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ORIGINAL PAPER

System assessment and analysis of dangers in water safety plan: a case study in a desert city in Iran in 2017

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ABSTRACT

Access to clean and safe drinking water has been the focus of officialsin charge of supplying water through many different methods. Water safety program is a new method for ensuring the safety of water by applying systematic prevention and risk analysis approach. The present study has been performed on a water supply system. Water Safety Plan contains 12 different steps which analyze topics such as system description, identifying dangers, risk analysis, etc. The checklist obtained by using the above steps will be applied as input information to a water safety program software named WSP-QATOOL. The risks identified and listed by experts in drinking water were scored using the world health organization data .Also, the results of data analysis are given in tables and graphs. The 12 different steps of analysis earned 212 points out of the total possible points of 440. Basins, water treatment, distribution network, and water outlet points earned 48.86 percent of these points and the reviewing step had 0.0 percent of the total points for coordination with water safety program. The questions related to the system description and identifying dangers and risk analysisstep with 100 percent point had the highest percentage in coordination with the program. System Analysis earned a score of 48.18 percent in general. In order to increase this score, the water safety program should be fully performed and a program should be developed to control the recognized risks with a specified amount to support it.

Keywords: Water Safety Plan, Water Distribution Network, Risk Management, Drinking Water, Assessment

Introduction

It is necessary to use healthy drinkable water in different aspects such as drinking, sanitary purposes, food products, and industry. Regarding the limitation of fresh water resources and the population growth rate, some suitable managerial methods should be used to protect these resources. In the topics of Sustainable Development Goals (SDG) it is mentioned that by 2030, access to the drinking water should be available for all societies.[1] The geographical changes, droughts, and floods have influences on water resources.[2] Access to fresh water is very important for sustainable development and protection of healthy life. Therefore, ensuring the quality and health of the water should be the main concern of the authorities.[3] According to the World Health Organization (WHO), there are almost 1.7 billion cases of diarrhea in the world which is the second most important cause of death among children.[4] It is necessary to have a framework consisting of goals based on health, water safety program, and independent monitoring such as the one given by Guidelines for Drinking Water Quality (GDWQ) and also the various guidelines which have been offered on how to

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protect these frameworks.[2,5] In this regard, WHO and IWA have presented a water safety program for healthy drinkable water supply which aims to decrease and eliminate the resources pollutions.[6,7,8,9,10,11,12] In some parts of Island, where this program has been implemented, the diarrhea problems have decreased substantially.[13] The Water Safety Plan (WSP) is a comprehensive program for ensuring the health of drinking water which comes from basin to the consumers;[14] this program has been implemented in 93 different countries up to now.[15] The method of WSP is one of the effective methods of providing healthy drinking water and consists of 11 modules.[16,17,18] Figure 1 shows the framework of supplying healthy drinking water based on the water safety plan which was mentioned in relevant guidelines.

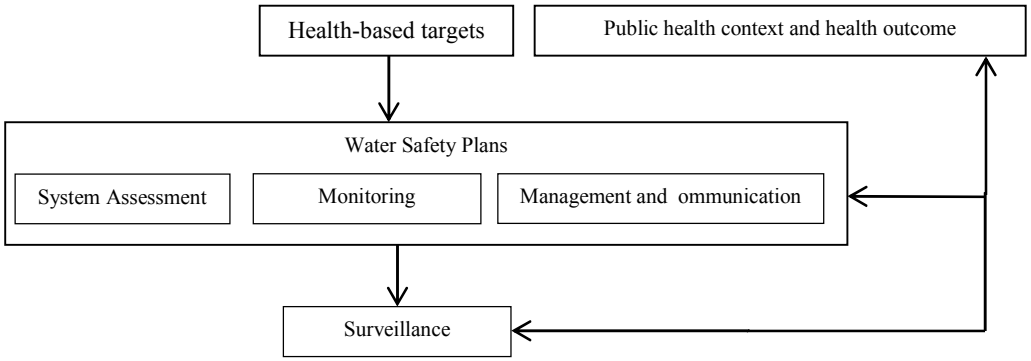

Fig. 1. Overview of the framework for safe drinking-water as set out in the guidelines for drinking-water quality[19]

The water distribution projects need a special attention in regards to risk management. The method of WSP is a suitable and acceptable program to identify and eliminate the dangers threatening the health of drinking water.[15,20,21] The main objective of this plan is to prevent or decrease the pollution of water resources, production systems, storage, and distribution of drinking water until it reaches the consumers.[22] Some of the advantages of this plan are the constant and precise analysis of the process, prioritizing the dangers in all operations, making obstacles in order to control dangerous accidents and taking some measures to reduce the effects, adapting to water quality objectives which are able to be conducted in all societies.[19] The officials had been planning to implement this program in Iran since ten years ago and finally, some provinces have recently started to use it.

The province of Qom is one of the smallest provinces of Iran which is adjacent to the central desert and is located in 36-37 degrees altitude.[23] Considering that Qom is a desert-like area, the water wells of this region are hard and salty which causes the supplier of the drinking water to use the surface water resources and water wells from adjacent regions. The WSP system has recently been implemented in this city. This analysis has been performed based on a water safety plan in order to identify the disadvantages and preventable factors in managing the transition and distribution of water in the city.

Materials and Methods

Study Area

Qom is a religious city adjacent to the central desert of Iran with a population of 1,202,000 people (based on 2016 census). It welcomes about 20 million tourists per year from different parts of the country.[24] The drinking water of Qom is supplied from the 15 Khordad dam, Koucheri dam, water wells of Aliabad region, and the water wells inside the city. The water transmitted from 15 Khordad and Koucheri dams enter the water treatment plant with a flow of 2 cubic meters per second. The transmission line from the water treatment plant to the city is about 68 kilometers. The length of the distribution line of sanitary water inside the city is about 2125 kilometers.

The First Part of the Study

World Health Organization and International Water Association presented WSP-QA TOOL software in 2010 in order to analyze the implementation process of the Water Safety Plan which has not been fully used for water quality management in many countries yet; this software was used in this research. The software helps the water suppliers to analyze their system while WSP is in process; and besides highlighting the advantages and disadvantages, it identifies the most needed parts for improvement and also it eases the reporting process for internal and external of the organization. It first prepares a checklist of the questions with respect to the WSP software and starts to fill out the list by the experts in the field of maintenance and operation through corresponding to the Qom Water and Wastewater Company. Afterward, the data is inputted into the WSP-QA TOOL software which is downloadable in the form of Excel files in WHO website. In this program, scoring is based on a five-point system (0 – 4) and each step could range from "not started" to "is finished completely". The results obtained from this software for each step in the WSP program was observed and the points which needed some corrections were identified.[25]

The Second Part of the Study

This study includes the risk analysis of transmission and distribution lines of Qom drinking water which is done by the experts of Qom Water and Wastewater Company. According to the Water Safety Plan guidelines and the matrix presented by the World Health Organization,[7] samples of the most common dangers which were in the system were prepared based on the books and conducted studies. In addition, we asked the experts in water production (treatment, distribution, etc…), health, and environment to prioritize the identified dangers. To ensure the accuracy of the given answers in two phases, we performed this action. Then the results were analyzed by the Cronbach's Alpha method using SPSS software.

Next, the rate and severity of the danger was identified through risk assessment matrix given by WHO which is shown in Figure 2 below and some suitable control measures were considered for the dangers with rates higher than 15 in the tables 1 and 2.

Table 1. Risk assessment Matrix [19]

Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	5	10	15	20	25
Likely	4	8	12	16	20
Moderately Likely	3	6	9	12	15
Unlikely	2	4	6	8	10
Rate	1	2	3	4	5

Table 2. Risk Assessment Matrix Interpretation[19]

Risk score	<6	6-9	10-15	>15
Risk rating	Low	Medium	High	Very high

Results and Discussion

The interclass correlation coefficient (ICC) was calculated by Cronbach's Alpha in posttest as r=0.710; CI 95%: 0.380- 0.913. Moreover, the test-retest was conducted to assess the consistency of the questionnaire and the Pearson Correlation Coefficient test was estimated as r=0.996, p<0.001.

The outputs of the software are shown in Tables 3-5 as well as Figures 2 and 3. Also, the hazard analysis matrix is shown in Table 6. Supply of healthy drinkable water should be the main goal in any water supply system.[26] Water safety plan is a useful program to ensure the health of drinking water.[27] As it can be seen in the given tables and figures, one of the

advantages of using the software is that it was used as a guide in the early stages of implementation of WSP and it also analyzed the performance of the program.

Table 3. Hazard identification and Risk assessment

Table	No. of questions	Total possible points	Score (% Implemented)
Stakeholder identification	2	32	100
Hazard identification	3	48	100
Risk assessment	2	20	100
Total	7	100	100

As it is shown in Table 1, the Qom water supply system received the full score in danger identification stage. Due to performing the WSP program, it seems the relevant organization has paid a special attention to this module and has completely identified the risks. In a study performed by Räsänen and colleagues in Laos in order to identify and control the dangers of flood, they suggested the programming of using the earth, alarming systems, and preliminary systems which emphasizes the rule of individual responsibility.[28]

The controlling criteria and developing programs gained the least scores in all parts of the water supply system which means they need to pay more attention to this issue. Performing WSP program requires financial assistance and enough time. These requirements may differ based on the complexity of each system.[29] Developing programs are activities which with relying on items such as developing knowledge and human skills and increasing management system capacities try to deliver safe water which in most cases refers to learning WSP program. These programs indirectly support the safety of water. The programs which end in the optimization of processes such as quality development in a laboratory may be available at present but they often have been forgotten.

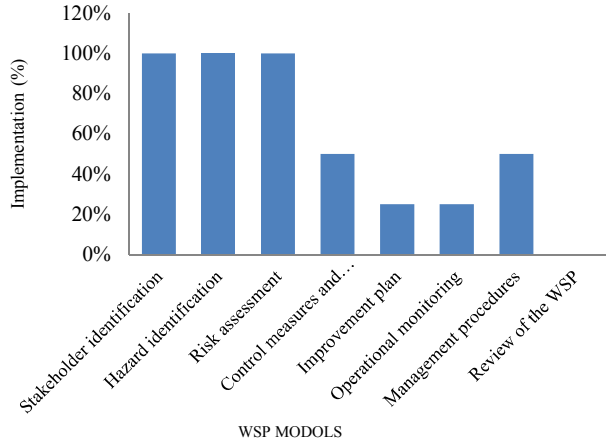

Fig. 2. Quantitative information for Catchment, Treatment, Distribution, Point of Use

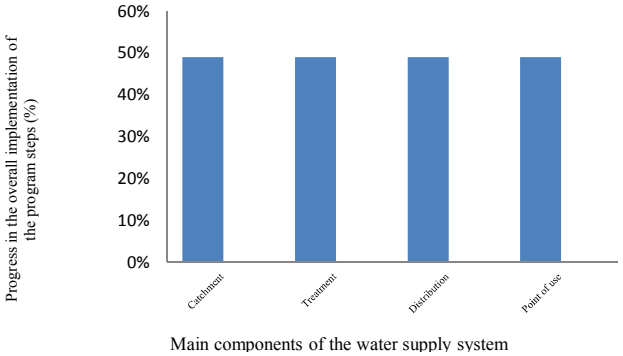

Fig. 3. Results by Component

Table 4. Results by Verification

Table	No. of questions	Total possible points	Score (%Implemented)
Verification monitoring	5	20	4.20 (20.00%)
Auditing	2	8	0.8 (0.00%)
Consumer complaints	1	4	0.4 (0.00%)
Total	8	32	4.32 (12.50%)
Table	No. of questions	Total possible points	Score (% Implemented)
Verification monitoring	5	20	4.20 (20.00%)
Auditing	2	8	0.8 (0.00%)
Consumer complaints	1	4	0.4 (0.00%)
Total	8	32	4.32 (12.50%)

Table 5. Overall progress with WSP

Table	No. of questions	Total possible points	Score (% Implemented)
Table 3 – WSP team	5	20	95.00
Table 4 – System description	2	8	100.00
Table 5 – Hazard identification and risk assessment	7	100	100.00%
Table 6 – Control measures and validation	5	68	50.00%
Table 7 – Improvement plan	3	48	25.00%
Table 8 – Operational monitoring	4	64	25.00%
Table 9 – Verification	8	32	12.50
Table 10 – Management procedures	3	36	47.22
Table 11 – Supporting programs	2	8	25.00
Table 12 – Review of the WSP	5	56	0.00
Total	44	440	48.18 (212)

Table 6. Matrix analysis of dangers of Qom Water Supply System

Corrective actions	Risk assessment			Dangerous event	Location	Danger
	Risk	Severity	Possibility			
Installation of cut off valve at the end of inlet line and protection against pollution	20	5	4	Malfunction in draining system	Reservoirs	Physical
Draining polluted water and preventing from entering to the network Informing consumers and make recommendations Check reservoirs for pollutants and washing Repeat chlorination in outlet and make sure of water safety Repeated tests until elimination of pollution Designing suitable civil system for water inlet to reservoir to eliminate mixing of sediments Decreasing the time of staying water in the reservoir by designing and forecasting dewatering program for cycling of the water in reservoir	15	5	3	Increasing microbial factors over the limit in inlet and outlet	Reservoirs	Biologically
Changing the depth of watering Decreasing water inlet to the treatment plant Stop watering during the high pollutions Deviating flow of local floods Controlling the pond from entering of people into it Matching the downstream processes in eliminating pollutants considering their type and nature	16	4	4	Rapid change in quality of water resource by seasonal change, hard raining in basin and dam (decreasing in water inlet)	Basin and dam	Physical, chemical, biological
Installation of alarm systems Monitoring and inspection program of the organization of the contractor performance Utility safety analysis and elimination of defects in periodic times	15	5	3	Leakage of chlorine gas	Water treatment	Chemical
Draining the pond periodically and inspection and maintenance of all utilities and recording them in technical files Inspection of overflows and analysis of the cavitation's and decay. Inspection of painting and maintenance of overflows.	20	5	4	Problems in clarifiers and overflows	Water treatment	Physical, chemical, biological
Urgent analysis of the cause or causes of changes in water quality and other items. Quality of items up to reaching results Reviewing complaints of consumers about water quality, like taste, odor, color, opacity, and etc., lookup and problem solving.	25	5	5	Inappropriate water quality after elimination of accidents	lines	Physical, chemical, biological

The advantages of the system are in identifying stakeholders, dangers, and system analysis stages and the disadvantages of the system are in developing programs, monitoring, and reviewing stages. Also, management programs which have earned 50 points need special attention. In a study performed by Baum and colleagues, they declared that a principled and suitable management system is necessary for supplying healthy drinking water systems.[20] Nijhawan and colleagues in their study have suggested the following Management plans and technologies such as the creation of a free telephone line to improve the customer service, monitor employee performance, etc.[27] In general, the Qom water supply system earned the score of 48.18 which requires more planning and actions to coordinate more with WSP programs.

As it is shown in Table 4, the threatening dangers of water supply system can be controlled by performing control measures.

Conclusion

All parts of the Qom Water Supply Project were recognized as the most important criteria for controlling water crisis in Qom and they were subjects of monitoring. The twelve steps of analysis, which were analyzed, earned 212 points (48.18%) out of 440 possible points. From these scores, the basin, water treatment, distribution line, water splits had 48.86 % and the reviewing step had the least score (zero percent) for implementation of water safety plan. Questions related to system description and the step of "risk assessment and dangers recognition" had the highest score of 100%. In order to increase the score, the Water Safety Plan should be fully conducted and to control recognition risks, a developed program with enough budgets should be considered. Monitoring of water supply components, especially water treatment should be performed by the organization's specialists and the results should be presented to managers monthly. Thus, the reports can be reviewed and necessary feedbacks should be given to contractors. Monitoring documents should be reviewed monthly by organizations' management, all guidelines should be documented and updated and it should be assured that all personnel follows the latest version and also the assurance of the water safety should be thought through workshops and training courses by personnel of the organization and contractors.

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