Stadt Zürich
Wasserversorgung

A brief introduction to germs in drinking water

Useful information from the laboratory on bacteria, viruses and water fungi

natürlich züri wasser

From sewage to drinking water
Useful information on how microbes and humans live together

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Preliminary remarks: drinking water as a natural product

Natural waters – and thus also healthy drinking water – not only contain H_2O but also various substances. These substances are both desirable and also – when they exceed certain levels – undesirable. This also applies to germs.

What are germs?
Germs include bacteria, viruses and fungi. As plant-based microorganisms, algae are of no relevance for drinking water consumption – although some species do produce toxins. These toxins are removed during water treatment, meaning there is no need to worry about them.

The fact that microorganisms such as bacteria have a negative image is unfair. Among other aspects, they stabilise the natural equilibrium in water and thus have a positive effect on people's lives. They provide the motor for the natural treatment process, so to speak.

Drinking water (just like the air around us) contains bacteria. This is completely normal and follows natural laws. These bacteria do not pose a risk to human health and live primarily inside pipes, where they form biofilms on the pipe walls. In heavily populated areas, the most diverse bacteria live in close contact with each other.

It is fundamentally wrong to classify bacteria as "good" or "bad" as they form an essential part of all ecosystems. Usually, the presence of germs only becomes unsafe when certain germs are allowed to multiply en masse. Drinking water is regularly tested and attention is paid above all as to whether any changes are detected. The nutrient or substrate content in biostable water does not form a basis for the growth of pathogenic germs.

Water – clearly the best

In Zurich, 70% of the drinking water originates from the lake. All germs are killed by the ozone when treating the water. Bacteria that protect the water are then fed into the drinking water via the biological slow filter. This is in addition to the water-purifying bacteria that originate from the biofilms in the pipe network.

Natural cleaning powers
80% of Swiss drinking water originates from controlled springs and groundwater reserves. A natural cleaning process takes place in the soil layers. This water is bacteriologically safe and can be drunk without issues, whereby around 60% of this water is treated additionally before distribution in steps of varying complexity.

The quality of water in Zurich is constantly monitored.

Microbiological quality control at the Zurich waterworks

Water suppliers have to provide drinking water of high quality at all times. This is checked periodically by measuring the physical, chemical and microbiological parameters of the water. This ensures that the drinking water in Zurich is always of excellent quality.

This brochure examines germs (bacteria, viruses and fungi) in more detail, particularly the world of bacteria in the drinking water.

Microbiological laboratory at the Zurich waterworks.

The content is structured in such a way that a quick overview of the topic is given right at the beginning.

The individual chapters then examine specific aspects in more detail or shed light on various links and relationships between them. Certain topics thus repeat themselves, meaning the e-book can be used both for looking things up as a reference work or for leisurely browsing.

Drinking water analyses

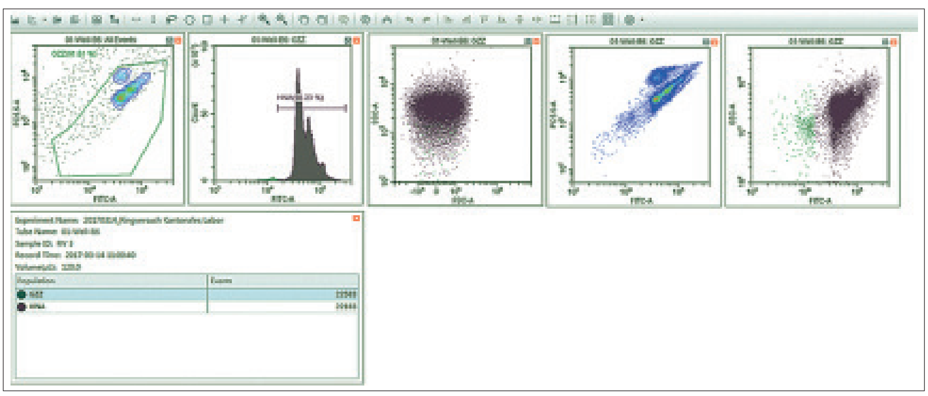
Samples taken by the supervisory authorities (Cantonal Laboratory of Zurich) confirm the perfect quality of the drinking water in Zurich. As part of its extensive mandate, the laboratory carries out wide-ranging routine inspections of the sewage water, treatment processes, reservoirs and distribution network. Over 10,000 samples are analysed each year, thus providing comprehensive confirmation of the quality of the drinking water.

The latest findings on bacteria in drinking water

In order to make timely and precise statements on the microbiological condition of water, quick and simple methods are required. As the educational institute responsible for water research, the Swiss Federal Institute for Environmental Science and Technology (Eawag) has developed a new measuring method. The Zurich waterworks were also involved here. It was then possible to verify what we already knew. Perfect drinking water has between 100 and 10,000 times more bacteria than were able to grow using the original counting method.

The research by Eawag will continue in earnest in future. The aim is to measure the bacteria in drinking water in order to gain an in-depth understanding of its microbiology and how it works. To do this, the entire process is taken into account, involving the collection, treatment and distribution of water from the source to the tap.

As knowledge grows, bacteria are increasingly in the spotlight. This brochure thus provides both basic and specialist information in order to better understand the bacteria living in drinking water and the relationships seen in the wide world of microbes. The information collected here is intended to increase confidence in our drinking water. After all, the quality of drinking water in Zurich is always perfect, as proven both in tests in the laboratory at the waterworks and also by chemists working on behalf of the canton.



Assessing a sample: mapping a cluster distribution. In this way, the quantity of both small and large bacteria can be seen.

Important inspections
In those rare cases where drinking water poses a danger to health – in other words, where warnings have to be made to consumers not to drink the water – these events are almost exclusively due to microbiological reasons. As a result, microbiological analyses of drinking water are an essential part of inspections.

Preparing a sample.

Measuring using flow cytometry

Flow cytometry was originally used as a measuring process in biology and medicine. This method was adapted and tested by Eawag and several major water suppliers in order to measure the microscopic cells seen in the drinking water flora.
Fluorescent dyes are used to determine the number of all cells present in a sample. After the cells have been dyed and a short exposure time has elapsed, the sample flows through the flow cytometer. Each cell that passes the laser beam generates a fluorescence radiation of varying strength depending on how much it is dyed. This is then recorded and assigned to a specific fluorescence by the analysis software. In this way, more than 1,000 small and large cells can be recorded every second. The entire procedure takes no more than quarter of an hour. This method enables all cells present to be recorded, including those that would not grow to form colonies on nutrient plates. The quantity of cultivable cells in a sample can also vary between 0.01 and 10% of the available cells. The drinking water in Zurich thus does not have between 0 and 10 CFU/ml (colony-forming units) as originally indicated using the aerobic mesophilic germ method, but instead between 80,000 and 150,000 cells/ml in normal cases. These are values that are also commonly found in bottled still mineral water.

The detailed inspections also showed that 80 to 90% of the cells present in water samples from the environment usually have an intact cell membrane and are thus viable.

Even though more cells are recorded using the new method, it goes without saying that the good quality of the water has not changed. Nonetheless, it is clear that the quantities now measured demand a rethink and corresponding acceptance of the variety of bacteria on show, not only in the drinking water industry but also among consumers. Therefore, it is important to understand bacteria in more detail.

The microbiological laboratory at the Zurich waterworks

Working in sterile conditions.

The Zurich waterworks carry out several quality control measures. This includes monitoring Lake Zurich and the phytoplankton (algae) and zooplankton levels, and also chemical and microbiological inspections both during and after water treatment. Microbiological inspections also include bacterial analyses.

Drinking water analyses

The Federal Food Safety and Veterinary Office (BLV) defines limits for the substances and microorganisms found in drinking water.

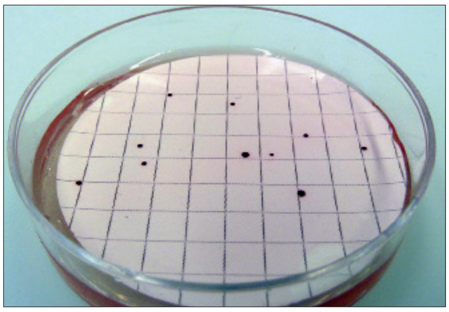
The microbiological laboratory is a protected area with various safety levels in place. Access is only permitted with protective clothing, such as lab coats and shoe covers.

Adherence to these limits is ensured via self-inspections made by the water suppliers and federal inspections made by the cantonal authorities or cantonal chemists.

The microbiological laboratory

The latest methods allow for a quicker and more detailed analysis of the microbiological condition of the drinking water. Different processes can also be combined with one another.

The classic method of bacteria cultivation on substrate plates is still being carried out today. Bacteria colonies are cultivated here on Petri dishes with agar embedded



Enterocooci.
Photo: Archive WVZ

History
Robert Koch (1843–1910) is the founder of modern scientific bacteriology. He introduced the use of plates to harvest bacteria cultures, a method that is still used today.

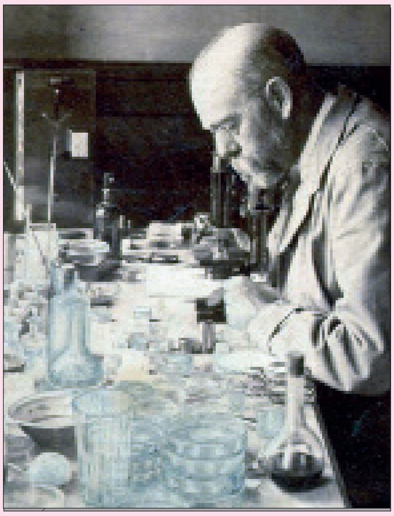


Photo: Wikipedia

History
From the 1960s to the 1980s, chemical substances in water (e.g. nitrates, pesticides) were primarily of interest. Today, knowledge of the microbiology of drinking water is more important than ever, as past incidents have clearly shown that these were usually due to microbiological reasons.

(nutrient plates) in order to be able to determine any changes in the drinking water. Filtered drinking water is also applied to selective media (cultivated) on a regular basis in order to be able to react to any contamination caused by faecal bacteria.

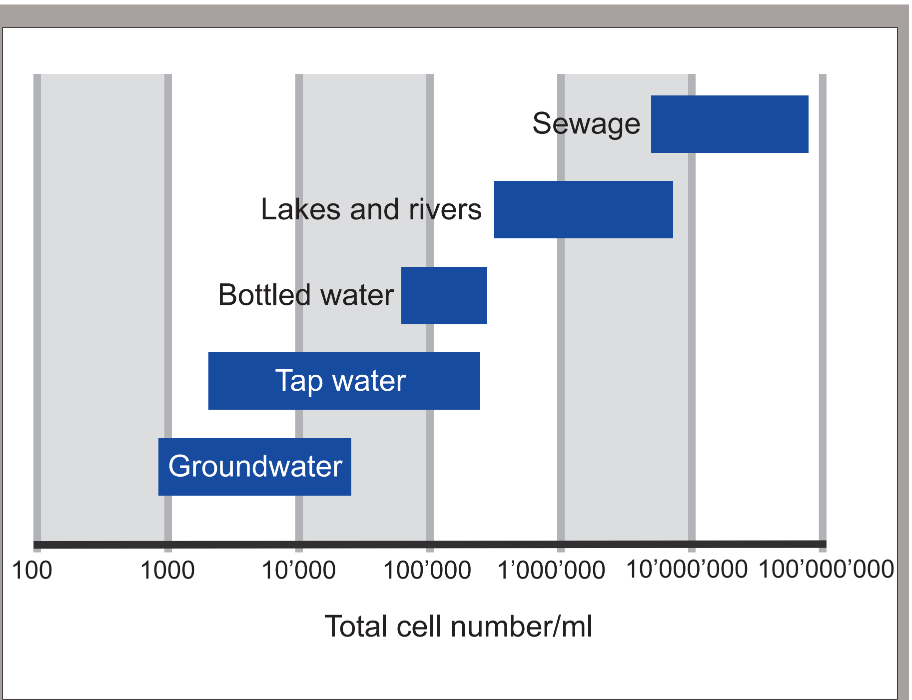
Clean drinking water may not contain more than 300 colony-forming units of aerobic mesophilic germs. In order for such germs to grow in the first place, three days at a temperature of 30 °C are required. If a search has to be made for specific pathogens (e.g. legionella in warm water), an analysis can also take significantly longer. The classic method remains a good, cost-effective way of monitoring water quality.

Creating the culture media for cultivating bacteria (boiling agar).

Flow cytometry has made the quality control process much faster. In this method, the bacteria in a water sample are dyed with fluorescent dyes and then channelled through a glass capillary so that the individual cells flow past a laser beam one after the other. The generated optical signals are then analysed by a detector or corresponding software. The total cell count can be ascertained within just 15 minutes. Moreover, bacteria populations can also be determined according to different cell size. The “fingerprints” of the water samples that are created allow changes in populations to be determined or a distinction to be made between living and dead cells through the use of special dyes.

Germs are nothing to be afraid of

The results provided by flow cytometry have led to a rethink in how drinking water is assessed from a microbiological standpoint. In and of itself, a high cell count is not something negative. The ability of water-purifying bacteria to utilise even the smallest amount of nutrients means that pathogens that cause cholera, typhus or dysentery only have a minimal chance of survival in water – with further multiplication even rendered impossible.



Overall cell counts (cells/ml) as normally recorded using flow cytometry.

The importance of bacteria

Usually, humans live together in harmony with bacteria. For example, bacteria are essential for the production of certain vitamins in the human gut and the mucous membranes are all teeming with bacteria. Meanwhile, bacteria have also been used in food production for millennia – be it bread, beer, wine, vinegar, yoghurt, cheese or sauerkraut. Levorotatory lactic acid bacteria are extremely popular at the moment. Probiotics are compounds containing live microorganisms, and are considered as being beneficial to health. Healthy drinking water typically contains between 20,000 and 150,000 bacteria per millilitre. This is roughly the same as bottled still mineral water.

History
In 1855, John Snow (1813–1858) published his findings on the spread of cholera through water pumps in London.

The smallest bacteria can only be detected using powerful laboratory microscopes.
Image: Microscope from 1879 produced by Carl Zeiss, as used by the German physician and microbiologist Robert Koch. As there was no light on the microscope, Koch often had to wait for sunshine to carry out his experiments.
Photo: Wikipedia

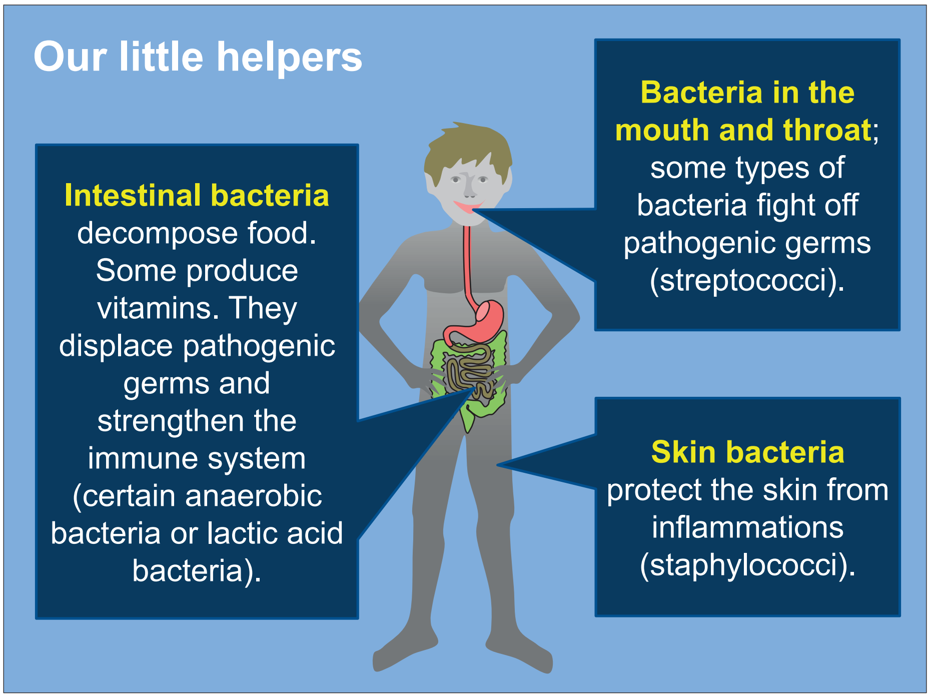
Natural yoghurt. In a similar way to the metabolic products (acids) in lactic acid bacteria seen in yoghurt, water-purifying bacteria ensure substrate degradation. This has a stabilising effect and increases the useful life of the drinking water.
Photo: Internet

Bacteria performance:
Lactic acid

Bacteria and their metabolic products have been used for refining and preserving foodstuffs for millennia.
Many products contain a mixture of dextrorotatory and levorotatory lactic acids, not only in dairy products but also in many fermented foodstuffs, such as sauerkraut, pickled vegetables, olives and raw sausages. The lactic acid produced by the bacteria creates acidic conditions in which other bacteria can no longer multiply well, meaning the products then have a longer shelf life.

Clean water

Bacteria ensure that drinking water is clean and healthy. This is then known as biostable water by the water suppliers. Due to the low nutrient content (substrate content) in drinking water, bacteria grow slowly or not at all (cell division does not take place).



Bacteria are indispensable companions for humans.

The number of bacteria remains more or less consistent. If excessive substrates (nutrients) are present, this would lead to significant multiplication (contamination). This is undesirable as these would then be ideal conditions for pathogens to thrive, which could then negatively affect the odour and taste of the drinking water.

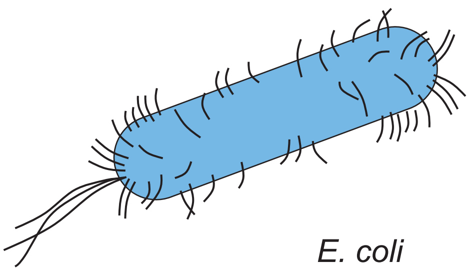
Preferred living conditions for bacteria

Bacteria can be divided up into two groups. On one hand, many of the pathogenic bacteria require a high nutrient content in the water to live and multiply. On the other hand, bacteria in water are very easily satisfied and utilise the few nutrients available. Therefore, either one or the other bacteria group flourishes depending on the nutrient content (nature of the substrate).

During the treatment process in lake water plants, the particles containing nutrients are filtered out mechanically in the fast filter. The nutrients dissolved in the water are utilised directly by the bacteria. Additionally, the oxidising power of the ozonation prepares the substrate for better utilisation (feed intake). The water-purifying bacteria in the slow filters benefit from this. The resulting degradation products are metabolised by the bacteria.

Quality control

During routine drinking water analysis, the bacterial count is determined, more specifically the number of *Escherichia coli* and the number of Enterococci are evaluated. *Escherichia coli* and Enterococci belong to the intestinal bacteria and indicate a faecal contamination of the water.



E. coli

Settled and nomadic bacteria

Different bacteria prefer different living conditions. Settled bacteria prefer living in biofilms, where they have more time to utilise the available molecules – including large molecules. In contrast, planktonic bacteria favour open water and utilise smaller molecules. The AOC content (assimilable organic carbon) of the bacteria is important here. This is part of naturally occurring organic carbon, but occurs more predominantly during disinfection or ozonation of drinking water. Oxidation makes degradation-resistant compounds open to bacteria again during the treatment process.

Safety through controlled diversity

One can assume that up to 2,000 bacteria species live in clean drinking water. Just 20 years ago, the variety of bacteria was hardly analysed as most species are not cultivable. Moreover, many bacteria are able to lower their metabolism to a minimum in the event of unfavour-

Chemical performance (enantiomers):
What is the difference between dextrorotatory and levorotatory lactic acids?

Different types of lactic acids have the same chemical compound yet have different characteristics. This can be seen in the optical activity, a property exhibited by some transparent materials that allows the plane of polarisation to be rotated in one direction or the other.

Bacteria performance:
“Healthy” food

Sauerkraut is both a food and probiotic dietary supplement in one. It is packed with highly effective and vital microorganisms. These microorganisms strengthen the human immune system and protect the organism against certain diseases, parasites, diverse viruses and harmful bacteria.

Biologically stable water does not require chlorine
Bacteria also require nutrients – assimilable organic carbon, or AOC – to grow. As a rule of thumb, microbiologically stable water has less than 50 micrograms of AOC per litre. Provided the pipe network is intact, the addition of disinfectant (chlorine) can be completely dispensed with.

Unwelcome guests
Some bacteria can produce substances with intensive odours – including in water in rare cases. While these organisms are not hazardous to health, they are unpleasant in high concentrations and have no business being in drinking water.

A look at the glass storage.

able living conditions by stopping multiplication and entering a kind of hibernation.

Some bacteria species form endospores as a reaction to poor living conditions. These can survive for a long time. As soon as the conditions improve – such as the nutrient content (nature of the substrate), temperature or flow conditions – these spores can germinate to form a bacterium once again. Therefore, a good way of protecting against unexpected bacteria growth is to ensure uniform work processes, for example during the treatment and distribution of drinking water.

When compared to the overall number seen in nature, the number of microorganisms that can lead to infections in humans is very small. Most of these multiply in the surrounding environment – in water, soil, animals and plants, and food – without ever being noticed by humans or leading to health problems.

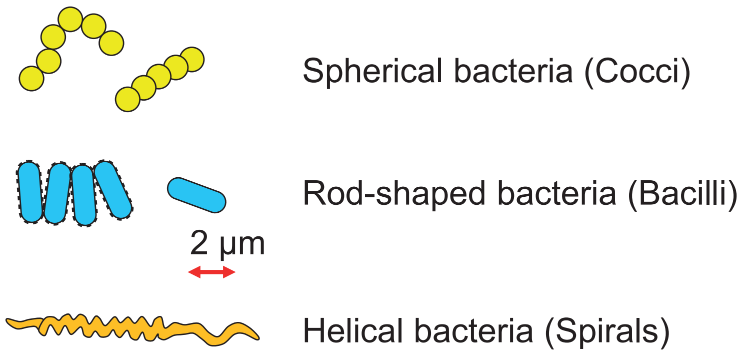
Germs large and small

In simple terms, bacteria, viruses and fungi are all considered as "germs". With a few exceptions, individual bacteria cells cannot be seen with the naked eye. The size of the bacteria varies greatly. Their diameter is around 0.1 to 700 micrometres (µm), with most measuring 0.6 to 1.0 µm. Drinking water contains bacteria ranging from large to very small, including "ultramicrobacteria" (UMB) measuring between 0.05 and 0.15 µm. As the living conditions in drinking water are unfavourable, it usually contains smaller bacteria.

Even smaller than UMB are viruses. Viruses are stray genes that search for a host (cell) in order to multiply. Bacteriophages – or simply phages – are specific virus types that specialise in using bacteria as host cells. This includes types that can be used to fight bacteria as they multiply in the bacterium until it decomposes.

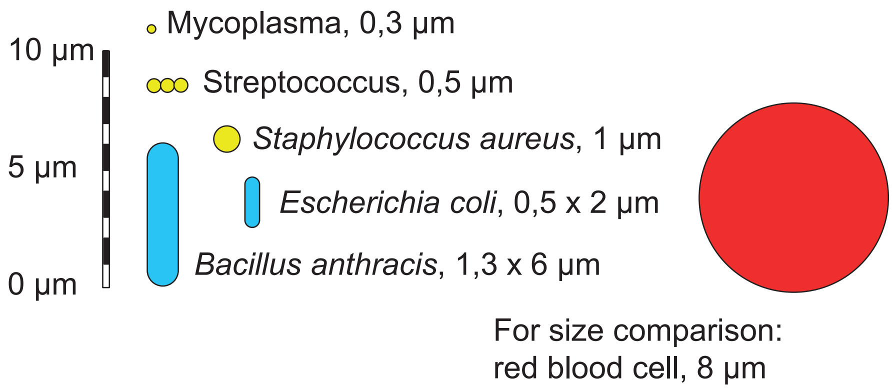
Bacterial forms

There are many different types of bacteria. Under the microscope, three basic forms can be roughly distinguished.



Dimensions comparison

Bacteria are unicellular creatures. Their size is a few micrometers (1 µm = 1 thousandth of a millimeter). They are therefore only visible with the aid of a microscope.



AOC (assimilable organic carbon) – what does assimilation mean?

Assimilation is the gradual conversion of foreign substances into endogenous substances, as seen in both plants and animals.

By playing outdoors, children are exposed to many bacteria – including soil and water bacteria. This strengthens their immune system.

Photo: Internet

In 2013, Switzerland became the world's first country to introduce flow cytometry as a recognised analysis method. The Zurich waterworks have taken on a key role here since 2011.

Preparing samples in the laboratory.

Good water!

The best protection against pathogenic microbes involves implementing protective measures at the source and working carefully when collecting, treating and distributing the drinking water. This is taken care of by the water suppliers.

Note: If the results of a spring water analysis temporarily do not meet the statutory provisions (e.g. following very heavy rainfall), a notice is put up at the corresponding pump (not suitable as drinking water) until the situation is rectified.

How water suppliers use water-purifying bacteria

Although drinking water is a natural, healthy product, it is not pure. Clean drinking water contains a number of different substances – such as calcium – and a wealth of natural, beneficial bacteria.
Germs in drinking water are also known as water-purifying bacteria. This includes vast numbers of lifeforms that do not pose a danger to health in their prevailing biodiversity and distribution.
The bacteria ensure that the natural cleaning power of water is maintained, even in an intact pipe network at the water supplier. Similar to yoghurt, this means that the water-purifying bacteria keep the water at the required standard.

Since the 1960s, a lot has become known about the biodiversity of water bacteria. This will continue in coming decades thanks to new methods of species identification.

Analysing bacteria

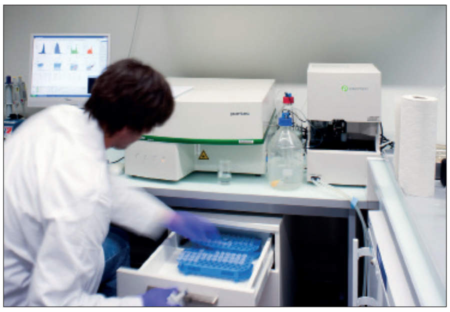
The number or germs living in a water sample alone does not reveal how polluted it is. Nonetheless, the intestinal bacterium *Escherichia coli* indicates that the water has become contaminated with wastewater. The more of these bacteria are found in the water, the greater the risk that the water contains pathogenic germs. As a result, there is zero tolerance of these germs in drinking water.

According to food legislation, no coli bacteria are permitted in drinking water (in 100 ml). Moreover, aerobic mesophilic germs – the bacteria group that requires a lot of nutrients – may not exceed 300 germs per millilitre of water.

From sum parameters to a precise measurement

The Zurich waterworks attaches great importance to inspections that are as comprehensive as possible. Flow cytometry can be used to detect problems (e.g. in the pipe network) in good time. An input of nutrients, for example, could lead to a higher germ count.

The potential of this measurement method has not yet been fully exploited. Using special dyes, a distinction can be made between living and dead bacteria. Studies



Measurements using the flow cytometer.

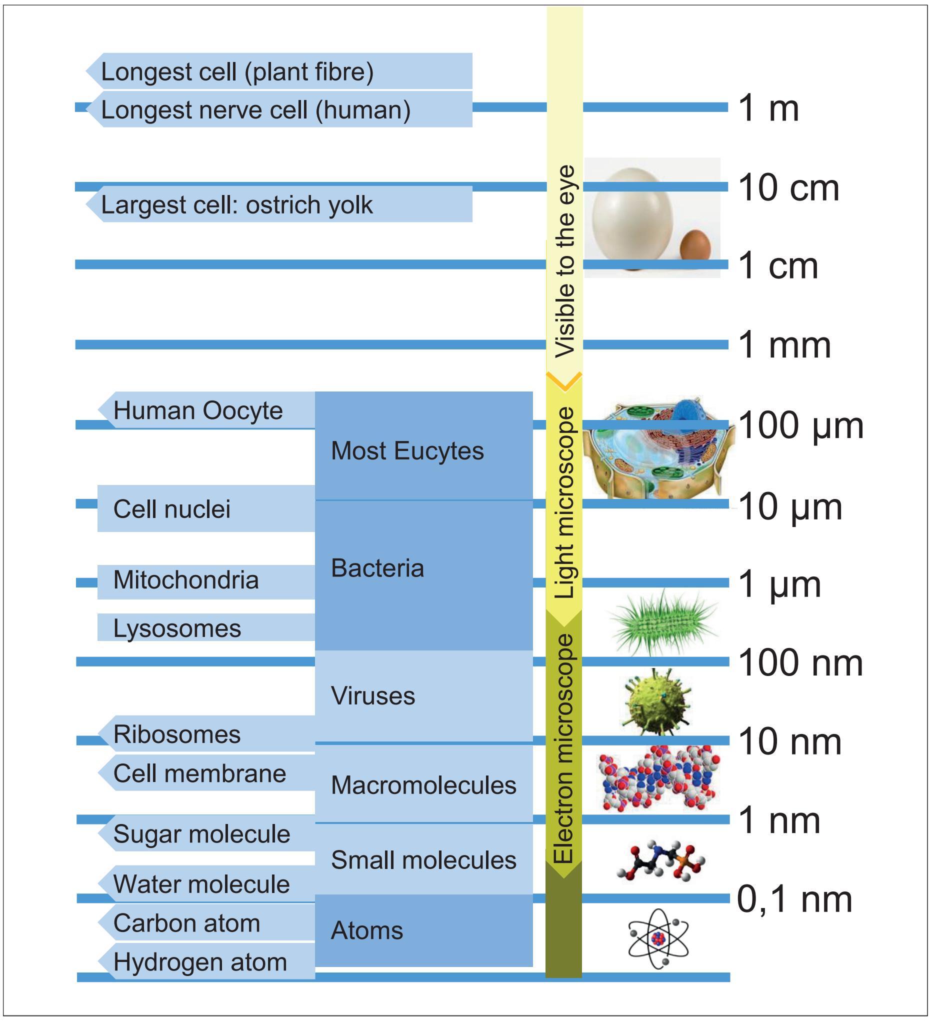
have shown that around 90% of microbes in unchlorinated drinking water are still active. Specific tests have already been made with fluorescent antibodies that become attached to the surface of pathogens.

The relatively high number of natural water bacteria does not pose a risk to humans. Quite the opposite, in fact, as the bacteria have a major advantage as occupiers of ecological niches.

Thanks to effective treatment processes, most Swiss water suppliers are able to provide unchlorinated, biostable water. This means that the drinking water has so few nutrients that there is no longer any undesirable contamination of the distribution networks.

Protecting spring water
The inner protection zone (S2) for spring water and groundwater is intended to prevent pathogenic microorganisms from entering the processed water.

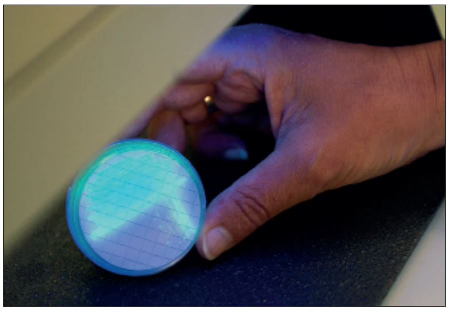
Preparing the Petri dishes.



Comparing the size of different cells.

The AOC compounds required for contamination occur as a result of natural degradation processes and during chemical oxidation processes (e.g. ozonation, chlorination) in drinking water treatment. The compounds are also slowly separated from the pipeline and seal material. These processes occur much quicker at room temperature compared to the temperatures commonly seen in the distribution network (usually < 10 to 20 °C).

As the air also contains many bacteria, sterile water would only remain free of bacteria for a short time.



Fluorescent bacteria.
Photo: Archive WVZ

Ensuring biostable water with flora in drinking water

Flow cytometry allows us to better understand the important function of natural microbiological flora in drinking water.

Measurements show that high-quality drinking water often has up to 100,000 cells/ml or more. It is exactly these microorganisms – or water-purifying bacteria – that occupy the ecological niches in drinking water and thus prevent the growth of undesirable microbiological intruders.

In Switzerland and other countries, drinking water is often fed to the distribution system without chemical disinfectants. However, the prerequisite for this is the presence of low-nutrient, high-quality groundwater or spring water, or treated drinking water from the lake. Dispensing with chlorine as a means of disinfecting the pipe requires meticulous microbiological quality control. In addition to the low nutrient content, a well-maintained pipe network that cannot be infiltrated by other water is important here.

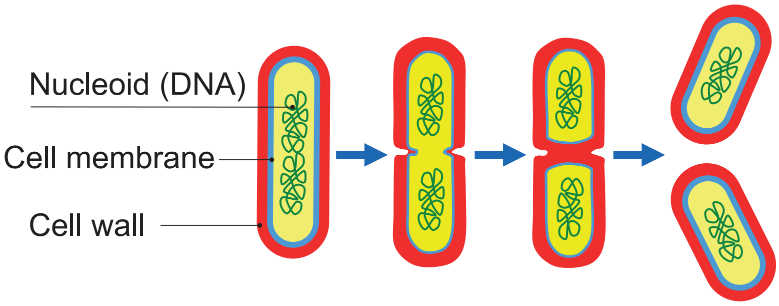
A key aspect when distributing drinking water is the prevention of undesirable contamination. Therefore, the uncontrolled multiplication of microbiological germs in reservoirs and the pipe system should be avoided.

Biologically stable water shows no meaningful growth of additional microorganisms due to the lack of nutrients. As a rule of thumb, the water may not have more than 50 µg/litre of assimilable organic carbon (AOC) compounds. This is because up to 10 million cells can be formed from just 1 µg of AOC.

Test methods for identifying bacteria via biochemical means; fast-testing system following 24 hours of incubation. Photo: Archive WVZ

Multiplication

Bacteria multiply asexually through cell division. If the living conditions are good, they divide very quickly. For example, the intestinal bacterium *Escherichia coli* doubles every 20 minutes in a suitable culture medium.



Multiplication of a bacterium by cell division.

For a long time, only the classic agar method was available for monitoring the microbiological water quality. This only records a small proportion of the bacteria. Over a period of three to ten days, bacteria are cultivated in Petri dishes on a solid culture media at temperatures of 20 to 45 °C, then counted by hand or using a colony counter.

Cultivating bacteria in Petri dishes (aerobic mesophilic germ method)

In order to determine and assess the microbiological quality of drinking water, the bacteria are cultivated in Petri dishes on solid culture media (agar gel). A wide range of bacteria can grow here. In this process, a water sample is applied to the culture media in a dish and then cultivated for a certain time at a specific temperature. The cells that multiply in these conditions then grow into a visible colony. Counting the colonies results in the number of colony-forming units (CFU) in a sample. These micro-organisms are classified as aerobic mesophilic germs. In this standard verification procedure, which was first discovered by Robert Koch in the 1890s, perfect drinking water has less than 20 CFU/ml following treatment and the pipe less than 300 CFU/ml. To compare, water from the spring must have no more than 100 CFU/ml (determination time: 3 days). Using a selective medium, similar methods can be used to look for faecal bacteria – also known as indicator bacteria. These include *Escherichia coli* and enterococci as hygiene-relevant parameters.

Incubator for gathering the bacteria culture.

The consequences of water treatment

It is important to note that ozone kills off germs during treatment.

Nutrients are broken down by the ozone during the treatment process and thus made available again to bacteria as nourishment. The biological filters contain the corresponding water-purifying bacteria that utilise these nutrients.

The water-purifying bacteria also find their way from the biological slow filter into the pipe network.

Microbiology makes the water biologically stable, resulting in minimal contamination.

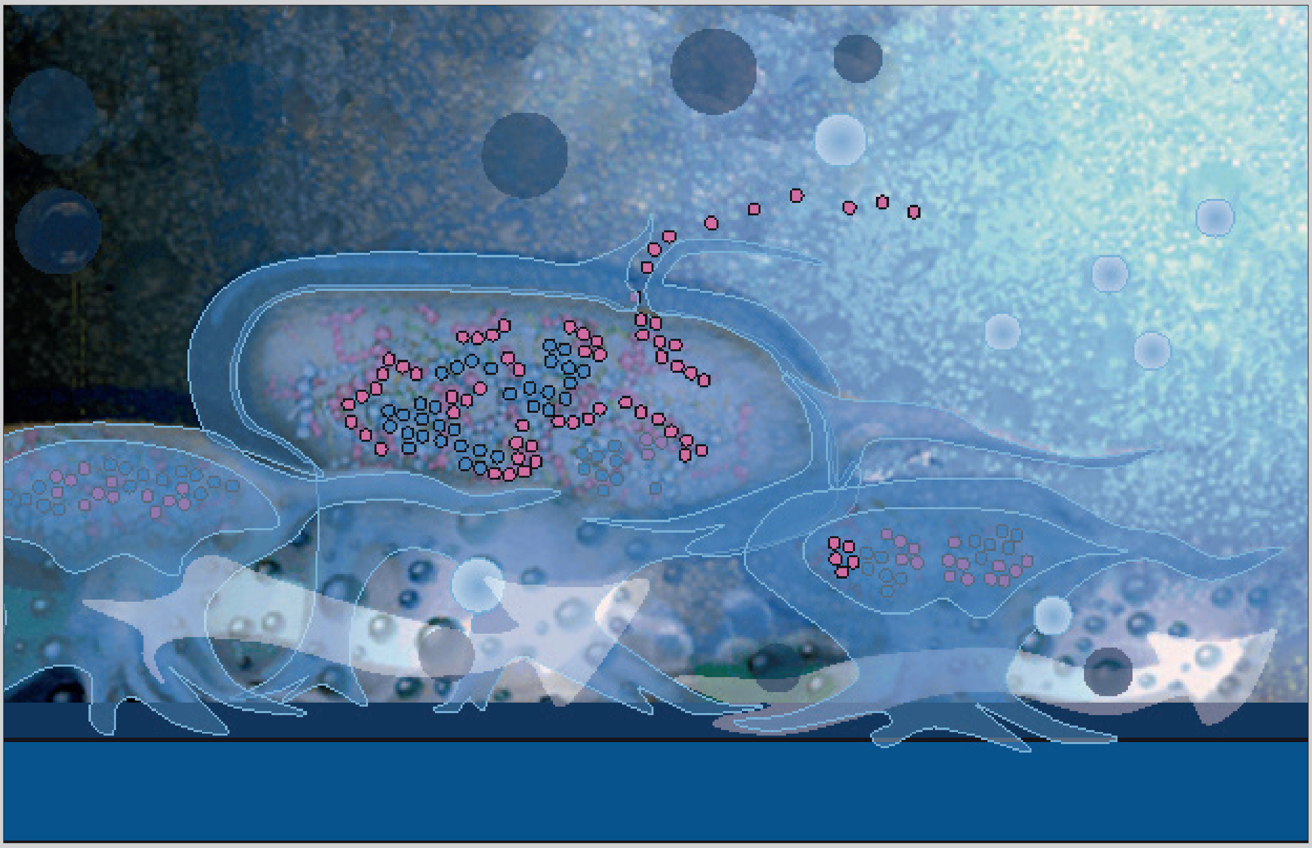
Biofilms – a breeding ground for bacteria

Biofilms are ubiquitous in drinking water distribution systems. These are usually relatively thin, irregular colonies in the form of single cells and microcolonies, although biofilms covering wider areas can also occur.

Obligatory pathogenic microorganisms are not present, while facultative pathogenic microorganisms (e.g. legionella) are sometimes present (in relatively low concentrations in the central supply network).

However, the use of disinfectants (chlorine) under practical conditions does not lead to the complete elimination of biofilms. Source: IWW Zentrum Wasser, Mülheim (Biofilm Centre)

Diagram: certain bacteria are involved in the development of a biofilm.



Life in plastic pipes

Fresh, wholesome drinking water flows directly out of the tap at home. Home owners and tenants are responsible for maintaining the water quality in the properties. Sensible maintenance and regular flushing out of the pipes ensure that the water remains safe and enjoyable to drink.

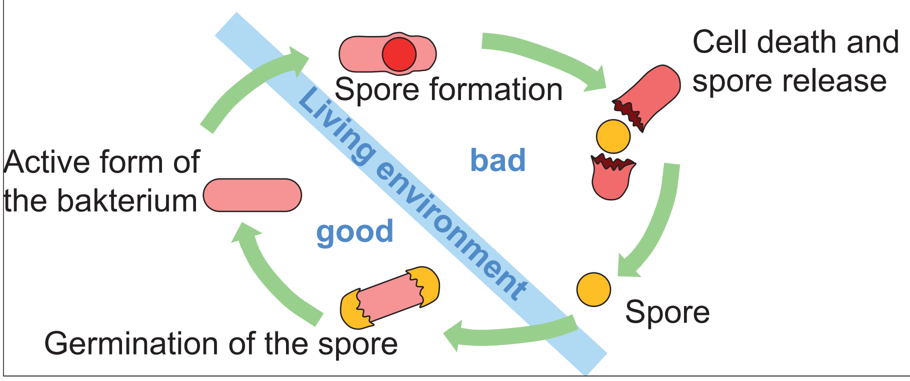
In general, drinking water pipes only emit small quantities of nutrients into the water. While plastic pipes release plasticisers, for example, this is hardly the case on HDPE pipes at the water suppliers.

Here too, the water-purifying bacteria that grow ensure that the biostability of the drinking water remains unchanged. On one hand, biofilms ensure that the nutrients do not multiply. On the other hand, the bacteria consider certain plasticisers as nourishment and metabolise them – an accumulation does not take place due to the short dwell time, among other reasons. As a result, there are hardly any notable quantities of foreign bodies in drinking water and these are also absolutely safe by modern standards.

The water supplier is responsible for ensuring that homes are provided with drinking water of perfect quality. Following long periods of inactivity, consumers should let the water run from the tap for a while until fresh water eventually flows.

Life cycles: Bacterial spores

Some bacterial species (e.g. *Bacillus anthracis*) develop persistent forms under unfavorable living conditions. These resistant spores are inactive. They can survive very long because they have almost no metabolism. In better living conditions they become active again and multiply.



Undesirable bacteria

Pseudomonads are a bacteria group that live and multiply predominantly in natural biofilms. In doing so, they build up a special protective skin around their bacteria colonies that protects them from external influences (e.g. chlorine). One of the notorious strains is *Pseudomonas aeruginosa*. This is a bacterium that can be pathogenic and thus harmful to humans in certain circumstances. A weakened immune system leaves the human body vulnerable to infections here, which is why this strain is considered a hospital germ. This bacterium also exhibits resistance against antibiotics.

When the bacteria are killed off, the ecological niches are taken over by new ones. This is also the case during water treatment processes, where the microbiological flora are partially eliminated, inactivated or killed off. Such processes include UV disinfection or chemical disinfection, for example. During a chemical oxidation reaction (chlorine or ozone), additional nutrients (AOC) are often formed, which leads to increased growth potential for the bacteria.

How bacteria diversity protects drinking water

Even low-nutrient drinking water maintains ecological niches for microorganisms to survive. Ultimately, these must be considered in a wider-ranging context together with the natural self-purifying ability of the water.
Simple filtration methods or disinfection (chlorine) only lead to a short-term reduction in the germ count, which then increases immediately once again to the former levels. However, this also leads to a drop in biodiversity to the benefit of the more adaptable species that know how to use the ecological niches to their own advantage.
In contrast with the earlier school of thought that bacteria that are harmful to humans could not survive in aquatic surroundings and would quickly die out, it has now been proven that bacterial pathogens such as certain coli strains can live for a time in lakes or drinking water where germs have been eliminated. However, these are in competition with the natural, harmless, freshwater bacteria flora. It thus makes no sense to eliminate germs from water, as this results in an unstable situation in which potential pathogens could survive for a long time in the now vacant ecological niches.

Coli bacteria

There are several different groups of coli bacteria, ranging from safe to extremely harmful species (serious diarrhoea).
If coli bacteria are present, other pathogens may also be present in the drinking water or even multiply there. Coli bacteria thus play a role as bioindicators.
In a completely filled ecosystem, pathogens face strong competition from the existing, well-adapted, natural microbiological flora when it comes to fighting for the few nutrients available. Either way, the potential for survival is thus very modest. An important prerequisite for preventing the build-up of pathogens is that the temperature of the water in the network remains low and does not rise significantly above 25 °C.

Protection against pathogens

When treating the lake water, the water supplier uses a multi-barrier system. This includes double ozonation, plus fast filtration, active carbon filtration and slow filtration.

Sterilisation

Typical sterilisation methods include ozonation of the water, the use of chlorine (for example, in the form of chlorine dioxide), or UV radiation. These only make sense if the aim is to kill off germs (disinfection). However, nutrients are also generated at the same time here.

Advantages of using biological filters

Subsequent biological treatment – such as slow sand filtration – supports the condition of the biologically stable water.

In the slow sand filter, the available nutrient content (AOC) is further reduced by the microorganisms attached to the grains of sand. Furthermore, as a result of colonisation of the sand body, varied and optimally adapted cells are passed into the water. These cells ensure a good initial occupation of the ecological niches in the pipe system.

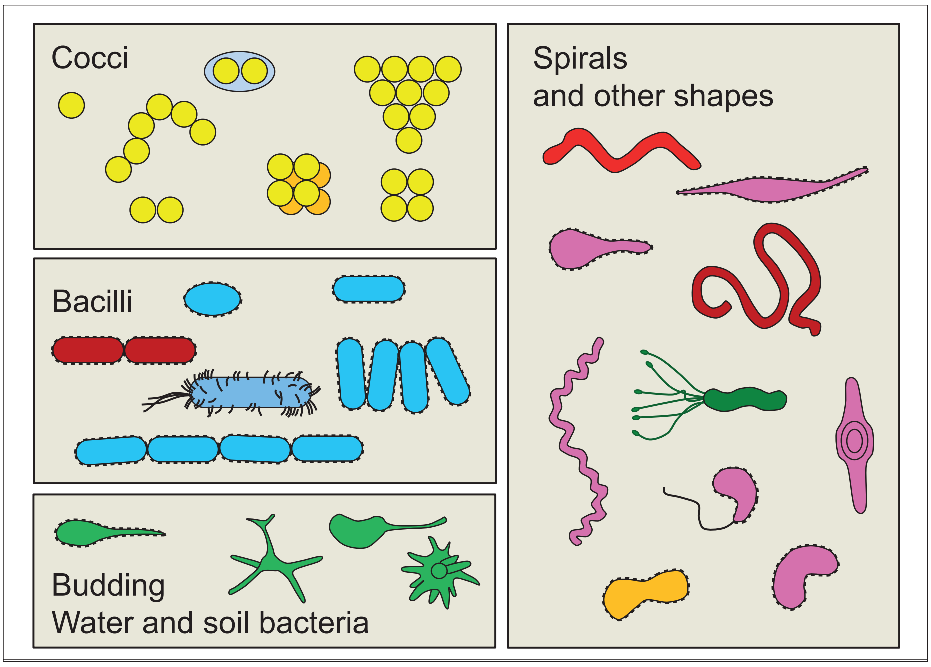
Note: With ultrafiltration (a treatment method that eliminates substances, bacteria and viruses with the help of special membranes), the process for maintaining the biological stability of the drinking water takes place directly in the pipe network.

Boiling water – an old wives' tale?

Although not necessary in case of normal consumption (letting the tap run briefly is sufficient), boiling drinking water offers the best protection against germs.

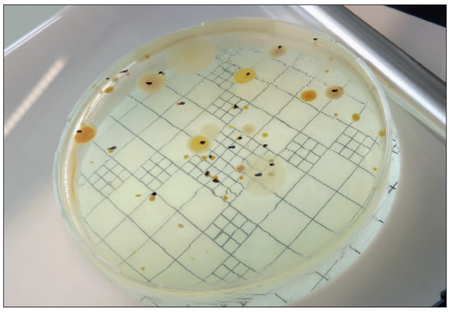
Brief, one-off boiling is sufficient to kill off all germs. This is a routine precaution when preparing meals in nurseries, for example.

The bacteria in drinking water are specialists in surviving with very few nutrients in cold surroundings. These bacteria have always lived in water and do not pose a danger.



The diversity of different forms of bacteria is very large. The cell shape of the bacteria says only little about its relationships.

Counting bacteria.



Petri dish containing counted bacteria (aerobic mesophilic germs). Photo: Archive WVZ

Clean water
Drinking water is free from toxic substances and pathogens.

Clean water in the home

In well-maintained distribution networks, the excellent quality of the drinking water remains unchanged. A suitable domestic installation is required in order for this quality to remain all the way to the tap. Most importantly, there is no need to worry about poor drinking water quality in the event of normal consumption.

The cell count can vary greatly in buildings following overnight water stagnation. A twofold to hundredfold increase in cell count is possible here. An excessive increase in cell counts in a domestic installation can be due to several reasons, including high temperatures (heating in the house), small pipe cross sections leading to large surfaces for biofilms to form, and unsuitable pipe material (plastics or old, damaged pipes).

Flushing out the lines after periods of absence or letting water run briefly from the tap periodically have long been standard methods for ensuring fresh drinking water from the tap in optimal quality.

Interpreting measured values

Interpreting the cell counts determined using the new flow cytometry method is almost impossible for consumers. Furthermore, only unsuitable comparisons can be made between the individual suppliers.

As a uniform assessment of the cell counts is not possible, each water supplier has to collect their own empirical values on the development of the cell count over a prolonged period and in different locations. Ultimately, the cell counts are just one parameter used when monitoring the overall quality and thus do not allow an all-encompassing assessment of the water quality to be made.

Maintenance of domestic installations

It is important to note that unused domestic installations must be removed and rarely used installations must be flushed out regularly.
The water supplier is responsible for the water quality up to the house connection. From this point on, it is the responsibility of the home owner.

Drinking water is a natural product
The composition of the bacteria in drinking water changes on the way from the spring to the tap, with the temperature and dwell time in the pipe network playing a corresponding role.
Biologically stable drinking water also remains clean after a slightly longer dwell time in the pipe network and reservoirs. This is helped by the drinking water biofilms as the source of water-purifying bacteria. The regular bacteriological inspections provide peace of mind and thus confirm the good quality of the drinking water.
Increased bacteria cell counts can be seen in domestic installations in certain circumstances, for example as a result of damaged pipes. However, this doesn't necessarily mean that the water is of a lower quality.

Chlorine-free
Due to the good standard of drinking water in Zurich, final disinfection with chlorine or chlorine dioxide can be dispensed with. However, such systems are on hand if a corresponding deployment should become necessary.

What does a domestic installation consist of?
– Internal water pipes leading from the house connection to the water meter
– All pipes leading from the water meter, equipment and fittings that are necessary for the drinking water supply
These installations are carried out by a licensed plumbing company.

Example: Dynamic bacteria composition

The composition of an average range of bacteria in drinking water can change over time. The following example shows a comparison of bacteria quantities: The most predominant bacteria are coryneform bacteria (45%), pseudomonads (up to 31%) and azotobacters (16%). Following a dwell time of 14 days in the pipes, the pseudomonads dominate with a share of 73%. Meanwhile, Gram-positive bacteria only have an average share of 1%.

Pathogens (legionella & co.)

There are countless different species of water germs. This includes some species that can develop a pathogenic character if the drinking water installation is handled inappropriately. A prime example of this is legionella, which can multiply rapidly in boilers that have not been heated sufficiently.

While some potentially hazardous bacteria species can be found in isolated cases, the majority of the remaining species are harmless. The overall bacteria composition ensures that any pathogens cannot multiply.

In clean drinking water and with a well-maintained pipe network, bacterial contamination with pathogenic germs is more or less impossible. At the same time, the build-up of any “spoilage flora” must also be ruled out through inspections.

Pseudomonads

Pseudomonads are abundant in nature. They are unfairly titled as “muddy puddle germs”, despite them being non-faecal in origin. Pseudomonads are found in the soil, water and on plants and animals. As a cold storage flora, some species are undesirable in connection with food storage. Pseudomonads are common in aerobic wastewater treatment facilities and are involved in the degradation of pollutants, including oils and greases.

Pseudomonads mostly subsist on dead organic material. Even though some of them are pathogens, many species have a positive effect on keeping drinking water clean as they force out the pathogens. Some species are able to reduce the nitrate content.

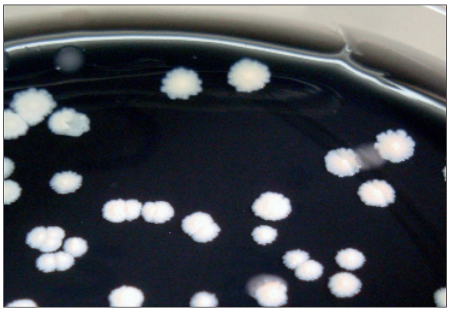
Pseudomonas aeruginosa is a widespread soil and water germ (wet germ) that is found in moist surroundings (including in tap water, sinks, showers, toilets, washing machines, dialysis machines, medication and disinfectants, in addition to damp soils and surface water). In hygienic terms, it is thus classified as a major hospital germ. However, it also plays a role in food spoilage. It can even survive in distilled water or certain disinfectants and can grow when the smallest traces of organic substances are present.

Legionella

Legionella are a strain of rod-shaped bacteria that can be found in water in isolated cases. They multiply at luke-

warm temperatures of 20 to 50 °C in boilers that have not been sufficiently heated, for example.
The set nominal temperature in a heating boiler without circulation should not be lower than 55 °C. Modern heating controllers for small heating systems regularly increase the boiler temperature for a brief period.
Respiratory infections are possible if a significant amount of legionella bacteria are inhaled via fine water droplets (aerosols) while showering. However, drinking water containing legionella does not pose a health risk. Fountains or mist generators are also a potential source of danger.
The water supplier is responsible for delivering water to the home. Inside the home itself, the home owner must ensure perfect water quality with the help of a licensed plumbing company.
Swiss plumbing companies usually set the temperature range so that bacteria cannot multiply and illness can then be ruled out.
Building measures are also a good precaution. Water that stands in pipes for a long time must be avoided. Unused pipes should be removed or automatic flushing equipment installed, for example.

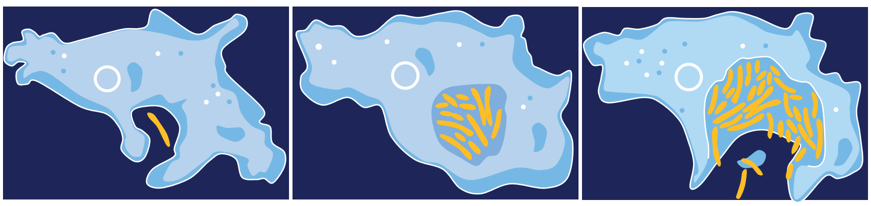
Legionnaires' disease
There are around 50 strains of legionella, whereby *Legionella pneumophila* is more common and well known as the cause of Legionnaires' disease (legionellosis). Legionnaires' disease acquired its name in 1976, when an outbreak of pneumonia occurred among people attending a convention of the American Legion at a hotel in Philadelphia. 182 cases were reported, of which 29 persons died. It is essential that those suffering from this illness, which is similar to pneumonia, seek medical treatment. There is also a milder form of the disease with flu-like symptoms, known as Pontiac fever.

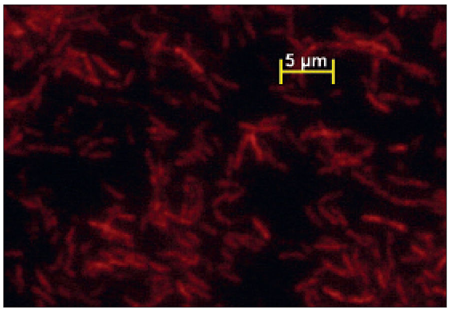


Legionella.

Amoebae in biofilm

Amoebae are host organisms for *Legionella spp.*, *Mycobacteria spp.* and other "Amoeba-resistant bacteria". These bacteria are absorbed into the amoebae without being digested and multiply there within the vacuoles (cell organelles). When the multiplication rate has reached a certain density, they are released from the vacuoles into the water.





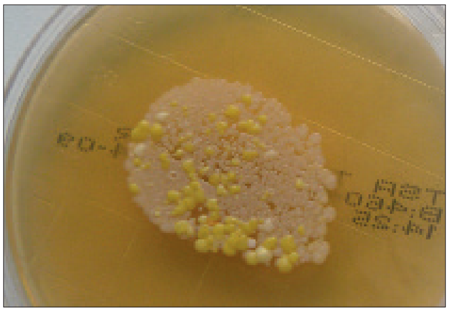
Under the microscope: Legionella pneumophila. Photo: Archive WVZ

Single-cell organisms, such as amoeba or flagellates, are of no relevance when supplying drinking water.

Temporary restrictions to pump water

Following heavy rainfall, undesirable microorganisms may temporarily enter the water source. If the measured values exceed the limits, a notice is put up at the corresponding pump (not suitable as drinking water) until the situation returns to normal.

In such cases, the water supplier can no longer guarantee the water quality and those drinking from the pump do so at their own risk.



Fingerprints in the agar from different people. Photo: WVZ

Quality assurance concept

Biological quality checks are made on a regular basis during the treatment of drinking water, at the source (including groundwater) and in the pipe network. Sampling points include water pumps and hydrants. In this way, even minor quality fluctuations within legal limits are registered, which allows for action to be taken in a timely fashion.

Dispensing with disinfectants (e.g. chlorine) allows any quality fluctuations in the network to be detected in good time. Suitable countermeasures can then be introduced faster. If disinfectant is added, possible problems may remain undetected for a long time as bacteria growth is suppressed. This can then reach serious levels without being noticed, before the situation then escalates and spreads dangerously.

Long periods of rainfall can lead to a temporary increase in the germ count at the water source. If the limits are reached, the water is disposed of – meaning it is diverted into a river instead of into the pump. If this is not possible, a notice is put up at the corresponding pump (not suitable as drinking water). This pump is then inspected on a regular basis until the values improve and the notice can be removed. The installation of a disinfection system or repairs to the source may be required.

Where can the quality be compromised without noticing it? If there are undetected leaks, pollutants can enter the drinking water network despite the pipe pressure of 3 to 10 bar. This can be caused by building work or by intense pressure as a result of water running off slopes. If end pipe sections are not in sufficient use, a slow build-up of germs may also be registered there. Immediate measures here include flushing the pipe or searching for and repairing leaks. In certain circumstances, any compromises in quality can also be rectified by reducing the pipe cross section.

Procedure in the event of reduced microbiological water quality

The affected pipe section is thoroughly flushed and subsequent samples are taken – on a daily basis, if required. It is important that the quality parameters are adhered to here in accordance with hygiene regulations.

Additionally, the source of the contamination must be found by detecting leaks, network modelling and taking targeted samples.

In the event of serious incidents, disinfectant (chlorine) is added and an announcement made that consumers should boil their drinking water, where appropriate.

Preparing a sample.

Household tips

1. Let the tap water run: If water stands for too long in the pipes (e.g. during a holiday), it is recommended to let the tap run until cooler water flows before using it for the first time.

2. Set a very high hot water setting on the boiler for hygiene reasons and preventing the build-up of legionella.
The temperature in the early morning at the furthest tap from the boiler must be at least 50 °C (and the boiler at least 60 °C).

3. Carry out regular boiler maintenance to keep deposits to a minimum.

4. Use modern, certified water installations to minimise the build-up of germs.

Looking forward: where is research heading?

In the laboratory analysis of the future, the focus will be on skilfully combining the many chemical and biological methods now in use in order to achieve a result that gives as comprehensive an overview of the water quality as possible.
A device that is able to deliver microbiological information in real time is on the verge of a breakthrough. This online flow cytometer is a further development of the proven laboratory equipment used to determine the cell count in water. Initial test measurements with the new device have shown encouraging results and confirm its potential for use in continuous process monitoring.
With all these developments, we are not only following up on our own scientific interest in drinking water, but are meeting the demands of both consumers and the authorities when it comes to providing a perfect and strictly controlled product.

Progress just around the corner

In the near future, online flow cytometry is expected to become an established method at many different points during drinking water analysis – both during treatment and in the pipe network.
Other methods are also a possibility when used in combination with existing tests. For example, the ATP test is a way of determining the stored energy when the metabolism is working correctly. Here, the amount of adenosine triphosphate (ATP) in the cells is measured. This allows bacteria, yeast and mould cells to be examined. Even more informative would be the use of genetic tests when determining species, although this is still very cost-intensive at the moment.
Population densities, species distribution and lifetimes of bacteria form a broad area that still has to be researched. For example, bacteria can produce completely different metabolic products with very different pH values.

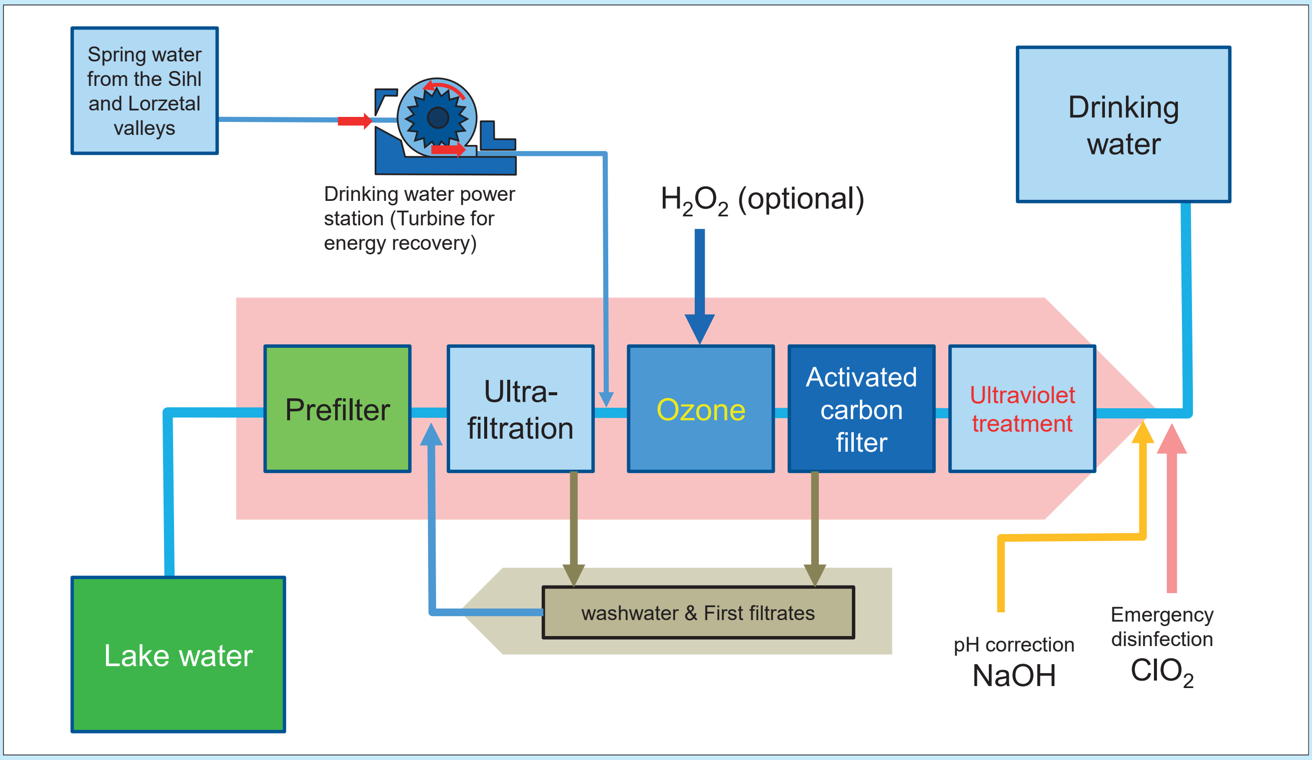
Analysing a microbial community in the pipes

A very precise sequencing technology – next-generation sequencing (NGS) – is responsible for the new findings on microscopic life that are being seen in water pipes. Formerly, less than 10% of the bacteria could be cultivated in drinking water using nutrient solutions (agar). The new method now shows a more comprehensive picture of the microbial community present in the biofilms of the pipes and drinking water.

Other options are available for monitoring the microbiological water quality, such as DNA analysis.

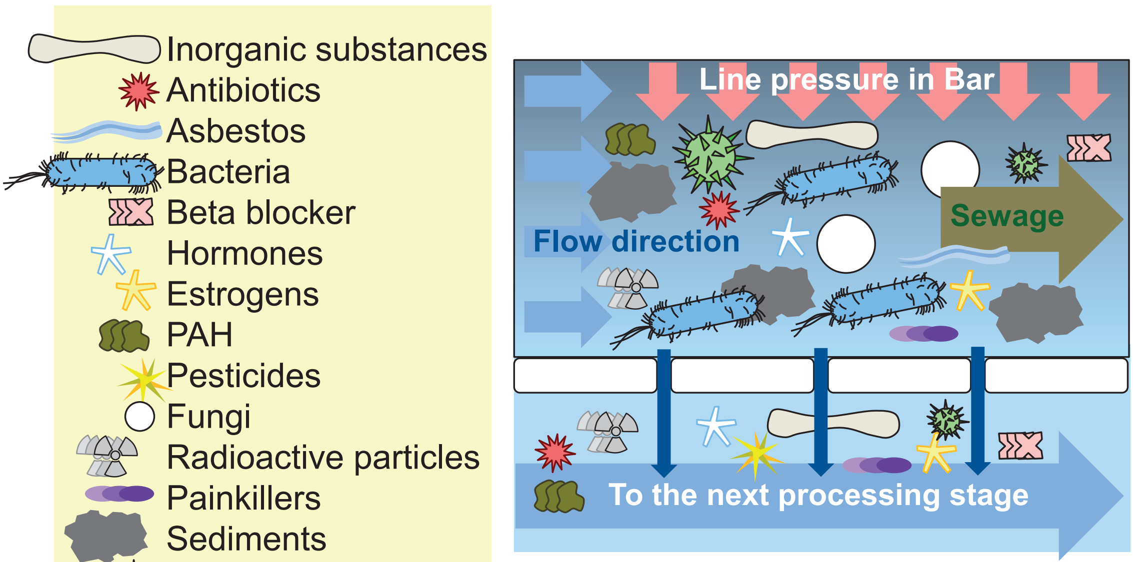
Ultrafiltration at the refurbished lake waterworks in Moos

The planned process chain is characterised by the use of membrane filters. This technology replaces the sand filters. The biological stability of the drinking water in the pipe network is maintained through the degradation of nutrients in the activated carbon filter.



Ultrafiltration is a modern treatment method that offers very effective protection against germs.

Disinfection: The killing (ozone) and separation (membrane) of microorganisms are efficient processes.



PAH: polycyclic aromatic hydrocarbons (combustion residues)

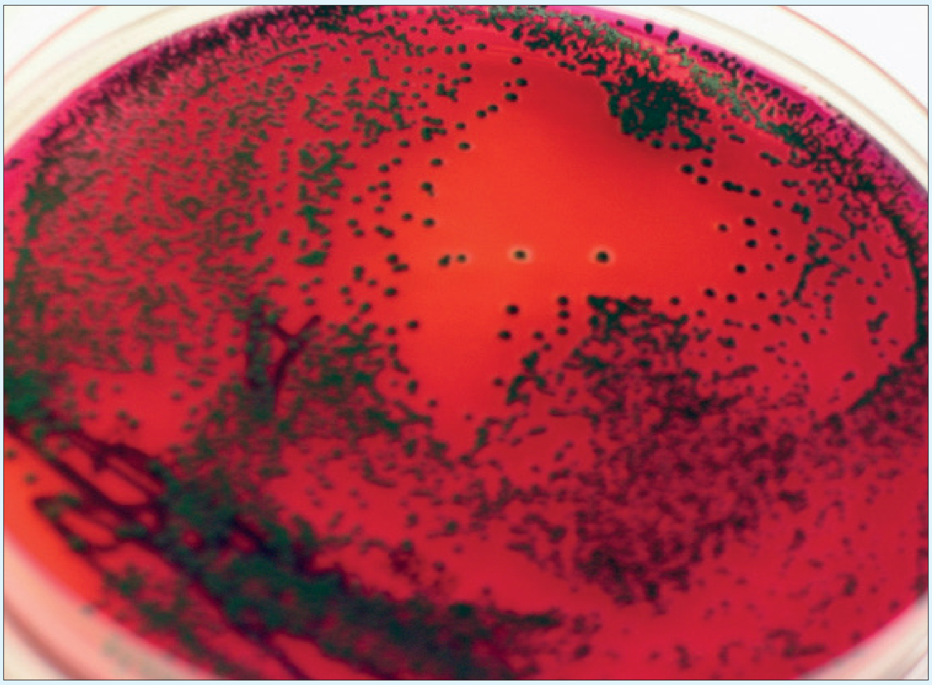
Bacteria performance:
How are holes in cheese made?
The answer is a simple one – the holes are made by gas bubbles that are produced by bacteria while the cheese matures. Microorganisms are added to the cheese during production. While the cheese matures slowly, the bacteria ensure that the lactose is almost completely broken down by the lactic acid to form propionic acid. The lactose is broken down completely around three months into the process.

Appendix: An introduction to the wonderful world of microbes

Bacteria live in many different ways. For example, phototrophic bacteria use light to generate energy, while luminescent bacteria generate light through bioluminescence. Bacteria are found almost everywhere.

Just 200 grams of soil contains around 1.5 billion microorganisms such as bacteria and algae. Meanwhile, one litre of clean lake water contains several hundred million bacteria. Among other places across the globe, the seabed off the coast of Namibia is home to the largest bacterium in the world. Living at a depth of 100 metres, *Thiomargarita namibiensis* (or the “sulphur pearl of Namibia”) has a diameter of 0.75 millimetres and can be seen with the naked eye. Normally, bacteria measure just a few thousandths of a millimetre.

Deciphering the world of bacteria
Despite being the most simple form of life (amoeba), people still used to believe that bacteria were a form of plant life. This is why the incorrect term water or gut flora is still common today (the correct term is gut microbiota). In contrast to other organisms, bacteria do not have a nucleus. They are known in science as prokaryotes (cells without a nucleus), in contrast to eukaryotes (all other

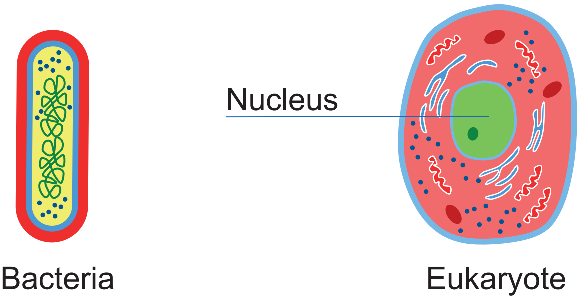


Salmonella in a Petri dish. Photo: Archive WVZ cells with a nucleus).

There are bacteria with oxygen respiration, others that can live both with or without oxygen, and others that cannot tolerate oxygen. Bacteria multiply via cell division.

Blueprint

Bacteria do not possess a real cell nucleus. The genetic material, DNA (deoxyribonucleic acid), is freely present in its interior as a ring-shaped, tangled molecule thread (nucleoid). They are therefore also called prokaryotes. Cells that have a nucleus are called eukaryotes. These include e.g. plant and animal cells.



For practical reasons, bacteria have been divided up by their shape and organisation according to formerly used classic systems up to now.

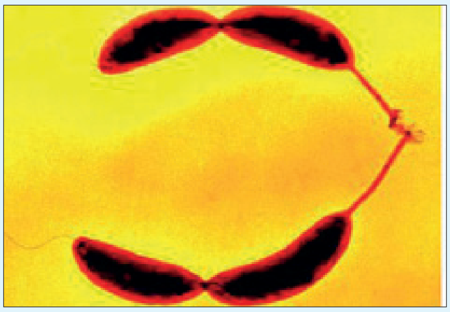
The three main shapes of classic bacteria are rod-shaped bacilli, round cocci and spiral bacteria.

Gram-positive and Gram-negative bacteria differ in terms of their structure. Gram-positive bacteria are usually cocci. Among other characteristics, they have a thick cell wall. These bacteria include staphylococci, streptococci, listeria, clostridia, mycobacteria and nocardia.

Gram-negative bacteria are usually rods. These have a thin cell wall. These bacteria include pseudomonads, legionella, bordetella, campylobacter, *Helicobacter pylori*, borrelia, chlamydia, neisseria and enterobacteria (such as *E. coli* and salmonella).

Gram staining

Gram staining is a method developed by the Danish bacteriologist Hans Christian Gram (1853–1938) for distinguishing bacterial species for microscopic analysis. This allows bacteria to be classified into two major groups (Gram-positive and Gram-negative) according to the thickness of their cell walls. However, not all bacteria species can be classified using this method – there are also Gram-variable and non-Gram-classified species.



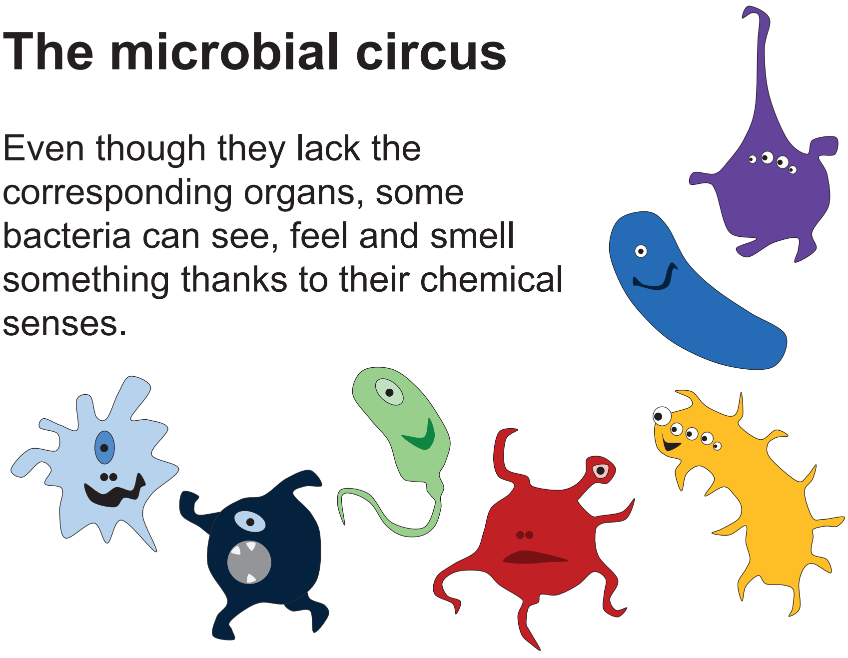
Individual bacteria cells forget things very quickly. However, bacteria groups can form a collective memory that helps them to better cope with stress. This was first proven in experiments as part of a study published in "PNAS" by Eawag and the ETH Zurich in 2016.
Pictured here is the "model bacterium" Caulobacter crescentus, whose memory was analysed by the researchers. Photo: Wikipedia

Where do pathogenic germs in drinking water come from?
In most cases, the pollution of water with pathogenic germs is caused by faecal contamination. As a result, drinking water and wastewater systems must not come into contact with each other.
Signs of infection caused by heavily contaminated drinking water include stomach cramps, diarrhoea and fever.

Microbiota (microflora)
Microorganisms (microbes) are microscopically small lifeforms that usually cannot be seen with the naked eye. These are predominantly single-cell organisms and include bacteria (such as lactic acid bacteria), many types of fungi (such as baker's yeast) and certain microscopically small algae.
A distinction is made between prokaryotes without a nucleus (bacteria and cyanobacteria with a cell size of 1 to 10 micrometres) and eukaryotes with a nucleus (fungi, plant and animal cells with a cell size of 10 to 100 micrometres).
Up to now, around 5,000 (4,500 exactly as of 2016) prokaryote strains (bacteria and archaebacteria) have been given a scientific name. Each year, around 500 to 800 prokaryote strains are discovered and named. Only around 200 bacteria species are pathogenic. Cholera, typhus and jaundice are typical water-borne illnesses that are usually only found in the tropics nowadays. However, pathogens also appear occasionally in wastewater and also in surface water in isolated cases.
Even a single litre of lake water may contain more than 20,000 different species of microorganisms. There are also still more than 10,000,000,000 unknown species, although many microbiologists remain sceptical as to whether the normal species definition can be used for prokaryotes.
Prokaryotes live in the atmosphere at altitudes of up to

The microbial circus

Even though they lack the corresponding organs, some bacteria can see, feel and smell something thanks to their chemical senses.



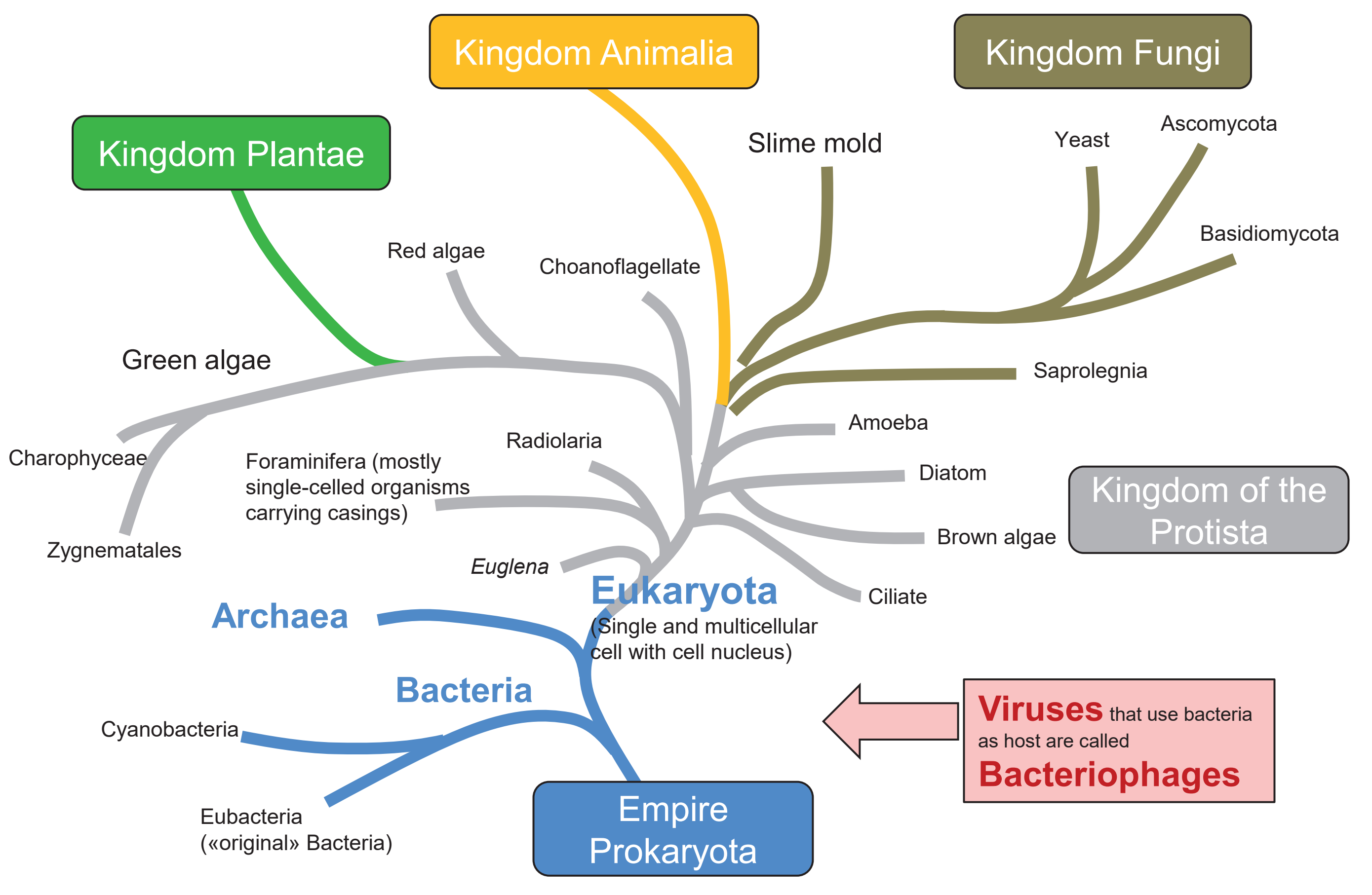
Bacteria in Petri dishes also have a certain scent: Each person has their own individual composition of bacteria living on their skin, which plays a role in body odour when mixed with sweat. This leads to a typical scent – which can be appealing to some or less so to others!

77 kilometres and up to 4 kilometres down into the earth. More than half of all prokaryotes live in soil at depths of between 10 and 100 metres.

Most microorganisms do not cause illnesses. Quite the contrary, in fact – they are essential in gut flora, for example. Vitamins (vitamin H, folic acid and vitamin K) are produced. The immune system is strengthened and the colonisation and spread of pathogenic bacteria and fungi is prevented. Bacteria have a positive effect thanks to their sheer quantity – around 2 kilograms of human body weight can be traced back to microorganisms. Even in healthy lungs, over 100 different species of bacteria can be found.

The skin flora plays an important role in protecting the skin and organism against pathogens. In total, around 10^{10} bacteria live on our skin.

Family tree of life



Dividing up lifeforms into different classifications is a constant part of research. As a result, various systematic classifications are made simultaneously and one after the other.

Useful information on germs

Germs thrive everywhere, whether in the home, at work, in public buildings and when travelling. Even unpolluted air contains around 100 to 1,000 bacteria and fungi per cubic metre.

Bacteria are everywhere

As unexpected as this may seem, the toilet is actually more hygienic than other areas of the home. A study by the University of Arizona found that there are over a thousand times more bacteria in the fridge than on the toilet. However, the largest bacteria density can be found on computer keyboards. Anywhere where people use the same computer, such as in schools or internet cafés, harbours a risk of illnesses being transmitted after touching the keyboard.

The most stomach-turning results were found at the Chapel of Mercy in Altötting (Germany). In a study carried out by the Institute for Hygiene at the LMU Munich, 100 million germs were found in just one millilitre of holy water. The water also contained threads, spores and beads, plus coagulase-positive staphylococci (which cause abscesses, boils and diarrhoea).

However, germs do not necessarily lead to health problems. Each day, the human body grapples with countless viruses, bacteria, parasites and fungi without getting ill, and thus trains its immune system. Problems only occur when a dangerous pathogen occurs in critical quantities.

Following the most important hygiene rules reduces the risk of infection significantly. Even something as simple as washing your hands regularly can break the transmission chain of the pathogens.

Aliivibrio fischeri

Aliivibrio fischeri was discovered in 1889 by Martinus Willem Beijerinck and is a Gram-negative, facultative anaerobic bacterium. It uses flagellae for movement and is also bioluminescent, meaning it emits light.

These bacteria are present in low concentrations in seas in all four corners of the world, particularly in symbiosis with other sea life such as herrings or squid.

Science:
On the hunt for cholera bacteria
Dübendorf, 23 August 2007 – Cholera bacteria can not only survive and even multiply in the human gut, but also in freshwater and in competition with the naturally occurring bacteria there. Previously, it was assumed that the pathogen could only grow in brackish water. The results seen by a team from Eawag using water from the Greifensee lake now allow for a more realistic estimation of the cholera risk.

Measuring the quality of wastewater
A. fischeri is used when inspecting the water quality. The bacteria are extremely sensitive to contamination and toxins. In line with EN ISO 11348, salt (NaCl) is applied to wastewater samples, which are then inoculated with a low concentration of luminescent bacteria. The luminescence is then measured. Following a 30-minute incubation period at 15 °C, the luminescence is measured once again. The difference in luminescence gives an indication of the water quality as the luminescent bacteria adapt their multiplication rate and luminescence according to the water quality. The decrease in luminescence is proportional to the amount of contamination in the water.

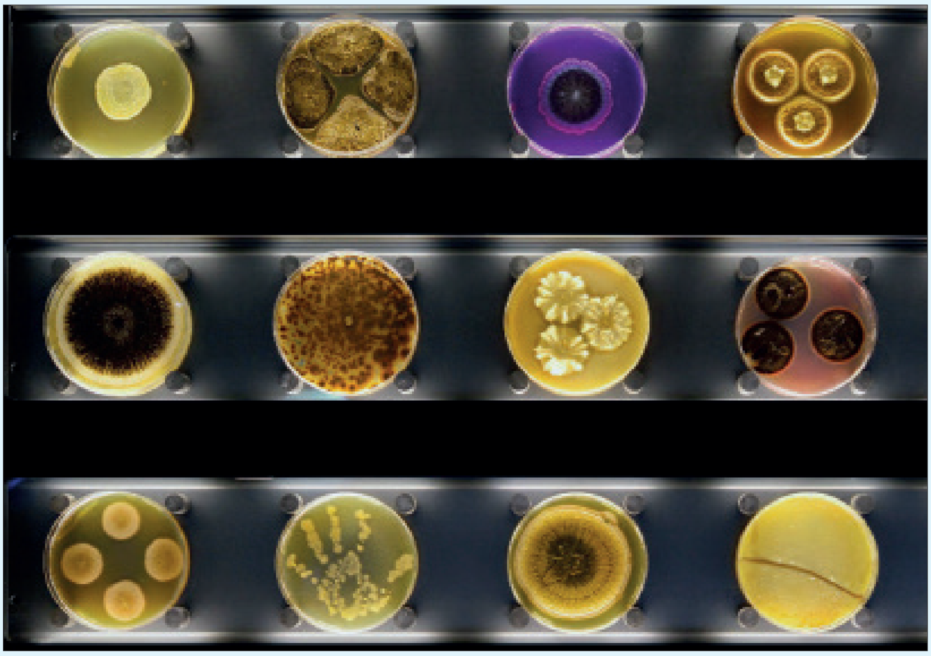
Bacteria performance:

A mysterious event in the US Civil War

The Battle of Shiloh in Tennessee (1862) was a bloody one, with 3,000 dead soldiers and around 15,000 wounded. The wounded had to survive for days in cold, damp April weather. The cause of death was often gangrene. On some casualties, the wounds emitted a blue glow. Those with such wounds often survived, which is why this miracle occurrence was given the name “Angel’s Glow”.

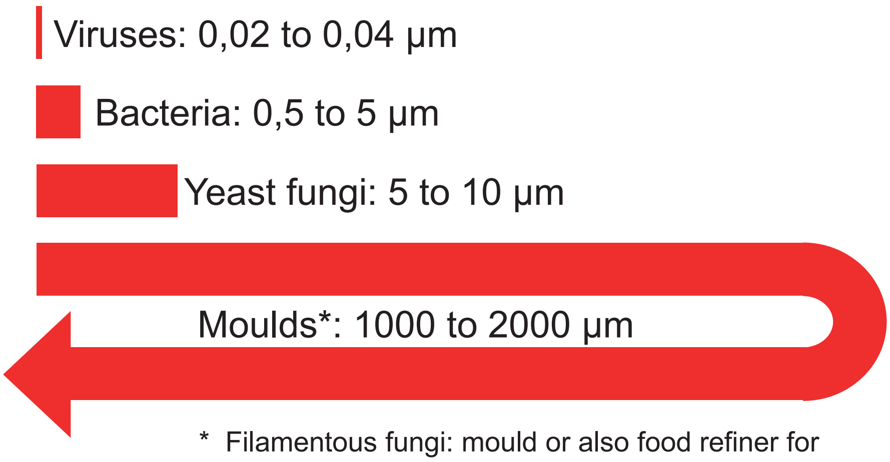
Decades later, the mystery was solved. This was probably caused by an infection of luminescent bacteria (*Photorhabdus sp.*). The bacteria occurs in the saliva of nematodes (worms). The worms transmit the bacteria to insects, after which the bacteria emits toxins that can kill the insects. Although the human body temperature is normally too high for these bacteria to multiply, the low outdoor temperatures allowed the bacteria to spread and they thus had an antibacterial effect on the wounds.

All luminescent bacteria – and possibly some fungi – have a biochemically similar luminescence system. The luminescence of bacteria is also an oxidation reaction. The wavelength peak of the transmitted light is around 490 nm. This is in the blue-green range of the light spectrum.



A microbe zoo in Amsterdam. A section of the wall with 150 Petri dishes containing various microorganisms. Online image source: Micropia; photo: Maarten van der Wal

Size comparison



* Filamentous fungi: mould or also food refiner for mould cheese and salami, organic source for antibiotics (penicillin).

General information on pathogens

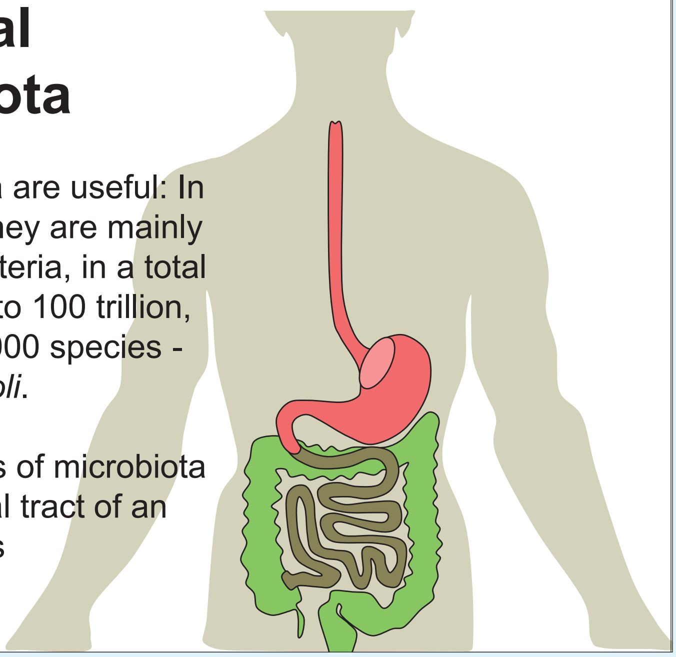
Wet germs (also known as water germs, water-borne germs, muddy puddle germs and hospital germs) are those bacteria that multiply predominantly in moist surroundings and without many nutrients available. As seen in other bacteria groups, some species can also develop or acquire resistance to disinfectants. This then becomes problematic if the species is also harmful to humans.
The most well-known pathogens include *Pseudomonas aeruginosa, Proteus sp., Klebsiella sp., Acinetobacter sp.* and *Stenotrophomonas maltophilia*. These can be found in sink drains and even in shampoo. The legionellosis pathogen *Legionella pneumophila* multiplies in warm

Every person has their own individual bacteria composition – or "zoo" – in their gut. This then plays a decisive role in what the body can tolerate and in which quantities.

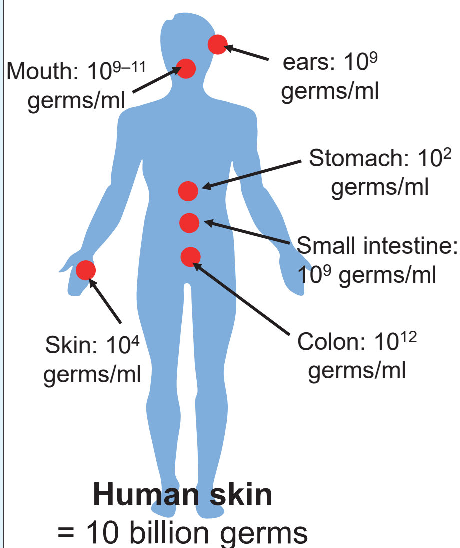
Intestinal microbiota

Some bacteria are useful: In the intestine they are mainly anaerobic bacteria, in a total number of 10 to 100 trillion, from over 35,000 species - including *E. coli*.

The total mass of microbiota in the intestinal tract of an adult human is 1-2 kilograms.



Germs comparison



Drinking water
10'000–100'000 cells/ml
0–300 CFU/ml

Still mineral water
~ 100'000 cells/ml

Good quality milk
100'000 CFU/ml and more

Mixed salad packaged
10'000'000 CFU/g

Whipped cream
10'000'000 CFU/ml and more

Sandwich (salad/sausage)
10'000'000 CFU/g and more

Heated meal
around 1'000'000 CFU/g

Table of pathogens and illnesses that can be transmitted via the faecal-oral route (humans and animals) in water:

Bacteria	Viruses	Protozoa (parasites)
Cholera	Poliomyelitis (polio)	Amoebiasis
Typhus	Hepatitis A and E (jaundice)	Giardiasis (*Giardia lamblia*)
Paratyphus	Enteroviruses	Cryptosporidiosis
Salmonellosis	Rotaviruses	Toxoplasmosis
Shigellosis	Adenoviruses	
Yersinia	Norwalk viruses	
Campylobacter	Coxsackie viruses	
E. coli (EHEC)	ECHO viruses	
Leptospirosis (Morbus Weil)		
Tularemia		

Pathogens that usually do not lead to serious illnesses (e.g. diarrhoea) can still lead to serious complications for people with health issues. For this reason, there is a zero tolerance approach here. Drinking water must not contain any pathogens.

water pipes, particularly at temperatures of between 20 and 50 °C. The hospital infections caused by these pathogens are also known as nosocomial infections.

Bacteria in food

Bacteria are involved in the production of many foodstuffs (e.g. lactobacilli in yoghurt production). However, bacteria are also responsible for food spoilage, as can be seen when putrefactive organisms come into play. Pathogens such as salmonella or campylobacter in food can lead to food poisoning.
At the laboratory, both the species and quantity of bacteria in a foodstuff can be determined. During routine analyses of drinking water, for example, the amount of aerobic mesophilic germs, *Escherichia coli* and enterococci are recorded. *Escherichia coli* and enterococci are gut bacteria and indicate faecal contamination of the water.
What is commonly known as food spoilage indicates the microbiological growth for utilising organic materials created in the ecological cycle (such as composting, for example). Bacteria and fungi ultimately play an important role here.

Germ-free
How long and at what temperature do meat, eggs and chicken have to be cooked in order to kill off any germs? The answer is 10 minutes at 75 °C. Boiling drinking water once is sufficient to kill off all germs. See the leaflet on water boiling by the Swiss Gas and Water Industry Association (SVGW).

Where do problems occur?
800,000 people die from water-borne diseases each year, predominantly in countries with a very poor water supply.

Practical use

In addition to undesirable, pathogenic germs, the total germ count primarily includes microorganisms that are safe or even desirable, such as lactic acid bacteria in fermented foods such as yoghurt or cheese. In these foods, the hygienic condition can thus be determined with the help of the aerobic mesophilic germs (germs seen in contamination).

Not the germ count is decisive, but instead the number of inspections Essentially, a high total germ count is indicative of the poor microbiological quality of a non-fermented food. However, further specific tests are necessary to provide a precise statement on possible health issues.

However, the opposite conclusion is not possible. A low total germ count doesn't necessarily mean that a foodstuff is perfect – further indicators have to be specified in order to confirm this.

Fermentation

During fermentation, substances are produced that kill off or at least stabilise the microbiological flora (e.g. sour cream).

History

In 1993, around 400,000 people were infected during an outbreak of cryptosporidiosis in Milwaukee (USA) after wastewater entered the drinking water supply. Since then, the regular inspection of drinking water has gained even greater importance around the globe.

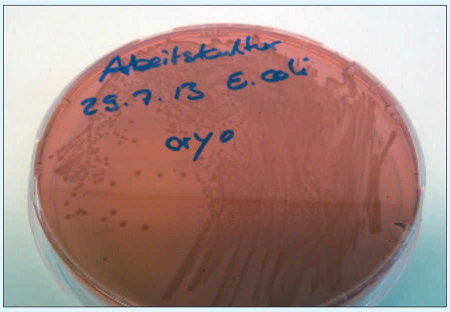
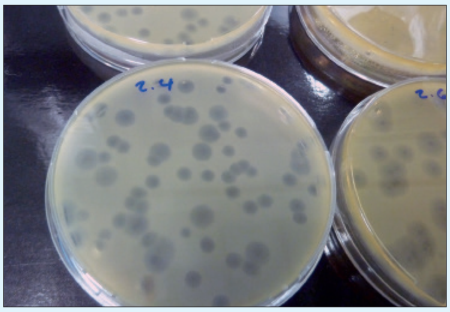


Plate with E. coli.



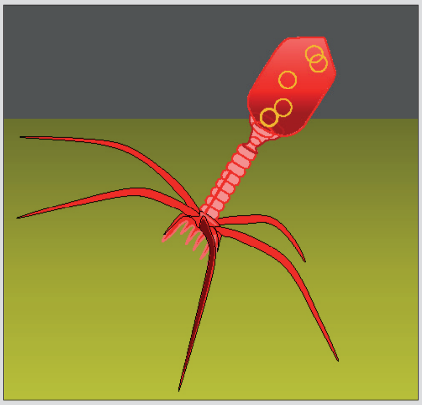
Positive plate with coliphages.
Photos: Archive WVZ

Antibiotic resistance in drinking water

Antibiotic-resistant bacteria can enter the wastewater following the improper use of antibiotics at high doses (e.g. through livestock breeding). However, no known cases of pathogenic, antibiotic-resistant bacteria have been discovered in drinking water in Switzerland to date. In a well-functioning multi-barrier system as seen in lake water plants, all bacteria groups are significantly reduced.

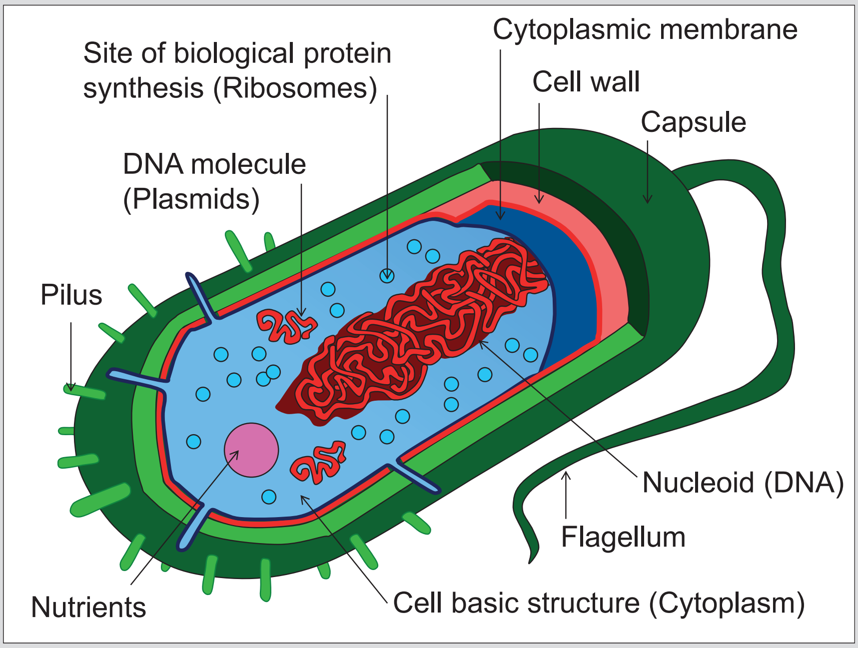
Different germ counts
Not only meat can be contaminated with dangerous germs. In 2015, a test by the “Kassensturz” TV show indicated for the first time that imported vegetables and herbs from Asia may be massively contaminated with antibiotic-resistant germs. One-third of the samples were contaminated.

Programmed to eliminate bacteria
Bacteriophages are the beacon of hope when it comes to fighting multi-resistant pathogens. Researchers are still in dispute as to how and where the treatments can be used.
Phages (see photo) are designed like tiny robots and destroy bacteria using a particularly insidious method. They attach themselves to the bacteria surface, inject DNA and reprogram the genetic material to form a blueprint for new phages. This leads to whole colonies that can destroy the bacteria shell using proteins and then infect further bacteria.



Close-up view of a phage.

Blueprint of a bacterium



Viruses

Drinking water is not free of germs. Even following correct treatment, it still contains harmless substances and bacteria and viruses in concentrations that do not pose a health risk following treatment.

In general, one must assume that surface water may be contaminated with viruses due to the introduced wastewater. However, the safety of the consumers is ensured by the performance of the water treatment plants.

Boiling drinking water is one of the classic hygiene measures for infants up to six months and also for children up to two years old due to their developing immune system and resulting susceptibility to infection. According to paediatricians, this measure is not required in Switzerland.

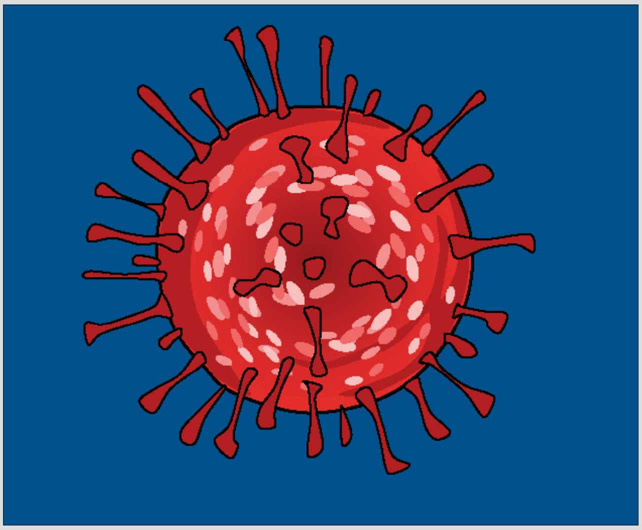
Note: Viral infections are most likely to be transmitted via the air in winter months as the air indoors is dry.

All documented epidemics seen in drinking water (caused by various viruses, bacteria and parasites) can be traced back to massive faecal contamination of the drinking water as a result of technical or human failures.

Noroviruses

Norovirus is resistant, highly infectious and forces its victims into spreading huge quantities of virus particles into the atmosphere. Once it has broken out, it spreads rapidly – particularly in places where many people live together in tight spaces. This is particularly the case in hospitals, care homes, army barracks and on cruise ships. Experts estimate that 200,000 children under five die of norovirus each year, above all in developing countries. In Europe, there is a significantly reduced risk of viral infection due to the standard of medical care.

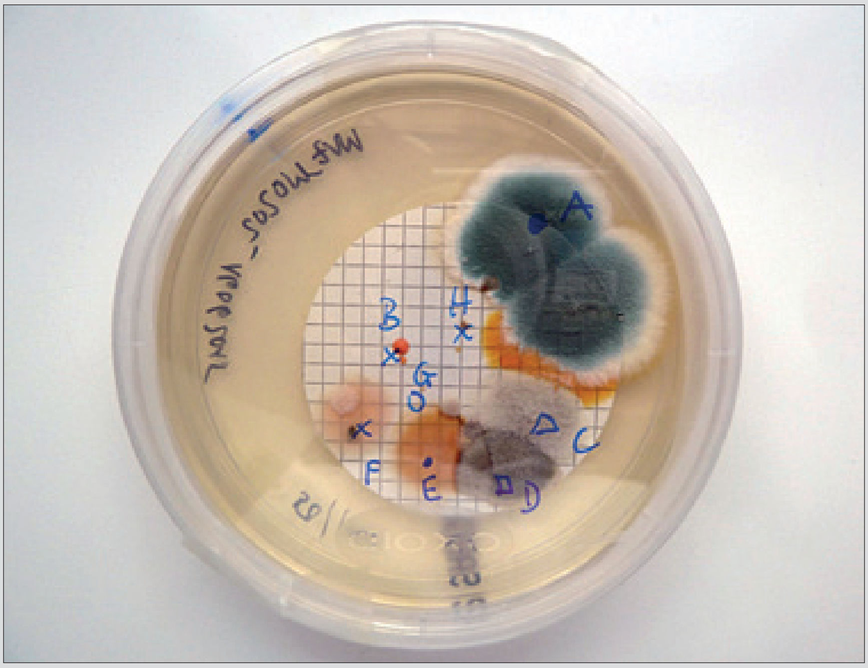
Noroviruses can survive in their surroundings for several days and remain infectious during this time. Contact with contaminated laundry (bedclothes, dirty clothing etc.) from those affected can be enough to pass on the infection. The correct handling of dirty laundry is thus important.



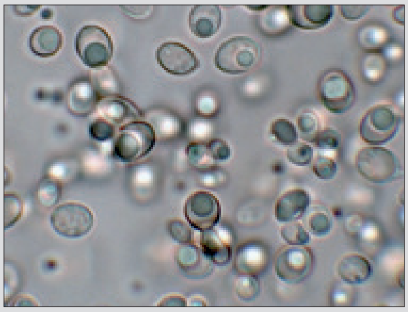
Artist's impression of a norovirus particle.

Fungi in water

"Water fungi" are found in natural waters (streams, rivers, ponds, lakes and oceans). They feed on the organic material in the water and thus support self-purification – including in the absorption of heavy metals. Some species can be hazardous (e.g. to fish and crustaceans) following rapid multiplication.
There are few fungi that can be found temporarily submerged close to water and countless species of single-cell or body-forming fungi in water. Wine and beer yeasts are the most well-known useful fungi among the single-cell strains.
Water fungi survive in water and are – in addition to bacteria – typical parts of complex symbiotic communities, in which it is assumed that they also play a varied role in the metabolism seen in natural waters. This also includes their presence in biofilms. Many of these fungi groups are also present as spores in the air.



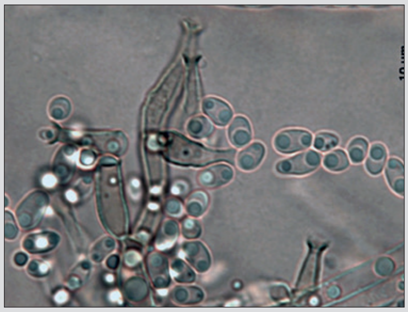
Fungi found in Lake Zurich at a depth of 30 metres: Raw fungi plate on Sabouraud agar (with added gentamycin and chloramphenicol [antibiotic]), A: *Penicillium expansum*, D: *Cladosporium spec.*, E/F: *Aureobasidium pullulans*; the remaining fungi could not be determined.



Exophiala castellanii, yeast type (e.g. at the tap).

Washed-out conidia (one of the asexual spore types) of *Dictyosporium spec*. from groundwater in the Zurich lowlands (fungus grows on wood and leaves, for example).

Conidia of *Clavatospora tentacula* (syn. *Heliscus tentaculus*), a "true" water fungus (Limmat).



Cadophora spec., phialides with collarette, conidia.

LEGAL NOTICE

Published by the Zurich waterworks (WVZ)
E-paper & print run of 10 copies (digital printing)

Text: Zurich waterworks (WVZ)
Photos: Maurice K. Grünig, Romano De Marchi, archive of the Zurich waterworks
Graphics: Hans Gonella

Editor: Hans Gonella
Proofreading: Lektorama, Zurich

Design: Schelbert Muota Design, CH-6436 Muotathal, muotadesign.ch

Publication: E-paper via GeoPrint-Shop, City of Zurich, Geomatics + Surveying department (GeoZ)
Digital printing: GeoPrint-Shop on 100% recycled paper

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Stadt Zürich Wasserversorgung

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