Life *needs* Water

Fresh water - our most valuable asset

English edition

Author: Christoph Scheffold

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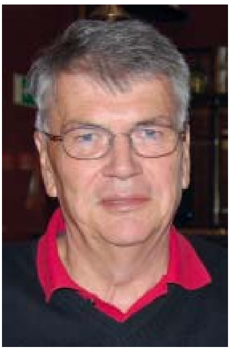

Preface

dinotec GmbH has been developing and distributing products and systems for water treatment for over 30 years. The company started to specialize additionally on systems for disinfecting water about 15 years ago. By now, the applications range from circulation water, drinking water and process water to industrial water treatment. A special division "dinotec Water Technology" was created, which allows the company to serve its customers in the best possible way. Innovative systems combined with professional advice and planning support provide our customers with efficient solutions.
Our fresh water is a precious commodity which we must treat with utmost care. dinotec is committed to this requirement. This book is therefore a matter that is close to our heart, and is our way to emphasize the vital importance of water.
The quality of fresh water determines the effort required to obtain drinking water. In Germany, we are still in a fortunate position, because we have access to sufficient groundwater reserves. 4.5 billion cubic meters of water were delivered to households, industry and small businesses in 2010. We have approximately 17,000 water protection areas in Germany. About 17% of the natural water resources are used. We must be aware, however, that these reserves are limited as well.
Drinking water is a food and should be available for use always without causing any health problems.
The following information is intended to make clear how important a responsible treatment and delivery of water is, it provides an overview of the current state of relevant regulations, and the technologies available to provide water that is safe for drinking.

Andreas Schmidt

Management of dinotec Water Technology GmbH

Auf einen Blick

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The Earth and its water

Two-thirds of the surface of our planet Earth is covered with water.

Figure ▶
Even though more than two-thirds of the Earth are covered with water, fresh water is still scarce

More than 97% of the global water resources consist of salt water and only about 3% is fresh water.
Two-thirds of fresh water is present in the form of ice on the poles and is therefore not accessible for us.

The fresh water resources on Earth are distributed as follows:

- about 0.02 % is contained in clouds and precipitation (rain, snow and hail),
- about 0.5 % in rivers, streams and lakes,
- about 30.5 % in ground water,
- about 69 % in glaciers and the polar ice.

Water moves in a continuous cycle.
The sun causes water to evaporate, which is then returned to the cycle as precipitation. Salt is left behind as part of the evaporation of salt water. This means that the evaporated water is fresh water. Only a small portion of the fresh water we find on Earth is easily accessible in rivers, lakes and in the ground.

The fresh water on Earth is distributed very unevenly. About 450 million people are currently living in countries facing water shortages. By 2050, nearly one in four people will live in a country where water will be scarce.
For a sustainable use of water, it is not the existing

reserves which are decisive, but the renewable fresh water resources in the form of precipitation falling from the sky. If more water is withdrawn from lakes and ground water than is replenished by precipitation, these supplies will dry up.

The Aral Sea is a good example. Formerly the fourth largest lake in the world, the Aral Sea has been steadily shrinking since the 1960s due to a greatly increased water consumption and continues to dry out.

- Originally the size of Bavaria
- In 2003 the size of North Rhine-Westphalia
- In 2009 large parts vanished

It is indispensable that we handle our freshwater resources with care. That also means that we must maintain the quality of the water and prevent damaging it by contamination.

Precipitation too is by no means clean any longer. Toxins brought into the air by gases are partly washed out of the air and brought back to the Earth in the form of precipitation.
The contamination of water bodies is caused by private households and agriculture, industry and commerce.
For a sustainable water policy, a conservation of the water quality therefore also requires an optimal disposal (sewerage and purification) of water.

About 37 million people live In the German Rhine river basin. The wastewater from the municipalities and industrial plants is discharged into the waters in the Rhine river basin via sewage treatment plants. Due to the possibilities for transport on the river Rhine, the industry along the river itself is disproportionately compressed, compared to the rest of Germany.

The Rhine supplies about 20 million people with drinking water at once, which is gained primarily through bank filtration.

The more the fresh water is loaded with impurities, the more difficult the drinking water abstraction from it.

Drinking water is a necessity of life.

Figure ►
Drinking water: Our most valuable asset!

Depending on the quality, however, the raw water required for the abstraction of drinking must first go through several treatment steps in the waterworks. This ensures the availability of high-quality drinking water.

In the middle of the 19th century, Louis Pasteur determined that people take in 90% of diseases by what they drink.

Figure ►
Louis Pasteur (December 27, 1822 – September 28, 1895)

Water is vitally important. Man can survive long periods without food, but can survive only a few days without water.

Water and the human body

Water has many functions in our body, a sufficient supply of water is therefore absolutely necessary. Each chemical reaction, and each process in the body is dependent on the presence of water, because it has ideal properties.

- Solvent: All body fluids consist mainly of water. Nutrients are dissolved in these body fluids as are substances that are left over as part of the metabolic processes. They are disposed of via the "water route".
- Means of transport: Water ensures the transport of various substances and cells from one location to another or even out of the body via blood or lymphatic fluid.
- Cooling medium: Water is a better conductor for heat than air. When the body temperature is too high due to exercise or disease, the body uses its water cooling system. When sweating, water is eliminated through the skin pores, ensuring a rapid heat dissipation.
- Reacting agent: Chemical reactions involving water take place in the body all the time, and they are only possible with water.
- Building material: In addition to minerals (for example the main component of bones and teeth), and protein (main constituent of muscles), water is the most important component of the body. The total content of water in the body decreases with age. In newborns, this content is 75 to 80 percent, in normal-weight adult men it is about 60 percent and in normal-weight adult women 50 to 55 percent.

Drinking water

Our water supply companies consistently provide a high-quality drinking water.

Figure ►
Karst spring in water-works

The German Nutrition Society (DGE) point out that drinking water is particularly suitable as a thirst quencher. Reason: hardly any food is controlled as regularly and frequently. Drinking water from the public water supply is impeccable. Drinking water is not sterile and contains microorganisms also when all legal requirements are met. The concentration of pathogenic gems is usually so small that there is no risk of damage to the health. The number of germs is mostly under the microbiological detection limit.

A central message of the new German Drinking Water Regulations (TrinkwV) dated 2011-11-01 is the requirement for the microbiological purity of drinking water according to § 4 paragraph 1.

§ ►

4 General requirements
The quality of drinking water must be such that there is no danger (especially due to pathogens) to the health by its use. It must be clean and fit for human consumption. This requirement is considered to be fulfilled if the generally accepted engineering standards for water treatment and water distribution and the requirements of §§ 5 to 7 Drinking Water Regulations are complied with at least.

In the German Drinking Water Regulations 2011, the minimisation requirement was extended not only to chemical additives, but also to microbiological requirements.

◄ §

§ 5 Microbiological requirements

(4) Concentrations of microorganisms that contaminate the drinking water or adversely affect its quality should be kept as low as is possible in accordance with generally accepted engineering standards and at reasonable expense, and by taking into account individual cases.

An absolutely sterile water with 0 CFU (colony forming units) is therefore not necessarily assumed. When the water is polluted with germs, it must be tested whether the infestation with microorganisms can be reduced through the use of disinfectants.

In § 5 para. 5 (TrinkwV), the use of chemical disinfectants is therefore expressly regulated.

§ ►

§ 5 Microbiological requirements

(5) If the contractor or owner of a water supply or water recovery plant or someone appointed by them determines facts in respect of microbial loads on the raw water, which could lead to the occurrence of a transmissible disease in terms of § 2 number 3 of the InfSchG (German Infection Protection Act), or if they assume that such facts are existent, a treatment must be carried out, if necessary including a disinfection in accordance with generally accepted engineering standards, taking into account § 6 paragraph 3. In distribution networks or parts thereof where the requirements of paragraph 1 or 2 can only be met by disinfection, the contractor or owner of a water supply facility has to provide a sufficient disinfection capacity according to § 3 paragraph 2 letters a and b, or, if the drinking water is supplied in the context of a commercial or public activity to letters d or f. The disinfection capacity is to be provided in the form of free chlorine, chlorine-dioxide or other suitable disinfectants or procedures that are listed by the German Federal Environment Agency in accordance with § 11.

Hence, the German Drinking Water Regulations provide clear regulations that there is an obligation to use a chemical disinfectant when the microbiological requirements can not be safeguarded in other ways. The operator of a drinking water supply facility is required in the medium-term to determine the systemic cause of the microbial contamination, and to eliminate it, if possible.

Water and its "inhabitants“

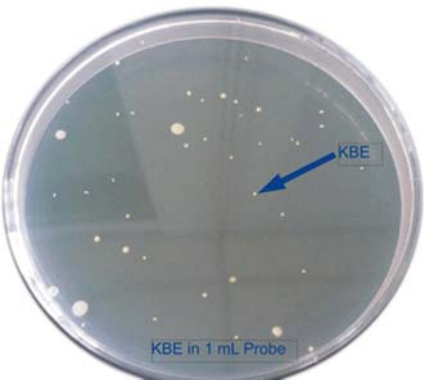
The operators of water supply facilities control our drinking water by means of regular water analysis.

◀ **Figure**
Drinking water analysis in a laboratory

As a general rule, the following microbiological parameters are checked:

- Total viable count at 22°C and 37°C
- Escherichia coli
- Coliforms
- Enterococci
- Pseudomonas aeruginosa
- Clostridium perfringens.

Total bacterial count at 22°C and 37°C:



◀ **Figure**
Cultured water sample 1 ml on culture medium

To determine the total bacterial count, a 1 milliliter water sample is cultured and incubated at 22/37° C in an incubator.
After incubation, the value of 100 colonies per ml should not be exceeded.
This guideline value is based on an investigation made by Robert Koch. A comparison he made during a cholera epidemic established that, whenever the colony count was below 100 colonies per ml, there was no epidemic.

As part of drinking water tests, the so-called indicator organisms are analyzed, which indicate faecal contamination. Testing for all pathogenic germs is too expensive.

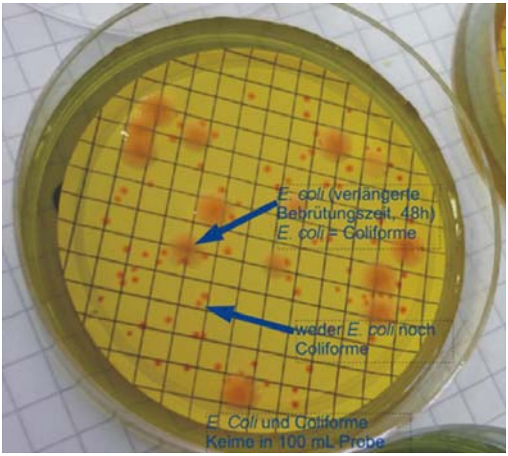
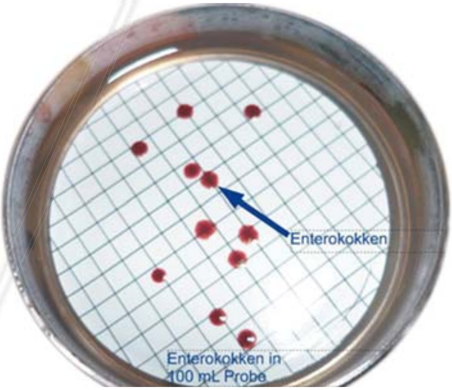


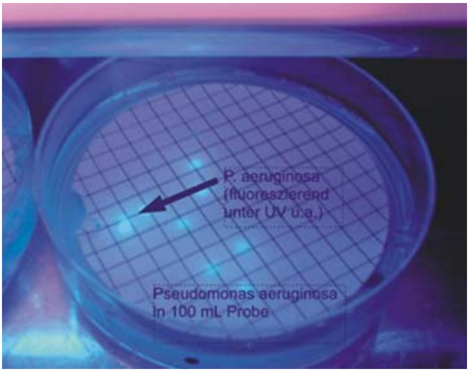
Figure ►
Escherichia coli

Escherichia coli is usually a completely harmless inhabitant of the intestines of warm-blooded animals and humans. There are only a few strains that can cause diarrhoea-like disease under certain conditions.
Escherichia coli is used as an indicator, so that it is not necessary to use separate procedures for each pathogen. When Escherichia coli is found, there is a very high probability that there are other pathogens.



◀ **Figure**
Enterococci

Enterococci are faecal streptococci, which also serve as faecal indicators.



◀ **Figure**
Pseudomonas aeruginosa

Pseudomonas aeruginosa is a microorganism that is frequently found in the environment (thrives in warm and moist areas). Food contaminated by it (drinking water) can lead to diarrhoea, pneumonia, meningitis, skin infections etc.
In drinking water supply facilities, this microorganism is found mainly in filter systems where particles accumulate, which are available as a nutrient. It is not possible to detect pseudomonas aeruginosa with the aforementioned faecal indicator organisms. In larger facilities, a separate determination for the purpose of a hygienic assessment is important for this reason.

Pseudomonas fluorescens is worth mentioning as well, and is also very often found in contaminated water samples.
The genus Pseudomonas is of special clinical significance, because the majority of its members are resistant to antibiotics. Given a higher cell density, they are also able to form biofilms (mucus), which protect them against antibiotics and phagocytes. While pseudomonads rarely cause disease in people with a healthy immune systems, they can cause infections in patients whose immune system is weakened (for example in hospitals).

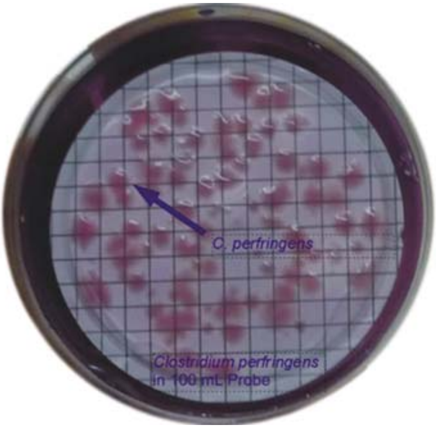


Figure ►
Clostridium perfringens

Clostridia are among anaerobic spore-forming microorganisms.
Among others, they are found in the sediments of lakes and in soils.
Clostridium perfringens can cause gangrene infections in wounds.
Contaminated food can cause symptoms of poisoning when consumed.

Germ reduction after drinking water treatment

If impermissible quantities of germs are detected after treatment of the water and before discharge into the utility grid, an additional disinfection must be carried out before discharge into the grid. A disinfection of this kind is also necessary in case of microbial contamination within the supply network.
The cause of the contamination is to be identified and eliminated, if possible.
It is possible that extensive renovation work will be required.

To prevent a microbial contamination in the supply network, the pipes are flushed. The higher flow rate in the supply pipes results in a partial reduction of deposits and biofilms. Deposits and biofilms provide an ideal basis for the reproduction of microorganisms. Deposits of lime and rust particles (iron) on inner pipe walls increase the surface area and provide microorganism with favourable conditions for colonization. In lines with a low flow rate, these deposits are growing very fast due to sedimentation.

Figure ▶
Flushing of the pipe network

Figure ▶
Impurities are flushed out

Different criteria are to be taken into account when selecting a disinfectant.
The depot effect is important in ensuring that a sufficient effect is also achieved in the water supply network.

Disinfection procedures

Chlorine/Chlorine gas

During chlorination, chlorine gas or sodium hypochlorite or calcium hypochlorite is added to the water. The effectiveness of chlorination is very much dependent on the pH value of the water.
It is possible that there are adverse effects on taste or smell and that undesirable reaction products such as chlorinated hydrocarbons develop, especially in organically contaminated water.

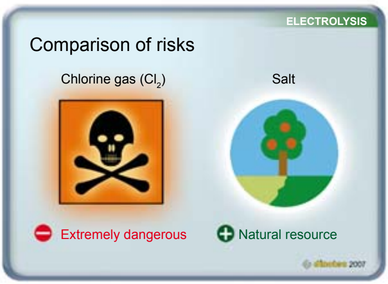


Figure
The dangerous chlorine gas is also used in weapons

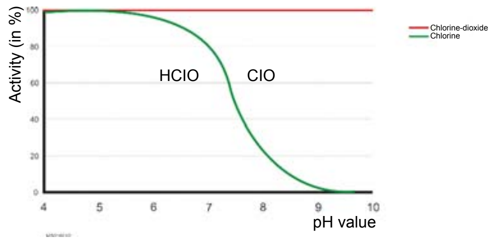
When using chlorine gas, the danger involved in the use, storage and transportation (especially in case of an accident) of this type of disinfectant must be considered. When using chlorine as a disinfectant, it is advantageous in many cases to safely produce the disinfectant right on site using an electrolysis system. These electrolysis systems are used to produce fresh, highly active chlorine from salt, water and electricity. In this case, neither transport nor regular handling of hazardous materials (chemicals) is required.

Figure
Chlorine production systems in waterworks

Chlorine-dioxide

In addition to chlorine in the form of hypochlorites, chlorine-dioxide has also been approved for the disinfection of drinking water according to the German Drinking Water Regulations. The DVGW worksheets W 224 and W 624 W provide a description of the active ingredient chlorine-dioxide as a disinfectant, and the methods of producing chlorine-dioxide. Chlorine-dioxide is a disinfectant that continues to replace chlorine in many applications due to its many advantages. Its effect is stronger and, above all, more independent of the pH level of water. Due to its specific chemistry, no chlorinated by-products can develop.

Figure ▶
Disinfection effect of chlorine and chlorine-dioxide dependant on pH level



The term „free chlorine“ refers to chlorine dissolved in water.
Depending on the pH value, there are chlorine compounds with different degrees of effectiveness.
In a slightly acidic range, chlorine is available almost exclusively in the form of hypochlorous acid.
From pH 6, the share of hypochlorous acid decreases and the share of hypochlorite - ClO - increases. When exceeding pH 9, hypochlorite predominates.

This correlation is important, because the disinfection power of hypochlorite – ClO – is only about 1% compared to that of hypochlorous acid.

Indicator parameters in drinking water

§ 7 Indicator parameters
(1) In drinking water, the limit values and requirements specified for indicator parameters in Appendix 3 must be complied with.
(2) In drinking water, which is intended for use in sealed containers, the limit value specified in Appendix 3, part 1, point 5 must not be exceeded.

◄ §

In § 7 German Drinking Water Regulations, the indicator parameters for drinking water are specified.

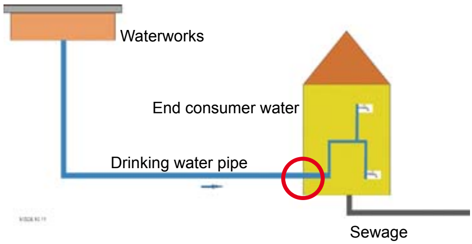
Appendix 3 - Indicator parameters part 1: General indicator parameters - Item 19 indicates the hydrogen ion concentration (pH value).
The limit value stated for drinking water is ≥ 6.5 and ≤ 9.5 pH.

It is essential to take the pH value into account when selecting a disinfectant.

Responsibility for the drinking water supply

The water supply companies are responsible for the quality of drinking water within the entire distribution system up to the water meter.
Beyond the water meter up to the water tap, the respective building owners are generally responsible for domestic installations. The Drinking Water Regulation 2011 formulates obligations for the construction and operation of water supply systems, which are to be observed by the operators.

The responsibility of the water supply company ends here



Obligations of owners of water supply systems

The Drinking Water Regulations as implementing regulation of the Infection Protection Act must be complied with by all public water suppliers. Violations are punishable as a regulatory or criminal offense. In terms of the Drinking Water Regulations, all persons and entities supplying drinking water (including landlords of private residential buildings) are considered public water suppliers.

The German Drinking Water Regulations 2011 incorporate new requirements for the housing industry.
These include the following:

1. Duty of disclosure of stock
2. Obligation to test for Legionella
3. Obligations to take measures in case certain values are exceeded
4. Obligation to keep tenants informed
5. Obligatory documentation requirement

It is recommended to carefully study the relevant information provided by the specialized press, who offer comprehensive and frequent reports about these obligations.

Legionella

What are Legionella and where do they occur naturally? Legionella are mobile, rod-shaped bacteria. There are different types found worldwide in surface waters and also in the soil.

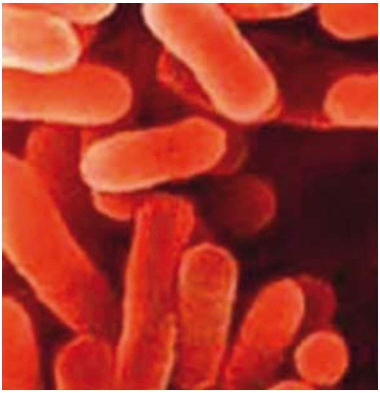


Figure ▶ Legionella

In the past it was assumed that they are only domiciled in freshwater. However, Legionella bacteria can also sustain themselves and multiply in saltwater.

Figure ▶ Natural freshwater area

Due to their natural distribution, Legionella occur also in low numbers in the groundwater. It is therefore possible that Legionella are found in drinking water supplied by waterworks.

Testing drinking water for Legionella

First, an exploratory analysis is to be conducted to determine whether there is a contamination in the drinking water system to be tested.

CFU / 100 ml	Assessment	Action	Further analysis	Follow-up analysis
> 10,000	Extremely high contamination	Direct danger prevention required, i.e. disinfection and restrictions as regards use, such as a shower ban	Without delay	1 week after disinfection
> 1,000	High contamination	Rehabilitation/ renovation requirements depend on further analysis	Immediately	---
> 100 < 100	Medium contamination	None	Within 4 weeks	---
< 100	No / low contamination	None	None	After 1 year/, after 3 years

◀ **Figure**
Legionella

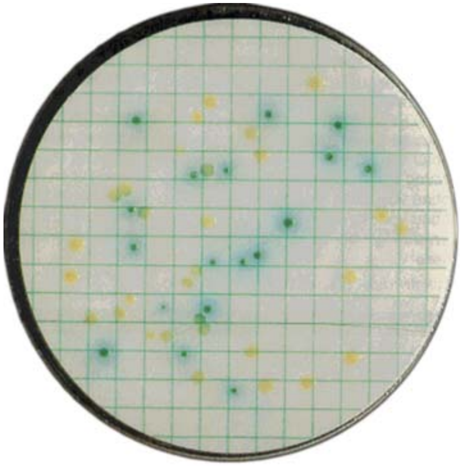


Figure ►
Legionella

The size of the contamination with Legionella is determined by enumeration of the colony forming units (CFU).
Depending on the findings of the exploratory analysis, a further analysis must be carried out.

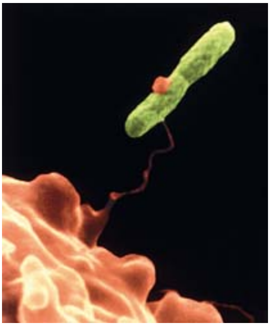
Further analysis of drinking water

CFU / 100 ml	Assessment	Action	Further analysis	Follow-up analysis
> 10,000	Extremely high contamination	Direct danger prevention required, i.e. disinfection and restrictions as regards use, such as a shower ban	Without delay	1 week after disinfection
> 1,000	High contamination	Short-term renovation required	Within 3 months	1 week after disinfection
> 100 < 100	Medium contamination	Medium-term renovation required	Within 1 year	1 week after disinfection
< 100	No / low contamination	None	---	After 1 year/, after 3 years

Biofilms

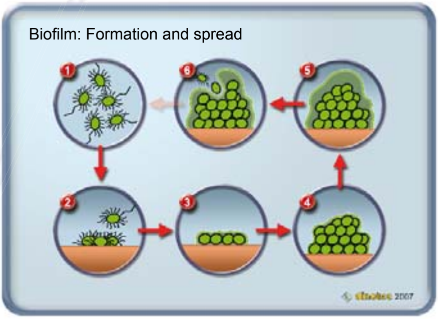
These biofilms present an "ecosystem", which also includes unicellular organisms such as the (harmless) amoeba that feed on the microorganisms available in this ecosystem.
Legionella are also eaten up, but are not digested inside the amoeba. As a result, they can even multiply and accumulate there.
Legionella use mainly amoebae as hosts, who provide the necessary nutrients to multiply.
Amoebae protect Legionella from many disinfection measures.

Figure ►
Amoebas



Legionella bacteria are trapped by amoebae.

Biofilms are preferred sites for Legionella multiplication. The formation of biofilm is shown in the graphic.

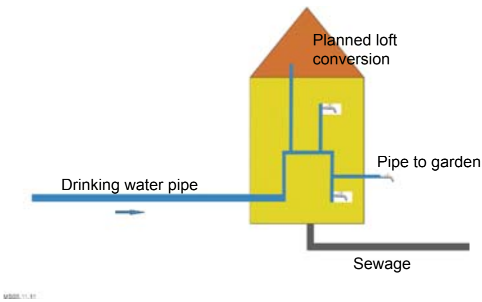


◀ **Figure**
Biofilm: Formation and spread

Growth phases of biofilm.

(1)	Bacteria and unicellular organisms that float in water
(2)	and attach to the surfaces of materials.
(3)	A biocoenosis forms as a result of cell division.
(4/5)	The metabolism of this biocoenosis forms a mucus layer that protects the residents from most disinfection methods.
(6)	Due to water movement, the hazardous cargo is released into the water.

A risk of contamination by Legionella and the formation of biofilms in drinking water installations is primarily given where no generally accepted engineering standards are complied with.



◀ **Figure**
Drinking water distribution in a house

Where drinking water is stagnating in the piping system for a longer time, biofilm can form. A special problem is posed by drinking water installations that "stock" water and are not often used.
Another problem is posed by a lower lead temperature of the hot water, allowing bacteria to multiply rapidly. Even in the cold water lines it is possible for biofilm to develop due to stagnation.

Preventing microbial contamination of the drinking water systems

The worksheet DVGW W 551 applies to all drinking water installations in private and in public buildings. The worksheet makes it imperative to comply with the technical rules during planning, construction, renovation, operation and monitoring of drinking water systems. When the technical rules are followed, the possibility of microbial contamination of drinking water systems is considered to be low:

The Basic rules in this respect are:

1. Circulation temperatures in the hot water system higher than 55 degrees.
2. A uniform flow by hydraulic balancing is to be ensured.
3. Hot water in boiler to be heated up to at least 60 degrees at boiler output.
4. Long hot water systems without circulation are to be avoided.
5. Unnecessary water connections are to be avoided.
6. Insulation of cold water pipes to prevent heating of the cold water.

In drinking water installations which are used only seasonally or sporadically, it is imperative that special care is exercised. In this case, the measures according to DIN 1988-200, the VDI 6023 and the duties of disclosure/ notification to Drinking Water Regulations must be observed.
This includes hotels, camping sites, schools, sports halls, etc. For these facilities, it is necessary to prepare plans for decommission and recommission of the systems. These plans must also include information on how often and how long the systems are to be flushed.

"**Water must flow**" - a wisdom dating back as far as Roman times.

Remedial actions after a contamination of drinking water systems

If the cause of the contamination in the drinking water installation is to be established, a complete analysis of the installation and all used components is imperative.
Since drinking water is a perishable food, it is to be ensured that there is a sufficient exchange of water in all parts of the water supply system.
In many existing properties, the drinking water pipes are not properly dimensioned (oversized), especially when there are changes of use. This results in increased biofilm growth due to low flow rates in the pipes. The only lasting remedy in this case is a dismantling of the system.
A microbial contamination also occurs in seldom-used parts of the cold water supply line, such as outdoor taps, little-used rooms with drinking water connection and "pipes laid in reserve". As a result of recontamination, the bacteria then spread throughout the water supply system.
It is possible to minimize a recontamination with a regular flushing of these pipes.

Methods of drinking water disinfection

In principle there are different possibilities for disinfecting drinking water. There are advantages and disadvantages which are to be compared in advance.
We distinguish between physical processes and chemical processes for disinfection of drinking water.

Physical processes

Physical processes are effective without the addition of chemicals. The effectiveness of disinfection is limited to the particular location. There is no depot effect.

Physical processes include the following:
1. Thermal disinfection
2. Ultra-filtration
3. Radiation of water with ultraviolet light

Thermal disinfection

In case of thermal disinfection, the entire hot water including the circulation water is heated to ≥ 70 ° C. To ensure a proper disinfection effect also at each extraction point, it is necessary that water with a temperature of ≥ 70 °C is extracted at each tap for at least 3 minutes.

Important: Thermal disinfection has limitations and risks:
- Legionella, which are protected in amoebae and biofilm, can survive.
- Biofilm is not removed and there is a renewed contamination.
- There is a danger of scalding at the taps during thermal treatments.
- In systems used around the clock, the risk of scalding is very high (Hospitals, nursing homes, hotels, etc.).
- Carrying out a thermal disinfection involves very high personnel costs.
- The entire installation is mechanically stressed by the high temperature. There is an increased risk of corrosion.
- The heating leads to increased lime deposits in the pipes. These lime deposits, in turn, provide a basis for enhanced biofilm formation.

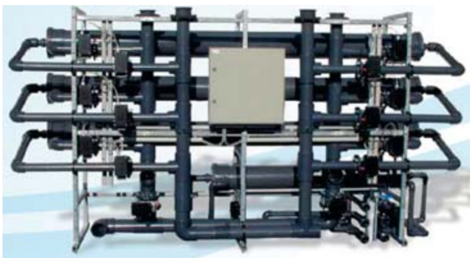
- The cold water installation is heated in case of inadequate insulation.
- Energy input/expenditure is very high.
- Thermal disinfection is very expensive for systems that are operated by solar energy or heat pumps, as additional heating is required.

Operators of a drinking water system must check in advance whether a thermal disinfection is reasonable in view of the disadvantages listed above.

Membrane filtration - Micro-filtration / Ultra-filtration

Depending on the pore size of filter elements, we distinguish between micro-filtration and ultra-filtration. In case of ultra-filtration, the filter elements used have a pore size of about 0.01 µm.

Figure ►
Membrane filtration system for circulation capacities 40-120 m³/h



Ultra-filtration provides a detention of bacteria and a wide range of viruses. The entire downstream drinking water installation must be sterile at the time of installation of the system. Ultra-filtration provides no depot effect and does not result in a degradation of biofilm in the system. Bacteria carried in, e.g. during maintenance and repairs, are not detected, which can result in a microbial contamination of the downstream drinking water system.
The operation of the system requires a high system pressure.

Radiation with ultraviolet light

UV-C radiation for disinfection of drinking water is effective against free floating microorganisms.
UV radiation changes the DNA of microorganisms. In this way the bacteria are inactivated and rendered harmless. The water quality is an important prerequisite for this process to be successful, e.g. iron, manganese and other substances that precipitate influence the effectiveness of UV disinfection.

◄ **Figure**
UV system

In case of new installations or non-contaminated systems, operation of a UV disinfection system can prevent or delay contamination of the drinking water facility. There is no depot effect in this case.

Chemical disinfection

When talking about a chemical disinfection of drinking water, we distinguish between a shock disinfection and permanent disinfection.

Shock disinfection

While a shock disinfection is carried out, no drinking water can be delivered.
In a shock disinfection, chemicals are used in high concentrations. It is possible to also use disinfectants that are not listed by the Federal Environmental Agency. Following a shock disinfection, a flushing of the piping system is required to remove the chemicals. It must be ensured that the water available at all taps has drinking water quality.

In case of a shock disinfection, biofilms are only partially removed, so that there is a risk of recontamination. Through the use of high concentrations of the disinfectant, there may be an increased corrosion in the system.

Permanent chemical disinfection

In case of a permanent chemical disinfection, only approved chemicals may be used.
The list of treatment substances and disinfection procedures in accordance with § 11 of the Drinking Water Regulations is maintained and regularly updated by the Federal Environmental Agency.
Limit values and the formation of disinfection by-products are to be observed in this respect.
In addition, the used treatment substances must be sufficiently effective and must not have any avoidable or unacceptable impacts on health or environment.

Treatment substances used for the disinfection of water:

From the list of the Federal Environmental Agency in accordance with § 11 of the Drinking Water Regulations, Part 1c:

- Calcium hypochlorite
- Chlorine
- Chlorine-dioxide
- Sodium hypochlorite
- Ozone

For a disinfection of drinking water outside of waterworks, sodium hypochlorite and chlorine-dioxide are preferably used.

Disinfection with chlorine

In commercially available forms, sodium hypochlorite has a content of approx. 150 g/chlorine per liter. The concentration of the solution does not provide long-term stability.
The chlorine content of the solution decreases by approx. 1g/chlorine per liter per day, depending on the temperature. Owing to the pH-dependent effect on water, the use of sodium hypochlorite should be limited to water with a pH value < 7.5 pH.

◄ **Figure**
Sodium hypochlorite tank with disinfectant solution

Use of electrolysis systems for the production of hypochlorite

Sodium hypochlorite breaks down during storage. To counteract this disadvantage, a fresh hypochlorite solution is produced on site using electrolysis systems.

The use of hypochlorite should also be limited to a pH value not exceeding < 7.5 pH.

Figure ▶
VoDes BlueWave by dinotec - On-site production of a disinfection solution

Electrolysis systems use salt, water and electricity for an on-site production of fresh, highly active chlorine.

No transport of chemicals is required.

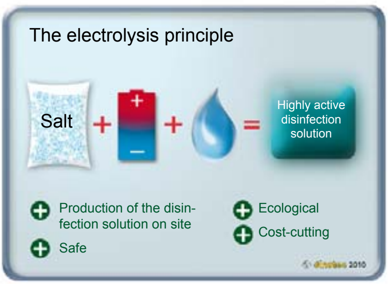


Figure ▶
The electrolysis process - plain and simple

Disinfection with chlorine-dioxide

Chlorine-dioxide is the second most powerful disinfectant, surpassed only by ozone.
Since a transport of chlorine-dioxide is not allowed, it must be produced on site for use in drinking water installations. There are different processes.
It is in particular the chlorite/hydrochloric acid process that is worth mentioning in this respect. In this process, chlorine-dioxide is produced as needed, using diluted chemicals.

◀ **Figure**
Chlorox 100 by dinotec - Chlorine-dioxide system

Chlorine-dioxide offers many advantages compared to chlorine-based disinfectants:

- Within a range of pH 4 - 10, the disinfection effect is almost unchanging.
- The disinfection power is 2.5 times that of chlorine.
- Excellent algicidal, bactericidal, viricidal and sporicidal properties.
- No development of resistance to microorganisms.
- Safe elimination of Legionella and degradation of biofilm.
- Long-lasting depot effect.

Approved methods of drinking water disinfection

Methods	Positive	Negative
Thermal disinfection	No chemicals	Danger of scalding, no biofilm degradation, high material stress caused by heating-up, no complete bacteria eliminati-on due to unequal distribution of temperature, very high energy consumption, cold water pipe is not disin-fected
UV radiation	No chemicals	No biofilm degradation, bacteria are only eliminated in the area of UV radiation, very high energy consumption
Chlorine	Biofilm degradation is delayed Positive effect up to pH 7.5	Use of chemicals, low depot effect, no biofilm degradation with drinking water concentrations of 0.3mg/l, formation of chloramines, chlo-rophenols, AOX, THMs
Chlorine-dioxide	High depot effect, no formation of chloramines, chlorophenols, AOX and THMs, biofilm degradation guaranteed even with low drinking water concentrations, excellent effect within a range of 6 to 9 pH	Use of chemicals Formation of chlorite

Comparison of chemical processes

Active substances	**Ozone**	**Chlorine/Hypo-chlorite**	**Chlorine-dioxide**
Depot effect throughout the entire water system	None	Low	Very good
Protection from bacterial regrowth	None	Low	Very good
Speed of disinfection	Very fast	Slower than ClO_2	Very fast
Effect on biofilms	None	Delayed, low impact on biofilms in con-centrations as used in drinking water	Effective degra-dation of biofilms and prevention of re-development
Microbiologi-cal efficacy	Excellent bacterici-dal, viricidal, algici-dal, sporicidal and fungicidal effect	Positive bacterici-dal, viricidal, algici-dal, sporicidal and fungicidal effect	Excellent bacterici-dal, viricidal, algici-dal, sporicidal and fungicidal effect
Effectiveness of pH	Independent of pH level	Positive effect up to pH 7.5	excellent effect within a range of 6 to 9 pH
Impairment of taste and smell	Low	High	Low
Corrosivity	Corrosive	Corrosive	Low corrosivity
Disinfection by-products	THM and bromate	AOX, THM, chlora-mines, chlorophe-nols	Chlorite

Compliance with the minimisation requirements when using chemical disinfectants.
In the list of treatment substances and disinfection procedures, the Federal Environmental Agency (UBA) defines in accordance with § 11 of the Drinking Water Regulations of 2011, how an addition of different disinfectants is to be analysed.

Scope of analysis and frequency of testing in accordance with § 11 Drinking Water Regulations 2011 for treatment substances used for disinfection.

Scope of analysis	**Frequency of testing**	**Documentation**	**Remarks**
Control of quantity added of used product (consumption)	Weekly	Operating journal	Not required if data is continuously measured and stored
Control of concentration of active ingredient in treated water	Daily	Operating journal + analytical result	Daily measurement is to be carried out by trained personnel as part of operational checks. Not required if data is continuously measured and stored.

Scope of analysis and frequency of testing in accordance with § 11 Drinking Water Regulations 2011 for treatment substances with a limited maximum concentration after treatment.

Scope of analysis	**Frequency of testing**	**Documentation**	**Remarks**
Control of quantity added of used product (consumption)	Weekly	Operating journal	Not required if data is continuously measured and stored
Control of concentration of active ingredient in treated water	Weekly	Operating journal + analytical result	Not required if data is continuously measured and stored.

Scope of analysis and frequency of testing in accordance with § 11 Drinking Water Regulations 2011 for all other treatment substances.

Scope of analysis	**Frequency of testing**	**Documentation**	**Remarks**
Control of quantity added of used product (con-sumption)	Weekly	Operating journal	Not required if data is continuously measured and stored

Simplification through the use of measurement and control technology

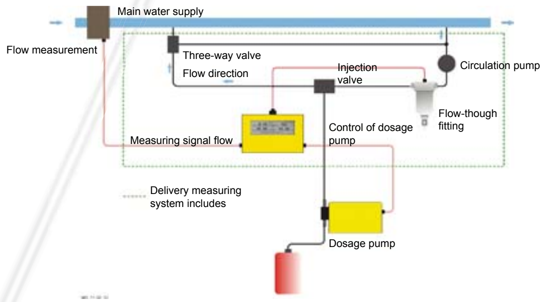
The use of reliable measurement and control technology makes it possible to reduce the analysis costs, frequency of analysis and amount of documentation, or to dispense with them. This is made possible with an automatic measurement and storage of data. The dosage of disinfectant should be made in proportion to quantity according to the technical regulations of the DVGW (German association for gas and water). The volume flow of the water is the command variable for this. An automatic adjustment of the dosing factor is possible so that deviations in the active ingredient content of the disinfectant can be balanced. Compliance with the limit values and guide values, also in respect of by-products, must be ensured.

Safe and demand-based addition of disinfectants

Modern measurement and control systems make it possible to safely add disinfectants as needed with minimum operating costs.

The disinfectant is added directly in the circulation circuit of the measuring system. This prevents a "cloud formation", which can also result in increased corrosion in the system. Modern measuring and control technology is able to test the signal of the disinfectant sensor by means of a plausibility check.
In addition to many supplementary monitoring functions, these systems also monitor the function of the circulation circuit. The entire system works under the operating pressure of the water supply. This ensures that there is no extra water consumption.

Example of process integrating measurement and control technology



◀ **Figure**
Measuring and control technology in the process cycle

◀ **Figure**
WaterInspector by dinotec - Measuring and control technology

Complete measurement and control system with integrated circulation circuit and mixing module.

Outlook

What prophylactic measures can be taken to prevent the occurrence of Legionella?

"Prevention strategies against Legionella must start with the prevention of biofilms in water-bearing systems. Studies have clearly shown that the formation of biofilm can be prevented by a continuous addition of the chemical disinfectant chlorine-dioxide (0.2 mg/l). At the same time, bacteria are killed in existing biofilms within a few weeks."

Quote Professor Exner, Institute of Hygiene, University of Bonn (Chairman of the German Drinking Water Commission)

<u>Literature:</u>
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German Federal Environment Agency (UBA) list of treatment products in accordance with § 11 Drinking Water Regulations
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Gelsenwasser AG
RheinEnergie
http://www.wikipedia.org
dinotec GmbH

<u>Abbreviations used:</u>

TrinkwV	Drinking Water Regulations 2011