High Pressure Water Misting System for adiabatic outdoor cooling in hot and dry areas.

- Combined with shading systems.

The report is based on the results from previous projects, physical and chemical facts, and my best knowledge and experience.

The report is written solely to Condair Group ag, and must not be handed out to others than people involved in outdoor cooling projects, and must not be published nor in full or in parts.

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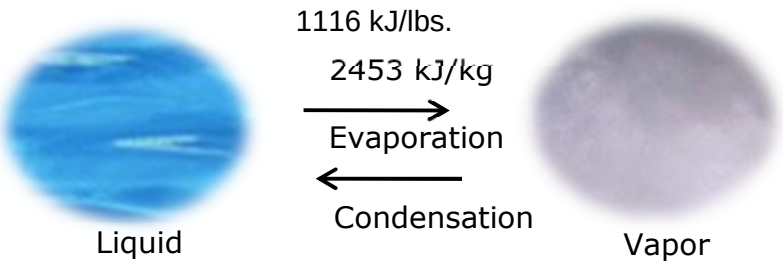
Part I.

Part II

1: General description – Adiabatic cooling.

It is well known that evaporation of water needs energy. This energy is take from the surrounding air, resulting in a reduction of sensible energy, and adding latent energy to the air.



The evaporation energy for water is:

Temp:	energy kJ/kg	energy kWh/kg
20 °C	2453 kJ/kg	0,681 kWh/kg
30 °C	2430 kJ/kg	0,675 kWh/kg
60 °C	2358 kJ/kg	0,655 kWh/kg

In the following an average temperature of 30 °C is used.

When he total amount of evaporated water is know the total adiabatic cooling energy can easily be calculated and evaluated.

Calculation of cooling energy in an example project:

Area to be cooled: 12 x 12 m = 144 m²
Effective misting capacity installed: 60 L/hr = 60 kg of water pr hr.
Evaporation energy needed for this amount :

60kg/h x 2430 kJ/kg = 145.800 kJ/h = 145,8MJ/hr = 40,5 KW

Cooling per m²: 40.500/ 144 ≈ 281 **W/m²**

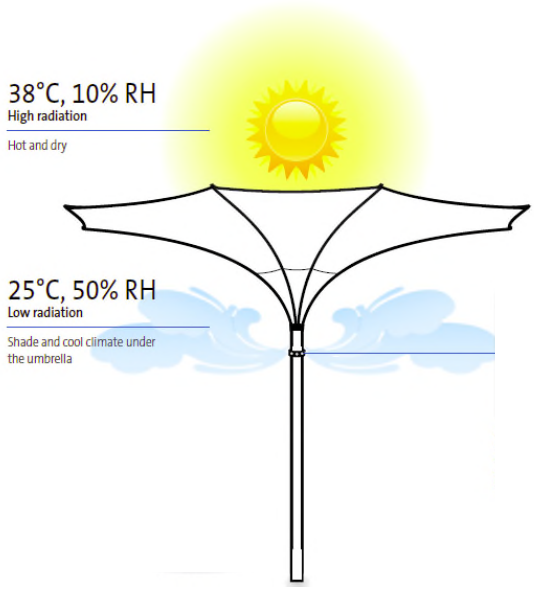
The cooling effect should be compared with the radiation from the sun, and the shading effect in the area. Solar radiation without shading in the target areas for outdoor cooling is in the range from 400-600 W/ m², during the hottest month of the year. In the following an average value of 500W/ m² is used.

Outdoor cooling is normally used in combination with a shading structure, e.g. foldable umbrella´s or similar structures.

With a shading effect of 40 % the radiation is reduced to 500* 0,6 = 300 W/ m² under shading structure.

With the above mentioned cooling effect, the adiabatic cooling system theoretically is able to eliminate:

281 x 100 / 300 = 93 % of the radiation heat in the area.



2: Water in general:

Water is one of the most complicated liquids. Water is a mixture of pure H2O molecules, different salts, minerals, bacteria, virus, and a lot of micro elements, depending of where the water comes from.

Water is able to dissolve practically all basic elements that comes into contact with the water. Some elements are of course easier to dissolve than others.
The content of salts and minerals in the water is called TDS = Total dissolved Salts, and is directly related to the conductivity of the water.

When the conductivity (EC) is know the TDS can be calculated from the rough rule:

TDS = EC/X , X can be between 1,5 and 1,8 depending on the type of water.

In the following X is set to be 1,6

2.1. Drinking water:

Drinking water is a mixture like described above, and there is WHO limits for the different components.

Water might be suitable for drinking, but not directly suitable for evaporation purpose. When water is going to be used for evaporation, the requirements has to divided into technical- and hygiene requirements.

2.2 Water seen from a technical point:

The water available for a specific project, must always be documented by a water analysis. This is available from the municipality or the drinking water supplier on site.
Each water contains a certain amount of salts and minerals, among these calcium and magnesium.

The total hardness of the water in water can be calculated from the following:

Content of Calcium x 0,14 gives the calcium hardness:
Content of Magnesium x 0,23 gives the magnesium hardness:
The total hardness of the water is the sum of these:

Problem with calcium and magnesium seen from a evaporative point of view is the following:

Calcium and magnesium has a low solubility in water and tends to form sediments in installation. Depending on hardness and pH of water this happens in the temperature range around 50 deg. C. (known from heating equipment etc.)

In areas with high ambient temperatures there is a great risk that temperature can exceed the temperature where sedimentation starts, forming lime stone particles in the installation.

These particles has to be kept back in filters, and it is critical that these particles does not reach the nozzles, as it will block them and create dripping and or malfunction.

Another technical challenge with calcium and magnesium in the water is blocking of nozzles from the outside. Every time the misting system stops, a micro drop will stay on the surface of the nozzle. When the H2O is evaporated the minerals stays and sediments on the outer orifice of the nozzle opening, and starts to form a “ring” of limestone and other sediments from the TDS content of the water.

In general it can be said that the lifetime of the nozzle is directly proportional with the content of salts and minerals in the water. High quality nozzles are normally not worn out, but stops to work because of particles or sedimentation on the outside.

In a typical project with an area of app. 1500 m² around 100 nozzles will be installed. Without reducing the hardness of the water, these nozzles will have to be replaced minimum once a year. The price for doing this in material and labor cost is high, and should be used to calculate a payback time for an eventual RO system.

3: Evaporation of water:

When the water molecules has evaporated the salts and minerals remains as micro particles, as they can not evaporate, but forms different chemical components depending on the content of positive ions, calcium, magnesium, Iron etc, and negative ions chloride, sulphate and nitrate combinations in the water.

Water droplets will evaporate down to a size where they are saturated with the salts in the water. As the droplets becomes smaller because of evaporation, the salts concentration increased and slows down the evaporation until the vapor pressure of the droplet equals the vapor pressure of the ambient air.

The size of the dust particles is difficult to predict but it is sure, that they are there, and a part will settle on the ground and a part will stay suspended in the air and blow away with the wind!

4: TDS and dust

TDS is equal to dust:

Let´s take an example: In the water analysis it is stated that TDS in the sample is 500 ppm = mg/L,

Example project: 1000 m², 250 L/hr operating 3000 hrs/year
Amount of dust with TDS level of 500 mg/L

The total capacity of the system:

250L/hr x 500 mg/L = 125.000 mg/hr = 125 g/hr = 0,125 kg/hr

Total dust load per year with 3000 hrs of operation:
0,125 x 3000 = 375 kg per year.

It might not sound that high, but for sure everything will be grey and dirty.

If a client decide to install a system without removing at least the biggest part of the TDS, it is necessary to inform him that additional cleaning of all items in the area is needed and has to be planned on forehand.

Everything will be grey from dust within 1-2 month operation time!

Like in standard industrial humidifying applications, like printing electronics etc, dust will also create problems in outdoor applications.

5: RO Water

The problem with dust is easy, - but expensive - to solve by installing a reverse osmosis (RO) water treatment system, between the raw water and the high pressure misting pump system.

RO systems is a well known method in water treatment, and is used, not only for desalination of seawater, but also as standard water treatment in many industries where clean process water is needed.

Different types of membranes are available depending on the incoming water, and depending on the needed reduction of TDS.

In a standard case a standard RO system with low pressure membranes will remove 95-98 % of the TDS from the water.

Dust load with RO system installed:

Dustload without RO: 375 kg per year.

Dustload with RO 95 % removal: 375 kg x 0,05 = 18,75 kg
Dustload with RO 98 % removal: 375 kg x 0,02 = 7,5 kg per year

For most outdoor cooling projects a removal of 95 % is considered acceptable.

The water analysis:

If our water from the example is passed through a RO system with 95 % removal the following values will be achieved:

TDS: 500 x 0,05 = 25 ppm (mg/L) after the RO system

If the total capacity of the cooling system, is above 300 L/hr, it is recommended also to use a water softener as pretreatment to the RO system. In a water softener, Calcium and Magnesium is replaced with Sodium in the water. With a water softener installed, an efficiency of app 75 % can be achieved. This means that 75 % of incoming water is coming out as treated clean water and 25 % will be flushed to drain. Thus to produce 1 m^3 of clean water app. 1,33 m^3 of drinking water is needed.
For smaller systems up to 300 L/hr, a lower efficiency is accepted, typical 50 % of water goes to drain. Depending on water prices in the region, it should be calculated if the extra waste water can pay for a water softener within a decent time period.

Installation of RO system will have the following advantages:

- Limited amount of dustload
- Less cleaning work.
- Longer lifetime for nozzles
- Better and quicker evaporation of water droplets
- Less maintenance cost with high pressure parts
- Improved hygiene in the system. (see risk evaluation).

Disadvantage:

- Higher water consumption
- Higher initial investment
- Higher maintenance cost for water treatment

6: Water for evaporative cooling:

From a technical point of view normal drinking water with a TDS level of 3-500 ppm, water can only be used for adiabatic cooling with the above mentioned problems with dust and blocking of nozzles, higher maintenance cost etc..

The maximum acceptable TDS for water used for adiabatic cooling without problems is estimated to be 70- 90 mg/L. This is the limit for a well working high pressure missing system, seen from a technical point of view.

Seen from a hygiene point of view, it is recommended to reduce TDS with 95-98 %, to reduce the nutrient content to a minimum. (see risk evaluation)

7: Controlling of the system:

A central control of the total misting system is foreseen. The misting system should be started and stopped on temperature and humidity limits.

Misting function should only be used with low wind speeds. Even at relative low wind speeds the mist will be carried away and limited cooling can be expected.

When fans and nozzles are spraying against wind direction, aerosols will stick together, form bigger droplets and fall down as rain. Bigger systems supported by fans, are less sensitive to wind, but the mist will still be carried away with the wind.

Measuring of temperature and humidity should be done under the shading structure.

From the water treatment, signals about water quality and alarms should be integrated in the controlling of the system.

Specific details about interface between water treatment, high pressure system, sensors and control system has to be discussed and coordinated by main contractor.

Part II.

8: Risk evaluation for high pressure humidifying and adiabatic cooling system

The risks involved in the above mentioned processes can be divided into

- Mechanical risks
- Chemical risks
- Microbiological risks

In the following only the relevant risk factors will be evaluated:

9: Mechanical risk:

As water under high pressure can be dangerous, precautions must be taken so that only authorized and trained people is allowed to do maintenance and repair on the system. System must be clearly marked with warning signs and pictograms. Supplier of High Pressure parts will be responsible for the mechanical safety of the system, according to normal CE standards.

10: Chemical risks:

Disinfection fluids: When system is sanitized it is important to have procedures to ensure that disinfection solutions is not sprayed out and evaporated in concentrations higher than allowed.

11: Microbiological risks:

Anywhere where water is present, bacteria's is also present. In drinking water there is national and international standard for the amount of bacteria´s that is accepted in drinking water.

Bacteria´s are small one celled microorganisms, that can be found all over: in air, on surfaces, food, surroundings, water etc.

The typical size for bacteria is between 0,2 µm and 50 µm. They can spherical- stick or spiral formed.

Common for all bacteria is that they need nutrient to be able to multiply. Nutrient can come from carbon, light, nutrient content in water. Under optimum conditions some bacteria´s can double in 20 minutes.

Most bacteria´s that are found in drinking water system is harmless to humans. When humans drink water, even with pathogenic bacteria´s up to a certain level, the stomach acid and the natural bacterial flora in the stomach will fight and kill most of them, and except from the risk of diarrhea most of them are harmless.

It is different when the water is used for humidifying and adiabatic cooling. When water is passed through the nozzles, millions of small aerosols is formed, and if bacteria´s is present, they are inhaled by people and goes to the lungs. Humans does not have the same resistibility in the lungs as in the stomach, so the water has to be free from pathogens when used for this purpose.

Pathogene bacteria´s in water systems:

Disease causing bacteria, especially Aeromonas hydrophila, Pseudomonas aeruginosa, Listeria monocytogenes and Legionella pneumophila. They are all 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:
The most known bacteria in connection with aerosols and adiabatic cooling is Legionella pneumophila. The bacteria can cause Legionellosis, or better known as Legionnaires' disease.

Incubation time is 2- 10 days and “only” 5 % of the people exposed to the risk will caught the disease. From these 30 % will die. In total 1,5 % of people exposed to the risk from Legionella will die!.

Legionella has a size 0f 0,3-0.9 x 2-20 µm, it is thin rod shaped gram negative bacteria.

Optimum temperature for the growth of Legionella is 35-43°C. Below 20 °C, there is no growth, and above 55 °C it starts to die out.

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.

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

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 risk in connection with it. There is always a small risk that Legionella can be introduced to the system, either from the drinking water, or from reservoir tanks, maintenance of the system etc.

The good thing about Legionella, is that it is never found alone. If Legionella is present there is also a high amount of other bacteria´s in the system. Testing and controlling the hygiene level of the system, thus can be done by testing for the total amount of bacteria´s and not test only for Legionella.

Most outdoor cooling projects are in a public area , where all kind of people will come, including people with reduced immunity against diseases, it is after my opinion essential to set up procedures to prevent growth of bacteria´s in the system.

The total bacterial count in the system should be kept at a level corresponding to drinking water standard, meaning a maximum count of 150 CFU/ml (measured on PCA (Plate count Agar) at 21° C, 72 hrs, and max 50 CFU/ml at 37°C, 48 hrs, or similar measurement method)

When BactiQuant measurement method is used the value should be below BQ 52.

12: How to protect against bacteria´s and growth of these.

It is almost impossible to prevent bacteria´s to enter the system, but it is possible to prevent them from multiplying into quantities, so that they becomes dangerous for humans..

The following precautions should be taken:

The water used for an outdoor cooling project should always be of drinking water quality. The general message is:

- If you would not drink it - don´t spray it out.
- Never allow the water to in the system to be stagnant for more than 6 hrs.
- Make sure that water in reservoirs is not kept for more than 24 hrs.

13: Prevention of forming biofilm in the system:

When dimensioning the supply lines for the misting system, it is important to ensure that the flow rate is high enough to prevent forming Biofilm: Experiments has shown that a velocity of minimum 0,3 m/ sec minimizes the risk of forming biofilm in pipes:

The following flow limits should be observed :

Pipe Size:	Minimum flow L/hr
1/8" DN 3	8
1/4" DN 6	35
3/8" DN 10	90

When the flow is above the mentioned limit, the risk for forming Biofilm is minimized.

If the flow velocity cannot be achieved under normal system operation, it is recommended to flush the system with high flow velocity minimum 6 times per day, for a period long enough to ensure that all water has been replaced in the pipes.

14: Prevention from entering nutrients to the system:

Common for all bacteria´s is that they need nutrient to grow. The best way to keep the growth of bacteria´s to a low level is to keep the nutrient content of the water low. By using RO water this will be reduced with 95-98 %.

15: Decontaminating with UV:

UV light with a wavelength of 254 nm, destroys the DNA structure of the bacteria´s, but it does not kill them.
It is recommended to install a UV system with a capacity of minimum 30.000 µWs/cm² (30mJ/cm²). This is standard on all Condair pump stations, used for outdoor cooling.

Maintenance on UV systems:

Common UV lamps has a life time of app. 8000 hrs, but another critical point is sedimentation on the Quarts glass normally covering the lamp. If the water contains calcium and magnesium, this will sediment on the quarts and reduce the effect of the UV.

If water with a TDS above 80 µS/cm is used, it is recommended to clean the Quarts every month. This has to be done by trained and authorized people only.

With RO system installed it is easier to keep the quarts clean, and cleaning twice per year will be enough.

16: Reservoir tanks:

Water reservoirs has to be kept clean, and inspection/maintenance entrance has to be locked and sealed. Air-venting filters has to be max 0,2 µ size, as absolute filter, not nominel!.
Stagnant water must be prevented. It is recommended to dump the water if it is not used within 24 hrs.

17: Disinfection of the system:

Disinfection means to bring the bacterial level down to a safe level, but it does not mean to sterilize the system.

Disinfection can be done automatically by adding equipment for this, or it can be done manually. In all cases it is important to have procedures to ensure that limits for disinfectants in air is not exceeded.

Automatic systems, is normally called CIP systems, (Cleaning in Place) system.

Disinfectants:

Hydrogenperoxide:

Hydrogen peroxide can be used for regularly disinfection of the piping system at maintenance intervals twice per year and at start up.

A disinfection at start up of the system should be done with a 3 % solution. The system has to be stagnant minimum 3 hrs before flushing out the liquid. The solution must not be evaporated out when people is in the area.

In between maintenance intervals preventive disinfection can be done once or twice a week upon need, with concentration up to 0,1 % hydrogen peroxide, and the residual liquid can be sprayed out at any time without exceeding the concentration limits for hydrogen peroxide in air.

Mixture of Hydrogenperoxid and silverchloride:

Tests has shown that the combination of silver and hydrogenperoxide works very effectively as disinfectant. At Condair we have good experience in using mixture of hydrogen peroxide and silver as disinfectant.

At start up a 0,1 % solution is used to secure a low start level of bacterias.

For sensible application we include a CIP system and add 200 ppm of a 5 % solution into the water. (in total a silver concentration of 0,013 mg/L is achieved)

Trade names for mixture products is among others Sanosil and HuwaSan .

Intervals for CIP cleaning cannot be established before testing of the water in the system.

The following limits must be observed:

Limits for silver in air:			0,01 mg/m³	
Limits for hydrogen peroxide in air			1,4 mg/m³ eller 1 ppm	

In periods where the system is not operated because of climate conditions, the system should be preserved automatically or manually with help from the CIP system.

Flushing programs should stay active, and used instead of shutting down the system, unless stopped for longer periods.

18: Hygiene management program:

A hygiene management system can be build up for the system according to recommendations from WHO as Water Safety Plans, or according to ISO 22.000 Hygiene management system.

Essential is, that there is a procedures for documentation for a clean system.

The hygiene management program for the water treatment system and the high pressure misting system , can be combined into one system.

The hygiene management program can be certified by external authorities if required from the end user.

Responsibility:

It is essential to make clear, who is responsible for what. The client is responsible for delivering water, that is chemically and microbiologically suitable for drinking. The supplier of the water-treatment system and the piping distribution line is responsible from the main water supply and up to the high pressure pump station. The supplier of the high pressure system is responsible that no additional growth will take place in the misting system.

19: Verification for safe system:

For the continuously trouble free operation of the system it is essential to set up instructions for test intervals for contamination.

If an RO system is installed the following intervals should be sufficient:

- Microbiological test at Watertreatment: 2 times per year
- Microbiological test at high pressure pump station: 2 times per year
- Microbiological test at nozzle units : 2 times per year.

Test reports from all water samples to be stored electronically for statistics and verification.

When bacterial levels exceeds the limits for drinking water, instructions for disinfection has to be implemented.

After disinfection new water samples should be taken to verify that the system is clean and safe.

20: Test methods:

Traditional test with measuring CFU/ml on Plate count agar, can be used and performed by local laboratory, and tested after the standards for testing drinking water.

Disadvantage by traditional methods is that it takes 3 days before the result is known, and if contamination level is too high it takes time before the system is disinfected and cleaned again.

BQ BactiQuant

Alternatively new methods can be used, where microbiological test can be performed on site, and result is known within 30 minutes. This allows immediate action and gives a higher level of security on the system. The new methods is called Bactiquant and measures enzyme activity in bacteria´s.

Test can be performed by trained and certified technicians doing normal maintenance on the system. Training and certification of technicians can eventually be a part of the high pressure misting contract.

21: Conclusions

Dimensioning, installing and commissioning outdoor adiabatic cooling system requires knowledge and care to avoid mistakes and unnecessary microbiological risks, but if the necessary steps are taken, a well working and long lasting can be achieved.

As water treatment, it is strongly recommended to Install a RO system, so that TDS level is reduced to a level, where it is acceptable, seen from a maintenance point, and seen from a dust point of view. A RO system is also recommended because of hygiene reasons in the system.

Flushing program has to be implemented into the controlling of the system, to ensure that water in pipes and lines is changed minimum 6 times per day.
Precautions mentioned under the single points should be observed when designing and implementing the complete system.

It is recommended to implement a hygiene management system for the entire project, and to verify the microbiological safety of the system minimum 2 times per year.

If the project is going to be installed in a sensible public area, where no microbiological risks should be taken at all. It is essential that the system is build up in a hygienically safe and reliable way, to ensure a successful installation and a long lifetime of the system.

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