Implementation and evaluation of the water safety plan approach for buildings
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ABSTRACT
The World Health Organization (WHO) promotes water safety plans (WSPs) – a risk-based management approach – for premise plumbing systems in buildings to prevent deterioration of drinking-water quality. Experience with the implementation of WSPs in buildings were gathered within a pilot project in Germany. The project included an evaluation of the feasibility and advantages of WSPs by all stakeholders who share responsibility in drinking-water safety. While the feasibility of the concept was demonstrated for all buildings, benefits reported by building operators varied. The more technical standards were complied with before implementing WSP, the less pronounced were the resulting improvements. In most cases, WSPs yielded an increased system knowledge and awareness for drinking-water quality issues. WSPs also led to improved operation of the premise plumbing system and provided benefits for surveillance authorities. A survey among the European Network of Drinking-Water Regulators on the existing legal framework regarding drinking-water safety in buildings exhibited that countries are aware of the need to manage risks in buildings’ installations, but experience with WSP is rare. Based on the successful implementation and the positive effects of WSPs on drinking-water quality, we recommend the establishment of legal frameworks that require WSPs for priority buildings whilst accounting for differing conditions in buildings and countries.

Key words | drinking-water, premise plumbing system, risk assessment, risk management, water quality, water safety plan

INTRODUCTION

Policy context

Current international policy developments promote improved water management in buildings. Sustainable Development Goal (SDG) 6 stipulates the principle of universal access to water and sanitation, which implies all settings, including households, schools, health care facilities and workplaces. At the launch of the International Decade for Action 2018–2028 – ‘Water for Sustainable Development’ on 22 March 2018 – the UN Secretary General made a global call to action for WASH in all health care facilities in order to prevent the spread of disease (United Nations 2018). In response to the 2030 Agenda for Sustainable Development and the call of the UN Secretary General, the World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) have taken action to promote safe and reliable drinking-water, sanitation and hygiene (WASH) facilities for every health care facility until 2030 (WHO 2018a). The 2019 World Health Assembly resolution emphasizes the urgent need for national policies on WASH in health care facilities (WHO 2019).

Improving the WASH conditions in schools and health care facilities is also in the focus of the United Nations
Economic Commission for Europe and WHO Regional Office for Europe Protocol on Water and Health (WHO 2018b). In the WHO European Region, the Ostrava Declaration on Environment and Health also promotes universal, equitable and sustainable access to safe WASH for all and in all settings, including schools and health care facilities (WHO 2017a). An assessment of the situation in schools in the WHO European Region revealed prevailing deficiencies in terms of availability, accessibility and acceptability of WASH facilities (Grossi et al. 2016). In 2018, the European Commission suggested introducing a risk assessment for building premise plumbing systems in their proposal for a revised directive on the quality of water intended for human consumption (European Commission 2018).

Microbiological problems in premise plumbing systems

The proliferation of pathogens, such as Legionella and Pseudomonas aeruginosa, can be traced back to various reasons related to premise plumbing systems, such as too cold warm water temperatures, too warm temperatures in cold water systems or stagnating flow conditions (WHO 2015), which are often induced by too low consumption or insufficient temperature control (WHO 2011; Bilinski et al. 2012). These pathogens are of greater concern for vulnerable people (WHO 2011; Exner 2012) than for people in good health. Especially in health care facilities, nosocomial infections are an increasing problem worldwide (Bilinski et al. 2012). Research findings from the United States of America (2013–2014) underlie the relevance of drinking-water safety in buildings: Legionella was the most commonly reported etiology and its presence in the drinking-water system the most frequent deficiency. Legionella was implicated in 24 outbreaks, 130 cases, 109 hospitalizations, and 13 deaths (Benedict et al. 2017). Surveillance data, gathered in the period of 1971–2006, showed an increasing trend in the number of reported outbreaks of Legionnaires’ disease caused by deficiencies in the premise plumbing systems in the USA (Craun et al. 2010). This fact reveals an urgent need to pay more attention to premise plumbing systems and point-of-use issues (Craun et al. 2010). Also, in Europe, a continuous increase of cases of Legionnaires’ disease has been observed. Although not every outbreak is associated with drinking-water, premise plumbing systems (warm and cold water) are one of the main sources of infection with Legionnaires’ disease (Robert Koch Institut 2015). In 2011, 4,921 cases were reported for 30 European countries, which equals an average rate of 1.0 cases per 100,000 inhabitants. In 2015, the number increased to 7,054 reported cases, which equals an average rate of 1.4 cases per 100,000 inhabitants (European Centre for Disease Prevention and Control 2017). The highest rate of 5.1 cases per 100,000 inhabitants was detected in Slovenia. The highest number of detected cases (1,589) were reported in France with an average rate of 2.1 and in Italy with 1,556 cases and an average rate of 2.6 cases per 100,000 inhabitants. In France, the number of cases has remained stable in recent years (Campese et al. 2015) and an investigation of private buildings showed the presence of Legionella in 26% of the analyzed hot water systems, which corresponds with further data from Italy (Totaro et al. 2017).

Other problems in premise plumbing systems

Drinking-water systems in buildings consist of complex piping installations and include various components: it begins with the point of entry into the building or the premise, water piping, storage systems, and devices for supplying hot water. Deficiencies in design, construction, operation and use of water installation systems can cause hazards that may also impact the safety of drinking-water. These deficiencies include cross connections with non-potable water systems (e.g. greywater, fire mains) or drainage systems and the use of inappropriate materials that leach hazardous chemicals (e.g. lead). Review data regarding 26 incidents of outbreaks associated with distribution systems demonstrate that cross-connections are one of the main deficiencies (Moreira & Bondelind 2017). Exceedence of the limit value of lead in the EU is mainly connected to the premise plumbing system in buildings (European Commission 2016).

Water safety plan approach

The WHO Guidelines for drinking-water quality recommend the water safety plan (WSP) approach, which is based on risk assessment and risk management principles, to consistently ensure the quality of drinking-water from the
catchment to the point of use (WHO 2017b). WSPs can be applied to all water supplies and it has already been successfully applied in buildings (e.g. Dyck et al. 2007; Kumpel et al. 2018). The key steps of a WSP are (Figure 1):

1. description of the water system;
2. system assessment, including the identification of hazards and hazardous events as well as the assessment of risks;
3. controlling risks by implementing control measures that prevent risk to become manifest, establishing operational monitoring to confirm effectiveness of established control measures and defining corrective actions; and
4. verification and auditing to confirm the safe operation of the whole system.

Water safety planning leads to a better understanding of the supply system, identifies potential sources of contamination, assesses risks to health, informs about technical and operational measures and stipulates effective operational monitoring (WHO 2017b). The WSP approach focuses on managing risks throughout all steps in the water supply chain from source water catchment through treatment processes to storage, distribution and handling of drinking-water (WHO 2017b). Thereby it supports achieving health-based targets set by regulations and leads to stepwise improvement of the water supply system. While the WHO provides specific guidance on how to implement WSPs in water supplies (WHO 2009) it also provides recommendations for the application of the approach for drinking-water installations in buildings (WHO 2011).

**WSPs in buildings**

In buildings, various stakeholders can affect the quality of the drinking-water at the point of use: plumbers, the owner or the management of the building as well as the final user. Plumbers are responsible for the construction of the premise plumbing system in accordance with technical norms and standards to avoid deficiencies that cause hazardous events and building owners are responsible for operation and maintenance of the drinking-water installations. The capacity of these stakeholders is essential for the success of the WSP in buildings.

A WSP in buildings always starts with the formation of a team whose members conduct the steps presented in Figure 1. After assembling experts with knowledge in design, operation and management of the drinking-water installation in the building and in public health, the WSP team should describe the drinking-water premise plumbing system, including a mapping of the piping and any point-of-entry or point-of-use treatment processes. To identify possible problems, sufficient knowledge and experience of team members is essential, it may be necessary to involve external expertise. Description and documentation of the system includes all necessary information, for example on water quality, building users, water uses, point of entry and point of use but also information about the water-use patterns, which determine the flow rate. This complete and validated documentation of the whole system is essential for the further steps of the WSP.

Afterwards, the WSP team systematically identifies and analyses microbial, chemical and physical hazards and hazardous events, which may introduce hazards to the system, in conjunction with the determination of existing control measures. The team validates the effectiveness, and puts in place procedures for regular operational...
monitoring to ensure that they remain effective. During the risk assessment, the WSP team evaluates hazards and hazardous events regarding their health significance by considering the number and vulnerability of exposed people and already established control measures. This assessment is supported by a risk matrix that correlates the likelihood of occurrence and the severity of consequences to facilitate the prioritization of risks and urgency of remedial interventions. Based on the results of the risk assessment, the WSP team identifies and implements additional new and/or modified existing control measures to improve the condition of the premise plumbing system and its operation. The following verification consists of two parts – testing the quality of drinking-water as end-product and assessing the WSP; it confirms the safe operation of the whole premise plumbing system and the effectiveness of the WSP.

Further elements of a WSP are supporting programs, such as training operational staff, information on the users and management procedures (e.g. developing emergency plans), and documentation. The latter includes reporting of surveillance data, and communication between building management, responsible agencies and building users. This approach is a continuous process that should periodically be reviewed to consider changes within the system and its operation (WHO 2011).

Legal situation in Germany

In Germany, the drinking-water ordinance (TrinkwV 2018) prescribes minimum requirements to ensure drinking-water quality. According to the ordinance, the building owner is responsible for the management of the drinking-water installation in buildings and for ensuring compliance with the drinking-water quality standards. The ordinance further requires operators of water supply systems to adhere to generally accepted codes of practice, which are laid down in technical standards, including those related to drinking-water installations. These standards are developed by experts and engineers in the field of water supply, and compliance with them should provide safe drinking-water in buildings. Whereas WSPs are not legally required by the ordinance, a so called ‘hazard analysis’ (DVGW 2011) is mandatory for building installations in case of contamination with Legionella (TrinkwV 2018). The German hazard analysis, however, is different from the definition of a hazard analysis in the WSP process; it covers several core steps of the WSP, including the site inspection, system description, hazard analysis and recommendation of control measures (DVGW 2011).

A complementary guidance document describes the requirements for the (German) hazard analysis in more detail (UBA & TWK 2012) and a technical standard with specified requirements for hygiene in premise plumbing systems has recently been published (VDI 2018). One essential part of the (German) hazard analysis is to verify whether relevant technical standards were considered during the construction of the premise plumbing system.

Inducment

Implementation of WSPs strongly increased globally since their introduction in the WHO Guidelines for drinking-water quality in 2004 (WHO 2004). In Germany, WSP principles are increasingly being recognized in water supply practice; Schmoll et al. (2011) have presented an evaluation of the early experiences and learnings from WSP implementation in Germany and an optional application of risk assessment has been introduced in the Drinking Water Ordinance in 2018 (TrinkwV 2018). Limited research is published about the application and advantages of the WSP approach in health care facilities (Biliński et al. 2012), especially with respect to the prevention of health care-associated infections (Dyck et al. 2007; Gamage et al. 2016; Spagnolo et al. 2016). However, even less has been published about the opportunities and challenges that come along with the implementation of a WSP in buildings for the relevant stakeholders.

This paper

This contribution presents the results of a pilot project that the German Environment Agency (UBA) conducted to assess the feasibility of the WSP approach for buildings in Germany. The project evaluated the experiences with practical implementation of WSPs in buildings and the advantages for managing drinking-water quality in buildings, considering various stakeholders’ perspectives –
building owners or property management, health authorities and technical staff. These project findings from Germany are complemented with information about the status quo on the application of a risk management for premise plumbing systems in European countries. Through a survey within the European Network of Drinking Water Regulators (ENDWARE), we gathered details about the individual national approaches and drew conclusions and recommendations for policy makers.

**MATERIALS AND METHODS**

**Pilot project**

UBA conducted a pilot project aiming at an assessment of the feasibility, applicability and added value of the WSP approach for safely managing drinking-water premise plumbing systems in buildings. The project was financed by the German Federal Ministry of Health. The overall objective of the pilot project was to provide a regulatory assessment of the WSP approach for buildings. To provide a practice-oriented basis for this assessment, WSPs were developed and implemented in four different public buildings or building complexes. The experiences made during this pilot project by the respective building operators and health authorities were systematically collected and examined.

**The buildings**

A summary of the characteristics of the four buildings is shown in Table 1. The buildings were selected on the basis of the following criteria: (i) the variety of building types and therefore the variety in the uses of buildings and different groups of people visiting, working or living in them; (ii) the willingness and interest of building owners or operators to participate in the project; (iii) the support by the local health authority responsible for drinking-water quality surveillance. The local health authorities knew these buildings from previous work and communication between building management and health authority existed before the beginning of the project.

Building A accommodated up to 107 care-dependent people who were attended to by 140 employees. The drinking-water premise plumbing system is connected to a sprinkler system. Apart from supplying water to the accommodation units of the inhabitants, further

| Building | A                          | B                          | C                          | D                          |
|----------|----------------------------|----------------------------|----------------------------|----------------------------|
| Type of building | Nursing home for the elderly | All-day school              | Psychiatric clinic          | Industrial production facility |
| Number of users | 247                        | 1,100                      | 457                        | 8,000                       |
| Existing documentation of the drinking-water installation before the project | yes                        | yes                        | no                         | yes                         |
| Technical staff with responsibility for the drinking-water installation | 2 people                   | 2 people                   | 3 people                   | 12 people                   |
| Characteristics of users | Elderly, nursing staff | Children, adolescents, teachers | Psychiatric patients, health personnel | Employees                  |
| Characteristics of water use | Bathroom (shower) in every accommodation unit, sprinkler system | Two separate warm water circulations: canteen, swimming pool and sport facility with showers | 25 separate buildings with varying drinking-water applications (e.g. showers) | Showers for workers, distribution systems for other liquids |
applications such as a kitchen and a cafeteria are existing in the building. An important aspect to consider for this building was the state of health of inhabitants with respect to dementia and their capability of taking care of their personal hygiene (e.g. bedridden patients). Two employees, who worked together closely with the building management, were responsible for operation of the system. They attended technical advanced training and were supported by external companies who conducted maintenance of the system. The quality of drinking-water was tested annually, which is more frequent than legally required.

Building B included a canteen kitchen, a swimming pool and public sport facilities with showers that were situated on an area of about 43,000 m². The kitchen and sport facilities were supplied by two separated warm water circulations. Increased concentrations of Legionella were detected in the past. After this incident the awareness of the building management for the risk of Legionella growth was raised, and due to that staff gained knowledge in the field of drinking-water hygiene and premise plumbing systems.

The hospital (building C) provided space for 207 patients, who were cared by 250 employees, in 25 separate buildings, resulting in a very complex premise plumbing system: the warm water distribution system had a length of 2 km and the cold water distribution system was 1 km in length. As part of reconstruction works, the warm water supply was mostly decentralized to reach a temperature of 60 °C in the whole warm water system. The three technical employees, who were responsible for the premise plumbing system, attended training that focused on the topic of drinking-water premise plumbing systems and therefore were aware of risks related to drinking-water.

Around 8,000 employees were working in the company building complex (building D) that consisted of ten individual factory halls with a total area of 260,000 m². Apart from a complex drinking-water premise plumbing system, there were networks for fire extinguishing, cooling and water used for non-drinking purposes, as well as networks for different liquids (such as oil). In response to a contamination event with Legionella, the company established a working group that was responsible for activities concerning drinking-water hygiene and had already implemented control measures to prevent Legionella contamination.

Application of WSPs

At the beginning of the implementation, project members (i.e. operators of the buildings and responsible health authority staff) participated in a workshop during which they received knowledge about requirements and steps of the WSP approach. A WSP manual, tailored to the building context, served as a reference throughout the project. This manual provided an introduction to the WSP approach and described the aims and actions of each step in detail (Figure 1). Furthermore, the manual featured a working example to illustrate how the theoretical concept may be implemented in practice.

WSP implementation in the pilot buildings was conducted by the project members; UBA staff provided advice and consultation upon request. The project was structured in three phases; each of them terminated with a meeting to discuss results, answer questions and plan the next implementation phase.

The first phase started with the formation of the WSP teams: each consisted of 2–3 technical employees, who were involved in the building operation, and two employees of the local health authority who are responsible for surveillance of drinking-water quality in Germany. The teams in buildings A and B also involved an external consultant. In building C, the management of the hospital and a representative of the regional health authority were additional team members.

Each of the team members contributed specific knowledge needed for the implementation of the WSP: the technical staff contributed expertise of the drinking-water premise plumbing system; the members of the health authority provided inputs about possible causes of drinking-water contamination and related health outcomes and the external consultants had experience with technical standards relevant to drinking-water premise plumbing systems. When specific information was needed, the WSP teams consulted with further experts. Once the interdisciplinary WSP teams were established, project members started with putting together the descriptions of the premise plumbing systems, based on a compilation of all relevant documents and an analysis of the users and uses in the buildings.

In the second phase, the WSP teams established a system-specific hazard analysis by identifying existing and
possible hazards and hazardous events, and undertook an initial risk assessment, based on a detailed inspection of the entire drinking-water installation of the building. Furthermore, samples were taken to assess the chemical and microbiological quality of the drinking-water.

During the third phase, WSP teams identified and documented new improvement measures to control the identified risks. The teams implemented these control measures as far as possible in the timeline of the project. Besides technical measures, standard operating procedures (SOP) were established to describe in detail tasks and responsibilities related to maintenance, cleaning, monitoring and inspection. This last phase concluded with a reunion of all project members and UBA in a joint workshop to review the results and benefits of WSPs for the four buildings.

To gain experiences, opinions and an overall assessment about the approach by the project members, their estimations regarding benefits and applicability in buildings were requested via a final evaluation sheet. This survey addressed the following topics:

- Assessment of the WSP approach and its applicability for building management;
- Assessment of individual WSP steps, their feasibility and usefulness;
- Resources needed for WSP implementation;
- Assessment of further support needs for a successful implementation;
- Identification of benefits of the WSP approach compared to previous practices;
- Evaluation of the potential of WSP outcomes to support the surveillance of buildings by health authorities.

Survey on the legal situation in Europe

Besides this pilot project, we sent a questionnaire to members of the ENDWARE network in June 2018, which represents drinking-water regulators for all EU member states and Norway. The purpose of the survey was to collect information on the legal requirements regarding the safety of drinking-water in buildings in the countries. The eight questions focused on the level of consideration of premise plumbing systems within the current national legal framework and available technical standards, on the experience with applying the WSP concept or other risk management approaches for buildings, and on existing control measures to prevent microbiological hazards in buildings. In total 15 countries and regions answered the questionnaire and thereby provided insights in the national approaches to addressing risks in drinking-water premise plumbing systems. The single-choice questions were evaluated in percentages and the individual comments summarized descriptively.

RESULTS AND DISCUSSION

The presented results of the pilot project focus on the feedback from all project members and the way they assessed the feasibility of the WSP approach, the availability of resources and the expertise needed. Furthermore, generally perceived benefits were determined as well as the impacts on the premise plumbing systems and the protection of drinking-water quality.

Impacts and benefits of WSP in buildings

Based on the feedback of the project members, Table 2 summarizes the impact of the individual steps of WSP implementation as the project members assessed them.

All project members assessed the formation of the WSP team and the resulting exchange of knowledge as beneficial for the implementation of the WSP. Due to the cooperation of different experts and stakeholders, they observed an increase of awareness of drinking-water issues. Project members highlighted the importance of involving the building management, especially for making financial decisions that become necessary when implementing identified improvement measures. They also evaluated the description of the system as helpful in order to consolidate and update all required technical information, although the related effort was high in buildings C and D due to the existing old and complex premise plumbing system that showed deficiencies. The project members observed that this compilation led to a valuable overview over the whole system and its deficiencies. During joint inspections of the premise plumbing system, the WSP teams analyzed potential hazards for the drinking-water quality; these inspections were assessed to be very helpful and efficient.
While building operators could fix some deficiencies detected during the inspections immediately (e.g. by dismantling rarely used taps to prevent stagnation), others were included in the building’s improvement plan. The use of the risk matrix was reported to be helpful for a first orientation; however, the teams supplemented the original matrices by annotations to the category definitions. However, team members of building A stated that it was difficult to determine a likelihood of occurrence, especially for microbiological hazards that had not yet occurred in their premise plumbing system.

Identified improvement measures led to better operation of the premise plumbing system and helped to control identified risks. In building C, team members stated that they implemented some improvement measures immediately; they also introduced organizational solutions, such as changing the usage of rooms to mitigate low water flows and thus prevent microbiological growth. The team emphasized that the documentation of activities during operation (e.g. regular flushing of the system) and operational measures is important to guarantee diligent water quality management in the building. Project members of buildings A and B, however, evaluated the documentation of operational measures, for example the routine exchange of shower heads and tubes, as too complex for practical implementation.

The initial conditions in building A were already good before project implementation. The premise plumbing system was constructed in accordance with technical standards and a complete and up-to-date map of the system existed at the onset of the project. The project members of building A, therefore, stated that WSP implementation did not lead to additional value; they assessed their existing practices in system operation as appropriate and deemed compliance with technical standards to be sufficient. The technical staff of building B, however, clearly confirmed the value of WSP for buildings: an intensive analysis of the premise plumbing system increased the awareness of all stakeholders. In building C, the team expressed a similar opinion, assessing that a WSP helps to emphasize hygienic issues and identify necessary improvement measures. Furthermore, a faster implementation of improvement measures was fostered by the WSP. The team of building D positively evaluated the simple structure of a WSP and its sustainable character. Due to the similarity of WSP to quality management systems that were already known, it was easy to accept by the employees.

The difference between the assessment of the WSP approach by the operators in building A compared to buildings B, C and D showed that the acceptance by the operators and the necessity to implement a WSP strongly depends on the prevailing conditions of the premise plumbing system. Although the WSP led to improvements of the premise plumbing system and its operation in all four buildings, the impact of improvements in building A was less significant due to the better initial conditions. Similarly, the efforts needed to implement the WSP also depended on the prevailing state of the system and on expertise of the technical staff. Due to the work within the team, all participants were able to broaden their knowledge and therefore they were well prepared for possible future difficulties. The cooperation between the different stakeholders was a main advantage to ensure sustainable operation of the system and monitoring.

Table 3 shows a more detailed description of the benefits of a WSP and how it improved the premise plumbing system and its operation, as reported by the project members, in accordance with the categorization provided by WHO (2017b).

The assessment of the implementation in buildings B and D exhibited the highest improvements: systematic examination led to an increased understanding of the whole premise plumbing system and therefore to an enhanced knowledge of existing hazards, hazardous events and risks by all stakeholders. An exchange of information and
knowledge due to intense cooperation with external experts and the local health authority was evaluated as one of the main advantages. The collection of information and update of documentation led to more transparency and to a profound justification of necessary improvement measures and maintenance.

### Applicability of WSP in buildings

The project members of the four buildings assessed the applicability of the WSP approach and the required effort differently. While implementation of all WSP steps was feasible in all buildings and the requirements of the WSP approach were clear for all project members, the team members of building A found that there was no need for further improvement measures and/or any amendments to the building management. Furthermore, they assessed that the risk assessment lacks practical relevance; especially, the occurrence of risks associated with microbiological growth was hard to determine.

The team members of buildings B, C and D mostly agreed in their assessment. They considered the WSP approach applicable to all buildings, but necessary financial and human time resources may be limiting factors for the implementation. The availability of resources was considered as the main parameter that influences the duration of the first WSP implementation cycle and the quality of the WSP; especially at the early stages of implementation, the required resources were experienced as high, depending on the scope of the investigations, but later the required resources decreased.

The team members of buildings B, C and D considered the use of a risk matrix to evaluate the prevailing risks as useful, but they also highlighted the importance of discussing the underlying definitions of the matrix within the WSP team and of having sufficient flexibility to define the scales of likelihood of occurrence and severity of consequences. The technique of risk assessment generally implied certain difficulties: it was difficult to appraise consistently the severity and the likelihood of a hazardous event leading to hazard occurrence. Nevertheless, the teams emphasized the benefit of discussing and systematically assessing prevailing risks, and the outcomes of these joint team evaluations were commonly accepted by building management. Team members noted, however, that the risk assessment required sufficient technical, water quality and health expertise of the team members in order to reach sound conclusions, and therefore external support may be required where such expertise is lacking.

### Responsibility of health authorities and WSPs’ advantages for their surveillance activities

In their assessment of the WSP approach, the local health authorities emphasized their limitation in human and time resources. They highlighted that a general involvement of the local health authorities into the entire process of WSP implementation is not feasible; their support had to be restricted to high priority buildings (e.g. with known problems concerning drinking-water or hosting vulnerable persons) and in response to incident situations. Furthermore their support should focus on key steps of the implementation such as hazard analysis, risk assessment and an external evaluation of the adequacy and effectiveness (audit) of the WSP.

The building management, in turn, asserted that the expertise of the local health authorities was indispensable during the WSP process. In particular, their health expertise and their impartiality of commercial interest was assessed

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**Table 3** | Benefits reported by the project members (yes: reported benefit; no: benefit not reported; N/A: project member did not provide a statement)

| Benefit                                      | Building |
|----------------------------------------------|----------|
| Improved system management                   | A        | B       | C       | D       |
| Improved managerial and operational procedures| No       | Yes     | Yes     | Yes     |
| Increased awareness and understanding among staff | No       | Yes     | Yes     | Yes     |
| Increased promotion and knowledge sharing    | Yes      | Yes     | Yes     | Yes     |
| Improved communication                       | Yes      | Yes     | Yes     | Yes     |
| Improved collaboration with health authority  | Yes      | Yes     | Yes     | Yes     |
| Improved monitoring                          | Yes      | Yes     | Yes     | Yes     |
| Improved record keeping and data collection  | No       | Yes     | N/A     | Yes     |
to be essential. So, the desired level of involvement of local health authorities in the WSP process was evaluated disparately by the health authorities and the building management.

The local health authorities emphasized the distinct advantages of a well-developed building WSP for the purpose of their surveillance activities: WSP always yielded an updated and complete documentation of the premise plumbing system and of the established control measures against contamination of the drinking-water. This documentation provides an overview for the local health authority and helps them to react quickly in case of an emergency and to decide profoundly. Furthermore, clear mapping of the whole premise plumbing system facilitated the determination of appropriate sampling spots, so that monitoring can be individually adapted to the critical points of the premise plumbing system. Additionally, employees of the health authorities assessed the information exchange with the building operators as beneficial, particularly during on-site inspections.

Local health authorities viewed implementation of the WSP approach beneficial for official surveillance purposes and for maintaining a cooperative relation with the building management. A complete documentation of the premise plumbing system – which is often missing – and of prioritized risks supported a systematic approach to the monitoring of local conditions. Additionally, through the WSP process, the local health authority’s expectations regarding drinking-water quality and the premise plumbing system became more transparent for the building management – therefore cooperation between them was enhanced and it was easier to comply with these requirements. Simultaneously, collaboration also ensures more confidence in the quality of the WSP.

Since project members considered it as not feasible to involve health authorities in the whole WSP process in every building, the support by external experts as well as adequate training of internal staff are critical prerequisites for developing good quality WSP, including a good understanding of technical standards and hygiene issues in drinking-water premise plumbing systems. Due to the intense involvement of the local health authorities within the project, in combination with their responsibility for official surveillance and control of drinking-water quality in buildings, their dual role in the WSP process may cause a conflict of interest, if practiced beyond the pilot project horizon. This can be addressed by involving external experts in the WSP team instead. However, to guarantee a WSP of high quality, it is necessary to involve the health authorities in the assessment and confirmation of the finally implemented WSP.

**Risk management in buildings in Europe**

The survey among the ENDWARE network revealed that water quality related aspects of premise plumbing systems within buildings are frequently considered in the national transpositions of the EU Drinking Water Directive – as indicated by 73% of the respondents. Especially, the prevention of back flow and materials in contact with drinking-water are regulated. In 60% of the responding countries and regions, no national technical specifications for premise plumbing systems besides European standards exist.

Several countries have established water quality standards for *Legionella* and *Pseudomonas aeruginosa*, which are of particular relevance for buildings. In 67% of the responding countries and regions, an upper value between 100 colony forming units (CFU)/100 mL and 100 CFU/L for *Legionella* is applied. In one country a stricter value of 0 CFU/100 mL is required. Only three countries reported established water quality standards for *Pseudomonas aeruginosa*, with an upper value of 0/100 mL stipulated.

Experience with the application of building WSP is missing in the majority of countries. Only 13% of the respondents declared having experience with the application of the WSP approach in buildings; however, the majority of them indicated that only a few WSPs are in a pilot phase. Eleven countries stated that another kind of risk management for buildings is required by law, or to have a different approach for ensuring water safety in buildings, which goes beyond the duty of complying with limit values at the tap, as required by the EU Drinking Water Directive. These risk management concepts typically focus on public buildings, especially health care facilities or schools. Approaches reported by responding countries include:

- Authorization of water suppliers to carry out regular inspections of fittings and to take action if issues arise;
• Use of specific recommendations for water suppliers and plumbers;
• Established requirements for maintenance and testing by a mandated authority, and depending on the test results, initiating remedial actions;
• Defined sampling frequency and testing parameters for priority buildings;
• Defined specific monitoring of lead;
• Control of Legionella, including specific recommendations for health care facilities and special legislation for an assessment for Legionella.

The findings indicate that countries are aware of the importance of reducing risks that are caused by deficiencies in the premise plumbing systems and have individual approaches to control them. However, a legally binding requirement for risk management in buildings is not in place in most cases, and if in place they focus merely on priority buildings.

Regulatory considerations

The experiences from the German pilot project clearly show that significant improvements of the premise plumbing system and its operation are possible. These experiences underline the value of WSPs in ensuring drinking-water safety through the application of a risk management approach for buildings, especially for buildings hosting vulnerable groups, including schools and health care facilities. The difference between the achievements in building A, as compared to buildings B, C and D, indicate, however, that a general legal requirement to implement WSPs for all buildings may be too demanding, particularly with regard to small residential buildings, where building operators lack the required expertise to undertake a WSP. In such settings, resources and external support would be needed to establish effective and ongoing risk-based management. Therefore, in establishing legal WSP requirements for buildings, costs and benefits need careful attention.

The necessity and acceptance of WSP implementation strongly depends on the prevailing conditions of the premise plumbing system itself, the type and number of reported building-associated water quality incidents or disease outbreaks. Further capacity factors may also influence WSP acceptance, such as the level of knowledge and awareness of responsible building operators and the availability of external expertise, including the local health authorities. Therefore, a regulatory requirement for the implementation of a WSP in every building may be hard to meet and enforce as it would require significant resources. An alternative approach, however, may focus on introducing WSP requirements exclusively for priority buildings that host vulnerable population groups, such as health care facilities, schools and nursing homes.

Though the WSP approach for buildings has been promoted by the WHO for several years, supported by a publication guiding the practical implementation (WHO 2011), the responses of the survey among EU member states indicate limited application of the concept in buildings on a voluntary basis. Thus, an explicit regulatory requirement, which stipulates WSP principles for buildings, would certainly support uptake in practice.

The results of the survey also underline that current practices and experiences regarding risk management in buildings differ between EU member states. To adopt and scale-up WSP-type approaches for buildings in the long-term, it is necessary to build capacities broadly. The WHO (2010) suggests the development of a road map to define key steps in support to long-term uptake of WSPs in the national context; such a road map may also be adapted to buildings’ settings. It may include several stages, ranging from attaining practical WSP experience, building supporting capacities and expertise, developing supporting tools for WSP implementation to establishing regulatory instruments. The formulation of such a national road map can help establish the rationale for WSPs in buildings and display supporting programs to enable long-term uptake, also in reflection of and in preparation for the forthcoming recast of the EU Drinking Water Directive, which may stipulate a risk assessment for drinking-water systems in buildings (European Commission 2018).

Legal approaches for implementing risk assessments for domestic premise plumbing systems, which aim at the safe operation of these systems, already exist in some EU countries and can form a basis for more comprehensive WSP implementation. For example, in Germany the hazard analysis (according to the definition provided above; UBA & TWK (2012) and VDI (2018)), which is legally
required, provides profound guidance on how to deal with the occurrence of *Legionella* in premise plumbing systems. It constitutes an easily applicable approach for smaller buildings because it is less extensive than a full WSP. It includes working steps that are similar to the core part of a WSP, specifically checking the documents of the premise plumbing system and compliance with current technical standards, monitoring of operational parameters (e.g. temperature) and on-site investigations. All these steps yield to a final assessment of the current situation with respect to *Legionella* control within the buildings. In Belgium, for example, a document verifying the backflow prevention of buildings at the point of transfer from the supply network is passed on to the new owner when a building is sold. A requirement for developing such a document could also be used and adapted in other settings towards a more comprehensive description of the condition of the premise plumbing system and documentation of all information necessary.

**CONCLUSIONS**

The experiences of the pilot project show that the WSP approach provides great potential to discover deficiencies and to improve the conditions of building’s premise plumbing systems and hence protect drinking-water from contamination. A WSP leads to smaller improvements in buildings with new premise plumbing systems that are planned and constructed in accordance with state-of-the-art technical standards and are well-managed, operated and maintained. The WSP approach will likely show more significant advantages and improvements for buildings which are complex, older and where diligent water quality management is not in place.

An up-to-date description of the premise plumbing system and the outcomes of the hazard analysis and risk assessment clearly support building operators in identifying existing deficiencies and implementing improvement measures in a structured way. The cooperation in the team increases knowledge and awareness of team members, and the periodic review of the WSP approach supports meeting water quality targets and sustainability of the system operation. The WSP approach also improves understanding and application of technical standards relevant to the management of drinking-water quality in buildings.

In settings where WSPs are in place, they can support surveillance by health authorities, including monitoring, guiding attention during on-site inspections and identifying remedial actions in response to incidents. Especially for buildings that host vulnerable population groups, such as hospitals or nursing homes, due managerial attention to safeguarding drinking-water quality is important and in these settings WSPs are particularly beneficial by providing a structured way of identifying and controlling risks.

Lack of expertise, financial and human resources are the main factors that influence the feasibility of WSP implementation. Especially in buildings that exhibit multiple deficiencies, resources needed particularly for the first cycle of WSP implementation are high. The project members considered this to impede the implementation of WSPs, although they assessed the positive effects to be convincing. Therefore, for building managers that do not have the resources to engage external experts, the availability of easy-to-use tools could assist building operators with WSP implementation and thus result in a broader WSP uptake in buildings.

Current studies (Dyck et al. 2007; Bédard et al. 2016; Benedict et al. 2017) and numbers of notified cases of Legionnaires’ disease reveal the importance of extending a risk-based management approach to the drinking-water premise plumbing system for ensuring the quality of drinking-water at the point of consumption. Therefore, it is advantageous to establish a legal framework that specifies minimum requirements for the principles that underpin a WSP and defines the responsibilities of all stakeholders. This process needs to consider several factors, including:

- existing legal requirements and technical standards;
- an analysis of required versus available expertise and resources needed for implementation;
- enforcement and reasonableness of such requirements for different types of buildings;
- the prevailing conditions of premise plumbing systems;
- reported compliance with drinking-water quality standards at the point of consumption; and
- known adverse health outcomes related to water quality in buildings.
Expertise regarding the implementation of WSP in buildings tends to be still low in EU member states. Therefore, time and resources are needed to build capacity and experience and to implement legal requirements for WSP profoundly. Cooperation and exchange of knowledge should be supported at all levels.

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SUPPLEMENTARY MATERIAL

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