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Dual system of water safety plan auditing in Hungary: benefits and lessons learnt

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ABSTRACT

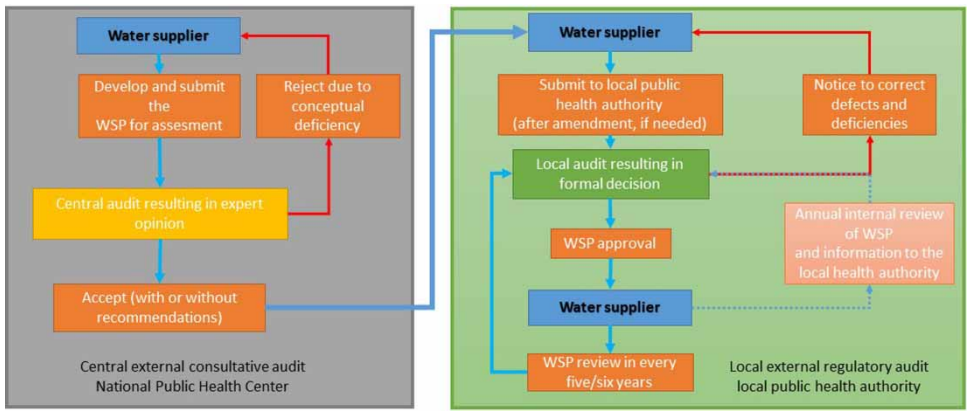
A risk-based approach is recognised worldwide as the most reliable means for the provision of safe drinking water. Efficient implementation of the water safety plan (WSP) approach, recommended by the World Health Organization (WHO), is facilitated by an auditing framework. In Hungary, development of WSPs is a legal obligation for water suppliers. WSPs are subject to a two-stage regulatory audit, a consultative central technical audit and a formal local audit. In 2019, a survey was conducted in cooperation with WHO to evaluate audit experiences of over 1,200 WSPs. Recommendations from the central audit significantly improved coherence and compliance of WSPs, confirming the efficiency of the dual approach. The use of a WSP template provided by the national authority further increased consistency and reduced time and work demand of the audit. Both water suppliers and public health authorities indicated a need for further capacity building on WSP development and auditing. The main challenge for water suppliers is the identification and risk assessment of hazards associated with the water source and distribution within premises. The recast European Union drinking water regulation is expected to accelerate the uptake of WSP and strengthen linkages to water catchment management and water safety in buildings.

Key words: audit, drinking water, risk-based approach, water safety plan, water supply

HIGHLIGHTS

- Experiences of a dual regulatory water safety plan auditing system were evaluated.
- Survey addressed audit outcomes of over 1,200 WSPs.
- Central (national) audit ensures consistent high quality of WSPs.
- Local regulatory audit complements with in-depth local knowledge and on-site visit.
- Regular trainings are essential both for water supply operators and authorities.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Risk-based approaches increasingly complement endpoint monitoring-based approaches to safeguarding drinking water quality. Compared to the 'too little, too late' outcome of endpoint monitoring, a risk-based approach offers a preventive, systematic, and flexible solution for water suppliers to prevent, detect, and manage potential water contamination before it reaches the consumer's tap. Further uptake of such a risk-based approach is expected in the World Health Organization (WHO) European Region, following its adoption as a legal obligation in the recent recast of the European Union (EU) Drinking Water Directive (Directive 2020/2184 2020). One of the most widely used risk-based frameworks is the water safety plan (WSP) approach, a core recommendation of the WHO Guidelines for Drinking water Quality (WHO 2004). The WSP process requires a comprehensive description of the water supply system from the water catchment to the point of consumption, systematic identification of hazardous events and hazards, assessment and prioritisation of risks to human health, identification of risk mitigation measures (including preventive, control and corrective measures, and interventions), as well as the establishment of systems for operational and verification monitoring. While all WSP steps should be documented, including operational procedures, the WSP is intended to be a 'living' planning and management tool for water suppliers, rather than a documented one-off assessment of the supply system (WHO 2017). According to the global status report of WHO, by 2017 already 93 countries have introduced WSP to some extent (WHO & IWA 2017). Different evaluation systems have been developed to assess the efficiency and the benefits of WSP implementation, but these methodologies are not harmonised across countries (Gelting *et al.* 2012; Lockhart *et al.* 2014). Most reports conclude that the key advantages of WSP implementation are improved drinking water quality, more efficient operation of the water supply system, fewer consumer complaints, decreased operational costs, and a lower number of potential water quality incidents (WHO & IWA 2009, 2015; Tsitsifli & Tsoukalas 2021).

Continuous revision and improvement are integral parts of WSP (WHO 2023). Such revision is usually carried out by the local team responsible for developing and implementing the WSP. Complementary internal or external audits provide an independent and systematic check to confirm that the WSP is complete and accurate, adequately implemented and effective (WHO 2017). In internal audits, a staff member of the water supply system (preferably one who did not participate in the development of the WSP) carries out the evaluation. External audits can be formal (e.g. by a responsible government authority) or informal (by an independent expert or technical organisation). The aim of both processes is to improve WSP through an assessment of the WSP methodology, its completeness and practical implementation. To maximise the benefits of such audits, even formal external audits should be supportive and consultative in nature rather than sanction-oriented. Audits are usually carried out using pre-defined guiding questions and associated templates to ensure consistency. On-site visits, which include field inspections and interviews with water supply staff, are important components of the audit. In 2015, WHO published a practical guide to auditing WSP as a point of reference for designing and establishing national auditing schemes (WHO & IWA 2009, 2015).

Regulatory requirements, criteria and implementation of external audits vary by country (WHO & IWA 2015). For example, regulations in Australia (Victoria), New Zealand and United Kingdom (England and Wales) require a formal external audit, while Portugal has an additional regulatory requirement to conduct internal audits. Some countries require special qualifications for external auditors. In formal audits, the regulatory authority can appoint auditors or officers of a responsible authority to carry out the audits. Audits usually include site visits, desk review of documentation, and interviews with the water supplier staff (WHO & IWA 2015). Audits focus on the review of adequacy of the hazard analysis, the risk assessment and identified risk mitigation measures, as well as confirming the status of WSP implementation in practice. Where a rolling system of auditing is in place, auditors can also check if there were changes in the water supply system since the previous audit and whether the outcomes of the previous audit were appropriately integrated into the WSP (WHO & IWA 2015).

As of now, a limited number of countries has gained experience in WSP auditing and published practices and results available. In Iceland, a risk-based approach based on the Hazard Analysis and Critical Control Points (HACCP) framework widely used in food industry was introduced in the quality assurance system for water utilities. An evaluation of the implementation confirmed that external audits and oversight of the water safety planning process by the authorities are needed to keep up the commitment of the management and staff of the water utilities. At the same time, insufficient financial capacity of the health authority was reported as the main limiting factor for closer supervision (Gunnarsdóttir & Gissurarson 2008). A study from Portugal also highlighted the importance of independent external audit and the role of health authorities within that

(Vieira 2011). A recent review also advocated for using independent audit to monitor progress over time and called for strengthening targeted capacity building (Ferrero *et al.* 2019).

1.1. Drinking water supply and regulation in Hungary

Approximately 95% of the Hungarian population is connected to centralised public utility-managed water supply. Though exact data are unavailable, a further 3% is estimated to rely on individual, private, or community-managed small supplies (serving individual facilities, such as hospitals, hotels, enterprises, informal communities, or housing for workforce in agricultural or industrial sites) and 2% uses single-household private wells.

Regulatory supervision of all water supplies (except private wells) is performed by the public health departments within the county or district government offices. The larger, county level administrative body is responsible for surveillance of large water supplies (supplying more than 1,000 m^3/day), while the district authorities supervise the smaller ones. Public health authorities reported 1,400 operating public utilities and 516 individual water supplies in 2021 (NPHC 2022). Public utilities were operated by 38 municipality or state-owned public utility companies (water suppliers) in 2023 (MEKH 2023). Size and number of water supply systems is geographically diverse: for example, Baranya and Somogy counties, where most people live in small villages, have the highest number of public utilities (140 and 155, respectively), while almost 1.9 million consumers are served by a single water supplier in the capital, Budapest and its agglomeration. Most public utility-managed small supplies operate in Bács-Kiskun, Jász-Nagykun-Szolnok, and Pest counties (75, 65, and 64, respectively).

Regulatory oversight of the water supply chain from the catchment to the consumer's tap is shared between several authorities in Hungary. Supervision of source water quality, including the monitoring of wells, is carried out by the county water directorates, while the protection of water sources falls under the responsibility of the water regulatory authority. Water abstraction and water treatment are monitored by the water suppliers, in accordance with the operational monitoring programme approved by the water regulatory authority. The data are not collected on a national level, but are periodically checked by the authorities during sanitary inspection visits. Quality of supplied drinking water is monitored both by the water suppliers (90% of the samples) and the public health authorities (10% of the samples). The drinking water monitoring programme, including the number, scope and location of samples, is approved by the local public health authority. Monitoring data are reported online to a national electronic database.

1.2. Implementation of the WSP approach in Hungary

The WSP approach was introduced in the drinking water legislation as a legal obligation for water suppliers in 2009 (Government decree No. 201, 2001). The legislation requires water suppliers to operate their systems under a hazard analysis and risk assessment framework that is integrated in a WSP. The legal requirement initially applied only to large water supplies (serving more than 5,000 consumers) but in 2013 was extended to all water supplies that fall within the scope of the regulation, i.e. all supplies that serve more than 10 m^3 water/day or more than 50 people. The obligation came into force gradually, starting with the largest supplies serving more than >100,000 consumers which had to finalise their WSP by 2012, and ending in 2017, when supplies serving 50–5,000 consumers had to complete their WSP. Legislation refers to the use of internationally recognised methodologies for risk assessment, such as EN 15975-2 or equivalent. It also lists the mandatory elements of WSPs: system description, including a process flow diagram; identification of hazards and risk assessment, including documentation of the risk assessment methodology; identification of interventions (preventive and risk reduction measures), control points, target values and monitoring including operational monitoring programme; for all steps of the water supply system (water source, water abstraction, water treatment, distribution, and consumer points).

Regulation also covers audit requirements. WSPs developed by the water suppliers are officially approved by the local public health authorities. The initial WSP audit and approval is a two-step process (Figure 1). In the first step, WSPs are submitted to the national public health authority, the National Public Health Center (NPHC), which performs a central level audit through desk review of the documents and provides an expert opinion. If WSPs receive a supportive opinion, they are submitted to the local public health authority, which in a second step evaluates and eventually approves the WSP. Water suppliers are obliged to revise WSPs every year and report changes to the local public health authorities. The local public health authorities re-evaluate WSPs every 6 years (as a formal regulatory audit). If the operation of the water supply is changed substantially (e.g. a new water supplier takes over the operation, a new water source or a new treatment technology is introduced), the central audit is also repeated.

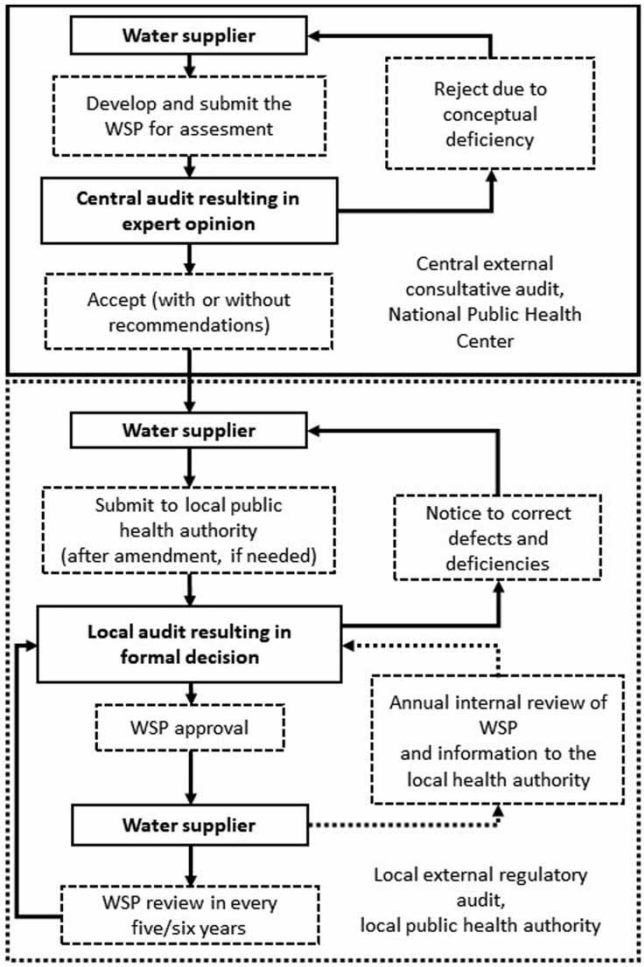


Figure 1 | Schematic of the initial and periodic audit of water safety plans in Hungary. Central level: National Public Health Center. Local level: public health departments of the county/district government offices.

The central level phase of the initial audit by the NPHC focuses on a detailed methodological and technical evaluation of the WSP documentation, following guiding questions laid down in an internal guideline. The review addresses the completeness and accuracy of the system description, the suitability of the hazard analysis and risk assessment methodology, the completeness and adequacy of the outcomes of the hazard identification and risk assessment process, as well as of the preventive, control, and risk reduction measures identified. The compliance of the monitoring system with the legal requirements is also evaluated. The objective of the central audit is to achieve a consistently high level of WSP implementation nationally through evaluation against a harmonised set of questions. It is a consultative process, which results in an expert opinion containing a list of recommendations for improvement. Only WSPs with major flaws (e.g. conceptual problems, such as a missing risk assessment) are rejected, but can be resubmitted after reworking. In WSPs accepted with recommendations, major identified deficiencies (such as missing elements in the system description or hazard identification) are mandatory to be addressed before submission to the local public health authority. Other, less urgent corrections should be implemented by the first yearly internal revision (e.g. recommendations on intervention thresholds).

The second part of the initial audit is the formal approval process by local public health authorities. In the audit process, they use their existing knowledge on the water supply system and consider water quality and other locally relevant information, as well as the outcomes of sanitary site visits. These data are used to complement the technical evaluation of the NPHC. Local authorities also check if the recommendations of the NPHC expert opinion have been incorporated in the WSP. Local public health authorities can formulate further recommendations or approve or reject the WSP.

1.3. Guideline and capacity development for WSP development and auditing

Central audits are performed by a multidisciplinary team of experts within the NPHC. Team members have various backgrounds and expertise (e.g. environmental engineering, health engineering, public health, chemistry, biology, laboratory analytics, disaster management, etc.). The team – especially in the primary phase of the WSP implementation – held regular internal consultations to ensure consistency and quality of the audits. New team members received training before engaging in the auditing process.

To support water suppliers and public health officers with the practical uptake of WSP after the introduction of the legal obligation, the NPHC has issued a series of guidelines and provided trainings. The first guidelines on WSP development were published in 2013, followed by a second edition as a joint publication of the NPHC and the Hungarian Water Utility Association in 2014. In 2017, the NPHC issued a simple template (NPHC 2017) to assist water suppliers in developing their WSPs, especially addressing operators of small systems with limited experience in water safety planning. The structure of the template facilitates appropriate presentation of the water supply system's technical properties and provides a framework for the development of a risk-based management system. It contains an inventory of hazards for each element of the water supply system (source, abstraction, treatment, and distribution). Water suppliers can select hazards and hazardous events that apply to their system (or add additional hazards/events as needed), which together form a comprehensive hazard analysis specific to the supply system. The guidelines on WSP development were revised in 2019 (NPHC 2019). Guidelines on WSP auditing were published in 2020 (NPHC 2020), covering both internal and external audits to be undertaken by water suppliers and public health offices. After the publication of the original and the revised WSP development guidelines, the NPHC organised training sessions both for water suppliers and public health authorities. The latter also addressed auditing.

Objectives of the present study were to (1) review the process of WSP implementation, (2) evaluate the efficiency of the dual audit system and the relative value of the various capacity building activities (guidelines and trainings), and (3) identify any gaps or bottlenecks in the uptake of WSPs as a routine practice of operation.

2. MATERIALS AND METHODS

Three surveys were conducted to analyse the experiences of WSP implementation in Hungary: one addressed to the water suppliers, one to local public health officers involved in WSP auditing, and one for the NPHC staff performing the central technical audit.

2.1. Survey for water suppliers

Experience of water suppliers on WSP implementation was compiled in the framework of the WHO global survey carried out in 2013 (WHO & IWA 2017). The survey was distributed to the drinking water service providers already applying WSP through the Hungarian Water Utility Association. The section aimed at water suppliers addressed the challenges of implementing WSP and meeting the legal requirements currently experienced or expected in the future, as well as the benefits experienced or expected at the operational or infrastructural level. The survey responses were collected electronically (Microsoft Word™ worksheet). Most questions were single or multiple choice, but space was also provided for free text comments. While this survey represents an earlier stage of implementation, subsequent communication (i.e. as part of the consultation process or at training events) between the NPHC and water utilities introducing WSP in a later phase mirrored the outcomes of the survey, and therefore the data are still of interest for the interpretation of audit survey data.

2.2. Data collection from the national and local authorities

To summarise the outcomes of the central audit, expert opinions on all WSPs submitted until June 2019 were reviewed. The study focused on WSPs of public utilities, individual supplies were excluded. A review was carried out along a set of 38 questions defined by the NPHC staff involved in WSP auditing to ensure a coordinated approach among team members (Supplementary material, Table S1). Responses were recorded in a Microsoft Excel™ worksheet.

Experience of local public health authorities was collected via an online survey prepared in Google Forms™ between October and November 2018. The questionnaire was sent to all county and district public health offices. The survey was anonymous and did not specify the responding office either. It contained a total of 73 questions (Supplementary material, Table S2). Results were exported to and processed in Microsoft Excel™.

The two questionnaires were not identical due to the different target audience, but the main thematic coverage was the same. Questions addressed three main topics:

- Structural completeness and integrity of WSP, alignment to other operational documentation.
- Completeness of system description and presentation of water production process (including catchment and abstraction, water treatment, distribution and consumer points, including vulnerable consumers and priority buildings).
- Completeness and soundness of hazard analysis and risk assessment outcomes (methodology and scoring).

Scores were assigned to sub-sections of questions; if it contained more than one question, the average score was used (see Supplementary material, Tables S1 and S2), as percentage of all answers.

Experiences of the WSP audit process were also evaluated. Workload and efficiency were estimated by the number of WSPs audited per person per year. The survey addressing local public health authorities asked whether on-site visits were carried out as part of the audit process, if central expert opinions were useful, and aimed to identify potential capacity gaps or needs for support. Information was also collected on the implementation of WSPs in practice to identify potential positive outcomes, such as better operational practices, improved drinking water quality, reduced number of non-compliances or reduction in the number of complaints.

3. RESULTS AND DISCUSSION

3.1. Water suppliers' perspective of WSP implementation

The legal obligation to implement WSP only applied to large (>50,000 consumers) water supplies at the time of the survey. Of the 25 water suppliers who had already started developing and implementing WSPs (for 37 supply systems), 19 responded to the survey. This is 50% of all public water suppliers in Hungary (MEKH 2023). WSP development in smaller water supplies was still in the early phases; water suppliers of those systems had limited experience either on the challenges or the benefits of WSP implementation. Responding water suppliers rated the lack of financial support, insufficient human capacities and limited availability of guidance and training as the most important challenges in WSP implementation (Figure 2).

Responders emphasised the lack of a dedicated financing mechanism for water suppliers to support development and implementation of WSPs. This was also a challenge in the later stages of implementation. Costs of implementation of the risk-based framework, including external expert fees, where applicable, had to be entirely covered from the water suppliers' budgets. WSP implementation required restructuring of the IT and electronic management information systems in many water utilities, which also entailed a significant financial burden.

More than half of the suppliers indicated that human capacities and the foreseen timeframe for WSP development and implementation were insufficient. The WSP team involves staff members from different departments; the WSP development process (i.e. participation in meetings, undertaking process reviews, preparation of documentation, etc.) as well as introducing WSP outcomes in daily operations require significant staff time. Most water suppliers reported an overall shortage of qualified staff and workforce fluctuation affecting the entire sector; thus the additional workload of WSP development added to already existing challenges of human capacities. The majority of the water suppliers (63%) did not expect significant improvement in the staffing situation in the near future. In the survey of the local public health offices after 6 years, authorities also perceived the lack of financing and human capacities as an important limiting factor, though to smaller extent (affecting approximately 22% of the water supplies) (Supplementary material, Table S2).

More than half (53%) of water suppliers considered the lack of guidelines and training as a significant bottleneck in the uptake of WSP at the time of the survey. Approximately one-third (37%) of the respondents explicitly mentioned the lack of Hungarian guidance documents, and more than 10% indicated the lack of knowledge on WSPs among staff. One-fourth of the respondents expected challenges related to capacity building to prevail in the longer term. Although the WHO WSP manual (WHO & IWA 2009) was published at about the same time as the Hungarian legislation introducing requirements on WSP in 2009, first Hungarian guidance was only issued in 2013 by the NPHC and the second edition as a joint guideline developed with the Hungarian Water Utility Association in 2014. Even after 5 years, when the regulatory survey was carried out, the vast majority (>90%) of public health authorities still indicated the need for regular training both on WSP development and auditing (Supplementary material, Table S2). At the time of the survey on auditing, updated guidelines for WSP development were available, though dedicated guidance on auditing was not yet published. Other obstacles mentioned by the water suppliers were the administrative burden, lack of finances, lack of support from the authorities and the perception of no added value compared to already existing management processes.

Experiences on enabling and limiting factors of WSP implementation from outside Hungary are similar to the findings of our study. For example, in Iceland, where WSP is also a legal obligation, the lack of guidelines and training was identified as a

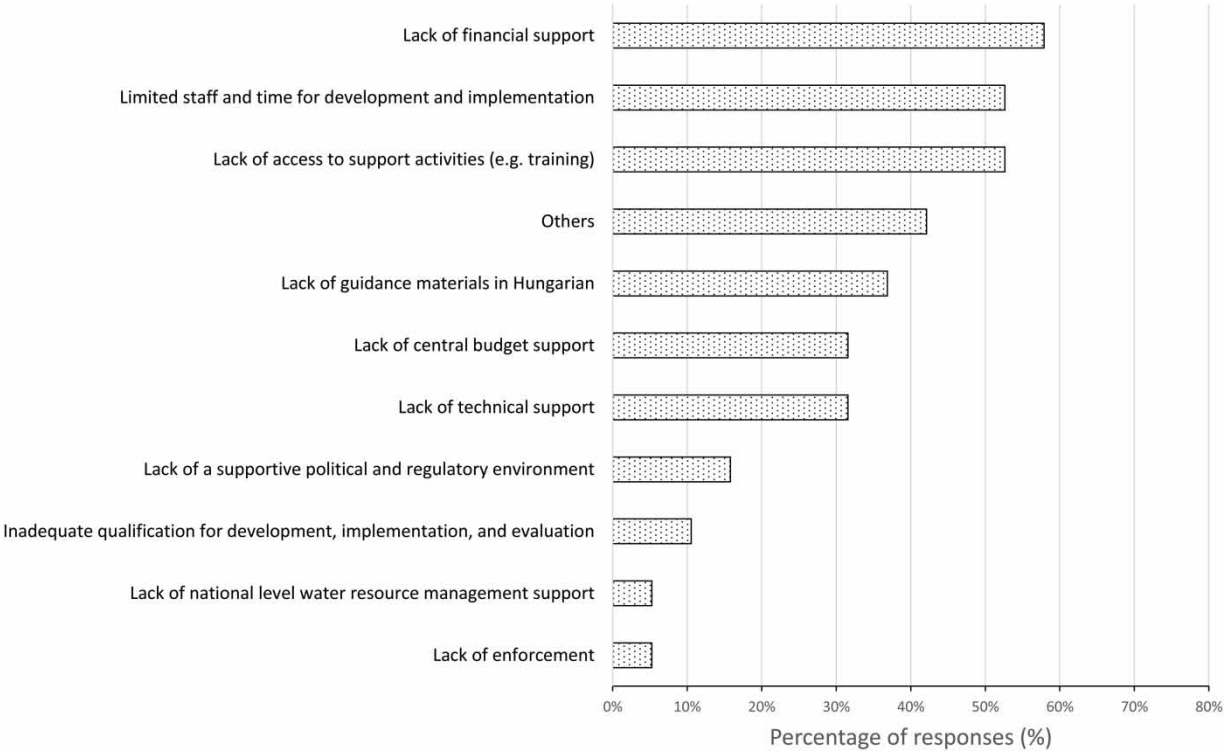


Figure 2 | Challenges in WSP implementation as indicated by water suppliers in the WSP survey. Percentage of all respondents ($n = 19$).

major bottleneck, together with the need for improved communication between stakeholders and better intersectoral cooperation (Gunnarsdottir *et al.* 2015). Other studies also mention the lack of financial and human resources (Amjad *et al.* 2016; Tsitsifli & Tsoukalas 2021), the lack of expertise in risk assessment (Tsitsifli & Tsoukalas 2021) and the lack of legal obligation or financial incentives that would support implementation (Amjad *et al.* 2016). A supportive organisational structure and dedication from senior water utility management were identified as important enabling factors on the water supply level (Summerill *et al.* 2010a, 2010b).

3.2. Experience of WSP auditing on the central and local level

In the evaluation of central audits, 1,348 expert opinions were reviewed (corresponding to 1,348 WSPs). The number of WSPs submitted for central audits peaked between 2016 and 2018 (Figure 3(a)). The sudden surge of requests required redistribution of tasks in the central authority and immediate training of the additionally allocated staff. The number of team members working on WSP auditing was increased from two to seven at the busiest period. In the initial phase of implementation, no formalised training was available on WSP auditing, but experience was gained through peer-to-peer learning. While the team members had different professional backgrounds, initial training and regular team meetings ensured harmonised and high-quality expert reviews.

Of the local authorities, 87 responses were received, corresponding to 1,210 locally audited and approved WSPs. In the local government offices, typically one or two staff members are involved in WSP auditing, who perform this task together with their other responsibilities in providing oversight of drinking water supply services. Workload related to WSP auditing was diverse; most respondents audited less than 20 WSPs, however 5% of them audited more than 40, particularly in those geographic areas where drinking water is supplied by many small water utilities (Figure 3(b)).

The survey for local authorities did not address the time period when the authorities performed audits, which makes it difficult to evaluate the actual workload. However, most water suppliers only submitted their WSPs for approval close to the legal deadline, and local authorities (unlike the central audit process) have to meet strict and legally binding deadlines in the approval process. It is therefore safe to presume that WSP auditing is at times a significant burden to local authorities, especially those supervising several small utilities. Lack of human capacities and high workforce fluctuation affected the

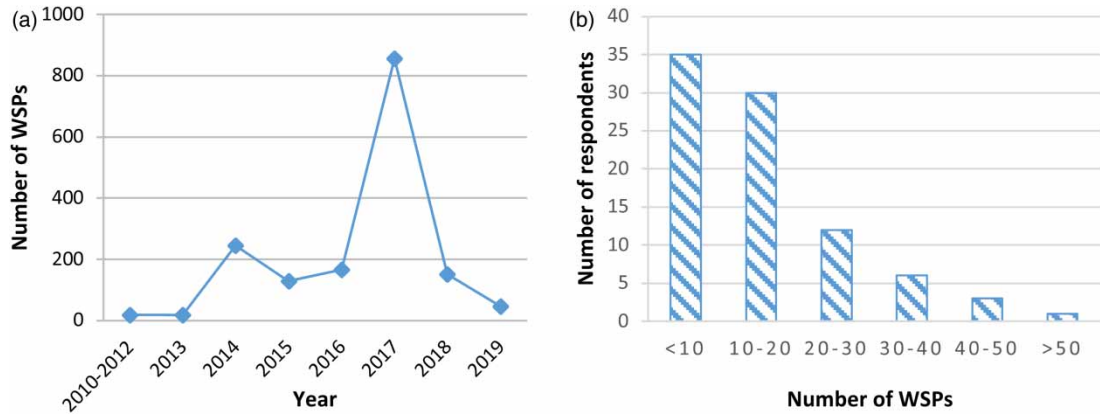


Figure 3 | Distribution of workload in WSP auditing: (a) number of WSPs submitted for central auditing by year ($n = 1,348$) and (b) number of WSP audited by the responding public health authorities ($n = 87$, total number of audited WSPs = 1,210).

regulatory sector as well. Meeting the additional and often uneven capacity needs of WSP auditing required flexibility of task distribution and continuous training of both the national and the local authorities.

Close to 40% of the local public health authorities reported that they do not have sufficient capacity to perform site visits as part of the WSP audit. Site visits are indispensable for the evaluation of WSP operation, especially for confirming the implementation of preventive control measures and monitoring efforts. The lack of site visits is therefore a serious gap in the auditing process. Sufficient time and logistics should be allocated to auditors to allow for on-site audit of WSP operation. In the periodic audits, this problem was resolved by integrating WSP audits into the yearly sanitary inspection visits of the regulatory authority at the drinking water supply plants (NPHC 2022).

Human capacity need is a major challenge in maintaining a dual auditing system. Good planning and staggered implementation of the legal obligation on WSP can support more even distribution of the workload.

3.3. Quality assessment of WSPs based on the central and local authority surveys

A desk review of WSP quality was performed at both audit levels, evaluating the suitability of both the method and the contents. In the central audit, structural compliance with WSP requirements was high (78%), and preventive, control and remedial measures were adequately described in the majority of the submitted documents (62%) (Table 1). Both figures improved, the latter significantly in the local audits (83 and 94%, respectively).

Similar ratios and tendencies were observed in the evaluation of the mandatory elements of a WSP. System descriptions covering the entire water supply chain from the water source, water abstraction, water treatment and distribution to points of consumption, were adequate in approximately two thirds of submitted WSPs (62–68%) in the first step of the audit (Table 1, Supplementary material, Table S1). Lowest rates were observed for the 'far ends' of the water supply system, which are not under the direct control of the supplier: the description of the water source, identification of potential sources of contamination in the catchment area, and the evaluation of consumer points. By the time of the local audit, WSPs were amended with more detailed descriptions, reaching high (93–98%) compliance rates with the requirements, with the exception of consumer points, which still remained a challenge (compliance rate 71%). Description of consumers was usually general and did not extend to the risk assessment of premise plumbing.

The risk assessment methodology was adequately described in approximately half of the submitted documentations. Most often, radiological hazards and the corresponding risk assessment were missing (52% compliance), or different types of hazards (e.g. chemical and microbiological) were not differentiated in the risk assessment (50%). These deficiencies had to be addressed before submission to the local public health office, and thus in the second round of the audit all WSPs fulfilled the requirements of risk assessment methodology.

Analysis of hazards and the assessment of risk by evaluating hazardous events severity and frequency of occurrence also improved between the two rounds of audit (from 55 to 67% and 69 to 91%, respectively) (Table 1). Nevertheless, public health authorities still reported that hazard analysis and risk assessment were the most challenging parts of WSP development for water suppliers (Supplementary material, Table S2).

Table 1 | Overview of the quality of WSPs in the central and local audit, expressed as the percentage of WSPs complying with the requirements of all WSPs

Category	Subcategory	Central audit	Local audit
1. Structural compliance	1.1 Agreement of the WSP with the other operational documents.	78%	82%
	1.2 Adequate documentation of preventive, control and remedial measures	62%	95%
2. Quality of WSP content, description of the water supply system and processes	2.1 Characterisation of water source, protective zones, water abstraction	66%	94%
	2.2 Characterisation of water treatment	64%	98%
	2.3 Characterisation of distribution system and consumer points	68%	96%
	2.4 Identification of vulnerable consumers and priority facilities	62%	71%
3. Hazard analysis and risk assessment	3.1 Methodology	50.5%	[a]
	3.2 Hazard analysis	55%	67%
	3.3 Determination of severity and frequency of hazards	69%	98%

[a]If risk assessment methodology was conceptually wrong or incomplete, correction or amendment was obligatory before submission to the local public health authorities. Only WSPs using correct methodology were included in the local audit.

Overall, the results of the surveys confirmed the efficiency of the dual audit system in improving the quality of WSPs. According to the survey of the public health authorities, almost all water suppliers (92% typically, 7% partly) integrated recommendations from the expert opinion provided by the central audit and corrected the identified deficiencies in the WSP before submission to the second round of audit. The overall experience of the local audits is an improvement of WSPs both in form and in content compared to the central audit, in every analysed aspect. This finding coincides with the subjective perspective of the local public health authorities: practically all of them reported that they found the expert opinion useful in the audit process (93% responded 'yes' and 6% 'partly').

WSPs submitted to the central audit were diverse both in format and content, but all of them had important elements missing or were incomplete. To facilitate the development of high quality WSPs, and at the same time simplify the audit process, a simple WSP tool was developed and made available to the water suppliers, consisting of a WSP documentation template and an inventory of potential hazards for each step of the water supply chain, containing over 700 items in total (NPHC 2017). Based on the central audit survey, 22% of the WSPs were developed using the template, while 64% followed the WHO methodology (either directly, or using the WSP guidelines of the NPHC, based on the WHO WSP manual (WHO & IWA 2015)), 11% the HACCP method and 3% other methodology (Supplementary material, Table S2). Only 4% of the public water suppliers in this study involved an internal expert in the development; this figure is higher in case of individual utilities (Supplementary material, Table S1).

Use of the template improved the quality of WSPs; they were more comprehensive, and less likely to omit some hazards in the assessment. Compliance rates of risk assessment for various steps of the water supply chain were considerably higher in WSPs developed using the template (Figure 4). Previous assessments also confirmed that WSP implementation is facilitated by developing guidance or templates for WSP development (Baum & Bartram 2018). Guidance should be clear and simple, including practical examples adapted to the local context, and should be disseminated widely, e.g. through training or workshops (Gunnarsdóttir *et al.* 2012). Training is an essential part of an enabling environment for WSP implementation (Ferrero *et al.* 2019), but in the present study only 26% of water suppliers indicated that they participated in training (either by the NPHC or by the Hungarian Water Utility association) (Supplementary material, Table S2). Public health authorities also signalled a need for further capacity building, 75% of them calling for regular training and an additional 18% for one-off training on specific topics (e.g. risks associated with water treatment, hazard analysis and risk assessment methodology or tackling taste and odour complaints) (Supplementary material, Table S2).

The most challenging parts for water suppliers in hazard analysis and risk assessment are the water catchment or water source and the water transfer between water supply systems. Information on consumer points (where available) covered the minimum requirement of identifying sensitive consumers and priority buildings but did not address risk assessment of

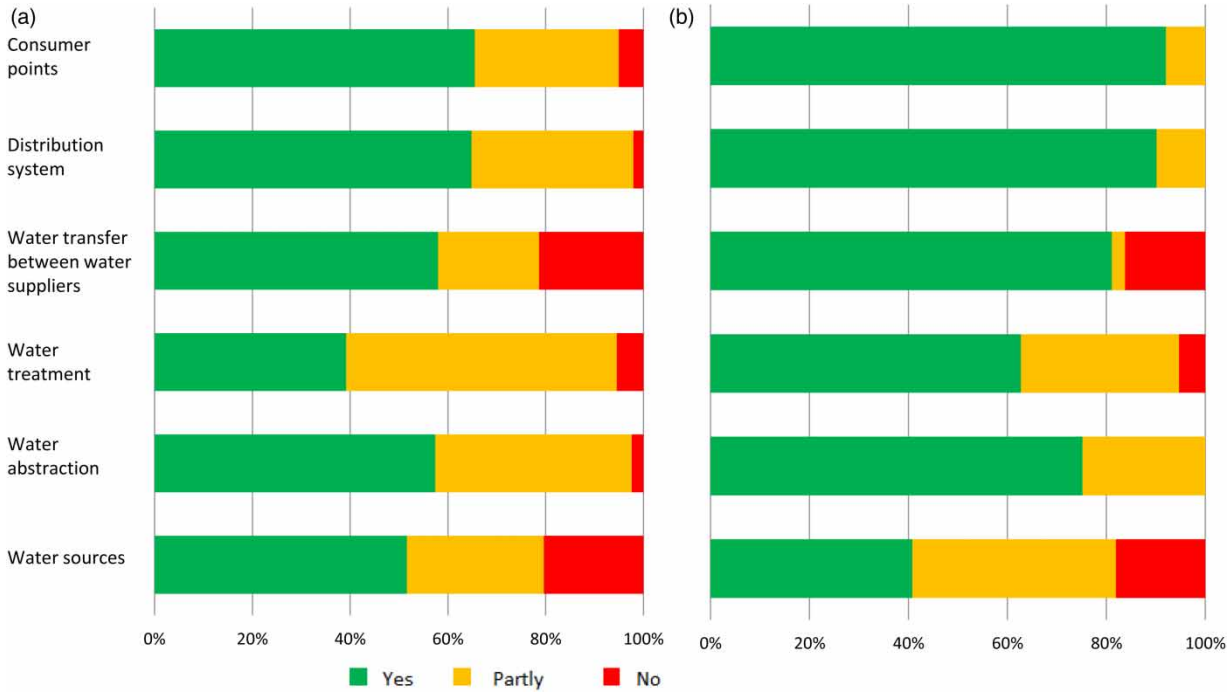


Figure 4 | Compliance of risk assessment of (a) all WSPs and (b) WSPs based on the offline template based on the central audit ($n = 1,348$).

buildings. Water suppliers have limited information and even less control over hazardous events which occur in these segments of the supply chain. Under the recast Drinking Water Directive 2020/2184 of the EU, there are specific requirements for the risk assessment of these areas, and it is strongly implied that other stakeholders (e.g. government organisations or building operators) have a role to play, rather than the water suppliers (Directive (EU) 2020/2184 2020). This was the guiding principle also in the transposition of the Directive in the Hungarian national law. WHO expanded its recommendation on WSP to buildings in 2011 (WHO 2011). In an evaluation on its implementation in Germany, building operators mentioned similar benefits as water suppliers, such as better understanding of the system, increased awareness, improved operation, and more efficient regulatory oversight (Schmidt *et al.* 2019). Information to the public and strengthening consumer awareness on good operation of premise plumbing are also instrumental in reducing hazardous events in building water systems.

3.4. Broader impact of WSP implementation

Most water suppliers had positive expectations associated with the introduction of WSP implementation. The main expected benefits reported were: increased expertise, improved understanding and knowledge of the system and better cooperation within the organisation (93%). Almost half of the respondents (44%) anticipated improved communication and cooperation with external partners as well (e.g. regulators, consumers, local public health, and water authorities). While suppliers did not expect significant impact on infrastructural developments, most of them (94%) agreed that WSP supports investment planning. Better operational practices are also a general expectation; 89% of the respondents mentioned improvement in operational and compliance monitoring, and control systems, 55% in management and operational procedures. Improved practices are likely to lead to higher consumer satisfaction, according to 82% of the suppliers.

These findings are in agreement with previous studies highlighting among the benefits of WSP implementation improved organisational culture and operation (Mälzer *et al.* 2010; Gunnarsdóttir *et al.* 2012; Amjad *et al.* 2016; Setty *et al.* 2018a); better internal and external communication (Mälzer *et al.* 2010; Amjad *et al.* 2016); including enhanced communication and trust from the public health authorities (Gunnarsdóttir *et al.* 2012; Kayser *et al.* 2019); prioritisation of interventions based on risk assessment (Mälzer *et al.* 2010); as well as consumer satisfaction (Setty *et al.* 2018a).

As an outcome from the national uptake of WSP, improvement of water quality and reduction of incidents was anticipated by 82 and 47% of the water suppliers, respectively. This expectation was not fully met; most public health authorities (87%)

did not observe change in identified water quality and none of them identified quality improvement which could be directly associated with the implementation of WSP. Other countries experienced increased compliance with the quality requirements and reduction of water related diarrheal diseases after the introduction of a risk-based approach (WSP or HACCP) (Gunnarsdóttir & Gissurarson 2008; Gunnarsdottir *et al.* 2012; Setty *et al.* 2018a, 2018b). Various factors may lie behind the failure to identify such improvements in the present study: water quality data were not analysed for the purpose of the statement given in the survey and the assumption of the public health authorities may only rely on a subjective assessment. Wider uptake of WSP overlapped in time with the National Drinking Water Quality Improvement Programme (DWQIP), which addressed geological pollution (arsenic, boron, fluoride, and ammonium) in water supply systems using deep groundwater sources. The Programme funded the installation of novel water treatment or other measures to mitigate water pollution in more than 300 water supplies across Hungary between 2013 and 2019, leading to significantly increased compliance of the above parameters and, as a secondary outcome, also of iron and manganese (Eionet Central Data Repository 2021). This voluminous change in water quality might disguise the more subtle impact of WSP uptake. Another confounding factor is the increasing deterioration of the water distribution systems in the same period. Some water supplies, especially the large ones, already had a management system in place; as it was observed in a German study, the added value of WSP in these cases is marginal (Mälzer *et al.* 2010).

4. CONCLUSIONS

Countries implementing a risk-based approach – as many European countries do presently in response to the requirement in the recast EU Drinking Water Directive – face important organisational decisions. Auditing is indispensable to ensure that WSPs are developed in line with international best practices and support effective risk-based operation of the water utilities. Countries can opt for setting up a new system for WSP auditing, use professional auditing services, or rely on existing structures and integrate WSP auditing into the mandate of the public health authorities responsible for drinking water surveillance.

In Hungary, WSP implementation started with a legislative, top-down approach; trained auditors or formalised trainings (either on WSP development or WSP auditing) were not available in the initial phase of implementation. Roles were assigned by the regulation to water suppliers to develop WSPs and drinking water regulators to audit and approve WSPs. As the current stock-taking exercise has shown, WSP implementation became a mutual learning experience, with both WSPs and audit reports improving in quality with time. The auditing process in Hungary established a dual approach, building upon the already existing complementary system of national and local public health authorities, where the latter is the primary regulator, responsible for the day-to-day supervision of drinking water services, while the former provides national oversight and expert support.

The present evaluation confirmed the practicability and efficiency of the dual auditing system of WSPs. The primary benefit is the synergy of two perspectives in the process. While the central audit provides a nationally uniform assessment of WSPs with stronger technical expertise, the local authorities contribute more 'hands on' knowledge on the operation of the water supply and can include on-site visits in the auditing process. Since the former is a non-regulatory process, it provides more time and more potential for a constructive consultative process. Recommendations from the central audit are integrated in the WSP by the water suppliers, resulting in higher quality WSPs and in turn in improved operational practices. Local audit practices can still vary; to address the problem of uneven expertise in the local public health offices, NPHC-published guidelines on WSP auditing in response to the outcomes of the current evaluation. Regular trainings would also be beneficial; however, after the publication of the guidelines the COVID-19 pandemic stalled such efforts.

We found that efficiency of WSP auditing is greatly increased and time demand is reduced if water suppliers use a harmonised structure, i.e. a template for WSP development. Templates also proved to be practical for water suppliers, especially small water suppliers who have less experience in WSP development. In the present study, both the local and the central auditors reported that hazard analysis and risk assessment was the main challenge for water suppliers: the hazard inventory and risk calculation matrix complementing the WSP template were developed to support water suppliers in this process, leading to improvements of the submitted WSPs. Electronic submission of the documents was also found to facilitate the auditing process.

Feedback from water suppliers and public health authorities confirmed that guidelines and trainings are essential both for improving WSP development and the process of auditing. National authorities – in the absence of continuing education

programmes on WSP for water utility and public health office staff – are well positioned and mandated to provide such capacity building, given their higher level of technical expertise. Cooperation and coordination with the professional associations (such as water utility associations) providing similar support to the water suppliers can be strengthened through joint activities (e.g. training workshops). In Hungary, elements of the WSP approach have now been integrated into the curricula of relevant graduate trainings (e.g. water engineers and public health officers).

The number of water suppliers using WSPs have considerably increased since the surveys presented in this study. There is also more experience in implementation. By 2023, all public utilities have been using WSP for at least 5 years, and 250 individual water supplies also developed WSPs. Available guidance has been improved in response to the outcomes of the study. Repeated evaluation would allow for tracking progress and a more reliable impact assessment of WSPs and the added value of the established auditing scheme.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Amjad, U. Q., Luh, J., Baum, R. & Bartram, J. 2016 Water safety plans: bridges and barriers to implementation in North Carolina. *Journal of Water and Health* **14**, 816–826. https://doi.org/10.2166/wh.2016.011.

Baum, R. & Bartram, J. 2018 A systematic literature review of the enabling environment elements to improve implementation of water safety plans in high-income countries. *Journal of Water and Health* **16**, 14–24. https://doi.org/10.2166/wh.2017.175.

Directive (EU) 2020/2184 of the European Parliament and of the Council on the quality of water intended for human consumption., 2020.

Eionet Central Data Repository 2021 *Drinking Water Directive – Report on Quality of Water for Human Consumption (Hungary)*. Available from: https://cdr.eionet.europa.eu/hu/eu/dwd/ (accessed 11.04.2023).

Ferrero, G., Setty, K., Rickert, B., George, S., Rinehold, A., DeFrance, J. & Bartram, J. 2019 Capacity building and training approaches for water safety plans: a comprehensive literature review. *International Journal of Hygiene and Environmental Health* **222**, 615–627. https://doi.org/10.1016/j.ijheh.2019.01.011.

Gelting, R. J., Delea, K. & Medlin, E. 2012 A conceptual framework to evaluate the outcomes and impacts of water safety plans. *Journal of Water, Sanitation and Hygiene for Development* **2**, 103–111. https://doi.org/10.2166/washdev.2012.079.

Government decree No. 201 on the quality of drinking water and the inspection procedure, 2001.

Gunnarsdóttir, M. J. & Gissurarson, L. R. 2008 HACCP and water safety plans in Icelandic water supply: preliminary evaluation of experience. *Journal of Water and Health* **6**, 377–382. https://doi.org/10.2166/wh.2008.055.

Gunnarsdóttir, M. J., Gardarsson, S. M. & Bartram, J. 2012 Icelandic experience with water safety plans. *Water Science and Technology* **65**, 277–288. https://doi.org/10.2166/wst.2012.801.

Gunnarsdottir, M. J., Gardarsson, S. M., Elliott, M., Sigmundsdottir, G. & Bartram, J. 2012 Benefits of water safety plans: microbiology, compliance, and public health. *Environmental Science & Technology* **46**, 7782–7789. https://doi.org/10.1021/es300372h.

Gunnarsdottir, M. J., Gardarsson, S. M. & Bartram, J. 2015 Developing a national framework for safe drinking water – case study from Iceland. *International Journal of Hygiene and Environmental Health* **218**, 196–202. https://doi.org/10.1016/j.ijheh.2014.10.003.

Kayser, G., Loret, J. F., Setty, K., Blaudin De Thé, C., Martin, J., Puigdomenech, C. & Bartram, J. 2019 Water safety plans for water supply utilities in China, Cuba, France, Morocco and Spain: costs, benefits, and enabling environment elements. *Urban Water Journal* **16**, 277–288. https://doi.org/10.1080/1573062X.2019.1669191.

Lockhart, G., Oswald, W. E., Hubbard, B., Medlin, E. & Gelting, R. J. 2014 Development of indicators for measuring outcomes of water safety plans. *Journal of Water, Sanitation and Hygiene for Development* **4**, 171–181. https://doi.org/10.2166/washdev.2013.159.

Mälzer, H.-J., Staben, N., Hein, A. & Merkel, W. 2010 Identification, assessment, and control of hazards in water supply: experiences from Water Safety Plan implementations in Germany. *Water Science and Technology* **61**, 1307–1315. https://doi.org/10.2166/wst.2010.026.

MEKH 2023 *MEKH – Engedélyesek listája Hungarian Energy and Utilities Regulatory Office; List of Certified Drinking Water Utilities*. Available from: https://www.mekh.hu/engedelyesek-listaja (accessed 11.04.2023).

NPHC 2017 *A Nemzeti Népegészségügyi Központhoz méltányos díjszabással történő szakvéleményezés céljából papír és elektronikus formában benyújtásra kerülő ivóvízbiztonsági tervek formai és tartalmi elvárásai 2. kiadás (Format and Content Requirements of Drinking Water Safety Plans to be Submitted to the National Public Health Center in Paper and Electronic Form for Expert Opinion at A Fair Rate, 2nd Edition)*. National Public Health Center. Available from: https://www.nnk.gov.hu/index.php/kozegeszsegugyi-laboratoriumi-foosztaly/kornyezetegeszsegugyi-laboratoriumi-osztaly/vizhigienes-laboratorium/ivoviz/ivovizbiztonsagi-tervezes-vbt (accessed 11.04.2023).

NPHC 2019 *Módszertani levél - Útmutató ivóvíz-biztonsági tervrendszerek kiépítéséhez, működtetéséhez (Methodological Letter – Guidelines for the Development and Operation of Drinking Water Safety Plan Systems)*. National Public Health Center. Available from: https://www.nnk.gov.hu/attachments/article/725/VBT%20%C3%BAtmutat%C3%B3%202019.pdf (accessed 11.04.2023).

NPHC 2020 *Módszertani útmutató az Ivóvízbiztonsági Tervek Auditálásához 2020 (Methodological Guide for Auditing Drinking Water Safety Plans 2020)*. National Public Health Center. https://www.nnk.gov.hu/attachments/article/725/VBT%20audit%20modszertan__2020_4.pdf (accessed 11.04.2023).

NPHC 2022 *Magyarország Ivóvízminősége, 2021. (Drinking Water Quality in Hungary - 2021)*. National Public Health Center. Available from: https://www.nnk.gov.hu/attachments/article/726/Iv%C3%B3v%C3%ADzmin%C5%91s%C3%A9g_2021.pdf (accessed 11.04.2023).

Schmidt, I., Rickert, B., Schmoll, O. & Rapp, T. 2019 Implementation and evaluation of the water safety plan approach for buildings. *Journal of Water and Health* **17**, 870–883. https://doi.org/10.2166/wh.2019.046.

Setty, K., Enault, J., Loret, J.-F., Puigdomenech Serra, C., Martin-Alonso, J. & Bartram, J. 2018a Time series study of weather, water quality, and acute gastroenteritis at Water Safety Plan implementation sites in France and Spain. *International Journal of Hygiene and Environmental Health* **221**, 714–726. https://doi.org/10.1016/j.ijheh.2018.04.001.

Setty, K., O'Flaherty, G., Enault, J., Lapouge, S., Loret, J. & Bartram, J. 2018b Assessing operational performance benefits of a water safety plan implemented in southwestern France. *Perspect Public Health* **138**, 270–278. https://doi.org/10.1177/1757913918787846.

Summerill, C., Pollard, S. J. T. & Smith, J. A. 2010a The role of organizational culture and leadership in water safety plan implementation for improved risk management. *Science of The Total Environment* **408**, 4319–4327. https://doi.org/10.1016/j.scitotenv.2010.06.043.

Summerill, C., Smith, J., Webster, J. & Pollard, S. 2010b An international review of the challenges associated with securing buy-in for water safety plans within providers of drinking water supplies. *Journal of Water and Health* **8**, 387–398. https://doi.org/10.2166/wh.2010.047.

Tsitsifli, S. & Tsoukalas, D. S. 2021 Water safety plans and HACCP implementation in water utilities around the world: benefits, drawbacks and critical success factors. *Environmental Science and Pollution Research* **28**, 18837–18849. https://doi.org/10.1007/s11356-019-07312-2.

Vieira, J. M. P. 2011 A strategic approach for water safety plans implementation in Portugal. *Journal of Water and Health* **9**, 107–116. https://doi.org/10.2166/wh.2010.150.

WHO 2004 *Guidelines for Drinking-Water Quality*, 3rd edn. World Health Organization, Geneva.

WHO 2011 *Water Safety in Buildings*. World Health Organization, Geneva.

WHO 2017 *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating First Addendum*, 4th edn +1st add. edn. World Health Organization, Geneva.

WHO 2023 *Water Safety Plan Manual: Step-by-Step Risk Management for Drinking-Water Suppliers*, 2nd edn. World Health Organization, Geneva.

WHO, IWA 2009 *Water Safety Plan Manual: Step-by-Step Risk Management for Drinking-Water Suppliers, Plans de gestion de la sécurité sanitaire de l'eau : manuel de gestion des risques par étapes à l'intention des distributeurs d'eau de boisson*. World Health Organization, Geneva.

WHO, IWA 2015 *A Practical Guide to Auditing Water Safety Plans*. World Health Organization, Geneva.

WHO, IWA 2017 *Global Status Report on Water Safety Plans: A Review of Proactive Risk Assessment and Risk Management Practices to Ensure the Safety of Drinking-Water*. World Health Organization, Geneva.

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