Code of practice –

The CEN/TR 16355 technical report of CEN/TC 164/WG 2 on Legionella applied to solar hot water systems

Version: Final draft

Date: 2 May 2012

Authors: G. van Amerongen

vAConsult (NL), liaison officer for TC312 in TC164

John V. Lee

Leegionella Ltd (UK)

Jean-Marc Suter

Suter Consulting (CH), deputy liaison officer for TC312 in TC164

This report was commissioned by the Solar Certification Fund and referenced under the acronym "Legio2010" and the title "Litarture study on Legionella".

THE AUTHORS:

vA Consult

Gerard A. H. van Amerongen
vAConsult, Fatswallerhof 22, NL-3069 PZ Rotterdam,
The Netherlands
Phone: +31 648 624 487
E-mail: vaconsult@vaconsult.net

John V. Lee
Leegionella Ltd, 46 Howletts Lane, Ruislip, HA4 7RS, UK
Phone: +44 1895 674141
E-mail: JohnVLee@leegionella.co.uk

Suter Consulting

Jean-Marc Suter
Suter Consulting / Multilingual written communication,
Aarstrasse 98, CH-3005 Berne
Phone: +41 31 311 49 42
E-mail: suter@suterconsulting.com

Contents

Foreword

The study on which this report is based did not include model calculations. For that reason, some reported values in the recommendations are currently only tentative. To finalize the Code of Practice a separate arithmetical modelling study is needed to improve the status of these values. This concerns the following recommendations:

- the method of subsection 6.1;
- the recommendation B.2 in annex B;
- the recommendation of section 4, paragraph 3a.

The authors of the report have in depth expertise in hot water systems, solar thermal systems and *Legionella* ecology and control. The recommendations are based on in depth knowledge, experience and published evidence. In order to reach agreement on the recommendations amongst concerned parties (potable water authorities and solar thermal industry) further actions are needed. The draft report should be offered to both the CEN/TC 164 and CEN/TC 132 for discussion, fine tuning and ultimately for acceptance. It would be most efficient if this is done in a common (ad hoc) working group of both TC's. However, if this is not possible the draft report can be handled by the CEN/TC 132 only.

There is a need for a carefully designed broad field study aimed at determining the frequency of occurrence of *Legionella* in hot water systems and especially systems including renewable energy sources in comparison with conventional hot water systems of otherwise similar characteristics in terms of age, complexity, design and construction materials. This should be a comprehensive study covering a representative part of Europe and most of the different types of hot water systems. A limited sized study is not recommended, since this may well cause more uncertainty than the one we are now experiencing.

The study may be financed by one of the European research programs (e.g. IEEE).

There is also a need for a trial of heat and other disinfection regimes using plumbing test rigs incorporating solar hot water heating and colonised with legionellae under natural conditions. This study should investigate the need for frequent heating to 60 ºC to control legionellae in such systems.

Introduction

The WG2 of TC164 prepared a technical report entitled: “Recommendations for prevention of Legionella growth in installations inside buildings conveying water for human consumption”, dated 2011-08-31 and referenced in this report as CEN/TR 16355.

The CEN/TR 16355 focuses on conventional hot water systems and does not consider the applicability of its recommendations to solar hot water systems.

This code of practice interprets CEN/TR 16355 to adapt its recommendations to solar hot water systems.

In the context of *Legionella* control the factors that need special consideration for solar hot water systems are:

- the use of storage tanks with frequently changing water temperatures in the range of 10 ^{o}C to 80 ^{o}C, so that part of the tank and water is within the temperature range favourable to the growth of *Legionella* species;
- the use of a storage tank that frequently and for long periods is at a temperature level above 65 ^{o}C and, as such, disinfects the *Legionella* and biofilms within the tank;
- the use of non-solar heat sources that may thermally disinfect the hot water.

Solar-only systems cannot guarantee a high enough hot water temperature at the draw-off points as required by EN 806-2 (60 ^{o}C) and many national regulations within Europe. As such, solar-only systems are not generally allowed within Europe, are not relevant for the CEN/TR 16355 report and do not fall within the scope of the present report. For informative purpose, Annex B gives recommendations for their safe use.

1 Scope

This code of practice provides recommendations on solar hot water systems and solar assisted hot water systems that minimize the risk of *Legionella* infection by the user of, and others exposed to, the system.

The report is limited to *solar assisted hot water systems*:

- with a solar collector that uses a liquid as the heat transfer fluid and is equipped with a transparent cover; and
- with one solar heat storage tank with a capacity larger than 30 litres per square metre solar collector.

This report supplements the CEN/TR 16355 technical report.

2 References

2.1 Normative references

EN 806-1	Specifications for installations inside buildings conveying water for human consumption – Part 1: General
EN 806-2	Specifications for installations inside buildings conveying water for human consumption – Part 2: Design
EN ISO 9488	Solar energy - Vocabulary
EN 12976-1	Thermal solar systems and components – Factory made systems – Part 1: General requirements
EN 12977-1	Thermal solar systems and components – Custom-built systems – Part 1: General requirements
EN 15316-3-1	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements)
98/83/EG	on the quality of water intended for human consumption. Adopted by the Council, on 3 November 1998
2002/359/EG	on the procedure for attesting the conformity of construction products in contact with water intended for human consumption, pursuant to Article 20(2) of Council Directive 89/106/EEC

2.2 Other references

- SIA 385/1, Anlagen für Trinkwarmwasser in Gebäuden –Grundlagen und Anforderungen [1]
- CEN/TR 16355, 2011-08-31, Recommendations for prevention of Legionella growth in installations inside buildings conveying water for human consumption
- TNO report, 2003-DEG-R014, 7 May 2003, Microbiological safety in solar domestic hot water systems

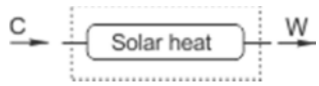
[1] Also available in French under the title “Installations d'eau chaude sanitaire dans les bâtiments – Bases générales et performances requises”.

3 Terms and definitions

For the purpose of this document, the following terms and definitions, derived from EN 806-1 and EN ISO 9488, apply:

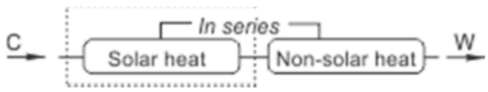
Solar-only system,

is a solar heating system without any auxiliary heat source. In this report, the heating service is defined as heating up cold potable water to the hot water temperature.



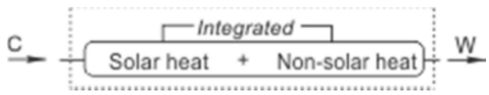
Solar preheat system,

is a solar heating system to preheat water or air prior to its entry into any other type of water or air heater.



Solar-plus-supplementary system,

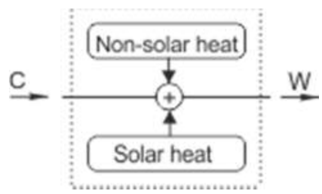
is a solar heating system that utilizes both solar and auxiliary energy sources in an integrated way and is able to provide a specified heating service independent of solar energy availability. In this report the heating service is defined as heating up cold potable water to the requested hot water temperature.



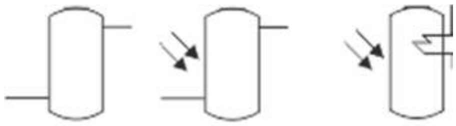
Solar assisted hot water system [2]

Generic term to designate a solar preheat system and its series-connected water heater, or a solar-plus-supplementary system. A solar assisted hot water system has a non-solar water heating part, named auxiliary part, and a solar heating part. There are various possible interactions between the two parts.

NOTE: Prevention of *Legionella* growth requires measures to be applied to all devices whose function is to heat up the potable water. As solar preheat systems do not include the series-connected water heater, a new definition is needed to include this water heater.



[2] French: chauffe-eau avec apport solaire. German: solar unterstützter Wassererwärmer

Auxiliary heater, is a source of heat, other than solar, used to supplement the output provided by the solar energy system.	
Instantaneous water heating [3]**,** is the action of instantaneously heating up hot water by means of a heat exchanger that is located outside the heat storage tank in a loop with forced circulation.	
Storage water heating [4]**,** is the action of heating up hot water by means of a device containing a volume of potable water. This includes a storage tank with process water with an integrated heat exchanger filled with potable water.	

Legionella	the name (epithet) of the genus of bacteria that encompasses over 50 species including over 20 that have been associated with infection in man. (*Legionella* is analogous to *Homo* the genus to which humans belong.)
legionella	a bacterium of the genus *Legionella* (analogous to a human)
legionellae	the plural of legionella (analogous to humans)
L. pneumophila	*Legionella pneumophila* or *L. pneumophila* is the name of a species where *pneumophila* is the species specific epithet (analogous to *sapiens* in *Homo sapiens).* The most common cause of legionnaires' disease.
decimal reduction time D	is the time taken to kill 90% of a population of bacteria or other organisms.

[3] French: chauffage instantané de l'eau. German: Wasserdurchlauferhitzung (?)

[4] French: chauffage de l'eau dans un accumulateur. German: Wassererwärmung im Speicher

4 Recommendations applicable to all solar hot water systems

All components containing potable water can potentially add to the risk from microbiological hazards. In order to manage the risk from *Legionella* the following recommendations are given for the components of solar hot water systems:

1) *Materials*
   a. Use materials and inner surface finishing of the heat storage tank in conformity with the requirements in use in the food industry.
   b. Use materials in accordance with national and European standards for materials being in contact with potable water (2002/359/EG and national implementations thereof).
   c. The following materials are recommended: stainless steel, copper or enamelled steel.
2) *Design of containers holding potable water*
   a) Design the container in such a way that the whole potable water volume is moved during draw-off and can be refreshed regularly.
   b) The storage tank design should be such that also the bottom part of the storage tank can be heated sufficiently. When a heat exchanger is applied, the lowest part of the heat exchanger should not be more than 5 cm above the lowest part of the storage tank.
   c) At least for storage tanks with a potable water volume greater than 400 litres, incorporate an inspection hatch at the bottom of the tank in order to be able to regularly remove deposits.
   d) Minimize or prevent the use of sacrificial anode and internal screw joints.
3) *Controller*
   a) Limit the setting of the maximum potable water storage tank temperature to 80 ^{o}C to prevent deposition of lime. Depending on the local potable water hardness, this temperature setting may be lower or higher (+- 10 ^{o}C).
   b) Install a device that signals any malfunction of the system to the user, especially that of the collector loop.
4) *Documentation*
   a) For systems incorporating a means of cleaning the containers holding potable water, the user manual and the maintenance manual should include instructions on the methods and frequency of cleaning.
   b) The user manual, installation manual and maintenance manual should include a procedure to check the correct operation of the system.
   c) The user manual should include a part dealing with recommendations to prevent microbiological risks, including the growth of *Legionella*.

5 Recommendations applicable to solar assisted hot water systems

The recommendations are structured according to the two main heating functions (solar and auxiliary) and the type of heating (instantaneous water heating or storage water heating).

- *The solar heating part of the system* includes all components that can only be heated up by the solar collectors (collector loop, part of the storage devices with their heat exchangers).
- *The auxiliary heating part of the system* includes the components that can be heated up by an auxiliary heater or by heat transferred from the solar heating part.

Both parts can be designed as two different types of devices: as an *instantaneous water heater* or a *storage water heater.*

The CEN/TR 16355 gives recommendations on both the hot water installation as a whole and the components that heat up the potable water. The following paragraphs focus on the components. The CEN/TR 16355 recommendations on the installation are assumed to apply.

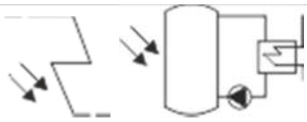
The following recommendation applies to all heat exchangers used as instantaneous water heaters.

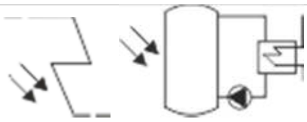
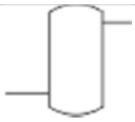
Recommendation:

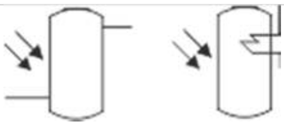
- When an external heat exchanger is used as an instantaneous heater, the pump in the loop should be controlled as such that the water is allowed to cool down in periods without draw-off.
- The heat exchanger cannot be insulated.
- The potable water should be heated in the heat exchanger in a single pass.
- A heat trap or return valve should be applied to prevent the heat exchanger from convective heating from the heat storage tank.

The following give recommendations on all combinations of functions and types.

5.1 System designs

	Solar thermal heating	Auxiliary heating
Type:	Instantaneous water heating	Instantaneous water heating
		
Recommendations:	None	

	Solar thermal heating	Auxiliary heating
Type:	Instantaneous water heating	Storage water heating
		
Recommendations:	R.1 (according to CEN/TR 16355)	

	Solar thermal heating	Auxiliary heating
Type:	Storage water heating	Instantaneous water heating
		
Recommendations:	– R.2 for low risk application, or – R.3 for medium or high risk applications	
Remarks:	Risk levels according to Table 1.	

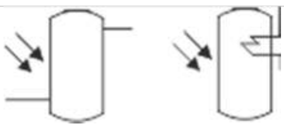
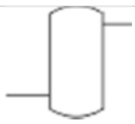
	Solar thermal heating	Auxiliary heating
Type:	Storage water heating	Storage water heating
		
Recommendations:	– R.4 or, – R.2 for low risk application, or – R.3 for medium or high risk applications	
Remarks:	Risk levels according to Table 1.	

Table 1 - Building categories and risk levels [5] based on SIA 385/1 (CH)

Risk Level	*Building Category*
low	– Single-family housing – Residential apartment building without central hot water supply – Administration – Schools without showers – Sale – Restaurants – Meeting rooms – Stores, repositories
medium	– Residential apartment building with central hot water supply – Schools with showers – Hotels, military barracks – Hospitals without the below mentioned departments – Sport facilities, indoor and outdoor pools
high	– Hospitals with intensive care units, transplant departments and / or special departments (oncology, haematology, etc.) – Housing for elderly and disabled people, prisons

5.2 Recommendations on system designs

Recommendation R.1

The temperature in the auxiliary heat storage tank should be ≥ 55 °C during the whole day or should be heated up to ≥ 60 °C for one hour each day.

Recommendation R.2

Apply at least one of the following measures:

a) Dimension the solar heating part in such a way that frequent thermal disinfection of the storage tank occurs according to the method described in 6.1 [6] and apply a warning device to indicate possible malfunctioning of the collector loop according to 6.3.1.

b) Thermally disinfect the heat storage tank(s) according to the method described in paragraph 6.2.

c) Apply one of the non-thermal disinfection techniques listed in annex C.

[5] Although legionellae are present everywhere in aqueous environments, only their introduction into the lung may be a potential health hazard. Therefore, apparatus and systems like, e.g., showers may present a risk through the aerosols that they create. In addition, the risk of getting sick increases if the person concerned has a weakened immune system.

[6] Under these conditions the storage tank is frequently fully disinfected and the biofilm destroyed by solar heat.

Recommendation R.3:

Apply the following measures:

a) Thermally disinfect the heat storage tank(s) according to the method described in paragraph 6.2.

b) Apply the recommendations of section 4 and follow the sampling procedure according to 6.4. Take appropriate measures when significant concentrations of *Legionella* are found.

c) Add a procedure in the maintenance manual for a routine check of the system well-functioning.

Recommendation R.4:

a) Dimension the auxiliary storage tank volume larger than ½ of the daily design hot water demand and keep this tank at 60 °C for the whole day [7].

b) Apply a warning device to indicate malfunctioning of the auxiliary heating part according to subsection 6.3.2.

c) In both the installer manual and the user manual, state that exceptionally large water draw-offs may result in a signal pointing to a malfunctioning of the auxiliary heating part.

[7] Under these conditions legionellae are effectively disinfected by the auxiliary heater. Both disinfection duration and temperature are critical. This recommendation exceeds the recommendation of 55 °C in the CEN/TR16355.

6 Methods

6.1 Intrinsic frequent thermal disinfection

The following method gives recommendations for the design of the solar assisted hot water system to create optimal conditions for frequent disinfection of the storage tank in the solar heating part.

- *Sizing of components*
  The sizing of the components should be such that the maximum storage tank volume of the solar heating part follows the recommendations given in Table 2.
  The climatic regions are detailed in Table 4, the categories of collector positioning are detailed in Table 3 and the application risk levels are detailed in Table 1.
- *Storage tank design*
  The storage tank design should be such that the bottom part of the storage tank can also be heated sufficiently. When a heat exchanger is applied, see section 4, paragraph 2b.

Table 2 - Recommended storage tank volume per unit of collector aperture area (L/m^2). The values given here are only tentative and should be verified by computerized simulation in a follow-up project. The table is only applicable for glazed collectors.

	Climate type (Table 4):		
	Average	Warmer	Colder
Application:	Low risk		
Cat. 1	60	70	50
Cat. 2	50	60	40
Application:	Medium risk		
Cat. 1	50	60	40
Cat. 2	40	50	30

Table 3 - Categories of collector positioning

Cat. 1	Collector azimuth in the range [-45° to +45°] (south-west to south-east), collector tilt angle in the range [latitude-20° to latitude+5°], no shadow on the collector from any obstacle.
Cat. 2	All other cases, provided that collector azimuth is within the range ± 90° (east to west through south) and the average height of obstacles above the horizon is less than 20°. All tilt angles are possible.
For all other collector positioning, no recommendations are given.	

Table 4 - Three climatic European zones - (to be detailed)

Colder climate
Average climate
Warmer climate

6.2 Forced thermal disinfection of a storage tank

The following method gives recommendations for thermal disinfection of a storage tank.

Heat up the whole storage tank as follows:

- 20 minutes at a temperature of 60 °C, or
- 10 minutes at 65 °C, or
- 5 minutes at 70 °C,
- every day for high risk applications, or every week for low and medium risk applications.

The conformity to these recommendations should be evaluated by means of temperature measurements in the storage tank or at its wall.

6.3 Devices to indicate malfunctioning

6.3.1 Malfunctioning of the collector loop

The design considerations on managing the microbiological risk assume a correctly functioning solar heat generation and transfer. As a consequence, when malfunctioning occurs, these considerations are no longer valid and the user should be made aware of that.

The malfunctioning of the collector loop should be communicated to the user by means of a warning light situated in a location that is clearly visible to the user. Stagnation in the collectors to prevent system over-temperature should not lead to the activation of the malfunction signal.

6.3.2 Malfunctioning of the auxiliary heating part

In the case of an auxiliary heater acting as an essential component for the thermal disinfection of potable water, the user should effectively be warned of any malfunctioning. Moreover, the user manual should include a description of how to react to this malfunction signal. The auxiliary heater is malfunctioning when it is not functioning according to the design assumptions.

Option 1 (preferred)

The preferred way of communicating a malfunction is through the hot water itself. When the auxiliary heater is malfunctioning, the hot water temperature at the user’s draw-off point should be significantly reduced. This could be accomplished through a controlled mixing valve that adds cold water or thru any other means.

In Figure 6.1 an example of such an installation scheme is given. The mixing valve, required by EN 12977-1 as scald protection, is used to close the storage tank output as soon as the auxiliary heater is no longer able to maintain the recommended temperature for thermal disinfection. This rapid reduction of the water temperature at the user's draw-off point warns the user that the auxiliary heating is no longer able to ensure the protection against *Legionella* growth.

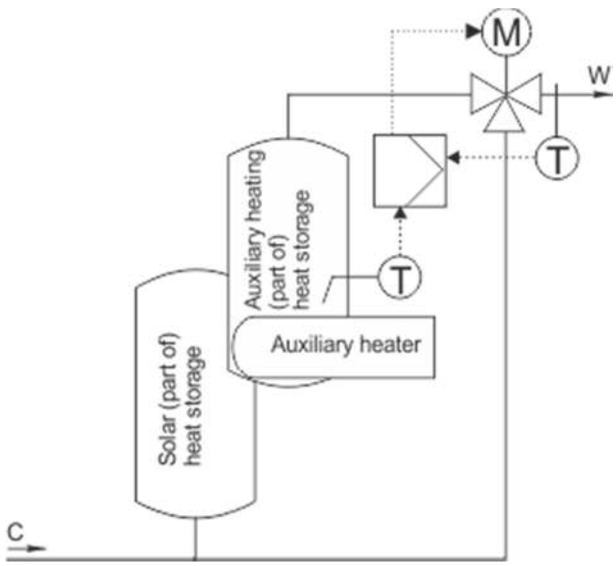


Figure 6.1 - Example of a device to detect insufficient auxiliary heating and react accordingly.

Option 2

Malfunctioning could also be communicated to the user by means of a warning light on a, for the user, clearly visible location.

6.4 Sampling procedure to check for Legionella

The following method gives global recommendations on how to perform a sample test for *Legionella* in the hot water system. In literature and national regulations more detailed methods are described.

Sampling frequency:	based on an adequate risk analysis but should be at least each three months.
Sample points:	30% of the draw-off points
Sampling location:	draw-off points (1) seldom used, (2) preferably at shower draw-off point and at a distant location of the hot water heating device

ANNEX A (Informative) - Background information

Review of reports of health risks from solar hot water systems

Since 2000, there have been expressions of concern about the potential for solar hot water systems (SHWS) to encourage growth of *Legionella* species, the cause of legionnaires' disease, to a greater degree than conventional hot water systems. The primary reason for this is the perception that SHWSs are more likely to contain a significant volume of water at a temperature conducive to the growth of legionellae. That is at temperatures between 20 and 50 °C and in particular between 32 and 42 °C.

The assessment of the risk of, or potential for, any equipment or system using water being a source of legionnaires' disease requires consideration of five points (Anon 2010):

a) *Contamination.* An evaluation of the likelihood of the equipment becoming contaminated by legionellae, including assessment of the cleanliness, temperature and integrity of the water supply.

b) *Amplification.* Consideration of the likelihood that any *Legionella* entering the system will proliferate, including an assessment of conditions such as the temperature, water change rate, areas of static or slow water movement, availability of nutrients from its construction materials and how conducive the conditions in general are to microbial growth.

c) *Transmission.* An assessment of whether droplets or aerosols are likely to form and spread.

d) *Exposure.* Determination of the risk that droplets or aerosols will be inhaled or contaminated water aspirated (pass into the lungs accidentally during swallowing of contaminated water).

e) *Host susceptibility*. An evaluation of the nature of the exposed population, taking account of their vulnerability when exposed to legionellae.

Legionnaires' disease was first recognised in 1976. Since then knowledge of the factors controlling the potential risk from recognised sources of legionnaires' disease, such as hot and cold water systems, has been derived from evidence obtained from the epidemiological and microbiological investigation of outbreaks of legionnaires' disease. In addition, once systems were identified as sources of legionnaires' disease, surveys including microbiological monitoring were carried out to establish the factors contributing to the colonisation of such systems. Outbreaks of infection inevitably occur most commonly where large numbers of people are exposed such as hotels and hospitals. In such large buildings conventional hot and cold water systems are much more common than SHWSs so that an appreciable body of information has been gathered on conventional systems but not hot water systems incorporating heating by solar collectors.

The lack of epidemiological evidence linking outbreaks of legionnaires' disease to SHWSs and the lack of microbiological evidence of the contamination of SHWSs has been cited as evidence that they are safe. However, legionnaires' disease is relatively rare and lack of epidemiological evidence linking the disease to SHWS probably reflects the relative scarcity of SHWS in comparison to conventional systems. In the preparation of this report, we have carried out extensive surveys of published peer-reviewed literature. In addition other evidence was sought by review of searches carried out using a variety of search engines and requests for information from members of the UK Water Management Society (a learned society of about 1000 members encompassing experts in all aspects of water safety and treatment).

The following databases were utilised: Google http://scholar.google.co.uk/Scholar; Information Bridge, US Department of Energy Scientific and Technical Information http://www.osti.gov/bridge; Medline Plus http://www.nlm.nih.gov/medlineplus/; PubMed http://www.ncbi.nlm.nih.gov/pubmed/; Scientific Commons http://en.scientificcommons.org/; Scirius http://www.scirus.com/; USA.gov for Science http://www.science.gov/index.html; WHO Injury Prevention Literature Update and Archive database http://www.safetylit.org/; WorldWide Science http://worldwidescience.org/.

Outbreaks of legionnaires' disease associated with hot water systems incorporating solar heating

An outbreak of legionnaires' disease occurred in a Brazilian hospital. Legionellae were isolated from the showers in the renal transplant unit that was fed from a solar heated hot water system. In the initial investigation the type of *Legionella* that was responsible for the patients' infections was only isolated from the condensate of a chiller battery in the air-conditioning system (Levin *et al.* 1991). This suggests the infection may have been of external origin. Following the outbreak, in an attempt to control the colonisation, the hot water system was periodically super chlorinated and flushed. Despite this, cases continued to occur and legionellae including *L. pneumophila* serogroup 1, the cause of the cases, continued to be detected in the hot water system. Colonisation and cases ceased to occur when the hot water system was replaced with cold water fed instantaneous electric showers (Levin *et al.* 1995). These observations clearly indicate that the hospital hot water system was the cause of the infections. However, the reports provide insufficient information on the system design and colonisation to determine if the solar component of the system was a critical or even contributory factor to the system becoming colonised with legionellae and causing the outbreak.

The outbreak in Brazil is the only report we have been able to find in peer reviewed publications, to date, implicating a hot water system that incorporated solar heating as the cause of an outbreak. There are two other instances known to the authors that have never been published in peer reviewed articles.

In September to October 1996 three cases of legionnaires' disease occurred in a hotel in Antigua. The town water supply to the hotel, and the hot and cold water distribution systems were contaminated with *Legionella pneumophila*. Highest concentrations were detected in the hot water system, particularly the hot water storage tanks and at taps in rooms that had not been used for several days. The hot water storage tanks were of the solar-plus-supplementary type with a solar storage tank filled with potable water and incorporating an auxiliary storage water heater. It was concluded that the hotel's hot water supply was the source of the outbreak (Hospedales *et al.* 1997 (abstract only) and JV Lee unpublished data). However, the solar heating system was in the process of being installed and it was concluded that the outbreak was the consequence of the disruption to the hot water system rather than the presence of the solar system itself.

In 1996, a small cluster of cases of legionnaires' disease was associated with a hotel in Marmaris, Turkey (J V Lee unpublished results). The hotel hot water system was implicated. During the cooler months of the year the water was heated by means of an oil fired boiler and during the summer by solar collectors. The cases occurred in the early part of the year and the solar tanks and associated pipes were implicated as the source of the infections because they had been left connected to the hot water system during the cool months and had been at temperatures conducive to the growth of legionellae (J V Lee unpublished data).

These three examples of outbreaks indicate that hot water systems incorporating solar heating can be the source of legionnaires' disease in much the same manner as hot water systems heated by other 'conventional' means.

Incidence of Legionella in solar hot water systems

There is very little information on the incidence of *Legionella* species in SHWSs. In preparation for the Olympics in Athens, Greece, 385 hotels were investigated for the presence of legionellae in their hot water systems (Mouchtouri *et al.* 2007b). Legionellae were not isolated when the sample temperature was greater than 60.3 °C. The majority of the systems were heated by oil but a small proportion were heated by electricity or by solar collectors. Approximately 10% of the SHWSs examined were colonised with legionellae in contrast to 69% of the systems heated by oil. It was concluded that storage water heating powered directly by electricity or solar water heaters were less likely to be colonised than those heated by oil.

However, the same workers found that thermal disinfection was more effective in hot water systems heated by oil than in the SHWSs (Mouchtouri *et al.* 2007a).

In Germany a survey of hot water systems in single-family residences showed that legionellae could not be detected in hot water systems heated by instantaneous water heaters whereas 12% of houses with hot water storage tanks contain legionellae with counts of up to 100,000 cfu/100 ml (cfu, colony forming units) (Mathys *et al.* 2008). Legionellae were only detected in two (4.2%) of the 48 SHWSs examined in contrast to 13% of 352 other systems. Solar hot water systems did not seem to promote the proliferation of legionellae but it should be noted that the authors did not report what time of year the survey was undertaken. This is an unfortunate omission as the time of year might have influenced the results for SHWSs. The authors concluded that the temperature of the hot water was the most important determining factor for the multiplication of legionellae. Hot water systems with temperatures below 46 °C were most frequently colonised.

In Denmark two studies were carried out on domestic water heaters. In the first, the growth of bacteria was compared in 12 'solar prepared' tanks and 12 traditional tanks. The work was undertaken in preparation for the new Danish building regulations which it was thought might make 'solar prepared' tanks mandatory. They found no significant difference in the bacterial counts which were low in comparison to other investigations on larger systems in flats. In the second follow up study hot water samples were taken from actual domestic hot water systems and checked for *Legionella*. Five out of 24 water hot water tanks contained legionellae. None were detected in the solar prepared tanks (solar heating tank with no solar collector connected yet), but one of the traditional hot water tanks and 4 out of the 8 solar tanks contained legionellae (Bagh and Ellehauge 2001). The solar prepared tanks that were not actually connected to solar collectors were included to see if the larger volume increased the risk of colonisation. However, since the solar collectors were not connected it is unlikely that these tanks reached temperatures that might be conducive to growth so it is not surprising that legionellae were not detected in them. In contrast the solar tanks that were connected to collectors would have reached temperatures conducive to growth and indeed legionellae were detected in these tanks.

Conclusion

There are very few studies published comparing the incidence of legionellae in conventional hot water systems in comparison to SHWSs. The number of SHWSs studied to date is too small to provide statistically reliable results. More data will be required to determine whether there is, in reality, any greater risk of SHWSs becoming colonised with legionellae than other types of hot water system. Such studies would need to be carefully designed and controlled to enable the comparison of SHWSs with conventional systems of otherwise similar age and construction. However, in the absence of such studies, it is clear that legionellae can occur in SHWSs just as they can in other hot water systems and that legionellae can sometimes multiply in SHWSs that can then become the source of legionnaires' disease. Thus SHWSs, like all water systems should be designed to minimise the risk of legionellae growing within them.

Effect of temperature on the survival of legionellae

It is widely recognised that *L. pneumophila,* the most common cause of legionnaires' disease, grows in water at temperatures between 25 °C and 45 °C with an optimal temperature in the range of 32 to 42 °C (Surman-Lee *et al.* 2007). Using a temperature gradient apparatus Konishi *et al.* 2006 found that *L. pneumophila* could not grow beyond 44.2 °C. Thus below 25 °C *L. pneumophila* grows slowly, if at all, but can survive for prolonged periods or even indefinitely whereas above 45 °C it begins to die. The effect of disinfectants is usually expressed as the decimal reduction time D which is the time taken to kill 90% of a population. Dennis *et al.* 1984 in England and Schulze-Robbecke *et al.* 1987 independently in Germany, studied the effect of temperature on *L. pneumophila* and achieved very similar results. At 50 °C the decimal reduction time was 111 min and at 60 °C about 2 min. These results would suggest that at 70 °C D would be only a few seconds.

The rate of death at temperatures above 50 °C

Stout *et al.* 1986 carried out a more extensive investigation of 75 isolates representing 10 *Legionella* species. At 60 °C the decimal reduction time ranged from 1.3 to 10.6 min. They found that for *L. pneumophila* at 60 °C, D was about 3 min (range 2.3 to 5.0) for most strains. The most resistant species was *L. micdadei* with a range of 4.5 to 10.6. At 70 °C D ranged from 0.7 to 2.6 min while at 80 °C the range was 0.3 to 0.7 min. Extrapolation of these results backwards would suggest that the decimal reduction time at 50 °C for *L. pneumophila* would be about 9 minutes. This appears to be far too short as, in the routine isolation of legionellae from water, samples are heated at 50 °C for 30 min to suppress the background flora while permitting good recovery of *L. pneumophila* and other pathogenic *Legionella* species. The higher decimal reduction time at 50 °C determined by other workers (Dennis *et al.* 1984; Schulze-Robbecke *et al.* 1987) appears to be a more likely estimate of the true value. All three groups of workers use very different methods and this may explain the differences found. The combined data from all the studies indicate that the decimal reduction time at 60 °C is about 2 to 3 min for most strains of *L. pneumophila*.

In the absence of appropriate control measures, it is common to detect *L. pneumophila* in the cool bottom of stratified hot water storage vessels at levels of up to 100,000 cfu per litre (J. V.

Lee unpublished results; Makin 2009; Mathys *et al.* 2008). *Legionella pneumophila,* in conjunction with natural supporting microflora, can be grown in model systems fed only with tap water and no additional nutrients other than those available from plumbing materials incorporated into the models. The conditions in these models systems simulate those in artificial water systems and under these conditions legionellae can grow in biofilms on surfaces of materials at concentrations of about 10,000 to 200,000 cfu per square centimetre and in the aqueous phase up to 10^6 cfu/litre depending upon the nature of the material and temperature (Rogers *et al.* 1994a; Rogers *et al.* 1994b). The highest numbers were achieved at 40 °C, lower numbers were detectable at 50 °C and none were detectable at 60 °C (Rogers *et al.* 1994b).

Legionellae have been shown to grow within the variety of protozoa both in natural and artificial water systems. Protozoa produce cysts which are a means of them surviving periods when environmental conditions are not suitable for their growth. The cysts are generally believed to be more resistant to physical and chemical agents than the vegetative protozoa and legionellae. However, legionellae can become incorporated within protozoal cysts and therefore be protected by them. Although protozoal cysts are generally considered to be relatively heat resistant there is little hard information available. *Acanthamoeba polyphaga* is an amoeba that occurs in household water systems, causes eye infections in humans and in which *L. pneumophila* can grow. Cysts of an *A. polyphaga* have been shown to survive for at least 60 minutes at 60 °C although they died slowly at 65 °C with the decimal reduction time of about 2.5 min. Thus theoretically, incorporation within cysts of *A. polyphaga* at least might enable *L. pneumophila* to survive heating at 60 °C for one hour. On the other hand heating to 60 °C has been shown to be effective at not only killing legionellae in the aqueous phase but also those growing in combination with supporting microflora including protozoa on surfaces in biofilms (Rogers *et al.* 1994b; Saby *et al.* 2005).

The rate of growth of legionellae in hot and cold water systems

To estimate the time necessary for a hot water system to become colonised following contamination with legionellae, or to become recolonised after disinfection, it is important to know how quickly legionellae can grow under the optimal temperatures for growth in water. There are surprisingly few estimates of the rate of growth of legionellae under natural conditions. In human monocytes doubling times of as little as two hours have been recorded (Horwitz and Silverstein 1980). However this observation is unique and other authors have recorded much slower growth rates. In a human cell line U937, similar to the macrophages that are infected during legionnaires' disease, at 37 °C the generation time was found to be 6 hours (Pearlman *et al.* 1988). The doubling time in *A. castellani* at 35 °C ranged from 7 to 28 hours depending upon the *Legionella* species and for most species it was about 10 hours. In continuous culture simulating natural growth conditions, dilution rates equivalent to generation times of 8 to 14 hours at 30 °C to 40 °C were used (Mauchline *et al.* 1994; Rogers *et al.* 1994a; Rogers *et al.* 1994b). Thus it appears likely that in nature the generation time probably ranges from between 6 and 14 hours at 37 to 40 °C.

Disinfection of hot water vessels

As noted above the cool base of stratified hot water vessels can harbour significant numbers of legionellae. This has been recognised for many years. A common strategy to control this in large hot water storage vessels in commercial buildings and hospitals is to ensure that the whole vessel is heated to 60 °C for at least an hour once-a-day (HSE 2000). This is commonly achieved by installing a small anti-stratification pump to circulate water from the top of the vessel to the bottom at periods of low use such as during the night. It has been suggested that a similar strategy be extended to SHWSs by ensuring that they are heated to at least 60 °C daily using supplementary heating as necessary. However, for this to be most efficient in solar heated tanks the supplementary heating, if needed, should NOT be undertaken at night as this could lead to insufficient cold water being present in the tanks in the morning for the solar collectors to work. With solar heated tanks the best time for supplementary heating to be applied, if it is needed, would be when the power of incident solar radiation is decreasing while the solar heated tank has reached its highest temperature of the day. This would normally be at least 4 hours after solar noon. The disadvantage of this approach is a requirement to use non-solar energy sources on days when the solar input is insufficient to raise the temperature to at least 60 °C. It is clear that, as with conventional hot water storage vessels, there is some risk of legionellae growing in solar hot water tanks when the temperature does not reach temperatures that will kill legionellae.

The risk of a hot water system being the source of legionnaires' disease depends on a number of factors. The hot water storage vessel is often the first point of amplification of legionellae in a hot water system. The organisms growing within the vessel may subsequently be transported elsewhere within the system to colonise other parts particularly in the region of the draw-off points. It is colonisation of the draw-off points that is usually responsible for infection. Prevention is multifactorial and minimisation of growth within the hot water storage vessels is only one factor. The greater the complexity of a hot water system the greater the risk of it becoming colonised at one or more points. Thus, hot water systems in hotels and hospitals are at greatest risk of becoming colonised and causing infection. The risk of a single household hot water system becoming colonised is generally less because there are fewer points to become colonised and water turnover is often relatively high. In contrast multi-occupancy buildings such as a block of apartments with a shared hot water system are at a high risk of becoming colonised (Lück *et al.* 1993). With high risk systems in buildings housing high risk populations, such as hospitals, there is clearly a need to ensure the hot water storage vessels do not become colonised and daily heating of the vessel to 60 °C or above is a reasonable precaution. However, whether this is necessary for relatively low risk systems such as single household systems (see Table 1 and section 6.2) to reliably minimise the risk of legionellae growing is questionable.

Heat disinfection and recolonisation of a 250 L solar hot water tank?

Let us consider a worst case scenario for a 250 L solar hot water tank incorporating a dedicated 105 L solar volume and a total internal surface area of the tanks plus coils of 42,000 cm^2. Assume in the vessel has been between 35 and 45 ºC for some weeks and the population of *L. pneumophila* in the water has reached 10^6 cfu/L and in the biofilm on the surfaces is $2 \times 10^5 / cm^2$.

The total *L. pneumophila* population = Population in water + population on surfaces

Therefore total population = $(250 \times 10^6) + (42{,}000 \times 2 \times 10^5) = 2.5 \times 10^8 + 8.4 \times 10^9 = 8.65 \times 10^9$

Note that about 98% of the *L. pneumophila* population is on the surfaces which is a typical value determined in model systems and infected plumbing test rigs (Rogers *et al.* 1994a; Saby *et al.* 2005).

Assuming that at 60 ºC the decimal reduction time D for *L. pneumophila* is 2.5 – 5.0 minutes (Stout *et al.* 1986) heating the vessel to 60 ºC for one hour will achieve at least 12 log reductions so that the *Legionella* population should effectively be eliminated from throughout the vessel.

If the vessel became reinoculated immediately with a single *L. pneumophila* and the supporting flora how long would it take to reach a population in the water that is considered not acceptable in national guidelines? In the UK, the national HSE guidelines suggest that legionellae should ideally remain below 10^2 cfu/L, i.e. undetectable by the most commonly used methods of culture. If the count reaches 10^3 cfu/L, disinfection is generally recommended. If we assume that 98% of the *Legionella* population is on the surfaces then 10^2 cfu/L would be equivalent to a total population of 5×10^5 in the whole vessel. Assuming a generation time of 6 – 14 hours under optimal conditions it would take 19 generations ($2^{19} = 524{,}288$) or 114 – 266 hours or 4.75 – 11 days to reach such a population. This calculation assumes worst-case conditions of optimum temperature throughout the vessel and no water usage. However, if the vessel were initially inoculated with a larger number of legionellae it would take proportionally less time to recolonise the vessel to the same level. None the less, these calculations suggest that daily heating of the solar hot water tank to 60 °C in practice is probably excessive to achieve reasonable levels of control in solar hot water vessels. In practice the vessel achieving at least 60 °C for at least one hour once a week should achieve adequate control for the single household situation (see section 6.2). It is suggested that such a regime should be investigated by incorporating solar hot water vessels in test rigs similar to those utilised by (Loret *et al.* 2005) to study disinfection methods for hot water systems.

The use of methods other than heat to control legionellae

A wide variety of methods have been used as alternatives to heat for the disinfection of water systems and for long term control of the growth of legionellae where water temperatures are in the regions supporting the growth. Chlorine and chlorine dioxide have been used extensively for both disinfection by single (shot) dosing or long-term control by continuous dosing at lower levels. Copper silver ionisation can also be used for long-term control but the levels of silver (20 to 40 µg/L) required to achieve control (HSE 2000) are in excess of those permitted for drinking water in some countries such as France (Loret *et al.* 2005). Periodic chemical disinfection does not appear to be as efficient at controlling biofilm as thermal disinfection at 70 °C or maintaining hot water temperatures throughout the system at greater than 55 °C (Saby *et al.* 2005). Chemical disinfectants may have long-term adverse effects on pipe materials and may also produce disinfectant by-products that are considered potentially carcinogenic. The use of chemical disinfectants therefore requires a degree of careful control and management that is probably not suitable for application in single households.

References

Anon (2010) Water Quality: Risk Assessments for *Legionell* control - Code of Practice. London: British Standards Institute.

Bagh, L. K. and Ellehauge, K. (2001) Bacterial growth in solar heating prepared and traditional tanks. International Energy Agency, Solar Heating & Cooling Programme.

Dennis,P.J., Green,D. and Jones,B.P. (1984) A note on the temperature tolerance of Legionella. *Journal of Applied Bacteriology* **56**, 349-350.

Horwitz,M.A. and Silverstein,S.C. (1980) Legionnaires' disease bacterium (Legionella pneumophila) multiples intracellularly in human monocytes. *J. Clin. Invest* **66**, 441-450.

Hospedales, C. J., Joseph, C., Lee, J., Lewis Bell, K., Michael, L. and Francis, M. (1997) International investigation of an outbreak of Legionnaires' Disease at a major hotel associated with potable water - Antigua, 1996. pp. 31.

HSE (2000) Legionnaires' disease - the control of legionella bacteria in water systems Approved Code of Practice and Guidance. Sudbury: HSE Books.

Konishi,T., Yamashiro,T., Koide,M. and Nishizono,A. (2006) Influence of temperature on growth of Legionella pneumophila biofilm determined by precise temperature gradient incubator. *J. Biosci. Bioeng.* **101**, 478-484.

Levin,A.S., Caiaffa Filho,H.H., Sinto,S.I., Sabbaga,E., Barone,A.A. and Mendes,C.M. (1991) An outbreak of nosocomial Legionnaires' disease in a renal transplant unit in Sao Paulo, Brazil. Legionellosis Study Team. *J. Hosp. Infect.* **18**, 243-248.

Levin,A.S., Gobara,S., Scarpitta,C.M., Warschauer,C.L., Sinto,S.I., Rodrigues,E., Mendes,C.M., Sabbaga,E. and Boulos,M. (1995) Electric showers as a control measure for Legionella spp. in a renal transplant unit in Sao Paulo, Brazil. Legionellosis Study Team. *J. Hosp. Infect.* **30**, 133-137.

Loret,J.F., Robert,S., Thomas,V., Cooper,A.J., McCoy,W.F. and Levi,Y. (2005) Comparison of disinfectants for biofilm, protozoa and Legionella control. *J. Water Health* **3**, 423-433.

Lück,P.C., Leupold,I., Hlawitschka,M., Helbig,J.H., Carmienke,I., Jatzwauk,L. and Guderitz,T. (1993) Prevalence of Legionella species, serogroups, and monoclonal subgroups in hot water systems in south-eastern Germany. *Zentralbl. Hyg. Umweltmed.* **193**, 450-460.

Makin, T. (2009) Legionella bacteria and solar pre-heating of water for domestic purposes. Report for the Water Regulations Advisory Scheme http://www.wras.co.uk/PDF_Files/Preheated_Water_Report.pdf .

Mathys,W., Stanke,J., Harmuth,M. and Junge-Mathys,E. (2008) Occurrence of Legionella in hot water systems of single-family residences in suburbs of two German cities with special reference to solar and district heating. *Int. J. Hyg. Environ. Health* **211**, 179-185.

Mauchline,W.S., James,B.W., Fitzgeorge,R.B., Dennis,P.J. and Keevil,C.W. (1994) Growth temperature reversibly modulates the virulence of Legionella pneumophila. *Infect. Immun.* **62**, 2995-2997.

Mouchtouri,V., Velonakis,E. and Hadjichristodoulou,C. (2007a) Thermal disinfection of hotels, hospitals, and athletic venues hot water distribution systems contaminated by Legionella species. *Am. J. Infect. Control* **35**, 623-627.

Mouchtouri,V., Velonakis,E., Tsakalof,A., Kapoula,C., Goutziana,G., Vatopoulos,A., Kremastinou,J. and Hadjichristodoulou,C. (2007b) Risk factors for contamination of hotel water distribution systems by Legionella species. *Applied and Environmental Microbiology* **73**, 1489-1492.

Pearlman,E., Jiwa,A.H., Engleberg,N.C. and Eisenstein,B.I. (1988) Growth of Legionella pneumophila in a human macrophage-like (U937) cell line. *Microb. Pathog.* **5**, 87-95.

Rogers,J., Dowsett,A.B., Dennis,P.J., Lee,J.V. and Keevil,C.W. (1994a) Influence of Plumbing Materials on Biofilm Formation and Growth of Legionella pneumophila in Potable Water Systems. *Applied and Environmental Microbiology* **60**, 1842-1851.

Rogers,J., Dowsett,A.B., Dennis,P.J., Lee,J.V. and Keevil,C.W. (1994b) Influence of temperature and plumbing material selection on biofilm formation and growth of Legionella pneumophila in a model potable water system containing complex microbial flora. *Applied and Environmental Microbiology* **60**, 1585-1592.

Saby,S., Vidal,A. and Suty,H. (2005) Resistance of Legionella to disinfection in hot water distribution systems. *Water Sci. Technol.* **52**, 15-28.

Schulze-Robbecke,R., Rodder,M. and Exner,M. (1987) [Multiplication and killing temperatures of naturally occurring legionellas]. *Zentralbl. Bakteriol. Mikrobiol. Hyg. B* **184**, 495-500.

Stout,J.E., Best,M.G. and Yu,V.L. (1986) Susceptibility of members of the family Legionellaceae to thermal stress: implications for heat eradication methods in water distribution systems. *Applied and Environmental Microbiology* **52**, 396-399.

Surman-Lee, S., Fields, B., Hornei, B., Ewig, S., Exner, M., Tartakovskii, I., Lajoie, L., Dangendorf, F., Bentham, R., Cabanes, P. A., Fourrier, P., Trouvet, T. and Wallet, F. (2007) Ecology and environmental sources of *Legionella*. In *Legionella and the Prevention of Legionellosis* ed. Bartram,J., Chartier,Y., Lee,J.V., Pond,K. and Surman-Lee,S. pp. 29-38. Geneva: WHO.

ANNEX B (informative) – Solar-only systems

In a solar-only system a minimum hot water temperature cannot be secured. If such a system is fitted with a so called electrical emergency heater, this is only to prevent freezing hazard. EN ISO 9488 states that the electrical heater has to be turned off for at least 315 days a year.

This system type has a potential *Legionella* risk due to the mid-level temperature in the storage tank during operation and the lack of thermal disinfection capacity by an auxiliary heater. For that reason, such solar heating systems should not be applied in high risk applications (Table 1).

In order to minimize the risk of *Legionella* growth the following recommendations are given.

Recommendation B.1

For an instantaneous solar water heater, a warning should be attached at a clearly visible location on the solar-only system with the following text:

> “Flush the system when not used for more than 2 weeks!”

The following text shall be added to the user manual of the solar-only system:

> “When no hot water has been used for more than 2 weeks, the system must be flushed for 5 minutes at a draw-off point other than a shower.”

Recommendation B.2

for all solar-only systems not fulfilling the recommendations of recommendation B.1:

The solar-only system should be dimensioned such that

- the temperature of 65 °C is reached at the top of the store and 50 °C at its bottom, for one hour, once a month, with a probability of 99%, and
- the temperature of 60 °C is reached at the top of the store and 45 °C at its bottom, for one hour, once a week, with a probability of 90%.

The conformity to this recommendation can be evaluated by means of a computerized simulation and a system inspection.

The model used in the simulation should use the following reference conditions:

- the climatic conditions of Athens;
- for single-family applications the tapping profile Nr: 3 according to EN 15316-3-1 and for other applications an evenly distributed tapping profile valid for the design conditions of the solar-only system.

A system inspection should verify that the system design is such that the bottom part of the storage tank can be heated by the solar heat. An integrated heat exchanger should be applied according to chapter 4, point 2b.

Figures are indicative only and have to be checked by simulation.

Recommendation B.3

for all solar-only systems, not fulfilling the recommendations of the recommendations B.1 and B.2:

The solar-only system should be equipped with a device that either disinfects the storage tank every week or the outgoing potable water, or prevents the growth of *Legionella* in the storage tank or heat exchanger in any other way.

ANNEX C (informative) – Non thermal disinfection techniques

Several methods have been proposed as an alternative to thermal disinfection.

Disinfection by adding chemicals:

1. Chlorine

There are a variety of ways in which chlorine can be generated to treat water but the most common method used for supplementary treatment of water is the addition of sodium hypochlorite (NaOCl). Chlorine can be added continuously at a low concentration (0.5 – 2 mg/L) to inhibit microbial growth or as a single (shot) high disinfecting concentration of 20 mg/L for 2 to 3 hours. Chlorination can be applied to all downstream parts of the system. Disinfection is very dependent upon pH which should ideally be between pH 6 to 7 for effective disinfection and certainly no higher than pH 8. Chlorine also volatilises away with increasing temperature. In some countries, the limit for potable water is 0.5 mg/L. There may also be a need to obtain discharge consent depending upon national legislation and/or to neutralise the biocidal activity before discharge to waste.

Allowance: exemption from authorities (drinking water and environment)

Extra installation parts: dosing system

Maintenance: refills of dosing system

Remarks: noticeable by taste and smell and high doses are corrosive for copper piping and possibly some plastics

2. Chlorine dioxide dosing (ClO_2)

Chlorine dioxide can be generated in a number of ways and is a recognised means of treating water to help control the growth of legionellae. Like chlorine, it can be used continuously at a low concentration (up to 0.5 mg/L) to inhibit microbial growth or as a single (shot) high disinfecting concentration of up to 20 mg/L for 2 to 3 hours. The ClO_2 will treat all downstream parts of the system as well as the tanks and is not affected by pH or temperature to the same degree as chlorine. The limit for treating potable water in some countries is 0.5 mg/L and this low level is not always effective at controlling *Legionella* in contaminated systems. Prolonged continuous dosing at 2 mg/L has been used to control legionellae in colonised water systems.

Allowance: exemption from authorities (drinking water and environment)

Extra installation parts: dosing system

Maintenance: refills of dosing system

Remarks: Some plastics may be damaged by chlorine dioxide

3. *Chloramine dosage ($ClNH_2$)*

Monochloramine up to 2 mg/L is used to disinfect drinking water but equipment capable of dosing single buildings has only recently been developed and still has limited availability. Hospitals receiving municipal water treated with monochloramine have been shown to be less likely to contain legionellae in their water systems and have a lower incidence of legionnaires' disease. Continuous dosing at up to 2 mg/L) could be applied and will penetrate to down-stream parts of the installation.

Allowance: exemption from authorities (drinking water and environment)

Extra installation parts: dosing system

Maintenance: refills of dosing system

4. *Copper / silver ionization,*

is a preventive measure with effects in all downstream parts of the installation. It has been widely used to control legionellae in hot water systems in particular. The levels of silver (20 – 40 µg/L) recommended to achieve control exceeds the permitted levels for potable water in some countries.

Allowance:

Extra installation parts: Ionization device and (possibly) a system to control the pH

Maintenance: cleaning electrodes, check concentration copper and silver, decalcification, replacement of electrodes

Remarks: may encourage corrosion in combination with some iron pipes and may cause staining of sanitary ware.

5. *Other systems*

A variety of other chemicals have been proposed at potential methods for controlling legionel-lae in water systems but there is too little information on their effectiveness at present to war-rant their inclusion here.

Disinfection by applying devices:

1. *Membrane filtration,*

is a preventive measure with only local effects in the installation (e.g. after the heat storage tank).

Allowance:

Extra installation parts: membrane setup

Maintenance: membrane cleaning and replacement

Remarks: Provided the filters are fitted correctly, they can completely prevent the release of organisms from the draw-off points but they do not reduce nor prevent colonisation. They are particularly useful for short-term emergency use.

2. Treatment with UV light,

is a preventive measure with only local effects at the point of application (e.g. after the heat storage tank). If the incoming water were heavily contaminated a small proportion of cells may survive passage through the UV unit.

Allowance:

Extra installation parts: UV light setup

Maintenance: cleaning (or device with automatic cleaning)

Remarks: Requires extra energy.

ANNEX D (informative) – Good practice for solar assisted hot water systems

Recommendation*:*

In all solar assisted hot water systems a mixing valve should be applied to prevent scalding at the draw-off points [8]. Preferably the mixing valve is located at the outflow from the auxiliary heater [9] and set at 60 °C ± 5°C.

A thermostatic mixing valve, applied to further reduce the outlet temperature (e.g. 45 ^{o}C), should be incorporated into the draw off point or fitted to it as close as possible.

Recommendation*:*

An instantaneous water heater as an auxiliary heater in a solar assisted hot water system should be able to tune the heating power to the inlet temperature.

Recommendation*:*

At least for solar storage tanks with a volume greater than 400 litres, the sediment from the storage tank and any scale within the tank should be removed in accordance with the local conditions but at least once a year.

Recommendation*:*

Solar preheat systems, applied in a hot water system with circulation of hot or mixed water to maintain part of the distribution lines at high temperature, should be connected in such a way that in summer the solar heat can be used to compensate for the heat losses of the circulation loop.

Recommendation*:*

In solar assisted hot water systems, circulation of blended water should be avoided and the distribution temperature should be set such that 30 s after fully opening a draw-off valve, the water temperature should not be less than 60 °C (according to EN 806-2).

---

[8] This mixing valve is required by EN 12976-1 and EN 12977-1.

[9] A thermostatic mixing valve aimed at reducing the hot water temperature to a comfortable temperature of use, should always be located as close as possible to the user's draw-off point.