Code of practice

- Minimizing the risk of *Legionella* in solar assisted hot water systems -

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Foreword

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 312 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 could be handled by the CEN/TC 312 alone.

The Code of practice is mostly based on the report "Legionella and solar water heaters" [4]. This report covers a literature study on the subject and computer assisted mathematical simulations. Nevertheless, it is noted that there is a need for additional research on the subject.

Introduction

TC164/WG2 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. CEN/TR 16355 focuses on conventional hot water systems and does not consider the applicability of its recommendations to solar water heaters. This code of practice interprets CEN/TR 16355 to adapt its recommendations to solar water heaters.

In the context of *Legionella* control the factors that need special consideration for solar water heaters 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 60 ^{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 assisted hot water systems that minimize the risk of *Legionella* infection by the user of, and others exposed to, the system.

For the sake of completeness, recommendations on solar-only systems, although out of the scope of the CEN/TR 16355 technical report, are provided in Annex B.

This 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 volume, dedicated to the storage of solar thermal energy, larger than 25 litres per square metre solar collector (aperture).

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
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
SIA 385/1	Anlagen für Trinkwarmwasser in Gebäuden –Grundlagen und Anforderungen [1]
CEN/TR 16355	Recommendations for prevention of Legionella growth in installations inside buildings conveying water for human consumption (2011-08-31)

2.2 Other references

1. Report “Legionella and solar water heaters”, April 2013, G. van Amerongen (vAConsult), John v Lee (Leegionella Ltd), Jean-Marc Suter (Suter consulting).

[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:

Hot water installation,

the complete installation, from cold water supply to draw-off points, and all components in-between.

- **Auxiliary heater**,

  a source of heat, other than solar, used to supplement the output provided by the solar energy system;

- **Solar water heater**,

  a generic term to designate a solar thermal system of type preheat system with auxiliary heater, solar assisted hot water system or solar-only system.

  - **Solar-only system**,

    a solar water heater without any auxiliary heat source.

  - **Solar assisted hot water system**,

    a 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 [2].

    - **Solar preheat system**,

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

    - **Solar-plus-supplementary system**,

      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.

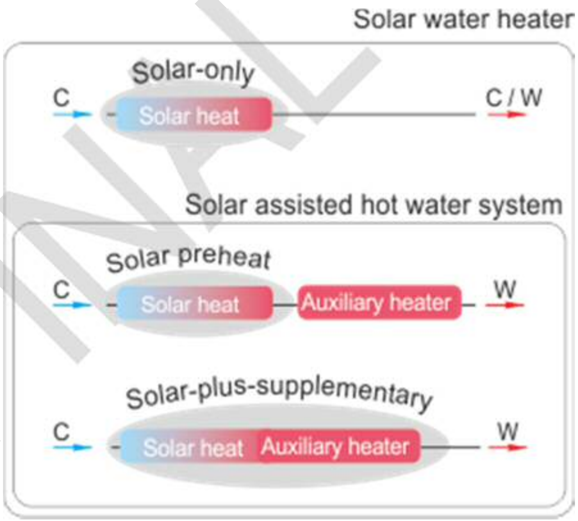

Figure 1 - Graphical representation of the different solar water heater types ('c': cold water, 'w': warm water).

Application,

the way that the solar water system is applied (e.g. collector orientation, heat demand, climatic region).

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[2] Prevention of *Legionella* growth requires measures to be applied to all devices whose function is to heat up the potable water.

***Legionella*,**

the name (epithet) of a 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,

the name of a species for which *pneumophila* is the species specific epithet (analogous to *sapiens* in *Homo sapiens).* The most common cause of legionnaires' disease.

decimal reduction time D,

the time taken to kill 90% of a population of bacteria or other organisms.

doubling time

the time taken for a population of bacteria to double in number. Also known as the generation time.

4 Recommendations applicable to all solar water heaters

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 water heaters:

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 heat storage tank holding potable water*
   a) Design the tank in such a way that the complete potable water volume is affected during draw-off.
   b) The storage tank design should be such that also the bottom part of the storage tank can be heated to at least 60 °C . 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) For storage tanks with a potable water volume greater than 400 litres [3], incorporate an inspection hatch at the bottom of the tank to enable the regular removal of deposits.
   d) Minimize or prevent the use of sacrificial anodes and internal threaded female screw joints.
3) *Controller*
   a) Limit the setting of the maximum potable water storage tank temperature to 80 °C to prevent deposition of lime. Depending on the local potable water hardness, this temperature setting may be lower or higher (+ / - 10 °C).
   b) Install a device that signals any malfunction of the system to the user, especially that of the solar collector loop.
4) *Documentation*
   a) For systems that incorporate a means of cleaning the heat storage tank that stores 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 detail 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*.

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[3] In single-family houses the level of maintenance of installations is usually poor. It is expected that tanks will not be regularly inspected and cleaned. Since small tanks are normally fitted in single-family residences, a recommendation to add an inspection hatch would be an ideal but in practice unlikely to be used. However, specific national regulations may require them.

5) *Warning signs and signalling*

When applicable, warning signs or signals should be located so that the user or the service technician is clearly confronted with the warning. For applications that are infrequently inspected by service personnel, the warnings signs should be immediately obvious to the user..

5 Recommendations applicable to solar assisted hot water systems

The recommendations are structured in four different configurations, representing all combinations of the functions of the solar and auxiliary heating.

	Solar heating	Auxiliary heating
Storage type	Solar heat is accumulated in a storage tank filled with potable water.	Auxiliary heat is accumulated in a storage tank filled with potable water.
Instantaneous type	Solar heat is transferred to the potable water through a heat exchanger (not integrated in a buffer tank).	The potable water is contained in a heat exchanger, directly or indirectly, heated by a heater.

The solar and auxiliary functions can be separate in two tanks or combined in one heat storage tank.
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. It is assumed that the CEN/TR 16355 recommendations on the installation as a whole are applied.

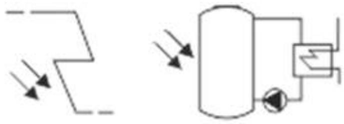
The following recommendation applies to all heat exchangers used as instantaneous water heaters.

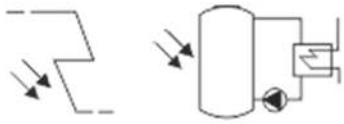
Recommendation:

- When an external heat exchanger is used as an instantaneous heater, the pump in the loop should be controlled so that the water is allowed to cool down in periods without draw-off.
- The heat exchanger is not insulated.
- The potable water should be heated in the heat exchanger in a single pass.
- A heat trap 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 heating	Auxiliary heating
Type:	Instantaneous	Instantaneous
		
Recommendations:	None	

Type:	Instantaneous	Storage type
		
Recommendations:	R.1 (according to CEN/TR 16355)	

Type:	Storage type	Instantaneous
		
Recommendations:	– R.2 for low risk application, or – R.3 for medium or high risk applications Risk levels according to Table 1.	

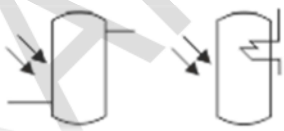
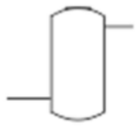
Type:	Storage type	Storage type
		
Recommendations:	– R.4 or, – R.2 for low risk application, or – R.3 for medium or high risk applications Risk levels are according to Table 1; see paragraph 5.2 for an explanation of R1, R2, R3 and R4.	

Table 1 - Building categories and risk levels [4] 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 – Sport facilities, indoor and outdoor pools
high	– Hospitals, 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 [5].

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.

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[4] Although legionellae are present everywhere in aqueous environments, only their introduction into the lung may be a potential health hazard. Therefore, apparatus and systems such as 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.

[5] Although this is in accordance with the CEN/TR 16355, [4] shows that once a week should be sufficient.

[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 to the maintenance manual describing a routine check to ensure the system is functioning correctly.

Recommendation R.4:

a) Design the auxiliary storage tank volume to be larger than ½ of the daily design hot water demand and keep this tank at 60 °C for the whole day [7].
b) Install a warning device to indicate any 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 the 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.
– *Storage tank design*
  The storage tank design should be such that the bottom part of the storage tank can also be heated to at least 60 °C. When a heat exchanger is applied, see section 4, paragraph 2b.

Table 2 -Recommended (solar) storage tank volume per unit of collector aperture area (l/m^2)

V_{sto} / A_{col} [l/m^2] ≤ ...	**Recommended...**
...25	...for Legionella safe design for all applications
...40	...in North & middle Europe [a)] under optimal collector orientation [b)]
...55	...in South Europe [c)] under optimal collector orientation [b)], or ...if the collector orientation is optimal [b)], $V_{sto} \le V_{daily}$ and there is a "Legionella warning" [d)]
Notes:	a) latitude > 45°
	b) azimuth SW ↔ SE and tilt angle between latitude -20° and latitude +5°
	c) latitude ≤ 45°
	d) V_{sto}: volume of solar dedicated part of storage tank V_{daily}: daily draw-off volume explicit warning to the user of the system stating that the system becomes vulnerable to *Legionella* when seldom used

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.

Confirmation of achieving these recommendations should be established by means of temperature measurements in the storage tank or at its wall.

6.3 Devices to detect 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, if malfunctioning occurs, these assumptions are no longer valid and the user should be warned of this.

The malfunctioning of the collector loop should be indicated 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

When an auxiliary heater is used to provide the essential function of thermal disinfection of the potable water, there should be a clear alarm warning the user of any malfunctioning. Moreover, the user manual should include a description of how to act on 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.

Warning: the cold feed to the valve could become a deadleg vulnerable to legionella growth if it only feeds this safety valve. To avoid this the cold feed to the valve should be as short as possible and taken from a pipe feeding a frequently used outlet such as a wash hand basin or toilet cistern.

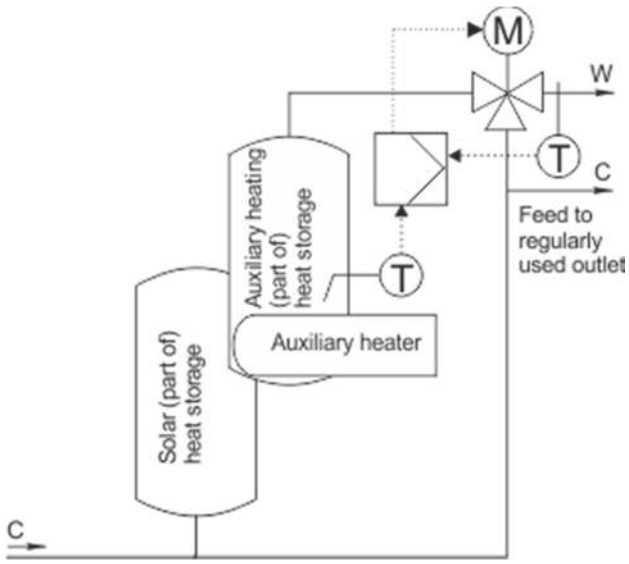

Figure 6.1 - Example of a device to detect insufficient auxiliary heating and react accordingly.

Option 2

Malfunctioning could also be communicated to the user by means of a warning light situated in a location clearly visible to the user..

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 and standards more detailed methods are described.

Sampling frequency:	based on an adequate risk analysis but should be at least once every 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 from the hot water heating device

Annex A - Consulted literature

Anon (2010) BS 8580 Water Quality: Risk Assessments for *Legionell* control - Code of Practice. London: British Standards Institute.

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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 .

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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.

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ANNEX B (informative) – Solar-only systems

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

This type of system 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 water heaters should not be applied in high-risk applications (Table 1).

Due to the fact that solar-only systems are not equipped with an auxiliary heater, the hot water is used on average at a lower (demand) temperature. Assuming that the same heat quantity is needed in both solar-only and preheat systems, this means that solar-only systems effectively show a higher water throughput. This effect is comparable with a preheat system with an under dimensioned tank volume, implying a lesser vulnerability for high concentrations of Legionella in the tank.

The absence of an auxiliary heater on the one hand makes a solar-only system more vulnerable to *Legionella* growth whereas the higher annual water throughput, could mitigate this risk. Overall it is defendable to apply the same rules as for preheat systems to a solar-only system.

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

Recommendation B.1

A warning should be included in the user manual with the following text:

- For thermosyphon systems:

  “The system is vulnerable to the risk of Legionella growth when not in use during a period of more than 14 days in winter time. The system is not vulnerable again when the heat storage tank is heated up above 55 °C.”

- For systems with forced circulation in the collector loop:

  “When absent for more than 14 days during the winter time, the collector pump, or the collector pump controller, should be disconnected to safeguard against Legionella vulnerability.”

Recommendation B.2

For all solar-only systems not fulfilling the recommendations of Recommendation B.1:

The components of the solar-only system should be sized as such that

- the volume of the heat storage tank is smaller or equal to the designed daily hot water consumption.
- the ratio V_{sto} / A_{col} [l/m^2] should conform to table 2.
- 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.

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 (potable 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 (potable 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 potable 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 downstream parts of the installation.

Allowance: exemption from authorities (potable water and environment)

Extra installation parts: dosing system

Maintenance: refills of dosing system

4. *Other systems*

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

Disinfection by applying devices:

1. *Terminal membrane filtration,*

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

Allowance: No information available

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 and colonise the system downstream of the UV unit..

Allowance: No information available

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*:*

The winter time is the most Legionella vulnerable period of the year. When the system is not in use during a significant part of this time, the collector pump should be switched off.

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.

If for special situations a thermostatic mixing valve, applied to further reduce the outlet temperature (e.g. 45 °C), is applied, it 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*:*

[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.

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).