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Original Article

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Conducting a Water Safety Plan (WSP) Relied on WHO Recommendations for the Assessment of Qom Desalinated Water Supply System

Shahla Shafiei[1], Mohammad Khazaei[2], Ramin Nabizadeh[3], Mohammad Fahiminia[1*], Mostafa Leili[2], Vahid Razmju[4], Reza Ansari[5], Mina Aghaei[3]

[1]Department of Environmental Health Engineering, Qom University of Medical Sciences, Qom, Iran
[2]Department of Environmental Health Engineering, School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran
[3]Department of Environmental Health Engineering, Tehran University of Medical Sciences, Tehran, Iran
[4]Department of Environmental Health Engineering, Semnan University of Medical Sciences, Semnan, Iran
[5]Quality Control Department, Qom Water and Wastewater Company, Qom, Iran

***Correspondence to**
Mohammad Fahiminia, Department of Environmental Health Engineering, Qom University of Medical Sciences, Qom, Iran.
Tel: +982537842239;
Email: fahimina.m@gmail.com

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Abstract

This work aimed to apply the water safety plan (WSP), a plan suggested by the World Health Organization (WHO), to evaluate desalinated water supply system in Qom province of Iran, assisting a systematic prevention approach based on risk assessment. Major portion of Qom drinking water is supplied by an integrated membrane-based desalination system through a private water network. WSP includes 12 phases comprising chapters like "System Description", "Hazard Identification", and "Risk Assessment". The abovementioned phases were conducted according to filled checklists which finally served as the input data for WSP software, namely WSP QA Tool. The processed information by the software attributed to each step was presented finally as appropriate tables and histograms. Total score obtained for Qom desalinated water supply system via WSP was 302 whereas, the full obtainable score considered in WSP was 440. Accordingly, 68.6% of the total WSP obtainable scores was acquired. The scores achieved in steps "catchment", "treatment", "distribution", and "point of use" were 67%, 67%, 64%, and 65%, respectively. The minimum obtained score was 25% assigned to the step "Improvement Plan". The maximum scores were 100% and 97% attributed to "Identification of Stakeholders" and "Hazard Identification and Risk Assessment", respectively. The score of 68.6% from WSP was achieved by Qom desalinated water supply system. The step "Improvement Plan" should be performed simultaneously with the entire WSP to improve the coordination for better enforcement of the plan. To enhance the current condition, the funding demands assigned to each uncontrolled risk which is attributed to each improvement program must be supplied, ranked, and enforced.

Keywords: Water safety plan, Water distribution network, Risk management, Drinking water, Qom

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1. Introduction

Although two-thirds of the Earth's surface is covered by water, 97.4% of the world's water are saline water and only 2.6% is freshwater (1). According to researchers, half of the world's population will face the freshwater scarcity in the next 25 years (2). The availability of safe and sanitary drinking water is the real and vested right of all human beings; otherwise, it causes so many diseases which result in so many consequences. Therefore, the quality of drinking water in communities must always be controlled (3,4). In this regard, access to healthy and safe drinking water has been taken into consideration by water supplying authorities in different countries in recent years through various programs and methods.

For assessing and ensuring the water quality, the World Health Organization (WHO) and other water safety authorities and sanitation organizations have provided several programs such as the HACCP plan in the water supply system for the first time in the Melbourne, Australia in 1999 (5). This plan was then used in countries such as New Zealand, Belgium, Germany, Italy, Sweden, and the United Kingdom. In addition, this method was utilized in the water supply and distribution system of Isfahan city of Iran in 2011(6).

In 2004, WHO released a statement based on Water Safety Program (WSP) in order to implement programs

to improve the water quality of communities. This is a new method to ensure the safety of drinking water with a systematic prevention and risk assessment approach. WHO has annually provided the guidelines for the WSP since 2004 (3,7). According to the initial results of International Water Association (IWA) and WHO, approximately 90 countries have implemented the WSP and 40 countries have the regulations for this program (8).

Unlike the chemical and microbiological analyses, this method provides the solutions to prevent the penetration of pollutants into the water supply system according to the standards of each country (9). WSP's main goal is the prevention or minimization of the contamination of the sources, supply and distribution systems of the drinking water during storage and distribution (10). To ensure the safety of the water supply system, there should be a comprehensive management in compliance with the health-based targets, a safe water plan and monitoring system. In fact, WSP can cover all stages of water supply from the intake to the consumption (2,11,12)

WSP's merits include the regular and accurate assessment of processes and prioritization of risks in all operations, the creation of operational barriers to control the dangerous events and measures to reduce the effects, the compliance with water quality objectives, use of best practices for ensuring the water safety and prevention of the accidents and events (10,11). Moreover, the implementation of the WSP can help to maintain the public health, to improve the compliance with regulations, operational efficiency and investment (13). Based on the goals of the National Strategic Reference Framework for Improving the Quality of Drinking Water adopted by the Cabinet of Ministers, the Ministry of Health has required the cooperation with relevant organizations for implementation of WSP in the country (3).

The WHO and the IWA provided the WSP QA Tool software in 2010 to assess the implementation steps of the WSPs. This software has not yet been used in many countries for water quality management or has not been fully implemented (14). In our country, despite the offer of the WSP from 12 years ago, no efficient measure has been taken to utilize this method, and research is limited to a few points of the country such as the studies of Gholami et al and Mosaferi et al (10,15).

Qom city with a population of more than 1 000 000, is the capital of Qom province and constitutes 95% of the province's population; and since it is the second largest city of pilgrimage in the country, there are lots of population fluctuations in different seasons and times (16). Qom water causes the dissatisfaction of the consumers due to the high levels of salinity and hardness. This study intended to use WSP-based water monitoring programs to ensure the good, stable and reliable quality for improving the second water supply system of Qom. In other words, the aim of this study was to identify the weaknesses of the quality of second drinking water supply system of Qom and prevent them. It is expected that this study would highlight the role of WSP in improving drinking water quality. Moreover, according to the results of this plan, it is possible to distinguish areas requiring improvement.

2. Methods

2.1. Study Area Features

This study was conducted on Qom second water supply network in 2016. The length of water pipeline in this network is 174 km and the water is provided by 13 wells in Ali Abad area between Jafariyeh and Tehran former freeway. It is directed into 2 reservoirs (5000 m^3) of Salariyeh region located in Qom Water and Wastewater Company. The water treatment plant of the second network consists of four reverse osmosis filters with a capacity of 1500 m^3/d. Then, the water enters into 1200 distinct divisions and 280 public points.

2.2. Introduction of WSP

The main objective of WSP is to ensure a lasting safety of the drinking water supply system. Developing and implementing WSP solutions for each drinking water supply system include: creation of a group and decision on the WSP implementation method; identifying all risks and serious events that affect the safety of a water supply system from the drainage basin to the purification, distribution, and user points of the consumer; assessment of any risk and risky incidents; considering whether there are effective controllers and barriers for any significant risk at the site; validation of the effectiveness of controllers and barriers; implementing a developmental plan if needed; proving the systemic safety; regular review of risks and controls; and maintaining the accurate documentation for transparency and justifying the results (7).

The data collected from the study area included: supplier information, water supply system, covered population, drainage basin, water treatment plant and so on. The study variables included a checklist and questions and the information obtained from them was imported into the software. In order to complete the questions raised by the staff of the water and sewage company of Qom, an interview was conducted and an inspection was performed on various parts of the drinking water supply system (e.g. reservoirs supply, treatment plan). Then, Qom second water supply network was evaluated using the WSP QA Tool, free version 1.3 and the WHO's WSP Manual (17).

It is a collaborative work of IWA and WHO and is based on Microsoft excel, so that it is compatible with Microsoft Excels 2003, 2007, and 2010. Importing the data into the software was done through 12 tables; in fact, the tables were steps of the WSP which were outlined in the handbook of safety program published by WHO (7).

A ranking system was used for rating (evaluation) based

on five levels from 0 to 4. Each step had a range from *not started* to *fully completed*. The description of each of the evaluation levels is as follows:

- The score of 0 should be given to the steps that have not begun yet.
- The score of 1 should be given to the steps that have just begun.
- The score of 2 should be given to the steps that have been partially implemented and documented.
- The score of 3 should be given to the steps that have been substantially completed and documented.
- The score of 4 should be given to the steps that are fully completed and implemented, and the evidence of their implementation is readily available.

The results of evaluation are presented as tables and graphs after analyzing the input data. Output results from this software can be viewed in the order of each WSP (15).

3. Results and Discussion

This software examined the status of the drainage basin, water treatment plant, distribution network and water harvesting points in compliance with the goals of WSP, where the results are listed in Table 1.

WSP could improve the quality of the resources to the point of water harvesting. The use of this program would have very beneficial results especially in developing countries (18). As shown in Table 1, the coordination of drainage basins, water treatment plant, distribution network, and water harvesting points with implementation of WSP were 67%, 67%, 64%, and 65%, respectively; this is due to not fully implementation of WSP. And in this regard, all the goals of the program could not be achieved. Figs. 1 to 4 show the assessment results in the catchment area, the treatment plant, the distribution network, and the water harvesting points.

As shown in Figs. 1–4, the lowest score (25%) was attributed to the developmental programs. This result can be due to financial constraints. The identification of stakeholders with a score of 100% achieved the highest score due to the implementation of the *risk identification* and *risk assessment*. This step is shown in Fig. 4 with a score of 100%. It seems that the organization has a special attention to the water harvesting points and has fully identified the risks.

The study conducted by Nijhawan et al on the implementation of the WSP for large pipelines in Nagpur, India, showed that the water supply network, especially the distribution network, was very vulnerable and the main causes of this event were people unawareness about the proper use of the system, and the benefits of water treated and unregistered network repairs (19).

Gholami et al showed that 25% and 33.33% of the WSP were derived from stakeholder identification and the step of identification of hazards and risk assessment. Similarly, the water treatment plant and the catchment area did not receive a concession at this stage. It seems that attaining a low score in this study may be due to the failure of implementation of the WSP and the inadequacy of the

Table 1. Evaluation Results of Components of Water Supply System

System Components	No. of Questions	Total Possible Points	Score (%)
Catchment	23	88	67
Treatment	23	88	67
Distribution	23	88	64
Point of use	23	88	65
Total	92	352	65.63

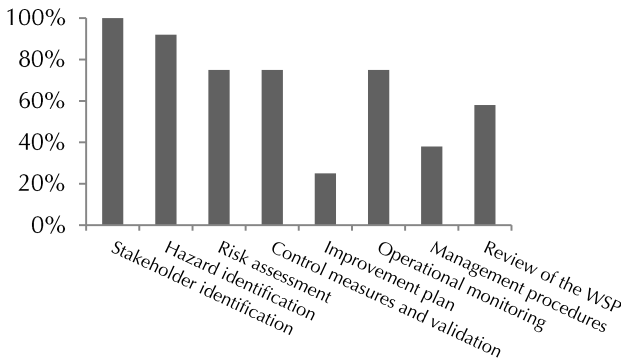

Fig. 1. Results of WSP Data in the Catchment.

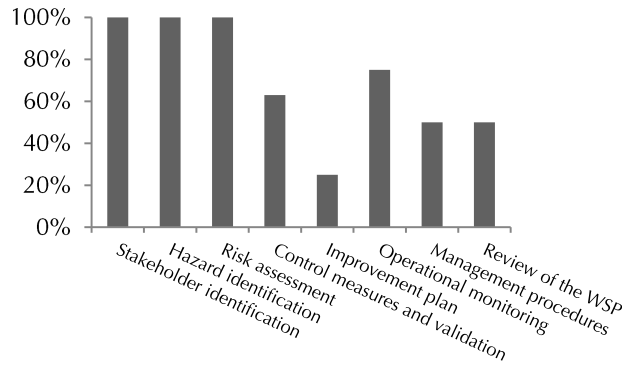

Fig. 2. Results of WSP Information in the Treatment.

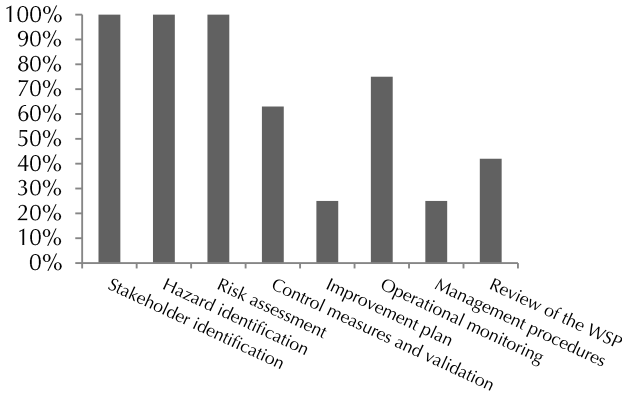

Fig. 3. Results of WSP Information in the Distribution Network.

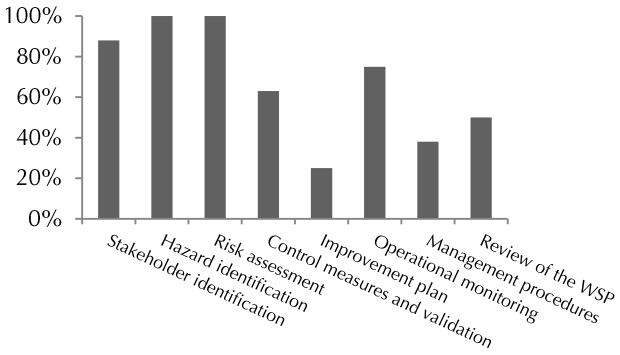

Fig. 4. Results of WSP Information at the Points of the Use.

current management control approach (10). The results of the *identification of hazards* and *risk assessment* steps are reported in Table 2. As shown, the steps of *identification of risks* and *risk assessment* earned a total score of 97%. The reason for this score is probably consideration and implementation of these steps by the organization as important steps. The study conducted by Mosaferi et al in Lighvan, Iran, revealed that many of the risks and risks of pollution, especially in small communities, can be controlled by implementing a WSP (15). The results of the overall evaluation of WSP phases are reported in Table 3.

As shown in Table 3, these 12 steps evaluated in the WSP of the second water supply system of Qom water and wastewater company achieved 302 scores out of 440. In this study, the *development plan* step acquired the lowest score (25%). It seems that this result is related to the limited financial resources allocated in this regard. In the *system description* phase, the score was 100%. Obtaining a full score in this phase is probably due to the significant recognition of the status of the second water supply network by program executives in Qom.

The study established by Baum et al on WSP showed that the *system description* step in the United States was consistent with drinking water laws. On the other hand, Baum and colleagues' study showed that there was a discrepancy between the *regulatory and supervisory practices* as well as the *risk assessment* step with US drinking water laws (20).

Table 2. Identification of Hazards and Risk Assessment

Table	No. of Questions	Total Possible Points	Score (%)
Stakeholder identification	2	32	96.88
Hazard identification	3	48	97.92
Risk assessment	2	20	95
Total	7	100	97

It seems that the system weaknesses are related to the steps that require adequate and specific funding, as well as management practices that have been so far traditionally carried out and WSP has been partially implemented till now. One of the major problems in the progress of the implementation of WSP is the management practices that are only the instructions and it requires the sufficient knowledge about the system and financial facilities (21). However, since the second water supply network of Qom has a good quality and a decent purification system, it has resulted in a good overall score. The obtained scores by phases of the WSP team, risk identification and assessment, controlling criteria and their validation, operational monitoring, review, management procedures, support programs, and revising were 65%, 97%, 63.24%, 75%, 96.88%, 38.89%, 87.5%, and 51.79%, respectively. Overall evaluation of the system showed that the second water supply network in Qom has generally obtained a score of 68.64%.

4. Conclusion

As stated, one of the most important measures to improve the quality of drinking water in Qom was the construction of a second (private) water supply system. In this study, the weak points and preventable points in the qualitative management of the second system of drinking water in Qom city were identified as relatively acceptable. According to the results of this research, it is possible to distinguish the areas in need of improvement. Earning a score of nearly 70% indicates that the system is in fair

Table 3. Results of General Evaluation of WSP

Table	No. of Questions	Total Possible Points	Score (%)
WSP team	5	20	65
System description	2	8	100
Hazard identification and risk assessment	7	100	97
Control measures and validation	5	68	63.24
Improvement plan	3	48	25
Operational monitoring	4	64	75
Verification	8	32	96.88
Management procedures	3	36	38.89
Supporting programs	2	8	87.5
Review of the WSP	5	56	51.79
Total	44	440	68.64

decent position. Not achieving a full score (100%) may be related to the lack of fully implementation of WSP in this system. Therefore, in order to improve the status of Qom's second water supply system and increase the rating points, the followings are recommended:

- Provision of a sufficient funding to continue the program;
- Compilation and fully implementation of undone steps;
- More training programs for employees;
- Allocation of sufficient funds for any uncontrolled risk; and
- Prioritization and fully implementation of development and improvement programs.
- Furthermore, achieving desired goals of the program requires the attention of the authorities responsible for implementing WSP, both in national and provincial levels.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

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