ENVIRONMENTAL IMPORTANCE OF WATER SAFETY PLANS IN WATER PURIFICATION PLANTS

Palomero-González J [1] , Bernat Quesada F [2] , Soler Serena P [2]

[1] Universidad De Valencia, Valencia, Spain

[2] EMIVASA, Valencia, Spain

Abstract

The emerging pollutants presence in the water is an environmental problem. In addition to this, their presence involves a drinking water quality problem of concern in developing and developed countries around the world because of its impact on the population health. Nowadays, thanks to improvements in the analytical sensitivity methods for the measurement of these chemicals at very low concentrations we can control water quality with the aim to treat it in water purification plants for reduce health risks. The contamination concentration increase in water supposes a human health risk and the traditional management and treatment could not be useful to resolve this current problem. The experience shows the value of preventive management approaches that range from water resources to the consumer. The most effective way to ensure the drinking water supply system safety is to apply a comprehensive approach to risk assessment and risk management covering all stages of the supply system, from the catchment basin to its consumer distribution. Water Safety Plans (WSP) are an integral water supply management focus on identifying pollutants, their risks and can indicate how to eliminate them. The WSP main objectives are: ensure the safety of drinking water supplied, reducing the health risks and guarantee a quality water distribution system. This elimination is done in the water purification plants obtaining the health risk reduction and an environmental benefit. The paper's objective is to show the environmental role of the water purification plant.

Key words: Water Safety Plans, Environmental importance, Risk analysis, Monitoring

Introduction

Fresh water is water that contains minimal amounts of dissolved salts (less than 500 ppm). Although it is a renewable natural resource, it is distributed very irregularly over the Earth's surface and it is limited by availability and seasonal factors. It only represents 3% of the total water on Earth. This water is very important in continental ecosystems for the environment and for humans (United States Geological Survey).

Water is not only vital for the consumer, but also for the environment. It is an essential element in the nutrition of living things, especially of vegetables, it is of vital importance for the control, purification and good condition of terrestrial ecosystems and it has an influence on the weather. In addition to this, water has historically been a crucial element in the development of civilization. Many cities owe their wealth to their connection to, or the presence of, water which historically favored their growth and prosperity.

The main water supply sources are: water wells, rivers, and reservoirs. If the water supply sources are of good quality, it is possible to have good quality water free of health risks requiring minimal water purification treatment and the costs that entails. It is a service that is taken for granted in Western countries, and little thought is given to the importance of protecting all water ecosystems but all of them are, or could be in the future, needed as a water supply source.

The Water Framework Directive regulates the good management and protection of water. The objective is to prevent further pollution, to protect and improve water ecosystem quality, to guarantee fresh water quality, and to ensure sustainability and quality of supply (2000/60/EC).

The Directive lays down in Article 4 the environmental objectives. These objectives are to protect surface water, improve and regenerate water ecosystems, prevent water contamination and prevent or limit the entry of contaminants into groundwater. These objectives are more stringent for protected areas. In addition, Article 7 stipulates that both current and future water supply sources must be protected. To ensure compliance with these objectives, countries must develop basic control measures and, if necessary, complementary control measures.

In order to obtain the economic resources to pay for and maintain the basic and complementary control measures, Article 9 establishes the cost recovery of all water-related environmental services. Consequently, users must pay to have good quality water and water ecosystems.

Since 1994 the World Health Organization (WHO) has been developing Water Safety Plans (WSP) to manage drinking water based on the Hazard Analysis and Critical Control Points methodology of the food industry. The first WSP was published in the

WHO's third *Guidelines for Drinking Water Quality* in 2006 (Matía & Paraira 2004; Matía et al. 2008; World Health Organization 2006; Ganzer Martí et al. 2008).

WSPs are integral management plans based on risk assessment at all stages of the water supply system whose purpose is to ensure the safety of the water supplied. Their main advantage is that they are exclusive management plans, drawn up specifically for water supply systems, regardless of type and complexity. They are compatible with all International Organization for Standardization (ISO) norms and certifications, creating good synergies when implemented together. WSPs constitute a dynamic and practical management approach. They have been developed to organize and systematize the best practices in the management of drinking water, ensuring water quality and minimal health risk (WHO 2006; Davidson et al. 2005; Bartram et al. 2009). There are several case studies in the literature on the implementation of WSPs in different water supply systems in Australia, the United Kingdom, Latin America and the Caribbean and Spain (Davidson et al. 2005; Bartram et al. 2009; Ganzer Martí et al. 2011).

There is an important aspect of WSPs that should be highlighted: one of the aims of a WSP is to facilitate communication between the different actors who intervene in the management of the water supply system: water companies, city councils, river basins, users, and so on (Davidson et al. 2005; Bartram et al. 2009).

Objectives

The objectives are to highlight the environmental importance of WSPs in monitoring the sources of the water supply. To demonstrate their environmental importance, the Delphi methodology will be used to identify and evaluate the risks to the catchment point and to identify control parameters focusing on environmental and public health impact of these risks.

Methods

The stages of the WSPs implementation are: the creation of a multidisciplinary team and choice of methodology; hazard analysis of the water supply system; risk determination and monitoring to measure the risk detected; development of improvements and plans to minimize risks; making a control analysis plan; revision of the analysis and plans to adapt the WSPs to the current situation; and finally, informing users (Davidson et al. 2005; Bartram et al. 2009).

The most important part of WSPs is the determination of risk. Experts recommend the use of quantitative or semi-quantitative methodologies for risk assessment, for example, the development of risk matrices, the Delphi method, or questionnaires to be completed by experts, a new methodology based on cost-effectiveness analysis of the risk reduction measures required to reach the objectives of water security, and so on (Davidson et al. 2005; WHO 2006; Bartram et al. 2009; Lindhe et al. 2011).

Delphi is a research methodology that is characterized by consulting a group of experts with the aim of reaching a consensus on any issue or matter that involves subjective judgements. This survey is carried out through questionnaires that are filled in by participants, who then receive feedback on the responses, in an iterative process until all the responses are convergent. The Delphi technique is based on sequential consultations in order to seek consensus on priority issues by a procedure of voting over a choice of topics (Dalkey & Helmer. 1963; Lindstone & Turoff 2002).

The process is viewed as a series of rounds; in each round, participants communicate their opinions through a questionnaire that is returned to the researchers, who collect, edit, and return to every participant a statement on the position of the panel and the participant's own position. The summary of expert judgements (in the form of quantitative evaluations and written comments) is provided as feedback to the same experts as parts of the next round of questionnaires.

The Delphi method is based on the elaboration of a questionnaire that has to be answered by each expert. Once the overall results are analyzed, another questionnaire is answered again by the same experts, after informing them of the results obtained in the previous consultation. The experts then reevaluate their views in the light of this information, and a group consensus tends to emerge. Finally, the study manager will draw his or her conclusions from the statistical exploitation of the data obtained.

Delphi studies employ multiple iterations of questionnaires and feedback to develop a consensus of opinion concerning a particular problem or topic. The Delphi method is used for the identification of risks and dangers in various fields such as climate change (Adam-Poupart 2013), agricultural land uses (Jozi & Ebadzadeh 2014), or installation of industries with environmental impacts, such as the gas industry (Jozi 2015). In the water field, the Delphi method is used to identify risks and water contamination hazards related to industrial activities (Kumar et al. 2016) or the installation of desalination plants (Sepehr 2017).

To implement a WSP to control the water input in a water supply, the first step is to choose the critical points, and then, the control parameters. We created a multidisciplinary panel specialized in water management. This panel was composed of engineers, chemists, pharmaceutical experts, biologists, and environmentalists. As recommended by the Delphi method, the research consisted of two steps. In the first stage, questionnaires were sent to the respondents or panelists. Upon receipt of this first round of responses, the data was analyzed. In the second stage, the questionnaires were returned to the panelists along with a statistical analysis of early results.

The first task of this multidisciplinary panel was to identify the critical points and their risks and hazards in the water input in a water supply. Once the new control points had been established, the second task of the panel was to evaluate the risks and hazards. To do this, the panel carried out a review of the literature using the principal databases. They then evaluated the risks and hazards.

The multidisciplinary panel assessed and quantified the risk, severity and probability of the event, assessing each parameter independently. Then, they assessed the risk as the product of probability of occurrence and the severity of its effect. To make it easier to understand the results, the risk is expressed on a scale of 5 categories (Very Low - Very High) as shown in Table 1.

Risk Categories	**Risk Score**
Very low	01 – 05
Low	06 – 10
Middle	11 – 15
High	16 – 20
Very High	21 – 25

Table 1: Risk Categories and score. Source: Authors

Results

The focus in the tables below is on water wells, rivers and reservoirs because they are the principal sources of water supplies. This risk analysis should be done as part of a WSP when analyzing the water purification plant risks. Tables 2, 3 and 4 show the results obtained by the panel.

Water well risk sheet				
Events	**Potential hazards**	**Gravity**	**Probability**	**Risk**
Water available insufficient for extraction below the water table	Supply scarcity	5	2	Low
Aquifer contamination	Chemical and microbiology contamination	5	3	Middle

Well contamination during its construction	Construction waste	2	2	Very Low
Infiltration	Chemical and microbiology contamination	5	4	High
Drought	Increased turbidity and contaminants	4	4	High
Organic and/or inorganic elements dissolved in water contaminate the water well	Increase Turbidity, Organic matter, TOC, microorganisms and chemical contaminants	4	2	Low

Table 2: Risk sheet from the supply source: Water Wells. Source: Authors

River risk sheet				
Events	**Potential hazards**	**Gravity**	**Probability**	**Risk**
Drought	Increased salt concentration Water composition variation	3	4	Middle
Water available insufficient	Supply scarcity	5	1	Very Low
Spilled Microbiological Contamination	Microbiological contamination	5	5	Very High
Spilled physical – chemical Contamination	Contamination by metals, pesticides, organic matter (animal waste)	5	4	High

Contaminated rains with inorganic elements	Turbidity, Increased COT, Organic matter	3	3	Low

Table 3: Risk sheet from the supply source: Rivers. Source: Authors

Reservoir risk sheet				
Events	**Potential hazards**	**Gravity**	**Probability**	**Risk**
Water level variation in the reservoir	Increased microbiology and chemical contamination	2	5	Low
Contribution of tributaries to the reservoir	Microbiology contamination	4	1	Very Low
The same risk as in River risk sheet				

Table 4: Risk sheet from the supply source: Reservoirs. Source: Authors

The risk analysis shows that the main differences between rivers, reservoirs and water wells are scarcity and vulnerability to contamination. Water wells are more scarcity vulnerable than rivers or reservoirs, but are more resistant to contamination. However, in the case of water wells, despite being less vulnerable to contamination, once contaminated, it is very difficult to recover the initial water quality. Rivers and reservoirs are more at risk from spills by microbiological and physical-chemical contamination. Both risks have a big impact on the environment and public health.

In general, well water is an important source of groundwater since it is not susceptible to receiving point discharges, in contrast to rivers and reservoirs. Because of this, chemical and microbiological control in treatment plants is of great environmental importance in order to ascertain the environmental health of well water. At the same time, the control of the water table is necessary to determine the quantity of water that can be made available for other uses, such as agricultural or environmental. As soon as the water table drops below an acceptable level, the basin organization is notified and action is taken.

The main contamination source of water wells is agricultural activity or industrial spill on the surface in the well water charge zone. To prevent this contamination, it is very important to know the hydrogeology of the area where the water well is located. As has already been said, when a water well is contaminated, it is very difficult to recover its initial quality, so the best control measure is to prevent contamination in the first place.

Aquifer depletion due to water extraction is another challenge in managing water well used as a water supply source. Apart from the risks mentioned above, when the water level is below the water table the rest of the ecosystems that depend on the water from that water well is affected. Moreover, water can only be extracted when the water level is below the water table by using a pump.

As for surface water (rivers and reservoirs), the greatest risks are always those produced by uncontrolled discharges into rivers, as these affect both the water supply system and the flora and fauna of the river's own ecosystem. When water supply is being monitored the environmental quality of the river and its ecosystem is also being monitored.

There are several kinds of pollutants in rivers and reservoirs depending on the type of industry characteristic of the area through which the river flows. Consequently, contamination by pesticides and herbicides will occur in areas with mostly agricultural activity, inorganic contaminants in areas with livestock industry, and contamination by heavy metals when the river passes through industrialized areas. WSPs take this into consideration in their evaluation and they prevent possible contamination with control measures to protect public health.

It is important to highlight two factors that affect rivers. The first one is that, if there are wastewater treatment plants near water supply catchment points, their effluents must be monitored, otherwise they could reach the environment and consequently contaminate the water supply system. Monitoring and analysis are required to check for possible contamination, by for instance, an increment of organic matter, microbiological contamination, or contamination from chemical products.

The second factor is rivers' dependence on the climate. The river flow determines the quantity of water that can be extracted for the water supply system, given that the environmental flow must be respected. The concentration of pollutants also depends on the volume of water carried by the river. Consequently, it is very important to consider this when a river is managed as a water source, especially in water-stressed areas, such as the Mediterranean area.

All these risks that affect rivers also affect reservoirs. A specific problem in regard to reservoirs is a decrease in the water level since this changes its physical and chemical characteristics and negatively affects the microbiological population, phytoplankton and other organisms. In addition to this, any change in the tributaries that arrive at the reservoir will also have an effect on it.

WSFs have a very important environmental role thanks to their methodology of risk analysis and assessment, which improves awareness of the water supply system. The monitoring of the water supply source provides valuable information about the environmental health of the water source. Therefore, it is very important to develop and implement WSPs, in view of their environmental importance, as well as the role in both the improvement of water quality and minimization of health risks.

Conclusions

Water is very important both for the environment and society. Its protection is necessary to guarantee water supply systems and protect, maintain and improve the environment. Its importance is such that the European Union legislates on its protection. Improving water quality needs a lot of monitoring and the implementation of measures to protect it. At the same time, WSPs establish risk analysis as a methodology to control water quality and minimize health risk.

The risk analysis carried out in the WSPs shows the importance of monitoring. When the water source that is the input in a water supply system is analyzed at the same time the environmental health of the water source is also monitored. As a result, any contamination can be detected at an early stage. The same parameters that are used to control water quality can also be used to evaluate the health of the environment.

The principal water supply sources are: water wells, rivers and reservoirs. The risk analysis carried out during the implementation of the WSP, shows that water wells are sources of higher quality water but may not be able to satisfy water demand whereas rivers and reservoirs are at greater risk from contamination but is more likely to be able to satisfy consumer demand.

The results show the importance of monitoring in order to guarantee both water source quality and a healthy environment. By monitoring water supply sources any contamination can be detected at an early stage and corrective measures taken. WSPs represent a very effective instrument for protecting water ecosystems while at the same time monitoring water supply sources.

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