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Experience of Implementing Water Safety Plan in Iran: A Systematic Review

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ABSTRACT

Introduction: The water safety plan is a systematic approach that aims to ensure the quality of water distributed to consumers. In 2004, the World Health Organization issued a statement implementing the water safety plan. The plan is underway in Iran. The purpose of this study is to review the studies conducted from 2004 to 2020.

Materials and Methods: Present article is a systematic review study to search for keywords in a combination of "water safety plan" (WSP), "Iran", "Hazard Analysis and Critical Control Points", (HACCP) and "water" in international databases including: PubMed, Science Direct, Google Scholar, as well as national databases include: Magiran and SID.

Results: In the initial search, 671 articles were found that after screening based on the Prisma checklist, 15 articles were included in the study for further review. The results showed that in the implementation of WSP, the highest score is related to Qom city with 68.64% and the lowest value is related to Khoy city with 17.5%. Improvement and upgrade program, support program development, and review of WSP courses have received less attention. Low staff familiarity with WSP, insufficient team composition and lack of coordination between them in holding regular meetings can be the reason for poor implementation of WSP in Iran.

Conclusion: The full implementation of the water safety plan controls the risks in the water supply system and reduces costs, as well as improves and increases the quality of water distributed to consumers.

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Introduction

Water resources are one of the main factors of sustainable development in any society and in addition to quantity, it is very important to perusal its quality [1]. Lack of needed water resources has always affected the lives of humans, plants and animals in many countries, including Iran and this problem is considered as one of the indicators of economic and agricultural development in any country [2]. Therefore, in 2010, the United Nations recognized access to safe water as a human right due to the importance of the issue [3, 4]. According to World Health Organization (WHO) statistics in 2016, the majority of disease outbreaks and about 3.3% of deaths in the world (about 2 million out of 123 million deaths per year) were due to lack of access to safe water [5, 6]. These statistics always show the impact of natural and unnatural factors on water resources and may have irreversible effects on the health of people in any society. Therefore, one of the main concerns of managers and officials supplying safe water is monitoring the potential risks, protecting the public health of water distribution network consumers, and ensuring that all members of the community have access to adequate and safe water [6-8]. One of the most effective ways to ensure the safety of drinking water is to use a comprehensive method of risk assessment and risk management that identifies and controls the critical points and hazards that threaten the water supply system from the Catchment to the point of consumption [7, 9-11]. Such an approach is called the Water Safety plan (WSP) [12]. Water safety plan is a tool that provides principles for risk management practices such as Hazard Analysis and Critical Control Points (HACCP), multiple barrier modeling, and risk assessment [13]. WSP is a preventive management approach and consists of three main components; the goals are based on health, a safe water plan and an independent monitoring system [9-11]. For this reason, this plan is superior to traditional methods of water quality assessment. In the traditional method, sampling and analysis of results is time consuming and always reports past water quality. Therefore, it is not able to detect the occurrence of accidents and hazards in the water supply system and cannot reduce the subsequent consequences [14,15]. Due to the importance of the issue, WHO ordered the implementation of the water safety plan in 2004 [16]. Since then, the implementation of the WSP has been considered in various ways by the world's water authorities, which are implemented by 93 countries. In 69 other countries, such as New Zealand, Belgium, Germany, Italy, Sweden and the United Kingdom, they are being developed as a regulatory or mandatory policy [17,18]. Iran is currently implementing WSP [9]. The first published study of the use of WSP in Iran was conducted by Jahed et al. The present study is a review of WSP studies conducted in Iran. The results and recommendations collected from this study can be compared with studies in other countries and show the main obstacles to the application of this program in Iran. It also identifies key risk factors in aquatic systems in which WSP has been implemented.

Materials and Methods

Search strategy

Considering that 2004 was recognized by the WHO as starting point for the implementation of WSP, English and Persian articles published from January 1, 2004 to November 1, 2020, that included WSP applications in Iran, via searches in international databases including PubMed, Science Direct, Google Scholar and national databases including Magiran and SID were identified. The key words searched in this study were included "water safety plan", "WSP", "Iran", "hazard analysis and critical control points", "HACCP" and "water". The search strategy consisted of combinations of these words (in both English and Persian). Prisma checklist principles were used to articles screening process.

Inclusion and exclusion criteria of the study

Articles that met the following criteria were eligible for inclusion in the study; 1- Studies conducted in the time limit of 2004 to 2020, 2- Original studies, 3- Existence of full text, 4- Performed in Iran, 5- Use the semi-quantitative risk matrix method recommended by WHO to assess the risk of water systems.

Data extraction and analysis

An Excel data entry form was developed. Data structure includes; name of authors, year, language of study, province and urban or village, type of water system, risk management method and WSP impact assessment. Two researchers independently checked the data extraction forms for accuracy and completeness. Finally, the extracted data includes; results of the general evaluation of the steps of WSP, the progress rate information of WSP, provincial distributions of reported studies, prioritization and risk assessment of the most important hazardous event, was analyzed by Excel software. In this study, 15 articles were included.

Results

A review of published WSP studies in Iran

In this study, during the initial search according to figure 1, 671 articles were found, and after removing the duplicate results, 652 items were selected. The titles and abstracts of 652 articles were reviewed by researchers to identify their relevance to the subject of study. Based on the inclusion and exclusion criteria, 54 studies were selected for full text review, of which 38 articles were excluded from the study due to non-Iranian and one article due to not using the WHO recommended risk matrix. Finally, 15 articles were included in the study for further review that implemented WSP, Risk Assessment, and HACCP program. According to the results extracted in table 1, out of 15 selected papers, 8 had implemented WSP, 5 had performed risk assessment and 2 had implemented HACCP. 11 studies have been published in English and 4 studies in Persian. The reported WSP studies have been performed on surface and groundwater systems, which include a total of 291 water supply systems, 7 surface water supply systems, 280 wells and 4 springs. More studies have been conducted in urban areas and only one case is dedicated to village areas, indicating that more studies have focused on large-scale (urban) water systems and less on small-scale (village) scales.

In terms of geographical distribution, studies have been conducted in 10 provinces of the country, mostly in the central provinces, including; Qom, Isfahan, Semnan, Zanjan and Hamedan (n = 7), northwestern provinces including; Ardabil, East Azerbaijan and West Azerbaijan (n = 5) and the east of the country include; the provinces of Khorasan Razavi and South (n = 3). Provincial dispersion of published studies is shown in figure 2. As can be seen, no report of WSP studies has been published in the northern and southern provinces of the country.

Table 2 shows the results for the scores obtained in the 10 WSP steps for 11 studies. Studies have shown that in most studies except Hamedan and Qom, some WSP steps have not been performed and have not scored. These steps are shown in the table as a dash.

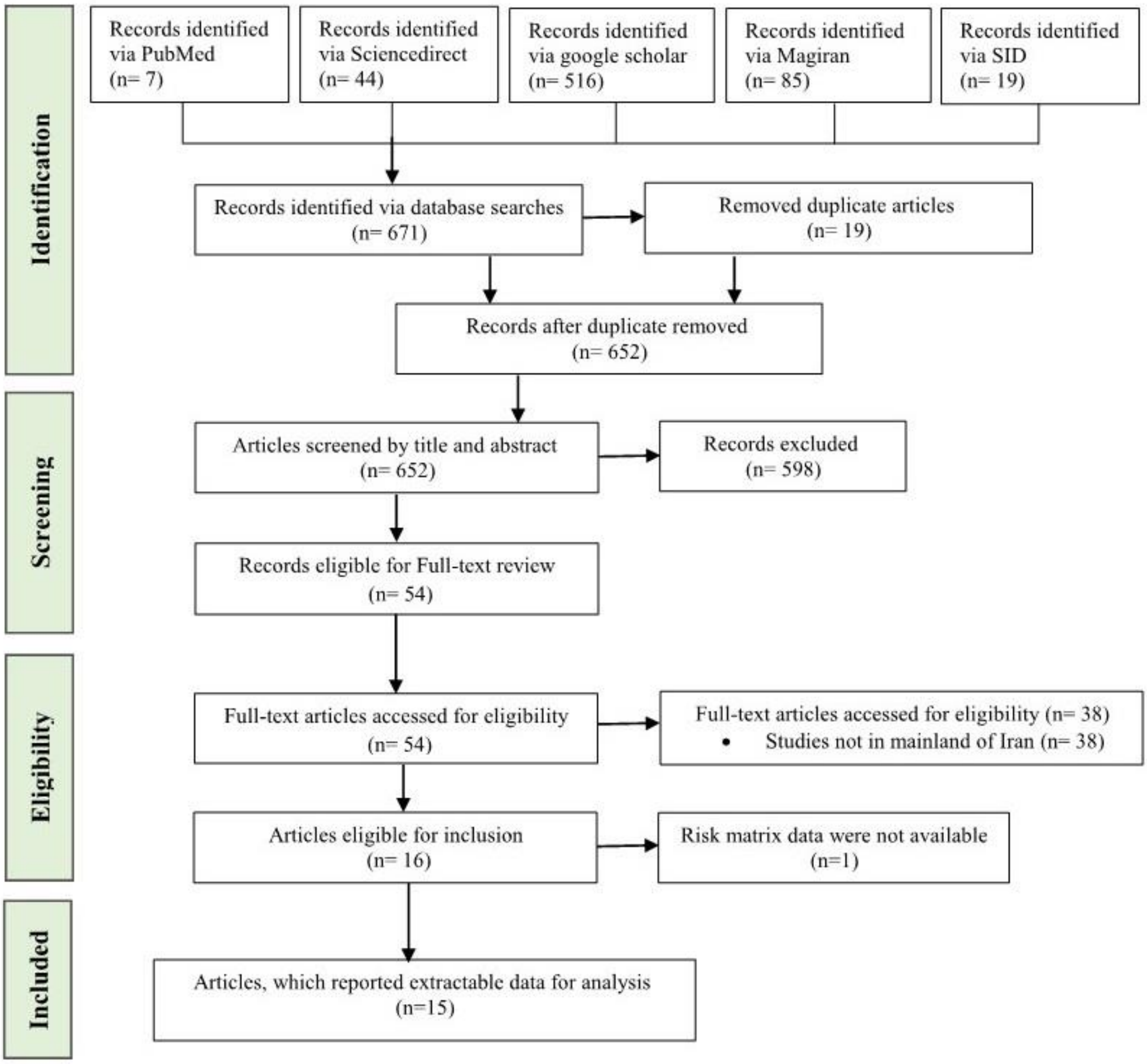

Figure 1: Papers screening process for eligible studies

Table 1: Characteristics of studies included

No of Study	Author, year	Language	Province	Urban or village	Type of water systems	WSP impact evaluation method	Risk management method	Reference
1	Jahed et al, (2009)	English	Ardebil	Germi city	Surface water	Water quality test	HACCP	19
2	Bina et al, (2010)	Persian	Isfahan	Isfahan city	Surface water	Water quality test	HACCP	17
3	Boodaghi et al, (2011)	Persian	West Azerbaijan	Khoy city	24 wells	Water quality test	WSP	13
4	Mahvi et al, (2014)	English	Ardebil	Ardebil city	Surface water	Water quality test	Risk Assessment	20
5	Mosaferi et al, (2014)	English	East Azerbaijan	Lighvan village	Spring and well	Water quality test	WSP	21
6	Fanaei et al, (2015)	English	South Khorasan	Birjand city	32 wells	Water quality test	WSP	9
7	Fanaei et al, (2015)	Persian	South Khorasan	Sarayan city	4 wells	Water quality test	WSP	22
8	Sohbatloo et al, (2016)	English	Zanjan	Zanjan city	Ground water (65 %, 56 wells) and surface water (35 %)	Water quality test	Risk Assessment	23
9	Shafie et al, (2016)	English	Qom	Qom city	13 wells	Water quality test	WSP	24
10	Hassanzadeh et al, (2016)	English	Hamadan	Hamadan city	Surface water (70 %) and ground water (30 %, 115 wells)	Water quality test	Risk Assessment	25
11	Razmju et al, (2017)	English	Semnan	Semnan city	Spring and well	Water quality test	Risk Assessment	26
12	Shafie et al, (2017)	English	Qom	Qom city	Ground water and surface water	Water quality test	Risk Assessment	27
13	Barikbin et al, (2018)	Persian	Razavi Khorasan	Torbat-e-Jam city	23 wells	Water quality test	WSP	28
14	Fanaei et al, (2019)	English	West Azerbaijan	Bukan city	12 wells	Water quality test	WSP	29
15	Ghafuri et al, (2017)	English	Qom	Qom city	Surface water and ground water (Treated using reverse osmosis system)	Water quality test	WSP	30

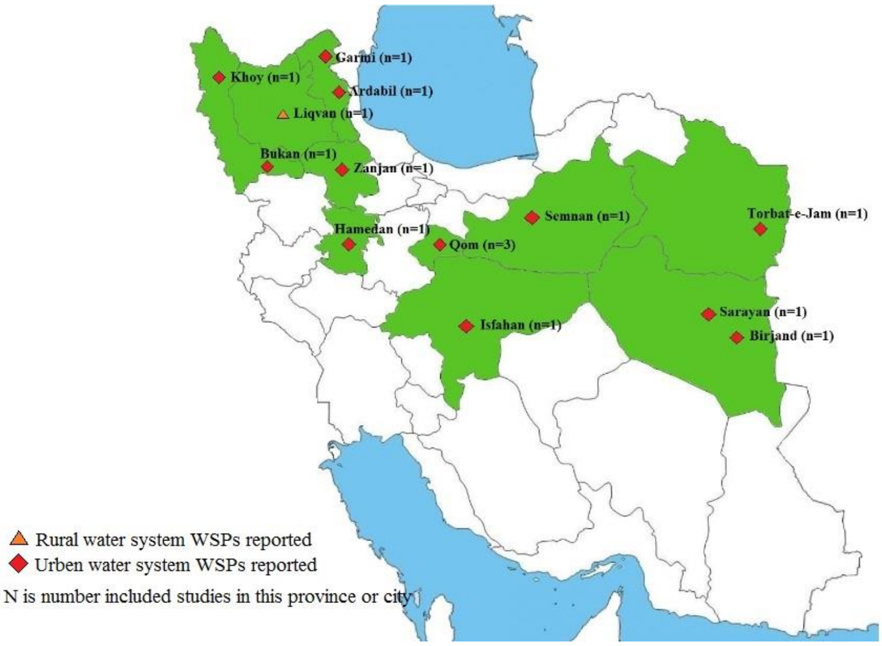

Figure 2: Provincial distributions of the reported studies in Iran

Table 2: Results of the general evaluation of the Steps of the WSP for the drinking water supply system in Iran

No. of steps	Steps of WSP	Results (%)										
		Qom (2017)	Qom (2016)	Sarayan	Khoy	Torbate-Jam	Birjand	Bukan	Semnan	Ardebil	Zanjan	Hamadan
1	WSP team	95	65	70	30	10	60	65	90	40	30	85
2	System description	100	100	50	62.25	50	87.5	73	100	62.5	100	75
3	Hazard identification and risk assessment	100	97	59	12	52	52	51	52	32	79	86
4	Control measures and validation	50	63.24	48.53	8.82	39.71	64.71	48.2	19.12	17.65	35	17.65
5	Improvement plan	25	25	-	-	18.75	-	-	-	-	38	32.25
6	Operational monitoring	25	75	51.56	31.25	51.56	67.19	42.7	14.06	0.25	38	62.5
7	Verification	12	96.88	78.13	78.5	25	71.88	75.2	68.75	50	63	28.13
8	Management procedures	47	38.89	58.33	-	66.67	25	52.9	44.44	11.11	92	77.78
9	Supporting programs	25	78.5	-	-	-	-	12	75	-	63	87.5
10	Review of the WSP	-	51.79	-	-	-	-	17	21.43	-	29	-
Total (%)		48.18	68.64	42.95	17.5	36.14	43.18	43.7	35.45	21.14	52.95	50

Figure 3 shows the average percentage of each implementation step of the WSP. As shown in the figure, the steps for Development of improvement plan, the Development of supporting programs and the periodic review of WSP, are stages of the plan that have not been implemented in some studies and have earned fewer points. According to the table 2, the highest score of water safety plan in Iran is related to Qom city with 68.64% and the lowest value is related to Khoy city with 17.5%.

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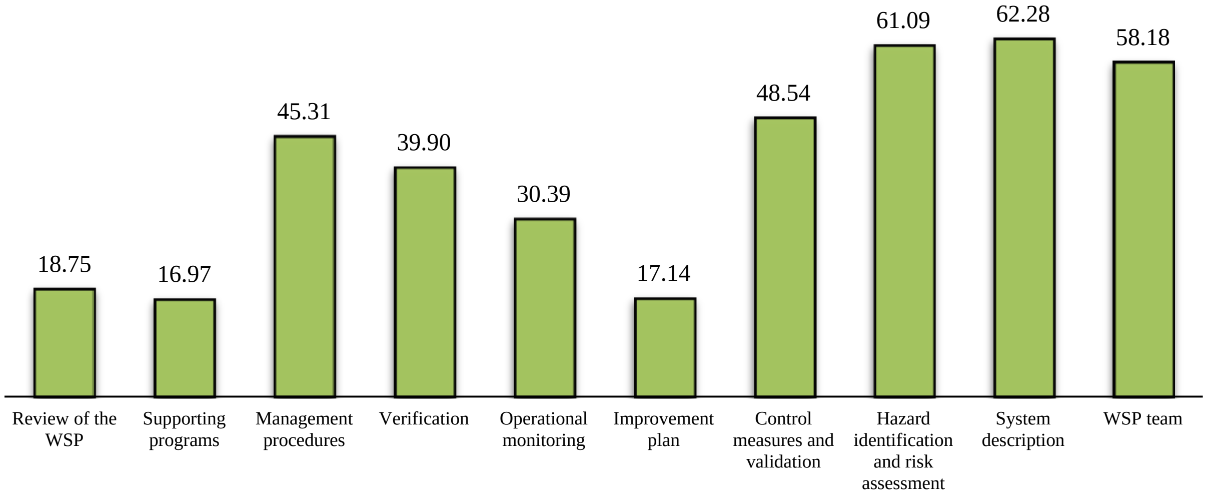

Figure 3: Results of the progress rate information of WSP in drinking water supply system in Iran

Review of risk assessment in published studies

According to the 5 × 5 risk rating matrix recommended by WHO (Table 3), the results of the study of important risks; that are analyzed and interpreted; presented in table 4. In this table, risk factors and risk events are classified as very high and high risk. These factors and events were selected in 291 Water systems and 15 studies.

Table 3: Risk assessment Matrix [31]

Severity or consequence Likelihood or frequency	Insignificant or no impact - Rating: 1	Minor compliance impact - Rating: 2	Moderate aesthetic impact - Rating: 3	Major regulatory impact - Rating: 4	Catastrophic public health impact - Rating: 5
Almost certain/ Once a day- Rating: 5	5	10	15	20	25
Likely/ Once a week- Rating: 4	4	8	12	16	20
Moderate/ Once a month- Rating: 3	3	6	9	12	15
Unlikely/ Once a year- Rating: 2	2	4	6	8	10
Rare/ Once every 5 years- Rating: 1	1	2	3	4	5
Risk score	< 6	6- 9	10- 15	> 15	
Risk rating	Low	Medium	High	Very high	

In a water safety plan, risk refers to all the potential biological, physical, chemical, and radiological hazards that may be associated with water supply or quality. While dangerous accidents can directly and indirectly cause water pollution. Risk assessment can be classified into four levels according to the risk score: Low (< 6), Medium (6–9), High (10–15) and Very high (≥16). (Table 3)

In drinking water quality management, it is sometimes difficult to differentiate the risks, and therefore all events with very high risk and high risk are summarized in Table 4 in this article. According to the results of the study, the most important hazards that have been determined with a very high risk rating in the source, distribution network and point of consumption are; in water resources; discharge of sewage and garbage into the catchment area by villagers and local communities, in the water distribution network; problems with clarifiers and overflows for treatment, inability of manpower, equipment and facilities in specialized operations and at the point of consumption include; lack of performance in the drainage system for tanks, well construction at home and low consumer awareness.

Table 4: Prioritization and risk assessment of most important hazardous event in Iran water supply system

Location	Danger	Dangerous event	Risk assessment				Corrective actions
			Severity	Possibility	Risk	Risk rating	
Source water	Physical, chemical, biological	Discharge wastewater and solid waste in catchment area by Villagers	4	5	20	Very High	Construction of treatment plant, Increasing villagers awareness about the risks of discharge into water/catchment area [20, 25]
		Corrosion or incomplete wall inside the well	5	2	10	High	Check existing wells exactly and schedule for monitoring and regular upgrades [23, 26]
	Physical	Lack of quality online monitoring system	5	3	15	High	Provide adequate credit for installing equipment, use of portable laboratory devices until the installation of online devices [26]
		Floods resulted from seasonal rainfall and change in quality and quantity of water source	3	4	12	High	Watershed and flood control in catchment area, Deviations of local floods, storage of water in dam or source [23]
	Chemical	Wastewater of mining	4	5	20	Very High	Construction and management of treatment plant and applying fines in the event of drainage into the water [25]
		Release of Pesticides and fertilizers in catchment area	4	4	16	Very High	Collection and management of agricultural runoff and encouragement farmers to replace chemical fertilizers with green fertilizers [23]
		High concentration of nitrite and nitrate	4	3	12	High	The removal of polluted wells from consumption cycle and replacing with better sources, Collection of wastewater and Using supporting pipes for wastewater exclusion wells, Combination of high nitrate water with sources of low nitrate [23]
Treatment process	Physical, chemical, biological	Problems in clarifiers and overflows	5	4	20	Very High	Draining the pond periodically, Inspection and maintenance of all utilities especially of overflows, Analysis of the cavitation's and decay [27]
	Chemical	Leakage of chlorine gas	5	3	15	High	Alarm systems installation, Monitoring and inspection, Utility safety analysis and elimination of defects in periodic times [27]
	Chemical, biological	Blockage of filters	4	3	12	High	Create an appropriate water backwash and Change of filters on time [25]
Water distribution	Physical, Chemical, biological	Entry of polluted water to distribution network during an incident such as explosion, disruption, leakage or water supply pipelines repair	4	3	12	High	Passive control (local action for elimination of daily incidents), Active control (regular and continuous leakage detection plan), Renewal of network (replacement of pipes and other compartments), Management of network pressure, Management of executive operations of the network [23]
	Physical, biological	Old pipes and infrastructure	3	5	15	High	Replacing worn pipes, Continuous inspection [20, 25]

Location	Danger	Dangerous event	Risk assessment				Corrective actions
			Severity	Possibility	Risk	Risk rating	
	Physical, chemical	Fracture of pipes due to the installation of facilities and excavation	4	3	12	High	Installing the panel in the Length of the distribution network, Preparing Geographic Information System (GIS) map for Pipe Line, Coordination with relevant departments to create facilities [25]
	Biological	Inadequate residual chlorine in sources and distribution network	4	3	12	High	Education of operational staff in applying chlorine, Super chlorination in pipes or sources, Further disinfection through the path by booster dosing [20, 23]
		Proximity the sewage line with distribution pipe	5	2	10	High	Moving the water transmission path, Install leak detection systems [25]
	Physical	Pressure fluctuations and Pressure drop	4	3	12	High	Monitoring and recording the amount of pressure and maintaining sufficient pressure on the network [25, 26]
		Lack of proper number of water drainage valves	4	3	12	High	Determining the status of the valves and recording as a comprehensive plan, determining the exact location of the drain valve according to the test results of the blind and the endpoints of the network [26]
		Personneldisability, equipment and facilities in specialized operations	4	4	16	Very High	The use of mainline repair manuals, Establishment of training classes to increase the level of technical and specialized expertise [26]
Reservoirs	Physical	Malfunction in draining system	5	4	20	Very High	Installation of cut off valve at the end of inlet line and protection against pollution [27]
		Lack of equipment quality online	5	2	10	High	Provide adequate credit for equipment installation [26]
		Damaged electrical equipment	4	3	12	High	Elimination of defects by the expert, the expert at recruiting and defect fixes [26]
		Damage mechanical equipment	4	3	12	High	Periodic visits to the facility and Peripherals materials in the tank repairs, especially lions and Peripherals [26]
		Inefficiency of diesel generator	5	2	10	High	Close monitoring of equipment and storage of consumables [26]
Point of use	Chemical	Construction of wells in home	4	4	16	Very High	Prevent the construction wells, Informing on the dangers of using such wells [25]
	Physical, biological	Low awareness of consumer	4	4	16	Very High	Raising awareness between consumers, Developing the educational programs for children and teenagers, by presenting correct ways of consumption management, beliefs, attitudes, and as a result the citizens' manner toward ways of consuming drinking water has to be changed, Appropriate and honest informing of consumers, Reforming of consumers' life style, Legal and controlling actions [23]
	Physical, chemical, biological	Lack of consumer satisfaction of the water quality and the use of alternative sources	4	3	12	High	Immediate investigation of the cause or causes of water quality changes and other qualitative complementary analyzes to reach the desired results, investigating consumer complaints about water quality, Addressing and solving problems, providing educational package for consumers in order to protect their water safety in the field of health, proposing sound and safe methods. To replace the water supply section [26]

Discussion

The purpose of implementing the water safety plan is to increase the reliability of drinking water quality, prevent contamination of water supply sources, treatment water to remove or eliminate contaminants, and prevent secondary contamination during storage, distribution and consumption [29]. According to the results of WSP studies published in Iran (12 urban and 1 village), it shows that water safety plan is in the early stages of implementation. Therefore, more attention needs to be paid by water supply officials in urban and village areas. The water safety plan demonstrates the importance of ensuring the quality of water distributed to consumers [21]. Reports of the application of WSPs were available for different types of systems (ground water and surface water). More WSP studies were reported in urban areas. This is attributed to the higher population density and the huge number of water systems in urban areas. (74% urbanization in 2016) [32].

The 10 main steps of a water safety plan are listed in table 2 [20]. According to the table, in implementing WSP, some steps have been paid less attention, such as; The "Development of improvement plan" stage in the cities of Ardabil, Semnan, Buchan, Birjand, Khoy and Sarayan and the "Management procedures" stage have not been implemented in the city of Khoy. The steps "Development of supporting programs" has not been implemented in Ardabil, Birjand, Torbat-e-Jam, Khoy and Sarayan cities and the steps "Periodic review of WSP" has not been implemented in Hamedan, Ardabil, Birjand, Torbat-e-Jam, Khoy, Sarayan and Qom cities. In Ardabil water supply system, a small number of employees were familiar with WSP, and for this reason, the implementation of some WSP steps was briefly obtained. Some factors such as "Development of improvement plan", "Development of supporting programs" and "Periodic review of WSP" cannot be evaluated due to the lack of full implementation of WSP in cities (Ardabil, Birjand, Khoy and Sarayan) and their scores with the dash is shown in table 2.

In this study, according to the minimum scores obtained, the stage of Control measures and validation and development of improvement plan can indicate that the teams are not sufficient in terms of composition. (Despite highly coordinated steps such as the development of WSP team, Water supply system description and hazard identification and risk assessment). It seems that the planning and coordination of activities in the WSP team formed in Iran has not been well accomplished. For example, the WSP team in Hamedan consists of experts in various fields such as urban and village water and wastewater, environment, medical sciences, etc. Due to government nature and lack of coordination between them, meetings are not held regularly.

In all studies conducted on WSP in different cities of Iran (Hamedan, Ardabil, Birjand, Torbat-e Jam, Khoy, Sarayan and Qom) the results show that the periodic review of WSP has not scored and it can indicate a lack of attention be at this stage in Iran. Another problem of WSP in Hamedan is the lack of basic information due to lack of registration. Therefore, due to the lack of full implementation of WSP in Hamedan, the periodic review of WSP has not been done. The results obtained from the implementation of WSP in Iranian cities (Bukan, Birjand, Torbat-e Jam, Sarayan, Hamedan, Zanjan, Semnan and Qom) are relatively convincing and good, and the water supply system has a moderate level of safety. In Khoy city, due to the low percentage of general use of phases and the lack of attention of water supply organization to some parameters, the water supply system is not safe enough. Thus, general studies increase the flexibility of the system to change the current approach to quality management to WSP to improve and enhance water quality and consumer satisfaction.

In this article, we have summarized the most important risk events (high and very high level (≥ 10)) from water source to point of use. As shown in table 4, in water sources, the main risk was discharge of sewage and garbage into the catchment area by villagers and local communities. For water distribution network, problems with clarifiers and overflows for treatment, inability of work force, equipment and facilities in specialized operations were also identified as hazards. Lack of performance in the drainage system for tanks, well construction at home and low consumer awareness also threaten consumer water safety. By using WSP, the dangers in the water supply system can be identified more quickly and the necessary corrective measures can be taken to prevent drinking water quality problems creation.

Conclusion

The advantages, disadvantages and limitations of WSP implementation in Iran, which are mentioned in the studies, are:

Benefits of implementing WSP in Iran

- A good opportunity to upgrade the water supply system of urban and villages
- Inefficiency of the traditional approach in urban and villages
- The most effective tool for ensuring safety in drinking water supply
- Covering the water safety plan from the catchment area to the point of consumption
- Involvement of all relevant and relevant institutions in the implementation of WSP
- Improve the quality of distributed water
- Increase consumer satisfaction
- Reducing water-borne diseases
- Ensure a continuous supply of safe water
- Strict implementation of the water safety plan will increase public health, improve management efficiency and investment.

Disadvantages and limitations of WSP implementation in Iran

- Non-implementation of water safety plan in all cities and villages of Iran
- Relying on final tests
- Partial implementation of the water safety plan and failure to complete the steps in the guidelines of WHO
- Lack of awareness of the high importance of implementing a water safety plan for water and wastewater managers and employees
- The relevant institutions are governmental and do not convene regular meetings
- Lack of holding water safety plan training courses and familiarity of its importance for employees by relevant institutions
- Economic problems and insufficient funding to continue the program
- Lack of attention of the authorities to the implementation of WSP at the national and provincial levels

The full implementation of the water safety plan with the participation of relevant organizations and focus on all steps of the WSP, corrective actions and risk control, reveals the need to change the current approach (traditional method) relying on end-point tests. In addition, by reducing the costs of full implementation of the program, we can see the role of water safety plan in better performance and improving the quality of drinking water. For rural water supply systems, we propose a development plan using a simple method in which the strengths and weaknesses of the system are examined and by creating a favorable situation at the right time, the water safety plan is fully implemented for the villages.

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Conflict of interest

The author declares that there is no conflict of interests regarding the publication of this manuscript.

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