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Water Safety Plans and Climate Change Mitigation

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Definition

Quality water at affordable prices for all is a key condition for the promotion of public health, environmental sustainability, and quality and safety of life. In a context of growing external uncertainties arising from changes in the climate and the environment, ensuring these conditions is an upward concern and is of utmost relevance to increase scientific research on the impacts of climate change on water quality modification and in minimization/mitigation strategies.

Scientific data already 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, with water quality for human consumption being 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. 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, implementing adequate technology or practice to assess and address risks of extreme events (IWA 2019).

Adaptive changes are, therefore, already in course, with some expected to be compulsory, namely legal requirements for water quality parameters, the adjustment of treatment processes, and, most important, the implementation of new approaches, explicitly risk assessment strategies.

Water safety plans (WSPs) are regarded as part of the solution, contributing to minimize climate change impacts on water utilities services and, inherently, on water quality. This article presents WSPs as an important and strategic tool linked to public policies in the water supply sector.

Introduction

The United Nations (UN) General Assembly declared, in 2010, access to safe drinking water and sanitation a human right, essential to the full enjoyment of life and all other human rights. This formal statement recognizes that water quality at affordable prices for all is the key condition for the promotion of public health, environmental sustainability, as well as quality and safety of life.

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In 2015, a collection of 17 global goals was set for the year 2030 – the sustainable development goals (SDGs) in 2030 Agenda – and countries around the world have expressed strong political will to ensure drinking water is universally safe, as stated in SDG 6 (UN 2015; ICLEI 2017).

The measurement of this SDG 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. And, as stated by the International Water Administration (IWA 2019), the time has come for policymakers 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.

Yet, there are innumerous difficulties to tackle as water quality and supply are affected by several factors, including the type of water bodies, the hydrological regime, and many 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 2019).

In fact, long-term planning for an adequate and safe supply of drinking water should be set in the context of growing external uncertainties arising from changes in the climate and the environment. As stated by the World Health Organization (WHO), 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 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 2019).

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 (GDWQ) 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 (Jiménez Cisneros et al. 2014). And all these parameters need to be constantly updated, as an essential part of the continuous revision requirements in WSPs.

This chapter is inspired both by the fact that there is only limited information published in English on how to integrate climate change aspects into WSPs (Rickert et al. 2019) and 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.

Background on Water Quality for Human Consumption

Until the end of the nineteenth century, the assessment and control of risks to human health due to the transmission of diseases caused by water consumption were carried out empirically, relying primarily on the physical appearance of the water. The epidemiological investigations carried out by John Snow in 1855, demonstrating the close link between the consumption of water with fecal contamination and an outbreak of cholera in London, the discovery of the existence of microorganisms by Louis Pasteur, in 1863, and scientific advances in methods for the detection of microorganisms by Robert Cock through the isolation of the bacillus Vibrio cholerae, in 1883, constituted decisive scientific bases for the association of water consumption with public health, serving as a starting point for the establishment of practices and protocols for the control of its quality (Vieira and Morais 2005).

Due to the inherent unreliability of this analysis based on common sense, demanding that water should be clear, enjoyable to the taste, and without an unpleasant smell, and due to several waves of epidemic outbreaks of cholera and typhoid fever in Europe, technical and legal means for disinfecting water in public water supply systems have been developed.

In 1958 the WHO publishes the first International Standards for drinking water, specifically dedicated to the quality of water for human consumption and 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 establishing 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. 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).

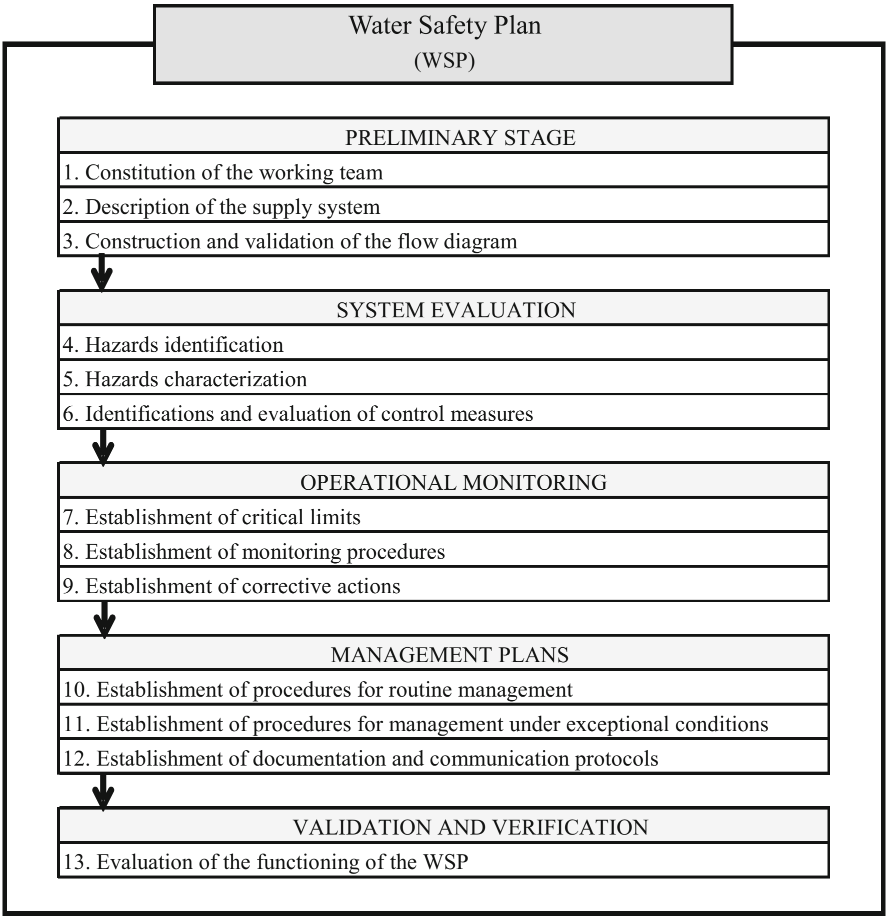
Nevertheless, change in aspects of an existing political system, or implementing innovative policies, contains a risk of failure. And governments are often risk averse, opting to do nothing or little, rather than implementing something that could cause them to be held accountable for failing. The risk aversion described by Howlett (2014) in the case of climate change can be extended to other domains, such as the mandatory adoption of WSPs, preferring to deny the need for substantive action to address the issue, rather than taking positive measures. This topic, together with necessary political decisions to mediate competing interests, competing ideas and values, is another aspect to consider when implementing, or making mandatory, the implementation of principles of risk assessment such as a WSP in the water system.

About Water Safety Plans

The concept of WSPs 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. Actually, an increasing number of water utilities worldwide are now using this procedure (Gunnarsdottir et al. 2015).

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 all 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.

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



Water Safety Plans and Climate Change Mitigation, Fig. 1 Framework for the development and application of a WSP. (Source: Vieira and Morais (2005))

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, as presented in Fig. 1:

- 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

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). Human activities are estimated to have caused approximately 1.0 °C of global warming above preindustrial levels, with a likely range of 0.8 °C–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 preindustrial 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 on the adoption and implementation of adaptation and mitigation options (IPCC 2018). Increasing awareness on 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 et 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 2017).

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 are generally to become wetter, while dry regions and seasons will 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 twenty-first century (Christensen et al. 2013).

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 groundwater quality (concentration), sometimes leading to water supply limitations. If surface water catchment can be directly affected by water quality degradation, pumping wells can be cutoff for sanitary reasons (groundwater quality) as well for security reasons (floods threats). However, even if these facts are well known, few scientific works have been published until recently 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 results 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 within 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, it is 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, and wetlands) and characteristics (water residence times, size, shape, and 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, runoff 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 carried out, as well as health risk assessment (following the WSP procedure).

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 influence 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).

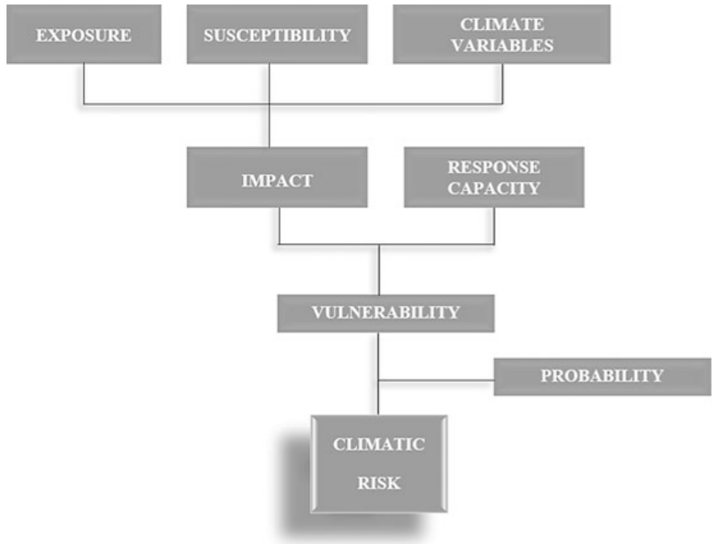
One of the major pathways through which contaminated water affects individuals is through drinking water. In management terms, these water supplies range from unimproved sources where the individual is effectively consuming raw water, to large, managed supplies where multiple barriers exist to prevent 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).

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 diarrheal disease burden 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.

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 2009). 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 et 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.

Strategies to Implement a WSP in a Context of Climate Changes

Consistent with the findings described above, climate change is very likely to influence the capacity of water utilities to sustain water service provision and the economic viability and cost-effectiveness of treatment and distribution (IWA 2019). Therefore, in order to guarantee water quality for human consumption and regarding the WSP implementation following the procedures presented in Fig. 1, the amendments to be done are expected to reduce the vulnerabilities of



Water Safety Plans and Climate Change Mitigation, Fig. 2 Methodology considering climate changes adaptation

business activities to climate change and extreme events and to increase the resilience and responsiveness of water systems to these changes and events.

The new scheme is as follows in Fig. 2:

In this context, it is relevant to promote the study of water supply subsystems and infrastructures to quantify and prioritize climate change risks, identify all necessary adaptation solutions, and plan the implementation of the measures, assessing the influence of climate and weather conditions on the operation of infrastructures. 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.

This monitoring allows 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, having as the most important consideration the potential impact on public health. Nevertheless, other factors such as organoleptic aspects, continuity of supply, and the public image/reputation of the supply water utility should also be considered.

Conclusion

Observations and model simulations indicate that climate change is taking place both at the global and regional levels. While some parameters, such as mean temperature, already show significant trends, others, like mean precipitation and climate variability indexes, are still rather difficult to analyze (Miranda et al. 2002).

As reported in several research papers (Patz et al. 2005; Casimiro et al. 2006; Levy et 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), 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. 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 comprise the timing and intensity of rainfall, directly affecting 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 encompasses the capacity of water utilities to sustain water service provision and the economic viability and cost-effectiveness of treatment and distribution (IWA 2019).

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 and Hrudey 2004; Pollard et al. 2008; MacGillivray et al. 2007) have been concerned with how to improve organizational competencies in risk management within the utilities and related sectors. Hence, ensuring appropriate water infrastructure, regular monitoring and appropriate management techniques, such as WSPs, is 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). This scenario is about to change as the EU Directive on water quality and national regulations are already mandating the implementation of risk assessment methodologies. In some countries, WSPs are already mandatory, as in Australia, Iceland, New Zealand, Serbia, Switzerland, Uganda, and the United Kingdom (Gunnarsdottir et al. 2015).

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 a climatic or ecological zone. 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 to the WSP process.

Water quality monitoring (from raw water and along all process points up to the consumers tap), is, therefore, an utmost priority and its monitoring is relevant as a contribution to WSPs implementation. It is relevant to acknowledge that there are many challenges when it comes to the implementation of a risk assessment methodology such as a WSP, not only regarding the operational perspective and technical options, but also in terms of governance issues. As Roeger and Tavares (2018) explain, there are four critical components in developing and implementing a WSP: leadership commitment, technical knowledge, governance, and interagency collaboration. In order to meet these challenges, adaptation efforts are needed and it is important to consider all basic approaches to improving public health, including civil and environmental engineering and behavior change efforts (Levy et al. 2006).

Needless to say, 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.

Cross-References

▶ Disaster Risk Reduction and Resilience Through Partnership and Collaboration
▶ Disaster Risk Reduction and SDGs in Developing Countries
▶ International Governance of Global Commons in the Context of SDG 17
▶ Partnerships for Flood Disaster Management
▶ Water Security

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