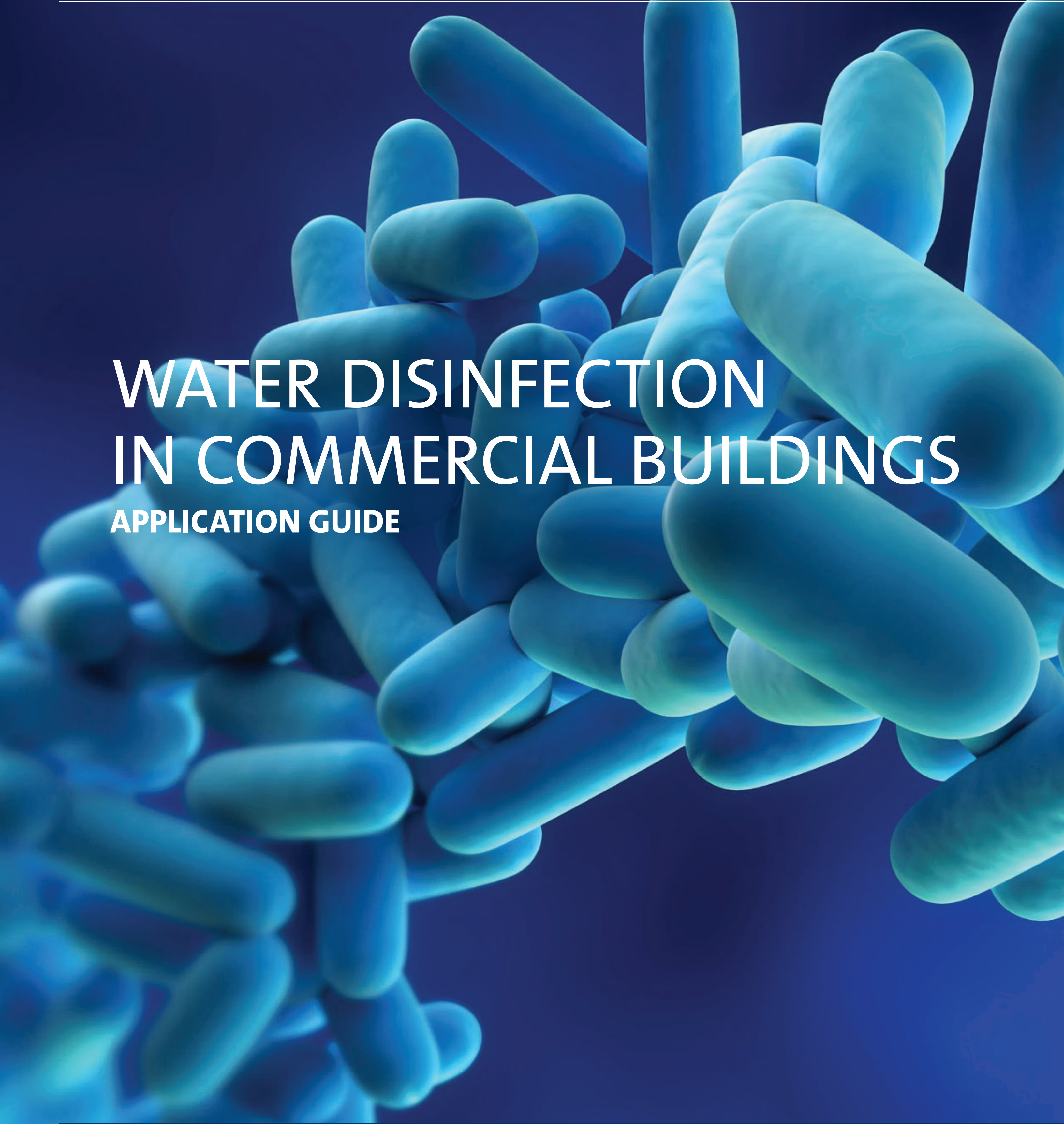

WATER DISINFECTION IN COMMERCIAL BUILDINGS

APPLICATION GUIDE

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Foreword

The health and livelihood of man basically depends on the availability of safe water. Increasing water demand from a growing population and urbanization calls for better management of water resources. Not only should water resources be protected, but the water distribution systems should also be safe and of high quality.

Domestic water or potable water is defined as water of such high quality that it can be consumed or used for domestic purposes, without risk of immediate or long term harm. Unfortunately, this is not always the case. Even though a water resource is managed well and safely distributed in a utility network, it often turns out to be contaminated with microorganisms by the time the consumer turns on the tap. In short, the internal water systems inside buildings often fail to prevent bacteria from multiplying in tanks, pipes and in water handling equipment, where conditions favor their growth.

When distributing and handling water for various purposes, such as in cooling towers, in pools and spas or for domestic purposes, numerous safety measures should be taken into consideration. Many stem directly from established best practices and legislation concerning the prevention and combating of waterborne disease. This is, however, not a simple task and many building owners or building operators have difficulties understanding and meeting these requirements.

This application guide describes the measures to be taken in order to ensure that water systems in commercial and residential buildings are kept safe. It describes what Legionella is and the sources of Legionella in a commercial building, and it shows how these sources are treated with the best possible effect.

INTRODUCTION

If we are to stay healthy, it is essential that the water we drink and shower in is clean. One of the most widespread health hazards in any drinking water installation is Legionella pneumophila – an exceptionally resistant type of bacteria.

Legionella is a mesophile bacterium and it thrives in any system where there is water and where the temperature favours its growth. These conditions are often present in evaporative cooling systems, spas, swimming pools and domestic water systems with low flow rates, areas of stagnation or badly serviced water tanks. A slimy layer of biofilm within pipes and tanks creates a protective habitat in which the bacteria breed and thrive. Water disinfection is of supreme importance in all buildings with drinking water services and most particularly in any application where water mist is sprayed into the air.

WHAT IS LEGIONELLA?

Legionella pneumophila – the bacterium associated with more than 90 % of all cases of Legionnaires' disease – is a bar-shaped bacterium of the Legionellaceae family.

Water, for domestic use in commercial buildings, is very often contaminated with Legionella pneumophila and special measures have to be taken in order to combat it. Because it, for the most part, is resistant to biocides.

Legionella pneumophila in microscopic analysis.

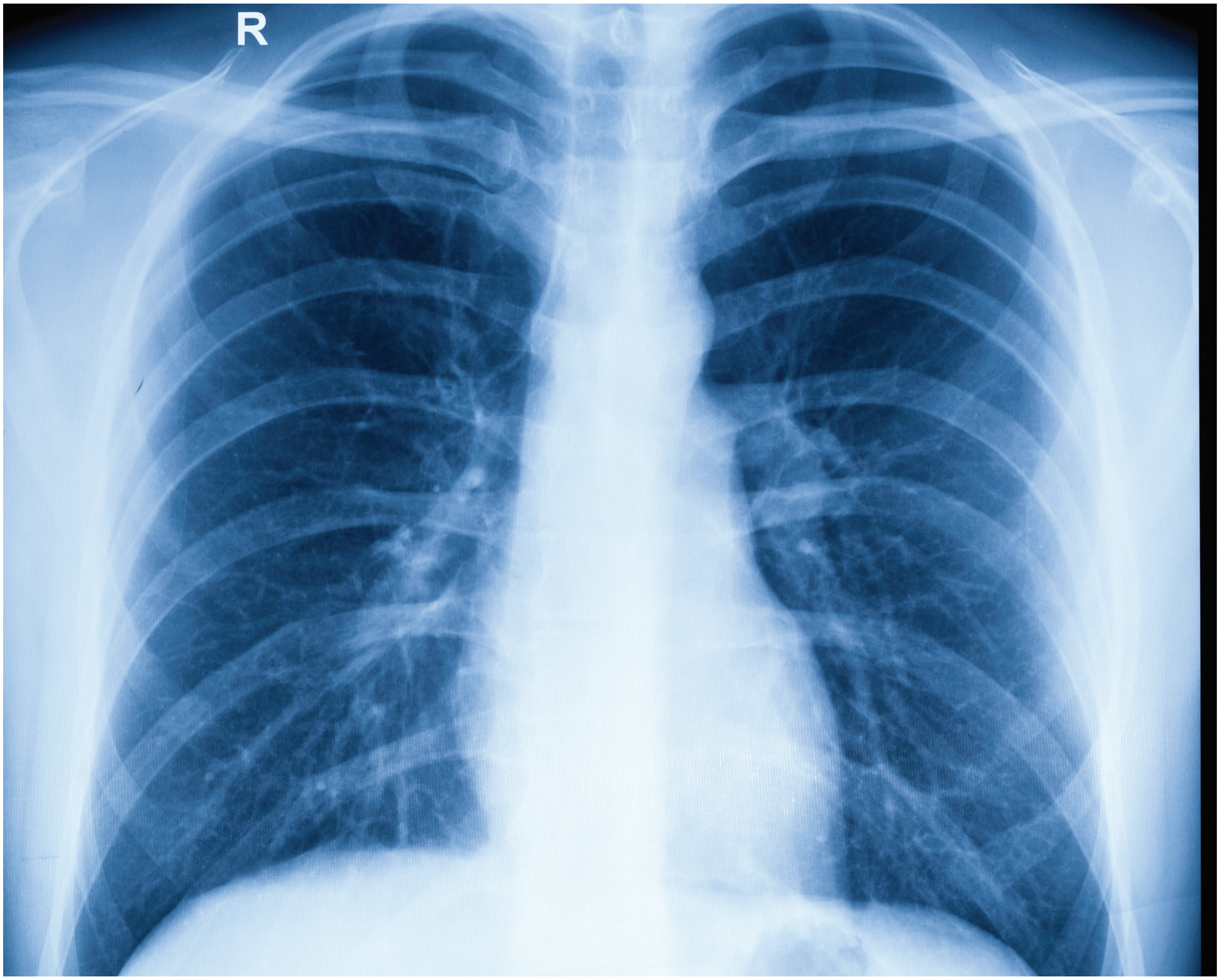
WHAT ARE THE EFFECTS OF LEGIONELLA?

Legionella can be transferred to the human respiratory system in any water aerosol with a droplet size of between 3 and 5 µm and aerosols of this size are easily created in environments such as showers and cooling towers. Even a relatively low concentration of bacteria in the aerosols is sufficient to infect a healthy person. Following an incubation period of 2-10 days, the Legionella pneumophila generates a special form of pneumonia (legionellosis), which can be accompanied by Pontiac fever.

Estimates from the CDC and OSHA indicate that each year in the United States 25,000 people contract legionellosis. Due to misdiagnosed cases, the actual incidence of legionellosis likely is higher. For people with weakened immune systems, such as the elderly, sick and those who smoke, the illness can be fatal if it is not treated within the first four days.

- The legionellosis disease rate is up to 5 % of those inhaling infected aerosols.
- The death rate is as high as 30% of those who succumb to legionellosis.

The Legionella bacteria may cause Legionnaires' disease which develops in the human lungs.



WHERE IS LEGIONELLA FOUND?

Small quantities of Legionella are found naturally in the microflora of rivers, lakes and ground water. These low concentrations are not generally associated with disease, but when favorable growth conditions are created, the bacteria can reach hazardous concentrations. Legionella travels into the water systems of buildings via intakes from both the surface and the drinking water network.

Generally, conditions in hot water systems such as low flow rate, low temperatures, stagnant water and poorly serviced water tanks offer optimum conditions for the growth of Legionella. Legionella reproduces abundantly in a temperature range of between 77°F and 115°F and lives in biofilms where it is shielded against most chemical disinfectants and most disinfection technologies.

Biofilm

Biofilm consists mainly of mixed colonies of microorganisms (bacteria, algae, fungi, protozoans) that are connected to one another and attached to a single substrate. They are integrated fully or partially in a polymeric organic mass (slime) produced by the organisms. This gel-like film offers the ideal growth conditions and the ultimate protection for the bacteria and attaches itself to all kinds of surfaces in contact with water such as tanks, pipes, pumps, etc.

On the inside of piping, biofilm may affect the transport and quality of water. The biofilm takes up space, reducing the effective diameter of the pipe, and increases pipe friction. Both factors increase system resistance, which results in increased power consumption and decreased flow.

Biofilm begins to develop when free-floating micro-organisms attach to a surface. If they are not immediately separated from the surface, they can anchor more permanently. The first colonists facilitate the arrival of other cells and begin to build the matrix that holds the biofilm together. Once colonization has begun, the biofilm grows through a combination of cell division and recruitment of new cells.

If anaerobic conditions develop in the biofilm, certain micro-organisms produce foul smelling gasses, such as methane and hydrogen sulphide, as a by-product of their anaerobic respiration.

Legionella occurs widespread in nature.

SOURCES OF LEGIONELLA IN COMMERCIAL BUILDINGS

There are a number of applications in any commercial building from which the Legionella bacteria can spread. Here are some potential sources of risk:

Cold water systems

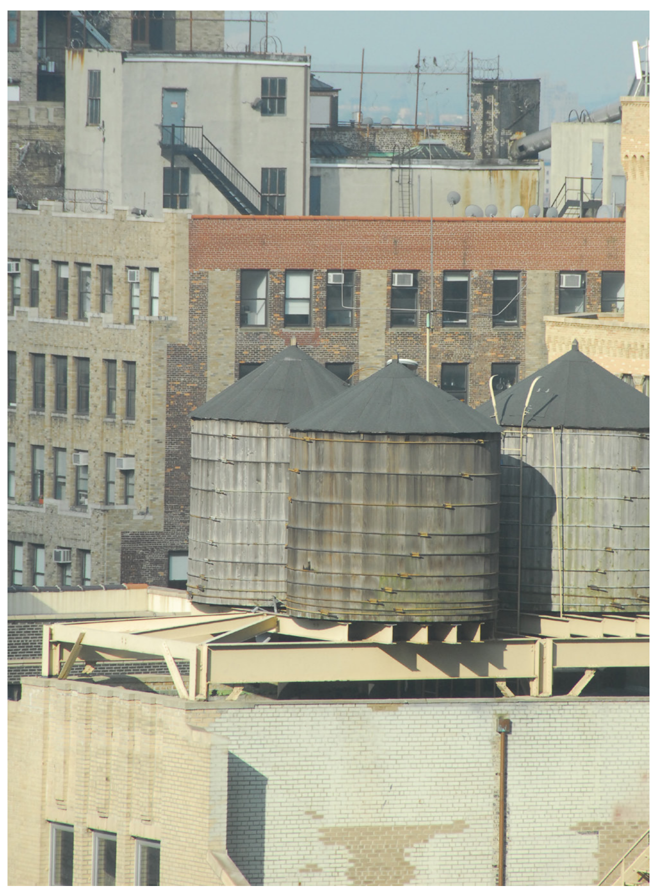
In commercial buildings, cold water frequently heats up to temperatures that create ideal growth conditions for several kinds of bacteria.

At the water's main point of entrance into the building, the cold water usually has a temperature well under 77°F. Beyond that point, the cold water temperature starts to increase owing to high surrounding temperatures. If the water ends its flow in an uninsulated roof top tank, a further increase in water temperature is likely to occur. After some hours in a roof top tank, the water re-enters the building for tapping. Even after rechilling this water is likely to contain high levels of bacteria.

There is an increased risk of bacteria growth in systems where:

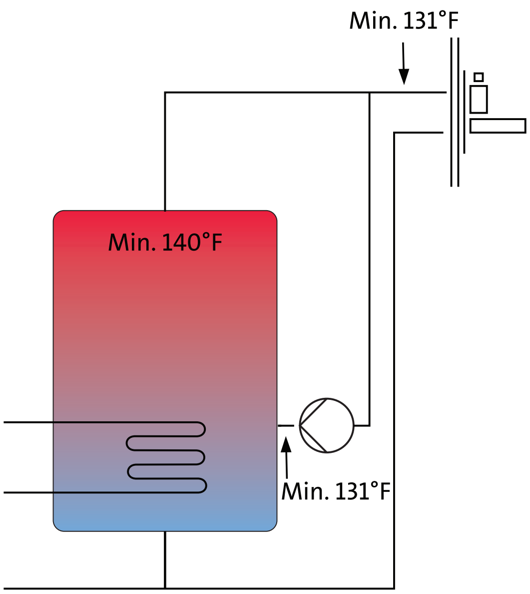
- The cold water pipe is used for hot water recirculation. The cold water pipe will heat up and there will be a severe risk of bacteria reproduction in the pipe.
- Cold and hot water pipes are co-insulated. Heat will travel from the hot pipe to the cold pipe.
- Roof top tanks and break tanks are used. If the use of tanks cannot be avoided, they should be located inside the building and should be sized for the lowest possible retention time.

Wooden roof top tanks in New York City.



Insulated hot water tanks in a commercial building.

Recommended water temperatures in hot water tank and pipe system.



- There are water tanks constructed of organic material in which the tank – itself serves as a food source for bacteria.
- Pipes are oversized. Stagnant water increases the risk of bacteria growth.
- Pipe material is prone to corrosion. Corrosion products also provide a good food source for bacteria.
- There are dead-legs where there is no water flow.

Normally, water from mains contains only small quantities of Legionella, but it should always be assumed that Legionella bacteria are present to some degree. Hence the designer should always design both cold and hot water systems to avoid growth of bacteria and avoid conditions where this might occur.

Hot water systems

All hot water systems are at risk of infection but there is an increased risk of growth in systems where warm water remains more or less stagnant due to low consumption and where the water temperature is between 77°F and 115°F. This temperature range is "ideal" for bacteria growth as Legionella is a mesophile bacterium, which breeds in exactly that temperature range. Poorly maintained systems with sediment, corroded material, scale and sludge that provides food sources for the bacteria are also at risk.

Hot water tanks

In order to reduce the risk of microbial growth in hot water systems, hot water tanks should be carefully designed, monitored and maintained in accordance with accepted best practices:

- The temperature in hot water tanks should be 140°F, while temperatures in the taps and circulation pipes should be no less than 131°F. If the temperature exceeds 140°F, unwanted scaling will occur in both tanks and pipes.
- Oversizing of tanks and pipes will result in stagnant water.
- Hot water recirculation pipes should always be conducted as a separate pipe. The cold water pipe should not be used for recirculation.
- Hot water exchangers should be preferred to tanks as there is no risk of stagnant water in an exchanger or so-called instantaneous hot water heaters.
- Dead ends with no flow should be avoided.
- Insulation should be applied to both tanks and pipes in order to keep temperatures up.
- All pipes should be insulated separately, to prevent heat transfer from hot to cold water pipes.
- Use of plastic pipes should be limited as they are suspected of giving off organic substances which might serve as nutrition for microorganisms.
- Use only non-corrosive, high-quality and approved pipe and tank materials.

Evaporative cooling applications

Cooling towers and evaporative condensers are used to dissipate unwanted heat to the atmosphere through water evaporation. Water is sprayed into the cooling tower through spray nozzles and tiny airborne droplets

The spray from a cooling tower can easily travel 3.5 miles.

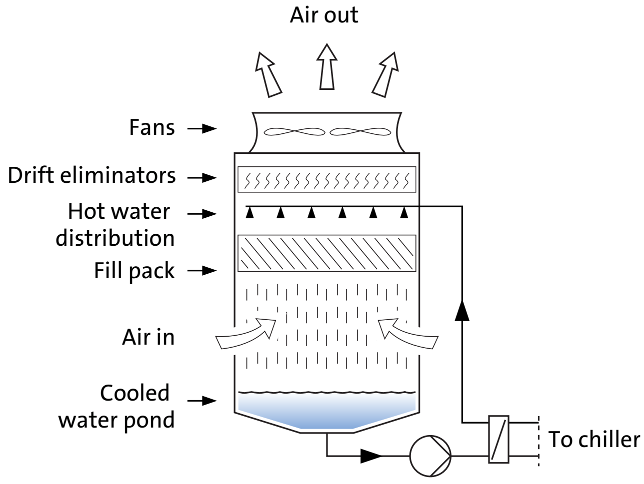


Fig. A. Cooling tower.

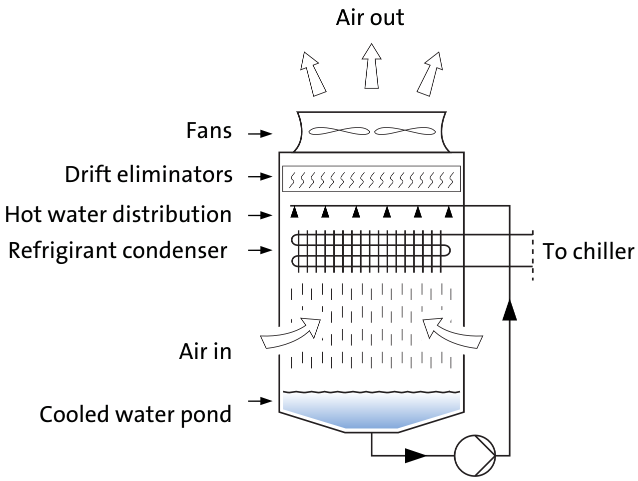


Fig. B. Evaporative Condenser.

are formed. While falling through the tower, some of the water evaporates while some droplets, known as drift, are carried out of the tower by the air stream produced by the fans. Legionella grows easily in the water and is easily dispersed together with the drift.

Cooling towers are a common way of rejecting heat in a cooling process. The heat is dissipated to the atmosphere by evaporation of the circulating water in the cooling tower. Here (see Fig. A), the circulating water in the cooling refrigerant condenser is located outside the cooling tower, usually at the chiller or in the proximity of it.

Having gained energy in the condenser, water from the pond at the base of the cooling tower is circulated in an open loop and distributed over the fill pack. The water runs slowly through the fill pack whilst it is cooled by the upward airstream and finally it drains into the pond. In the process, tiny droplets are formed which are easily carried out of the tower as drift. To avoid this from happening, the tower is supplied with drift eliminators that contract some of the drift.

Evaporative condensers are a less common way of rejecting heat in a cooling process. Here (see Fig. B), the refrigerant condenser is installed inside the tower. Water from the pond is circulated in an open loop and distributed directly over the refrigerant filled condenser where it picks up energy from the condenser coil and evaporates. Again, drift eliminators are used to reduce the amount of drift to the surroundings.

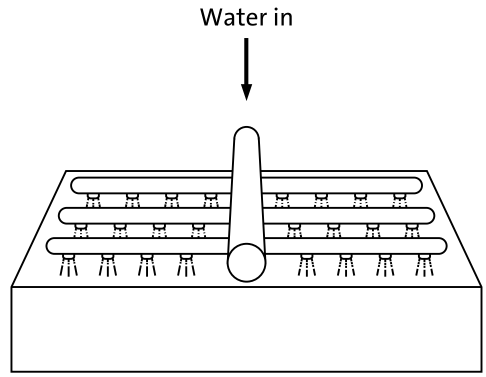
There are two types of water distribution principles for distributing water over the fill pack or condenser.

1. Spray type nozzles. With this arrangement, many droplets may be created which potentially can be carried away.

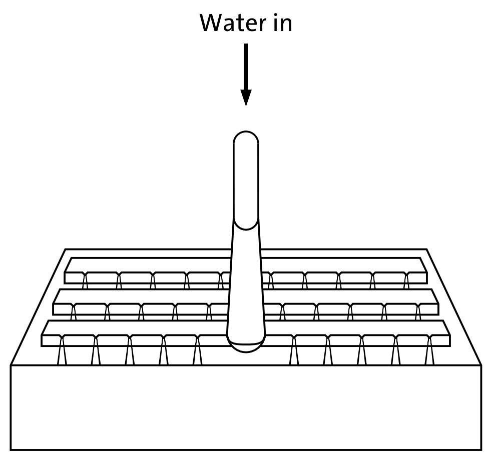
2. Trough and gutter. With this arrangement, far fewer droplets are formed, which reduces drift. However, both trough and gutter are sensitive to creation of sediment and algae growth.

Drift eliminators are essential to any type of evaporative cooling tower or condenser with any kind of water distribution system. The drift eliminators consist of a complex system of baffles on which the droplets are caught before leaving the tower. The baffle system allows the air to smoothly flow through. Eliminators are able to reduce the spray leaving the tower to an amount corresponding to approximately .01% of the circulating water flow. Example: If the water flow is 440 gpm the amount of spray will be about .05 gpm.

Cooling tower water is subject to microbacterial growth for several reasons. First of all the water temperature is of major importance. Water between 77°F and 115°F favors growth of Legionella and this temperature is not uncommon in evaporative cooling applications. Moreover, bacterial growth can be accelerated by the presence of deposits in the system such as sediment, organic matter, scale, and corroded materials which provide essential nutrients for growth. Biofilm in evaporative cooling systems is a common problem, which has to be dealt with. Biofilm is a breeding ground for not only Legionella but many kinds of bacteria.



Trough and gutter.



Spray type nozzles.

Water treatment in evaporative cooling applications

In order to keep control of microbacterial growth, water treatment must contain the following elements:

- Corrosion Control
- Water hardness control
- Dissolved solids control
- Filtration
- Microbacterial control

Corrosion control

Some components of an evaporative cooling system are susceptible to corrosion. Because the water circuit is an open system, the water contains a high volume of air which is one of the preconditions for corrosion. Corrosion may be accelerated by other mechanisms too, such as scale deposits, pH, sediment and corrosion materials.

Water hardness control

To avoid build up of scale and sediment formation, make-up water will have to have a certain softness. If groundwater is used for make-up water it might have a natural and sufficient softness. Otherwise, it will have to be treated with chemical softeners before it is supplied to the tower's water circuit.

Cooling tower water can also be supplied from other sources – for example via condensate from a steam system or condensate from the building's air-conditioning system. Dehumidification of moist outside air can be a major source of demineralized water.

Dissolved solids control

When water evaporates in order to reject heat, the impurities are left behind in the circulating water. The result is that the remaining

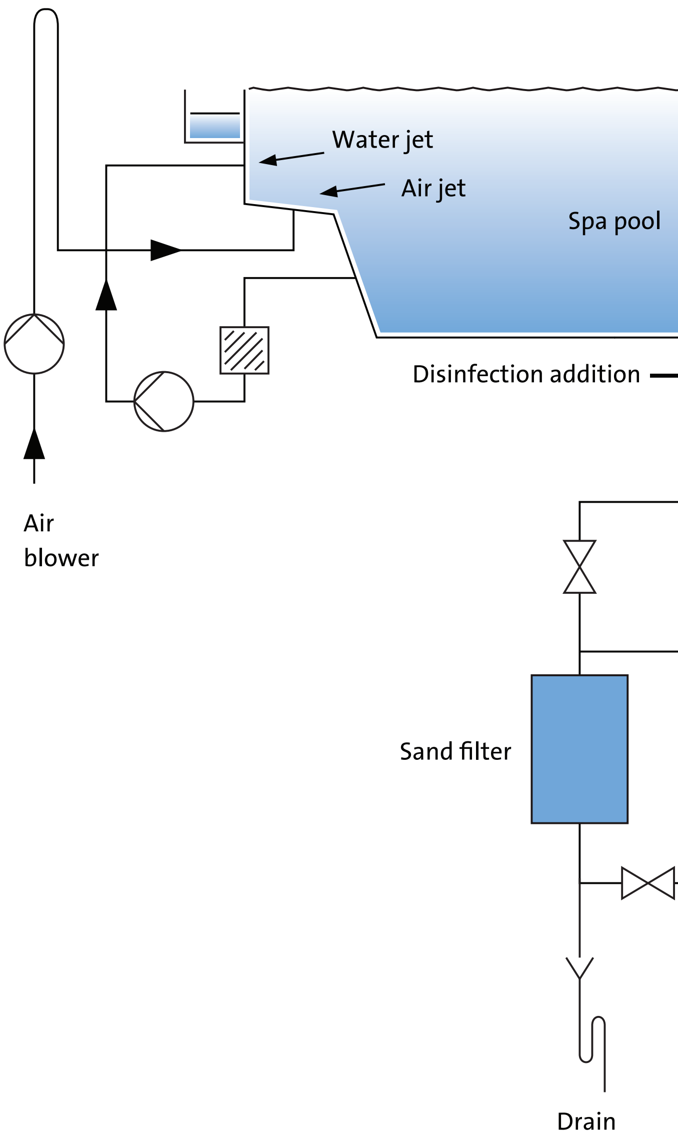
water becomes increasingly corrosive and more inclined to form scale deposits. To avoid this undesired effect it is necessary to bleed a certain amount of water to the sewer system and replace it with treated make-up water.
The evaporative heat rejection rate is not constant as it depends on several factors such as outside air temperature, outside air humidity and internal cooling load. In order to save water, blow-down and make-up water rate should be controlled by the actual and fluctuating demand. The water's electrical conductivity is normally used as an indicator for blow-down and make-up water need. Water use for evaporation and water blow-down can be huge. Water for evaporation depends on the cooling load and it can easily mount up to 9 gpm per MW cooling load. Additionally, chemicals such as flocculants and coagulants may be added to the water to encourage management of dissolved solids and proper blowdown.

Filtration

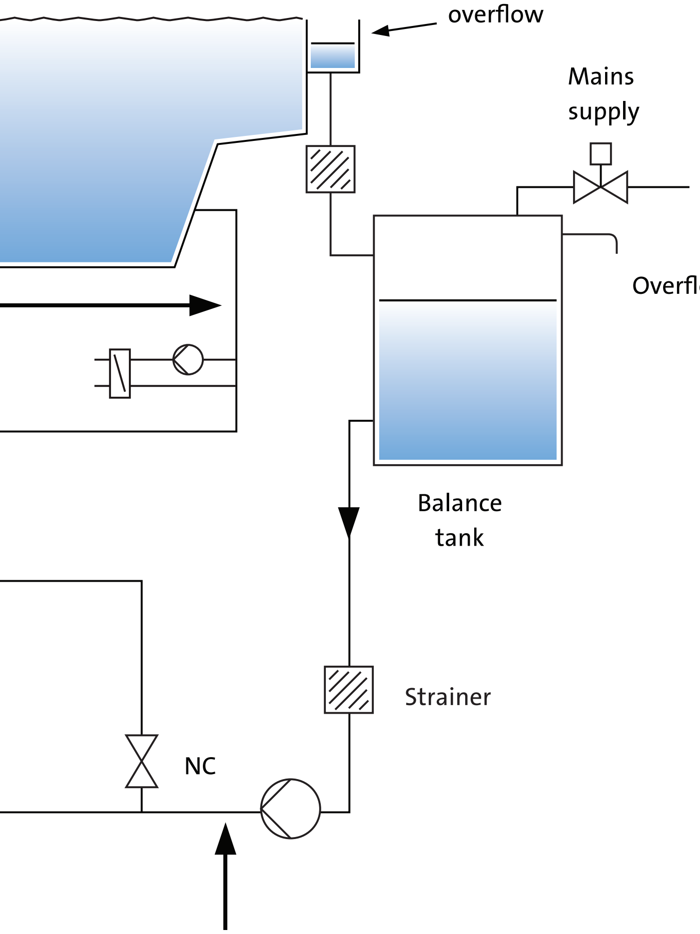
High content of particles in evaporation water may affect the effectiveness of water treatment chemicals used for descaling, corrosion inhibition etc. If the tower is located in areas with high particulate load, such as deserts or heavy industrial areas, strainers should be fitted to the system. Other particulate pollutants are leaves, insects, pollen, seeds and bird droppings.

Microbial control

Water treatment can be done with chemical dosing or with non-chemical means. Continuous dosing of chemicals has proven to be efficient to combat bacteria in evaporative cooling applications. Water treatment with continuous dosing offers the opportunity to add the chemicals according to the actual need. This ensures that at all times, an appropriate chemical content in the evaporation water, which reduces the risk of over/under dosing. Over/under dosing increases the general risk of corrosion and reduces the disinfection action. All water treatment



Spa system with water massage and air jets.



should always be supported by monitoring and evidence of the system's effectiveness to control Legionella and other microorganisms.

Common disinfection principles and chemicals to be used:

- Chlorine (Hypochlorite solution)
- Chlorine dioxide
- Ozone
- UV radiation
- Non-organic chemicals biocides

Spa baths

In spa baths there is increased risk of bacterial growth because virtually all pre-conditions are present. First of all the water in spas is usually maintained at 89° to 95°C, which is an optimum temperature for the mesophile Legionella bacterium to grow. The relatively limited volume of water and high user load result in water with a high content of dirt, dead skin cells and other organic matter, and combined with raised temperature, agitated and aerated water it makes for ideal conditions for all kinds of microorganisms. Bubbles imploding on the water surface create aerosols which are readily inhaled by the spa users. Also the "hidden" air and water circulation pipes provide a large surface area for the biofilm and bacteria to grow on. Biofilm in these pipes can therefore not be removed.

Spa baths should be monitored, maintained and cleansed daily.

Although chemical disinfectants are used for disinfection the following manual procedures have to be performed on a daily basis:

- Check of chemical dosing operation
- Cleansing of spa, overflows and spa surroundings
- Emptying of water filters
- pH-value and water clarity check

Common disinfection principles and chemicals to be used in spa baths:

- Chlorine/Hypochlorite
- Chlorine dioxide
- Ozone

Recommended free chlorine level in spa baths should be 3 – 5 mg/l. Sand filters are a very important component to secure clean water in spas. The sand filter ensures that particles and organic matter such as dead skin cells and human hair are filtered away. Flocking agents have to be dosed before the sand filter. Flocking or flocculation is a process where small suspended particles create flocs by the addition of a clarifying agent. In this way the dead skin cells, which are collided in flocs, can be removed. To ensure high efficiency, sand filters will have to be back-flushed. Common water attractions such as slides, fountains, etc. pose a greater risk for aerosols and require more careful treatment.

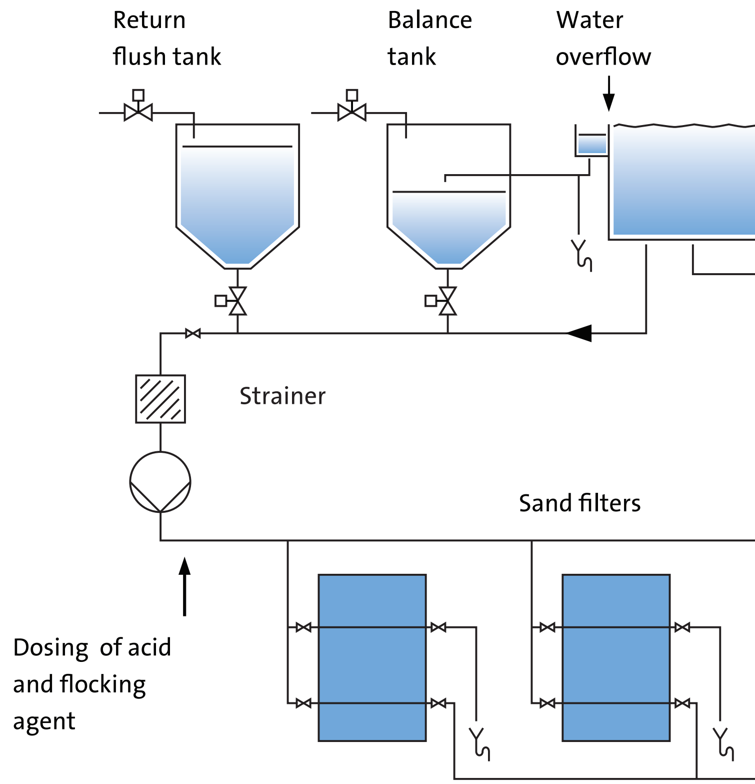
Swimming pools

Bacterial growth in swimming pools has to be addressed as well as in spa baths. However, swimming pools are characterized by having considerably lower organic load because pools are designed for much fewer persons per volume of water. A swimming pool is designed for swimming whereas spas are designed for people sitting next to each other. Furthermore, swimming pools do not include air and water jets. The water is not agitated and the aerosol creation is reduced.

Swimming pool disinfection

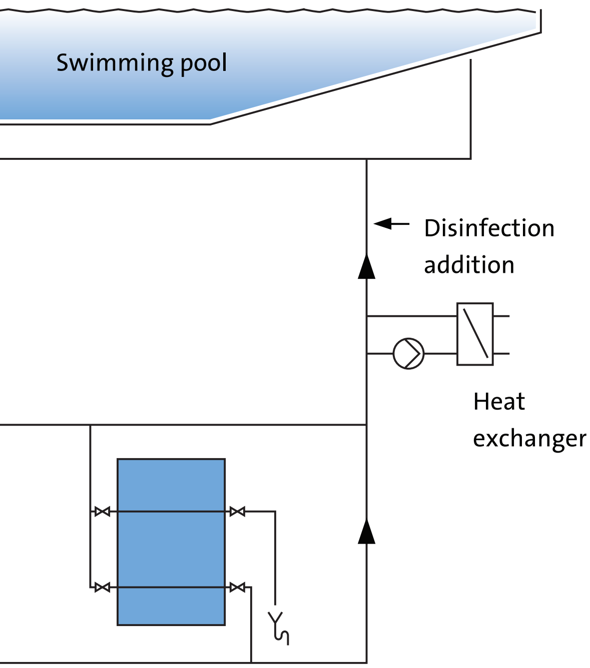
Sand filters as well as chemical treatment are employed in swimming pools. There are a variety of disinfection principles and chemicals to be used either combined or separately:

- Chlorine/Hypochlorite
- Chlorine dioxide
- Ozone
- UV radiation



Swimming pool system.

Water fountain in a shopping mall.



Supermarkets' green grocery department.

Decorative water fountains

Water fountains in places such as shopping malls, airports, hotels and fun parks are subject to bacteria growth. Water is sprayed into the air, airborne droplets are formed and then easily inhaled into the lungs. Fountain water is the same temperature as the surrounding air and at that temperature, Legionella and other bacteria grow readily in the water and biofilm.

Disinfection principles and chemicals to be used in fountains:

- Chlorine (Hypochlorite solution)
- Chlorine dioxide
- Ozone
- UV

Misting devices

Misting devices commonly used for evaporative cooling in public areas and to keep fruits and vegetables fresh for as long as possible. This procedure is not only able to reduce moisture- and weight loss of fruit and vegetables, it also promotes re-hydration. Re-hydration enables fresh produce to regain the moisture already lost since harvest and therefore extends fruit and vegetable life dramatically. Infected spray would be a major threat to the customers as it is easily inhaled into the lungs. Misting devices are also frequently used for cooling in hot climates such as at sporting events, in amusement parks and in retail outlets. These guidelines should be followed for such venues.

Moisturising water should be of drinking water quality, and should be maintained at a temperature of under 68°F and always be disinfected to reduce the risk of bacteria growth. Pipes and tanks should be designed to minimize the risk of stagnant water and to minimize thermal gain.

METHODS OF WATER TREATMENT

Thermal treatment

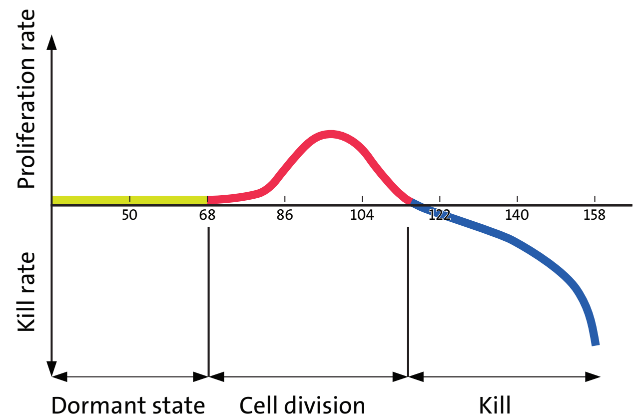
One of the most commonly used methods to combat Legionella is thermal pasteurisation. Legionella begins to die at temperatures above 115°F, which makes it possible to combat the bacterium by heating the infected water system. A temperature of approximately 158°F must be reached and maintained throughout the entire piping system over a period of around 10 minutes. However, this can rarely be achieved in typical installations because the water cools down as it reaches the water outlets.

There are relatively few advantages to thermal treatment:

- This procedure does not affect the smell and taste of the water.
- It is not sensitive to the pH-value of the water.
- The procedure is well known and easily understandable.
- There is no addition of biocides to the water.

On the other hand, there are many disadvantages to thermal treatment:

- There is acute risk of scalding if the water outlets are opened during pasteurization.
- Biofilm is left unaffected, which means that germs quickly build up again between treatment cycles. Thus, there is no long-term effect of the pasteurization.
- Dead-ends are not treated at all.
- An advanced tap-opening process must be implemented to make sure that all sections of the water system are treated. Needless to say that in large residential and commercial water systems, it is impossible to secure the flushing of all pipes.
- The consequence of heating up large water systems is very high energy consumption.



Legionella bacteria's ability to reproduce as a function of temperature.

- The desired temperature of 158°F can never be achieved in the whole system, because the water cools down before it reaches the water taps.
- This procedure produces increased lime scale deposits in pipes and tanks. This might damage systems and clog water taps.
- Thermal expansion in pipes can cause irreparable damage and leakages in older installations. The overarching conclusion is that thermal treatment is an inefficient and expensive procedure.

Chlorination

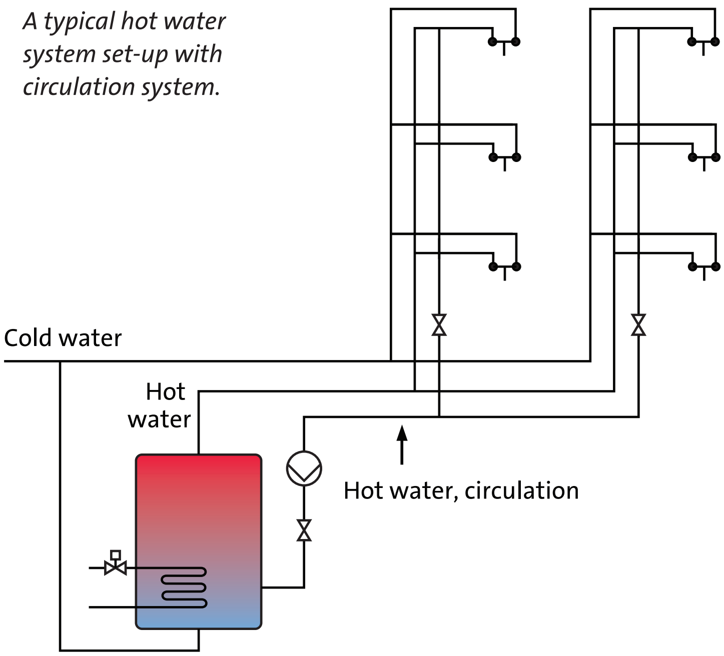
Chlorine has been used to treat drinking water for more than 75 years. Thanks to its high safety standards, it is the most widely used disinfectant worldwide. It is a highly effective oxidant and disinfectant. It sterilizes rapidly and efficiently, more or less completely destroying nearly all microorganisms, even at low concentrations that are harmless to humans.

In practice, three chlorine disinfection processes are used:

- Disinfection with chlorine gas. This is the most widely used process.
- Electrolytic chlorine generation.
- Dosing of liquid sodium or calcium hypochlorite solution. Liquid hypochlorite solution is primarily suited for cases where smaller quantities of water need to be treated.

When chlorine gas, electrolytically generated hypochlorite or a hypochlorite solution is dosed into water, hypochlorous acid (HClO) is formed. HClO is the active disinfectant. The disinfectant penetrates and degrades the cell membranes

A typical hot water system set-up with circulation system.



and disrupts the metabolism of the microorganisms. Of particular benefit is chlorine's relatively long residual effect. Chlorine is used as a disinfectant in a wide range of applications that stretch far beyond drinking water treatment. It is essential for disinfecting swimming pools worldwide and is often a statutory requirement.

Chlorination characteristics:

- The treated water smells and tastes of chlorine.
- The procedure is sensitive to the pH-value of the water.
- Long-term effect on bacteria is limited.
- Biofilm in hot water tanks and pipes is left unaffected.

Disinfection with chlorine gas

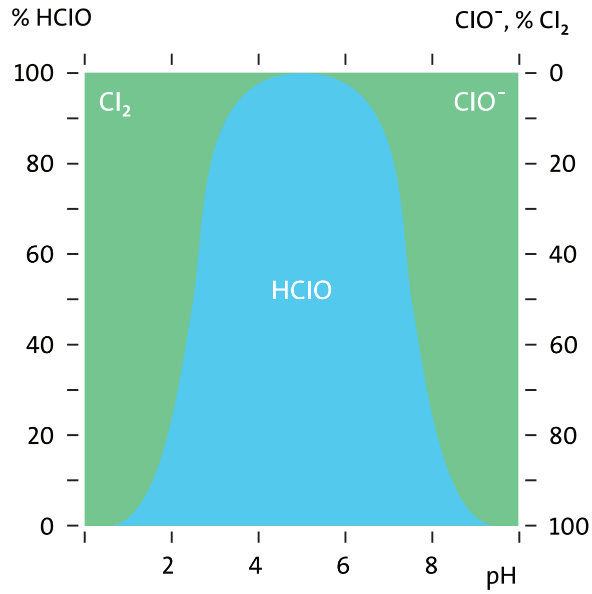
Gas dosing systems from Grundfos work according to the proven full-vacuum principle. In case of a pipe leakage, the vacuum system ensures that chlorine gas is kept within the pipe system. This can be used to regulate the addition of gaseous chlorine reliably and precisely. Typically, a full-vacuum system consists of a number of components: a dosing regulator, vacuum regulators, a chlorine gas absorber and a gas injector. Chlorine gas disinfection is common in swimming pool applications.

When gaseous chlorine is added to water the following hydrolysis reaction takes place:

$Cl_2 + H_2O$ <-> HCl + HClO

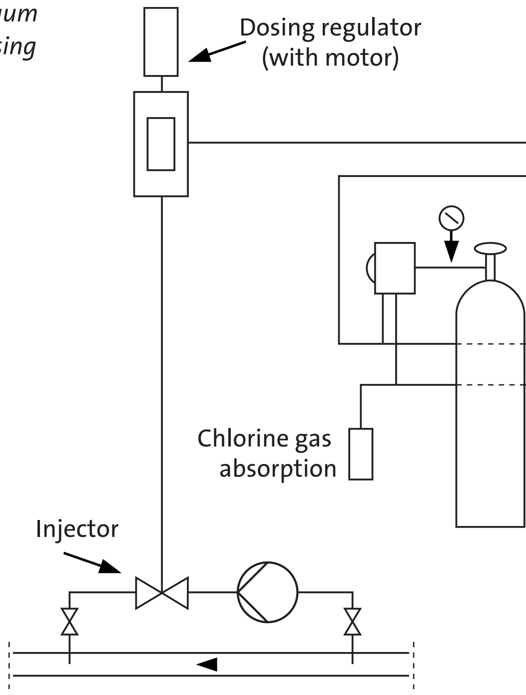
The Grundfos chlorine gas dosing range:

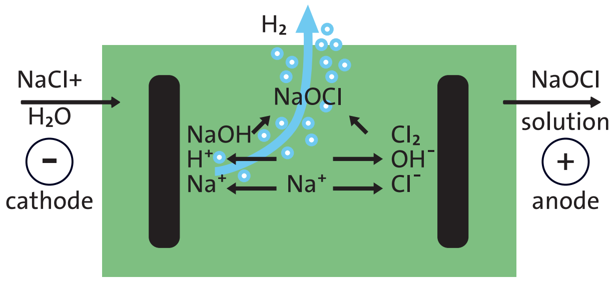
- Compact devices with a single point gas injector for direct installation on chlorine gas cylinders or header lines.
- Fully automated systems with PLC controller, integrated sensors and multiple injection points.



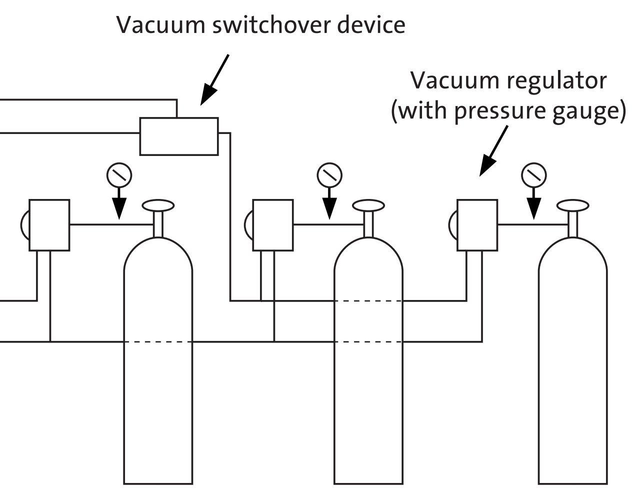
Graph showing how the disinfection efficiency is dependant of the pH-value. The blue area shows the concentration of the active disinfectant, HClO. pH-values below 3 or above 7.5, will reduce the disinfection effect significantly.

Typical full vacuum chlorine gas dosing system.





Generation of a hypochlorite solution in an electrolytic cell.



Electrolytic chlorine generation

With electrolysis, chlorine is produced directly from a solution of common salt using electricity. There are no significant by-products from this procedure.

The following reactions take place in the electrolytic cell:

$2\ NaCl + 2\ H_2O <-> 2\ NaOH + Cl_2 + H_2$

The chlorine produced reacts immediately with the caustic soda solution also formed, resulting in a hypochlorite solution:

$Cl_2 + 2\ NaOH <-> NaCl + NaClO + H_2O$

The product solution generated has a pH value between 8 and 8.5, and a chlorine concentration of less than 8 g/l. It has a very long half-life, which makes it ideal for tank storage. When the product solution is dosed into the water, the sodium hypochlorite reacts with the water and the active disinfectant HClO is formed.

$NaClO + H_2O <-> NaOH + HClO$

An electrochlorination system is characterised by low operating costs, as there are no expenses for safe transportation and storage of chlorine gas. Common salt is the only raw material required.

The Grundfos electrochlorination units range comprises complete plug and dose systems as well as systems built acccording to the customer's specifications.

On-site generation of chlorine with a Grundfos system is performed cost-effectively, reliably and with high operating convenience. Peak demands are handled by using the product tank as buffer storage.

Dosing of sodium hypochlorite solution

Sodium hypochlorite (NaClO) is a clear, slightly yellowish solution with a characteristic odor. As a bleaching agent for domestic use, it usually contains 5% sodium hypochlorite. Hypochlorite for commercial use is more concentrated. It contains a concentration of 10-15% sodium hypochlorite with a pH of around 13, which makes it very corrosive.

Concentrated sodium hypochlorite is an unstable compound, as it evaporates at a rate of 0.75 gram active chlorine per day from a one liter solution. The degrading process accelerates when sodium hypochlorite is mixed with acids, certain metals or when it is exposed to sunlight or high temperatures. Sodium hypochlorite is a strong oxidant.

These characteristics must be kept in mind during transport, storage and use of sodium hypochlorite.

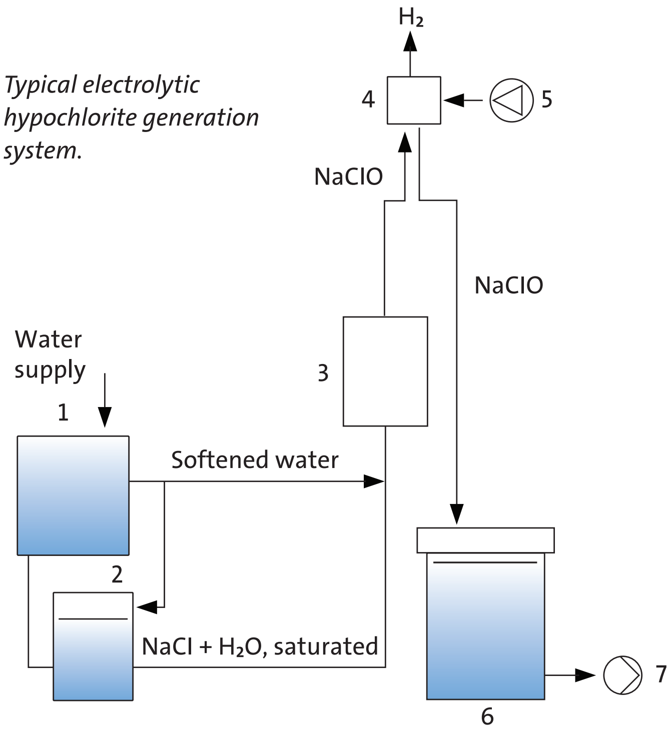
When sodium hypochlorite is added to water the pH-value of the water increases, due to the creation of lye (sodium hydroxide, NaOH) in the solution. When sodium hypochlorite is used for disinfection in water, hydrochloric acid (HCl) or sulphuric acid (H_2SO_4) is usually added to adjust the pH-value. The active disinfectant HClO is created when the hypochlorite solution is dosed to the water that has to be disinfected.

$NaClO + H_20 <-> NaOH + HClO$

Sodium hypochlorite as a disinfectant has the following advantages:

- Dosing of sodium hypochlorite is a simple and efficient process.
- Dosing of sodium hypochlorite is a safer solution compared to chlorine gas handling.

Typical electrolytic hypochlorite generation system.



1. Water softener required to prevent scaling in the electrolyser cell
2. Brine tank for preparation of the saturated salt solution
3. Electrolyser cell
4. Degasing device for hydrogen gas removal
5. Fan for dilution and venting the hydrogen gas
6. Storage tank for product solution
7. Dosing pump for injection of product solution

UV rays from the sun seen as deep violet in color.

Sodium hypochlorite as a disinfectant has the following disadvantages:

- Concentrated sodium hypochlorite is a corrosive substance; hence it should be handled with care.
- High degradation rate during storage. After 2-3 months of storage the sodium hypochlorite disinfection effect will be reduced by 50%.

Water treatment with sodium hypochlorite requires accurate and safe dosing solutions.

The Grundfos digital dosing pumps offer reliable, cost-effective and high-precision dosing processes for all commercial applications. Grundfos digital dosing pumps are independent from regional voltages. Integrated flow control function allows dosing of degassing liquids without interruption of the process.

UV radiation

UV functions with the use of ultraviolet rays. Infected water that should be disinfected is radiated with ultraviolet rays with a wavelength of 254 nm. The UV rays penetrate the cell wall and damage the genetic information of the bacteria and viruses, disrupting their reproductive systems. A UV-bulb is used for radiation of the water. UV units in domestic water systems can be installed at the water intake to the building, in circulation pipes or at the point of use.

Advantages:

- UV-treatment is effective against free bacteria that are exposed to the UV-rays.
- The procedure does not affect smell and taste of the water.
- No chemicals are added to the water
- UV-treatment is not sensitive to the pH-value of the water.

Disadvantages:

- This method is regarded as a ”gatekeeper” – only free bacteria that actually float by the UV-bulb and are exposed to the UV-rays are killed. There is no long-term effect on bacteria populations in the water system.
- Biofilm in the piping network – the basis for the multiplication of Legionella – is unaffected by this procedure and UV-radiation has no effect on bacteria that remains in the biofilm.
- The UV-bulb is very sensitive to particles and scale in the water. The addition of carbonic acid, for example, is necessary to avoid scale precipitation.
- The ultraviolet radiation system often includes an activated carbon filter to remove metals and particulates.

Filtration

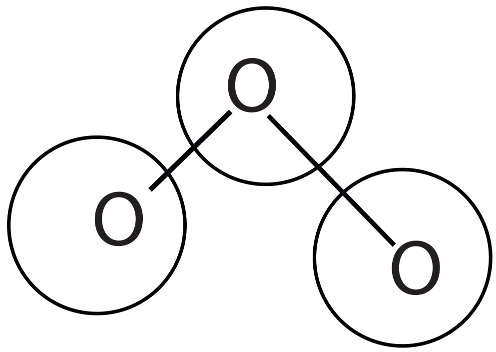
Ultra- or microfiltration is commonly used for domestic water supply. Membrane systems filter bacteria, viruses, suspended particles and other unwanted elements from the water. These devices are usually installed at the water intake to the building or in circulation systems.

Advantages:

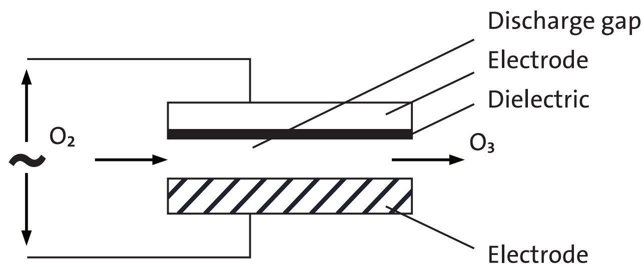
- Filtration is effective against free bacteria floating in the water.
- Filtration does not affect smell and taste of the water.
- Not sensitive to pH-value of the water.
- No chemicals are added.

Disadvantages:

- This method is regarded as a ”gatekeeper”. Only free bacteria floating in the water can be removed. There is no long term effect on bacteria populations in the water system..
- Biofilm in the pipes and water tanks – the basis for the multiplication of Legionella – is unaffected by this procedure.
- In case of malfunction, a large microbiological population can grow in the membranes.



Molecular structure of ozone, O_3.



Schematic ozone generator.

Ozone

Ozone is a sanitizer derived from the surrounding air which can be dissolved in water for the purposes of disinfection. It is produced by passing oxygen through a high intensity electrical field. Using this method, the oxygen gas is changed to ozone gas – a molecule with three oxygen atoms (O_3). Once generated, ozone must be used immediately as it breaks down rapidly. The half-life of ozone is less than one hour in best case. Ozone is the most effective oxidant which is used in disinfection processes but therefore non-selective which means that it reacts with all materials which can be oxidized. Not only organic compounds in the water but also pipe sealings and pipe material.

Small ozone generators are often used in cooling water circuits or fountain applications. In pool water applications ozone is used as additional oxidizer to reduce undesired by-products from the water.

Advantages:

- Ozone is effective against free bacteria floating in the water.
- Smell and taste of the water is not affected.
- Not sensitive to pH-value of the water.

Disadvantages:

- This method is also regarded as only a ”gatekeeper”, because of the breakdown time. As the retention time is very short there is no residual effect and no long-term effect on bacteria populations in the water system.
- Biofilm in the piping network – the basis for the multiplication of Legionella – is unaffected by this procedure and ozone has no effect on bacteria in biofilm.

Chlorine dioxide

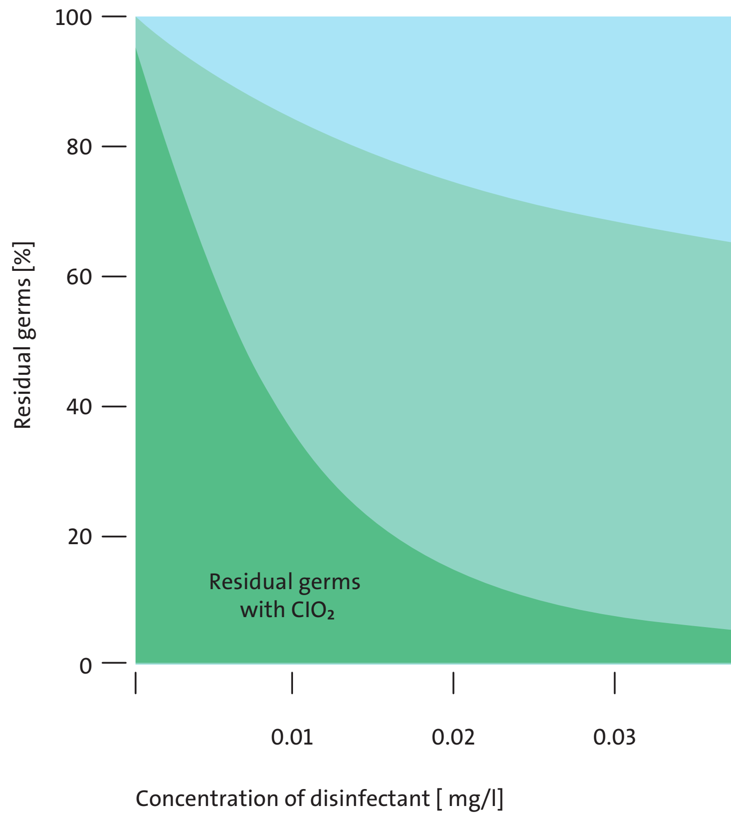
Chlorine dioxide is an oxide of chlorine with two oxygen atoms (ClO_2) with a completely different behavior compared to hypochlorite or chlorine gas. It does not react with water, but dissolves physically. Chlorine dioxide kills microorganisms in the water by way of irreversible oxidative destruction of the transport proteins in the living cells.

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 e.g. chlorine, which means that significantly fewer chemicals are required. Microorganisms that are resistant to chlorine, for example Legionella, can be killed completely by chlorine dioxide.

The significant advantage of chlorine dioxide in relation to chlorine or hypochlorite is the gradual effect it has on degrading biofilm at low doses. A chlorine dioxide concentration of 1 ppm will kill virtually all free-flowing Legionella and inactivate most of the bacteria in the biofilm within one day. A significant reduction of biofilm can be observed after several days. 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.

There are many advantages to chlorine dioxide:

- Chlorine dioxide removes biofilm effectively in the entire water system, ensuring that the basis for the multiplication of Legionella is removed.
- Effective against free bacteria floating in the water.

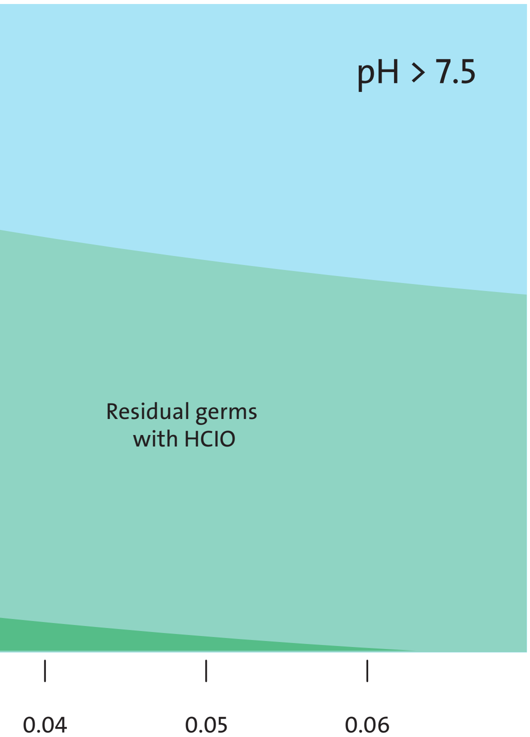


CHARACTERISTICS OF TY

This chart illustrates how the typical solutions for disinfection perform on a number of parameters. The chlorine dioxide solution of the Grundfos Oxiperm Pro system is superior to the rest.

Disinfection principle	
	Thermal treatment
	UV radiation
	Filtration
	Chlorination (hypochlorite sol.)
	Ozone
	Chlorine dioxide

Performance of disinfection technologies and disinfectants on a number of parameters.



Comparison of disinfection effect between chlorine and chlorine dioxide.

PICAL DISINFECTION SOLUTIONS

Removes biofilm	Effective against bacteria in biofilm	Effective against free bacteria	Affects water taste and smell	Sensitive to water-pH	Life cycle cost	User scalding risk	Long-term effect
No	Low	Mid	No	No	High	Yes	No
No	No	High	No	No	Mid	No	No
No	No	No	No	No	Mid	No	No
No	Mid	High	Yes	Yes	Low	No	Mid
No	No	High	No	No	Low	No	No
Yes	High	High	No	No	Low	No	High

- Effective against bacteria and biofilm in dead-legs, as the chlorine dioxide can dilute into dead-legs with no water flow.
- Extensive residual effect. If there are periods with very low or no flow, the chlorine dioxide stays in the water and protects the system for up to one week.
- Chlorine dioxide does not affect the smell and taste of the water.
- Chlorine dioxide is not sensitive to the pH-value of the water.

The only disadvantage concerning this procedure is the risk of handling the chemicals. If hydrochloric acid (HCl) and Sodium chlorite ($NaClO_2$) are mixed uncontrolled, chlorine dioxide gases are formed.

Grundfos chlorine dioxide generators are designed for use in commercial building applications. A safe and patented process ensures reliable generation of ClO_2. The compact design with integrated controller, product storage tank and digital dosing pump for the product solution allows installation in areas with limited space. These units are mainly used in treatment of incoming drinking water, circulating hot water or in cooling water cycles as well as in decorative fountains.

WATER QUALITY ASSURANCE AS A SHARED RESPONSIBILITY

Almost every country in the world has legislation regarding the prevention and combating of infectious diseases. The Environmental Protection Agency's (EPA) Safe Drinking Water Act says that:
National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water.

Although water utility companies are responsible for the quality of water up to the water delivery point, owners or operators of water systems in public or residential buildings bear the responsibility for the maintenance and quality of the water systems within those facilities. Basically, in both cases, all EPA and public health standards apply from treatment to point of use for potable water.

Because of the mounting concern over waterborne pathogens within commercial buildings ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) has proposed a new standard (ASHRAE 188P: Prevention of Legionellosis Associated with Building Water Systems) to strengthen guidance on recommended actions to prevent disease caused by Legionella in building water systems.

The initial focus of this effort has been on hospitals and medical facilities, in which there is the obvious, heightened risk (of infection) to compromised patients being treated within these facilities.

The goal of ASHRAE 188P is to specify a standard practice to prevent the spread of legionellosis associated with building water systems. The principle behind the standard is based on a type of risk management system used in many industries, including the food industry, called the hazard analysis and critical control point (HACCP) method.

In applying the HACCP approach to building water systems, three types of hazards; biological, chemical, and physical, are analyzed at each point in a building where water is processed. These locations include points where the water enters the building, the heating system, and distribution piping. In the case of hospitals, there is often a subsystem for processing water for drinking fountains that filters the water, cools it, and filters it again, and other subsystems that handle water used for fire suppression, ice machines, steam tables, and cafeteria service lines. Water in each of these subsystems should be processed in the same way as water for drinking fountains.

The increasing awareness of the responsibility of maintaining water quality , especially within medical facilities, is leading to the formation of HACCP committees. In many cases, the liability issues surrounding hospital acquired infections (HAI) is accelerating the implementation of the ASHRAE guidelines.

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Acknowledgement to Carsten Persner, Product Manager with Grundfos Water Treatment GmBH.

WATER DISINFECTION IN COMMERCIAL BUILDINGS

Grundfos is a leading supplier of full-range pump solutions from water treatment, heating and cooling to pressure boosting and every application in between.

At Grundfos, we think beyond the pump. From the largest, most complex applications to the smallest, we utilize our in-depth pump knowledge and our unrivaled range of intelligent pumping systems.

This approach has made us a preferred partner for contractors, consulting engineers, building owners, and many others as they look to boost performance and reduce energy consumption.

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