Guidelines for combating Legionella with Oxiperm® Pro chlorine dioxide systems

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Basics

What are Legionella?

Legionella pneumophila – the bacterium associated with over 90 % of all cases of legionnaires' disease – is a bar-shaped bacterium of the Legionellaceae family. This family can be further subdivided into a range of serogroups (usually 1 – 16). There are currently at least another 37 known species of Legionella and others, such as L. micdadei and L. feelei have also been associated with diseases.

Special measures need to be taken to combat Legionella since they can adapt to conditions that are fatal to many organisms and are, for the most part, resistant to biocides.

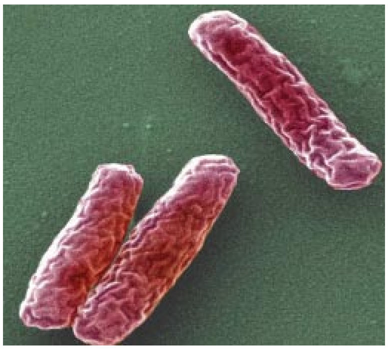


Figure 1: Legionella pneumophila in microscopic analysis

What effects do Legionella have?

Legionella become harmful to people when they occur in high concentrations, are spread by the build-up of aerosols (mist droplets in showers, air conditioning systems, etc.) and are inhaled. In this case, even a short period of contact is sufficient to cause infection in healthy people too.

Following an incubation period of 2-10 days, Legionella (especially Legionella Pneumophila) result in a special form of pneumonia (legionellosis) which can be accompanied by Pontiac fever. Estimates from the German Federal Statistical Office indicate that each year in Germany 25,000 to 30,000 people contract legionellosis. In people with weakened immune systems (the elderly, people with other illnesses, smokers, athletes after competing in an event), the illness can be fatal if it is not treated within the first four days. Victims are infected by inhaling water mist (aerosols) at drinking water outlet points. It is important to note that the definition of drinking water in this context extends far beyond the use of water as a beverage or to prepare food.

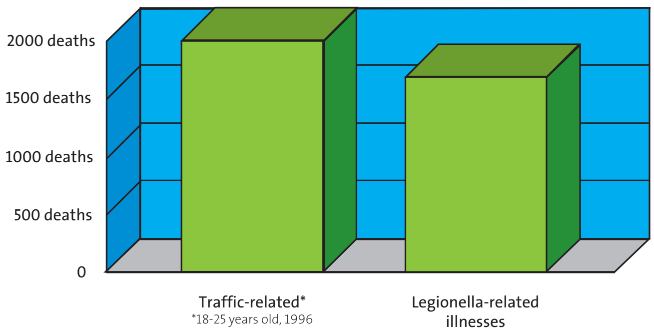


Figure 2: Number of traffic-related deaths and deaths caused by Legionella in Germany in 1996

Where are Legionella found?

Legionella are found naturally in the microflora of river, lake and ground water, albeit usually in small quantities. Conditions that encourage the growth of Legionella include water temperatures of between 20 and 50 °C and a food source – particularly other biological substances or deposits such as rust or limescale. Legionella travel via intakes from surface water into the drinking water network prior to water treatment in waterworks.

Generally, hot water systems with a low flow rate, areas of stagnation, or badly serviced boilers offer ideal conditions for the growth of Legionella. Legionella reproduce abundantly in a temperature range of between 30 and 50 °C and live in biofilms where they are shielded against most chemical disinfectants and all disinfection technologies that do not use chemicals.

A biofilm consists mainly of mixed colonies of micro-organisms (bacteria, algae, fungi, protozoans) that are connected to one another but attached to a single substrate and integrated fully or partially in a polymeric organic mass (slime) – an extracellular polymeric substance (EPS) – produced by the organism. This gel-like film offers ideal conditions – namely food and protection – for the permanent contamination of drinking or process water with pathogenic micro-organisms such as pseudomonads, fungi, mycobacteria, viral pathogens and particularly Legionella bacteria.

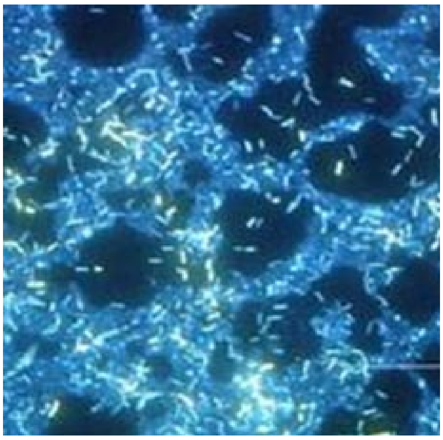
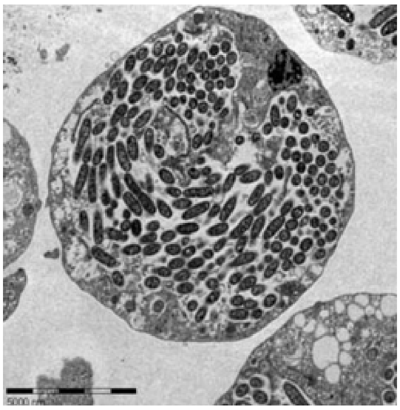


Figure 3: Legionella in a biofilm



Legionella also reproduce in their thousands in amoebae, which function as host bodies before being discharged from the biofilm by water flow. If these amoebae are then rinsed out through the aerator of a shower head or tap, the drop in pressure causes the host body to burst, releasing tens of thousands of Legionella. The aerosols are then inhaled by people, with the above-mentioned consequences.

Figure 4: Hartmannella vermiformis amoebae filled with Legionella pneumophila

When both factors are present – conditions that encourage the growth of Legionella and the formation of inhalable aerosols with a water droplet size of between 3 and 5 µm – the following systems are potential sources of risk:

- Hot and cold water supplies through taps and showers in private households, hotels, retirement homes, sports facilities, etc.
- Water systems incorporating a cooling tower
- Water systems incorporating an evaporator
- Air-conditioning units or humidifiers
- Other facilities and systems that transport water at temperatures that can exceed 20 °C and disperse water vapour when being used or serviced. Examples include whirlpools, spa baths, small decorative fountains and paint spray booths.

Laws and guidelines

What are the responsibilities of those operating water supply installations?

International organisations, laws and guidelines:

- The WHO (World Health Organisation) “Guidelines for Drinking Water Quality“ (2004)
- The WHO “Guidelines for Safe Recreational Water Environments“ (2006)
- The WHO “Guide to Ship (and Hotel) Sanitation“ (2007)

European organisations, laws and guidelines:

The Council of the European Union guideline 98/83 EC “Quality of water intended for human consumption”

- The EWGLI (European Working Group for Legionella Infections) “European Guidelines for Control and Prevention of Travel Associated Legionnaires’ Disease“ 2119/98/EC

The CDC (Center for Disease Control USA):

- The HICPAC (Healthcare Infection Control Practices Advisory Committee) “Guidelines for Environmental Infection Control in Healthcare Facilities“

In Germany, legal principles are primarily set out in:

1) The German Federal law for the prevention and combating of infectious diseases in humans – IfSG (Infection Protection Act)
2) The German Drinking Water Ordinance regulating the quality of water intended for human consumption

§37 of the IfSG states: *Water intended for human consumption must be supplied in such a way that its consumption or use will not adversely affect human health, especially through means of a pathogen.*

Pathogens that must be reported by law include Legionella (IfSG §§ 6, 7).

Owners or operators of water systems in public or residential buildings have full responsibility for the quality of the water systems right up to the water outlet.

Public health authorities are required to inspect water supply installations that distribute water for the general public. The Drinking Water Ordinance stipulates that water providers and public facilities regularly test water quality. Tests also need to be carried out periodically to check for the presence of Legionella in central heating facilities of the plumbing installation. If these test results are positive, operators, planners and technicians are called together to discuss remedial measures. Public health authorities are authorised to order the closure of water supply installations if specified limit values are exceeded.

Non-compliance with regulations is punishable in several countries.

- In consequence of non-compliance with regulations (intentional or negligent) a fine or a jail sentence can be imposed

If such penalties are to be avoided, it is important that bacterial contamination is effectively eradicated and that better preventive treatment is applied to the installation system.

Comparison of the methods

What methods are used to combat Legionella?

The methods and their properties	Disadvantages
Thermal treatment The most commonly used method of combating Legionella is thermal disinfection. Legionella begin to die off at temperatures above 60 °C, which makes it possible to combat the bacteria by heating the infected water system.	• A temperature of approximately 70 °C must be reached and maintained throughout the entire piping system over a period of several minutes. However, this can seldom be achieved in typical installations because the water cools down as it reaches the water outlets. • Not all water outlets are accessible (e.g. in residential buildings). • Acute risk of scalding if the water outlets are readily accessible. • Increased limescale deposits that damage systems. • Thermal expansion can cause irreparable damage and leakages in older installations. • The biofilm containing germs is unaffected, with the result that germs always build up again between treatment cycles.
UV radiation No chemicals are used. Sufficient protection can be provided when levels of bacterial contamination in the water are low.	• When levels of Legionella contamination are high, this method does not sufficiently kill off bacteria and additional shock treatment with chlorine and chlorine dioxide is also necessary. • Relatively large units are required to generate a sufficient intensity of UV light. Furthermore, if the Legionella are not killed off completely, the entire procedure will have been unsuccessful. • The biofilm in the piping networks – the basis for the multiplication of Legionella – is unaffected by this procedure.
Filtration Microfilters or membrane filters can screen bacteria, viruses, suspended particles and other unwanted elements from the water.	• Insufficient protection against Legionella and other micro organisms that can contaminate piping from the tap connections. • No affect on the biofilm.
Hypochlorite solution Effective alternatives include disinfectants that combat both pathogens and the biofilm. Chlorine is often used as a disinfectant in the form of a hypochlorite solution that is added to the installation system.	• Legionella are far more resistant to chlorine than many other bacteria such as Escherichia coli. Experiments have shown that chlorine needs to act 40 times longer on Legionella than on E. coli to achieve the same level of fatality on the Legionella population. • Only free Legionella are affected because the biofilm is not penetrated or broken down. With a chlorine surplus of at least 2 ppm in pipe networks with biofilms, the number of Legionella can be kept below the tolerance level of 100 CFU (colony-forming units) per 100 ml.

Why is chlorine dioxide the method of choice?

Chlorine dioxide	Benefits
Chlorine dioxide is becoming an increasingly popular disinfectant for combating Legionella.	• Chlorine dioxide has a far more effective disinfecting action than identical concentrations of chlorine. • Greater sustained-release effect for longer lasting disinfection. • Selective effect, i.e. toxic chloramines or haloforms (THM) are not formed and the smell and taste of the water are unaffected. • A key benefit of chlorine dioxide is that it attacks and destroys both free pathogens and the biofilm.

Chlorine dioxide

Why is chlorine dioxide the method of choice?

Chlorine dioxide is gas, which is yellowish orange in colour, has an ozone-like odour and is highly soluble in water. The chemical and biochemical effects are based on the conversion to chlorite during the disinfection process and reduction to chloride through purely chemical degradation processes.

Chlorine dioxide cannot be stored and therefore has to be produced at the location where it is to be used.

Because of its high redox potential, chlorine dioxide has a much more powerful disinfecting action against all kinds of germs and contaminants such as viruses, bacteria, fungi and algae than other biocides. The oxidation potential is higher than with chlorine, for example, so that far fewer chemicals are required. The longer dwell time is also particularly advantageous due to the selective disinfection. Even germs that are resistant to chlorine, for example Legionella, can be killed completely by chlorine dioxide. Special measures need to be taken to combat them since they can adapt to conditions that are fatal to many organisms and are, for the most part, resistant to biocides.

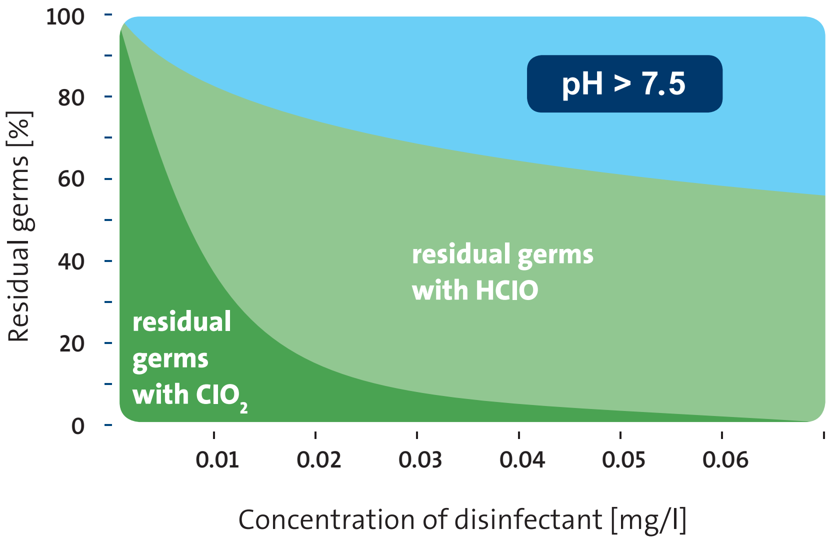


Figure 5:
Comparison of the disinfecting action of chlorine dioxide and chlorine at a pH level of >7.5

The major difference between chlorine dioxide and chlorine or hypochlorite is the gradual effect it has on degrading biofilm at low doses. A concentration of 1 ppm will kill virtually all Legionella in the biofilm within 18 hours. A marked reduction in the biofilm can be achieved within the same time for a concentration of 1.5 ppm. Furthermore, the disinfecting action of chlorine dioxide is virtually independent of the pH value, meaning that it can also be used without any problems in alkaline environments.

How is the application of chlorine dioxide regulated for the drinking water disinfection?

Generally, the addition of a maximum quantity between 0.2 and 0.8 mg/l is permissible. The addition of chlorine dioxide to drinking water must be carried out in proportion to the amount of water. Dosing must be carefully regulated and must not be carried out manually.

In case of concentration-controlled dosing into a closed water circuit, there is a risk from the concentration of the by-products to rise above the admissible limit value.

How does Oxiperm® Pro work?

Oxiperm® Pro is an automatic production system for chlorine dioxide. Chlorine dioxide is produced in the system using two starting chemicals – diluted hydrochloric acid (concentration of 9 % by weight) and diluted sodium chlorite solution (concentration of 7.5 % by weight). The resultant product solution is stored in a tank at a concentration of 2 g/l chlorine dioxide and added to the water flow on demand with the aid of a dosing pump. Dosing is carried out in proportion to the volumetric flow in such a way that the intended concentration of chlorine dioxide in the drinking water is kept constant.

A measurement value logging device is integrated into the control electronics of Oxiperm Pro so that the concentration of chlorine dioxide can be directly monitored by connecting a measuring cell.

Figure 6: Oxiperm® Pro chlorine dioxide production system with chemical tanks and catchment trays

Where is Oxiperm® Pro installed?

To ensure the pipe network in a building is properly protected against Legionella, the dosing point should be located as close as possible to the mains water connection. In the case of hot water pipes, the dosing point should be located downstream of the water heater.

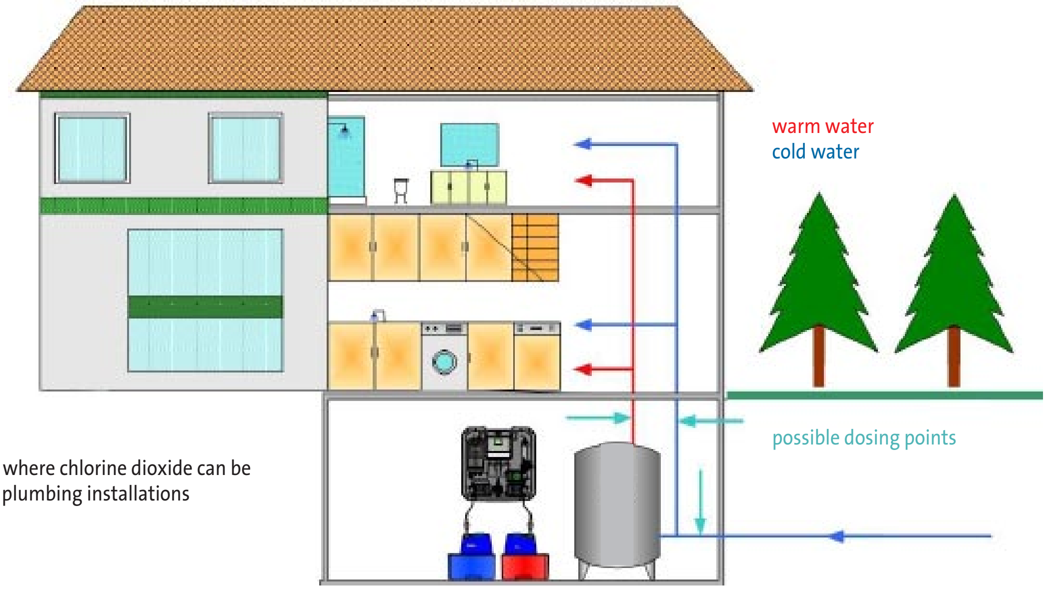


Figure 7: Points where chlorine dioxide can be integrated into plumbing installations

What installation variants are available?

Legend for the following installation variants:

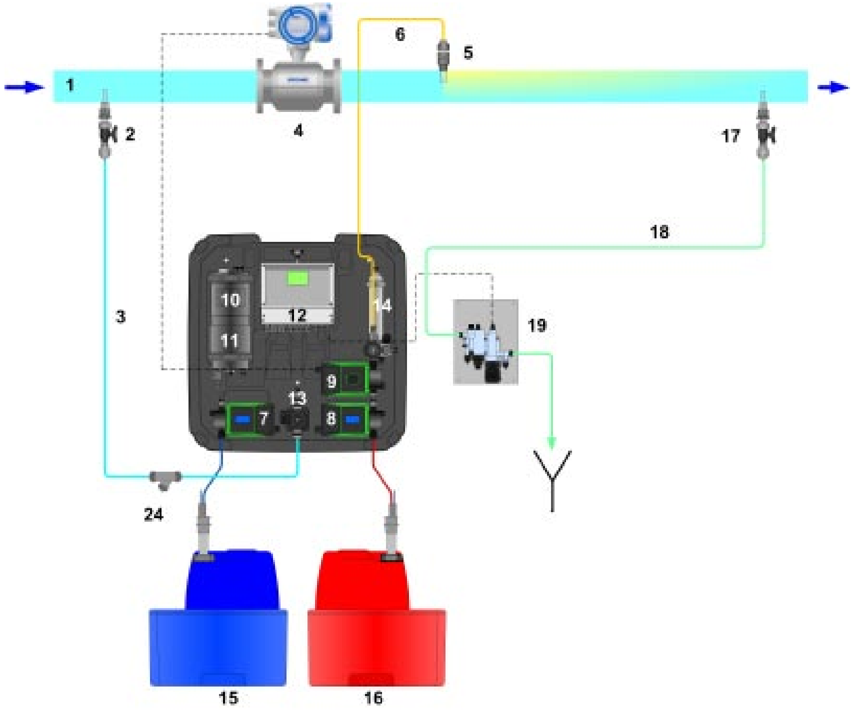
1. Main water pipe
2. Dilution water extraction point
3. Dilution water pipe
4. Flow measurement
5. Injection unit
6. Dosing line
7. Dosing pump for sodium chlorite
8. Dosing pump for hydrochloric acid
9. Dosing pump chlorine dioxide
10. Reaction tank
11. Chlorine dioxide storage tank
12. Control unit incl. measuring amplifier and display for chlorine dioxide measuring cell
13. Solenoid valve for dilution water
14. Activated carbon filter for reaction tank deaeration
15. Sodium chlorite tank with catchment tray
16. Hydrochloric acid tank with catchment tray
17. Measuring water extraction point
18. Measuring water pipe
19. Chlorine dioxide measuring cell
20. Tapping clamp
21. Mixing module
22. Measuring module
23. Second ClO_2 dosing pump
24. Dirt trap

1) One dosing point

It is usually sufficient for the chlorine dioxide solution to be added to a plumbing installation at a single point. This is usually the hot water system within the plumbing installation.

Variant A1

With this variant, chlorine dioxide is added directly to the main water pipe via an injection point or static mixer.



Variant B1

It is recommended that the Grundfos Alldos bypass module is used. Pipes do not need to be opened when using this variant, which means that the water flow does not need to be interrupted. Bypass water is removed and returned via tapping clamps. Chlorine dioxide is added in an injection point in the module. As a result, premixed disinfectant is added to the water flow and the risk of corrosion is minimised. Another benefit is the straightforward fitting without interrupting the water supply, which saves both time and money.

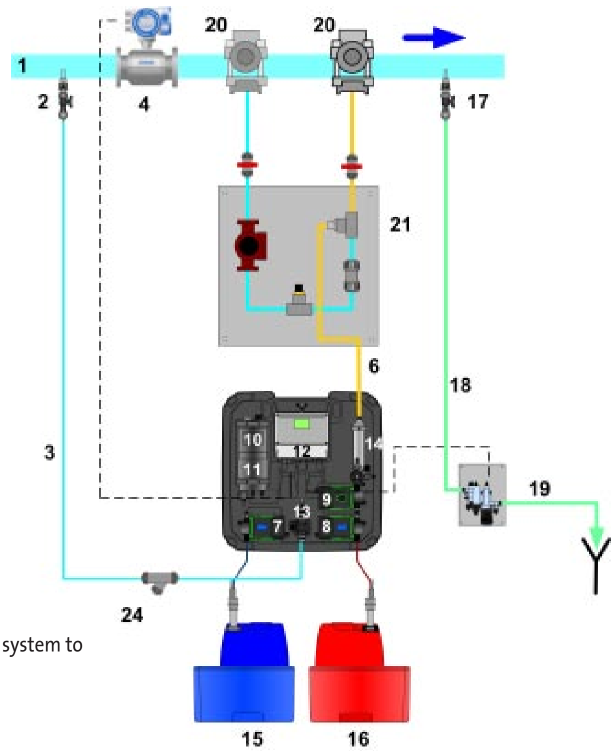


Figure 9: Connecting the Oxiperm Pro chlorine dioxide production system to the main water pipe via the bypass module

2) Two dosing points

In many building installations, hot and cold water circuits are located close together or are insufficiently insulated. This can mean that cold water pipes also become contaminated with germs. In such cases, it is advisable to use Oxiperm® Pro with two dosing points – one for hot and one for cold water. This is possible when the total volumetric flow does not exceed 12 m³/h (system with 5g/h) or 24 m³/h (system with 10 g/h). In other cases, two separate systems need to be installed.

Just as when a single dosing point is used, it is also possible either to add the dose directly into the installation or use the Grundfos Alldos bypass module.

Variant A2: Direct dosing

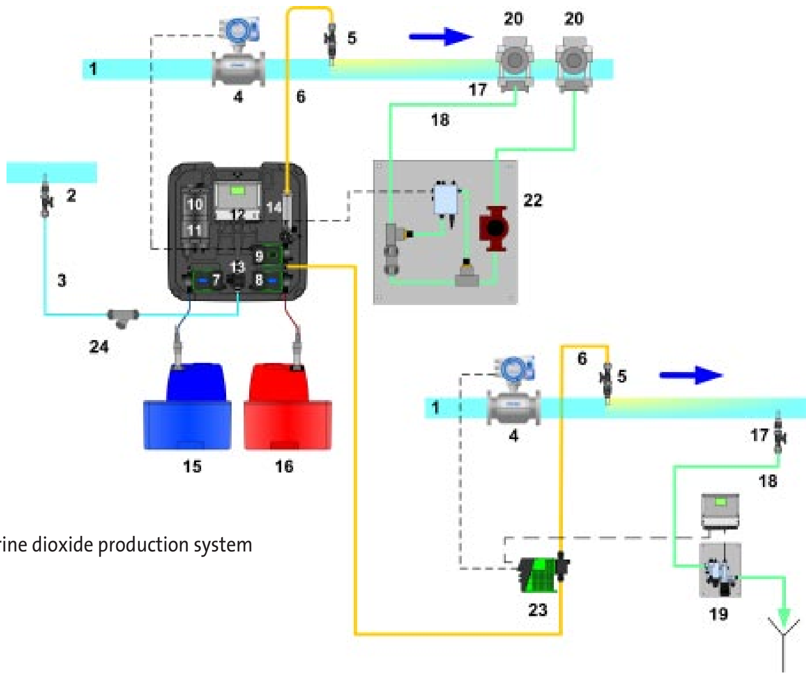


Figure 10: Connecting the Oxiperm® Pro chlorine dioxide production system directly to the hot and cold water system

Variant B2: Bypass

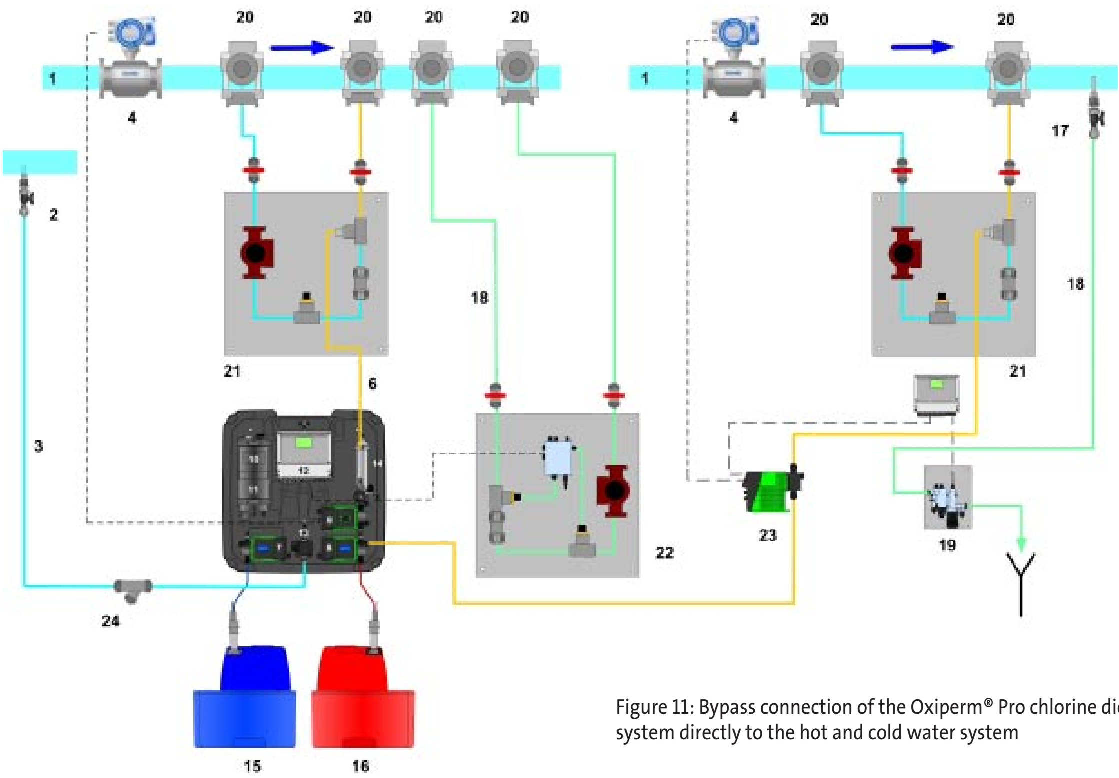


Figure 11: Bypass connection of the Oxiperm® Pro chlorine dioxide production system directly to the hot and cold water system

Decontamination

How can it be ensured that decontamination is successful?

When Legionella is discovered with CFU (colony-forming units) of < 1000 per 100 ml, decontamination can be carried out by adding chlorine dioxide directly into the pipe network.

CFU of > 1000 / 100 ml often indicate increased biofilm growth. In these cases, the installation system should be thoroughly cleaned either chemically or mechanically before chlorine dioxide is added.

In all cases, a meeting should be sought with the relevant health authority, the building operator and/or building owner. The cause of high levels of Legionella is usually found in the building installation itself. Several factors besides chemical disinfection can help ensure decontamination is successful:

- Improving the circulation of water
- Fixing broken or blocked pipes
- Separating fire protection systems from drinking water
- etc.

Precautionary installation vs. the minimisation rule

The guiding principle for keeping drinking water installations safe and germ-free is “use as many chemicals as necessary but as few as possible”. Precautionary disinfection is particularly recommended for sensitive locations such as drinking water supplies for hospitals, retirement homes, hotels and similar facilities.

An investigation carried out by the German health authorities revealed that, between 2004 and 2006, concentrations of Legionella that exceeded the permissible tolerance value (100 CFU / 100 ml) were found in approximately 30 % of water samples that were tested (from hospitals, retirement homes, hotels). This indicates the high level of risk to which inhabitants are exposed. As a result, some regions in Germany have since made the installation of disinfection systems a legal requirement for hospitals and retirement homes.

The various benefits of chlorine dioxide over alternative procedures enable discrete disinfection, using extremely low concentrations to ensure effective protection for inhabitants while avoiding high decontamination costs and preventing the closure of buildings.

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Thinking ahead makes it possible
Innovation is the essence

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