WHITE PAPER

ASHRAE 188-2015 Legionellosis: Risk Management for Building Water Systems

Written By: Leo Rasmussen
Date: March 15, 2016

condair

Table of Contents

List of Figures

List of Tables

Foreword

After 10 years of work, ASHRAE has now released a new standard, ASHRAE 188-2015 Legionellosis: Risk Management for Building Water Systems. The intention with the standard is to prevent the risk for Legionellosis, from water systems in any building, new or existing. This has some consequences for all suppliers within the humidification and evaporative cooling industry, be it for HVAC or Direct room use – mainly for the North American market.

Which Products Will Be Affected?

All adiabatic products for humidifying and cooling will be affected, as well as water treatment systems used with these products. Isothermal products are only affected in a very limited way. A few sentences in the equipment's operational manual will be sufficient to fulfill the requirement in the standard.

What Does ASHRAE 188 Require?

Every building owner has to perform and document a survey, to see if the building contains equipment that could cause a health risk. Cooling towers and evaporative condensers are the main focus, but also the following equipment is mentioned in the standard: fountains, misters, atomizers, air-washers, humidifiers, or other non-potable water systems or devices, that releases water aerosols in the building or on the site. (188, point 5.1,c). These are relevant for our industry.

Based on the survey of the building, the owner has to set up a risk management system to ensure that the water system is safe and under control. This is normally done by setting up a "water safety plan" or a hygiene management system.

Responsibility

It is important to point out from the beginning, that the responsibility for the equipment in the building is still on the building owner, this white paper will provide the owner with the correct information they need to be able to include the humidifiers and cooling equipment into the overall Risk Management System for his building.

This means we have to provide the building owner with a manual containing at least:

- Flow diagrams for the supplied system, with identification of the different components, filters, water treatment, humidifiers etc.
- Intended use of the product.
- Our own risk evaluation for the products – (relevant points for the user only)
- Preconditions for safe operation – water quality, temperature etc.
- Limits for bacterial level in the system.
- Instructions how and when to measure hygiene level of the system.
- Maintenance and service instructions, including instructions for cleaning and disinfection.
- Instructions for safe "startup" and "shut down" of the system.
- How the system is marked and labeled.

The material could be included in the manual, or handed out as a separate paper following the product.

For Isothermal products, only the relevant points should be included, as the risk for Legionellosis is eliminated when the water has been boiled and the product is properly installed.

The consequences for the different adiabatic systems vary from product to product but for all products it is necessary to have a proper risk assessment included in the manual as well as any additional instructions and procedures necessary for startup and shut down of the systems.

For some of the products supplied by Condair/Nortec, this is already in place as they have been risk evaluated and tested in terms of hygiene, this includes the DL Series for HVAC, and the Draabe and ML systems for Direct Room applications (DRS). The DRS systems however require a maintenance contract, and installation and service of these products should be done by certified technicians only, to ensure a proper hygiene level.

For the HP Series and ME Series, different options are available to improve hygiene of the systems. For both systems, it is possible to supply these systems to customers in a hygiene safe configuration, so that he can fulfill the requirement in ASHRAE 188. Also for this it will be beneficial to offer a service and maintenance contract to the customers, to make it easier for him to include the systems in his risk assessment of his building.

Background Material

Water safety plans: (WSP) and Hygiene Management Systems

In the food industry, it has been common for the last 40 years to implement hygiene management systems in the manufacturing of food for consumers to ensure that whatever reaches supermarkets and retail sales is safe to consume. A Hygiene Management System is built up in the same way as any other quality management system, with risk assessment, policies, aims, procedures, instructions, control measures, validation and documentation etc.

Today, the international standard ISO 22.000 is recognized in 40 different countries around the world, specifying how to build up a hygiene management system that can be certified by international certification organs, like SGS, Bureau Veritas etc.

ISO 22.000 is build up after the HACCP principles. (Hazard, Analysis and Critical Control Points)

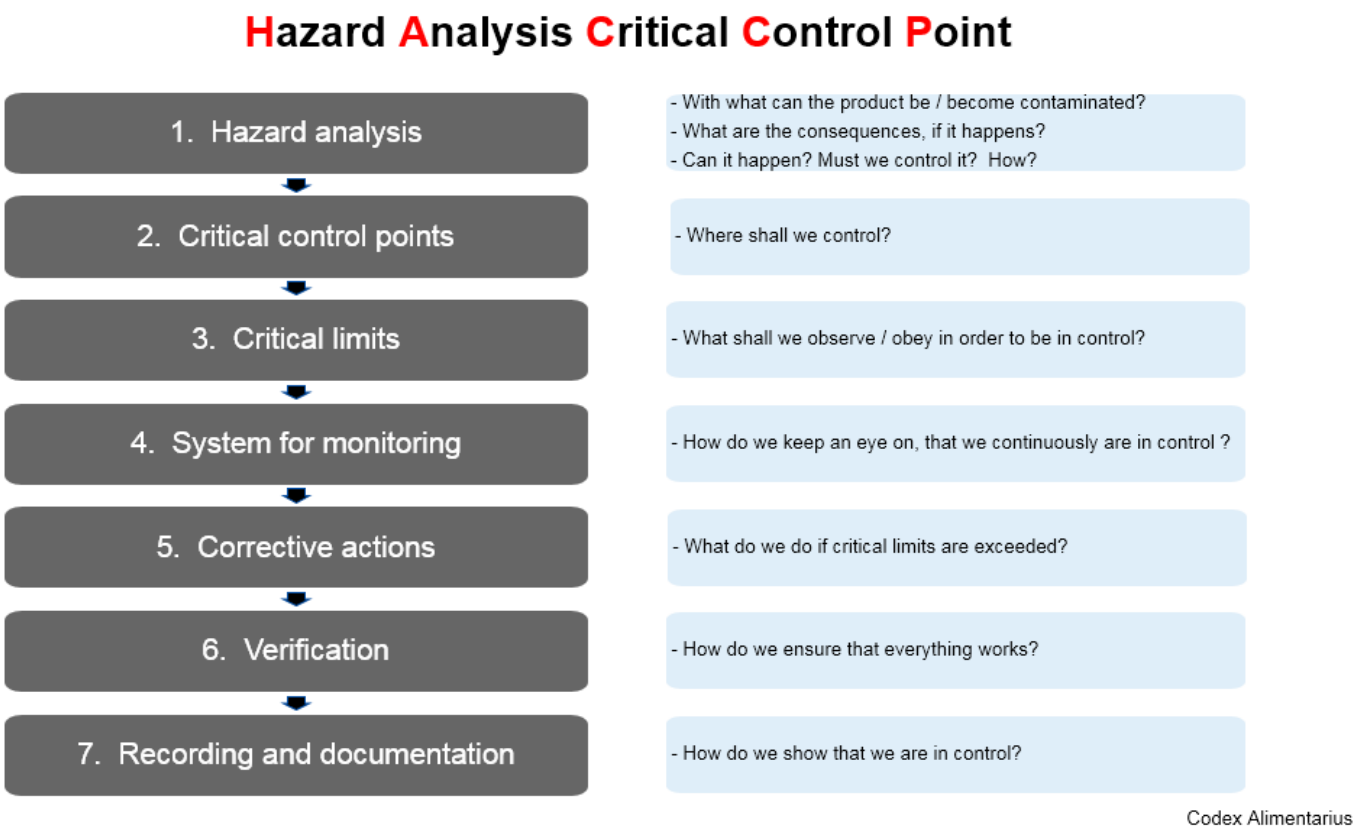


Figure 1 - Standard HACCP Principles

Hygiene Management in Drinking Water Systems

As drinking water is included in our food requirements, the same approach today been adopted by water suppliers to ensure safe drinking water to consumers.

The implementation of a Water Safety Plans has been promoted by WHO since 2004, with the publishing of the 3rd edition of the Guidelines for Drinking Water Quality (2004), and were later adopted by EPA in the US.

In Adiabatic cooling systems, especially cooling towers, the risk for Legionella has been one of the main triggers to promote the implementation of Water Safety Plans as well.

ASHRAE have been working with the issue for 10 years and earlier this year the new standard ASHRAE 188-2015 *Legionellosis: Risk Management for Building Water Systems was released*.

The main goal with this standard is to prevent the growth of Legionella, but the result is that it is necessary to keep a high level of hygiene in the entire water system to fulfill this.

As a new industrial standard, this will get legal status, and it is now the responsibility of the building owner to set up a Water Safety Plan, to ensure that the risk of spreading Legionella is minimized.

In other countries like the UK, France, the Netherlands, Italy, Spain and Australia, laws have been implemented over the last 10 years, giving the responsibility for safe water installations to the building owner.

Guidelines and templates for Water Safety Plans are available online, as well as WHO guidelines and ASHRAE 188-2015 which also describe the content of this. What is common between all these documents is that a responsible plan must be set up on each of the different sites.

A Water Safety Plan according to ASHRAE 188 should consist of the steps found in Figure 2.

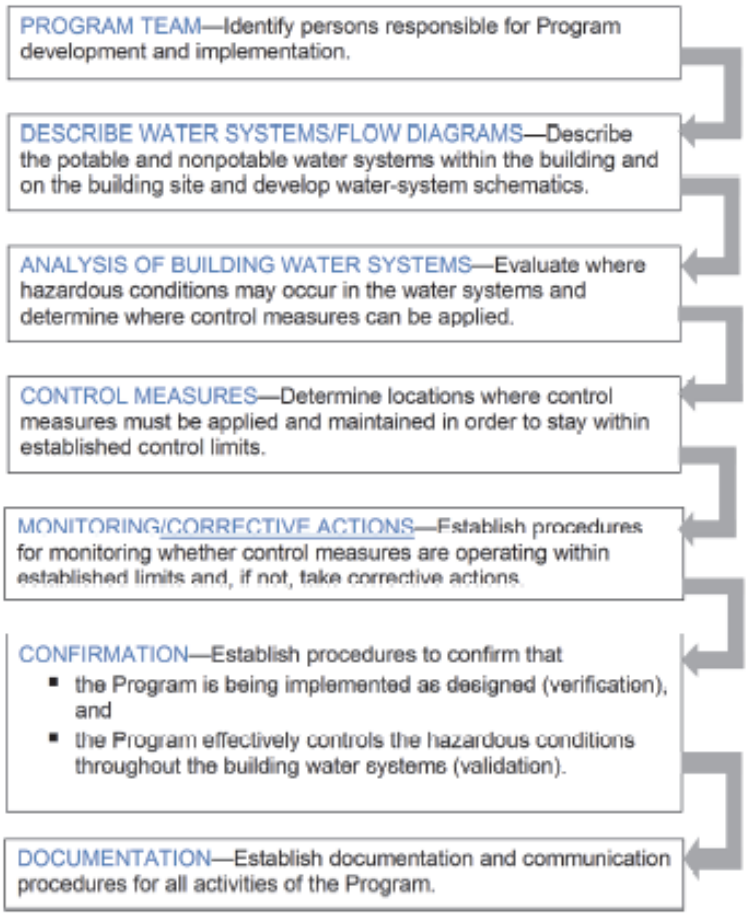


Figure 2 - Water Safety Plan from ASHRAE188-2015 – without permission

When a Water Safety Plan, or a hygiene management system has been implemented for a site, the goal is that there is no or limited growth of bacteria through the entire system. When water is clean and safe when it enters the building, the entire water system should be built and controlled in a way that the growth of bacteria is under control, and cannot reach a level where it can cause health risks for employees, or functional problems for the equipment in the building.

Risk Assessment of Water for Humidifiers and Evaporative Coolers

The risk assessment of water and water treatment systems for the above equipment is similar to other process water installations, and the main risks are as follows:

Microbiological risks - from growth of microorganisms

Chemical risks – from disinfection liquids.

Mechanical risks - general plant safety -

Migratory substances - from material in the installation.

In the following, only the microbiological and chemical risk will be covered, as it is assumed that the installed products are developed with inert materials, and designed in a way so that it does not affect the hygiene quality of the products.

Microbiological Risk

Pathogenic bacteria (Disease causing bacteria)

- Legionella pneumophilla
- Aeromonas hydrophila
- Pseudomonas aeruginosa
- Listeria monocytogenes
- Amoebas, Protozoa

Even though pathogenic bacteria is not supposed to be in drinking water, entering into the buildings, they can still be found in low numbers, so the growth of these must be prevented or at least limited to ensure a safe and healthy system.

To minimize the growth of bacteria, it is necessary to maintain a high level of hygiene in the entire system.

Water Safety Plans and Hygiene

The definition of hygiene is: Preservation of health and prevent spreading of diseases.

The purpose of a Water Safety Plan (WSP) is to ensure system hygiene. To get a better understanding of this, some background material is included at the end of this paper.

In adiabatic cooling and technical water systems, hygiene is important as it effects both the people exposed to the water, and the equipment used in the system.

Hygiene Risk in Adiabatic Systems in HVAC and DRS

In High Pressure Misting systems, (HPM) the main health risks occur when water is atomized and sprayed out through nozzles as microscopic aerosols typical in a size range from 10-20 µm size. If the water aerosols contain too much bacteria, and they get into the lungs of people, they can cause diseases.

Humans can drink water with a relatively high content of bacteria without issue, as our stomach acid will destroy most of the bacteria. However, when inhaled into the lungs, we do not have the same immunity and are much more sensitive to harmful bacteria.

Especially in HPM systems, it is important to maintain a high level of hygiene in the systems to minimize the risks for people exposed to the aerosols. In HVAC HPM systems are often installed in ducts and typically a mist eliminator is installed, after the spray section to capture non-evaporated aerosols. This limits the problem, but still a number of small aerosols can be found in the air after the humidifier, so it is important to keep the water clean.

The mist eliminators are also exposed to contamination from the incoming air, algae, insects, virus, dust etc. As a result, the final air quality in the duct depends not only on the water quality but also the air quality ventilated through the system.

If excess water from mist eliminators are recycled back to water tanks, the challenge to maintain hygiene level increased, compared to a setup where it is led directly to drain!

For Direct Room Systems it is obvious that the water has to be clean and safe, as the aerosols are sprayed out directly where people are present.

Evaporative Cooling Systems

When these systems are designed in a correct way, the risk of having aerosols in the air is significantly lower compared to high pressure misting systems. Water evaporates into the air, as the air passes through the media and are in vapor form. Only when air-velocity is too high there is a risk for aerosols that can contain bacteria. Some aerosols are created because of water splashes in the tanks under the pads, and where water is distributed over the media. However, it is a well-known problem in our business that velocity can vary over the media; and that carry over with aerosols is possible after the media.

Hygiene is still important to avoid fouling on the surfaces of the media which may result in the increased pressure drop and reduced efficiency of a system. If biofilm builds up in tanks and pipes, this can cause risk for people during service and maintenance of the system.

If the wash over water from the evaporative pads is contaminated, and this water is recycled back to tanks, the entire systems gets contaminated if necessary measures are not taken.

Endotoxins in the Air

When bacteria is treated and die, they release endotoxins from their cells. Endotoxins in the air are harmful for people as they can cause serious diseases.

When an evaporative system is turned off, the media dries out. As a result, some or most of the living organisms on the surface will die and release endotoxins to the air. During disinfection of the system, endotoxins are also released into the water.

Statement: The cleaner the water is, the lower the content of endotoxins in the air will be!

This is of course the same with mist eliminators from HPM systems.

Again - if excess water is recycled back to tanks, the entire system will be contaminated

To understand how to maintain a high level of hygiene, it is necessary to understand some of the basics in microbiology about bacteria, biofilm, UV disinfection etc.

Bacteria – What Are They?

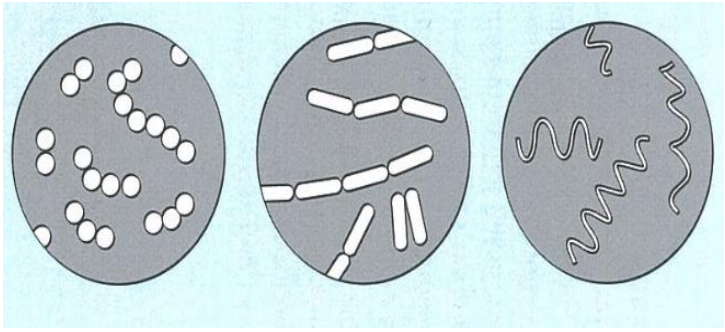


Figure 3- Structure of Bacteria

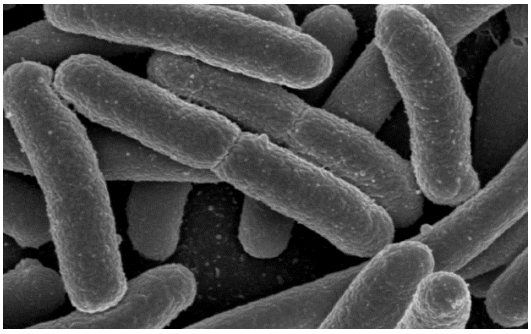


Figure 4 - Principle Structure of Bacteria

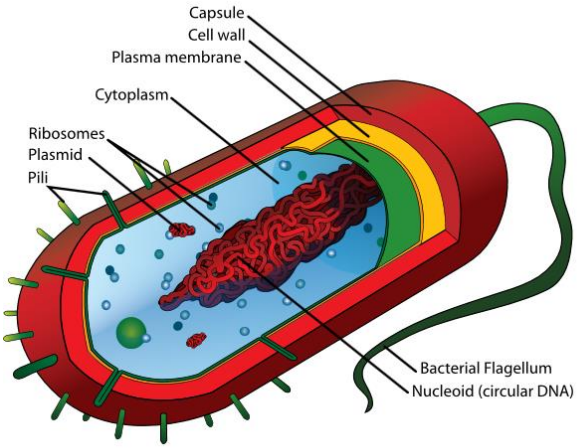


Figure 5 - Principal Structure of Bacteria

Bacteria are small single-celled microorganisms that are found everywhere in our surroundings, in the air, water, soil, our food, and the human organism. Bacteria are so small that they cannot be seen with the naked eye. They are between 0.2 and 50 microns (millionths of a meter). Once bacteria gain access to food, they can proliferate, and when they are numerous enough, certain types of bacteria pose a risk of disease.

We have to accept that bacteria enters into the system one way or the other, and we need to be able to handle them and ensure that we have it under control.

There are millions of different bacteria found in our surroundings. Each species of bacteria has their own DNA structure, like humans, so they can be traced if there is an outbreak somewhere. Bacteria can have different shapes and sizes as seen in Figure 4. Figures 3 and 5 show a microscopic image of bacteria and their principle structure respectively.

Before going deeper it is important to understand the sizes we are talking about:

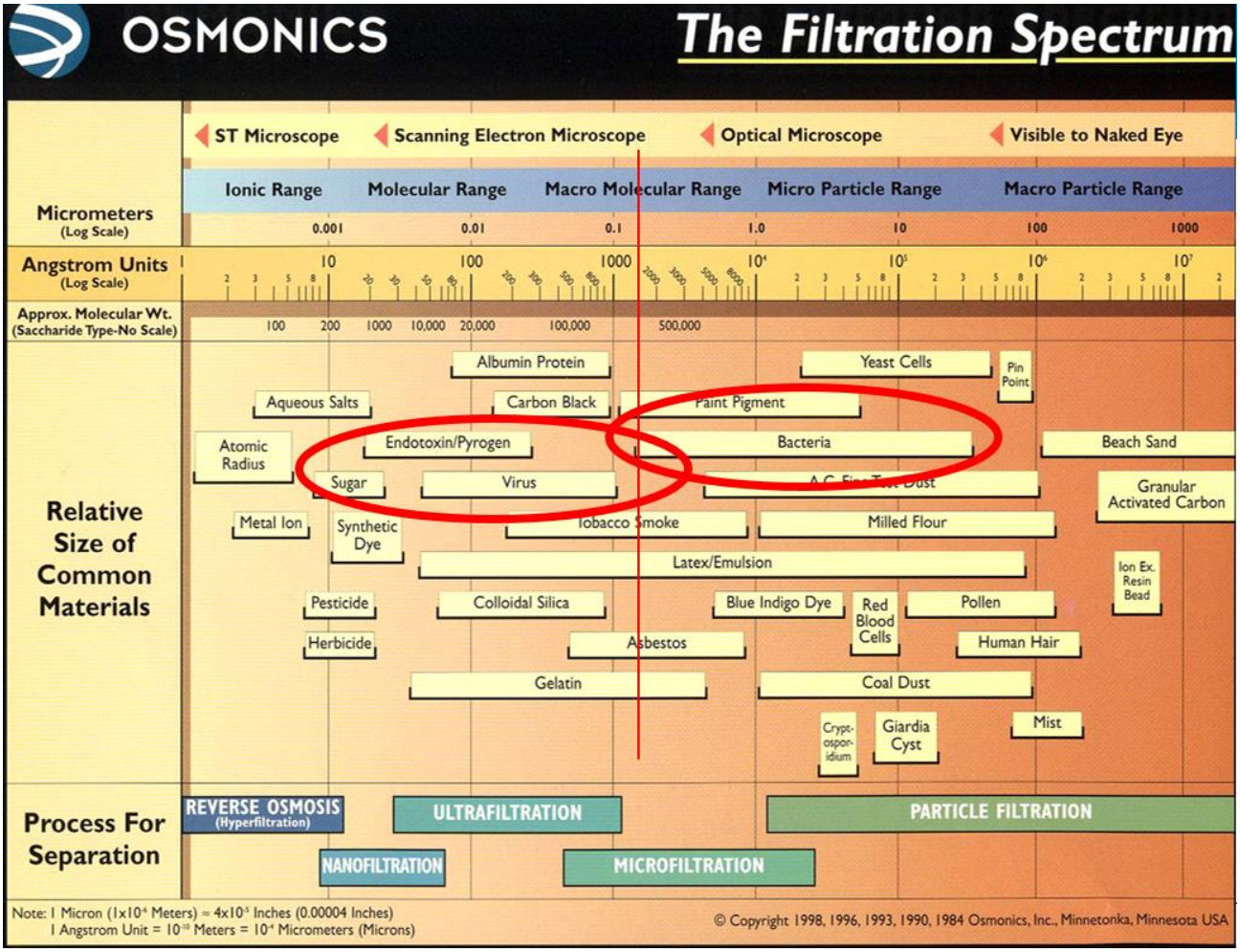


Figure 6 - Filtration spectrum - all bacteria are bigger than 0,2µ

All bacteria need nutrients to be able to multiply. Nutrients can come from Carbon, CO_2, nitrogen, salts and minerals in water including sulphur and phosphor, calcium magnesium, etc.

With sufficient nutrients and good conditions, some bacteria may begin to multiply within 20-30 minutes.

Growth of Bacteria - example with 30 minutes reproduction time:

Growth of bacteria

One bacteria can multiply to many millions bacteria if the conditions are good: food and temperature.

Time	
12:00	1
12:30	2
13:00	4
13:30	8
14:00	16
14:30	32
15:00	64
15:30	128
16:00	256
16:30	512
17:00	1.024
17:30	2.048
18:00	4.096
18:30	8.192
19:00	16.384
19:30	32.768
20:00	65.536
20:30	131.072
21:00	262.144
21:30	524.288
22:00	1.048.576
22:30	2.097.152
23:00	4.194.304
23:30	8.388.608
00:00	16.777.216

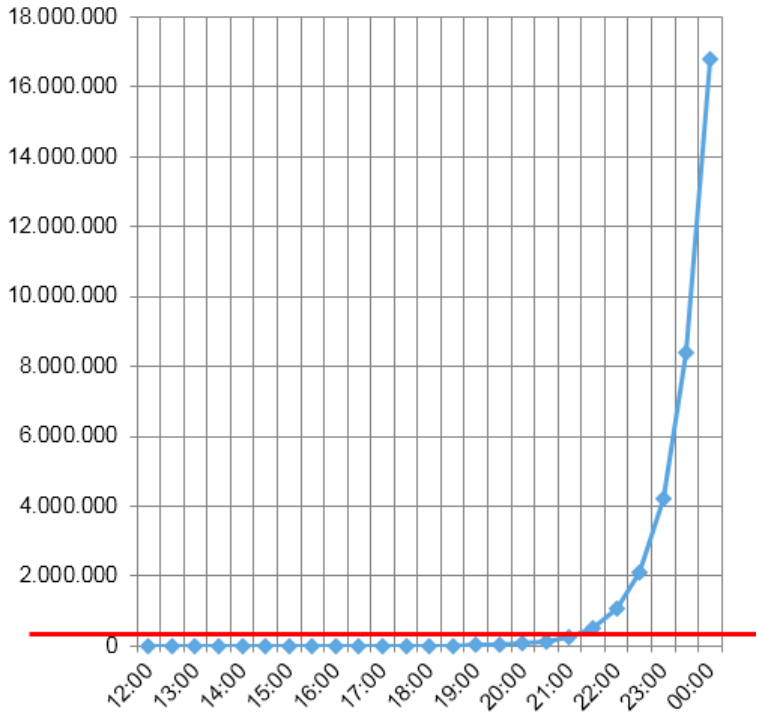


Figure 7 - Exponential Growth of Bacteria

The purpose of a hygiene management plan is to ensure that we stay under a certain limit, where the growth is under control, and the numbers do not cause any health risks.

If all water in the system could be used and replaced within 4 hours, we would have very limited problems with bacteria, but this is unfortunately not always the case. Storage tanks are used, and the consumption varies over the year.

It is recommended to limit the sizes of holding tanks to a minimum, and make it possible to reduce the levels in periods of the year with low consumption. In general, the water should be as fresh as possible.

Behavor of Bacteria

Bacteria does not like floating around freely in water. They want to stick to particles or to be together with other bacteria. They prefer to be where they can find nutrients and where they are not disturbed i.e. in stagnant water, filters, tanks, biofilm etc.

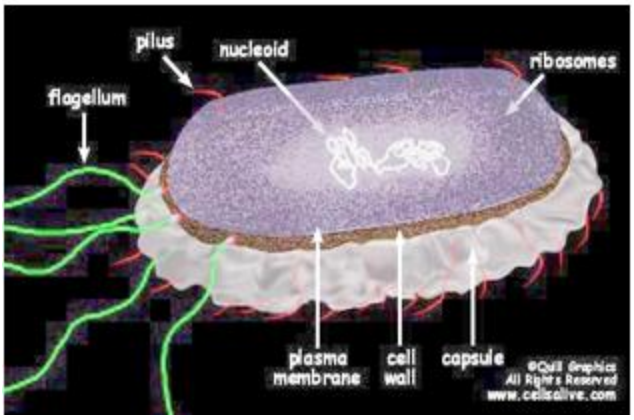


Figure 8 - Bacteria

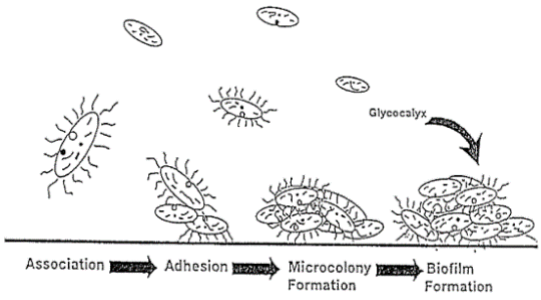
Most bacteria have flagels (seen in Figure 8), which allow them to move around and to stick to surfaces. On surfaces, they will stick together and start forming a Biofilm.

Biofilm in Water Systems

A biofilm is a microuniverse, where the different bacteria live from each other and from the food available from water, the surface etc. They build a protective layer around themselves, forming a slimy layer.

This can be observed on the inside of a water tank that has been sitting stagnant for a week or so. In an open tank with acces, it can be removed with hotwater and soap with little effort.

The challenge with a biofilm is that it is difficult to remove once formed inside a pipe or other areas with limited acces. When we disinfect a system with biofilm, we only kill the top layer of the biofilm and it is normal that the bacterial levels are higher right after a disinfection routine.



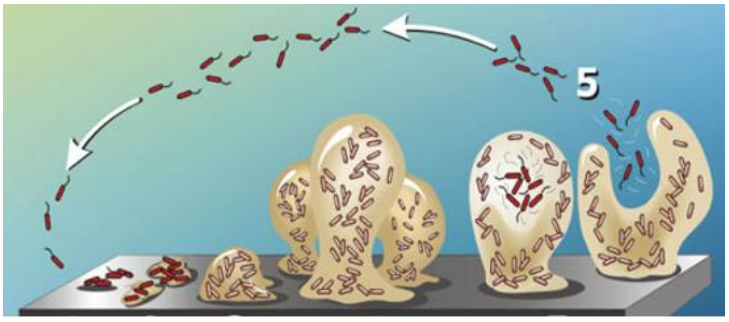


Figure 9 - Biofilm – A Micro-universe of different bacteria

A biofilm cleaning routine normally requires disinfection with short intervals, 1-2 days, and continue until the system is clean. A system that is clean means low or no bacteria in the water.

How Can Biofilm Be Avoided?

The forming of biofilm is related to flow velocity of water in pipes. It cannot be completely avoided but at least it can be minized by keeping high velocity of the water.

Minimum velocity should always be above 1 ft/sec (0,3 m/sec). In general the higher the better, but of course high velocity also causes pressure drop in pipes. For low pressure systems up to 10 bar/150 PSI, a max speed of 3 m/s (9,8 ft/sec) can be used as rule of thumb.

Taking this into account the following minimum flows should be obtained:

Table 1 - Recommended Minimum Flow in Pipes

Pipe	Minimum flow	
Size:	L/hr	gpm
½" DN 12	135	0,6
3/4" DN 20	340	1,5
1" DN 25	550	2,4
1 1/4" DN 32	880	3,9
2" DN 50	2200	9,7

It is well know that this is not always possible to keep a high velocity, so an alternative to this is to flush the pipes 4-6 times per day with high velocity to minimize the formation of biofilm.

Nutrients and Food Sources for Bacteria

If we analyse the mass of bacteria we will find out that they are quite similar to the human body, as 70% of the bodymass is water. See the figure below for the complete breakdown of components making up bacteria.

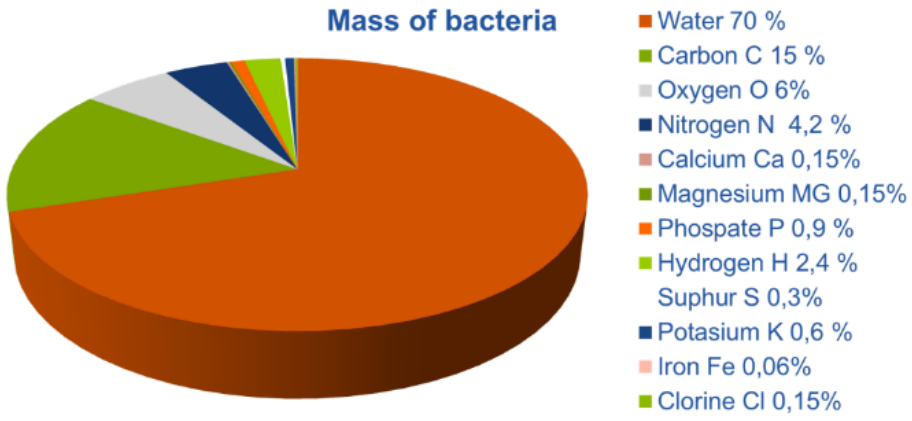


Figure 10 - Mass of Bacteria

This is important to know, as systems should be constructed with materials that do not support the growth of bacteria and which do not give them easy acces to organic material and traces of the elements they need.

One example: Legionella needs a high content of iron in the water to be able to multiply. If we remove 98% of the iron from the water in a RO system for a HPM system, we also reduce the risk for growth of Legionella.

From a hygiene point of view, the nutrient content of water should be as low as possible. The lower the TDS or conductivity, the lower the content of nutrients for bacteria will be, which will slow down the growth of bacteria.

Bacteria in Drinking Water

The municipality is responsible for the supply of clean and safe drinking water to the consumers.

Depending on country or state there might be different rules for maximum bacterial contamination in water, but in general the following limits are valid:

Total colony forming unit: < 200 CFU/ml

Total Coliform. < 1/100 ml

Pathogene bacteria are not allowed in drinking water, but they are often found in low numbers.

In general the water should be considered safe for humans and with low content of bacteria, when it enters into a building. This should be our precondition for all adiabatic products and the basis for all risk evaluations made for these.

Pathogen Bacteria in Water Systems

Among the disease causing bacteria, especially *Aeromonas hydrophila*, *Pseudomonas aeruginosa*, *Listeria monocytogenes og, Legionella pneumophila* are relevant. Because they are found in our water systems, and are very good to form biofilm. They can be found in our surroundings in a low concentration. Health risk will not occur until growth to a higher level has taken place.

Legionella Pneumophila

The most known bacteria in connection with aerosols and adiabatic cooling is *Legionella pneumophila*. This bacteria can cause Legionellosis, or better known as Legionnaires' disease, that can be fatal.

A Few Facts

Incubation time is 2- 10 days and “only” 5% of the people exposed to the risk will contract the disease. From these, 30% of cases will be fatal. In total, 1.5% of cases of people exposed to the risks from Legionella will end in fatality!

Legionella has a size of approximately 0.3-0.9 x 2-20 µm and is a thin rod shaped gram negative bacteria.

Optimum temperature for the growth of Legionella is 98-114°F (35-43°C). Below 70°F (20°C), there is no growth, and above 136°F (55 °C) it starts to die out.

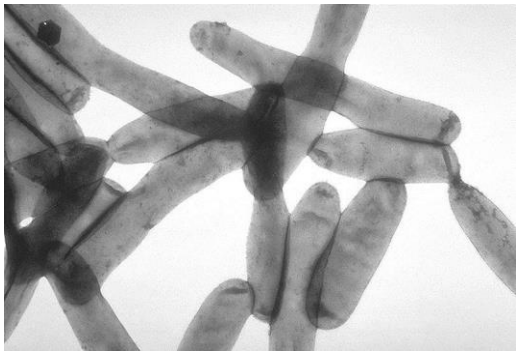


Figure 11 - Legionella Bacteria

Legionella is often found in hot water plants, cooling towers, air-condition plants, sprinkler systems etc.

Growth and survival of Legionella is advanced through the occurrence of other microorganisms and sediment.

Legionella is aerobe, (needs Oxygen) requires L-cystein (a common amino acid) and a relative high iron content in water to be able to multiply.

There is no description of occurrence of Legionella in Ultra Clean Water!

You will never find Legionella alone!

Necessary UV dosage for decontaminating of water for Legionella: 90 J/m² = 9mWs/cm² = 9000 µWs/cm²

Even though Legionella is not allowed in drinking water, it is necessary to take precautions against it because of the high risks associated with it. There is always a small risk that Legionella can be introduced to the system, either from the city water, or from reservoir tanks, maintenance of the system etc.

The risk for Legionella in technical water is the reason for creating the new ASHRAE 188-2015 standard.

One helpful quality concerning Legionella is that it is never found alone. If Legionella is present there is also a high amount of other bacteria in the system. Testing and controlling the hygiene level of the system can be done by testing for the total amount of bacteria and not only testing for Legionella. Be aware that in some countries, like the UK, it is mandatory to measure specifically for Legionella.

When we take precautions for Legionella, we also take precautions for other pathogen bacteria in the system. We do not have to deal with them one by one.

Setting Limits for Bacteria in Water for Adiabatic Cooling

The acceptable limit for bacteria in water used for adiabatic cooling depends on the location and where it is used. The general European standard for water in HVAC applications in industry is a max level of cultural microorganisms of 1000 CFU/ml @ 72°F (22 °C) measured according to ISO 6222 standard.

This limit was originally set by the German VDI 6022 engineering standard for HVAC.

For Legionella, the general industrial standard is <100/100ml as a max value. (Except UK where limit is set to <1/20 ml - Legal status L8 by HSE)

However, if the adiabatic cooling system is installed in a public area where everyone has access, it is strongly recommended to set a limit for bacteria corresponding to the local drinking water limit, e.g. 200 CFU/ml, instead of the industrial standard.

Recently, the VDI 6022 have come up with new values for HPM for direct room applications where the limit is set as low as 150 CFU/ml.

Opinion

If a Hygiene Management System or a WSP is implemented, where necessary actions are taken and the system is kept under control, it is acceptable to work with a limit of 1000 CFU/ml in industrial applications.

Prevention of Bacterial Growth

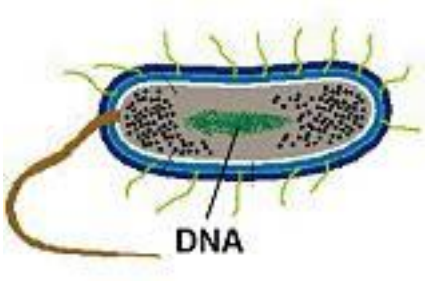


Figure 12 - Prevention of Bacteria Growth

Prevention of Growth with UV Systems

Ultraviolet light with a specific wavelength (≈ 253nm) destroys the DNA structure of bacteria so that they cannot multiply. However, as a note, the 'destroyed' bacteria are still alive and can act as nutrients for other bacteria in the system.

Different kinds of bacteria require different radiation level to destroy the DNA. There is data available to indicate the required dose necessary for specific bacteria destruction. Please see Table 2 below as an example.

Industrial standard for UV dose for technical waters is normally 30mJ/cm2. (30mWs/cm2).

Table 2 - UV dose to destroy DNA in different bacteria

BACTERIA	UV dose
Agrobacterium tumefaciens	8,500
Clostridium tetani	22,000
Dysentery bacilli (diarrhea)	4,200
Escherichia coli (diarrhea)	6,600
Legionella bozemanii	3,500
Legionella dumoffii	5,500
Legionella gormanii	4,900
Legionella micdadei	3,100
Legionella longbeachae	2,900
Legionella pneumophila (legionnaires disease)	3,800
Leptospira interrogans (infectious jaundice)	6,000
Mycobacterium tuberculosis	10,000
Pseudomonas aeruginosa (laboratory)	3,900
Pseudomonas aeruginosa (environmental)	10,500
Rhodospirillum rubrum	6,200
Salmonella (food poisoning)	10,000
Vibro comma (cholera)	6,500

This table indicates that only a 3.8oo mJ/cm² UV dose is needed to destroy DNA in Legionella pneumophila. However, other publications have shown that around 9900 mJ/cm² is needed to get 99,98 % safety.

Mold spores, algae and especially protozoa needs a very high dose of UV to be destroyed.

Table 3 - UV dose to destroy mold spores and algae.

MOLD SPORES	
Aspergillus flavus (yellowish green)	99,000
ALGAE	
Chlorella vulgaris	22,000
PROTOZOA	
Nematode eggs	92,000
Paramecium	200,000
VIRUSES	
Bacteriophage (E. Coli)	6,600
Hepatitis	8,000
Influenza	6,600
Poliovirus (poliomyelitis)	7,000
YEAST	
Baker's yeast	8,800

Precautions with UV

UV works best in clean water without any particles or impurities, as this can cause scattering of the light, and some bacteria might not be exposed to the radiation.

The UV dose varies with flow velocity through the system, and therefore flow must be ensured to stay within the specified range. If flow is too high, the required dose may not achieved, and if it is too low the water temperature may increase.

If the flow is not constant and if the water has a conductivity higher than 2-300 µS/cm, it is recommended to install UV systems in a recirculation loop where they can be operated with constant flow.

Scaling on Quarts Sleeve

Depending on the water chemistry, the risk for scaling and precipitation on the UV quarts sleeve increases with higher temperature. This is one of the critical points with UV. UV systems must be maintained and kept clean in order to work as expected.

To avoid scaling on the UV quarts sleeve, it is recommended to calculate the LSI index of the water under worst case condition – meaning lowest possible flow through the UV system. LSI index should be kept below 0,5.

Submerged UV lamps in stagnant water require intensive care and short cleaning intervals which should be adjusted based on the LSI index of the Water.

The lifetime of standard UV lamps is 1 year, so they should be replaced annually.

When used for decontamination of a storage tank, only measurements can determine how frequent the water needs to be treated. Contamination level is dependent on the microbiological activity in the tank.

Ultrafiltration after UV- Reduction of TOC

The effect of installing UV systems can be improved by installing ultrafiltration - or at least microfiltration < 0,2 µ - downstream of these. Additional downstream filtration would prevent the addition of organic material to the rest of the water system.

Temperature Influence on Growth

All microbiological processes increase with increasing temperature. A temperature increase of 18°F (10°C) doubles the speed of a process.

The area where reservoir tanks and water treatment systems are placed should be well insulated and kept as cool as possible to reduce the growth of bacteria. The higher the temperature, the quicker the bacteria may multiply!

If water temperature in reservoir tanks increases due to recirculation with UV, or for other reasons, it may be necessary to blow down water and refill with cold fresh water to bring down tank temperatures.

As water temperature is an important factor in water chemistry, temperature is normally measured at different locations. When the existing system is known, critical limits can be set up and controlled.

In a system with evaporative cooling pads, the wash over water increases in temperature, which also results in increasing microbiological activity in the water.

Stagnant Water

To minimize the growth of bacteria and the formation of biofilm, it is important to avoid stagnant water in systems. Optimized hygiene is achieved by avoiding water that is stagnant for more than 4-6 hours.

If a water system has been stagnant for more than 48 hours, it is always recommended to disinfect the entire system before continuing or restarting system use. If this is not possible, at minimum, a flushing of the system is recommended.

Piping

The piping from holding tanks and water treatment systems to adiabatic cooling systems should be flushed periodically to ensure that the water is replaced with fresh water every 6 hours. This can be done in different ways using flush valves at the end of the lines.

Holding Tanks

Recirculation loops with UV, and if necessary also ultrafiltration, can be used where the water is decontaminated frequently. How often this is necessary depends on the microbiological quality of the incoming water, temperature, and how big a portion of the water is used every day. For existing installations, the operation of decontamination systems should be based on bacteria measurements. If growth is known to take place in the tank, the frequency should be increased.

For all elements used in the entire water treatment system, it is important to set up a control to ensure that they are operated minimum once a day in order to keep them fresh and flushed. This includes carbon filters, water softeners and other filters.

Other Hygiene Barriers

In holding tanks, it is important to ensure that they are dark in colour, protected from light, and protected against any contamination from the surrounding air. They should always be vented through sterile filters, never bigger than 0,2 µ. Venting filters should be replaced every 6 months.

Reverse Osmosis System

In HPM systems, a RO system is required to remove total dissolved solids from the water. As seen in the Filtration Spectrum (Figure 6), they also filtrate away microorganisms from the water. Generally RO systems are also an effective hygiene barrier. They will remove around 98% of all microorganisms entering into the water treatment system and, as the TDS is removed, the trace elements and most of the nutrients desired by bacteria are also removed.

As an example, Legionella pneumophila needs a high content of iron in the water to be able to multiply.

When 98% of the iron content is removed in RO, the growth of Legionella will be minimized accordingly.

However, RO systems also have to be kept fresh. These systems should be operated at minimum once every day to ensure a proper hygiene in the system itself and to ensure no biofilm build up in the system.

Particle Filtration Down to 1µ

As mentioned above, all bacteria ranges in size between 0,2 µ no larger than ≈ 50 µ. All filters in this range will act as partial bacterial barriers. This is to some extent an advantage, however only if they are replaced after the recommended intervals of use. A filter surface is a perfect place for bacteria to sit as the flow velocity is low and the filter collects particles and dirt that can act as a food source for bacteria.

Bacterial "grow through" of filters is a well-known microbiological problem which must be addressed. Regular replacement of filters is required because even if they are not filled with dirt and particles, they might still be contaminated with bacteria.

Prevention of Growth by Drying

Evaporative Systems

As seen in Figure 10, around 70 % of the body mass of bacteria is water. Therefore, if water born bacteria is removed from their normal environment, where they have full excess to water, they become stressed. If the bacteria dry out from lack of moisture in the environment, they will die, or at least not be able to continue growth.

Emptying of sumps under evaporative media, and drying out the media once a day, will reduce fouling (biofilm and dust) on the media.

Sections of the adiabatic system, that are not needed for cooling or humidifying, should be kept dry if possible. It is well known that the cooling demands varies over the year, so if there is periods with limited need, a control strategy should be implemented, allowing a part to operate in an optimized way, with excess water, and the rest of the system should be kept dry.

This, however, requires that the piping to the evaporative media be constructed in a way so that pipes can be flushed without wetting the media. This is often not the case with existing systems, but should be implemented in future installations.

Drying Out HPM Systems

High Pressure Systems cannot normally be drained completely, therefore instead of trying to do so, it is recommended to keep these fresh by flushing at regular intervals and ensuring a complete replacement of water every 6 hours as a minimum. In periods where the systems are not in use for a longer period, they can be preserved using the same procedure as used for disinfection.

Water treatment systems, including carbon filters, softeners and RO cannot be dried. These systems must then also be kept fresh with flushing and regularly operations.

Contamination From Air

Adiabatic systems, and especially evaporative systems, can be exposed to contamination from air flowing through the evaporative pads. It is obvious that filtration of air is important to keep the water clean.

If insects and particles pass through the air filters and make contact with water, this will enhance bacteria growth on the media.

The filtration class or rating of air filters is always a compromise between pressure drop and air quality. In most industrial systems a filtration class of MERV 13 (US) F7 (EU) should be the recommended standard.

This filtration class includes filtration down to 1 µ particles (85% efficiency) However, viruses and around 60 % of all airborne bacteria can still pass through this class of filter. When the air gets into contact with the wetted surface of the evaporative pads, bacteria can get into the water, where they can contaminate the system downstream.

If insects and other organic material, living or dead, are observed in the sumps under the media, the air filter section should be examined for leaks, or defects, and necessary actions should be taken to correct this.

Disinfection

The definition of disinfection is: An action that brings microbiological activity under control.

The intention of disinfection is to bring the microbiological activity down to a controllable level. The resulting contamination after disinfection should be below the limits as set in the hygiene management plan.

When is Disinfection Needed?

Disinfection is needed when the normal strategies for a self-maintained hygiene system are not sufficient.

Disinfection should never be necessary for normal, safe operation of an adiabatic system. It can be used as preventive measure or as a part of regular maintenance of the system every half year.

If a chemical disinfection is necessary for normal safe operation, the system should be analyzed for possible design flaws and corrective action should be taken.

A continuous dosing of disinfectants to a system should only be used temporarily, until failures have been corrected and bacterial growth is under control.

In a WSP plan, water can replace chemicals, but chemicals cannot replace water!

Disinfection Strategies - How and Where to Kill Bacteria?

Disinfectants can be divided into different groups:

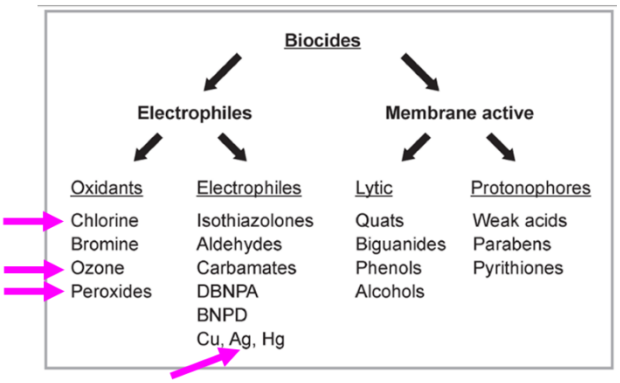


Figure 1: Mechanism of action of industrial biocides.

DBNPA *2,2-dibromo-2-cyanoacetamide*
BNPD *2-bromo-2-nitropropane-1,3-diol*

Figure 13 - Different Groups of Disinfectants

They act on the bacteria cell in different ways:

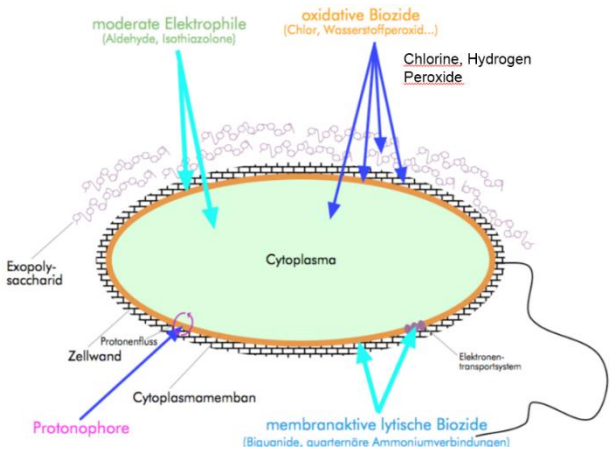


Figure 14 - Effects of Disinfectants on Bacteria

Oxidizing disinfectants kills the bacteria, and they are reduced to mainly CO_2, heat and water. The most common oxidizing disinfectants are chlorine, hydrogen peroxide and ozone. They are all cell membrane active – meaning that they destroy the cell of the bacteria.

Chlorine

In the US the most common disinfectant in drinking water and technical water is probably Chlorine. It is well known and available locally. Handling is also well known and described.

However, in adiabatic systems, especially in evaporative systems there are some limitations for the use of this. Please see figure below:

Chlorine gas rapidly hydrolyzes to hypochlorous acid **:**

$$Cl_2 + H_2O \rightarrow \mathbf{HOCl} + H^+ + Cl^-$$

Aqueous solutions of sodium or calcium hypochlorite hydrolyze :

$$Ca(OCl)_2 + 2H_2O \rightarrow Ca^{2+} + 2\mathbf{HOCl} + 2OH^-$$

$$NaOCl + H_2O \rightarrow Na^+ + \mathbf{HOCl} + OH^-$$

The two chemical species formed by chlorine in water, hypochlorous acid (HOCl) and hypochlorite ion (OCl –) are commonly referred to as **"free" or "available"**

Hypochlorous acid is a weak acid and will disassociate:

$$\mathbf{HOCl} \Leftrightarrow H^+ + OCl -$$

In waters with pH between 6.5-8.5, the reaction is incomplete and both species (HOCl and OCl –) will be present.

Figure 15 - Chemical Reaction with Cl2 in water

When Chlorine is dissolved in water, it hydrolyzes into Hypochlorous acid and hypochlorite that actually disinfect the water by oxidizing the cell of the bacteria.

As the water is evaporated, the Chlorine components do the same. This evaporation forms by-products such as trihalomethanes which are suspected to be related to causing cancer when inhaled. During disinfection, the airflow through the evaporative media being disinfected should be closed down until free Chlorine is reduced down to an acceptable level.

It is also well known that the disinfection effect of Chlorine is related to the pH of the water. At pH 7.5 there is an equilibrium between Hypochlorous Acid and Hypochlorite. The best disinfecting effect is obtained at a low pH (acidic), where the content of Hypochlorous acid is more predominant.

The disinfecting effect of Chlorine depends also on the content of other elements in water that can be oxidized i.e. iron, manganese, and organic material.

The available free Chlorine (FAC) can be measured with test strips or photometrically.

Max Level of Chlorine in the Air

As an acceptable level for Chlorine in air, the EPA value of max 0,5ppm can be used.

OSHA sets a legal limit of 1 ppm at ceiling height for workplaces as an absolute maximum.

In an evaporative or adiabatic system the max allowed concentration of free Chlorine in water should be calculated under worst case conditions, using the assumption that all the water vapor in air comes from the adiabatic cooling system:

If the water vapor content (the absolute humidity) in the air is 12 g/kg it can be calculated that the max allowed concentration of Chlorine in water is 50 ppm. Normally, a safety factor of minimum 5 would be recommended, resulting in a max dosing of 10 ppm. If below this, the max concentration in air is not exceeded, but the air may smell of “Chlorine” if the air-flow is not blocked through the media, being disinfected.

Dosing Level

The required dosing level of Chorine is always dependent on contact time and concentration (CT value = Concentration x Time). The higher the concentration, the shorter the dosage time required.

The dosing level should be adapted to the contamination and follow up measurements of microbiological activity a few days after the disinfection should be done. As a start, a 0,5 ppm dose can be used.

Dosing can be done with Dosing pumps and flow meters - or added manually.

Hydrogen Peroxide, H2O2

As an alternative to Chlorine based disinfectants, hydrogen peroxide can be used. It is well known and accepted in all industries, including food and beverage. A large advantage to Hydrogen Peroxide use is that it is reduced to water and Oxygen when it is “used” up in the system. There are no associated by-products.

Hydrogen Peroxide is also an oxidizer. It is considered weaker than Chlorine, therefore a higher concentration must be used to ensure the same disinfection effect.

If used in combinations with UV in a system, the UV lights should be turned off during disinfection as it may reduce the effect of H_2O_2 to some extent.

Max Hydrogen Peroxide in Air

If the water vapor content (the absolute humidity) in the air is 12 g/kg it can be calculated that the max allowed concentration of Hydrogen Peroxide in water is 100 ppm. Normally a safety factor of minimum 5 would be recommended, resulting in a max dosage of 20 ppm. If below this, the max concentration in air is not exceeded. Even though the smell will not be close to what is observed with Chlorine, it is still recommended to block the air-flow through the section being disinfected.

At Condair a/s, Hydrogen Peroxide has been used for many years with good results. 20 years ago, Hydrogen Peroxide was used in it's pure form. However, for disinfection of a new installations and for semi-annually maintenance, a 3% solution is used with a typical contact time set to 3 hrs.

Residual peroxide can be measure with test strips at the output of the system to ensure full disinfection.

Disinfection liquid should be added until the entire system is filled and a positive signal occurs at the far end of the pipes/nozzles.

Hydrogen Peroxide in different grades is available from most chemical suppliers. Standard industrial concentrations are 10, 30 and 50 % A food grade quality should always be used.

Hydrogen Peroxide in Combination with Silver Salts

In the last 10-15 years, combinations of Hydrogen Peroxide and Silver Salts have been developed to enhance the effect of Hydrogen Peroxide. The Silver Salts act as a catalyst in the oxidizing process which makes the effects of the Hydrogen Peroxide more effective.

With the combined products, the same disinfection rates can be achieved by using only a 0,1 % instead of a 3% solution of pure Hydrogen Peroxide.

At Condair a/s, the combined products have been used for HPM systems since 2004 and are risk evaluated according to our ISO 22.000 hygiene management systems.

In critical applications, like public areas, supermarkets etc., an automatic preventive disinfection is done once a week with a dosage of 10-12 ppm Hydrogen peroxide.

With a safety factor of 10, this can be sprayed out or evaporated without risk.

Examples of approved and listed combined Hydrogen Peroxide and Silver Salt products:

Europe: Sanosil S010, S015, From Sanosil ag: http://www.sanosil.com/

This is the only combined product listed in the EU Biozide Article 95

HuwaSan 50, available from: http://roamtechnology.com/

US: Only HuwaSan is approved (NSF approved)

Silver

Silver acts as a poison to bacteria. New investigations show that it blocks the oxygen transport to bacteria which causes the bacteria to eventually die. The process is slower than with oxidizing agents; but, it is effective against most bacteria.

Silver salts, or colloidal pure silver as nanoparticles, could be considered as a possible disinfectant for evaporative systems. Silver has been used for decades as a disinfectant and are used in small scale today. Among others, Condair ag uses this as an important part of the hygiene management of a hybrid humidifier. Also, Condair UK offers this as an option for evaporative systems to keep them clean.

Limits for Silver in air is 0,01 mg/m³ and limit for silver in drinking water is 0,01 mg/L in DK and 0,05 mg/L in the US.

Quaternary Ammonium Disinfectants

Quarternary ammonium combinations are often referred to as Quats. These disinfectants encompass a large group of disinfectants used in different applications. This type of disinfectant is what is recommended by some competitors for disinfection of the evaporative cooling pads as they are non-oxidizing, but, kill the bacteria by attacking the cell membranes.

Limitations for oxidizing agents

Limitations with Chlorine and Hydrogen Peroxide

Evaporative Systems

Be aware that some media types are designed in a way that does not allow oxidizing disinfectants to be used. It will degrade. This is the case for PAC standard media and for most Munters media as well. Always check with the media supplier for limitation. However, most media can withstand a low dose of 1-2 ppm in short intervals and only a few times per year.

If screening and bacterial measurements show that it is necessary to disinfect more frequently, this would require a bypass over the evaporative pads to be installed.

Chemical Resistant Evaporative Pads

The Hutek media from Condair/Nortec is chemical resistant up to certain degree. Hutek pads can be disinfected with 50 - 100 ppm Hydrogen Peroxide without any issues. The Hutek Pads can also be disinfected with up to 50 ppm Chlorine.

Disinfection of HPM Systems

For HPM systems, RO systems and pretreatment are used.

RO systems should be sanitized according to the manufacturer's instructions which is normally done in combination with other system maintenance.

RO membranes are sensitive to oxidizing agents as well. Membranes used in standard industrial RO system can only withstand a certain amount of chemical dosing. Standard membranes are rated to approximately 1000 ppm hrs. (1 ppm for 1000 hrs or 0,5 ppm for 2000 hrs etc.). This can be Chlorine or hydrogen peroxide dosing. Membranes can be sanitized with 50-100 ppm dose of either Chlorine up to 10 times without exceeding the rating; however, they should not be operated with a continuous dose.

Incoming water has to be dechlorinated because of a Water softener as well. The resin used in these will deteriorate if exposed to chlorinated water.

When disinfecting HPM systems, the disinfection liquid should be added in the permeate reservoir and pumped throughout the system. Chlorine should not be used as piping and nozzle arrays are normally made from stainless steel which chlorine is corrosive towards.

Best engineering practice for disinfecting HPM systems would be to use a Hydrogen Peroxide based disinfectant.

Semi-annual disinfection with a 3% pure H_2O_2 or a 0.1% combination H_2O_2 and silver salt mixture is recommended. If weekly preventive disinfection is needed to maintain appropriate hygiene levels, a concentration of 10-20 ppm can be added and sprayed out without shutting down airflow (risk analyses can be provided if required).

General Chemical Disinfection

No matter which chemicals are used for disinfection, it is necessary to follow instructions in the MSDS for the product concerning handling, transportation, storage and disposal of the product. Handling precautions normally varies depending on the concentration of the liquid.

Local codes may vary for content in waste and effluent water. Always be aware of and follow local codes; and, if necessary, neutralization might be necessary.

Validation and Verification of Water Safety Plans

To validate and prove that the hygiene management system or the Water Safety Plan works as expected, the microbiological activity or the hygiene in the system must be measured and kept within the limits that have been set up in the program.

This can be done using different technology and standards including HPC, DIP slides, ATP or BQ measurement.

How to Measure Bacteria in Water

Heterotrophic Plate Count (HPC)

The standard way of measuring water quality is to look at the total amount of colony forming bacteria in water. Most bacteria in water are heterotrophic, meaning they are dependent on other organisms to synthesize.

The standard method is described in ISO/DIN 6222 standard.

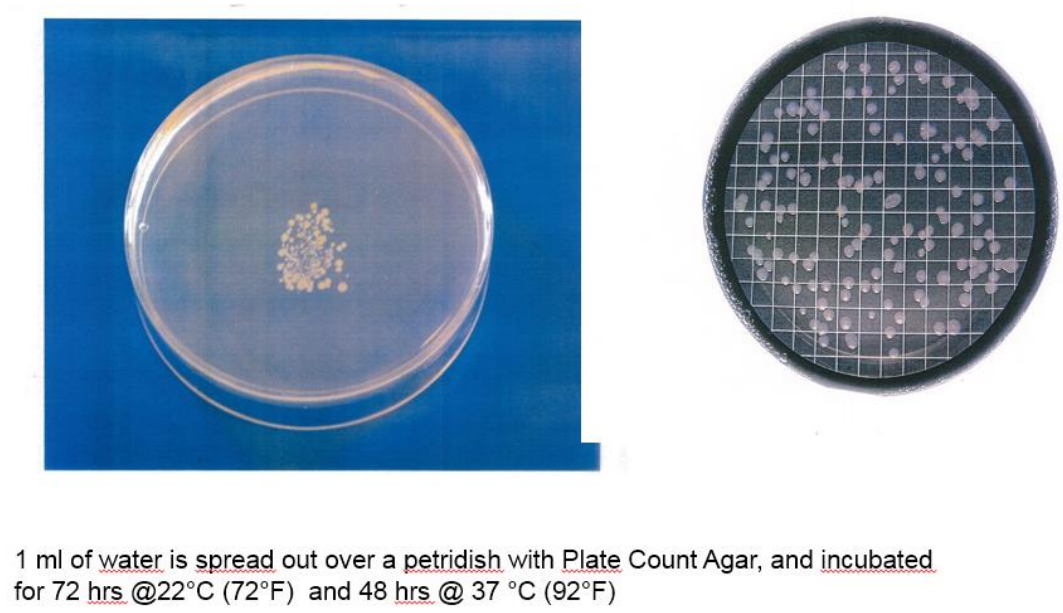


Figure 16 - Petri Dish with bacteria colonies

Each “dot” on the Petri dish is one bacteria that has multiplied so many times that it has formed a colony big enough to be seen with the naked eye.

This gives an indication of the general cleanness of the water and tells us about the microbiological activity in the water.

The general drinking water limits of 200 CFU/ml is in reference to this method.

It is well known that this method does not show all the microorganisms in the water. In fact, only less than 2 % of all bacteria are actually observed on the petri dish with agar (a common food source for bacteria). The remaining bacteria in the sample do not “like” PCA agar as a food source and do not multiply to form visible colonies.

One advantage to this method is that it is largely accepted and known worldwide and any new test methods are generally compared to this.

A similar method is used when looking for Coliform bacteria in water, but instead of PCA, RGA (Red violet Bile Pethone Agar) is used.

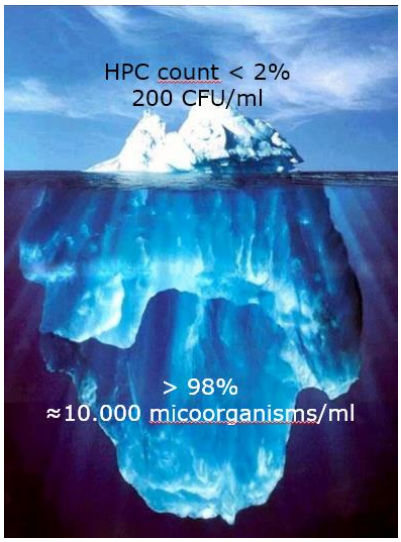


Figure 17 – HPC Method Analogy

The HPC method only really touches the tip of the Iceberg. As long as this is understood, there are no issues with the method, however it makes it difficult to compare the results from different methods to measure bacteria.

One large disadvantage of the HPC method is that it takes approximately 2 to 3 days to get a result. For industrial systems and field technicians in service and maintenance, this is not applicable.

DIP Slides and ATP Method to Measure Bacteria

DIP slides are indicative and can be used to verify hygiene levels of the system. They are not particularly accurate and should be used with care.

ATP Measurement

Different suppliers are selling these kits today and ATP is often used to check hygiene after cleaning of surfaces etc. Using ATP for water is a bit more tricky and also this should be used with care.

When Condair started to investigate different available quick measurement methods back in 2004/2005, ATP measurement was used from an international supplier.

After one year and around 400 parallel measurements with ATP and HPC, this method stoped being used because of too many false negative results in comparison to HPC counts. Instead, we started to use the EPA approved BactiQuant method described in the next section.

The ATP systems and the enzymes used today may have been improved since then. ATP measurement can still be used as hygiene indicators in a system to get a quick overview, but it should not be used as the only verification of a hygiene management plan.

BactiQuant (BQ) Method

BactinQuant is a culture independent technique for rapid detection and quantification of bacteria in water systems.

The system is patented and EPA approved in 2012. It is developed by Mycometer a/s in Denmark.

Similar to the ATP method, this is also an enzyme based method. The main difference is that the BQ method uses the hydrolase enzymes present inside the bacteria. As long as the enzyme is intact, the bacteria can be measured. The method is based on 3 simple steps:

Step 1: Filtration of a water sample through a 0,22 membrane filter

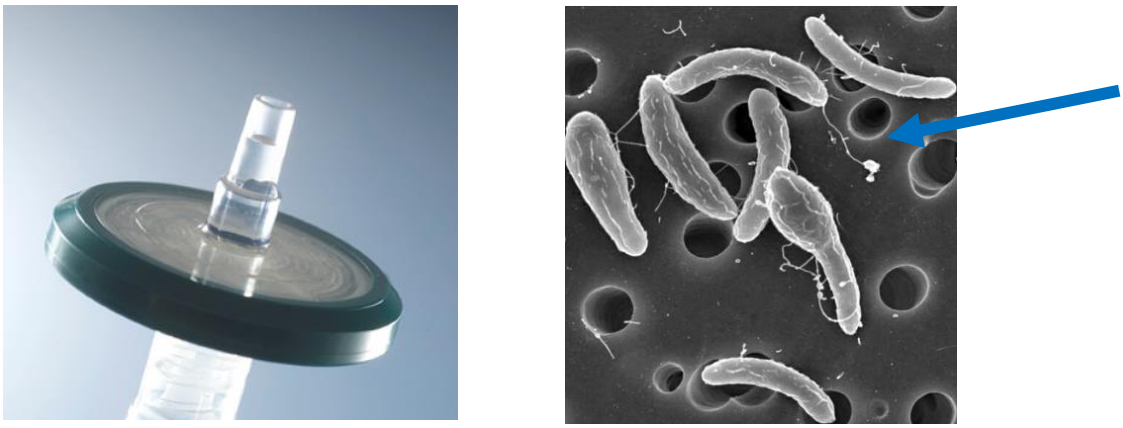


Figure 18 - Filtration of Water and Bacteria on Filter Surface

The bacteria are retained on the front of the filter. The amount of water filtered can be from 0,1 to 1 liter. If the water is heavily contaminated, only a small amount of water is needed.

If however it is very clean, more water is required for filtration to get a more accurate reading.

Step 2: Substrate addition

Figure 19 - Substrate Addition

A small amount of substrate (2,5 ml) is added to the bacteria on the surface of the filter.

As soon as the substrate is added, the enzyme activity in the bacteria starts to “break down” this substrate. The enzymes act as scissors, cutting the substrate into tiny bits and pieces. When the substrate is cut, a fluorescent compound is released.

The substrate used is a 4-Methylumbelliferone sodium salt. It is safe and stable, and can be stored up to 2 years in a refrigerator.

Step 3: Measurement.

After a waiting time of approximately 20-30 minutes, depending on the amount of water being filtered, the process is stopped and the signal is measured using the principle of fluorescence described in Figure 20. Figure 21 shows the instrument used to measure the fluorescence signal and quantify the value.

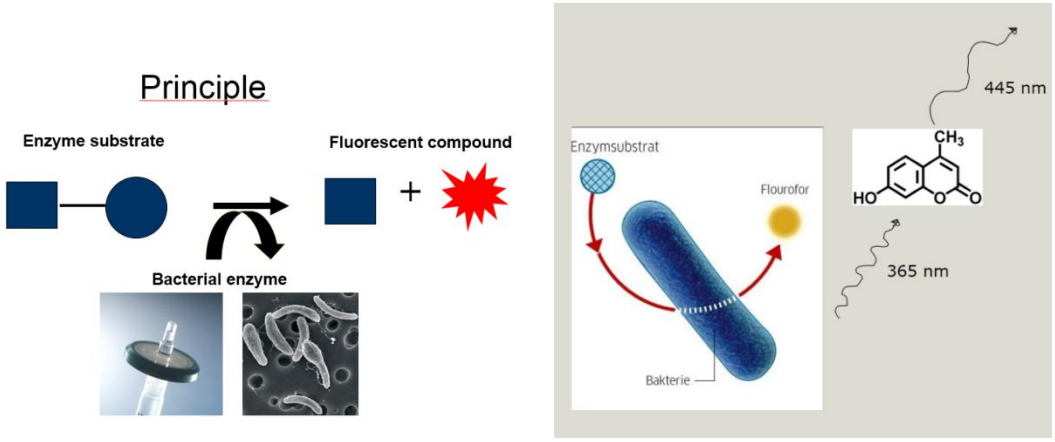


Figure 20 - Basic Principle of the BQ Method

Figure 21 - Instrument to measure fluorescent signal released from enzyme activity

When the signal is excitated with light with 365 nm, the fluorescent component is emitted with 445 nm light.

The amount of light emitted corresponds to the amount of enzymes – and bacteria – in the water.

The more bacteria present in the sample, the longer the incubation time and the higher the temperature the more light that is created.

The sample values are entered into a spreadsheet or into a BQ App, and a BactiQuant (BQ) value is calculated. See Figure 22.

The values are all correlated back to standard figures for the process, to calculate a BQ value that can be compared with values taken elsewhere.

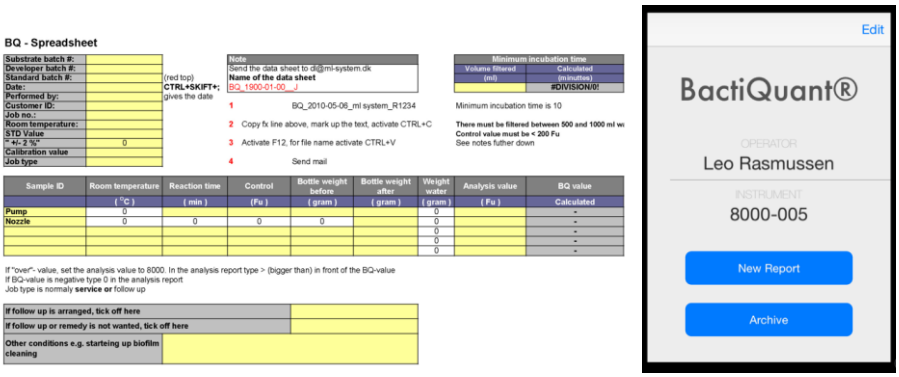


Figure 22 - Spreadsheet and App to calculate BQ values from samples

Everything needed to perform the analysis is stored in a suitcase as a complete kit seen in Figure 23.

Figure 23 - Complete BQ Test Kit

As mentioned above, the different measurement methods cannot be directly compared because of the different principles used.

However, when the BQ method was developed, a correlation against HPC was made. 900 water samples, both drinking water and laboratory samples, were tested using both methods, and using statistics a correlation was made.

Based on this, the following values were developed and are now used:

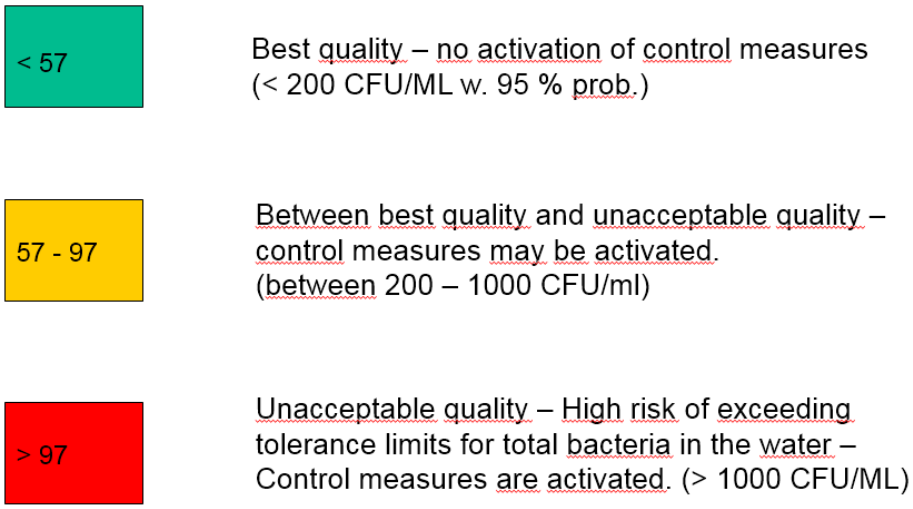


Figure 24 - Comparison of BQ Values with HPC Values

Who Can Use It?

To make sure that the analysis is performed in the same way, and that values can be compared, it is required that users of the system are certified. The certification program takes around 4 hours and is performed by authorized instructors only.

Advantages: It is a robust and easy to use process; results are available in approximately 30 minutes. It is a great tool to perform water analysis on a system and establish a baseline at different points in a technical water system.

UV treatment and Limitations with ATP and BQ Measurements

As mentioned in the description of the two systems, they both measure living bacteria. It is important to remember that bacteria are still alive; even if they have been treated with UV light. They might not be able to multiply, but they still contain ATP and the enzymes are still intact. Both ATP and BQ will exhibit similar results before and after a UV system.

This can be considered both an advantage and disadvantage.

It is a disadvantage when the results are compared with the HPC method, but on the other hand it tells us how much living organic material is within our system that can act as nutrients to support other bacteria which are able to multiply.

Comparison of Different Values

Based on the above information the following table can be set up:

Table 4- Comparison of values for different measurement methods

	Measurement method			
	HPC	ATP	BQ	
Hygiene Level	CFU/ml	RLU*	BQ	ACTION
Excellent	<200	<300	57	Only preventive disinfection
OK - Limited Growth	200-1000	300-750	57-97	Standard disinfection required, replace filters etc.
Over Max Limit for Growth	>1000	750-1500	>97	Disinfect, arrange follow up measurement, and eventual adjustment of flushing etc.
Out of Control	>10000	>1500	>1000	Action must be taken, Cleaning, Disinfection, Biofilm, cleaning, arrange follow up measurement, adjustment of flush times,

* Depends on type/manufacturer.

The necessary action to take is always dependent on where the measurement is taken in the system. Testing location should always be outlined in the water safety plan.

General Hygiene Level

When the general hygiene level of the system is within the green and yellow area, the system is under control, and the risk for having high levels of pathogen bacteria is low.

Coliforms and Legionella

Local regulations and laws might require specific measurements for coliform or Legionella bacteria (L8 in UK as an example).

Legionella testing should be made by authorized labs only and tests should be performed according to international standards, i.e. ISO 11731-3.

Coliform bacteria can be tested on site with quick methods as well; but, for the time being, this should be left to authorized labs as well if specific measurements are required.

The recommendation is still to keep the general hygiene level of the system as high as possible, thereby reducing the risks of having pathogen bacteria.

Where to Measure Bacteria in Adiabatic Systems

For each site a measurement plan should be set up depending on the flow diagram and the type of system.

The purpose of the plan is to find out where eventual growth takes place, and to get knowledge about the behavior of the system.

As a minimum, the following points should be measured:

1: Inlet water to the system

2: Water at humidifier or evaporative cooler

Frequency of Tests

It is recommended to measure hygiene level a minimum of every 6 month.

If a system is out of control, it might be necessary to measure more frequently until the reason for contamination is found and the problem has been solved.

Documentation

The values measured should be used to establish a baseline for the different points in the system. As long as values are within the safety range, baseline values are more important than accurate figures. Actions should be taken when fluctuations are observed; increasing values are more critical than decreasing values. Seasonal variations are normal and have to be taken into account.

Evaluation of the WSP

A hygiene management system or a WSP is not a static system. It should be evaluated by the management team frequently, improved and adjusted like any other quality management system. It can be integrated into the normal quality management system used in the building.

For each of the relevant elements in the adiabatic cooling system, instructions should be made indicating how to keep them in good hygienic shape and which corrective actions should be taken if any growth takes place in the systems.

PRP: Prerequisite Programs

The most important part of any WSP is the people involved. It is necessary to transfer knowledge about water and hygiene to technicians involved in the operation of the building. Without awareness and care, programs are not likely to be successful. This is normally described in a PRP handbook – or as a part of a quality handbook.

Final Remarks

Knowing the background of a Water Safety Plan allows you to advise the customer in the right way and gives us the possibility to offer service, maintenance and hygiene control of our installed systems to the benefit of the customers and our company.

Why Condair?

Condair specializes in the design and production of superior humidification systems. We create the most appropriate solutions to meet your specific needs in the most efficient and cost effective way. To this end, we draw upon our extensive experience to develop an ever growing range of products manufactured to our stringent ISO 9001:2000 certified quality standards that will provide our customers with maximum reliability, minimum maintenance and a choice of energy sources.

When you choose Condair, you are choosing the company that has built a reputation for superior quality humidification systems. Only with Condair can you select a system operating with electrode steam, subsonic air nozzles, high pressure nozzles, steam injection, steam exchange, or gas-fired technology.

USA 835 Commerce Park Drive Proctor, Ogdensburg, NY 13669
Canada 2740 Fenton Road, Ottawa, Ontario K1T 3T7
Tel 1.866.667.8321 **Fax** 613.822.7964 **Email** na.info@condair.com