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Overview and comparison of *Legionella* regulations worldwide

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Background: Legionnaires disease occurs worldwide. Many authorities have guidelines and regulations to prevent and control *Legionella* in water systems. These regulations are based on often very limited field and laboratory observations and measurements. They are, therefore, very different from country to country. This article aims to map the existing regulatory framework of worldwide *Legionella* control to assess the feasibility of regulatory unification.
Methods: This article gives an overview of the different standards, guidelines, and recommendations as well as how various authorities and/or countries deal with *Legionella* infection. A 3-step process is followed to identify current regulations.
Results: Although *Legionella* is a global concern with a common scientific base, the regulatory framework is different from country to country. The current guidelines and standards are not the best possible. Despite different regulatory frameworks, there is still broad unification of underlying principles. Common principles across regulations are avoiding and monitoring critical spots, avoiding water stagnation, and maintaining sufficiently high temperature (above 60°C, below 25°C). Differences between regulations are target group and dangerous *Legionella* concentration levels.
Conclusions: The comparative analysis of the framework is a good starting point for reaching future regulatory unification based on common ground.

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Legionellosis is believed to occur worldwide. Thirty-nine species of *Legionella* have been identified. The most common and dangerous for humans is *Legionella pneumophila*. *L pneumophila* exists as part of the natural microbial flora of many aquatic ecosystems. *L pneumophila* appears in most water supplies—including lakes, ponds, and rivers—in low concentrations and in a dormant stage, but *L pneumophila* from natural habitats can increase markedly in artificial hot water systems, where the temperature is optimal for their growth, which can reach dangerous concentrations.[1]

Various countries have different recommended strategies for preventing *L pneumophila* growth. Important differences can be noted in the way they measure dangerous concentrations, employ water sampling frequency and *L pneumophila* alert levels, and institute required actions. Recommended strategies depend on local regulations, though the problem is occurring worldwide since *Legionella* is naturally present in water. Geographic differences are not sufficiently significant to require customization of infection control practices by region.

The incidence of community-acquired Legionnaires disease varies widely, according to the level of surveillance and reporting. In the United States, reported cases of Legionnaires disease have grown by nearly $4^{1}/_{2}$ times since 2000. It is unclear whether this increase has occurred because of increased awareness and testing, increased susceptibility of the population, increased *Legionella* presence in the environment, or a combination of factors.[2] In Europe, the United States, and Australia, there are about 10-15 cases per million reported annually.[3] This is still believed to be a serious underestimation since many countries lack sufficient surveillance systems or appropriate methods of diagnosing the infection. This means the actual rate of occurrence is unknown.

Many countries have guidelines or standards for the control of *Legionella* in water systems and for the prevention of legionellosis. These guidelines and standards are based on field and laboratory observations and measurements. In this article, existing guidelines and standards are identified and investigated to gain insight into how and whether scientific knowledge about *Legionella* growth is translated into these protocols. The article also provides an overview of the most relevant features of existing *Legionella* standards and guidelines.

For better understanding, technical terms used throughout the article are indicated visually in the diagram in Figure 1.

WHY MORE UNIFORM REGULATIONS ARE NEEDED

Although there are different environmental circumstances worldwide, more uniform regulations are needed. Since 1985, studies have shown that *Legionella* is present in all segments of community water supplies, including treatment facilities.[5,6,7,8] The 1985 Legionella Criteria Document states that *Legionella* is widely distributed in the natural environment worldwide.[9] *Legionella* exhibits the ability to survive in an extremely wide range of conditions in both natural and artificial aquatic habitats. Its survival is enhanced by symbiotic relationships with other microorganisms. For example, *Legionella* has the unique ability to multiply within protozoan cells, which helps it survive over a wide temperature range and resist the effects of chlorine, biocides, and other disinfectants.

Current regulations include a wide range of climatologic circumstances, and the same measures are recommended for different environmental circumstances worldwide, as environmental

circumstances are not important to the growth of *Legionella*. What does matter, independent of the dominating climate, is the design of the domestic hot water (DHW) system in a building.

Seasonal changes in environmental humidity do not influence the etiology of *Legionella* infections.[10] There is only one environmental parameter that is important, and that is fresh water temperature. If the temperature is too high (in warmer countries), some regulations allow chemical disinfection because a significant correlation is observed between higher fresh water temperatures and the presence of *L pneumophila*. However, the same circumstances do ensure whether growth will occur because this is not dependent on the dominant climate but on the domestic hot water installation characteristics. A higher fresh water temperature only provokes a time shift in *Legionella* growth, meaning growth will occur earlier in warmer countries. Hence, comparing these frameworks can be a first step on the path to future regulation unification. Clearer and more uniform and unambiguous regulations would facilitate their implementation.

METHODS

Guidelines are advisory, whereas standards and codes of practice have a more formal standing and are supported by legislative enforcement. From this point in the article, the word "regulations" will be used to refer to all categories. Current regulations vary in scope but usually include certain common features, such as a risk management approach. This plan can include specific information on managerial responsibility and operator competency.[11] Some guidelines are very broad,[12,13] whereas others deal with specific circumstances, such as infection control within health care facilities[14,15,16] or travel-related disease.[17,18,19,16,20,21]

In the next sections, a description is given of how the regulations —included in this article—are identified so as to be methodologically reproducible. Afterward, the most relevant regulations are discussed. The authors first focus on worldwide standards, and then regional and national standards are discussed.

Methodology for identifying regulations

Identification of current guidelines occurred in 3 sequential steps. First, the authors performed a literature review in which *Legionella* research was classified based on geographic context. Based on this identification, experts were contacted per region, and questions were asked about the current guidelines and standards in their country. At the same time, government websites were researched to identify missing documents. As a final step, documents were then translated.

Literature review on Legionella

A standard literature review starts by searching online subscription-based websites that provide scientific citation indexing services. However, guidelines, standards, and regulations cannot be found in this way. For this article, a literature search was performed only with the aim to identify the most influential *Legionella* researchers.

In Figure 2, research published over the years about *Legionella* is shown. When performing a literature search for the key word "*Legionella*" in scientific journals in all fields—meaning the word "*Legionella*" appears at least once in the whole article—15,589 results were found. Research on *Legionella* has been published since the 1970s. The number of articles has been increasing since 1979. When looking for the more specific key word "*Legionella pneumophila*" (all combinations of capitals) in all fields, 7,615 results were found. The curve is an offset of the curve in Figure 2, meaning publications follow a similar evolution over time.

The next step was looking for the key word "*Legionella pneumophila*" in the abstracts, titles, and key words of journal articles— meaning the words "*Legionella pneumophila*" appear at least once in
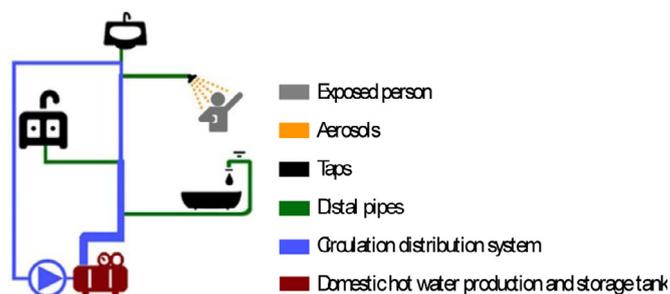

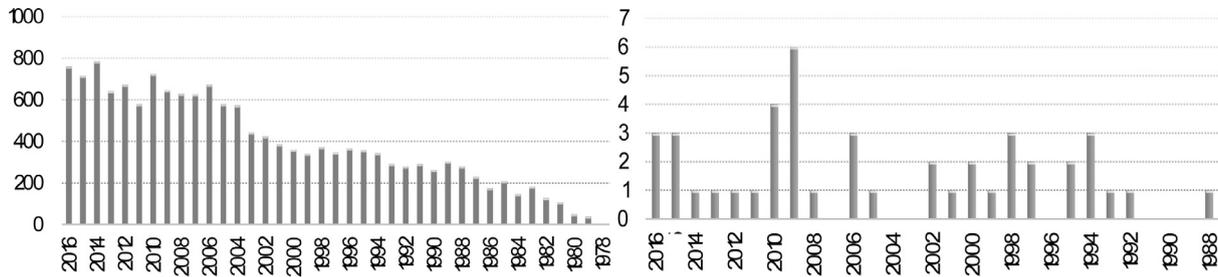**Fig 1.** Domestic hot water system with indication of components (adapted from Tetra[4]).

Fig 2. (A) Literature search using key word "*Legionella*" in all fields gave 15,589 results. (B) Literature search using "*Legionella pneumophila*" AND "domestic hot water" in all fields gave 45 results.

these sections instead of the article as a whole—and 1,109 results were found from 1979 to 2016. This follows the same trend as the curve in Figure 2A, with a peak in 2014.

Because regulations focus on *Legionella pneumophila* in DHW, the next step was to look for the combined key words "*Legionella pneumophila*" AND "domestic hot water" or "*Legionella pneumophila*" AND "DHW" in all fields. This resulted in only 45 hits (Fig 2B).

These results were looked at in more detail. The results were divided into different categories based on the geographic context of the article (ie, country where the research was executed, in most cases the country where a case study was conducted) (Fig 3).

Based on this last literature search step, experts per country/region were identified and contacted, and questions were asked about the current guidelines and standards in their country/region. At the same time, government websites were researched to identify missing documents.

The authors started on a macroscale, with clearly identifiable parts of the world, and narrowed the focus in the next steps. More attention was given to industrialized countries because they have central water systems that enhance bacterial growth. This methodology does not guarantee completeness, but most of the world—especially the regions with the most *Legionella* infections—was covered. As a final step, all collected documents were translated.

Fig 3. Research on "*Legionella pneumophila*" AND "domestic hot water" divided by geographic context.

Legionella *regulations worldwide*

World Health Organization

The goal of the World Health Organization (WHO) is to build a healthier future for people all over the world. Working through offices in more than 150 countries, WHO works side by side with governments and other partners to ensure the highest attainable health level. WHO currently provides information and guidance on *Legionella* risk assessment and management in 7 principal documents (Appendix A).

These documents review the current state of knowledge about the impact of *Legionella* on health. They provide an overview of the sources, ecology, and laboratory identification of *Legionella*. They provide guidance on assessment and management of risks associated with potentially hazardous environments. The documents also identify necessary measures for preventing or adequately controlling *Legionella* exposure risk in each particular environment. WHO gives some information about preferential temperatures for cold water, stating that to prevent *Legionella* infection, the recommended temperature for cold water storage and distribution is below 25°C and ideally below 20°C. For hot water, the organization states only that maintaining temperature within buildings is an important control measure for preventing or minimizing *Legionella* growth. No quantitative information about critical levels is mentioned. Because of the difficulty in determining what represents an acceptable *Legionella* limit level, WHO states that health-based targets usually focus on controlling the proliferation of *Legionella* and the production and release of aerosols. However, sometimes health-based target levels for *Legionella* safety are set nationally and applied locally.

European Union

European Working Group for Legionella *Infections (government)*

The European Working Group for *Legionella* Infections (EWGLI) was formed in 1986. Its membership comprises scientists with an interest in improving knowledge and information regarding the epidemiologic and microbiological (clinical and environmental) aspects of Legionnaires disease. EWGLI is coordinated and managed by the European Centre for Disease Prevention and Control in Sweden.[22]

The technical guidelines formulated by EWGLI support all member states of the European Commission.[23] This makes the information more concise and less specific. Furthermore, the measures are valid for both cold and hot water installations. On the other hand, the scope of application is not restricted to public establishments, although it is in some member state regulations.

The possible measures put forward by EWGLI can be divided into 3 methods, each of which can independently limit the growth of *L pneumophila*. First, proper monitoring of the DHW system is of great importance. Critical spots need to be inspected properly in order to notice problems quickly and limit possible infection; the principles are mentioned in Appendix A. Second, the most commonly used
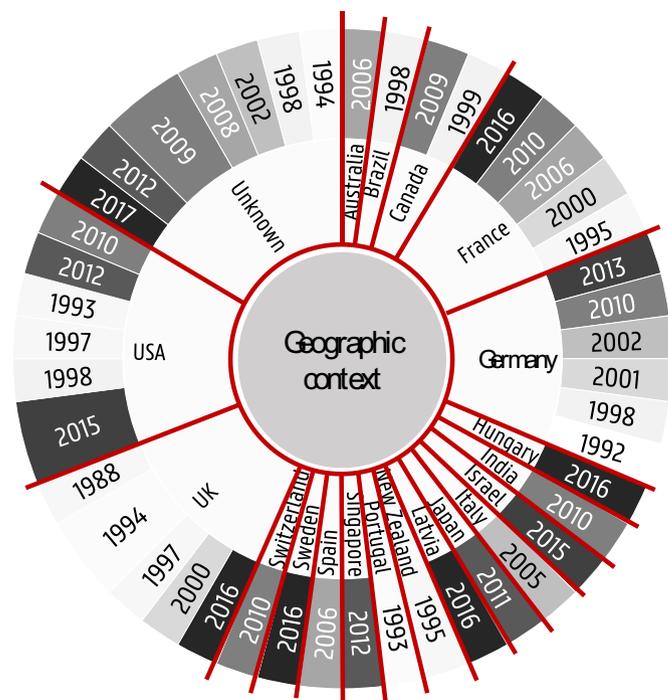
Table 1
Critical concentrations of *L pneumophila* according to EWGLI[23]

Concentration limit		Measure
Between 1,000 and 10,000 cfu/L	<20% of samples	Resampling necessary If, after resampling, a similar number of samples are infected, it is recommended to take measures to lower the concentration
	>20% of samples	Obligation to take measures to decrease concentration Disinfection should be considered
More than 10,000 cfu/L		Resampling necessary Take immediate action to lower concentration (for example, disinfection)

EWGLI, European Working Group for *Legionella* Infections; *L pneumophila, Legionella pneumophila.*

measure in many countries is the requirement of a sufficiently high temperature at the storage tank to prevent *L pneumophila* growth. An overview of measures affecting temperatures in the installation is given in Appendix A. Third, to prevent proliferation of *L pneumophila*, water stagnation in certain parts of the system should be avoided. Possible measures are given in Appendix A. The critical *L pneumophila* concentrations and associated measures, according to EWGLI, are summarized in Table 1.

Critical concentrations, as set by EWGLI, can be interpreted separately by each country. An example is given of limit values for *Legionella* concentrations in health care settings in France, where 2 levels are specified. Health care buildings destined for patients with individual risk factors, such as the elderly and those with alcoholism or tobacco addiction, need to comply with a target level of <1,000 cfu/L of *L pneumophila*, an alert level of 1,000 cfu/L of *L pneumophila*, and a maximum level of 10,000 cfu/L of *L pneumophila*. For high-risk patients, such as those with severe immunosuppression or transplantation, the levels are stricter—target level of not detectable and alert level of 250 cfu/L of *Legionella* spp.

Because a count of 0 cfu/L of *L pneumophila* does not guarantee a total absence of the bacteria, it is very difficult to ensure eradication of *L pneumophila* from a complex DHW system. The counting of viable and culturable *L pneumophila* bacteria is done by accredited laboratories working with the International Organization for Standardization or local standards that should also be linked to ISO 11731-2.[24]

Federation of European Heating, Ventilation and Air Conditioning Associations (industry)

Federation of European Heating, Ventilation and Air Conditioning Associations guidebook No. 18, "Legionellosis prevention in building water and HVAC systems," was published in 2013.[24] This guidebook is a practical guide for design, operation, and maintenance to minimize the risk of legionellosis in building water and HVAC systems. The subject of the guidebook is installations that are at the highest risk level: air conditioning (with humidification), production of hot water for washing, evaporative cooling towers, and energy efficient (ie, low temperature) installations. In the following section, 2 examples of EGWLI implementation are discussed, followed by an overview of European countries.

Authorities of European countries

Germany. In Germany, there is Code of Practice W551 (2004) for drinking water installations, which recommends some best plumbing practices, as can be seen in Appendix A[25,26].

In Association of German Engineers/German Technical and Scientific Association for Gas and Water (VDI/DVGW) guideline 6023, which focuses on water installations, action limits are determined

and the importance of staff qualification and training is emphasized. Regarding action levels, Germany follows the levels determined by the European Union.[27] They add that when 10,000 cfu/100 mL is measured, immediate action should be taken. This concentration is 10 times higher than the highest action level set by EWGLI. W556 (2015) contains a flowchart about actions required when an existing drinking water installation is infected.

Belgium. In Belgium, legionellosis is a notifiable disease. The critical *Legionella* levels vary between 1,000 and 100,000 cfu/L, depending on the risk. Belgium's 3 regions are subject to different regional regulations. Only 1 guideline and 1 regulation apply to all of Belgium: hospitals are subject to the advice of the Health Council, and employees are protected at work from the risks related to biological agents by Codex: Koninklijk Besluit Biologic Agents (Royal Decree 1996). Additionally, in Flanders, the *Legionella* decree and best available techniques (BAT) are applicable.[28] The best available techniques give an overview of the best available methods for controlling *Legionella*. In Brussels and Wallonia, there are complementary *Legionella* regulations regarding only public swimming pools. In addition, both regions include requirements on cooling towers in environmental building permits.

Summary of European regulations per country

Regulations in several European countries are summarized in Table 2. In the first column, the country is listed. In the second, the object to which the regulations apply (in green) is listed. In the third column, the allowed critical concentration levels are displayed, if deviant from the critical concentrations set by EWGLI. In the fourth column, the context of the origin of the regulations is listed. In the last column, the name of the document is stated, with some additional information, if relevant.[11]

United States of America

In the United States, there were only guidelines—no regulations—until 2015. In 2015, the first official requirement to test for *Legionella* in cooling towers was released. This was followed in 2016 by the requirement to test for *Legionella* in health care facilities.[35]

American Society for Testing and Materials (ASTM) and Centers for Disease Control and Prevention (CDC) (government)

Centers for Disease Control and Prevention guidelines exist for prevention of and reaction to outbreaks.[16−19,36] There is a toolkit available on their website that is very useful for developing a *Legionella* water management program.[37,38] There is also the Industrial Hygiene Association guideline (IHA), with recommendations for *Legionella* testing.

American Society for Testing and Materials (ASTM) D5952-08, "Standard guide for the inspection of water systems for *Legionella* and the investigation of possible outbreaks of legionellosis," dates from 2015.[39] The guide explains appropriate responses by employers, building owners and operators, facility managers, health and safety professionals, public health authorities, and others to the concern that a water system may be infected with *Legionella* and to the identification of one or more cases of legionellosis (ie, Legionnaires disease or Pontiac fever).[40]

In 2016, *Legionella* made the drinking water contaminants list of the United States Environmental Protection Agency (EPA). In 2017, the Centers for Medicare & Medicaid Services (CMS) released a mandate requiring all certified hospitals to have potable water testing and water management plans that meet American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) industry standards to reduce *Legionella* risk.

Table 2
Summary of regulations and guidelines in European countries (adapted from WHO)[29,30,31,32,33,34]

Country	Object of regulations/guidelines						Critical levels if deviant from EWGLI	Context of regulation	Document
	Drinking water systems	Spa pools	Swimming pools	Cooling towers	Air-conditioning systems	Process water			
Austria								• Health • Bathing hygiene	• Aspects of drinking water (decree of Ministry of Health) • Special decree for prevention in spa pools and water systems of swimming pools • Some provinces: regulations by public health authorities
Belgium (Flanders)							1,000 - 100,000 CFU/L	• Environment • Public health • Labor safety • Biosafety	• Guidelines for hospitals and policy rule on working conditions (KB biological agents) • *Legionella* decree and code of practice for prevention of Legionnaires disease (BAT) (Flanders)[29] • Regulation for pools and cooling towers (Brussels and Wallonia) • Different risk levels covered
Bulgaria								• Public health	
Croatia								• Public health	• Guidelines - law on communicable diseases
England and Wales								• Health and (management of) safety at work • Health	• Primary legislation: Approved Code of Practice and Guidance[31], Other legislation: reporting of diseases, water supply (water fittings), notification of cooling towers, TM13[32], HPA[33] HPSC[34], BS[35]
Finland								• Health protection • Housing health • Building code • Communicable diseases	
France	partially						250 - 10,000 CFU/L	• Public health • Drinking water • Environment	
Germany							10,000 CFU/ 100 mL	• Public health • Drinking water	• Code of practice W551 (April 2004), W556 (2015), VDI/DVGW Guideline 6023 (2012)
Hungary									• There are plans to develop regulations on general prevention of legionellosis
Ireland								• Labour safety	• Guidelines • Special attention is given to potential risks of dentist systems and high risk in hospitals
Italy								• Public health	• Guidelines for the prevention and control of legionellosis
Latvia								• Labour safety • Public health	
Lithuania	hot water only							• Public health • Drinking water	• Recommendations mainly aimed at clinical manifestation, diagnostics, and treatment of legionellosis • Lithuanian hygiene standard • Draft of regulations for legionellosis aimed at prevention in institutions and accommodation where water is stored or used for work
Malta								• Public health	• Code of practice for prevention of Legionnaires disease in hotels and other establishments
The Netherlands							100 CFU/L	• Drinking water • Bathing hygiene • Safe labour • Infectious diseases • Public health	• Drinking water decree and guidance document (ISSO-publicatie 55)[36] • Decree on bathing locations and guidance document • Policy rule on working conditions • Public Health Act • Act on infectious diseases
Poland									• Regulations on *Legionella* prevention in drinking water under discussion • Regulation of new building construction under discussion • Act on infectious diseases and infections
Portugal									• Elaboration of legislation concerning installation and use of air-conditioning and cooling tower equipment • Prevention guidelines
Slovenia								• Environment • Water • Building construction	
Sweden								• Public health • Building construction	• Mandatory regulations and general recommendations
Turkey									

BAT, best available techniques; *Bruss. and Wall.*, Brussels and Wallonia; *BS*, British Standards; *EWGLI*, European Working Group for Legionella Infections; *Fland.*, Flanders; *HPA*, Health Protection Agency; *HPSC*, Health Protection Surveillance Center; *ISSO*, Instituut voor Studie en Stimulering van Onderzoek: *KB*, Koninklijk Besluit; *TM13*, Technical Memorandum 13; *VDI/DVGW*, Association of German Engineers/German Technical and Scientific.

ASHRAE standards and guidelines (industry)

ASHRAE guideline 12-2000, "Minimizing the risk of legionellosis associated with building water systems," provides specific environmental and operational guidelines for minimizing the risk of *Legionella* infection in building water systems.[41] ASHRAE is currently working on a revision of these guidelines (2017).

In 2015, ASHRAE released a standard for *Legionella* risk management; this was the first *Legionella* standard in the United States. American National Standards Institute (ANSI)/ASHRAE Standard 188-2015, "Legionellosis: risk management for building water systems," provides minimum legionellosis risk management requirements for the design, construction, commissioning, operation, maintenance, repair, replacement, and expansion of new and existing buildings and their water systems and components.[42] The publication includes a description of environmental conditions that promote *Legionella* growth and the creation of a risk management process to be implemented by building owners or managers.

The applicability of the standard depends on a survey of the building's risk factors (based on listed criteria)[43] and provides a basis for identifying systems that pose a risk of legionellosis. If the building has one or more risk factors, then application of the standard is dependent on the nature and number of risk factors identified. In some cases, it also requires the site manager to develop a water management program. There is also a particular section that provides specific guidance for health care facilities. The standard does not provide a large amount of guidance on temperatures, water treatment strategies, or testing limits,[43] and no critical levels of concentration are mentioned.

However, in the public review draft of Board of Standards Review (BSR)/ASHRAE Standard 188P, "Prevention of legionellosis associated with building water systems," water temperature recommendations for *Legionella* control are as follows: the hot water heater outlet temperature should be at or above 60°C; the hot water temperature at the coldest point in the hot water heater, storage tank, or distribution system should be at or above 51°C; and the cold water temperature in any part of the system should be at or below 25°C. If the hazard analysis and critical control point team determines that these temperatures cannot be achieved, then it may conclude that additional hazard control measures are required.[44]

Asia

China

In China, there is a code of practice for only water-cooled air-conditioning systems (2006).[45] Additionally, there is a code of practice in Hong Kong. The "Code of practice for prevention of Legionnaires disease" was first published by the Prevention of Legionnaires' Disease Committee (PLDC) in 1994 and was subsequently revised in 2000, 2007, and 2012.[46] Taking into account the experience and the evolving knowledge of other countries, as well as lessons from past major cases, the newest revised edition formulates strategies for Legionnaires disease prevention. It features enhanced precautions for hot and cold water supply systems, from which it is possible to derive broader practical guidelines for proper design, operation, maintenance, and handling of related facilities or materials to avoid the spread of *L pneumophila* bacteria. The objects of the code are cooling towers, air-conditioning systems, hot water supply systems, cold water supply systems, architectural fountains, spa pools (whirlpools), and other water-using devices. The code contains several chapters (Appendix A).

The code states that the hot water storage tank of the system (eg, directly or indirectly heated calorifier, storage vessel) shall be designed to operate at 60°C or above to effectively kill the bacteria and that the water temperature in all distribution pipework prior to the thermostatic mixing valve or tap outlet (for systems without mixing valve) shall be at least 50°C. However, in places where people with decreased self-care ability may use hot water (eg, pediatric, geriatric, and psychiatric wards of hospitals; homes for the elderly; residential care homes for persons with disabilities), to prevent accidental scalding, the hot water supply temperature at outlets shall not exceed 43°C. No critical concentration levels are mentioned.

Singapore

In Singapore, there is the "Code of practice for the control of *Legionella* bacteria in cooling towers," published by the Institute of Environmental Epidemiology (IEE).[47] No critical *Legionella* concentration levels are mentioned.

Dubai

In Dubai, there are *Legionella* guidelines and regulations, both of which are enforced. In contrast to other countries, there is a large focus on the use of seawater. Dental clinics have separate guidelines.[48]

Russia

In 1981, the first Russian *Legionella* guidelines appeared, with an update in 2017. In total, there are 7 national guidelines and recommendations (2007) concerning monitoring. In 2010, national rules for prevention of legionellosis were enforced and target levels were determined. For hospitals, for example, there is zero tolerance (0 cfu/L).[49]

Other countries

New Zealand and Australia have a combined standards association air handling, water systems of buildings, and microbial control.[50]

New Zealand

The guideline "The prevention of legionellosis in New Zealand: guidelines for the control of *Legionella* bacteria" aims to increase awareness of the hazards associated with *Legionella*, improve the management of potential sources of *Legionella*, and improve reporting and investigation of cases of legionellosis.[51] It provides up-to-date information, advice, and guidance for minimizing the risk of significant infection in water of cooling towers and cold and hot water distribution systems. It is intended to assist all those concerned with *Legionella*, including public health service providers, territorial local authorities, building owners, air-conditioning engineers, employers, and others dealing with building maintenance. No critical concentration levels are mentioned.

Australia

In Australia, there are over 25 guidelines, codes, and regulations, but they are not always in agreement.[56] There have been guidelines for the control of Legionnaires disease since 1988—with an update in 1999—and a code of practice for the control of Legionnaires disease since 2004.[52−55] The purpose of the code of practice is to assist and provide guidance to all those concerned with various aspects of microbial control in the specific systems that may harbor *Legionella*. This code emphasizes water and air systems of buildings, but the content is equally applicable to equivalent industrial processes, such as power stations and process heat rejection devices that use water. No critical concentration levels are mentioned, except the threshold level of 10 cfu/mL for cooling towers.[58] There is also a guide to developing risk management plans for cooling tower systems.[57]

Africa

South Africa has the "Regulations for hazardous biological agents," in which *Legionella* is identified. They demand the acceptance of responsibility for the control of exposure of individuals to *Legionella* and highlight the need for adequate training and information, risk assessment, monitoring, and record keeping.[58,59] However, this is

limited by the fact that the regulations are generic and applicable to all entities identified as hazardous biological agents, with no defined or legislated code of practice specific to *Legionella* monitoring and control.[59] No guidelines are applicable to other parts of Africa.

South America

Most countries in South America also refer to ANSI/ASHRAE Standard 188.[44] In Brazil, *Legionella* is not a notifiable disease. *Legionella* is included in Federal Law 6.938/81, the environmental act, which mentions that, in cases of human negligence, the responsible party is liable for *Legionella* infections resulting from not taking reasonable measures to prevent proliferation.62

Key factors of regulations

The key points of the regulations are summarized in Table 3. In the first column, the authority (organization, country, or continent) is listed. In the subsequent columns, the following questions are answered: Is *Legionella* a reportable disease? Are there any testing guidelines? Have action levels for sampling results been determined? Are there maintenance strategies? Are there mitigation plans?

What about temperature levels?

Different authorities have different temperature regulations.[61] These regulations are summarized in Table 4. In the first column, the authority (organization, country, or continent) is listed; in the second column, the required temperature at the water heater is listed; in the third column, the required temperature at the return loop is listed; and in the fourth column, the required temperature at the point of use is listed.

Concerning chemical disinfection techniques

The use of chemical disinfection is region-dependent. For the most part, free chlorine is used either at low concentrations as a secondary disinfectant (0.2-0.5 mg/L) for the maintenance of water quality in distribution systems or at higher concentrations as an installation disinfection treatment called "hyperchlorination."[62] Chlorination has many disadvantages, including the fact that 4-6 mg/L of chlorine kills only 90% of *L pneumophila* species.

The national/local regulations concerning the admissible quantity of free chlorine in drinking water (at the user outlet) can vary from 0.1-1 mg/L.[24,60] In Belgium, for example, the maximum concentration of chlorine is 0.25 mg/L.[63] In Germany, 0.2-0.4 ppm of chlorine dioxide can be injected into water; the 0.4 ppm limit is the highest in Europe. In Denmark, the addition of chlorine dioxide is prohibited in cold water; it is only allowed in hot water. Overall, in countries like Germany and Belgium, chemical disinfection is avoided because of its disadvantages. First, it can damage plumbing components; second, the long-term effect on human health is unknown. German risk regulation states, "Water is free from any micro-organism which constitutes a potential danger to human health."[27] In Germany, Belgium, and The Netherlands, disinfectants are not used as preventive measures but are used during outbreaks. In Italy, this is impossible because the high cold water temperatures cause *Legionella* growth in cold water.

In Europe, thermal treatment is recommended. Alternative treatments are only permitted when thermal treatment is insufficient. Alternative treatments are recommended in the following order: (1) physical disinfection (pasteurization, ultraviolet radiation, micro- and ultrafiltration); (2) electrochemical disinfection (copper-silver ionization, anodic oxidation); and (3) chemical disinfection (free chlorine, chlorine dioxide, etc).

Table 3
Key factors of regulations

	Reportable disease	Presence of testing guidelines	Action levels for sampling results	Preventive maintenance strategies	Mitigation plans
WHO	Reportable in some countries	Testing is recommended; requirements and frequencies are included	Only for cooling water systems	Temperature (recommended temperature for storage and distribution of cold water is below 25°C and ideally below 20°C. For hot water, they only state that hot water temperature should be maintained)	Disinfection, cleaning, monitoring, and regular service and maintenance
EWGLI	Reportable in some counties (eg, United Kingdom), reporting of travel-associated cases	Testing is recommended; requirements and frequencies are included	Different actions required between 1,000 and 10,000 and above 10,000 cfu/L	Temperature (total volume of the tank needs to be heated up to 60°C for at least an hour a day or a week, depending on the risk; cold water below 25°C), chlorination in Italy	Risk assessment and management plan in combination with regular measurements
USA	Reportable	Recommendations for *Legionella* testing	Not included	Temperature (hot water heater outlet temperature should be at or above 60°C at the coldest point in the hot water heater, storage tank or distribution system at or above 51°C, and cold water temperature in any part of the system at or below 25°C), standard chlorination	Creation and implementation of a risk management process and *Legionella* water management program
Asia	Only reportable in Hong Kong	Not included	Not included, only target levels in Russia	Temperature (hot water production above 60°C)	Not included
Other countries					
New Zealand	Not reportable	Some recommendations	Not included	Temperature	Not included
Australia	Reportable	Not included	Not included, except for 10 cfu/mL for cooling towers	Temperature	Risk management plans for cooling tower systems
Africa	Not reportable	Not included	Not included	Temperature	Not included
South America	Only reportable in Brazil	Not included	Not included	Temperature	Not included

EWGLI, European Working Group for *Legionella* Infections; *USA*, United States of America; *WHO*, World Health Organization.

Table 4
Comparison of temperature regulations by different authorities[58]

	Water heater	Return loop	Point of use
WHO	>60°C	>55°C	≥50°C (after 1 minute)
EWGLI	≥60°C (1 hour a d/wk)	≥55°C	≥55°C (70°C should be possible)
UK	≥60°C	≥50°C/loop	≥55°C (health care)
France	>55°C (recommendation ≥60°C)	>50°C	≥50°C
USA	≥60°C	≥51°C	≥43.3°C to 49°C (health care)
Asia	≥60°C	Not included in regulations	≥50°C/≤43°C (health care)

EWGLI, European Working Group for *Legionella* Infections; *UK*: United Kingdom; *USA*, United States of America; *WHO*, World Health Organization.

RESULTS

Similarities in current regulations

In reviewing existing *Legionella* regulations and guidelines, it can be noted that they have multiple similarities. Despite different regulatory frameworks, there is a broad unification of 3 principles. First, almost all guidelines have a section about avoiding and monitoring critical spots. Critical spots are locations in a hot water installation where water stays in the *L pneumophila* growth temperature range for a certain time. These spots need to be inspected properly so that problems can be noticed quickly, limiting possible infection.

Second, several guidelines discuss measures for avoiding water stagnation in certain parts of the system and thus preventing *L pneumophila* proliferation.

Third, the most commonly used measure in many countries is the requirement of a sufficiently high temperature to prevent the growth of *L pneumophila*. Most countries set cold water temperature requirements as well as hot water temperature requirements for the water heater, the return loop, and the points of use. EWGLI recommends that the total volume of the storage tank needs to be heated to 60°C for at least an hour a day or a week, depending on the risk. It should be possible to achieve a temperature of 70°C at every tap. Cold water temperature should be kept lower than 25°C. The temperature at the end of the circulation system cannot be more than 5°C lower than the supply temperature at the storage tank. The code in China states that the system's hot water storage device shall be designed to operate at 60°C and that water temperature in all distribution pipework shall be at least 50°C. Other standards (like ASHRAE) do not provide a large amount of guidance on either water treatment strategies or temperatures, except temperatures mentioned in the draft version of Board of Standards Review (BSR)/ASHRAE Standard 188P, which has, however, not been included in ANSI/ASHRAE Standard 188.

Comparison with other references

Many of the published guidelines and standards are not necessarily evidence-based. That is why, for each common item that has been identified, references to scientific (clinical) studies that support the importance of these items are given, if available. The precision, accuracy, and effectiveness of ways to estimate the risk of higher *Legionella* numbers have only rarely been empirically assessed in practice, although there is a broad consensus regarding the impact of these risk factors.[66]

Avoiding and monitoring problematic locations in the system

The article by Harper[65] deals with the engineering implications of Legionnaires disease outbreaks. The aim of the article is to set out steps that might be taken when a hospital outbreak occurs and a water system is identified as the source. Results are based on case study experience. Cabanes et al[66] presented preliminary data concerning a method of risk assessment of a water distribution system in France and emphasized the lack of data (especially in France) regarding risk evaluations of the development of *Legionella* in individual hot water supply systems. Ha et al[67] wrote a combined biological/engineering article dealing with an outbreak in Pas-de-Calais, France. Frayne[68] discusses the need for, and the use of, active monitoring, control, and management of waterside environments in cooling, heating, and potable water systems. Blanky et al[69] wrote a combined biological/engineering article dealing with monitoring the presence of *Legionella* from potable water to treated graywater. Vance et al[70] researched the ecological niche of *Legionella*, the diagnosis of human infection, and its isolation from the environment.

Avoiding water stagnation points in the system

Stagnation within water systems has been cited by numerous authors as a condition that favors *Legionella* replication.[71,72] However, the effect of low-flow conditions on the presence of *L pneumophila* in a water system has not been scientifically evaluated.[73] Völker et al[64] found by logistic regression modeling that occurrences of *L pneumophila* (>100 cfu/100 mL) at single outlets were significantly correlated with 3 parameters: (1) temperature after flushing until no significant changes in temperature can be obtained; (2) stagnation (low withdrawal, qualitatively assessed); and (3) pipe length. They also predicted the impact of each variable on *Legionella* infection risk.

Appropriate temperature management to prevent growth

Multiplication of *L pneumophila* is dependent on water temperature. This relationship has been found by studying *L pneumophila* bacteria in laboratory conditions.[74] At temperatures below 20°C, the bacteria become dormant but remain viable for months. The bacteria grow best at temperatures between 20°C and 45°C, with an optimum range around 35°C-41°C. Beyond 45°C, pasteurization starts, and higher temperatures will eventually kill the organism. The time needed to double the number of *L pneumophila* cells in water is less than half a day at 41°C, and at 70°C, 90% of *L pneumophila* die in less than a minute.

Spinks et al[75] investigated the health risks of using harvested rainwater in DHW systems and found that a temperature range of 55°C-65°C was critical for effective elimination of enteric/pathogenic bacterial components, supporting the thesis that hot water systems should operate at a minimum of 60°C.

Differences in current regulations

Notwithstanding the multiple similarities, it can also be noted that current *Legionella* regulations and guidelines have some differences. First, the target group is often very specific. A large proportion of documents are applicable to a limited group of buildings, namely health care facilities and cooling towers. In health care facilities, the risk of infection is higher due to the user's age and health status. Furthermore, the typical type of hospital system is a circulation system, which is more vulnerable to *Legionella* infection. Other services, such as collective DHW systems in sports centers or apartment buildings, are often not part of the guidelines or regulations; only sufficiently high temperatures should be maintained in their storage tanks. This, at least, is remarkable because the European Union (EWGLI) sets no

restrictions on public establishments, and their measures are valid for both cold and hot water installations.

Second, the definition of what constitutes a dangerous *Legionella* concentration level varies between countries. EWGLI demands different measures for concentrations between 1,000 and 10,000 cfu/L and more than 10,000 cfu/L. European countries are not obliged to follow the critical concentrations set by EWGLI, which results in differences between countries. The defined critical concentration limit is lowest in The Netherlands (100 cfu/L for priority institutions). In neighboring Belgium, a similar device (eg, in a hospital) should be closed to use after repeated occurrences of 10,000 cfu/L in the installation. A factor 100 difference is at least remarkable in a period of ever increasing integration of European legislations. Most non-European documents (like ASHRAE) do not include critical levels, nor do they provide a large amount of guidance on testing limits.

Finally, most guidelines and regulations talk about *Legionella* in general, but if *L pneumophila* is what is actually meant, this could be specified in future updates and a unification of the guidelines.

Comparison with other references

Although there is no information available on the infective dose in humans, it can be assumed to be low in susceptible people, as illnesses have occurred after short exposures and at 3 km or more from the source of the outbreak. The likelihood of illness depends on the concentration of *Legionella* in the water source, the production and dissemination of aerosols, host factors such as age and preexisting health conditions, and the virulence of the particular strain of *Legionella*. At the same time, it has to be recognized that most exposures do not cause illness.[3]

DISCUSSION

Comparing frameworks can be a first step on the path to future unification of *Legionella* regulations. Current regulations involve a wide range of climatologic circumstances. Still, the same measures are recommended in different environmental circumstances worldwide because it is the characteristics of the DHW system that dominate over different climatic conditions. Clearer and more uniform and unambiguous regulations will facilitate their implementation. Finally, we can ask the question, Do we have clear, uniform, and unambiguous *Legionella* guidelines and regulations? The answer is obviously that we do not. However, despite different regulatory frameworks, there is a broad unification of principles.

CONCLUSIONS

This article documents a broad summary of how various authorities worldwide deal with *Legionella* prevention and infection through the use of different standards, guidelines, and recommendations. Comparative analysis is a good starting point for reaching future unification of the different regulatory frameworks. The current guidelines and standards are not the clearest or most uniform or unambiguous, but the underlying principles are already broadly unified. In a global market, it should thus be possible to reduce the number of guidelines, standards, and regulations so that more unified documents can be created without losing important country-specific nuances.

In the future, with the aim of more energy-efficient building in mind, the question of whether we can reduce temperatures for hot water production during certain periods of time will be raised. Simulating *L pneumophila* growth can ultimately result in a more accurate prediction of bacterial concentration, and, based on that gain in knowledge, energy-saving alternatives can be researched. As such, *L pneumophila* simulation can provide a firm scientific basis for updating existing standards and guidelines.

APPENDIX A. SUPPLEMENTAL MATERIAL

World Health Organization

WHO currently provides information and guidance on *Legionella* risk assessment and management in 7 principal documents:

- "Epidemiology, prevention and control of legionellosis."[76]
- "Recommended surveillance standards."[77]
- "Guidelines for drinking water quality."[78]
- "Revision of the international health regulations."[79]
- "Guidelines for safe recreational water environments."[80]
- "Guide to ship sanitation."[21]
- "*Legionella* and the prevention of legionellosis."[11]

European Working Group for Legionella Infections (government)

Limiting possible infection can be done using the following principles:

- Preparation of a risk assessment and management plan, in combination with regular measurements.
- Presence of temperature sensors at the start and return of the circuit.
- Presence and use of valves in circuits to isolate parts that will not be used for a longer period of time.
- Presence of inspection covers at the level of the nonreturn valves.
- Possibly emptying the storage vessels so they can be cleaned on a regular basis.

An overview of measures affecting temperature in the installation is given below:

- When a storage tank is present, the total volume of the tank needs to be heated up to 60°C for at least an hour a day or a week, depending on the risk. The authors of this review article state there is some evidence this may not be sufficient, and that this temperature is often kept constant for reasons of safety and simplicity.
- It should be possible to achieve a temperature of 70°C at every tap.
- When a circulation distribution system is present, the temperature at the end of the circulation system cannot be more than 5°C lower than the temperature of the supply at the storage tank. An exception to this rule is the use of end-use pipes at the different outlets that are no longer than 5 m and contain less than 3 L.
- Insulated pipes cause less heat loss, meaning supply and return temperatures vary less and adaptation of the allowed flow rate is not necessary.

The authors of this review article state that insulating all pipes is not always the best solution. End-use pipes should cool down as soon as possible to limit the amount of time spent in the critical temperature range for *Legionella* growth, so insulating them should be avoided.

- Cold water temperature should be kept lower than 25°C to prevent growth in the cold water circuit.
- To avoid cold water heating up and hot water cooling down, cold and hot water pipes cannot be located too close to each other.

The following measures avoid stagnation of water in certain parts of the system and prevent proliferation of *L pneumophila*:

- A simple system with few turns reduces pressure loss and the risk of water stagnation.
- Regular use of hot water avoids dead pipe ends (ie, tap that is no longer used).

- Rarely used outlets need to be installed upstream to limit the length of pipes with stagnant water.
- Pipes need to be flushed after a period without water use.
- Buffer reservoirs should be limited in size and number.
- Not insulating distribution pipes ensures stagnant water cools rapidly to room temperature (ie, shorter stay in critical temperature range). The authors of this review article indicate that this contradicts earlier information.

Germany

In Germany, there is Code of Practice W551 (2004) for drinking water installations, which recommends some best plumbing practices, including:[25,26]

- Keeping the stored water volume small.
- Keeping hot water temperature above 60°C when leaving the tank and at or above 55°C in circulation distribution pipes. This is in accordance with DIN 1988-200, section 10.2.3.
- Keeping noncirculating (like end-use) pipes short.
- Avoiding stagnation.
- Regular maintenance and inspection of the system.
- Rehabilitation, such as the use of insulation and the use of electronic self-flushing taps.
- Performing hygienic-microbiological examinations.

China

The "Code of practice for prevention of Legionnaires' disease" contains several chapters:

- "Guidelines on design, operation and maintenance of water using apparatus."
- "Collection of water samples from water using apparatus for testing *Legionella*, Heterotrophic Colony Count (HCC) and other water quality parameters."
- "Control measures during outbreaks of Legionnaires' disease."
- "Design, operation and maintenance records."
- "Handling garden soils, composts and potting mixes."

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