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A Critical Evaluation of Water Safety Plans (WSPs) and HACCP Implementation in Water Utilities †

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Abstract: The use of traditional risk management systems has proven to be insufficient to safeguard the safety of drinking water. Nowadays, it is preferable to apply preventive instead of corrective systems. Two of the most commonly used systems are the Hazard Assessment and Critical Control Points (HACCP) and the Water Safety Plans (WSPs). The major benefit of their implementation is the improvement of drinking water quality. Of course, the successful implementation of HACCP and WSPs in water utilities can be limited by a number of factors such as the lack of financial resources. However, the importance of implementation's difficulties is minimal in relation to the benefits that may result from the application of HACCP and WSPs in water utilities.

Keywords: drinking water; HACCP; WSPs; risk assessment; water utilities

1. Introduction

As water is a valuable and indispensable ingredient of life, drinking water's safety is extremely important both for ensuring the consumers' health and for the proper functioning of the ecosystem [1]. In a survey carried out in early 2006, it was found that the proportion of the world's population consuming drinking water from certified and controlled water sources was 87%, which is significantly higher than the corresponding proportion (77%) which was recorded at the beginning of 1990 [2]. Also, according to the current trends, it is estimated that over 90% of the world's population is supplied with water from controlled sources [3]. However, 2.3 billion people worldwide suffer from diseases related to drinking water [4]. Also, over the past three decades, significant drinking water contamination incidents took place in developing and developed countries, creating several health problems to consumers [5].

Nowadays, it has been proven that traditional risk management systems, based on addressing and correcting the failure after its occurrence, are inadequate. In recent decades, it is preferable to apply preventive compared to corrective systems (prevent hazards rather than correcting them) across the entire water supply network from the water source to the final point of consumption [6]. Several tools have been developed to identify and prioritize the potential hazards that may arise throughout the drinking water abstraction, treatment and distribution system [7]. HACCP and WSPs are two of the most popular, effective and commonly used tools for the management of drinking water quality and safety [8–10].

In the early 1990s, HACCP application in water utilities was initially investigated [10,11] while at the end of the same decade the development of WSPs has been introduced [12,13]. Since then, HACCP and WSPs have been adopted by many water utilities around the world either because they

are a legal requirement, or they are considered as a reliable system for assisting the production of safe drinking water [14–20].

It is found that these systems have a satisfactory application for the risk assessment in water utilities [21–23]. Furthermore, several researches were referred to the effectiveness, benefits and difficulties of implementing HACCP and WSPs in water utilities of developing and developed countries [13,19,22]. This paper tries to evaluate the theoretical effectiveness of the two risk assessment strategies with an extensive reporting and evaluation of the different numerical data. These numerical data are derived from the observation of important physicochemical and microbiological parameters as well as the conduct of clinical studies related to the possibility of diarrheic diseases arising from the consumption of inappropriate drinking water. Also, it is considered necessary to further investigate the effectiveness of implementing WSPs and HACCP under different environmental conditions, different initial water quality, water sources, treatment process, storage conditions and distribution networks, etc. [24]. In addition, it is believed that it would be advisable to conduct research to investigate the effectiveness of implementing HACCP and WSPs in low-capacity water supply companies [13] as well as in entire national supply water networks [25]. Therefore, the aim of this paper is: (a) the critical evaluation of WSPs and HACCP in European water utilities; (b) the summary of benefits and difficulties of WSPs and HACCP implementation; and (c) the identification of the critical success factors for their effective implementation.

2. HACCP Implementation in European Countries

HACCP is a systematic and scientifically documented system, which has been designed to identify potential hazards in production processes resulting in an unsafe final product. Furthermore, it determines preventive and corrective actions to reduce these hazards to a safe level. In essence, HACCP constitutes an effective tool for both food industries and health authorities to prevent food-borne diseases. HACCP is not a system that validates the safety of food and beverages. Instead, it is a precautionary food management system that prevents hazards through the identification of critical control points and their ongoing monitoring. This system is applied to identify the biological, chemical and physical hazards that could cause potential negative consequences to consumers' health. The main feature of HACCP is that it can be applied in any food and beverage production line and it can be adapted to the particular production conditions of any product [26]. Therefore, HACCP is considered as one of the most useful risk assessment tools, which are specifically designed for the evaluation of hazards in water utilities.

Bryan (1993) [11] and Havelaar (1994) [10] were the first scientists that implemented HACCP to water utilities. Bryan (1993) [11] presented the development of HACCP as a way to improve drinking water treatment processes in order to reduce the possibility of causing water-borne diseases. Furthermore, the necessity of maintaining and repairing the distribution network was emphasized in order to avoid contamination of drinking water. On the other hand, Havelaar (1994) [10] focused on the implementation of HACCP in order to avoid microbiological contamination in drinking water treatment lines. In relation to Bryan (1993) [11], a general HACCP system was designed and developed that included the water source, the water treatment and the distribution network. For each stage, a list of possible risks and preventive actions was listed, as well as critical control points, monitoring systems and corrective actions were determined.

From the primary applications of HACCP, it was found that the most important point for the success of this system was the effective definition of critical control points. Unlike most food and beverage industries have usually designated one or two critical control points to prevent the growth of micro-organisms, water utilities may need to identify more critical control points due to the diversity of water source, treatment and distribution network. Since then, several water utilities have implemented HACCP to ensure the safety of drinking water [20]. In particular, Switzerland [27], Germany [17], Ireland [28], France [23] and Iceland [21] are European countries where HACCP is applied to a greater or lesser extent in their water supply companies.

The application of HACCP principles to food and beverage companies including water utilities is mentioned in Article 11 of the Swiss Hygiene Regulation. To be able to comply with this

requirement, the publication of a regulatory guideline (W1002) entitled "Recommendations for a simple system of quality assurance for water suppliers" was deemed necessary for the water utilities [29]. The main causes of potential risks to Switzerland water utilities can be summarized in staff shortages, inappropriate materials (chemical additives, equipment's construction material, etc.) coming in contact with drinking water, processing equipment and the implementation of incorrect procedures related to the management of the distribution network [27]. However, the consistent HACCP application resulted in the reduction of potential hazards in a short time period which has resulted in improved drinking water quality and safety. In addition, internal audits revealed the increase in employee awareness of compliance with the guidelines and the content of the quality assurance system.

In 1995, Iceland became one of the first countries to legislate the use of systematic preventive management to secure safety of drinking water. Thus, the following year, Samorka (Association of Icelandic Water Companies) issued guidelines for the application of HACCP to water utilities [30]. In May 1997, HACCP principle was applied to several water companies in Reykjavik. Subsequently, between 1997 and 2009, HACCP was implemented in 31 water utilities in Iceland serving over 80% of the population. Generally speaking, HACCP development and implementation by Icelandic water utilities has been beneficial [21]. On the one hand, the awareness of the importance of protecting water resources has been raised and on the other hand many corrective actions and improvements have been implemented to produce safe drinking water. Furthermore, the application of HACCP improved compliance with regulated drinking water quality standards in the town of Reykjavik and Akureyri. Specifically, the mean compliance value for bacterial count for 22°C in Reykjavik city improved from 94% (during 1991–1997) to 99% (during 1998–2006) while a similar increase was observed in town Akureyri city from 88% (during 1992–1999) to 99% (during 2000–2004) [13].

Some of the benefits of the application of HACCP in European water utilities include the thorough assessment and identification of hazards, the optimization of monitoring systems, the improvement of drinking water quality, the better understanding of risk management, the improvement of employee awareness and the compliance with legislation (Table 1) [13,28,31]. On the other hand, several factors have been observed that may jeopardize the successful implementation of HACCP. The high degree of heterogeneity of potential risks, the large extent of the distribution network, the lack of external audit, the limited staff experience and incorrect management procedures consist some of the limiting factors of the effective application of HACCP (Table 1) [13,27,32].

Table 1. The main benefits and difficulties of HACCP implementation in European water utilities.

Benefits	Difficulties	References
Reduction of potential hazards Improvement of drinking water quality Employees awareness	Staff shortages Limited staff experience Inappropriate materials Incorrect management procedures	[27]
Better understanding of water supply network	Application for communication reasons	[23]
Improvement of drinking water quality Establish appropriate monitoring system for critical parameters Prevention of hazardous incidents Prioritize hazards		[31]
Systematic assessment and identification of hazards Improve understanding of water safety issues Increase of consumer confidence Better response to emergencies from authorities		[28]
Increase of employees' awareness Application of appropriate corrective and preventive actions Increase of compliance with legislation Improvement of drinking water quality Better understanding of risk management Faster response to failures Creation of a system for recording deviations	Lack of external audit Inadequate control by health authorities	[13]
	Heterogeneity of potential risks Large extent of the distribution network	[32]

3. WSPs Implementation in European Countries

WSPs, as described by the World Health Organization [33] and advocated in the Bonn Charter (IWA, 2004), are presented as the most effective way to ensure the safety of drinking water. WSPs are unique and are part of the "Framework for Safe Drinking Water" and therefore are guided by health-based targets and overseen through drinking-water supply surveillance [6]. WSPs consist a systematic approach to the management of drinking water safety that encompass all steps in the water supply from catchment to consumer by applying a multi-barrier methodology [9,33]. The main goal of WSPs is to protect the consumer health, which can be achieved by the effective implementation of the three basic components of WSPs. These components are the system assessment, the operational monitoring and management-communication plans [6].

Its difference compared with other drinking water safety management methodologies lies in the fact that it mainly focuses on preventing the occurrence of hazards rather than just suppress them and reduce their undesirable consequences [8]. Although, the basic principles for developing and implementing a WSP are the same in all countries, there is no rigorous methodology that dictates a specific way of developing it. Therefore, WSPs can be applied to a wide range of water utilities regardless of their location, degree of complexity and production capacity [34].

The first countries involved in the implementation of WSPs were Iceland in 1997 [13] and Australia in 1999 [12]. Since then, WSPs are being implemented in water utilities in both developed and developing countries [9,13,16,18,19,25]. Up to now, over thirty five countries worldwide have multiple drinking water systems that are proven to implement WSPs at a voluntary or mandatory level as well as equivalent risk management systems under other names [35]. Among them, several water utilities of Austria, Belgium, France, Germany, Hungary, Iceland, Lithuania, Netherlands, Portugal, Spain, Switzerland and United Kingdom implement some form of WSPs or equivalent systems in order to ensure the safety of drinking water [15,18].

In 2003 WSP methodology was implemented by the first Portuguese water utility [36]. Since then, extensive scientific research has been carried out in order to adopt the practices of WSPs by water utilities in Portugal. In this direction, manuals for the implementation of WSPs have been published and training programs have been developed. The successful implementation of WSPs in individual Portuguese water utilities has shown that they can be implemented at a more systematic and organized scale at national level. The absence of legislation and the need to establish appropriate monitoring systems constitutes crucial importance for the wide application of WSPs in Portuguese water utilities [36]

In the Scandinavian countries, groundwater is used to provide drinking water in small and medium-sized cities while larger cities are supplied with water by surface water treatment plants. In Iceland and Denmark drinking water is produced either exclusively or overwhelmingly from groundwater. Groundwater quality and safety may vary according to the geology of each area, but groundwater is generally classified as of high quality and usually meets the requirements of drinking water legislation [37]. However, several cases of health problems have been observed in Scandinavian consumers consuming drinking water from groundwater sources [38]. This is due to the fact that the assessment of the risks that can occur in groundwater is not complete.

All Scandinavian countries follow the Directive 98/83/EC [39] but at the same time they have national legislation aiming to protect the quality of surface and groundwater in each country. Additionally, most of them implement WSPs or similar approaches to pumping, treatment and distribution of drinking water. A typical example is Iceland, which is one of the countries that has legislated the mandatory application of WSPs to water utilities. The adoption of WSPs principles significantly affected the number of non-compliances, the total population of the heterotrophic microflora and the number of diarrheal incidents. In particular, the mean annual non-compliance with the Icelandic Drinking Water Regulation requirements declined approximately 80% after the WSP implementation. Furthermore, a significant decline in median HPC bacteria following WSP implementation was found overall, at the source and in the distribution system. In addition, the importance of WSPs implementation is also derived from the analysis of diarrheal incidents recorded by seven Primary Health Care Centers in Iceland before and after the implementation of the Water

Safety Plans. The WSPs application has led to an overall significant reduction of diarrheal incidence [40].

The main benefits of WSPs implementation include the better analysis of observed deviations, the improvement of drinking water quality, the increase in compliance with regulation, the improvement of employees' performance, the better monitoring in water source, the effective risk assessment and the decrease in customer complaints (Table 2) [19,36,40–42]. On the other hand, the successful implementation of WSPs in water utilities can be limited by a number of factors, such as the absence of legislation, the inappropriate monitoring system, the limited staff experience, the difficulty in assessing all potential hazards and the lack of supporting activities (Table 2) [36,40,42].

Table 2. The main benefits and difficulties of WSPs implementation in European water utilities.

Benefits	Difficulties	References
Better analysis of observed deviations	Absence of legislation Inappropriate monitoring systems	[36]
Increase of compliance with legislation Decrease of diarrheal incidents Improvement of drinking water quality	Lack of financial resources Limited staff experience	[40]
Better monitoring in water source Better control of microbial contamination Systematic collection and processing of physicochemical and microbiological data Increase of production efficiency Improvement of employees' performance		[19]
Assessment the risks of extreme weather events		[14]
Effective risk assessment associated with compounds that are not controlled by routine monitoring Increase of consumer confidence		[43]
Increase of consumer awareness Finding of financial resources Development of drinking water safety management strategies	High residual concentrations of hazardous substances Inappropriate design of landfills Inadequate sewerage network	[44]
Effective risk assessment Avoid of serious failures Increase of reliability Facilitation of communication		[41]
Improvement of drinking water quality Efficient treatment of drinking water Increase of compliance with legislation Decrease of diarrheal incidents		[45]
Increase of water utilities reputation Increase of consumer confidence Decrease of costumers' complaints Identification of unknown hazards Improve of drinking water quality Better response in emergencies Increase of employee awareness Improve of record keeping procedures	Limited access to chemicals- materials approved for contact with water Difficulty in assessing all possible hazards Limited staff time Lack of financial resources Lack of supporting activities Lack of adequate equipment	[42]

4. Conclusions

The development and implementation of HACCP and WSPs have innumerable benefits and several difficulties. Many of them are common in both drinking water safety management systems while others are unique for each system. The major benefit of HACCP and WSPs implementation is that they contribute to improving the drinking water safety and quality. Other remarkable benefits are the reduction of potential hazards, the prevention of hazardous incidents, the identification of unknown risks, the better response to failure and emergencies situations, the effective risk assessment and the better understanding on risk management.

Furthermore, the employee awareness, the consumer confidence, the compliance with regulation, the reliability and the production efficiency were increased while the diarrheal incidents and consumers complaints were decreased by either HACCP of WSPs implementation. In addition,

the successful implementation of these systems has led to establishment of monitoring and recording systems as well as to the application of most appropriate preventive and corrective actions.

On the other hand, the main difficulties of their implementation are the incorrect management procedures, the limited staff experience, the lack of infrastructure, the heterogeneity of potential risks, the large extent of distribution network, the inability to find financial resources and the absence of legislation.

The critical success factor for HACCP and WSPs implementation are quite difficult to determine because there is a great diversity in the ability of development of both drinking water safety management systems in water utilities between different counties and between regions in the same country. Several factors can contribute to these application non-uniformities such as the production capacity, the employees' skills and experience, the corporate culture, the kind of water supply (groundwater, surface water and seawater), the distribution system, the legislation, etc.

Moreover, any implementation difficulty if it is properly addressed and resolved, it can turn to a success factor. For example, the lack of financial resources or the untrained staff are two important limitations in the successful development of HACCP and WSPs. Of course, the finding of financial resources and the training of employees can transmute these difficulties to critical success factors.

In addition, as additional critical factors of successful HACCP and WSPs implementation could be referred the involvement of all staff in system development, the support of senior management, the internal and external audits, the thorough risk assessment, the employees training and the implementation of prerequisite, operational prerequisite and supporting programs. Also, the legislation of the mandatory HACCP and WSPs implementation in water utilities could be considered as one of the main motivation for the successful application of both drinking water safety management systems.

References

1. Weitz, J.S.; Wilhelm, S.W. Ocean viruses and their effects on microbial communities and biogeochemical cycles. *F1000 Biol. Rep.* **2012**, *4*, 17.
2. WHO/UNICEF. *Progress on Drinking Water and Sanitation: Special Focus on Sanitation*; World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply Sanitation (JMP): Geneva, Switzerland, 2008.
3. Vieira, J.M.P. A strategic approach for water safety plans implementation in Portugal. *J. Water Health* **2011**, *9*, 107–116.
4. UNESCO. *Water for People, Water for Life*; The United Nations world water development report; United Nations Educational, Scientific and Cultural Organization: Paris, France, 2008.
5. Hamilton, D.P.; Gale, P.; Pollard, J.T.S. A commentary on recent water safety initiatives in the context of water utility risk management. *Environ. Int.* **2006**, *32*, 958–966.
6. WHO. *Guidelines for Drinking-Water Quality*, 4th ed.; World Health Organization (WHO): Geneva, Switzerland, 2011.
7. Hokstad, P.; Rostum, J.; Sklet, L.; Rosen, L.; Pettersson, T.J.R.; Linde, A.; Beuken, R.; Kirchner, D.; Niewersch, C. *Methods for Risk Analysis of Drinking Water Systems from Source to Tap-Guidance Report on Risk Analysis*; Techneau: Marigny, France, 2009.
8. Bartram, J.; Corrales, L.; Davison, A.; Deere, D.; Drury, D.; Gordon, B.; Howard, G.; Rinehold, A.; Stevens, M. *Water Safety Plan Manual: A Step-by-Step Risk Management for Drinking-Water Suppliers*; World Health Organization (WHO): Geneva, Switzerland, 2009.
9. Davison, A.; Howard, G.; Stevens, M.; Callan, P.; Fewtrell. L.; Deere, D.; Bartram, J. *Water Safety Plans. Managing Drinking Water Quality from Catchment to Consumer*; Water, Sanitation and Health Protection and the Human Environment World Health Organization: Geneva, Switzerland, 2005.
10. Havellar, H.A. Application of HACCP to drinking water supply. *Food Control* **1994**, *5*, 145–152.
11. Bryan, J.J. Hazard Analysis and Critical Control Points and Their Application to the Drinking Water Treatment Process. In Proceedings of the AWWA Water Quality Technology Conference, Miami, FL, USA, 7–11 November 1993.
12. Byleveld, P.M.; Deere, D.; Davison, A. Water safety plans: Planning for adverse events and communicating with consumers. *J. Water Health* **2008**, *6*, 1–9.

13. Gunnarsdottir, M.J.; Gissurarson, L.R. HACCP and water safety plans in Icelandic water supply: Preliminary evaluation of experience. *J. Water Health* **2008**, *6*, 377–382.
14. Curk, C.B.; Rozic, Z.P.; Daskalou, O. Activity 4.4 Water (re)sources protection and cross border water (re)sources management. In *Cross Border Resources Management*: *Water Safety Plans*; DRINKADRIA: Ljubljana, Slovenia, 2006.
15. Davidovits, Z. The effects of changes in legal regulations on planning drinkingwater safety. *Hadmernok* **2014**, *9*, 234–240.
16. Jayaratne, A. Application of a risk management system to improve drinking water safety. *J. Water Health* **2008**, *6*, 547–57.
17. Kistemann, T.; Dangendorf, F.; Exner, M. A geographical information system (GIS) as a tool for microbial risk assessment in catchment areas of drinking water reservoirs. *Int. J. Hyg. Environ. Health* **2001**, *203*, 225–233.
18. Mälzer, H.-J.; Staben, N.; Hein, A.; Merkel, W. Identification, assessment, and control of hazards in water supply: Experiences from water safety plan implementations in Germany. *Water Sci. Technol.* **2010**, *61*, 1307–1315.
19. Mayr, E.; Lukas, A.; Aichlseder, W.; Perfler, R. Experiences and lessons learned from practical implementation of a software-supported water safety plan (WSP) approach. *Water Sci. Technol. Water Supply* **2012**, *12*, 101–108.
20. Yazdanbakhsh, A.; Manshuri, M.; Nabizadeh, R.; Jahed, G.H.; Fallahzadeh, R. *Guidelines of Water Safety Plan Based on Hazard Analysis and Critical Control Point System*, 1st ed.; Avay e ghalam: Tehran, Iran, 2008.
21. Gunnarsdottir, M.J.; Gissurarson, L.R. HACCP in Icelandic Water Supply—Evaluating eight years of experience. In Proceedings of the NVK Conference, Reykjavik, Island, 8-10 June 2006.
22. EPA. *Application of HACCP for Distribution System*, 1st ed.; United States Environmental Protection Agency: Washington, DC, USA, 2006; pp. 21–63.
23. Metge, S.; Brodard, E.; Conan, M. Lyonnaise des Eaux: Application of HACCP principles for in drinking water. In Proceedings of the Water Safety—Risk Management Strategies for Drinking Water, Berlin, Germany, 28–30 April, 2003; Umweltbundesamt (Federal Environmental Agency): Dessau-Roßlau, Germany, 2003.
24. Tavasolifar, A.; Amin, M.M.; Ebrahimi, A.; Jalali, M. Implementation of hazard analysis and critical control points in the drinking water supply system. *Int. J. Environ. Health Eng.* **2012**, *1*, 32.
25. Mahmud, S.G.; Shamsuddin, S.A.J.; Feroze Ahmed, M.; Davison, A.; Deere, D.; Howard, G. Development and implementation of water safety plans for small water supplies in Bangladesh: Benefits and lessons learned. *J. Water Health* **2007**, *5*, 585–597.
26. Da Cruz, A.G.; Cenci, S.A.; Maia, M.C.A. Quality assurance requirements in produce processing. *Trends Food Sci. Technol.* **2006**, *17*, 406–411.
27. Bosshart, U. HACCP–Hazard Analysis and Critical Control Points at the Zurich Water Supply. In *HACCP in Drinking Water Supplies in Switzerland*; Swiss Gas and Water Industry Association: Zurich, Switzerland, 2003.
28. FSAI. Safety of Potable Water in Ireland. In *Report to the Board of the Food Safety Authority of Ireland*; FSAI: Dublin, Ireland, 2006.
29. Swiss Gas and Water Industry Association. *W1002 Regulation-Recommendations for a Simple Water Quality Assurance System for Water Supplies*; Swiss Gas and Water Industry Association: Zurich, Switzerland, 2003.
30. Palmadottir, E.; Bjarnason, E.; Bergmann, J.; Gunnarsdottir, M.J.; Palsson, P.; Stefansson, S. *Guidelines on HACCP*; Samorka–Association of Icelandic utilities: Reykjavík, Iceland, 1996.
31. Halliwell, D.; Burris, D.; Deere, D; Leslie, G.; Rose, J.; Blackbeard, J. *Utilization of Hazard Analysis and Critical Control Points Approach for Evaluating Integrity of Treatment Barriers for Reuse*, 1st ed.; WateReuse Research Foundation, Virginia, USA, 2014; pp. 111–115.
32. Hellier, K. Hazard Analysis and Critical Control Points for Water Utilities. In Proceedings of the 63rd Annual Water Industry Engineers and Operators' Conference: Warrnambool, Australia, 6–7 September 2000.
33. World Health Organization (WHO). *Water, Sanitation and Hygiene Links to Health. Facts and Figures*; World Health Organization (WHO): Geneva, Switzerland, 2004.
34. Perrier, E.; Kot, M.; Castleden, H.; Gagnon, G.A. Drinking water safety plans: Barriers and bridges for small systems in Alberta, Canada. *Water Policy* **2014**, *16*, 1140–1154.

35. Baum, R.; Amjad, U.; Luh, J.; Bartram, J. An examination of the potential added value of water safety plans to the United States national drinking water legislation. *Int. J. Hyg. Environ. Health* **2015**, *218*, 677–685.
36. Vieira, J.M.P. Water Safety Plans: Methodologies for risk assessment and risk management in drinking water systems. In *Water in Celtic Countries: Quantity, Quality and Climate Variability*; Ferreira, J.P.L., Vieira, J.M.P., Eds.; IAHS: London, UK, 2007; Volume 310, pp. 57–67.
37. Katko, T.; Lipponen, M.A.; Rönkä, E.T. Groundwater use and policy in community water supply in Finland. *Hydrgeol. J.* **2006**, *14*, 69–78.
38. Guzman-Herrador, B.; Freiesleben de Blasio, B.; MacDonald, E.; Nichols, G.; Sudre, B.; Vold, L.; Semenza, J.C.; Nygård, K. Analytical studies assessing the association between extreme precipitation or temperature and drinking water-related waterborne infections: A review. *Environ. Health* **2015**, *14*, 29.
39. Directive 98/83/EC. The quality of water intended for human *consumption*. Official Journal for the European Communities, L 330/32, 05/12/1998. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998L0083&from=EN (accessed on 25 May 2017).
40. Gunnarsdottir, M.J.; Gardarsson, S.M.; Elliott, M.; Sigmundsdottir, G.; Bartram, J. Benefits of Water Safety Plans: Microbiology, Compliance, and Public Health. *Environ. Sci. Technol.* **2012**, *46*, 7782–7789.
41. World Health Organization; United Nations; Economic Commission for Europe. Small-Scale Water Supplies in the Pan-European Region. 2011. Available online: http://www.euro.who.int/__data/assets/pdf_file/0018/140355/e94968.pdf?ua=1 (accessed 26 May 2017).
42. Loret, J.F.; Blaudin de Thé, C.; Martin Alonso, J.; Puigdomenech Serra, C.; Kayser, G.; Bartram, J. Assessing the costs and benefits of water safety plans. In Proceedings of the IWA World Water Congress, Brisbane, Australia, 9–14 October 2016.
43. Lucentini, L.; Achene, L.; Veschetti, E.; Fuscoletti, V.; Nigro Di Gregorio, F.; Colagrossi, R.; Di Benedetto, A. Water Safety Plan implementation in Italy. In Proceedings of the International Symposium on Sanitary and Environmental, Rome, Italy, 19–23 June 2016.
44. Samwel, M.; Jorritsma, F.; Radu, O. *Lessons from Water Safety Plans for Small-Scale Water Supply Systems as Developed by Schools in Romania*; Water and Sanitation–Facts and Experiences; 2010. Available online: http://www.wecf.eu/download/2010/03/wsp_romania.pdf (accessed on 5 June 2017).
45. Setty, K.E.; Kayser, G.L.; Bowling, M.; Enault, J.; Loret, J.F.; Serra, C.P.; Alonso, J.M.; Mateu, A.P.; Bartram, J. Water quality, compliance, and health outcomes among utilities implementing Water Safety Plans in France and Spain. *Int. J. Hyg. Environ. Health* **2017**, 220, 513–530, doi:10.1016/j.ijheh. 2017.02.004.