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Benefits, challenges and success factors of water safety plan implementation: A review

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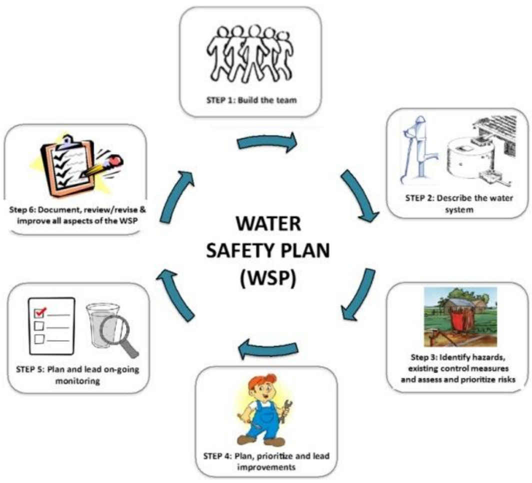
Graphical abstract



Abstract

Drinking water supply is a preeminent to public health, environmental protection, quality of life, economic activity, and sustainable development. Many disasters are being recorded due to poor water quality every day. In this case, it is essential to assure safe water demand through continuous enhancement and improvement of all practices and processes related to the water supply. The Water Safety Plan (WSP) concept has become a globally recognized and accepted approach to drinking water supply management and operation. This study aims at reviewing the WSP as a risk management approach and the implementation status around the world. In addition, the four success factors of WSP implementation are discussed. The benefits, difficulties, as well as recommendation from recent studies that implemented WSP is presented. The benefits include Improved operational efficiency, improved water quality, reduced consumers, reduced production cost and reduced potential hazardous incidents. However, the main difficulties for effective WSP implementation were lack of staff training, insufficient time and fund were the main challenges. According to a literature scan, the water utilities in Arab gulf region countries do not implement WSP, thus, the author encourages water utilities in these countries to conduct WSP to improve water quality management.

Keywords: Water safety plan; water consumption; risk management; public health.

1. Introduction

Water consumption throughout the world has increased six times in the last 100 years and continuously grow as ecosystems economic growth, health, and food security all need water resources (Baum and Bartram, 2018; WHO, 2007) Water supply is important to the quality of life, public health, environmental protection, sustainable development, and economic activity. Generally, water supply service is provided by natural resources monitored by authorities which should conform to principles such as continuity, universally, equity in pricing, efficiency and adequacy in quality and quantity (Herschan *et al.*, 2020; Roeger and Tavares, 2018).

Water quality is an essential factor to determine the agreement of water resources for the need's requirements (Ferrero *et al.*, 2019; Serio *et al.*, 2021) The water quality can be affected by many factors such as climatic, biological factors, geomorphological, geochemical as well as y anthropogenic influences. To prevent water-borne diseases such as leptospirosis, intestinal nematode and cholera infections, access to adequate sanitation and safe drinking water is inevitable (Bakir, 2020).

Water quality management is an essential issues of natural resources administration that change back and forth between governance systems different types, ranging from protecting water resources, implementing enforcement directives, monitoring and maintaining water quality standards, and remediation water contamination (Kelly *et al.*, 2020; WHO, 2017b) Accordingly, it is essential to take into considerations the water safety requirements when designing and operating water supply systems as well as take all effective and efficient actions to continually improve the quality of water quality (Kayser *et al.*, 2019; Peden *et al.*, 2021) In many countries, the recent development of technology and increasing concerns about the environment and public health have led to great enhancement in water quality(Bartram *et al.*, 2009).

Among the water resource management tools, Water safety plans (WSPs) are an essential tool in water sector management (WHO, 2017a). The goal of WSP is to guarantee the quality of water resources by intergrading site-specific elements analysis, taking into consideration any potential threat of chemical, physical, microbiological, or radiological nature that may exist on the system, propose and evaluate the measures actions, and make new strategies aimed at preventing and/or reduce the risk to the level that agrees with regulatory limits(Bereskiea *et al.*2018; Lane *et al.*, 2018; WHO, 2019a) Effective application of WSP need alteration from dependence on end product water quality to the combination of risk management and water quality testing, thus, WSP can be implemented in low-resole settings (Friederichs et al, 2017). The unique aspect of WSP is flexibility, WSP implementation and impact could be seen in developed and developing countries. However, the development level and water supply availability may determine the degree of implementation (Ekwere *et al.*, 2021; van den Berg *et al.*, 2019). In all countries, many benefits have been observed after WSP implementation, these benefits are improved water quality, increasing knowledge, awareness, and understanding among staff as well as improving collaboration and commination among stakeholders, and improving the overall water supplies system managements (Charles *et al.*2020; String and Lantagne, 2016).

WSP is a systematic and proactive risk assessment and management approach that leads to deeply understand the water supply system, identifies possible contaminant source, evaluate potential health risk, supposes possible mitigation measures, and designate effective control and monitoring systems (Oluwasanya and Carter, 2017; WHO, 2019b). The WSP approach mainly focuses on managing and control risks throughout water supply system from water source to storage, distribution network, and tab. By that, WSP support regulation to achieve health-based targets that leads to great improvement of water supply system (Pérez-Vidal *et al.*, 2016; Serio *et al.*, 2021).

This paper discusses the recent deployment of WSP in a number of nations throughout the world, as well as the major elements that lead to WSP's successful implementation. Furthermore, the goal of this review is to show and debate the impact of key factors such leadership commitments, technology knowledge, governance, and integrity collaboration on the effective implementation of WSP in small communities. The review goes in the same manner as a fellow, with section 2 providing a historical overview of water safety strategies. The next section introduces the WSP application's risk management and risk assessment strategy, as well as the advantages of employing WSP as a water quality management tool for both developed and developing countries. The fourth portion looked at the impact of WSP's major dimensions. The fifth section examines the benefits and problems of WSP, as well as the necessity for WSP in Gulf countries and the advice for WSP implementation water management plans.

2. Background

Ensure the water quality from a public water distribution system is a key component of public health and environmental policies (Bross *et al.*, 2021). Until the 1920s, the quality of drinking water was mainly determined by its organoleptic properties. Nevertheless, parametric rules were applied to guarantee water intended for public consumption owing to the intrinsic unreliability of this process. Technical and legal means ensuring the disinfection of water in public supply systems have been developed in this context. On a large scale, the control of diseases caused by microbiological contamination transmitted through water has been improved (Manuel *et al.*, 2005).

The first International Standards for Drinking Water, dedicated specifically to the quality of water for public consumption, are published by the World Health Organization (WHO) in 1958. The three volumes of the first edition of the Guidelines for Drinking Water Quality (GDWQ) were published in the 1980s: Vol 1 - Recommendations; Vol 2 - Health criteria and other supporting information; and Vol 3 - Surveillance and control of community supplies. This method was a game-changer in public health protection because it allowed for the evaluation of health risks posed by chemicals, microorganisms, and radionuclides. Moreover, in many countries, this method served as the foundation for establishing public policies and regulatory procedures, and it continues to serve as the foundation for water quality control for human consumption in the majority of them.

The WSP established by WHO in 2004 (Gorchev and Ozolins, 2004), which were later transposed to the regulatory level, thus include combined prevention and control system based on site-specific risk analysis that extends to the entire hydro-drinking chain, which represents a critical step toward improving water quality to protect human health. In 2009, the WHO published a manual that describes the step-by-step WSP procedure (Bartram *et al.*, 2009).

The WSP was recently incorporated into European Directive 2015/1787 (European Commission, 2015), which governs the quality of water intended for human consumption. Appropriate WSP implementation thus provides an important opportunity to engage in and encourage preventive risk management within water utilities (Summerill *et al.*, 2010). For these reasons, several countries have decided to introduce the WSP on their own water regulation. WSPs are currently being implemented to different degrees in 93 countries worldwide, with 30%

of countries in an early implementation stage; 46 countries report having policy/regulatory instruments that promote or require WSPs, and another 23 countries are developing such instruments (WHO, 2017c), for example, in France (Setty *et al.*, 2018), China (Kayser *et al.*, 2019; Li *et al.*, 2020), Germany (Schmiege *et al.*, 2020), Portugal (Roeger and Tavares, 2018, 2020), India (String *et al.*, 2020), Chile(Page *et al.*, 2020), and Italy (Collivignarelli *et al.*, 2018; Muoio *et al.*, 2020).

WSPs are a systematic approach to managing drinking water safety that use a multi-barrier methodology across the entire water supply chain, from catchment to consumer. (Davison *et al.*, 2005). The goal of WSPs is to protect public health by preventing water supply pollution, preventing risk in the water supply system, and taking steps to prevent recontamination during drinking water distribution and storage. (Narayan *et al.*, 2021). One of the main characteristics that differentiate WSPs from other drinking water safety management tools is their concentrate on preventing the occurrence of hazards instead of trying to suppress risks and minimizing their negative effects (Aghaei *et al.*, 2017). Furthermore, because there is no strict technique that dictates how these systems should be implemented, WSP can be implemented to a wide range of water utilities, regardless of degree of complexity, their location, or production capacity. WSPs has been established according to hazard analysis and critical control points (HACCP). As shows in Figure 1, a six-step approach is used to create WSPs: (1) assembling a team; (2) system analysis; (3) operational monitoring; (4) management and communication; (5) review, approval, and audit; and (6) assessing experience and future needs. Preparation; system description; risk assessment; identification of hazards and determination of corrective actions; monitoring and verification; and revision are all essential management components in both HACCP and WSPs (Bartram *et al.*, 2009).

Preparation	Model 1.	Assemble the WSP team
System Assessment	Model 2.	Describe the water supply system
	Model 3.	Identify hazards and hazardous events and assess the risks
	Model 4.	Determine and validate control measures, reassess, and prioritize the risks.
	Model 5.	Develop, implement, and maintain an improvement/upgrade plan.
Operation Monitoring	Model 6.	Define monitoring of the control measures
	Model 7.	Verify the effeteness of the WSP
Management and Communication	Model 8.	Prepare management procedures
	Model 9.	Develop supporting programs
Feedback and improvement	Model 10.	Plane and carryout periodic review of the WSP
	Model 11.	Revise the WSP following an incident

Figure 1. The main steps of WSP (Bartram *et al.*, 2009).

3. Risk management and risk assessment in water safety plan

Risk management is an important function in the utility sector. A crucial requirement is the effort to identify and analyze risk, as well as to plan and implement preventive actions to improve risk control (Roeger and Tavares, 2018). If the purpose of risk management in the water supply sector is to ensure water safety, therefore understanding the concept of water safety in connection to the goals that underpin water safety planning becomes critical. The first section discusses the concepts and purposes of water safety plans, while the second and third sections look at existing literature on WSPs in developed and developing countries.

3.1. Water safety: concepts and goals

Since 2004, the WHO has advocated theWSP methodology, which attempts to improve the safety of drinking water supplies. WSPs are currently utilized all around the world and are legally mandated in several countries (Gunnarsdottir *et al.*, 2012).

Gunnarsdottir *et al.* (2012) conducted a study using comprehensive surveillance data, to examine the impact of WSP implementation on regulatory compliance, microbiological water quality, and the incidence of clinical cases of diarrhea. The results indicate that where a WSP was implemented, there was a significant decrease in the incidence of diarrhea, and the results also show that the population where a WSP was implemented is 14 percent less likely to develop clinical episodes of diarrhea. Goodwin, *et al.* (2015), analyzed the possibility of transforming the WSP into a water reuse strategy. Also specifically discusses the need to establish an overarching risk management framework to locate a Water Reuse Safety Plan (WRSP) approach alongside (and adapted from) the Framework for Safe Drinking Water (FSDW). The findings emphasize the need for risk management reflecting on and facilitating the inclusion of larger contexts and objectives for water reuse schemes.

A recent study conducted by Tsitsifli and Tsoukalas (2021) reviewed the status of the risk assessment tool of Water Safety Plans implementation around the world and outlined the benefits and challenges encountered during the process. The results show that the benefits of Water Safety Plans implementation include improved water quality, increased operating efficiency, fewer complaints from customers, lower production costs, and fewer potentially hazardous situations. In addition, there are several critical success aspects of Water safety plan implementation as financial and human resources, staff training, effective identification of essential control points, accurate estimation of the occurrence and severity of hazards, effective coordination, and efficient monitoring.

3.2. Water safety plans: the state of the art in developed countries

In 2013, a study conducted by Hubbard *et al.* (Hubbard *et al.* (2013) to investigate the experiences of five Latin American nations throughout the implementation of the WSP. The findings show that WSP adoption is more common than previously thought. In addition, the WHO Guidelines for Drinking-Water Quality are widely utilized as a model for country-level drinking-water legislation, according to respondents, resulting in widespread adoption of the WSP methodology.

A study conducted by (Perrier *et al.* (2014) explores the barriers and bridges in the context of early Drinking water safety plan (DSWP) adoption in small towns across rural Alberta, Canada as seen through the views of small system operators. The findings indicate a variety of challenges connected with relationships between decision-making bodies, regulatory authorities, and water operators, all of which have the ability to assist or hinder DWSP adoption. Findings also show that a DWSP can serve as a bridge, offering a much-needed tool to enhance communication regarding water supplies and support and manage relationships amongst stakeholders.

Setty *et al.* (2018) conducted a study to investigate the potential value of many operational performance indicators utilized for a WSP at a drinking water company in southwestern France. The results showed a considerable reduction in the duration of low-chlorine events at one manufacturing plant, as well as a large reduction in customer complaints about water quality. A study conducted by Gunnarsdottir *et al.* (2020) to assess the impact of implementing enhanced contemporary pathogen and microbial indicator detection techniques developed in the EU FP7 Aquavalens project on drinking water safety and WSP plan management. Data on water safety risk factors were collected via a questionnaire aimed at determining risk factors and the stage of implementation of Water Safety Plans, as well as site-specific surveys known as Sanitary Site Inspection, for five large water supplies in Denmark, Germany, Spain, and the United Kingdom, and fifteen small water supplies in Scotland, Portugal, and Serbia. The results showed that some of the techniques when implemented as part of water safety management, could detect quickly the most common waterborne pathogens and fecal pollution indicators, and thus have a high early warning potential. Also, can improve water safety for consumers, can validate whether mitigation methods are working as intended, and can confirm the quality of the water at the source and at the tap.

A recent study conducted by Serio *et al.* (2021) in in Salento (South Italy) to implement the Water Safety Plan in three businesses in Salento, in the province of Lecce. The case studies confirmed the model's applicability even to tiny drinking-water systems, despite the fact that it required more effort in studying the incoming water, the local intended use, and the possibilities for controlling the containment of the risks to which it is exposed.

3.3. Water safety plans: the state of the art in developing countries

A study was conducted by Alazaiza and Moghier (2013) to develop a Gaza Strip Water Safety Plan by assessing the water delivery infrastructure from desalination plants to taps and identifying the hazards that could be introduced at each stage (source, distribution, and storage). The results showed that the WSP was not used in the Strip, where a lot of procedures were required to ensure the safety of drinking water. In addition, the main hazardous incidents in the desalination water distribution system occurred in the system delivery trucks and residential tanks during the second and final stages. The authors suggested that it is critical to monitor and follow up on these desalination plants in order to ensure that they are complying with the conditions and terms of water quality.

Kanyesigye *et al.* (2019) studied the status of WSP in Uganda, which was one of the first African countries to design and operate a WSP, with the first WSP dating back to 2002. The result of their study showed that, over the last 15 years, the development of the 20 WSPs has been mostly incomplete and different. In addition, the majority of WSPs concentrated on system evaluation and improvement but left out WSP monitoring, verification, and administration. The authors concluded that inadequate training, erroneous perceptions, team composition and deployment, and the inability to evaluate WSP efficacy were highlighted as the key barriers to WSP adoption. On the other hand, public health responsibility, management commitment, financial availability, solid customer relations, and dependable laboratories were the most important enabling factors of WSP implementation.

Razmju *et al.* (2019) studied the weak points in the Iran, Semnan water supply system based on WSP. The water safety plan quality assurance tool (WSP QA tool) software was used to assess the water safety plan's weaknesses and progress. The results of their study show that the most hazardous events were recognized as old infrastructure, old pipes, and, as a result, pressure loss at the site of usage. Since the Semnan water supply is groundwater, the authors believe that by focusing more on other areas such as basins, transmission and distribution lines, and points of consumption, as well as fully implementing the water safety program in this system, more favorable results and coordination rates can be obtained.

Abuzerr *et al.* (2020) conducted a study in the Gaza strip, to study health-related hazardous incidents in order to determine the optimal risk-reduction solutions in the Gaza Strip's drinking water supply. The goal was to conduct additional tests on the chlorine residual, nitrate concentration, and electrical conductivity in 109 small-scale water desalination plants, 197 tanker trucks, 109 water wells, and 384 residences spread throughout five governorates in Gaza. The results of their study showed that the chlorine residual amounts observed on average were lower than the prescribed national and international limits. Furthermore, none of the water samples fulfilled the necessary requirements, indicating that the groundwater in Gaza is unfit for human consumption. Furthermore, the study discovered a higher level of electrical conductivity in desalinated water in desalination facilities compared to desalinated water in households. The authors recommend that more efforts be made, and more control mechanisms are used to limit the danger of hazardous occurrences on drinking water supply systems and to supply safe drinking water to the population in accordance with Palestinian water authority requirements.

A study was conducted by Bazgir *et al.* (2020) to assess the risk of the Tahm dam on Zanjan City's drinking water supply and distribution systems by executing WSP in 2019. The results of the risk assessment revealed that the three most prominent dangers of the analyzed water supply systems were rural sewage discharge in the catchment region, inadequate consumer understanding, and old pipes and aging water infrastructure. In addition, the authors suggested that more attention should be made to the weaknesses and strengths based on the risk assessment of the findings of this water system in the catchment region and the endpoint of usage.

A study conducted by Herschan *et al.* (2020) in Low- and Middle-Income Countries to identify the factors that contribute to a WSP's performance. The results showed that the most three essential success variables identified were technical capacity building, community engagement, and monitoring and verification. I addition, Factors specific to small drinking water supplies in Low-Middle Income Countries include support from non-government organizations, integration into existing water sanitation and hygiene (WASH) programs, simplicity, and community engagement. Moreover, the study highlights the need for further data collection and research focused on success factors in these settings.

4. Key dimensions of water safety planning

Management and stakeholder engagement are two essential aspects of WSP. As organizational culture is defined as the experiences, attitudes, norms, values, and beliefs shared by the organization members, the operation of the organization to promote or retard the adoption of new tasks is affected by stakeholders and managing knowledge (Schein, 2010; C Summerill *et al.*, 2010). This section discusses how the WSP four dimensions; leadership commitment, technical knowledge, governance and integrity collaboration may affect the successful implementation of WSP.

Strong leadership commitment is an essential key for successful WSP implementation by water management bodies. The importance of senior management engagement and involvement for the success of WSP was reported by a study by Summerill et al (Corinna *et al.*2010)which presented the effect of organizational culture. The study found that organizational culture had some weaknesses although internal commitment to risk management was observed. Those weaknesses hindered the achievement of full application of WSP. Some organizational cultural characteristics such as camaraderie, customer service mentality, proactive leadership, transparency, competent human resource, and accountability support the overall process. Other organization culture traits such as miscommunication, interest or reward, lack of flexibility and knowledge, and coercion hindered the implication of WSP. The study concluded that considering the effect of organizational culture on the WSP adaptation is essential towards a sustainable practice of WSP.

Barriers between management and workers result in a breakdown in relationships and communication and directly affect the WSP. The success of WSP is related to dependence, trust and identification with managers. In WSP projects, when workers lost belief in themself and their value and usefulness as a result of the gap between managers and workers (low level of internalization), the failure in project implementation appears. Thus, the internationalization management commitment is essential for the team as well as WSP successful implementation (Kostova and Roth, 2002).

Thiel (2015) revised 5 case studies from the United States of America and conclude that the shape of water governance is highly affected by the internal dynamic. In addition, Amendment of institutional arrangements over time to react with the changing awareness and understanding forming public attitudes and performance (Schlager and Blomquist, 2008). Thus, WSP in countries where their character is not shaped, highly depend on the strong political component. Changing the political system may fail, therefore, governments are often play it safe, choose not to change the present situation rather than conduction something new that could bring an unaccountable risk.

Several studies highlighted the importance of external communication which can understand by the terms of end-users The traditional belief stated that external communication is conducted between management bodies and drinking water end users, but in realty the external communication covers a wide range of agencies and stakeholders (Ferrero *et al.*, 2018). Similarly, Kot *et al.*(2015) stated that public readiness can be translated to resource, leadership, and awareness and widespread knowledge about safe drinking water is essential for WSP implementation. To conclude, leadership commitments promote external communication in the organization and enhance internal communication, resulting in improvement of stakeholder's engagements and fulfillments. In addition, a serious commitment of management bodies and involvement of stakeholders is essential for successful WSP implementation.

The WSP implementation process depends on effective collaboration, thus interagency collaboration is considered challenge and opportunity for water utilities (Bartram *et al.*, 2009). Jalba *et al.* (2010)) come up with an emergency management structure depend on cooperation between public health sector agencies and public water supply agencies, as part of risk management. The authors establish qualitative research to determine the aspects that affect the effective interagency relationship. They identify six critical elements of institutional relations which include communication, creativity, training, confidence, exchange of experience, and regulation. All six aspects are essential for effective institutional relations. Breakdown in one aspect might lead to failure in a future event. For instance, do not share experiences can cause delays in investigation and possibly compromise the solution.

Enhancements in water governance are methods to ensure the water supply quality for human consumption. Availability of safe water may be improved when certain governance challenges are discussed: enforcement and monitoring of water quality regulations, interagency collaboration between countries and ministries that relate to drinking water services, and technical knowledge to enhance water supply system managements (Kayser *et al.*, 2015). Implementation of WSP has many benefits for the governance level as it enhances document management.

Many enhancements in technical knowledge can be achieved during and /or after WSP implantation. For example, WSP assures the provision of safe water while also improving security in terms of water quality assurance and public health protection. Moreover, WSP enables the systematic identification of risks, as well as the creation and formalization of procedures and activities for risk prioritization and minimization/ mitigation. However, WSP implementation necessitates a high level of technical expertise to gain a thorough understanding of the supply chain (Tsoukalas and Tsitsifli, 2018).

In a broader sense, the four key components may be found in different utility industries. (Finnveden *et al.* (2013) demonstrate how a Strategic Environmental Assessment (SEA) framework incorporates a variety of analytical tools in the energy industry, including Life Cycle Assessment, Risk Assessment, Economic Valuation, and Multi-Attribute Approaches. This variety is capable of accommodating disparities in the beliefs and worldviews of different stakeholders and, as a result, stimulates collaboration and understanding in environmental assessment procedures, promoting credibility and relevance. Clearly, the SEA tool recommends dedication, technical expertise, governance, and interagency collaboration (Herschan *et al.*, 2020).

5. Water safety plans; Benefits, Challenges and Recommendations

This section addresses the implementation of WSP in the context of water policy in several countries. In addition, the benefits of WSP implementation and the difficulties, as well as the recommendations, are presented. Table 1 summarizes the recent studies that discussed the implementation of WSP around the ward and illustrate the benefits and difficulties as well as the recommendation for WSP effective practice.

In a study by Setty *et al.* (2018), the authors tried to validate the relationship between WSP implementation and health outcomes in high-income countries. They used time series to investigate the site-specific relationship between acute gastroenteritis rates and water-related exposures at three locations in France and Spain. The results showed that, in some cases, the risk assessment approach of WSP succeed to mitigate gastrointestinal illness risk. In another study, (Amjad *et al.* (2016), investigated the applicability of US water utility to use WSP for water quality management in the state of North Carolina. The results showed that water utilities in North Carolina have a reactive culture more than preventive, which means, risk preventive management tools such as WSP need prioritization of resources and time, thus, the water utilities in North Carolina are not able to implement WSP due to lack in resources and time.

Table 1: The application of WSP: benefits, difficulties and recommendations.

Country	Benefits	Difficulties	Recommendations	References
France and Spain	• WSP controls on turbidity and chlorine enhanced the water quality.	• The results of the longer-term implementation of WSP, health improvement and water quality, may need more time to observe.	• For effective WSP implementation strategies, creating a connection between input/output, impacts of WSP and outcomes is essential. • Hidden dangers such as “tokenism”, poor long-term adherence and poor fidelity should take into consideration.	(Setty *et al.*, 2018)
North Carolina	• Improved risk management, enhanced the organization of information, and decrease the operation and maintenance cost.	• Perceived duplication of existing practices and insufficient staff time are the main barriers to WSP implantation.	• More research is needed to get full insight into whether the implementation of WSP in the US may bring benefits.	(Amjad *et al.*, 2016)
China, Cuba, France, Spain, Morocco	• Increased water safety awareness among personnel, new hazards addressed, increase water quality, and enhanced surveillance of pollution sources in the watershed. • enhance record-keeping and data collection, improve process management,	• Difficulty in determining the hazards assessment limits. • Extra office work such as (review, hazard controls, audits) is loaded for personnel	• To enhance communication benefits, improve WSP training, create a certification system for WSP, improve cost management, and track outputs; lessons should be shared across the international WSP system.	(Kayser *et al.*, 2019)

	and better respond to alarms. • Improved control of chlorination and THMs in distribution systems.	and management.		
Asia-Pacific region (22 counties)	• Infrastructure improvements. • significant enhancement in operations and management practices. • The qualitative data indicated that knowledge and training obtained by water system staff through. • Improved the Water system staff knowledge and training. • Increased the staff awareness towards water quality, and that lead to increase testing to enhance their insights of the water supply system and their motivation to assure water quality.	• Due to financial deficiencies, many water utilities cannot implement the WSP risk mitigation measures. • Low building capacity restricted WSP implementation.	• Capacity-building may improve by conducting training programs and enhancing the data collection process.	(Kumpel *et al.*, 2018)
European countries (Germany, Denmark, Spain, UK, Serbia, Portugal and Scotland)	• WSP implementation developed infrastructure and helped to identify new hazards. • Improved control processes, knowledge of the catchment and water quality. • Regarding management, professionalism improved, and user confidence increased. • Internal communication was improved.	• WSP is costly and time- consuming as well as involving a lot of paperwork.	• WSP implementation may improve water supply infrastructure and solve the unregulated water problem.	(Gunnarsdottir *et al.*, 2020)
China	• After WSP implementation, the competence of employees improved, water quality was improved, and control and monitoring measures were enhanced. • A deeper understanding of the wastewater treatment plants was achieved.	• The main challenges hindered the application of WSP were, lake of attention to risk management, lake of training and guidance lake of motivation and lake of efficient technical guidance. • In rural areas the main obstacles were, poor infrastructure and weak external support.	• For rural areas in China, simplified WSP is strongly needed to enhance the water services • For urban settings, the government should provide policy and technical support.	(Li *et al.*, 2020)

	• WSP implementation enhanced water services emergency management plan.			
South-East Asia region	• WSP are helping to institutionalize good practice in the operation and maintenance of water-supply systems.		• Adequate WSP implementation and independently audition are needed to achive safe water at the tap.	(Sutherland, 2021)
Chile	• Preventive management approach may support water management bodies against of hazardous events.	• Water utility companies' certification such as quality management standards (ISO 9001), environmental management standards (ISO 14001), organization and occupational safety standards (OHSAS 18001) are not specified to water sector.	• Water utilities in Chile must change the water quality management system from a reactive approach to a preventive approach.	(Carvajal *et al.*, 2021)
Iran	• WSP implementation of is recommended to water supply organizations as the most efficient tool to ensure security in water supply.	• Incomplete implementation of WSP hindered the development of the supporting program and the evaluation process of WSP.	• Depending on the final test is ineffective for groundwater management practice. It's recommended for full WSP implementation for effective and safe groundwater management.	(Aali *et al.*, 2021)

In a multi-nation interview study, Kayser *et al.* (2019) interviewed 20 WSP implementation teams from five different countries (Cuba, China, Morocco, France and spin) to validate the cast and benefits of WSP implementation, and to determine the necessary environmental emblement for WSP implementation. The results showed that the start-up cost mainly from staff time averaging 16.2 full-time equivalent person-months. Moreover, additional costs from hiring consultants, training staff, purchasing equipment and certifying WSPs were found. The results indicated that the main benefits were improved hazard control, record keeping, treatment practices and client and health agency confidence. In another study, \ Kumpel *et al.* (2018) examined the benefits of applying WSP of 99 water supply systems in 12 counties in the Asia-pacific region. The results showed that the implementation of WSP resulted in infrastructure improvements in 82 water supply systems. In addition, 37 sites were showed an increase in financial support. Remarkably, considerable enhancements were noticed in management and operation practice, water quality testing activities, the number of meetings related to water safety, and consumer satisfaction monitoring. Nevertheless, many challenges were observed such as insufficient capacity and financial constraints.

Gunnarsdottir *et al.* (2020) evaluated the implementation of WSP for water supplies in seven European countries (Germany, Denmark, Spain, UK, Serbia, Portugal and Scotland). The results showed that WSP implementations may increase the rapid detection of the most common faecal pollution and waterborne pathogens and this improve the early warning potential which can enhance water quality; can grantee the water quality at source and tap, and can observe the efficiency of mitigation measures. In another review study, Li *et al.* (2020) reviewed 18 studies that implemented WSP in China from 2004 to 2018. They evaluated the WSP implementation for the 311 water system. I addition, they extracted and analyzed data such as water supply risk factors and risk matrix. The results showed that the use of WSP in china was applied on a pilot-scale only, on the other hand, the full implementation of WSP in China remains in early stages. The authors concluded that the WSP implementation is an efficient tool for enhancing water supply systems in rural areas of China.

In a recent study, (Sutherland *et al.*(2021) reviewed the implementation of WSP for 10 years in the South-East Asia region. The results revealed that during 12 years, the WSP improved the performance of water supply systems and prevented the occurrence of chronic waterborne diseases. Moreover, WSP has improved infrastructure, management and system operation, increased stakeholder collaboration, enhanced water quality tests and improved consumer satisfaction monitoring. In another study, Carvajal *et al.* (2021) evaluated the gaps in the risk management approach depending on Australien experience in WSP implementation as it is implemented in Chile. Water utilities in Chile focused on verification and reporting without taking into consideration a preventive approach regarding risks in water supply systems. The results from the study concluded risk management from the resource to the tap should be considered as a valuable tool for improving current management practices and shifting from a reactive to a proactive approach in Chile. Aali *et al.* (2021). Implied WSP principles for the groundwater system in Talesh city in Iran. The results concluded that production sources have gained more attention of organizations compared to other water supply system parts such as transmission lines, reservoirs, distribution networks and water consumption points.

6. Recommendations

Because of the different challenges that drinking water systems face and the scarcity of original research on the subject, future research should this emphasizes on more data collection, and research on success factors in these settings. In addition], The success factors should be identified to aid water supply managers in enhancing the uptake and long-term sustainability of WSPs in drinking water supplies in low- and middle-income settings. Pilot schemes are useful for verifying and demonstrating the efficacy of methodologies, especially in the context in question, prior to mainstream WSP execution. therefore, more researchers should implement on pilot scale to get full insight. Additionally, pilot schemes can aid in demonstrating benefits and challenges, as well as providing knowledge gained and scaling capacity.

7. Conclusions

Public health, environmental protection, quality of life, economic activity, and sustainable development all depend on safe drinking water. Every day, numerous disasters are reported as a result of poor water quality. In this case, it is critical to ensure safe water demand by enhancing and improving all water supply practices and processes on a continuous basis. WSP is a risk assessment tool that is used all over the world to improve the quality of drinking water. The application of risk assessment and risk management principles in the production and distribution of water for human consumption enhances water quality assurance and public health protection by complementing "end of the line" compliance monitoring. The major benefit resulting from WSP is that it helps to the management of potential hazards which enhance the safety and quality of drinking water. The main difficulties that prevent the successful application of WSP are the lack of capacity building management procedure as well as finical resource and staff training. Water management bodies in Arab Gulf country regions are encouraged to implement WSP as it improves the water practice in those countries.

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