included.

This International Standard specifies the requirements for a food safety management system combining the following key elements, which are generally recognized as essential, to ensure the safety of foodstuffs along the food chain, until their final consumption:

- Interactive communication;
- System management;
- The prerequisite programs;
- The HACCP principles.

This International Standard therefore integrates the principles of HACCP and the stages of application developed by the Codex Alimentarius Commission. Via auditable requirements, it associates HACCP with the prerequisite programs. Hazard analysis is the essential element of an effective food safety management system, as it helps to organize the knowledge necessary to establish an effective combination of control measures. This International Standard requires that all hazards reasonably expected to occur in the food chain, including hazards that may be associated with the type of process and the facilities used, be identified and assessed. As such, it provides the means to determine and document why certain identified hazards need to be controlled by a particular organization and others do not.

The purpose of this International Standard is to harmonize, globally, the requirements for food safety management by food chain operators. It is particularly intended for application by organizations seeking a more focused, coherent and integrated food safety management system than is generally

required by legislation. It requires the organization, through its food security management system, to meet all applicable statutory and regulatory requirements related to food security, and water for human consumption may be included in this context.

Finishing this brief description concerning strategic documents that guide public policies in the water sector, specifically the standards that are most relevant to the present work, it is also important to refer again the document issued by the WHO - Guidelines for Drinking Water Quality.

In its preamble it reads: “Access to safe water is essential for health, a basic human right and a component of effective policies for the protection of health”.

In fact, the importance of water, wastewater sanitation, waste collection and hygiene for health are themes that have been reflected in the results of a whole set of international political forums, namely health-oriented conferences, since the years seventy of the last century.

The Millennium Development Goals adopted by the United Nations General Assembly in 2000 and the results of the World Conference on Sustainable Development in 2002 are two more examples from which the importance of such themes emanates, adding the reference to declaration by the UN General Assembly for the period 2005-2015 as the International Decade for Action "Water for Life". Also, a reference to the 17 Sustainable Development Goals (SDG) for 2030, of the UN, where the theme of water has a high profile, namely at the level of its objective 6 - drinking water and sanitation. More recently, the UN General Assembly has declared access to drinking water and sanitation essential human rights for the full enjoyment of life for all other human rights.

The three editions of the GDWQ were published in 1983-1984, 1993-1997 and 2004, as successors to the previous international standards for drinking water, already published in 1958, 1963 and 1971. Beginning in 1995, the guidelines were kept up to date through a review process, which led to the regular publication of addenda that add or replace information contained in previous volumes, as well as expert assessments of necessary key issues. preparing for the development of the Guidelines.

The WHO's Water, Sanitation, Hygiene and Health Unit led the process of developing the fourth edition of the Guidelines, under the Chemical Safety Program, providing information on chemical risks. The Radiation and Environmental Health Unit provided information on radiological risks, with the work having received consultation and advice from all six regional offices of the WHO and also in close partnership with EU Member States.

The edition replaces the previous editions of the International Guidelines and Standards and develops concepts, approaches and various information from previous editions, including the global risk management approach aimed at guaranteeing the quality of drinking water, considering:

• Water safety, including minimum procedures and specific values, and how the latter are intended to be used;

• Approaches used in determining guidelines, including reference values;

• Microbial risks, which continue to be the main concern in both developing and developed countries. Experience has demonstrated the importance of a systematic approach to guarantee microbial safety. The updated edition of the document is based on the principles of prevention introduced in the third edition in order to guarantee the microbial safety of drinking water, highlighting the importance of protecting the water source;

• Climate change, which results in changing water and rain temperature patterns, severe and prolonged drought or increased flooding, and their implications for water quality and water scarcity, recognizing the importance of managing these impacts as part of water management strategies;

• Chemical contaminants in drinking water, including information on chemicals not previously considered, such as pesticides used for control, reviews of existing chemical technical data sheets, taking into account new scientific data, and, in some cases, reducing the coverage of the Guidelines in light of new information that suggests a lower priority;

• The main chemicals responsible for large-scale health effects through exposure, including arsenic, fluorine, lead, nitrate, selenium and uranium, providing guidance on identifying local priorities and how to manage them;

• The role of different stakeholders, in order to ensure that water is safe. The fourth edition of the Guidelines promotes the discussion introduced in the third edition regarding the roles and responsibilities of the main stakeholders to ensure safe drinking water;

• Orientation to situations other than traditional ways of supplying communities, such as rainwater collection and other systems.

The guidelines, aimed primarily at water and health regulators, policy makers and their advisors, to assist in the development of national standards, are accompanied by a series of supporting publications, which include examples of risk assessments in international peer-reviewed publications, and other publications explaining the scientific basis for the development of the Guidelines and providing guidance on good practice in their application. It also presupposes guidelines for the surveillance and control of supply, monitoring and evaluation of drinking water quality in community sources.

Recognized as representing the United Nations system's position on drinking water quality and health issues by "UN-Water", the body that coordinates United Nations agencies and programs concerned with water issues.

1.5. RELEVANCE OF THE STUDY

Water is the sector with the most comprehensive coverage in EU environmental regulation. EU water directives have effected considerable changes in national legislative statutes even in the countries with the most developed environmental regulation. Being a cornerstone of EU environmental policy, the emphasis has gone from public health protection to environmental protection *per se*, and from ''end-of-pipe'' solutions to preventative and integrated management approaches (Kallis and Butler, 2001).

The transposition of all new strategies concerning mandatory risk assessment in the water sector to the Portuguese national legislation imposed the revision of public policies in use and the impacts on water utilities were expected to be severe in technical, economical and in governance terms. Moreover, all previous experiences with the application of risk assessment procedures in the water sector were not actively monitored, nor were their results published, and, therefore, there was a striking lack of knowledge and practical information.

Being water supply a structural and irreplaceable service, essential for the promotion of public health, economic activities and environmental protection, ensuring that these conditions are preserved is a rising concern, compounded by the growing and worrying problem that changes in the climate and the environment represent. Adaptive changes are already taking place, and others are expected to be required, contributing to the minimization of climate change impacts on water utilities and, inherently, on water quality. Still, during the bibliographic research, it became clear that the impacts of climate change on water quality modification and the strategies to minimize all its effects was not a common issue as limited scientific papers have been published until recently. So, promoting a study about this theme became of utmost relevancy.

Therefore, it is the author's conviction that this thesis and its topics are of greatest importance and very timely, allowing and contributing to a more vigorous reflection about water sector policies by Portuguese Public Administration, water utilities and the scientific community. This discussion is decisive for an enhanced implementation of all the changes that are currently underway in the sector and in the related public policies.

Additionally, in all this context, it is relevant to acknowledge that water utilities in Portuguese municipalities and its management models are very much associated with local authorities' decisions. In fact, the water supply sector is highly fragmented into a large number of utilities with different management models, which is, partly, the result of the fragmented nature of urban policies with an implicit variety of urban agendas that is reflected in many political and practical domains (Pires and Fidélis, 2015), as the discretionary political decisions in the water sector.

In sum, issues involving water quality for human consumption and the strategies to promote concerted and structured control action throughout the supply system, from the origin of raw water to the consumer's tap, are crucial to the water sector. In addition, governance issues cannot be neglected as they play a fundamental role in all processes, namely concerning water utilities internal e external relations, assuring the necessary resources and technical skills, and promoting the best interagency relations.

1.6. METHODOLOGICAL APPROACH AND RESEARCH QUESTIONS

The methodological approach involves a mix of methods, defined and applied according to the objectives of each of the three main dimensions of the thesis.

After the introductory chapter, Chapter 2 provides an historical background on public water supply, safety problems and an extended review of the empirical literature on water safety planning by separately focusing on developed and developing countries. It is also relevant to the identification of the main factors affecting the implementation of water policies and, more specifically, water safety planning guidelines and procedures, reviewing the international evidence of the adoption and implementation of WSPs in water utilities all over the world. This first part is intended to conduct a diagnosis that allows a better understanding of the state of the art. It seeks to list key lessons that can be learned from those WSPs experiments documented in the empirical studies and help the Portuguese legislator to better implement the necessary adjustments to the national legal framework as result of the publication of the Directive (EU) 2015/1787, October 6th, on water quality for human consumption, as well as the strategies to allow for a better and successful implementation.

The analysis of the case studies and findings suggests that there are four critical dimensions and key elements of accomplishment in developing and implementing WSPs: leadership commitment, technical knowledge, governance, and interagency collaboration. This chapter concludes that there are

many challenges associated with implementing a risk assessment methodology such as a WSP, not only regarding the operational perspective and all technical options, but also in terms of governance issues.

And exactly because it was relevant to better understand the Portuguese state of the art concerning risk assessment strategies in the water sector that a more specific study in that matter became fundamental to prevent any constrains when adjusting the national legal framework as result of the publication of the Directive (EU) 2015/1787. Consequently, the factors that determined the voluntary implementation of WSPs in Portuguese water utilities before it became a mandatory public policy tool were extremely relevant to extract a set of recommendations for further efficient implementation of WSPs projects.

The second objective of this study, presented as Chapter 3, was, therefore, to learn about which factors influenced the voluntary adoption of a risk assessment process by water utilities in Portugal, prior to the changes performed to the national regulatory framework. Specifically, it explores whether the governance arrangement of water utilities – in-house bureaucracies, municipal corporations, concessions to private firms or public-public partnerships – affects the likelihood of adoption of a WSP.

So, the first hypothesis formulated was the following:

H1: The mode of governance of water utilities affects the likelihood of adoption of a WSP.

The dimension of the water utility was also explored to perceive if it is a relevant factor:

H2: Water utilities serving more population are more likely to adopt a WSP.

On the other hand, the technical capacity of the water utility can be recognized for its prior experiences in implementing standard management procedures, such as quality certification, and, for that purpose, we tested the following hypothesis:

H3: Water utilities with prior experience in water quality certification and international standards are more likely to adopt a WSP.

In order to answer all hypothesis/questions, the research carried out was exploratory, based on a cross-section study of the universe of Portuguese water utilities, in the period of 2016/2017. Data was collected through a questionnaire using a tool of open-source surveys, complemented with an in-depth interview with the Regulatory Authority for Water and Waste Services (ERSAR).

Survey questions were selected and organised in three different components. Firstly, regarding the identification and characterization of each water utility:

- Identification of the water utility;
- Classification depending on the activities carried out (*upstream* system/ *downstream* system);
- Model/structure of governance;
- Certifications;
- Dimension.

Secondly, technical questions about the specific subject of the implementation of WSP:

- Methodology used;
- Scope of application;
- Resources used;
- Advantages and disadvantages observed;
- Major difficulties encountered;
- Reasons of application/non application.

Finally, questions that embody governance issues:

- Administrators´ role and involvement;
- Regulator´s role and involvement;
- Advantages and disadvantages observed;
- Major difficulties encountered;
- Reasons of application/non application.

The questionnaire targeted 258 utilities and 179 utilities responded to our survey, representing 69.4%. The survey was carried out with the direct collaboration of ERSAR, as was presented to the water utilities via e-mail, with indication of the link to the questionnaire, also placing it in a forum of its Portal. This represented a huge benefit, as it was possible to have a larger gamut of answers.

The main findings of this stage of the research support the idea that governance arrangements make a difference when it comes to the adoption of a WSP methodology, suggesting that water utilities run by in-house bureaucracies are less prone to adopt WSPs. This finding should alert ERSAR to the need for an eventual appraisal of the governance models of the water sector, otherwise the new mandatory strategy may be compromised. A similar problem may be found in smaller utilities, as the dimension of water utilities is also an important determinant, with utilities serving above 50 000 residents or more than 10 000 m^3/d being more likely to implement WSP. Lastly, the results also suggest that certification is an important pre-condition for the adoption of WSPs, even if the type of certification is not determinant. Even though the legal framework in place has that requirement regarding Quality, Environment and Safety and Health, and the sector's performance indicators has its implementation as a positive criterion, it has not

been regarded as mandatory nor has been promoted or sponsored by ERSAR nor by national policies. This should also be a matter of consideration.

Chapter 4 presents the third paper, having climate change as the central topic and newly required approach regarding the implementation of risk assessment strategies. Hence, the third dimension of the study intended to explore the problems in water quality and quantity connected to climate change and its implications in the water sector policies. Having that in mind, we reviewed the literature on climate change effects on water quality and public health, including several technical publications and documents from the two water utilities that were the scope of this third paper.

As WSPs are viewed as part of the solution, contributing to minimize climate change impacts on water utilities and, inherently, on water quality, the research question *Are climate change concerns an input considered in updating Water Safety Plans?*, seeks to examine the adjustments made over time to the WSP of an upstream system comprising a pioneer multi-municipal system in the implementation of a risk assessment strategy and of a downstream system, both Portuguese water utilities.

Results gathered by studying all WSPs documents and their modifications show that the WSPs of both water utilities are being amended in response to new public policies and regulations designed to mitigate climate change, always aiming to attain water quality for human consumption.

Overall, we propose a set of relevant guides to integrate climate change concerns in this process of the mandatory implementation of WSPs. The goal is to define, in advance, the measures that will enable this legal obligation to be transformed into an effective opportunity to implement EU public policies in the water sector with the desired success.

CHAPTER 2

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

2.1. INTRODUCTION

Water supply is essential to public health, quality of life, environmental protection, economic activities 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.

2.2. 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.

2.3. 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.

2.3.1. 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:

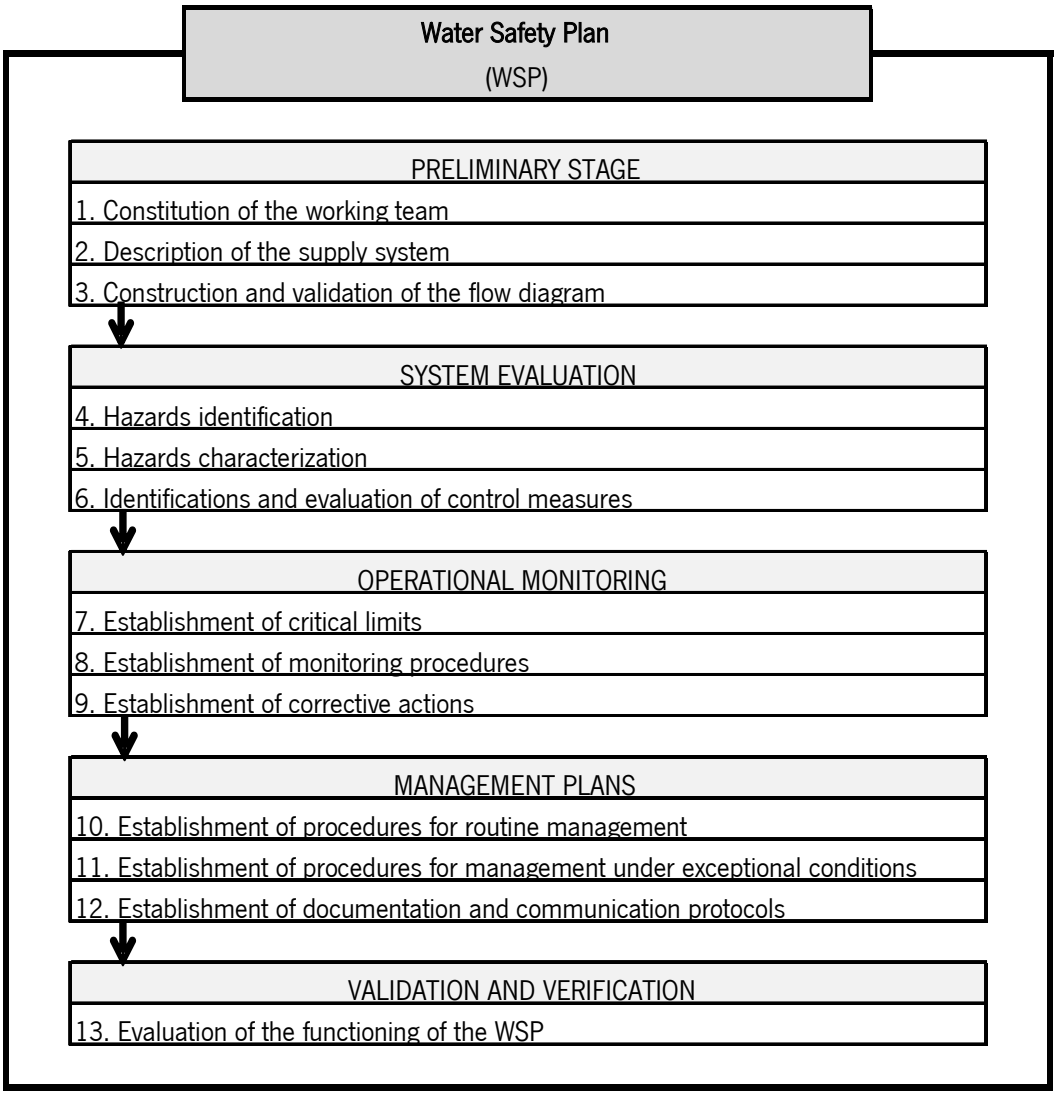
• System Evaluation – process analysis and risk assessment encompassing the entire supply system, from the water source to the consumers' taps;

• 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.



Source: Vieira and Morais (2005)

Figure 2.1. – Framework for the development and application of a WSP

2.3.2. 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[1] 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.*, 2012a; 2015).

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.,* 2012a; 2015) and an important instrument for improving water quality and minimizing illnesses (Gunnarsdottir *et al.*, 2012).

Australia has legal requirements for water safety planning. And 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

[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.

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 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.

2.3.3. 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 and Phil-Eze (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.

2.3.4. 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).

Several empirical studies underline the need for a strong 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 relations, 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 *et al.* 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: coordination and data sharing 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.* (2003) 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 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 2.1. – 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)

Table 2.1. – (continuation) Dimensions of Water Safety Planning Extracted from the Literature

MAIN CONCLUSIONS	AUTHOR
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) Ezenwaji and Phil-Eze (2014) Kayser *et al.* (2015) Omar *et al.* (2016) Perrier *et al.* (2014) Petterson and Ashbolt (2016) 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)

2.4. 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.

2.4.1. 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 result of these investments, national coverage of water supply services 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).

2.4.2. 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, other systematic data describing the outcomes of WSPs are not available yet.

2.5. 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 and Phil-Eze, 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.

CHAPTER 3

DO GOVERNANCE ARRANGEMENTS AFFECT THE VOLUNTARY ADOPTION OF WATER SAFETY PLANS? AN EMPIRICAL STUDY OF WATER UTILITIES IN PORTUGAL

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ABSTRACT

What factors influence the voluntary adoption of Water Safety Plans (WSPs) by water utilities? EU Directive 2015/1787, October 6th, on water quality for human consumption, mandates the implementation of a risk assessment process for all water utilities. The strategic approach of WSPs may be decisive for this purpose, allowing utilities to pursue a phased process of effective risk assessment with positive repercussions for public health and environmental protection mechanisms, as well as for the governance of the water sector. This article investigates the factors influencing the voluntary adoption of WSPs by water utilities in Portugal prior to the change in the national regulatory framework. More specifically, it seeks to explore whether the governance arrangement of water utilities – in-house bureaucracies, municipal corporations, concessions to private firms or public-public partnerships – affects the likelihood of adoption of a WSP. The results indicate that governance arrangements can make a difference when it comes to the adoption of this methodology, suggesting that water utilities run by in-house bureaucracies are less likely to adopt WSPs. The dimension is also a relevant factor as utilities serving above 50 000 residents or 10 000 m^3/d are more prone to adopt WSPs. Moreover, water utilities with quality management systems are more predisposed for the adoption of WSPs. Broadly, the article urges all stakeholders, mainly water utilities and national regulators, to implement measures that lead to the best results possible considering that the implementation of WSPs is a major upgrade in what water quality assurance is concerned.

Key Words: Water Safety Plans; Water utilities; Water supply; Drinking water quality; Governance; Ownership

3.1. Introduction

In 2010, the United Nations (UN) General Assembly declared access to safe drinking water and sanitation a human right, essential to the full enjoyment of life and all other human rights. This recognition that water quality at affordable prices for all is the key condition for the promotion of public health, environmental sustainability, and quality of life implies an obligation for States to respect, protect and ensure that right.

Water quality for human consumption represents, therefore, an utmost important issue for public health and the environment, and recent technical and scientific advances have led to new policy approaches. Besides concentrating the obligation of compliance on essential quality parameters, the safe supply of water for human consumption requires rigorous and structured control action throughout the entire supply system, from catchment to consumer (Vieira and Morais 2005; WHO 2011).

Still, a distressing prevalence of water quality-related crises outbreaks remains in the developed world, with causes ranging from technical failures to institutional lapses and, in the extreme, negligence of operating and managerial staff (Hrudey and Hrudey 2004; Plummer *et al.* 2010; Jetoo *et al.* 2015). In order to tackle these issues, the water sector is formalizing and adopting explicit approaches to risk management and decision-making that have formerly been implicit (Pollard *et al.* 2004, 2008). In the European Union, Directive 2015/1787, October 6th, explicitly refers to the adoption of water safety plans (WSPs) as new tools to achieve comprehensive risk management of water supply services for human consumption.

As stressed by the World Health Organization (WHO), WSPs are a comprehensive risk assessment and risk management approach from catchment to consumer, with the aim of consistently ensuring the safety and acceptability of a drinking-water supply. Globally, much of the responsibility for providing drinking water is assigned to local governments (Prudham 2004) and water utilities, as organizations responsible for implementing this new strategy, are at the center of this goal (WHO 2011).

Prior empirical studies have investigated the contextual factors of the adoption and implementation of WSPs. Several authors stress the lower rates of adoption and the challenges posed to their implementation in small sized communities (Perrier *et al.* 2014; Kot *et al.* 2017; Oluwasanya and Carter 2017; Szpak and Tchórzewska-Cieślak 2019), whereas other studies have underlined the role of community readiness as a pre-condition for successful implementation (Kot *et al.* 2015). Communities lacking technical, financial and human capacity are also likely to require simplified procedures to implement WSPs (String and Lantagne 2016). Prior experiences with water quality certification through

hazard analysis and critical control points (HACCP) and international standards such as ISO 9001 and ISO 14001 have also been associated with the likelihood of adoption of WSPs (Baum and Bartram 2017).

Yet, despite the importance of the implementation of WSPs in multiple countries across the globe, academic research on the role of water utility governance modes in the adoption of WSPs remains conspicuously absent. This article aims to fill this important lacuna by investigating the factors influencing the adoption of WSPs in a single country. While this may pose some limitations in terms of the generalizability of the study, it has the advantage of controlling for institutional and contextual variation, given that water utilities in Portugal operate under the same national legislation and regulatory framework.

The recognition of the importance in securing the highest standards in drinking water quality for human consumption has led several water utilities in Portugal to voluntarily adopt and implement WSPs. Water supply in Portuguese municipalities is managed by water utilities with varying governance arrangements, including direct provision by the municipality (in-house bureaucracy), municipal corporations, intermunicipal corporations, partnerships between the municipality and the national government (public-public partnerships), and concession contracts to private firms. This research investigates whether the governance mode is associated with the likelihood of adopting a WSP while controlling for other key enablers, such as size, number of water supply areas, prior experience with water quality certification, and the perception of the role played by the national regulator of the water sector.

The article proceeds as follows. After this introduction, section two presents an overview of WSPs, focusing primarily on prior empirical works studying the factors influencing their adoption and implementation and the gap in investigating the role of ownership and mode of governance. Section three introduces the key hypotheses of this research. Section four describes the research context. Section five introduces the methodology employed in this research and section six presents the results of the analysis. Section seven discusses the findings and policy implications for managing the water sector. The last section identifies the limitations of the investigation and the opportunities for future research.

3.2. Background on the Implementation of Water Safety Plans

Since 2004, WSPs have been recommended for preventive management of water supply in the WHO Guidelines for Drinking Water (WHO 2004). The application of WSPs has also been advocated by the International Water Association (IWA), launching the Bonn Charter for Safe Drinking Water with the overall goal of assuring "good safe drinking water that has the trust of the consumer" (IWA 2004). The emphasis on the IWA Bonn Charter, like the WHO Guidelines, is that governments need to define roles

and responsibilities through legal and institutional arrangements, preventive management, cooperation between all stakeholders, and communication of risk and water quality to consumers (Gunnarsdottir *et al.* 2015).

Data on WSPs application worldwide is unclear. A few years ago, the WHO estimated that pilot projects existed in 17 countries, while WSPs had been implemented in many water utilities in 28 countries and were required by national water regulations in eight countries (Chang 2011). Recent data suggests that over 90 countries have implemented WSPs, but widespread uptake is still uncertain due to the limited reporting of outcomes and impacts (String and Lantagne 2016). The WHO and the IWA published a report stating that 93 countries have implemented WSPs, even though at different stages of development. This report indicates that of the approximately 100 countries for which relevant data were available, 46 countries have policy or regulatory instruments in place to promote or require WSPs, with such instruments under development in an additional 23 countries (WHO and IWA, 2017). Countries where WSPs implementation is mandatory include Australia, Iceland, New Zealand, Serbia, Switzerland, Uganda, and the United Kingdom (Gunnarsdottir *et al.* 2015), while other countries have promoted technical recommendations for preventive risk management.

The WHO report (2017) presents a broad range of benefits, including improvements in operations and management, institutional knowledge, and water quality. The analysis of several case studies worldwide suggests that the implementation of WSPs in different countries, with all kinds of dissimilarities and different legal approaches, shows, nevertheless, some commonalities (Roeger and Tavares 2018): 1) the systematic identification of risks and the definition of formal procedures and activities to minimize/mitigate them; 2) a greater focus on monitoring and reporting, improved document management, and increased understanding of the supply system as a whole, supporting the supply of safe water from the source to the consumer tap and the enhancement of public health; 3) better external communication and increased stakeholder satisfaction, especially end users, as well as the improvement of internal communication in the organization; and, lastly, 4) the need for a stronger involvement of working teams, a serious commitment of leadership, and more effective inter-agency work.

In contrast, an IWA survey discusses a range of barriers that have prevented water suppliers from implementing WSPs effectively, such as lack of skills, knowledge and financial capacity, poor institutional arrangements, and uncertainty over how to best implement them (Zimmer and Hinkfuss 2007). This uncertainty may result in an unwillingness to invest in the development of WSPs. Reasons for this resistance include more work-hours for staff, competition with other projects, resistance to

change/cultural barriers, cost and time constraints, and the absence of upfront investment due to the lack of demonstrable outcomes (Zimmer and Hinkfuss 2007).

The significant variation in the adoption and implementation of WSPs, both between and within countries, justifies a closer inspection of the motives conducive to such variation. This research extends prior efforts aimed at uncovering the factors enabling WSPs (see Baum and Bartram (2017) for a recent review) by investigating the role played by the governance mode and ownership of water utilities.

3.3. Hypotheses

The aim of this research is to investigate the factors influencing the voluntary adoption of water safety plans in water utilities. More specifically, it seeks to explore whether the governance arrangement/ownership of water utilities affects the likelihood of adoption of WSPs. In order to answer this research question, the literature review serves as a source of information for elaborating a set of key hypotheses. Besides this main goal, we were also interested in whether the factors mentioned as constraints in the empirical literature apply to the context of water utilities in Portugal. This section develops these hypotheses.

The implementation of WSPs requires significant investments in human and technical capacity, particularly if the plans are to be implemented in their complete format. While financial outcomes in the form of cost savings have been reported in the literature (String and Lantagne 2016), there is also evidence that the costs entailed by the preventive measures included in the WSPs are highest at the beginning phase of implementation (Chang *et al.* 2013). As a result, water utilities relying on external funding, either through private firms or partnerships with other public sector organizations, may be in a better position to successfully adopt WSPs.

Private firms are better able to secure bank loans or issue debt bonds in financial markets. They benefit from specialization and do not have to compete for budget allocations as water utilities run by in-house bureaucracies. The same applies to municipally owned corporations, since the widespread corporatization of water utilities in the 1990s replaced politics with professionalism (Grossi and Reichard 2008; Bourdeaux 2013; Voorn *et al.* 2017) and demonstrate higher efficiency (Pérez-López *et al.* 2015). Lastly, water utilities are often managed as partnerships, either with the national government or with other municipalities. Smaller utilities run as partnerships, in particular, are more likely to benefit from scale economies and additional revenue sources, and may be better equipped to deal with the financial pressures associated with the initial investment in WSPs (Bel and Warner 2015).

Given the arguments advanced above, it is expected that:

H1: The mode of governance of water utilities affects the likelihood of adoption of a WSP.

Compared to water utilities run by the municipality's own bureaucracy:

H1.1: Water utilities managed by private sector operators are more likely to adopt a WSP.

H1.2: Water utilities run as municipal corporations are more likely to adopt a WSP.

H1.3: Water utilities managed by public-public partnerships are more likely to adopt a WSP.

The challenges faced by water utilities serving small communities have been documented extensively in the literature (Kot *et al.* 2017; Szpak and Tchórzewska-Cieślak 2019). On one hand, smaller communities lack the technical capacity required to develop a comprehensive WSP. Utilities in rural and less populated communities face human resource limitations preventing specialization and a high degree of professionalization of water utility officials and staff, making them less likely to have full time staff allocated to the implementation of a WSP (Kot *et al.* 2017). On the other hand, less population served also means higher costs per capita, which discourages WSP implementation. In addition, smaller communities are also less likely to keep detailed records to allow mapping the water system, making it more costly to overcome the initial risk assessment (Perrier *et al*. 2014). In contrast, water utilities in urban areas are more likely to secure the human and technical capacity to enable the adoption of WSPs.

For all the reasons stated above, it is expected that:

H2: Water utilities serving more population are more likely to adopt a WSP.

Preventive risk management practices have not started with the adoption of WSPs. In fact, many water utilities around the world have invested in risk management since the early 2000s by following guidelines and standards promoted by international organizations. Hazard analysis and critical control points (HACCP) was adopted by the food industry since the late 1960s (Baum and Bartram 2017) and, at the suggestion of Havelaar (1994), imported by water utilities to manage risks associated with the supply of drinking water. Similarly, international standards such as ISO 9001 and ISO 14001 underlined the importance of quality control and certification at every step of the water supply system, in stark contrast to earlier practices of end product testing (Martel *et al*. 2006; Baum and Bartram 2017). Experience with these practices contributed to change the organizational culture of water utilities (Kot *et al*. 2017) and to create an enabling environment for the successful implementation of WSPs (Baum and Bartram 2017).

H3: Water utilities with prior experience in water quality certification and international standards are more likely to adopt a WSP.

The literature reports situations where the water sector regulator acts as an external auditor of the components of WSPs for compliance (Bartram *et al.* 2009). Conversely, lack of support from the national regulator is likely to cause delays in the diffusion of WSPs across the water utility sector (Gunnarsdottir *et al.* 2012, 2015). Moreover, having a positive perception of the role played by the national regulator is perhaps as important as the provision of financial and regulatory incentives to the implementation of WSPs. Regarding the adoption and implementation of WSPs as a national goal is likely to contribute to instill a preventive risk management culture and produce the desired effects among water utilities. As a result, it can be expected that:

H4: Water utilities with a positive perception about the role of the national regulatory body are more likely to adopt a WSP.

Next, these hypotheses are tested using data from water utilities in Portugal. The following section describes the water utility sector in Portugal, with a special emphasis on the adoption and implementation of WSPs.

3.4. The Water Utility Sector in Portugal

In order to understand better the adoption of WSPs in Portugal, it is important to characterize the Portuguese water sector. Water utilities have shown a positive evolution in terms of preventive strategies in recent years, as evidenced by their gradual convergence towards the national objectives defined by the 2007-2013 national strategic plan. Because of significant investment efforts sustained by a consistent framework of public policies and co-financing by European funds, the goal of serving 95% of the country's population by public water supply systems was achieved in 2011 (ERSAR, 2018a).

The Portuguese Water and Solid Waste Regulatory Authority (ERSAR) has been a major player in the water sector in Portugal and fulfills its mission by developing a quality service evaluation system for water utilities based on the use of indicators. The system seeks to develop quantitative measures of efficiency and effectiveness of the services provided by water utilities. The outcome of this process is an annual report summarizing the most relevant information related to the quality of water for human consumption. The analysis included in the report uses data from water quality control carried out by all water utilities of public supply systems in mainland Portugal as of December 31st of the previous year.

The 2017 annual report concluded that Portugal reached the target of 99% compliance with the parametric values set for water quality in the Strategic Plan for Water Supply and Sanitation of Waste Water 2014-2020 (RASARP, 2018). Since the EU deliberated that the value of 99% is compliant with Directive 98/83/EC, this represents the standard of excellence for the quality of water intended for human consumption. The achievement of this goal indicates that water at the consumer's tap corresponds to high quality levels. This value is consistent with the compliance with the regulatory frequency of sampling and water quality analyses very close to 100%, which is a remarkable evolution when compared to the year 2000, when the value was around 80%.

In terms of water sector operators, systems are classified as *upstream* and *downstream*, depending on the activities carried out by water utilities (ERSAR, 2018). This classification comprises multi-municipal systems, mainly responsible for providing services to municipalities who serve as shareholders (*upstream* systems) and water utilities serving the population through municipal systems (*downstream* systems) providing water and sanitation services.

Currently, all water utilities that supply *upstream* services are of a corporate nature and concessions are the governance mode that clearly dominates the sector. As of December 31, 2017, these utilities represented about 72% of the population and 79% of the number of municipalities in mainland Portugal. Multi-municipal concessions are the predominant governance mode in the *upstream* business, covering 174 out of 308 municipalities and more than 5.1 million inhabitants (out of a total population of 10 million). Additionally, a single company (EPAL) under delegation from the national government serves 25 municipalities with approximately 1.8 million inhabitants. In another set of municipalities, supply is vertically integrated, performing water collection and treatment as well as distribution to end-users (*upstream* and *downstream*). In mainland Portugal, this governance model covers 120 municipalities and a total of 3 million inhabitants, mainly in the north and center of the country. Lastly, 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 very low-density areas.

In contrast with *upstream* services, *downstream* water supply services are highly fragmented, as evidenced by the large number of utilities, most with an intervention area equal to, or less than the area of the municipality. In-house bureaucracies stand out, covering 70% of all municipalities and approximately 52% of the population in mainland Portugal. In the densely populated urban area of Lisbon, the governance model is one of State delegation, as in the *upstream* service, serving approximately

500.000 inhabitants. Private contracting and municipal or intermunicipal companies are also governance models with a significant share of the *downstream* water supply sector.

In-house bureaucracies dominate the *downstream* water supply. However, in the last two decades there has been a trend towards increased corporatization in the water sector. In the first decade of the 21st century, the governance models of private contracting and municipal corporations represented only 20% of the population, whereas currently they represent almost half, more than doubling their weight in the sector. This trend is also witnessed in Europe – the UK, France, Spain and Italy have all been involved in privatization processes, with diverse results (ERSAR 2018; Abbott and Cohen 2009; Berg and Marques 2011).

3.4.1. Water Safety Plans in Portugal

In Portugal, Vieira (2011) refers specifically to a WSP case study beginning in 2003 in a multi-municipal company that had an enormous success and gathered the recognition of the national regulator (ERSAR), which extended the recommendation of this risk management methodology to other water utilities. This initiative also sparked the launching of a pilot project (2008-2010) in ten water utilities of different sizes and governance arrangements, but the results of this project were never formally published (Roeger and Tavares 2018).

According to ERSAR (2018), several water utilities in Portugal have been developing and implementing voluntarily the WSP methodology in accordance with the recommendations of the WHO and the IWA. However, this has been done in an uncoordinated manner, since the national legislation on the quality of water for human consumption has only recently included this approach. With the publication of Law-Decree 152/2017, this risk management approach became mandatory and it is now based on European and international standards, in particular EN 15975-2, and the structure of the WSP approach promoted by the WHO.

3.4.2. Data and Methods

The main goal was to investigate the determinants of the voluntary adoption of WSPs. Assessing these factors should allow authorities in Portugal (and elsewhere) to identify and remediate potential shortcomings in water utilities not implementing WSPs. Gathering all relevant information about the voluntary implementation of WSPs in Portugal was vital to fulfill this goal. For that purpose, a survey

targeted at Portuguese water utilities was conducted with the direct support of the ERSAR, the National Regulator of Water and Solid Waste Services.

The empirical analysis relies on cross-sectional data collected from Portuguese water utilities in 2016 using a survey questionnaire. An email with the information of the link to an open source survey tool was sent to all water utilities with the direct collaboration of ERSAR. This represented a significant benefit, as it was possible to obtain answers from a wider range of water utilities.

The sample targeted was 258 water utilities out of a total of 319 (*upstream, downstream*, and both *upstream and downstream*) that comprise all water utilities in mainland Portugal (ERSAR 2018). The survey was not sent to 61 water utilities as they supply water to less than 1,000 inhabitants each. We received responses from 179 utilities, representing 69.4% of the 258 utilities in the targeted sample. Thirty-five utilities reported having voluntarily implemented a WSP, which represents about 20% of the answers. Almost two-thirds of the 35 utilities have only been implementing this tool since 2014, and 25 water utilities reported having a WSP under-development and expect to approve it by 2019.

In order to test the hypotheses stated above, we employ probit regression analysis with the coefficients estimated through maximum likelihood. Probit models are appropriate when the dependent variable is a binary outcome (Long 1997). In this particular case, the dependent variable is the adoption of WSPs by water utilities and is coded "1" if the water utility has adopted a water safety plan and "0" otherwise.

Three variables are included in the regression models to assess the first hypothesis: the choice of governance arrangement influences the likelihood of adopting a WSP. The first dichotomous variable indicates whether the water utility is run as a concession to a private firm (yes=1; 0=no). If the water utility is part of the local corporate sector, a second dichotomous variable takes the value of "1" and zero otherwise. This governance arrangement includes both municipal corporations with 100% of the shares owned by the local government and inter-municipal corporations with the capital shared by two or more municipalities. Lastly, the third dichotomous variable takes the value of "1" if the water utility is a partnership between the municipality and the national government (public-public partnership). The direct management governance arrangement – water utilities run by in-house bureaucracies – is the omitted category.

In order to test the effect of water utility size, the analyses include a dichotomous variable that takes on the value of "1" if the organization serves a population above 50 000 residents or over 10 000 m^3 of daily water supply. The third hypothesis states that water utilities with prior experience with quality

or environmental certification are more likely to engage in WSPs. In order to assess this, the first model specification includes a dummy variable taking the value of "1" if the water utility received at least one type of certification. As an alternative specification, the second model specification includes four dummy variables taking the value of "1" for each type of certification: quality certification (ISO 9001 or similar), environmental certification (ISO 14001), safety and security certification (SST), and other certification (HACCP, ISO 22000 and company manual). No prior certification is the omitted category.

The fourth hypothesis states that water utilities with a positive perception of the role played by the national regulatory authority are more likely to adopt a WSP. In order to assess this assertion, the models include three dichotomous variables indicating positive perceptions of the auditing, technical, and financial support provided by the ERSAR. Positive coefficients are expected for all the variables.

Lastly, both model specifications include two control variables. The first is a dichotomous variable for water utilities managing only *downstream* services, whereas the second is a count variable of the number of supply areas managed by the water utility. Table 1 displays the descriptive statistics for all the variables included in the empirical analyses.

Table 3.1. - Descriptive Statistics

VARIABLE	OBS.	MEAN	STAND. DEV.	MIN.	MAX.
Water Safety Plans	179	0.20	0.40	0	1
Concessions	179	0.12	0.33	0	1
Corporatization	179	0.13	0.34	0	1
Public-public partnership	179	0.04	0.19	0	1
In-house bureaucracy	179	0.70	0.46	0	1
Quality certification	179	0.29	0.46	0	1
Environmental certification	179	0.16	0.37	0	1
SST certification	179	0.15	0.36	0	1
Other certification	179	0.09	0.29	0	1
Any certification	179	0.33	0.47	0	1
Size (>50 000 inhabitants or >10 000 m^3/d)	174	0.20	0.40	0	1
Auditing (ERSAR)	179	0.21	0.41	0	1
Technical support (ERSAR)	179	0.86	0.35	0	1
Financial support (ERSAR)	179	0.23	0.42	0	1
Downstream system	179	0.55	0.50	0	1
Supply áreas	179	15.68	22.04	1	149

3.5. FINDINGS

Thirty-five water utilities have voluntarily implemented a WSP, representing 20% of the 179 respondents. In slightly over 60% of the cases, utilities state they adopted WSPs for innovation reasons and in about 40% in order to achieve a better knowledge of their system. 83% of water utilities implementing WSPs have seen improvements in the knowledge of their systems, 63% stated a better capacity for emergency response, 53% saw improvements in teamwork and more trained staff, and 43% have registered improvements in internal and external communication. None of the respondents identified lower costs as a relevant benefit.

Of the 179 respondents, five are *upstream* systems, of which three have implemented a WSP. Seventy-six water utilities have both *upstream* and *downstream* systems and, of these, 15% have adopted a WSP. As for the 98 *downstream* water facilities, 12.5% have implemented a WSP. About 70% of the water utilities are run as in-house bureaucracies, of which more than half (55%) are *downstream* systems. The majority of water utilities classified as private concessions and municipal corporations are also *downstream* systems (near 60%).

Water utilities serving more than 50 000 inhabitants or 10 0000 m^3/d embody 20% of the respondents and, 55% of these have implemented WSPs. Thirty percent have implemented quality management systems (ISO 9001) and approximately 20% have safety health and environment management systems (namely OHSAS 18001 and ISO 14001).

Table 2 reports the results of the probit regression analysis of the determinants of the adoption of WSPs by water utilities in Portugal. Both models perform very well, with an overall significance of 99.9% and pseudo-R^2 of 0.453 and 0.516, respectively.

The first hypothesis receives empirical support from the analysis. Water utilities run as concessions to private firms (H1a) or as municipal corporations (H1b) are more likely to adopt WSPs than in-house bureaucracies. This confirms the idea that governance arrangements can make a difference when it comes to the adoption of this methodology. In contrast, the public-public partnership model does not appear to be associated with an increased chance of adopting WSPs compared to in-house bureaucracies. These results also suggest that water utilities run by in-house bureaucracies (the omitted category) are less prone to adopt WSPs.

The empirical analysis also confirms the second hypothesis. Water utilities serving populations above the 50 000 residents or 10 000 m^3/d threshold are more likely to adopt WSPs.

Table 3.2. - Probit Regression Analysis (Dependent variable: Water Safety Plans (1=Yes) (2-No))

VARIABLES	(1)	(2)
Concession	1.15997***	1.38818***
	(0.408)	(0.458)
Corporatization	1.37911***	1.43772***
	(0.372)	(0.398)
Public-public partnerships	0.58222	0.07218
	(0.945)	(1.319)
Size	1.08946***	1.08444***
	(0.355)	(0.387)
Certification	0.77535**	—
	(0.308)	
Quality certification	—	0.47752
		(0.432)
Environmental certification	—	5.69381
		(330.207)
SST certification	—	-5.66734
		(330.207)
Other certification	—	1.54161***
		(0.558)
Auditing (ERSAR)	-0.43842	-0.90596*
	(0.367)	(0.464)
Technical support (ERSAR)	-0.15230	-0.11477
	(0.419)	(0.457)
Financial support (ERSAR)	0.44893	0.34909
	(0.369)	(0.417)
Downstream system	0.50322	0.34692
	(0.330)	(0.345)
Supply areas	0.00619	0.00694
	(0.009)	(0.009)
Constant	-2.41860***	-2.34219***
	(0.573)	(0.616)
Observations	174	174
LR chi^2 (13)	75.15	85.63
Prob > chi^2	0.000	0.000
Pseudo R^2	0.453	0.516

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Regarding the third hypothesis, the results are a bit more mixed. The first specification (1) uses a single dichotomous variable indicating whether a water utility has received at least one certification (of any kind). The results of this specification suggest that certification is an important pre-condition for the adoption of WSPs. The second specification (2) breaks down certification by type and the findings are less convincing. All the certification variables miss statistical significance with the exception of the "other certification" variable (HACCP, ISO 22000, and company manual).

Lastly, the analysis does not provide empirical support to the fourth hypothesis of this research. In general, all coefficients associated with the role played by the national regulator (ERSAR) appear to be unrelated to the adoption of WSPs. One exception is the negative coefficient obtained for the auditing variable in the second specification, suggesting that a positive perception of the regulator in terms of an auditing function reduces the likelihood of adoption of WSPs.

3.6. Discussion

While a WSP approach is considered the best method for achieving safe drinking water, the potential impact of such an approach is often overshadowed by implementation challenges (Kot *et al.* 2015). A similar conclusion can be drawn from the results obtained in our study, as 91% of Portuguese water utilities recognize the importance of a WSP, but only about 20% of those surveyed have voluntarily implemented it. In fact, half of the water utilities that implemented a WSP resorted to consulting and, among the difficulties identified by non-implementers are the scarcity of human resources (31%), the costs involved (28%) and, as the main motive, the fact that implementation was not yet compulsory (36%).

Water suppliers may view a WSP approach as creating additional and otherwise unnecessary work for already over-burdened water operators and managers (Williams and Breach 2012). For example, utilities already meeting water quality regulations may feel less motivated to adopt a WSP, seeing little incentive in proactively seeking out new or additional potential risks (Zimmer and Hinkfuss 2007; Mayr *et al.* 2012). In contrast with these findings, only 3.5% of Portuguese water utilities regard WSPs as having no benefit to the organization. This may be due to the relevant role ERSAR plays in raising awareness among all water sector stakeholders.

Where water suppliers already have quality management programs in place, the shift to a WSP approach may be seen as redundant. In a study of five German water utilities, Schmoll *et al.* (2011) found between 70% and 90% of their current practices aligned with those suggested by the WSP framework. While this did not create a barrier to a WSP integration *per se*, the authors noted that the utilities expressed concern that transitioning to a WSP might be both a financial and a time burden. More generally, utilities may perceive WSPs as a burden in terms of having to "step up their game" in response to some of the more rigorous aspects inherent in a WSP approach (Summerill *et al.* 2010a; Mayr *et al.* 2012). Our results indicate that additional costs and the need to hire qualified human resources are two of the main problems, but they also show that 69% of water utilities that have voluntarily implemented a WSP also have a Quality Management System implemented, and that may be considered as a trigger to

the voluntary implementation of a WSP. The multivariate results partially confirm this assessment, even if the positive coefficients for quality and environmental certification fail to reach statistical significance at standard levels.

Less than 10% of water utilities supplying <50 000 inhabitants or <10 000 m^3/d have voluntarily implemented a WSP. The size of the water utility is, therefore, a significant factor in the voluntary implementation of a WSP and this finding is fully confirmed in the multivariate analysis. Small water utilities are less predisposed to that commitment, presumably due to limited resources. When drawing the new legal framework, and specifying the supervisory criteria and fines, this matter needs consideration in order to secure compliance. Moreover, water utilities pointed out the lack of experience and human resources dedicated exclusively to the project as the main difficulties in the implementation of a WSP. These results confirm the findings for small-and medium-sized municipalities in Austria: financial and personnel resources are usually of very limited availability (Mayr *et al.* 2012).

While 35 national water utilities have adopted WSPs, in *upstream systems* the percentage reaches 60%. When it comes to water utilities that meet both classifications, *downstream* and *upstream*, the results are 14,5%, while *downstream systems* have a total percentage of voluntary implementation of 21,4%. These results suggest that *upstream systems* were readier to implement a WSP voluntarily. The reasons to explain this tendency are the dimension of the water utilities, as well as the fact that all are companies of the *Águas de Portugal Group*, which has procedures that recommend adoption and has a long history of implementation. The first study in this matter was conducted in 2003 in *Águas do Cávado*, one of the *Águas de Portugal* most dynamic companies in the water sector, and the replication to other companies within the same Group became an immediate reality at that time.

When it comes to concessions and corporatization, 53% have a WSP implemented and that includes *upstream systems*, both *upstream* and *downstream systems*, and *downstream systems* (respectively 11%, 25% and 64%). Only about 5,5% of water utilities under the direct management model report having voluntarily implemented a WSP, of which 43% are both *upstream* and *downstream systems* and 57% *downstream systems*. The results show a clear difference between water utilities that have a governance model of concession and corporatization and those run by direct management model. The latter are mainly represented by *downstream systems* or *upstream* and *downstream systems* of a smaller dimension, with fewer resources and less professional staff required to implement a WSP project. This result is quite robust, since the multivariate analysis indicates that the differences in the likelihood of

implementation between concessions and municipal corporations and direct management still hold after controlling for size.

3.7. Conclusions and Recommendations

This research sought to understand what factors influence the voluntary adoption of WSPs by water utilities. Three main conclusions stand out after the descriptive and inferential analyses. First, governance arrangements can make a difference when it comes to the adoption of this methodology, suggesting that water utilities run by in-house bureaucracies are less prone to adopt WSPs. Second, the dimension of water utilities is also an important determinant, as utilities serving above 50 000 residents or more than 10 000 m^3/d are more likely to implement WSPs. Lastly, the results also suggest that certification is an important pre-condition for the adoption of WSPs, even though the type of certification is not determinant.

In order to meet the requirements of Directive (EU) 2015/1787 on risk assessment and to underline all aspects to be taken into consideration in the implementation of the new legal diploma at the national level, we include a series of recommendations as the outcome of the research. First, the implementation of a risk assessment methodology is a priority to promote safe drinking water policies and should be required by law. National regulators should define the implementation of WSPs as a key performance indicator, both for benchmarking purposes and to improve performance by water utilities.

The second recommendation relates to the capacity and level of professionalization of water utilities. The implementation of WSPs requires sufficient technical capacity to attain in-depth knowledge of the supply chain, as well as a strong involvement by working teams and management bodies. In order to secure the means to implement a risk assessment methodology like a WSP, it is necessary to provide technical documentation and to invest in educational programs and training, particularly for small and midsize utilities. Financial incentives should also be considered to accomplish these goals. Water utilities run by the municipalities' workforce should be primary targets for these policies as they are the most resistant to adoption.

A third recommendation focuses on the certification of quality, environmental, and health management systems. Prior experience with certification facilitates the implementation of risk assessment methodologies. While making certification mandatory for all utilities may be impossible to demand at this time, these practices should be incentivized in order to highlight the benefits of risk assessment processes and produce the organizational buy-in as emphasized in Bartram *et al.* (2009).

Lastly, national regulators play a crucial role in the dissemination of WSPs. The implementation of management systems, as well as of WSPs, requires effective inter-agency work and engagement by the ERSAR in Portugal and other national water regulatory agencies elsewhere. In order to make inter-agency work effective, national regulators, and health and environmental organizations should have specific responsibilities and mandatory procedures to accomplish, including the publication of benchmarking reports. Although the analysis does not provide empirical support to relate the adoption of WSPs to perceptions about the national regulator, it suggests that the auditing function of the regulator negatively affects the implementation of WSPs. This should alert the regulator for the need to implement different approaches regarding this role towards water utilities by focusing on more collaborative and training strategies.

CHAPTER 4

ASSURING WATER QUALITY IN A CLIMATE CHANGE ENVIRONMENT: IS CLIMATE CHANGE AN INPUT IN THE UPDATE OF WATER SAFETY PLANS?

ABSTRACT

In a context of increasing external uncertainties deriving from changes in the climate and the environment, ensuring water in quantity and quality for human consumption is a growing concern. Studying this issue is extremely relevant, as few scientific studies have been published until recently on the impacts of climate change on water quantity and quality and in the resulting need for new strategies and revised public policies to be implemented. Even though adaptive changes are already on the way, and others are expected to be mandatory, namely legal requirements for water quality parameters, the adjustment of treatment processes and, most important, the implementation of new explicit risk assessment strategies are fundamental. Water Safety Plans (WSP) are regarded as part of the solution, contributing to minimize climate change impacts on water utilities and, inherently, on water quality.

But, are climate change concerns an input considered in updating Water Safety Plans?

After a brief description of the evolution of European and Portuguese national guidelines, we investigate the adjustments made over time to the WSPs of an *upstream system* comprising a pioneer multi-municipal system in the implementation of a risk assessment strategy and of a *downstream system* in Portugal. We assess the data regarding water quality parameters and evaluate their legal compliance, assessing whether those amendments to WSPs were the outcome of this new concern with climate change. Results show that the WSPs of both water utilities are being amended in response to new public policies and regulations designed to mitigate climate changes.

Key Words – Drinking Water Quality; Climate Change; Water Safety Plans; Water Utilities.

4.1. Introduction

Adopted by all UN Member States in 2015, the Sustainable Development Goals (SDGs), also known as the Global Goals, represent a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030.

Recognizing that action in one area will affect outcomes in others, the 17 SDGs of UN 2030 Agenda balances social, economic and environmental sustainability and countries around the world have expressed strong political will to ensure that drinking water is universally safe, as stated in SDG 6 and as already declared in 2010th UN General Assembly, that access to safe drinking water and sanitation is a human right (UN 2010; UN, 2015; ICLEI, 2017).

The measurement of this SDG 6 – Clean Water and Sanitation - is to be carried out through the indicator "safety managed drinking-water services", emphasizing the need for structured actions to prevent contamination throughout the water supply system. The time has come for policy makers and practitioners to embrace the concept of water safety planning, which is widely considered the most reliable and effective way to manage drinking-water supplies and safeguard public health (IWA, 2019).

Yet, there are innumerous difficulties to tackle as water quality and supply systems are affected by several factors, including the type of water bodies, the pollutants of concern, the hydrological regime, and many other possible sources of pollution. In addition, due to the global challenges faced with climate change, most utilities have realized that planning is key in preparing for the future and are currently building their resilience through several preventive and planning approaches (IWA, 2019a).

In fact, long-term planning for an adequate and safe supply of drinking water should be set in the context of growing doubts arising from changes in the climate and the environment. As stated by the World Health Organization (WHO), water safety plan (WSP) processes offer a systematic framework to manage these risks by considering the implications of climate variability and change (WHO, 2017). In a similar vein, the International Water Association (IWA) argues that WSPs provide a simple and robust framework for water utilities to make climate resilience assessments and to plan for progressive adaptation to climate change and current challenges, such as changing input parameters, in fulfilling their mission as water service providers (IWA, 2019a).

Thus, WSPs represent an important opportunity to contribute to the realization of the SDGs and to the human right to water, as well as to ensure social inclusion in the improvement of drinking-water supplies (WHO, 2019). Described in the WHO Guidelines for drinking-water quality as the most effective

way to ensure the safety of drinking water supplies, WSPs have been implemented in at least 93 countries worldwide, of which 69 countries reported policy instruments, either in place or under development, that promote or require WSPs or an equivalent (WHO and IWA, 2017). Water safety planning policies and practices are expected to continue to expand throughout the SDG period due to an increased focus on the safe management of water supplies.

In addition to the impacts of climate change, the future of freshwater systems will also be determined by demographic, socioeconomic, and technological changes, including lifestyle changes (Jimenez Cisneros *et al.*, 2014). All these parameters need to be constantly updated, as an essential part of the continuous revision requirements in WSPs.

This study is inspired by the commitment of the WHO and the IWA to WSPs as an optimal policy instrument to integrate all circumstances, including climate change concerns, perceived to influence the performance and quality of water utilities. We investigate the adjustments made over time to the WSP of an *upstream system* comprising a pioneer multi-municipal system in the implementation of a risk assessment strategy, and to the WSP of a *downstream system* that comprises only one municipality. We assess the data regarding water quality parameters and evaluate their legal compliance, assessing whether those amendments to WSPs were the result of this new concern with climate change.

With the research question *Are climate change concerns an input considered in updating Water Safety Plans?,* this paper proceeds as follows.

After this brief introduction, section two presents an overview about climate change and follows information on water quality for human consumption, including legal aspects and data on water quality. Next, we present information about WSPs and their implementation status. Section four describes the research context and this is followed by a description of the methodology employed in this research and results of the analysis. The last section of the article discusses the findings, identifies the limitations of this research, and highlights opportunities for future research.

4.2. ABOUT CLIMATE CHANGE

Climate change is an example of a global tragedy of the commons, since human activity moved by the benefits that accrue to self-interested individuals will have an overall negative impact on the collective, unless there is an agreed upon intervention (Patz *et al.*, 2005). More substantively, human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels,

with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018).

Global warming from anthropogenic emissions since the pre-industrial period to the present will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea level rise, with associated impacts. Risks depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and the adoption and implementation of adaptation and mitigation options (IPCC, 2018). Increasing awareness of the causes of climate change is considered key to gather public support for mitigation and adaptation policies. However, higher awareness might not always relate to higher risk perceptions (Luís *e/ al.*, 2018). In fact, climate change is a complex, multifaceted phenomenon involving various interacting systems and actors. The intensities, locations, and timeframes of the consequences of climate change are hard to predict and a cause of uncertainty (Visschers, 2018).

Climate change affects water quality through a complex set of natural and anthropogenic mechanisms working concurrently in parallel and in series. Projections on climate change scenarios are difficult to perform and interpret because they require not only the integration of the climate models with models employed to analyze the transportation and transformation of pollutants in water, soil and air, but also the establishment of a proper baseline. As a result, there are few projections of the impacts of climate change on water quality and, where available, their uncertainty is high (IPCC, 2018).

However, it is evident that water quality projections depend strongly on (a) local conditions; (b) climatic and environmental assumptions; and (c) the current or reference pollution state (WHO, 2017a). In its Fifth Assessment, the United Nations' Intergovernmental Panel on Climate Change (IPCC) for assessing the science related to climate change acknowledges, among other conclusions, that wet regions and seasons will become wetter, while dry regions and seasons become drier. There will be more frequent or intense droughts, increasing the need for artificial water storage, and there will be a decrease on natural storage and availability of water (IPCC, 2013).

Regional climates are the result of complex processes that vary strongly with location and respond differently to changes in global-scale influences. However, there is high confidence in model projections and some of the more relevant conclusions suggest that it is very likely that temperatures will continue to increase throughout the 21st century all over Europe in general, and the Mediterranean region in particular. The length, frequency, and/or intensity of warm spells or heat waves are very likely to increase throughout

the whole region and there is medium confidence in an annual mean precipitation decrease in the summer (Christensen *et al.,* 2013).

In Portugal, few research programs were financed to assess the effects of climate change in water resources and Santos (2014) elaborated a comprehensive summary:

- Progressive reduction in the annual river runoff during the 21st century;
- Runoff reduction is larger in the south, thereby increasing the current spatial asymmetry of water availability in Spain and Portugal;
- The concentration of precipitation in winter and the estimated general increase in the frequency of heavy precipitation events is likely to increase the number and severity of floods, particularly in the northern part of the Iberian Peninsula;
- Water quality will be degraded by higher water temperatures and by river flow reduction in the summer, particularly in the south.

Santos (2014) concludes that water management authorities must consider climate change as a decision variable.

4.3. Impacts on water quality

Climate change is already affecting the hydrological cycle and these changes comprise the timing and intensity of rainfall, directly affecting the quantity and quality of water resources for different users (IWA, 2019). Floods and droughts are the main impacts of climate change on water availability. Besides these quantitative impacts, surface water quality is also affected by climate change, as a drought may imply at least a modification of surface or ground water quality (concentration), sometimes leading to water supply limitations. If surface water catchment can be directly affected by water quality degradation, pumping wells can be cut off for sanitary reasons (groundwater quality) as well as for security reasons (floods threats). However, even if these facts are well known, few scientific works have been published on the impacts of climate change on water quality modification (Delpla *et al.*, 2009).

Jiménez Cisneros *et al.* (2014) showed identical conclusions as climatic and environmental issues such as floods, droughts, increased temperature, and rising sea level risks as outcomes of the changes in the hydrological cycle have a clear impact on drinking water safety. Increased drought is often associated with long-term poorer water quality, whereas more intense precipitation events tend to mobilize contaminants into water. Once present in water, low flows and reduced water levels tend to increase the concentration of pollutants and nutrients.

With concerns about climate 'extremes' growing, water is often the focus – either too much or too little. That is no coincidence: climate and the hydrological cycle are tightly coupled, and water is essential to ecosystems and societies. However, it is not just the quantity of water that matters, but also its quality. Impaired water quality is a global and growing problem, limiting resources for drinking, domestic use, food production and recreation, as well as harming ecosystems (Michalak, 2016). The types and causes of compromised water quality range from excess nutrients feeding harmful algal blooms and hypoxic 'dead zones', to bacterial, viral and chemical contamination, to pollution by personal-care products and pharmaceuticals. Cases of extreme impairment often lead to disproportionate human and ecosystem impacts. Because the most severe water quality impacts are exacerbated by weather, climate change plays a crucial part. Runoff of nutrients from farmland spikes after heavy rains and warmer temperatures accelerate the growth of bacteria and phytoplankton. As climate change alters weather patterns and variability, conditions conducive to severe water impairment are likely to become more frequent (Michalak, 2016).

Delpla *et al.* (2009) claim that research on climate change impacts on surface water quality considers the effects (droughts and floods) of the two main factors - temperature and rainfalls. These impacts depend on natural or man-built environment, and the consequences can be different according to water body type (rivers, lakes, dams, ponds, wetlands...) and characteristics (water residence times, size, shape, depth...). At the resource level (surface water), climate change may cause significant hydrologic variations, water temperature upswings, and increases of pollution load (chemical and microbiological). For treatment plants, considering that all remediation actions have been implemented (pollution source reduction, run off limitation, fertilizers and pesticides reduction management, among others), adaptation measures must be envisaged for improved efficiency, particularly concerning extreme events (heavy rainfalls and droughts). These measures integrate complementary treatment steps and process control even for smaller water supply systems. Moreover, water quality monitoring with analysis of micropollutants, including emerging substances and treatment by products must be carry out, as well as health risk assessment (following the WSP procedure).

4.4. Impacts on human health

The WHO estimates that the warming and precipitation trends due to anthropogenic climate change of the past 30 years already claim over 150.000 lives annually. Many of today's influences on population health result from the unprecedented pressures that urbanization, long-distance trade, intensified food production, energy generation, landscape transformations, and water engineering are

placing on the natural environment. These environmental changes are regional or global in scale; they involve changes in diverse and complex natural systems; their impacts on health are both direct and indirect and climate change acts mostly as a multiplier of existing health problems (McMichael and Wilcox, 2009).

As waterborne and water-related diseases are sensitive to environmental conditions, changes in interactions between the water cycle and the climate system will modify the risk of waterborne diseases from the physical impacts. They will also impact the risk of famine, water shortages, decreased water quality, increased habitat for mosquitoes, shifts in seasonality of diseases, and contaminated recreational waters (Nichols *et al.*, 2018). Furthermore, there is consensus that climate change affects human health in a number of ways, and the impacts vary both geographically and between different populations (Patz *et al.*, 2005). A growing and ageing population in much of the world means that the proportion of the population vulnerable to the effects of climate change will increase in the future (Melrose and Careas, 2015).

Although the exact health impacts of climate change are still under debate, these are likely to include heat stress and increased risk of vector-borne, waterborne and food-borne diseases. In addition, the increased frequency of extreme weather events such as droughts, floods and hurricanes will also have a range of public health impacts. Nevertheless, linkages between public health and climate change are complex and interact with other factors (Bouzid *et al.*, 2013).

The main outcome of the literature review on climate change impacts on surface water quality (from source to tap) is that there is a degradation trend of drinking water quality, leading to an increase of at-risk situations with regard to potential health impacts, mainly during extreme meteorological events. Among water quality parameters, dissolved organic matter, micropollutants and pathogens are susceptible to rise in concentration or number as a consequence of temperature increase (water, air and soil) and heavy rain falls in temperate countries (Delpla *et al.*, 2009).

One of the major pathways through which contaminated water affects individuals is through drinking water. In management terms, these water supplies range from unimproved sources, where the individual is effectively consuming raw water, to large, managed supplies where multiple barriers exist to prevent chemical and microbiological contamination of water supplies. A review of the impacts of climate change on surface water contamination concluded that it was likely to increase the risk associated with drinking water supplied, mainly during extreme climatic events. Pathogen risk may rise mainly due to elevated temperatures and extreme rainfall, especially in temperate countries (Nichols *et al.*, 2018). In

addition, recent reviews demonstrated a clear trend for fecal contamination to be more common during the wet season, a finding that was generalizable across fecal bacteria indicators, methods of measurement, population setting, source type, and equatorial climate zone (Kostyla *et al.*, 2015).

So, there is a positive association between diarrhea and temperature, heavy rainfall, flooding, and drought, and all these meteorological conditions are expected to increase with climate change. These trends occur in both developing and developed countries and, in 2012, an estimated 842.000 diarrhea related deaths were caused by inadequate water, sanitation, and hygiene in low and middle-income countries. While the burden diarrheal disease has been declining globally, climate change has the potential to slow the progress in reducing the diarrheal diseases, particularly diseases linked to unsafe water, sanitation, and hygiene (WaSH) conditions (Levy *et al.*, 2006). Corroborating these findings, Bouzid *et al.* (2013) state that the impact of climate change on waterborne diseases in wealthy countries, relying on well-maintained water treatment plants, is likely to be negligible. The disease burden will fall largely on those reliant on small systems with inadequate treatment and intermittent supply.

Focusing on the Portuguese reality, few studies have been published describing changes in the burden of climate-sensitive diseases in Portugal in response to changes in weather and climate. Casimiro *et al.* (2006) argues that this fact makes identification of the potential future health impacts of climate change difficult. Their study focused on three potential climate change–related health impacts: heat-related mortality, air pollution–related health effects, and vector-borne diseases. Based on the results presented, together with the fact that the urban population in Portugal is getting larger and older, heat-related mortality is likely to be of the highest public health concern. However, the assessment of the risk of transmission of vector borne diseases suggests that (regional/local) climate change may increase the risk levels of zoonoses, such as leishmaniasis, Lyme disease, and Mediterranean spotted fever, which currently pose the greatest risk to public health. In general, climate change has the potential to change most of these factors to favor an increased (global) risk of infected vector introduction as well as imported (human) disease cases.

Overall, our societies have not yet gotten the full measure of the risks posed by climate change, particularly the risks to health, even though it might be clear that climate change will act mostly as a multiplier of existing health problems. (McMichael and Wilcox, 2010). The scarcity of health and environmental data and the significant number of knowledge gaps in the relationship between climate and health result in many uncertainties, requiring urgent actions in order to conduct more profound national assessments on public health vulnerability to climate change (Casimiro *el al.*, 2006). As Bouzid

et al. (2013) claim, despite substantial peer-reviewed and gray literature investigating potential health impacts of climate change, less attention has been paid to adaptation options. While implementation of effective control interventions is the only way to reduce the disease burden of climate change, evaluation of the effectiveness of public health interventions is lacking.

Consistent with the findings described above, climate change is very likely to impact water utilities' capacity to sustain water service provision and the economic viability and cost-effectiveness of treatment and distribution (IWA, 2019). The goal of this paper is, therefore, to assess whether these concerns are being taken into account in the current development of WSPs and if it will be of interest to include its obligation in new public policies in the water sector.

4.5. Legal aspects and technical guidelines

Until the early 20th century, drinking water quality was assessed primarily through its organoleptic characteristics. However, due to the inherent unreliability of this process, it became imperative to introduce policies allowing the implementation of parametric rules that could translate, objectively, the characteristics that water intended for human consumption should have. It is in this context that technical means and legal requirements have been developed for guaranteeing the best water treatment in public supply systems (Vieira and Morais, 2005).

As legislation should reflect scientific and technical progress, its systematic review is fundamental and the most recent Portuguese law on water quality, Law-Decree No. 152/2017, December 7th, translated into the national legal system the amends to annexes II and III of Directive No 98/83/EC, enacted by Commission Directive (EU) No 2015/1787, October 6th, 2015.

One of the main insertions is the need to perform a risk assessment procedure, such as a WSP, defined as "a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer" to ensure safe drinking-water. It is described in the WHO's Guidelines for Drinking-water Quality (GDWQ) as the "most effective means of consistently ensuring the safety of a drinking-water supply" (WHO, 2017b: 45), and "an organized method, i.e., an operating system of water quality management in which three basic stages can be identified" (Vieira and Morais, 2005; Vieira, 2011).

These guidelines, together with EN 15975-2 on safety in water supply systems intended for human consumption, constitute internationally recognized principles with regard to the production, distribution, control and analysis of parameters of water for human consumption. As stated by

Gunnarsdottir *et al.* (2015), governments need to define roles and responsibilities through legal and institutional arrangements, preventive management, cooperation between all stakeholders, and communication of risk and water quality to the consumers in order to monitor the risks to human health. Control programs must ensure that measures are taken throughout the entire water supply chain and to analyze information from water bodies used for the uptake of drinking water, as these procedures are vital in a climate change environment.

Just recently, the WHO and the IWA published a report that refers that 93 countries have implemented WSPs, even though at different stages of development (WHO and IWA, 2017). Given the increasingly relevant role played by WSPs and the global movement surrounding climate change concerns, it is relevant to investigate whether water utilities are adjusting their WSPs to these new challenges and if it is of interest that public policies in the water sector should comprise that obligation.

This case study involves two water utilities chosen from its characteristics and representativeness, as studied in a previous Portuguese work (Roeger and Tavares, 2020), and stands as a first attempt at describing and analyzing changes introduced to WSPs motivated by climate change concerns.

4.6. METHODS

This research aims to investigate if climate changes are a new factor in the amendment of WSPs, namely in order to guarantee water quality for human consumption. The study employs a case study method using document analysis to generate qualitative data (Yin, 2003). The research approach identifies a set of common parameters that, when compared, provide an answer to the research question: Are climate change concerns an input considered in updating Water Safety Plans?

The water utilities studied were chosen for their significant differences: an *upstream system* comprising a pioneer multi-municipal system in the implementation of a risk assessment strategy and a *downstream system* municipal corporation. By choosing cases that differ significantly, it is possible to obtain information regarding the significance of particular circumstances to the case (utility) processes, operation, and output (Flyvbjerg, 2006; Summerill *et al.*, 2010).

Generalizability in comparative case studies is problematic. However, Przeworski and Teune (1970) argued that if the same phenomenon is observed in multiple social systems, the outcome could not be attributed to system characteristics. In the words of Yin (2003), when conducting multiple case studies, if two or more cases support the same theory then replication can be claimed. This potential for

generalizability was discussed by Steinberg (2015), who suggests that a study conducted in one political system can improve our understanding of the phenomenon of interest in another political system.

Translated to the case under analysis, this system resonance means that the study of the effect of climate change concerns on water supply systems in general, and WSPs amendments in particular, in two water utilities of different natures will be relevant for understanding the same phenomenon in other water supply systems. Following these recommendations, our research follows the most-different systems approach to case selection. Hence, despite the significant differences between both utilities (see Table 4.1.), we hypothesize that the key factor thought to affect WSPs amendments – climate change – will have similar effects on both utilities.

Table 4.1. – Key Characteristics of Water Utilities

WATER UTILITY INFORMATION	UTILITY 1	UTILITY 2
Type of system	*Upstream*	*Downstream*
Governance model	Multi-municipal concession	Municipal corporation
Dimension	560 employees	110 employees
Water distribution (m^3/year)	Aprox. 70.000.000	Aprox. 2.000.000
Total of consumers	Aprox. 1.250.000	Aprox. 60.000
Number of water supply sub-systems	99	7
Number of water sub-systems with WSP	41	7
Management Systems	Quality Environment Health and Safety Social Accountability Energy Management	Quality Environment Health and Safety Social Accountability
Safe Water Indicator *	99,8%	100%
Date of first WSP implementation	2003	2014
Number of revisions	Undisclosed	2

Sources – Water Utilities Annual Reports and RASARP (2018)
* Percentage of controlled and good quality water calculated as the product of the percentage of compliance with the frequency of sampling by the percentage of compliance with the parametric values set in the legislation.

4.7. Water Safety Plan - Utility 1

Utility 1 is an *upstream system* pioneer in the implementation of the WSP methodology as defined by the WHO and as described in the guide produced by the Portuguese national regulatory authority for the water sector (ERSAR). Since its first WSP, in 2003, the document has evolved in order to follow all technical and regulatory developments, political orientations, and all new circumstances, namely climate changes. When preparing the first draft, Utility 1 followed the scheme prepared by the team responsible

for the procedures guiding the implementation of the WSP and for the elaboration of the technical support documents and manual, as presented in Figure 4.1.

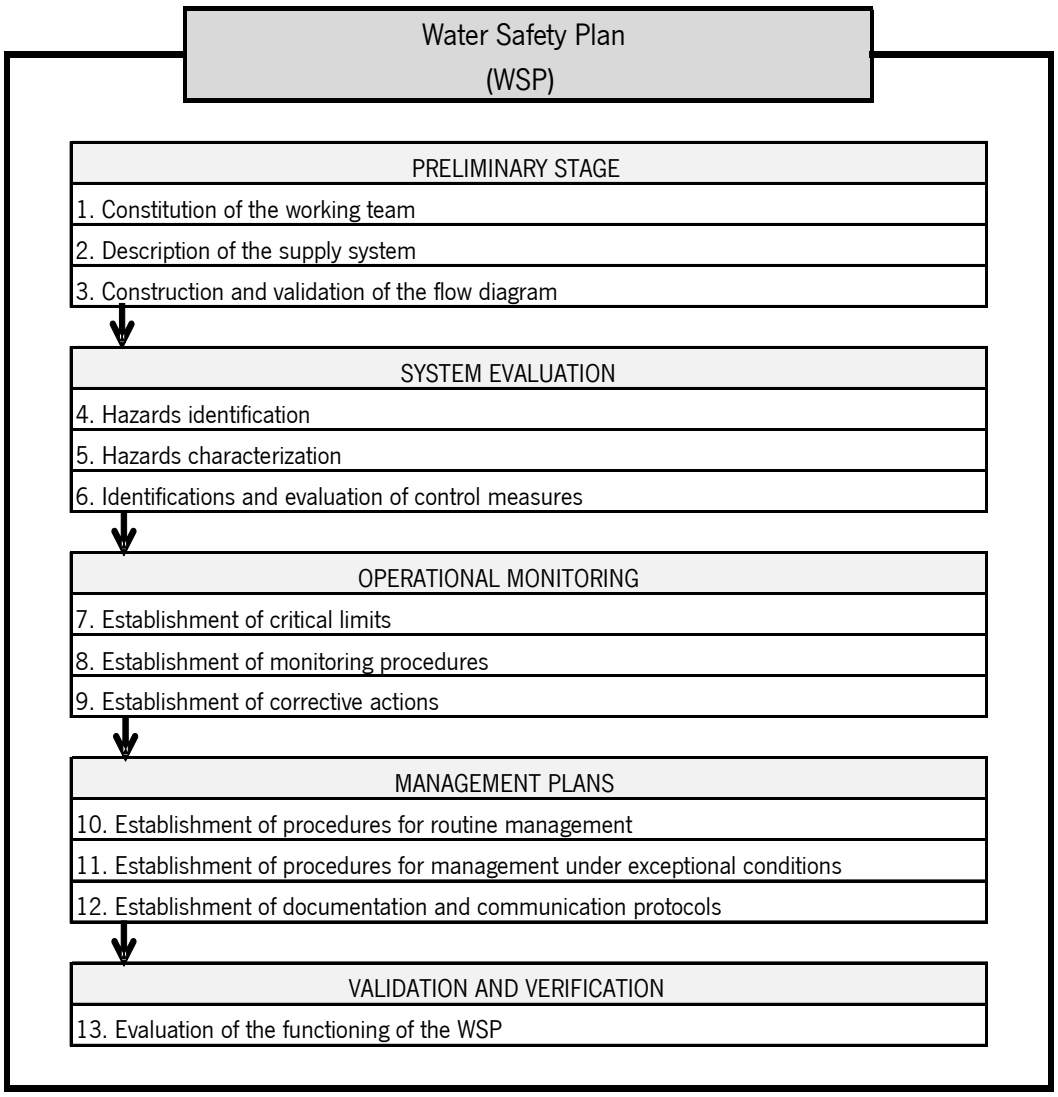

Figure 4.1. – Framework for the Implementation of Water Safety Plans (Vieira and Morais, 2005)

Intending to extend WSPs to all national multi-municipal concessions, Utility 1 prepared several upgrades of its initial WSP, following the recommendations of an implementation manual (AdP, 2011). The latest version, dating from 2015 and prepared for the country of Mozambique, reflects the procedures described in Figure 4.2. (AdP, 2015).

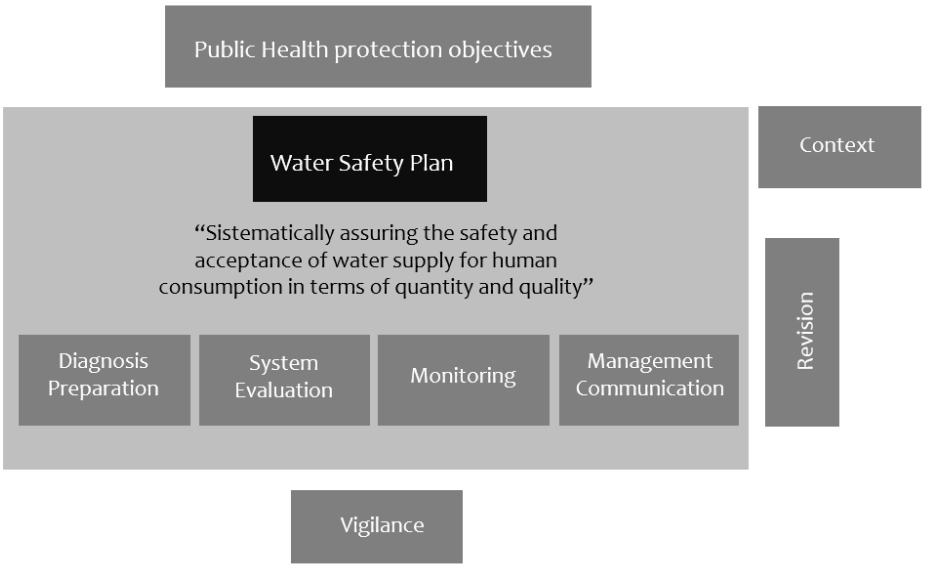

Figure 4.2. – Scheme for the Implementation of Water Safety Plans (AdP, 2015)

More recently, Utility 1's 2018 Annual Report presents an all-new approach regarding climate change – the Strategic Plan for Climate Change Adaptation. This plan aims to "contribute to the improvement of the ecological and chemical status of water bodies as set out in the National Water Plan and the Water Framework Directive and promote actions to adapt to climate change as well as nature conservation".

With this aim in mind, a tactical plan was designed to establish a short, medium and long-term adaptation strategy. Its implementation is expected to reduce the vulnerabilities of business activities to climate change and extreme events, and to increase the resilience and responsiveness of water systems to these changes and events. The methodology to achieve these goals is presented in Figure 4.3.

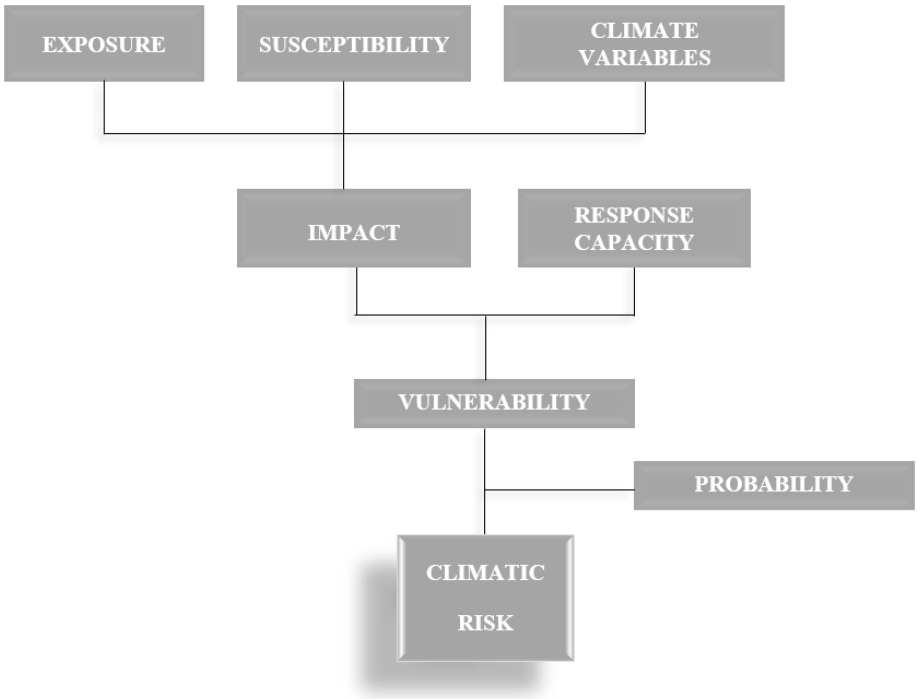

Figure 4.3. – Scheme Representing Utility 1 - Methodology for Climate Changes Adaptation Plan.

In this context, Utility 1 promoted the study of its water supply subsystems and infrastructures to quantify and prioritize climate change risks, identify all necessary adaptation solutions, and plan the implementation of the approved measures. Utility 1 conducted a survey to assess the influence of climate and weather conditions on the operation of infrastructures. The study identified 123 events, of which 62.1% were directly associated with climatic phenomena, such as drought/water availability, and 28% related to degradation/alteration of water quality. The events were registered with a frequency of at least one per year and mainly affected water origins and service quality indicators. More specifically, the degradation of raw water quality and its availability were the factors that led to impacts with greater consequences, reflecting on the reliability and quality of the service, as well as on the water sources.

This monitoring allowed the definition of priority investments, grouped as reformulation or increase of system capacity, alternative sources and systems, reduction of water losses, increase of reserve capacity, and protection of water bodies and ecosystems. For a better understanding of the instruments used in the evaluation and monitoring procedures, we present a set of supporting tables.

Table 4.2. expresses the consequences related to impacts on service, assets and water origins, regarding quality, quantity and reliability issues.

Table 4.2. – Classification of Consequences related to Impacts on Service, Assets and Water Origins

IMPACT	CONSEQUENCE			
	CLASSIFICATION 4	CLASSIFICATION 3	CLASSIFICATION 2	CLASSIFICATION 1
SERVICE	Very High	High	Medium	Low
	Quality			
	Severe impact on compliance of legal regulations with impact on public health	Impact on regulatory compliance - potential indicators of the presence of microorganisms or chemical parameters that may have an impact on public health	Minor impact of compliance with impact on consumer / user acceptability	No impact on legal compliance
	Impact on compliance with legal regulations, non-compliance with discharge permits and changes in the quality of water bodies	Impact on compliance with legal regulations, with failure to discharge license	Minor compliance impact with non-compliance with Emission Limit Values (VLE) but no discharge license non-compliance	No impact on legal compliance
	Quantity - population served			
	Affected population >50%	30% ≤ Affected population <50%	Affected population <30%	No impact on served population
	Reliability			
	Service interruptions lasting longer than 6 hours	Service interruptions lasting between 3 hours and 6 hours	Operation-controllable interruptions lasting less than 3 hours	No service interruptions
ASSETS	Very High	High	Medium	Low
	Permanent and complete loss of asset capacity	Permanent loss of 50% of asset capacity	Permanent loss of 20% of asset capacity	No damage or negligible damage to assets
WATER ORIGINS	Very High	High	Medium	Low
	Significant long-term impact on water quality and / or quantity	Medium term impact on water quality and / or quantity (1 month to 6 months)	Short term impact on water quality and / or quantity (up to 1 month)	No impact on water quality and / or quantity

Following, Table 4.3. presents a scale of vulnerability, from low to very high, according to the event taking place.

Table 4.3. – Classification related to Vulnerability

VULNERABILITY			
CLASSIFICATION 4	CLASSIFICATION 3	CLASSIFICATION 2	CLASSIFICATION 1
Very High	High	Medium	Low
System/service operation is fully affected by the event (downtime). The system is unable to handle the event.	System/service operation is greatly affected by the event. The system has difficulty handling the event, requiring high resources.	System/service operation is disturbed by the event. The system is capable of handling, but requires some time and resources to respond to the event.	System/service operation is not affected by the event. The system is capable of handling the event (responsiveness).

Table 4.4. – Classification relating frequency of the climatic event

FREQUENCY OF THE CLIMATIC EVENT	
CERTAIN TO OCCUR CLASSIFICATION: 4	Observed at least once a year
PROBABLE TO OCCUR CLASSIFICATION: 3	Observed at least twice a year
PROBABLE TO OCCUR CLASSIFICATION: 2	Observed at least once every 5 years
UNLIKELY TO OCCUR CLASSIFICATION: 1	Observed only in exceptional circumstances, in a period of time superior to 5 years

As supported by the evidence, Utility 1 implemented an updated document that aims to understand the exposure and sensitivity of systems and services to climate risks and climate change, and to reduce vulnerability and increase responsiveness. For operational management, the procedure involves, for each event, the corrective actions and the monitoring strategies, as described in Table 4.5.

Table 4.5. – Operational Management

OPERATIONAL MANAGEMENT										
EVENT	Sub-system	Asset	Impact	Perception of vulnerability			Susceptibility			
EVENT RESPONSE	Monitoring						Corrective Action			
DESCRIPTION	What	Critical Limit	Method	When	Where	Who	Description	How	When	Who

Finally, the process closes with the definition of adaptation measures and investments, as showed in Table 4.6.

Table 4.6. – Adaptation Measures

ADAPTATION MEASURES								
Event Assets Sub-System	Adaptation measure		Investments					
	Description	Responsibility	Code	Description	Initial date	Closing date	Status	Estimated cost (€)

4.8. WATER SAFETY PLAN IN UTILITY 2

Utility 2 is a *downstream system* with an excellent record in achieving top water quality performance (100%). Its WSP was recently revised and climate change impacts have been considered. Four hazardous climatic events that may have catastrophic consequences were considered in this new approach, and were integrated into three Emergency Intervention Schemes that will be explained below.

It is relevant to say that Water Utility 2 promoted the revision of its WSP despite still waiting for national recommendations on risk scales developed by health authorities to conclude the review and amendment. Nevertheless, its strategy (same in both the 1st document produced and in its first revision) is as follows.

Having EN 15975-2:2013 as a support methodology, the prioritization of risks associated with a hazard or hazardous event identified in the supply system is essential for the definition of control measures. The risk associated with each hazard identified can be defined as the likelihood of a hazard causing harm to a given population exposed to it within a given timeframe and considering the magnitude of that damage. Thus, a risk can be translated as the product of the likelihood of an unwanted event occurring by its effect on a given population. Hazardous events with greater severity of consequences and greater likelihood of occurrence should be given greater consideration and priority over those whose impacts are insignificant or whose occurrence is very unlikely.

In this regard, the most important consideration is the potential impact on public health, but other factors such as organoleptic aspects, continuity of supply, and the public image/reputation of the supply manager should also be considered. The aim is to distinguish significant risks from less significant ones. The risk assessment is based on the experience, knowledge, and understanding of the process of water supply for human consumption of each of the WSP team members, good practices and the technical

literature. It should be noted that the reliability of risk characterization associated with a supply system requires the existence of a database for monitoring water quality and service delivery and its analysis. The procedures associated with operational control will have a direct impact on risk assessment. The more complete the assessment is, the more reliable, comprehensive, and efficient will be the operational control and management of the supply network. This process is particularly difficult in the absence of a history of incidents.

In order to assess the risk associated with each hazard, the likelihood of its occurrence was established through a Probability Occurrence Scale (Table 4.7.), and the consequences for the population were assessed through a Consequence Severity Scale (Table 4.8.). These scales were established in accordance with WHO/IWA guidelines and the experience of the technicians operating the utility supply system.

Table 4.7. – Probability of Occurrence Scale

PROBABILITY OF OCCURRENCE	DESCRIPTION	VALUE
ALMOST CERTAIN	High probability of occurring (daily)	5
VERY LIKELY	The probability of occurring is not daily but very high (once or more per week)	4
PROBABLE	The probability of occurring is not high, but there are some records of occurrence in history (on average, one to three times a month or more than six times a year)	3
SLIGHTLY PROBABLE	The probability of occurrence is not high, but there is at least one record of occurrence in the history (on average one to five times per year)	2
RARE	It has never been reported or can occur in exceptional situations (once in 5 years)	1

Table 4.8. – Severity of Consequences Scale

SEVERITY OF OCCURRENCE	DESCRIPTION	VALUE
CATASTROPHIC	Impact on public health (certain or very likely)	5
SIGNIFICANT	Regulatory impact	4
MODERATE	Impact on consumer quality of life	3
SMALL	Visual and / or organoleptic impact which may affect consumer confidence	2
INSIGNIFICANT	No detectable impact for the consumer	1

The risk is then calculated by multiplying the probability of occurrence and the severity of the consequence, as showed in the following Table 4.9.

Table 4.9. – Risk Rating Matrix

PROBABILITY OF OCCURRENCE	SEVERITY OF CONSEQUENCES				
	Insignificant (1)	Small (2)	Moderate (3)	Significant (4)	Catastrophic (5)
ALMOST CERTAIN (5)	5	10	15	20	25
VERY LIKELY (4)	4	8	12	16	20
LIKELY (3)	3	6	9	12	15
UNLIKELY (2)	2	4	6	8	10
RARE (1)	1	2	3	4	5

In order to prioritize the risks of the system, Utility 2 has a corresponding qualitative matrix (Table 4.10.).

Table 4.10. – Qualitative Risk Prioritization Matrix

PROBABILITY OF OCCURRENCE	SEVERITY OF CONSEQUENCES				
	Insignificant (1)	Small (2)	Moderate (3)	Significant (4)	Catastrophic (5)
ALMOST CERTAIN (5)	Low	Moderate	Moderate	High	Extreme
VERY LIKELY (4)	Low	Moderate	Moderate	High	Extreme
LIKELY (3)	Low	Moderate	Moderate	High	Extreme
UNLIKELY (2)	Low	Low	Moderate	High	Extreme
RARE (1)	Low	Low	Low	Low	Extreme

After the identification of dangerous events and associated hazards, an evaluation of risk characterization is made using a Risk Rating Matrix (Table 4.11.). Finally, control measures, or risk mitigation measures, are described as the activities and processes of the drinking water supply system that directly affect its quality and ensure that water permanently meets established quality targets, applied to reduce risks. The planning and assessment of control measures based on hazard identification shall ensure that public health objectives are achieved. Thus, the level of control applied should be commensurate with the results obtained in risk prioritization. Several control measures are required to control various hazards, just as some hazards require more than one control measure to be taken to control them.

Table 4.11. – Risk characterization associated with hazards identified in the system components and respective control measures

	DANGEROUS EVENT	ASSOCIATED HAZARD	RISKS CHARACTERIZATION			CONTROL MEASURES	OBSERVATIONS
			Probability	Severity	Classification		
SYSTEM COMPONENT							

After defining the control measures for each hazardous event at each stage of the supply system, it is essential to ensure that the system evaluation procedures are done properly. Thus, operational monitoring safeguards the necessary knowledge support to the management of the system operation and contributes to the effective implementation of all control measures. Monitoring the control points is essential to support risk management as it demonstrates if the control measure is effective and allows for timely action if a deviation is detected. That is very important as action can be taken to prevent quality targets from being compromised.

In the case of Utility 2, the operational monitoring was integrated into the Operational Control Program, which was already part of the Corporate Management System of the utility. The later constitutes a document that allows the proper management of the systems operation, where several points are established, including parameters to be monitored and their critical limits, monitoring procedures, responsibilities and corrective actions to be taken if the defined limits are exceeded. In addition to this Program, there are other plans and procedures in the company that have their own autonomy and are fundamental to ensure the implementation of control measures.

Routine management is ensured through expedited procedures, work instructions, plans, inspections, and analyses. Given that a properly implemented Corporate Management System (Quality, Environment, Health and Safety at Work and Social Responsibility) already existed, the practice of having procedures and records was already in place prior to the WSP. Thus, the existing procedures were optimized and the new and needed ones created. The entire WSP is now formalized in operational and support procedures, managed by a documentary database that ensures that they are always available, up-to-date, listed and controlled, and where responsibility and distribution lists are clearly defined.

The possibility of occurrence of events with catastrophic consequences recommends that contingency plans be prepared to address them. Thus, Utility 2 defined four hazardous events that could

have catastrophic consequences, and which were integrated into three Emergency Intervention Schemes, subjected to simulacrum exercises to verify their effectiveness:

- Water contamination of the supply network with serious public health consequences;
- Upstream system supply interruption;
- Water supply interruption.

4.9. Special remarks

Observations and model simulations indicate that climate change is taking place both at the global and regional levels. While some parameters already show significant trends, such as mean temperature, others, like mean precipitation and climate variability indices, are still rather difficult to analyse (Miranda *et al.*, 2002). More than a decade ago, Portuguese scientists concluded that climate change is taking place, and their findings are not different from the consensus conclusions in the international community.

And, similarly, there is also consensus that climate change affects human health.

As reported in several research papers, many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heatwaves, to altered transmission of infectious diseases and malnutrition from crop failures (Patz *et al.*, 2005; Casimiro *et. al*, 2006; Levy *el al.*, 2006; Delpla *et al.*, 2009; McMichael and Wilcox., 2010; Bouzid *et al.*, 2013; Santos, 2014: Melrose and Careas, 2015; Kostyla *et al.*, 2015; Nichols *et al.*, 2018). Climate-health relationships pose increasing health risks under future projections of climate change and the warming trend over recent decades has already contributed to increased morbidity and mortality in many regions of the world.

Scientific data also shows that morbidity and mortality are directly related to climate change effects, as changes in the timing and intensity of rainfall, directly affect the quantity and quality of water resources for different users (IWA, 2019), with water quality for human consumption severely affected. The impact of climate change on water quality places additional pressure on water utilities' capacity to sustain water service provision and the economic viability and cost-effectiveness of treatment and distribution (IWA, 2019).

For that matter, there is a growing sense of urgency for utilities to build resilience towards weather extremes as an integral part of a water supply management (IWA, 2019), implementing adequate technology or practice to assess and address risks of extreme events. This is to be done through an

approach that should be part of a coherent and holistic strategy to ensure sustainable water resources and safe and secure water supply (IWA, 2019a).

Recognition of the limitations of *post hoc* analysis is driving the water sector to supplement it with more proactive approaches to risk management, whereby utilities identify potential weaknesses and eliminate root causes of problems before failure occurs (MacGillivray *et al.,* 2006; Pollard *et al.,* 2004). Many researchers (Pollard *et al.,* 2004, 2008; Hrudey *et al.*, 2006; Pollard *et al.,* 2008; MacGillivray *et al.*, 2007) have been concerned with how to improve organizational competencies in risk management within the utility and related sectors. Hence, ensuring appropriate water infrastructure, regular monitoring and appropriate management techniques, such as WSPs, are likely to be increasingly important to address changing risks (Nichols *et al.*, 2018).

Still, it is important to highlight that while a WSP approach is considered the best method for achieving safe drinking water, the potential impact of such an approach is often overshadowed by implementation challenges (Kot *et al.*, 2014). For example, 91% of all Portuguese water utilities recognize the importance of a WSP, even though only about 20% have voluntarily implemented it (Roeger and Tavares, 2018). But that scenario is about to change as the EU Directive on water quality and national regulations are already imposing the implementation of risk assessment methodologies.

To strengthen climate resilience through the WSP process, it is important to understand current and future risks posed by climate variability and change, which are often similar across climatic or ecological zones. WSPs at the local scale could therefore benefit from the assessment of the vulnerability of water resources at a regional scale. This regional climate vulnerability assessment will provide important inputs into the WSP process.

Water quality monitoring (raw water and along all process points up to the consumers tap) is, therefore, a prime concern and monitoring is relevant as a contribution for the implementation of WSPs. Both utilities studied are complying with national regulations, including changes that are being made compulsory as regulations evolve, and the results confirm water safety indicators of 99,8% for Utility 1 and of 100% for Utility 2 (RASARP, 2018).

The research question guiding this article was whether climate change concerns are an input considered in updating Water Safety Plans. The results show that both utilities under analysis have been implementing updates to their WSPs in order to integrate this new reality, and Utility 1 has even implemented a Strategic Plan for Climate Change Adaptation, with direct impact in the revision of its WSP.

It is relevant to underscore that ERSAR, the national water regulatory agency, has a major role to play in this new approach, as government's technical support was crucial when transposing the EU water directive to the national legal framework, adopting mandatory risk assessment procedures, and publishing recommendations and manuals for all water utilities.

The scientific community is building better climate models and feeding them with more reliable emission (or concentration) scenarios. There is a need to produce climate impact assessments at the regional scale, keeping in mind that they are intrinsically provisional, but using at each time the "best available science". Those assessments will certainly have to be updated on a regular basis, at the pace of the scientific and technological advancements that are taking place (Miranda *et al.*, 2002), and all subsequent actions must be undertaken using the best developments and knowledge.

4.10. Conclusions and Recommendations

Prior literature shows that climate change is affecting human health, namely due to alterations in water quality and there is the need to use predictive tools as models for decision support to monitor and to assure compliance with legal requirements. This will allow a better assessment of water service systems and therefore, through risk assessment methodologies, it will be possible to define and implement appropriate remediation and adaptation measures.

Inspired by the idea that WSPs are an optimal policy instrument to integrate circumstances that could endanger water quantity and quality for human consumption, the main objective in this article was to verify whether those issues are being considered in WSPs of two water utilities that already have that risk assessment methodology in place. As changes in the climate and the environment are proven to occur, as well as its negative effects, this should be a primary concern of the management bodies of water utilities and of national authorities.

The study allows us to conclude that both utilities are integrating climate change variables into their WSPs in order to achieve the best and the most secure approaches in their management tools. Moreover, it is easily recognized that this upgrade is also the result of the new legal framework that is triggering and accompanying these trends. Both utilities are highly recognized for their excellent results, namely regarding their ERSAR performance indicators, and a great number of national water utilities display a similar behavior (RASARP, 2018).

As for the limitations of this study, and considering the entire national water sector, we only focused on water utilities with WSPs in place. There is a significant number of smaller utilities that are

still far from this state of development, as it can be ascertained by their ERSAR performance indicators (ERSAR, 2018). This means that it would be important to study a wider set of utilities to guarantee a more adequate representativeness. This broader set of utilities would also allow verifying the legal compliance regarding the implementation of a risk assessment strategy and provide information about whether their current plans are considering climate change as an input.

As stated by Levy *el al.* (2006), climate change itself will not change the basic nature of the threats to water services, but it will change their likelihood and severity, and potentially the geographical range of some threats. In adaptation efforts it is, therefore, important to consider those influences in adjusting WSPs strategies.

Besides, there are factors affecting water quality and quantity that should be monitored and statistically studied to be incorporated with positive impacts in WSPs amendments. For instance, demographic development and water demand from other sectors, like agriculture and tourism, should also be accounted for (Rickert *et al.*, 2019). Local climate specific data could also be of particular interest, and, for that matter, smart city projects that involve the installation of sensors for monitoring environmental parameters is another recent recommendation.

CHAPTER 5

CONCLUSIONS

5.1. Main Findings

Public policies in the water sector have been undergoing significant changes to become more specialised as the result of the development of technical knowledge, legal framework and regulation, and growing concerns to ensure public health. In order to operationalise all the requirements, the water sector relies on a set of norms, regulations and tools, namely WSPs, and this risk assessment methodology is being used progressively by water utilities around the world, either by means of legal imperative or via voluntary implementation.

With the publication of Directive (EU) 2015/1787, October 6th, on water quality for human consumption, national law was to be revised to comply with the Directive and it became possible to anticipate the compulsory adoption of a risk assessment strategy in all water utilities in Portugal. As previously stated in the Introduction, this occurs observing the process of Europeanization involving a policy network that is constituted by the Parliament, which legislates under the influence of European directives, the Government, which is responsible for implementing the legislation, the Regulatory Authority (ERSAR), which controls the implementation by water utilities, and the public, which assesses the service provided.

These changes in public policies in the water sector are mainly due to the developments that have occurred in recent years in scientific and technological terms. These changes have led to its correction and to a new framework that integrated new measures aiming to improve water quality assurance, namely risk assessment processes. On the other hand, this policy cycle had also the important contribution of the reform strategies adopted to change the structure and functioning of Public Administration, with the focused on the use of privatization mechanisms, internal markets, organizational performance and productivity incentive, with repercussions in the (re)organization of the water sector.

WSPs are expected to play a key role in all new water policies for the reason of being the advocated tool by international organizations like the WHO and the IWA. Therefore, one of the main objectives of this study was to determine how to transpose the Directive guidelines and amend the national legal framework in order to achieve the best possible version that would allow successful implementation of both the Directive and the above-mentioned risk assessment strategy. Moreover, regarding the current context of growing external uncertainties resulting from changes in the climate and the environment, the study also aimed at evaluating how a methodology such a WSP would have to be rewritten to integrate those aspects.

Hence, the first step was to learn from previous experiences and case studies, identifying the key constraints that should be taken into account and extracting all guidelines that could be important when

drafting the new Portuguese national legislation. According to this review of prior studies about the subject, mainly experiences at the international level, several authors describe success cases with a set of common traits. In fact, one of the main findings is exactly the positive consequences regarding the compliance with water quality guidelines and public health protection mechanisms that can be gained by means of a WSP implementation, as well as relevant improvements achieved in terms of governance of the sector.

Concerning the main dimensions that lead to successful water safety planning, four aspects can be highlighted: a strong commitment from senior leaders, an organizational culture committed to public service, the presence of technical knowledge, and effective stakeholders and interagency collaboration in order to pursuit the active management of the WSP. In other words, besides technical aspects, good governance is a crucial element to capture all the benefits promised by this water policy tool. These results are corroborated by more recent findings. String and Latagne. (2020) refers that leadership, advocacy among promoters and customers (not just implementers) and purposeful knowledge management are critical to WSP success. Pérez-Vidal et al. (2020) confirms that the WSP is an important tool for decision-making by water-service companies—improving their administrative, financial, organizational, and operational management. It also shows that it is essential that their senior management and other stakeholders be part of the WSP team at each stage of implementation of the DWSS.

These primary conclusions were essential to initiate the discussion about the factors that were considered by previous experiences to be determinants of success in the implementation of a risk assessment methodology in water utilities and allowed to better prepare a set of guiding manuals and procedures to help both technical and administration teams.

Another purpose of this study was to appraise the status concerning the adoption of WSPs by Portuguese water utilities. The goal was to understand what factors influenced the decision to voluntarily implement this instrument and to predict the conditions that favor its application, as well as the strategies to minimize failure in execution. For that intent, Chapter 3 presented the second dimension of the thesis, involving the evaluation of aspects like governance arrangements, the dimension of water utilities (which relates to technical knowledge and financial availability) and previous experiences of water utilities in management systems, namely certification of quality, environmental, and health and safety standards.

With the support of the national regulator, ERSAR, we applied a questionnaire to water utilities. On one hand, the results suggest that the dimension of the utility is an important determinant, as smaller

ones are less prone to adopt a WSP. In Portugal, more than 75% of water utilities have that same dimension, serving less than 50.000 inhabitants, and serious limitations are anticipated to occur when the methodology becomes compulsory. On the other hand, utilities without prior experience in management systems - quality, environment and health and safety standards – also struggle to adopt WSPs. More than 65% of national utilities had no previous practice regarding these procedures and it was possible to conclude that certification is an important pre-condition for the adoption of WSPs, even though the type of standard is not determinant. Finally, governance arrangements make a difference when it comes to the adoption of a WSP methodology, suggesting that water utilities run by in-house bureaucracies, which represent near 70% of the water utilities in Portugal, are less prone to adopt WSPs.

These results were extremely useful to characterize the water sector in Portugal regarding the use of WSPs and the main factors preventing their application. This led to a better understanding of what are the barriers that the sector will likely face and the problems that will have to be minimized and solved, especially by ERSAR as the major responsible for all public policies in the water sector.

Still, it is important to highlight that while a WSP approach is considered the best method for achieving safe drinking water, the potential impact of such an approach is often overshadowed by implementation challenges. This finding is completely evident in the study, as 91% of all Portuguese water utilities recognize the importance of a WSP, even though only about 20% have voluntarily implemented it (Roeger and Tavares, 2018).

Lastly, this research focused on a relevant and timely issue: the exposure and sensitivity of systems and services to climate risks imposes the revision of WSPs in order to reduce vulnerability and to increase systems' responsiveness. Hence, the research explored whether climate change concerns are already an input considered in updating WSPs in progress and the corresponding results were shown and discussed in Chapter 4. The findings indicate that climate change is affecting human health, namely due to alterations in water quantity and quality. Water quality must be monitored and there is the need to promote sustainable use of predictive tools as models for decision support to allow better system evaluation and to define and implement adequate remediation and adaptive measures by means of risk assessment methodologies. Both utilities under analysis are, in fact, implementing updates to their WSPs as a means to achieve the best results, integrating climate change impacts in their management tools. Nevertheless, it is of the utmost importance that this input will be considered to be compulsory in new generation of WSPs, as research examining and evaluating adaptation options and future impacts at the

climate-water-health nexus is absent and should become a top priority, given the urgent need for this evidence to inform climate change policies, actions, and interventions (Harper *et al.*, 2020).

In sum, the organisation and the findings of the study are described in the scheme presented in Figure 5.1:

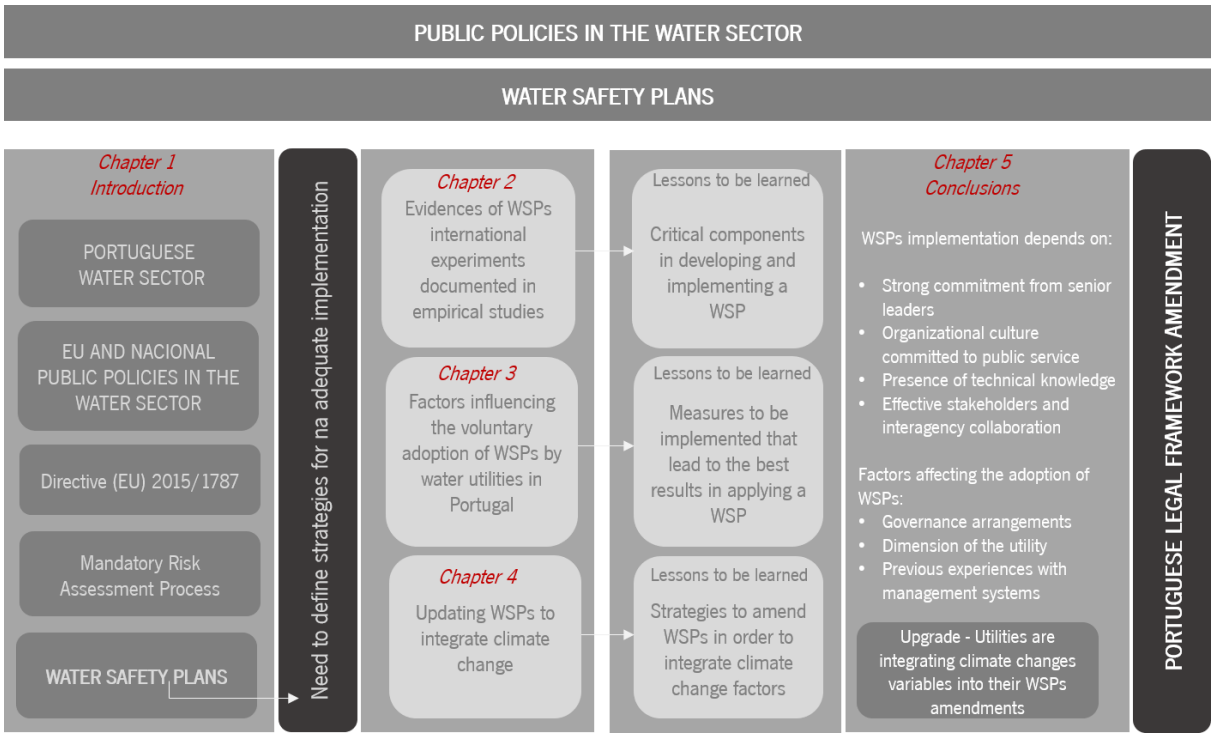

Figure 5.1. – Study Framework and Findings

5.2. Policy implications and recommendations

The implementation of a risk assessment methodology is becoming a priority in public policies that aim at securing safe water for human consumption and it is already being required in the current legal framework. The EU Directive imposes a degree of professionalization that is absent in the majority of water utilities. As a result, the national government and the national regulator will have to look at the requirements imposed via the new legal diploma to find ways to support water utilities with a severe lack of experience in management procedures, technical skills, and financial capacity.

Precisely because one of the main constrains in WSPs implementation is the lack of technical and financial capacity to meet the requirements of this methodology, one recommendation relates to the necessity of enhancing technical skills and level of professionalization. Some measures include investing in educational and training programs and the distribution of technical documentation, as well as the provision of well-prepared consulting teams, eventually sponsored by ERSAR.

In order to assure the successful implementation of WSP to protect the public interest, the national regulator plays a major role and this agency should focus on different approaches to promote more collaborative and training strategies. Needless to say, the strategies related to financial incentives are of utmost importance to meet these goals, and public policies should account for this purpose, namely when preparing EU or national funds notices.

Alongside the fragmentation of the water sector/small dimension of Portuguese water utilities, the governance structure also represents a factor of concern, as utilities run by the municipalities' workforce face difficulties in the exact same domains (lack of technical skills and level of professionalization, as well as economic and financial problems). Therefore, in-house bureaucracies should be primary targets for these policies as they show resistance to adopt the methodology, mainly due to the lack of resilience to cope with those pressures. Ultimately, one cannot forget that the choices of decision-makers about the preferable governance structures to manage water utilities should be grounded on technical evidence and management bodies selected by their expertise, as the latter is a major factor that influences the success of any organization, and of its projects and procedures. As referred by Overman *et al.* (2020), to secure a positive organizational image and the authority crucial for public agencies to operate, the performance management turn in the public sector may need to be supplemented by an enhanced organizational attention to procedural and moral aspects.

On the other hand, it would be relevant to look at the water sector as a whole and think thoroughly about its organization, promoting the fusion/absorption of small and low supply systems by more professionalized systems.

Another recommendation focuses on the importance of prior experiences with the certification of quality, environmental, and health and safety management systems. It facilitates the implementation of risk assessment methodologies and, even though the requirements in force are already mentioning their importance and establishing their obligation, these practices should be encouraged and could use the same strategies mentioned before to highlight the benefits of risk assessment processes.

The national regulator plays a crucial role in promoting WSPs. The implementation of management systems, as well as of WSPs, requires effective interagency work and engagement by the ERSAR in order to make inter-agency work effective, and health and environmental organizations should have specific responsibilities and mandatory procedures to accomplish, including the publication of benchmarking reports.

Moreover, monitoring and supervision are aspects that must be considered by the national regulator for an effective execution, not only by means of periodic inspections, but also by considering the implementation of WSPs by water utilities as a key performance indicator, for both benchmarking purposes and monitoring of the improvements in the overall performance of water utilities.

Finally, a brief reference to the importance of incorporating climate change impacts in defining strategies to strengthen water utilities resilience through the WSP process. This establishes another goal to the future of public policies in the water sector as ERSAR should encourage the new legal framework to incorporate this new input.

Regarding all the above, Figure 5.2. presents an overview of the main findings, policy implications and recommendations.

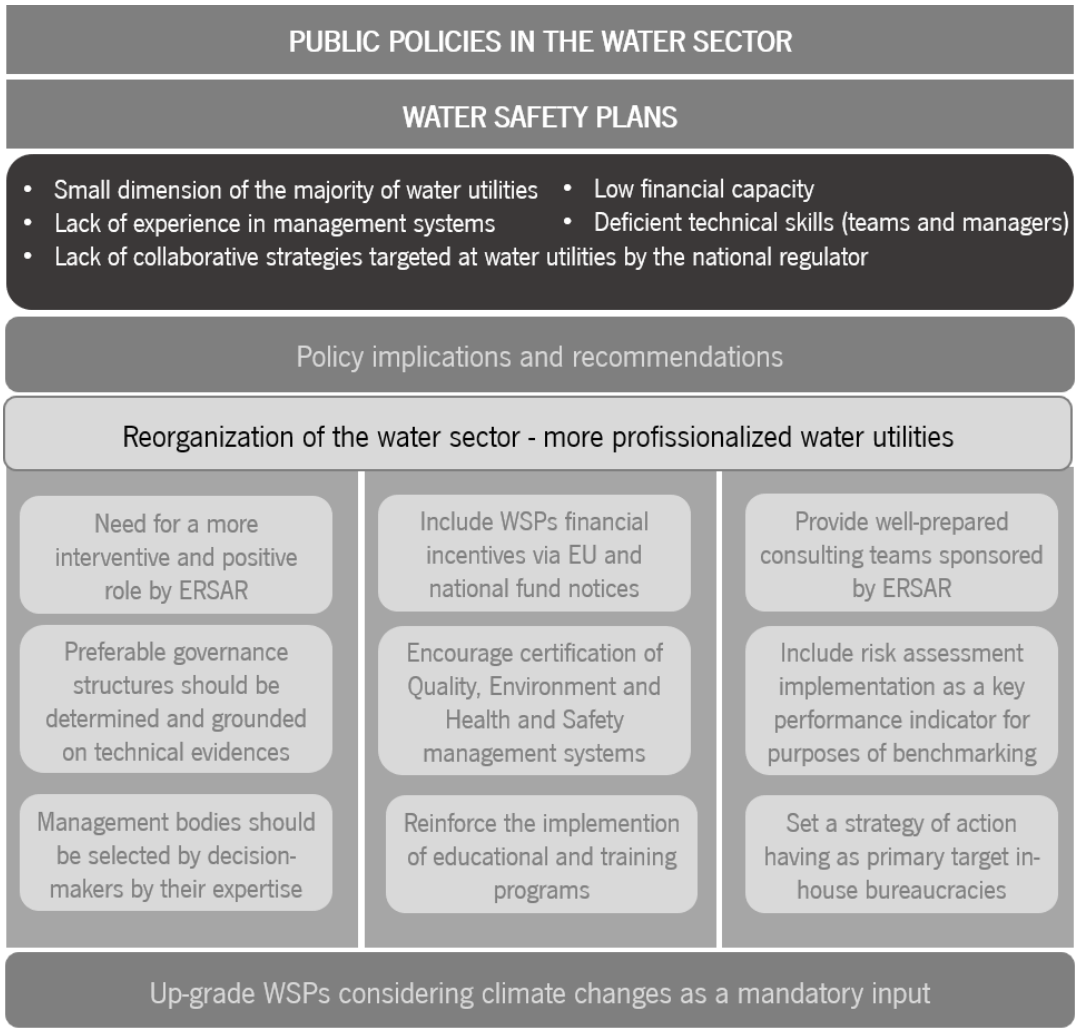

Figure 5.2. – Main findings, policy implications and recommendations

5.3. MAIN DIFFICULTIES AND FUTURE RESEARCH

The present thesis gathered comparative data about water safety policy problems, reviewed the extant literature, and answered three research questions related to water safety planning. Some international evidence was found, but all previous experiences with the application of risk assessment procedures in the water sector in Portugal were not actively monitored, nor the results published, and, therefore, there was a striking lack of knowledge and practical information. This represented a challenge to the completion of this thesis.

This difficulty is not exclusively a national problem nor a water sector issue. According to Cruz *et al.* (2019), the gap between the scholarly research focus and the perceptions and requirements of city administrators represents a major challenge for the field. Furthermore, global and comparative research on urban governance is confronted with an absence of systematically collected, comparable data. Therefore, it is important that future research in this field addresses this gap.

The questionnaire applied to water utilities captured important information, mainly for drafting the new legal framework, even though it is possible to conclude that data limitations on the implementation of WSPs by Portuguese water utilities prevented us from analyzing additional data regarding the profile of the early adopters.

Future research should focus on assessing further information about the current status on water safety planning in Portugal through a survey methodology or by calculating a performance indicator, in order to understand how this public policy tool is being implemented. This monitoring is extremely relevant, as it would reveal if the new national regulation is accomplishing these goals and standards, and whether there is a need to adjust strategies to improve implementation.

Another subject of interest relates to the compliance problems with European policies, as the implementation of EU policies usually requires, as Börzel (2000) refers, considerable legal and administrative changes imposing economic and political costs on public administration. Portugal still lacks some capacity to enforce international commitments in the water sector, and even though current efforts have been significant, authorities may have to review the management strategies in/for the sector in order to prevent the negative consequences associated with noncompliance.

At last, a major follow-up would be to investigate whether climate change has become an effective input to WSPs. In fact, given the global nature of this problem that affects water quantity and quality, causing severe impacts in public health, the first version of the WSPs of Portuguese utilities, as well as

their updates, should take this issue into account and public policies ought to require these upgrades in noncompliant. A new inquiry on this topic would be of interest at a future date.

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ANNEX

QUESTIONNAIRE

QUESTIONNAIRE

1. Identification of the Water Utility

2. System typology
2.1. *Upstream* system
2.2. *Downstream* System
2.3. Both Systems

3. Water Utility governance model
3.1. Delegation (inter-municipal company)
3.2. Delegation (municipal company)
3.3. Delegation (company resulting from partnerships Municipalities/State)
3.4. Direct management
3.5. Concession

4. Certification of management systems implemented in the Water Utility
4.1. Quality
4.2. Environmental
4.3. Safety and Health
4.4. Other
4.5. None

5. Does the Water Utility serves more than 50,000 inhabitants or 10,000m3/day?
5.1. Yes
5.2. No

6. With the transposition into national law of Directive (EU) 2015/1787 of 6 October, it will be expected to be required the implementation of a risk assessment procedure or a WSP. In what terms do you think such a measure should be implemented?
6.1. Yes, I agree with the mandatory risk assessment procedure
6.2. Yes, I agree with the mandatory WSP
6.3. Yes, I agree with the mandatory risk assessment procedure but with an adaptation period. What?
6.4. Yes, I agree with the requirement of a WSP but with a period of adaptation. What?
6.5. No, I disagree with its implementation

7. How do you understand ERSAR´s role in the WSP implementation process
7.1. Essential in the WSP audit phase
7.2. Essential in technical follow-up
7.3. Essential as a supervisory body
7.4. Other (specify)

8. How many Supply Zones/Delivery Points (ZA/PE) does the Water Utility have?
(number indication)

9. Do you have a WSP implemented in the Water Utility?
9.1. If yes, proceed to question 10.
9.2. If not, proceed to question 21.

10. How many ZA/E are under the PSA?
(number indication)

11. Since what year does the Water Utility has a WSP implemented?
(date indication)

12. What is the methodology followed in the implementation of the WSP
12.1. ERSAR Guide
12.2. OMS Guide
12.3. HACCP
12.4. ISO 22000
12.5. Other (specify)

13. For the implementation of the WSP resorted to external entity/consultancy?
13.1. Yes
13.2. No

14. What are the motivations that led to its implementation?
14.1. As a measure of innovation
14.2. For economic reasons
14.3. By existence of operational problems
14.4. To improve the knowledge of the system
14.5. Participation in the ERSAR project
14.6. Other (specify)

15. What benefits do you see from its implementation?
15.1. Improving system knowledge
15.2. Improving response capacity to occurrences/emergencies
15.3. Improving internal communication
15.4. Improving teamwork
15.5. More training of teams and employees
15.6. Reduction of operating costs
15.7. Minimisation of impacts on end-users
15.8. Improving external communication
15.9. Improving water quality contents
15.10. Rationalised and planning of improvement actions
15.11. Other(s) (specify)

16. What factors have been taken into account in the formation of the team for the preparation and implementation of the WSP?
16.1. Multidisciplinary
16.2. Knowledge of the operational process
16.3. Analysis and implementation of risk assessment methodology
16.4. Other (specify)

17. Do you think it is important to audit the WSP by an independent entity?
17.1. Yes
17.2. No
17.3. I don't know

18. What are the greatest difficulties in the development and implementation of a WSP?
18.1. Lack of capacity/involvement of the management bodies
18.2. Lack of data/records
18.3. Lack of data on origins
18.4. Costs
18.5. Other (specify)

19. Is/has been top management involved in the process?
19.1. If yes, proceed to question 22
19.2. If not, proceed to question 23

20. Do you have information on the direct costs of implementing the WSP?
20.1. If yes, proceed to question 24
20.2. If not, proceed to question 26

21. Why has the Water Utility not yet implemented a WSP?
21.1. Lack of training in human resources
21.2. Increase in costs for the Water Utility
21.3. Need to hire human resources
21.4. Lack of prospect of any added value for the Water Utility
21.5. It is not a mandatory legal requirement
21.6. Other(s) (specify)

22. Was the involvement relevant to the successful implementation of the WSP?
22.1. Yes
22.2. No

23. Has the lack of management bodies support detracted the implementation of the WSP?
23.1. Yes
23.2. No

24. What is the percentage weight of the WSP´s implementation on Water Utility´s turnover?

25. What is the percentage weight of the WSP´s implementation in the overall cost structure?

26. What is the percentage (estimate) of employees involved in the project?