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Water safety plan: a novel approach to evaluate the efficiency of the water supply system in Garmsar

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ABSTRACT

Access to an improved water supply is essential for health. The water safety plan (WSP) approach developed by the World Health Organization (WHO) can provide safe drinking water. This study evaluated the progress of the Garmsar drinking water supply system (DWSS) through WSP. First, using the WSP quality assurance (QA) tool and its checklist, the implementation rate of this approach was examined. After classifying the most critical risks, the reliability of the risks was obtained with intra-class correlation coefficient (ICC), and then the risks were prioritized and evaluated by the semi-quantitative matrix recommended by WHO. The results showed that 80.4% of the drinking water was supplied from the system under study, and six persons (13.95%) participated in the implementation of the WSP team. The "system description" and "verification" steps with scores of 75% and 65%, respectively, had the highest levels of compliance, and the "supporting programs" and "review of the WSP" steps with scores of 29% and 25%, respectively, had the least consistent with WSP. The points obtained by the catchment, treatment, distribution, and point of use were 43%, 38%, 35%, and 35%, respectively. Risk identification demonstrated that "direct discharge of wastewater/sewage in the sources by the villagers living in the basin in the catchment area" had poor reliability (ICC = 0.25), and so it was discarded. The risk assessment of the DWSS identified the "microbial contamination, pesticides, and fertilizer caused by agricultural use and activities in the catchment area" as high-risk. The lack of implementation of some steps in this program prevented the realization of many goals of this approach. The awareness of drinking water supply organizations with the aims and benefits of this program and increasing the skill of the WSP team can enhance these conditions.

Keywords: Water safety plan; Risk assessment; Drinking water; Garmsar

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1. Introduction

Water is vital for all aspects of healthy life on Earth and is of great importance to human beings with many uses such as drinking, food production [1], sanitation, and industry [2–4]. However, if pathogenic organisms contaminate water resources, acute watery diarrhea (including cholera) [5,6] can occur, especially in children under five years of age [7], as well as other serious illnesses such as Guinea worm disease [8], typhoid [9], and acute bloody diarrhea (dysentery) [10]. Also, due to the presence of excessive chemicals (fluoride, heavy metals, etc.) in water, other diseases such as skeletal disorders, hypertension, Alzheimer's disease, and infertility may occur [11–13]. An element such as fluoride can be absorbed by the body from other compounds, but due to the high solubility of fluoride in water, it can be a risk in the drinking water [14].

According to the World Health Organization (WHO), ~3.4 million people die every year from water-related diseases [15]. Therefore, the provision of safe and healthy drinking water has been a goal of sustainable development and should be on the agenda of governments' health promotion programs [16,17].

Access to safe drinking water, as the primary goal of drinking water supply systems (DWSS), is vital for health and one of the fundamental human rights [7]. According to the reports by the WHO, one-third of the population living in cities in developing countries lack access to safe drinking water [18,19]. Endemic and epidemic diseases contracted from unsafe drinking water affect all communities [20]. Thus, monitoring and the health risk assessment and risk management of water supplies are necessary for health promotion programs. To this end, several strategies, such as qualitative microbial risk assessment (QMRA) [21], hazard analysis critical control point (HACCP) [22], and the water safety plan (WSP) have been developed to ensure access to healthy water as well as the safety of DWSS.

The WSP is a step-by-step preventive risk assessment framework introduced by WHO in 2004 for drinking water quality [23]. Its main objectives are the minimization of water resources' pollution, elimination, or reduction of contamination through treatment procedures, and prevention of water pollution during storage and water supply management [24]. In the WSP, critical control points such as assessing the risks to water quality from inland to the point of use, identification and control measures, monitoring, and management plans are considered [25,26]. In many countries, water supply organizations focus only on specific parts of the water supply system and do not assess system risk or pay attention to the entire system, while this approach encompasses the entire system of the water supply chain from the catchment to the consumer [27–29].

Several European countries have adopted WSP for drinking water supplies of urban areas [30], but there are few studies and little global evidence on the implementation of WSP [31]. Therefore, the present research investigated the principles and applications of the WSP for implementing a methodological guide on the actual use, and attempted to describe the effectiveness of this program in promoting the quality of drinking water supplies in Garmsar, Iran, in 2018.

2. Materials and methods

2.1. Study area

The city of Garmsar is the capital of Garmsar County, Semnan Province, one of the central regions of Iran, and encompasses an area of ~10,686 km^2 which is ~11% of the total area of Semnan Province. The altitude of this area is ~868 m above the sea level and it is geographically situated at the latitude 35.2031° N and longitude 52.3294° E. According to the 2016 official census results, the population of Garmsar was 62190 persons. Fig. 1 illustrates the location of Garmsar County, Semnan Province.

Garmsar has a desert climate and relatively warm and dry weather in summer and cold weather in winter, and is considered as an extreme semi-desert region of Iran. The mean relative humidity and average annual precipitation of the studied area have been estimated to be 42% and 115.7 mm, respectively.

The permanent river of HablehRood is the primary source of water supply in Garmsar and is the only permanent river in the province. This river is 241 km long and originates from the north of Alborz Mountains. The flow rate of this river in the rainy season and favorable conditions is ~3 m^3/s. The water treatment plant of the studied area is located 5.5 km away from downtown. Fig. 2 shows the spatial location of HablehRood and Garmsar's water treatment plant, which has an area of ~176,217 m^2.

Table 1 presents information about the water treatment plant of Garmsar.

2.2. Development of the WSP

The WSP in the present research was developed according to the WHO guidelines [32] in cooperation with Garmsar Water and Wastewater Organization.

The development of WSP had three sections that are discussed below.

2.2.1. First section

The WSP is not usually developed individually; rather, it needs continuous teamwork, involving all those who have an interest in the community water supply, who can take action to promote it, and who have education in and experience with water supply and quality. The preliminary step is to form a team to develop the WSP. This team should comprise engineers (operations, preservation, and design), managers, water quality controllers (chemists and microbiologists), and technical staff involved in day-to-day operations. All parts of the team should have enough knowledge of the water system [33].

2.2.2. Second section

The WSP quality assurance (QA) tool version 1.1 was developed. The first part of the software, which is an MS Excel-based tool, displays the main menu and its settings (Fig. 3). The second part provides a general guide to the users. The third part has 12 tables, and each table has its own quantitative and qualitative questions. The process of entering the assessment data into the QA tool is presented in

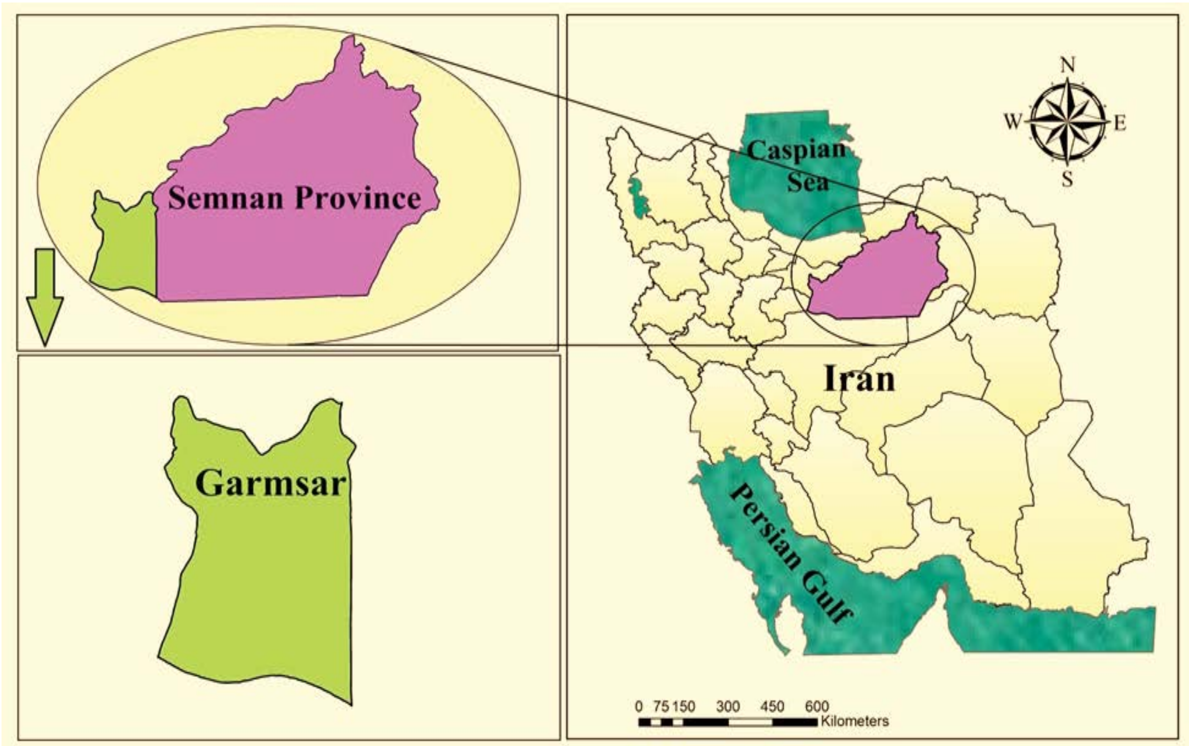

Fig. 1. Geographical location of Garmsar.

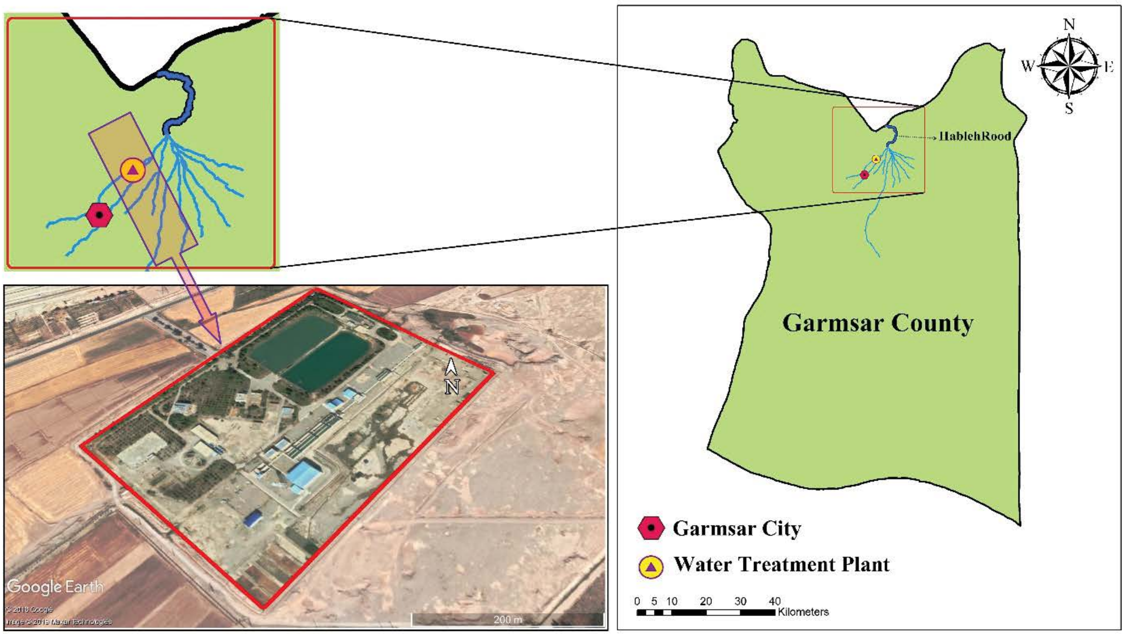

Fig. 2. Location of Garmsar's water treatment plant.

Table 2. Part 1 consists of two tables, and Part 2 consists of 10 tables related to the WSP approach.

The QA tool was developed based on the WSP Manual [32] by WHO and IWA as editors. It has default questions, and the user can add additional questions to be included in the assessments. The software's checklists were provided to the WSP team, and the responses were then inputted to the software. The fourth part of the software presents the results of the experts' response to the Garmsar DWSS in Excel in the form of tables and graphs with the following titles: the result of general information, result by WSP step, and result by component.

2.2.3. Third section

The risk assessment of the Garmsar drinking water system was performed by the WSP team and by experts with a thorough understanding of the catchment areas, treatment plant, distribution network, and point of use. The team consisted of employees of the Garmsar Water and Wastewater Organization.

All the significant risks that threatened the water supply system from the catchment to the point of use were identified and listed with the assistance of the water suppliers. In total, 43 potential risks were identified; the watershed had 10 risks, the treatment plant and distribution network each had 12 risks, and the point of use had nine risks.

Next, the WSP team analyzed and classified the critical hazards and risks belonging to each part of the water supply system, from the most to the least important. This process was repeated two weeks later. Subsequently, the validity of the experts' prioritization was assessed by the intra-class correlation coefficient (ICC) test in IBM SPSS version 16.00 (SPSS Inc., Chicago, IL, USA) [34,35]. ICC is an experimental method for examining the correlation between different classes of data, especially in clinical research. This test can be utilized in repetitive measurements (such as the present study) and can display information in a categorized manner. It also determines the reliability of the data [36].

As a rule of thumb, it is suggested that ICC values <0.5 are indicative of poor reliability, values of 0.5–0.75 indicate moderate reliability, values of 0.75–0.9 indicate good reliability, and values >0.90 indicate excellent reliability [37].

Table 1
Water supply information for the selected water utilities

Water treatment plant	
Region	Garmsar County (West of Semnan Province, Iran)
Latitude and longitude	35°15′ 38″ N, 52°22′ 23″ E
Area	17.6 hectares (176,217 m^2)
Ownership	Public
Water source	Surface water (HablehRood)
No. of consumers	62,190
Water treatment process	Conventional

Table 2
Process of entering the assessment data into the QA tool

Part 1: Two tables	
Table 1	General information on the water supplier
Table 2	General information on each water supply system
Part 2: 10 tables	
Table 3	WSP Team
Table 4	System description
Table 5	Hazard identification and risk assessment
Table 6	Control measures and validation (reassessment and prioritization of risks)
Table 7	Improvement plan
Table 8	Operational monitoring
Table 9	Verification
Table 10	Management procedures
Table 11	Supporting programs
Table 12	Review of the WSP (periodic reports and following incidents)

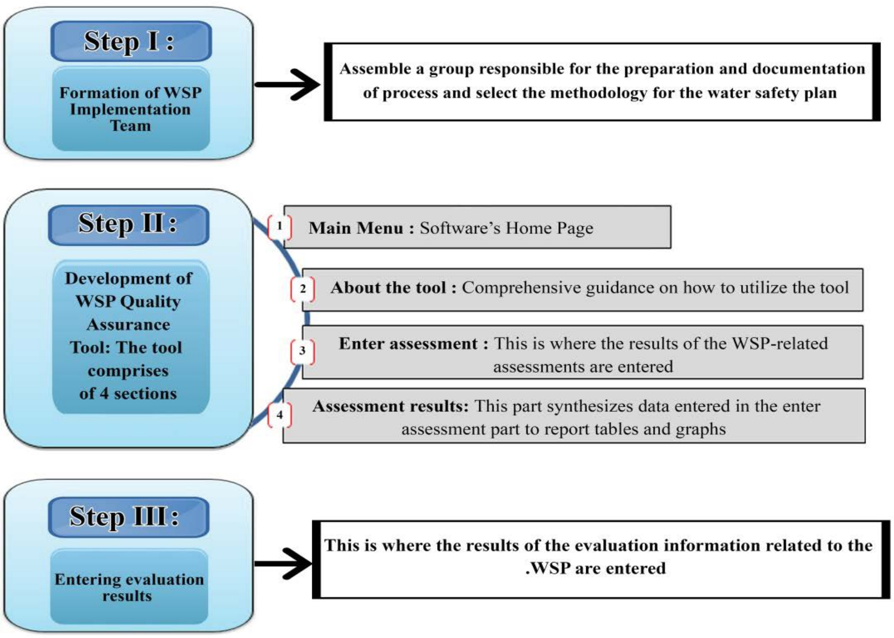

Fig. 3. Main methodological steps applied in the WSP.

Many methods for risk assessment involve the use of the scoring system. Semi-quantitative risk assessment provides an intermediary level between the textual evaluation of qualitative risk assessment and the numerical evaluation of quantitative risk assessment by evaluating risks with a score [38]. This approach includes simple, measurable parameters that use scoring methods and indicators [39]. In the remainder of this study, the semi-quantitative risk assessment matrix, recommended by WHO, was adopted to rank the significant risks from among the identified risks (Table 3).

3. Results

About 80.4% of the population of Garmsar received their drinking water from the water distribution system on which WSP had been implemented. Besides, 16.6% of the residents, including those residing in the surrounding villages, used other water sources such as underground and deep wells. Only six persons (13.95%) of the total staff of the Water and Wastewater Organization (drinking water supply organization) participated in the implementation of the WSP and took part in its team. Table 4 gives general information about Garmsar's water supply system.

According to the results of evaluating the overall progress of WSP in the Garmsar water supply system, system description (75%), review (66%), and WSP team (50%) with the highest scores showed the highest percentage of adjustment with the WSP, whereas the phase related to support programs (25%) and water safety review (29%) with the lowest score had the lowest percentage of adjustment with the WSP. Fig. 4 displays the overall progress of all sections.

The progress of each component of Garmsar's water supply system is presented in Table 5.

Table 3
Interpretation of the semi-quantitative risk assessment matrix

Indistinguishable from 0–5, Low-risk		Severity of the potential risk				
6–10, Moderate-risk 11–25, High-risk		Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Likelihood of the risk happening	Almost Certain (5)	5	10	15	20	25
	Likely (4)	4	8	12	16	20
	Possible (3)	3	6	9	12	15
	Unlikely (2)	2	4	6	8	10
	Rare (1)	1	2	3	4	5

Table 4
General information about the water supply system of Garmsar in 2018

Information	Percent (%)
Population that supplies water from this DWSS	80.4
Ratio of the WSP team to all the staff of the Water and Wastewater Organization	13.95
DWSSs fully implemented the WSP	0

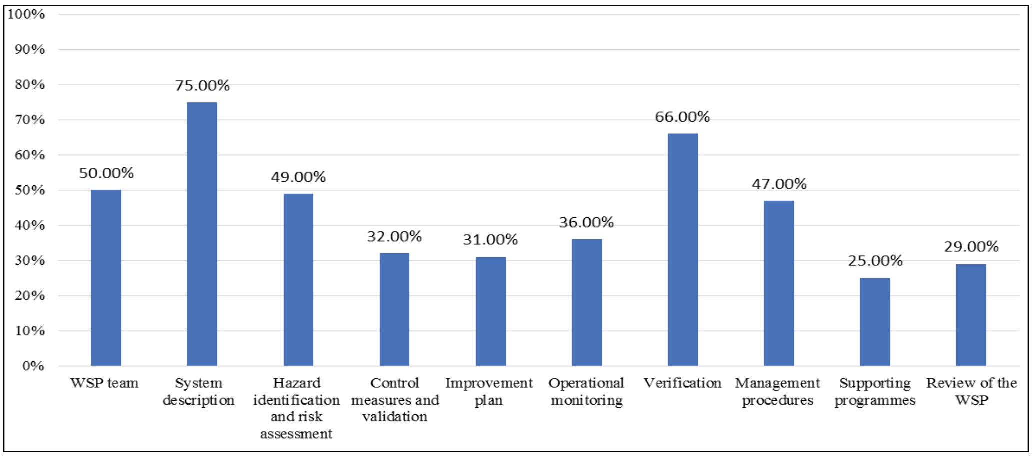

Fig. 4. Total results of the WSP implementation in the water supply system of Garmsar (2018).

Tables 6 and 7 list the results of the ICC test and the reliability of the expert opinion in identifying the most critical risks that threaten the DWSS, respectively.

4. Discussion

According to the existing assessments, one-sixth of the human population lacks access to safe and healthy water resources within 1 km of their home [40], and one-fifth lacks access to any form of adequate excreta disposal [41]. The WSP is a novel approach to accessing safe drinking water and reducing the burden of water-borne diseases [33,42].

4.1. Implementation of WSP steps

One of the most powerful steps in advancing a WSP is team formation. The WSP team in Garmsar consisted only of six members of the Water and Wastewater Organization staff, while other offices such as health organizations and the municipality could have been involved. Although effective communication may not establish between the members at first, partnerships will be formed over time based on the expertise of the members. Increasing intersectoral communication and sharing experiences are positive results of implementing a WSP that increase system efficiency [43]. The members of other departments know their stakeholders and are aware of their problems. For example, the Department of Health deals with clients who suffer from water-borne diseases [44]. Garmsar water supply system is still failing to form a certified and skilled team of the WSP because of the lack of coded guidance and qualified staff with sufficient knowledge of the approach [23].

The second step in the WSP approach is system distribution. One of the main tasks of the WSP team is to have sufficient knowledge of the DWSS. To identify the system, the information in the earlier documentation can be used, and when there is no information, the panel can collect and update the required details via field visits. If the system description is not accurately performed, it is not possible to distinguish the hazards and assess the risk of the DWSS. In general, the system description starts with the catchment assessment and completes with checking the water quality at the point of use. Also, to identify interventions in this step, knowledge of standards is essential [32]. The results demonstrated that the water supply system of this city had been adequately described. Defining the system from the source of raw water to the point of use helps the identification of the risks of the water supply system [45].

The third to fifth steps of this approach are identifying and assessing risks, control measures, validation, and development plan. In these stages, all the stakeholders in all parts of the water supply system should be identified and be sufficiently familiarized with their responsibilities in the implementation of this program. In this study, the most critical hazardous events that threatened the DWSS were identified in the fields of environment, public health, and the social/human rights risks [46,47].

The results of evaluating these three steps in the Garmsar water supply system showed that the stakeholder's identification (53%), hazard identification (50%), and risk assessment (40%) had the highest rates. These statistics indicate deficiencies in domains such as risk identification and severity and the likelihood of their occurrence, lack of documentation, and lack of descriptive and predictive data. Also, the control and validation criteria were briefly completed and documented in all four components (source, treatment, distribution network, and point of use), which ultimately lead to a slight improvement (32%) in the water supply system. The improvement plan was also incomplete in this water supply system, and there was no upgrade program due to the lack of identification of all risks [33].

The sixth step of the WSP is operational monitoring. The progress of this phase in Garmsar water supply system had not fully completed since the hazard identification and risk assessment steps had not been fully implemented. The full achievement of the primary objectives of the WSP depends on the three main elements of the approach: system evaluation, operational monitoring, management and communications [48].

In the seventh step, the WSP should be reconsidered. In this step, factors such as monitoring of validation, recording, and examination of consumer complaints are taken into account. The health department, as the supervisory organization, is responsible for recording and investigating the complaints and dissatisfaction of the people of Garmsar in terms of the quality of drinking water.

Effective control of the quality of drinking water depends on the accurate implementation of the eighth step of this plan, that is, updating management disciplines and standards, based on the standard operating procedures (SOPs) and enforcement of laws, guidelines, and standards [49]. It was found that the previous factors had been almost completed and documented. Guidelines and national laws can help establish and improve the WSP. The use of legal pressure, especially in small water supply systems, will enhance the advancement of this approach [50].

Table 5
Implementation of the WSP in each component of Garmsar water supply system in 2018

Component	Number of questions	Total possible score	Acquired score (%)
Catchment	23	88	43
Treatment	23	88	38
Distribution	23	88	35
Point of use	23	88	35
Total	92	352	38.7

The ninth step is supporting programs. Results revealed that there was no special assisting and education program in Garmsar to update the employees' awareness of the aims of this approach. The final step is to review the WSP. Updating and revising the management disciplines and standard operating instructions in each section of the water supply system are done by one-year monitoring [32]. The results demonstrated that since the previous steps had not been fully implemented (e.g., a defect in the review of instructional programs), this step is briefly updated and reviewed and little progress has been made.

Compared to the results of the present study, the results of Baum et al. [26] in the United States in 2015 showed that the US drinking water laws are aligned with the WSP steps in the system description, monitoring, and control measures. Nevertheless, there were still conflicts in the formation of the team and its training, risk assessment and prioritization, management disciplines, and programs. In a similar study carried out in 2015 in sub-Saharan Africa [23], due to the lack of technical expertise on land-based WSP, the control measures and validation, management procedure, and review of the WSP were not fully developed.

Also, the results of the study by Aghaei et al. [28] in 2014 in Ardebil, Iran, showed that the system description (62.5%) and management procedures (11.11%) gained the highest and lowest scores, but due to lack of attention to all the stages of the plan, the control approach did not have enough efficiency in providing safe drinking water.

4.2. WSP in Components of DWSS

Assessment of the implementation and progress of the WSP in each component indicated that the highest rate of application was in the catchment (43%). Protecting the source and preventing it from contamination can play a key role in providing clean drinking water to consumers. For example, fencing, periodic monitoring of the water source, and increasing the frequency of quality assessment can reduce the source's risks [51]. According to the most recent standards [52], the quality of drinking water at the point of use requires measurement of the amount of free chlorine residual, turbidity, pH, and temperature, and the number of *Escherichia coli* or fecal coliforms in water in the distribution network must be zero [53]. Also, the number of free chlorine residuals and the required microbial samples is determined based on the population distribution. The Water and Wastewater Organization, as the supplier, must daily test the water in the treatment plant, and the Health Department, as the monitoring organization, must control the drinking water based on the population it covers. Raw water with high quality also reduces health risks and the cost of water treatment processes. This can be achieved by using a WSP because this approach is an optimal tool for providing safe drinking water [54]. After the catchment, the treatment plant is the only area that can eliminate water pollution. Due to the conventional water treatment process in Garmsar, dynamic solutions for the success of this sector include the use of expert staff and sufficient disinfectants. Distribution can be a suitable site for secondary pollution in drinking water because old broken pipes, negative pressure, turbidity, and metal corrosion are observed in this part. If preparations are not made to maintain water safety at the point of use, the health of the consumers will be threatened. To prevent re-contamination, increasing consumer knowledge, especially on the storage of water at home, is an important factor [55].

Similar to the results of this study, the results of Shafiei et al. [56] in 2017 showed that the most progress in the WSP was in the source and treatment plant, while the least progress was in the distribution network.

Improving general health, increasing compliance with standards, and delivering safe drinking water are some benefits of the WSP implementation since this approach is based on systematic risk assessment and management from the catchment to the point of use [46,57]. The results of the reliability of risk prioritization by experts in two stages for the DWSS of Garmsar revealed that the identified risks had high reliability, but one case (direct discharge of wastewater/sewage in the sources by the villagers living in the basin and the catchment area (C3)) had less than moderate reliability and was discarded. The DWSS risk assessment in Garmsar indicated that microbial, pesticide, and fertilizer contamination caused by agricultural activities (in the catchment), and the changes and fluctuations in the quantity and quality of water (in the treatment plant) were the high risks. Notwithstanding several studies, there is still no particular standard or indicator for estimating the effectiveness of a WSP, as it requires special flexibility in each geographic region. Still, one can claim that WSP is a fundamental strategy for providing safe drinking water and supporting health owing to its risk assessment and management [44].

4.3. Risk assessment

The concept of risk assessment in the water supply system is the delivery of safe drinking water to the consumers, drinking water that does not cause any disease after consumption. The WSP includes all domains of water system evaluation, including water supply system analysis, risk identification, barrier identification, critical control point, operational monitoring, preventive measures, and a review of the water supply system [46].

The source of freshwater in the city of Garmsar is in the vicinity of agricultural lands. The existence of these fields, livestock grazing, and the use of domestic animals in farms increase the likelihood of contamination of water resources. Farmers usually use manures for more fertilization. Because there is farmland around the Hableh Rood River, the farmers also use herbicides and pesticides to kill pests which, eventually, contaminates the raw water source of Garmsar. Chemical methods such as the electrocoagulation method, chemical precipitation method, or physical methods such as polymer hydrogels [58] should be adopted to remove nitrogen and phosphorus. Garmsar water treatment plant performs the conventional treatment of drinking water, has screening units, grit chamber, turbidity and pH meter, ozone injection, rapid mixing, slow mixing, sedimentation, sand filters (with backwashing), chlorine injection, and storage tanks, respectively, and needs advanced physical or chemical methods for removing nitrogen and phosphorus elements [59]. Due to the lack of required efficiency in the treatment plant, these risks in the catchment should be controlled because, as evidence has shown [60], these elements can cause several diseases in humans [61]. The use of animal waste can increase concerns about the leakage of elements such as nitrogen, phosphorus, and organic matters into water resources, and this risk can be prevented by assessing the quality of water in the source as well as paying attention to the standards. In this regard, in a study by Ye et al. [31] in China in 2015, the use of agricultural fertilizer for the land around water resources and the inefficiency of employees in controlling the amount of disinfection were considered as high and medium risks, that are similar to the risks identified in the catchment areas and treatment in the present study. Also, the results of Shafiei et al. [62] in 2017 included risks such as increased microbial inputs and outputs (catchment), rapid changes in the quality of resources due to seasonal changes, and the poor quality of water after the events in the distribution network were considered as the most important risks.

Variations in the quantity and quality of water flow can affect the ecosystem around a catchment. Changes in water quality can increase the costs associated with operations and treatment processes, whereas changes in water flow, especially in catchments affected by seasonal rainfall and where a dam is built on the river (such as Garmsar DWSS), affects the life of aquatic organisms. Also, this risk becomes more important in hot seasons when the amount of water intake and consumption increases, especially in Garmsar, which is one of the drier regions of the country and has continuous hot seasons, with a large population feeding on the Hableh Rood River [63].

Infrastructure, old pipes, and contaminated water entering after incidents to the distribution network were the other important risks identified in Grammar's DWSS. Pressure changes, heavy fluctuations, and lengthy transmission lines and drinking water distribution networks can break rusty pipes, thereby contaminating the drinking water [64]. Similarly, in the Icelandic water supply system, some parts of the old distribution network pipes and the increased bacterial load in water samples motivated the reconstruction of parts of the system [65]. Moreover, a study in Semnan (neighboring Garmsar County) showed that old pipes, inadequate infrastructure, and thus pressure fluctuations in

Table 6
Reliability test response

Code (Catchment)	ICC	Code (Treatment)	ICC	Code (Distribution)	ICC	Code (Point of use)	ICC
**C*1	0.63	**T*1	0.99	**D*1	0.99	**P*1	**0.99**
*C*2	0.94	*T*2	0.82	*D*2	0.99	*P*2	**1**
*C*3	**0.25**	*T*3	0.71	*D*3	0.98	*P*3	**0.98**
*C*4	0.56	*T*4	0.98	*D*4	0.99	*P*4	**0.96**
*C*5	0.94	*T*5	0.97	*D*5	0.99	*P*5	**0.90**
*C*6	0.91	*T*6	0.99	*D*6	0.97	*P*6	**0.97**
*C*7	0.94	*T*7	0.99	*D*7	0.98	*P*7	**0.99**
*C*8	0.73	*T*8	0.99	*D*8	0.96	*P*8	**0.98**
*C*9	0.96	*T*9	0.98	*D*9	0.97	*P*9	1
*C*10	0.74	*T*10	0.99	*D*10	0.74	–	–
–	–	*T*11	0.91	*D*11	0.98	–	–
–	–	*T*12	0.99	*D*12	0.92	–	–

**C*: catchment, *T*: treatment, *D*: distribution, *P*: point of use.
The bold risk has poor reliability.

Table 7
Risk assessment of the DWSS in Garmsar in 2018

Component	Hazardous events	Likelihood	Severity	Risk
Catchment	Microbial, pesticide, and fertilizer contamination caused by agricultural uses and activities in the catchment zone	4	3	12
	Livestock grazing and discharge of animal feces (drainage of livestock wastes in the river)	4	2	8
Treatment	Changes and fluctuations in the quantity and quality of water entering	5	2	10
	Poor operator skill and inadequate staff knowledge	3	2	6
Distribution	Infiltration of contaminated water into the distribution network through explosion, fracture, leakage or repair of water supply lines	3	3	9
	Insufficient chlorine in the reservoirs and distribution network	3	3	9
	Infrastructure and worn out pipes	4	2	8
Point of use	Low awareness of consumers	3	3	9
	Contamination of household storage tanks	3	2	6

water flow are the major risks in the water supply system, thus supporting the results of the present study [66].

Disinfection is essential to the provision of safe drinking water. It is an effective barrier against many pathogens during the treatment of drinking water, and the destruction of microbial pathogens is essential, which is usually done by using chemical agents such as chlorine [67]. Garmsar treatment plant uses two disinfectants. The first substance is ozone gas which is injected into the water before the rapid mixing unit, and chlorine is a secondary disinfectant used because ozone gas does not create residues in the water and is injected into the treated water in the last stage, after sand filters, and before storage tanks. Insufficient chlorine in reservoirs and the distribution network is a moderate risk in the distribution network, and the existence of this risk in Garmsar DWSS was important because the type and amount of disinfectant affect the safety of drinking water, and the risk of fecal contamination and discharge of animal manure around the catchment is critical [68]. A study by Sorlini et al. [69] in Italy in 2017 states that defective disinfection pumps are medium-risk; in the present study, insufficient residual chlorine in reservoirs and the distribution network that can be due to a defect in the treatment was identified as medium-risk. The implementation of the WSP increases the quality of drinking water, improves the performance of the DWSS, promotes the awareness of the employees, assesses the effective risk, and earns the trust of the consumers, thereby controlling and reducing the dangers identified in Garmsar (e.g., poor operator skills in the treatment) and increasing consumer knowledge about drinking water consumption and storage at the point of use. The quality of drinking water at the point of use is crucial because diarrhea is a serious disease causing children mortality [22,70]. Also, the methodology used to implement the WSP can serve as a well-designed training program for employees [71].

All WSP stages are essential to all these purposes, and all the steps should be developed with sufficient accuracy and experience. According to the results, Grammar's DWSS did not completely succeed in implementing several steps of the WSP. The full alignment of the "control measures" step requires the establishment of control measures for each hazardous occurrence in each component of the system, the assessment of their effectiveness under any circumstance (normal or incidental), and the establishment of a validation method for each control criterion. Completion and documentation of the improvement plans for any uncontrolled risk in each water supply system component and the implementation of improvement and development plans in various components of the water supply system can be helpful in the "improvement plan" step.

An examination of control measures and the existence or absence of documents and reports can be considered in the step of "operational monitoring." Planning and performing management practices, especially the implementation of standards, as well as the availability and updating of management guidelines, can boost the success of implementing "management processes."

"Supporting programs" is among the steps with the least development in the Garmsar water supply system. This step can be improved by designing training programs to identify the existing gaps, and by raising awareness among the staff and the WSP team with the methodology and objectives of the program. "Review of WSP" is an important step in identifying the operational defects of the approach, which can be modified by timely review of the WSP in all parts of the water supply system, a review of this plan after each incident, and a review of disadvantages. Moreover, examination of the deficiencies, management practices, and SOP can contribute to the success of this plan. When comparing the risk of our results in Garmsar with that of other studies, serious events such as fecal contamination of water in the source, inadequate disinfection, pressure fluctuations, lack of operational strategies and the national guidelines, water pollution in domestic tanks, and lack of awareness of stakeholders about the type of WSP performance were recognized as the most well-known risks of the drinking water supply system [51,68].

5. Conclusion

The most effective way to ensure the safety of drinking water is to adopt a comprehensive risk assessment and management approach that includes an evaluation of all the stages of water supply from the catchment to the point of use. WSP is a powerful tool for drinking water suppliers to manage the supply of high-quality drinking water. The present study found that the Garmsar DWSS made good accomplishments in the system description and verification, but has not yet completed all the steps of this plan, and the review of WSP and supporting programs had the least progress. The evaluation of the implementation of this plan in different components of the water supply system showed that the source of raw water has received the most attention. Although paying more attention to the source and control inputs increases the quality of drinking water, the implementation of this approach should support all components of the system (from raw water to the point of use). A more reliable application of this approach requires the cooperation of all the stakeholders and the use of methods such as the implementation of instructions and the exercise of legal pressure, staff training, and online tools.

Similar to other studies, this study suffers from certain limitations. So far, no detailed or archived study has been conducted on the city's DWSS. There is also no organization in the city that controls the performance of the WSP team. All the information in this study was collected by field investigations made by the researchers.

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