Domestic hot water - cost effective legionella treatment. Perfect comfort and hygiene

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Abstract:
We use Domestic Hot Water on daily base, for personal and general hygiene. However, we rarely consider if the DHW is clean enough and if it serves us in a positive way. Looking forward for energy savings, sometimes we may overlook health aspects while we are focusing on low running costs and comfort level. Treating DHW is more and more actual subject, as we apply for low temperature heat sources. The paper is looking to make a comparison between heat- and chemical treatment of DHW and cost related issues.

Key words : *Energy Savings, Comfort, Domestic Hot Water, Hygiene, Legionella.*

Rezumat:
Folosim Apa Caldă Menajeră în mod constant, zilnic, pentru a asigura nivelul general de igienă. Cu toate acestea, doar rareori ne preocupă cât de igienică este Apa Caldă Menajeră, și dacă ne ajută realmente. În timp ce căutăm soluții de economisire, asigurarea unui confort ambiental, se mai întâmplă să ignorăm aspectele de sănătate generală. Igienizarea ACM este un subiect de actualitate având în vedere tendințele de utilizare a soluțiilor de încălzire cu temperaturi reduse. Lucrarea abordează calitatea ACM prin două metodologii, dezinfecția termică și dezinfecția chimică precum și costurile aferente.

Cuvinte cheie : *Economisirea de energie, Comfort, Apă caldă menajeră, Igienă, Legionella.*

1. Introduction

We use the domestic hot water (DHW) on daily base for shower, tooth brushing, cleaning and washing. We may generally say we use for hygiene applications, beside of food preparation. Water companies does make huge efforts to offer us drinking water from different sources. Considering the route of water from Water Company until the tap for consumer, there is a long journey. Due to public health regulations, the water we get at the tap as drinking water is always treated against different bacterias and microorganisms. From this point we can say that water leaves in perfect conditions the Water Company Treatment Plant. The distribution network is basicly under pressure, this avoids or at least reduces chances of getting anything outside in. We always have to be aware the fact that drinking water is not distillate water, so it does not contain only H_2O, but also other substances and also

microorganisms. As long as water is circulated and used the drinking water quality remains, but if the water stays for long time, it may start to change its chemical components and also developing different bacterias cultures.

Norms does allow only certain levels of bacterias and microorganism, as long as supplying distillate water does not help health of people neither. In EU the water quality level is set by 98/83/EC – article 5, Annex I.

2. Legionella – part of our life?

Some bacterias are part of the water as said before, so is for example Legionella, which is harmless in cold water, but is in the water most of the cases. What does happen, that Legionella in a low quantity in cold water is not going to be harmful unless the water settle for long period.

Legionella is a bacteria (figure.1), which has been discovered in 1976 in US, while the Air Conditioning system of a hotel infected over 221 persons, all of them veteran soldiers. Despite of the Hospital sever treatment and medical contribution, 34 persons died because of this [11.].

Legionella pneumophillas most dangerous version is subfamily Pontiac.

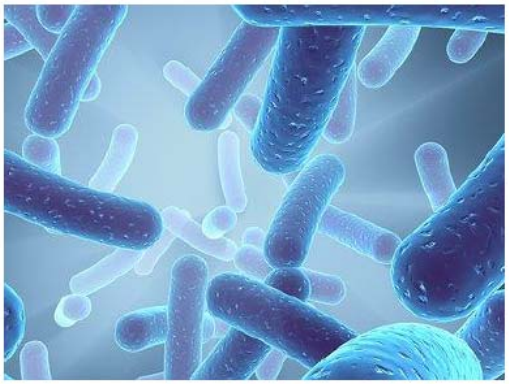

Figure 1 – Legionella culture – microscopic picture

Legionella is an aerob bacteria. It starts growing in steady water of 20-50C, highest division rate is between 30°C and 45°C (see fig. 2).

The Colony Forming Unit number (CFU) is the number that shows the bacteria content of the water. CFU number does not have a strict criteria regarding minimum number, to generate any healt issue or infection on humans. It is highly depending on the immune system of the peoples getting in contact with them. Legionella will remain harmless until it is a sever subfamily or it is in a significantly high number.

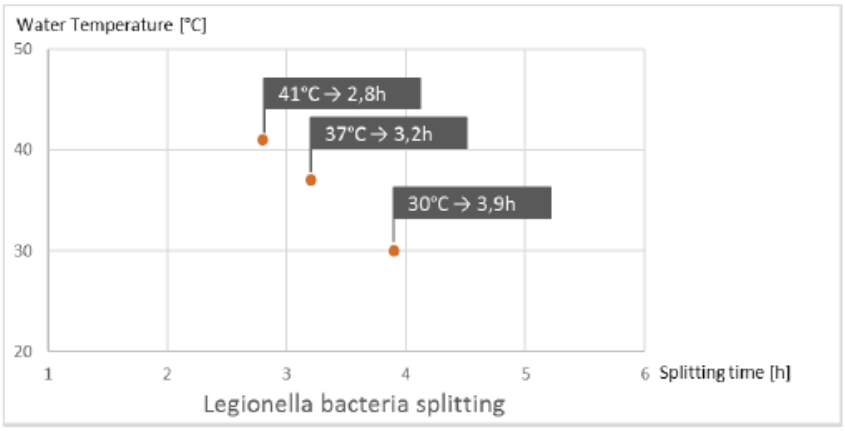

Figure 2 – Legionella culture – splitting speed depending on water temperature

In case of temperatures above 50°C Legionella bacteria stops splitting, so no more growth is recorded, while at temperatures of 60°C it resists only 30 minutes, after dies. If temperatures rises above 70°C Legionella lasts only 3 minutes.

During the time, some subfamilies of Legionella developed their resistance against high temperature. In this case, they either hide in biofilm layers on pipe walls or they uses amoebas to "cover themselves".

However, temperature definitely reduces number of Legionella, but having that said, we can not say that water above 70°C does not contain any Legionella Bacteria.

For best results on reducing, eliminating the Legionella we can approach by new systems, that does not have biofilm layers on pipe walls, and pipes used are high quality pipe, reducing biofilm forming possibilities (e.g. stainless steel pipes).

Another solution in getting rid of the Legionella and other bacterias is UV filtering or chemical dosing of water, killing germs and bacterias.

Assuming that water is locally treated, softened (scale reduction) means that heating system (inside DHW storage tank and distribution pipe does not form).

If we use chemical treatment of water – to kill bacterias and germs, will consequently reduce or eliminate biofilm forming on pipes internal wall, so we can reduce to minimum possible Legionella in system.

3. Disinfection of DHW using thermal treatment.

As previously pointed we can reduce or mainly eliminate Legionella by using heat treatment, which means, that we have to increase DHW storage tank temperature above 60°C for a period of at least 1 hour. If we consider that Legionella does survive 30 minutes at 60°C, we can say that water with temperature of 60°C±5K will kill the Legionella.

German norms states in DVGW-W 551 that DHW systems with over 400l water content must be washed by 60°C water once a day. Same norms does also state, that all systems of water pipes where volume exceeds 3l must be equipped with recirculation. In this way the standard maximise the disinfection area of distribution loop.

This solution is quite easy, but some important issues pop up as follows:

- Using temperatures above 60°C in the distribution loop creates danger of injuries, scald. In this term, solution could be the use of protective mixing valves, which allow reduction of the temperatures. Control of the water leaving temperature at user interface tap is important to be controlled, especially at elderhomes, kindergardens, and hospitals. However, user water at tap should not exceed maximum 43°C for human use. In this case, the area of nonrecirculated DHW should be less or equal to 3l volume content.

- Heating up DHW in boiler is quite cost effective. Heating up 1000l water from 45°C to 60°C means about 17,5kW extra energy above the normal heating. Biggest challenge comes with renewable energy sources. For example where main heat energy generator is a Heat Pump solution, they typically works with up to 50-55°C heating water temperatures. This means, that they can't rise water temperature in DHW storage tank over 60°C, consequently needs to have additional heating solution, like electric resistance gas fired boiler. Nevertheless, the higher the heating water temperature is, the lower the COP of Heat Pump will be. In this case, we could assist at higher costs then estimated initially.

Our subject for evaluation will be a centralised DHW system for a smaller hotel with storage tank. DHW is prepared in several alternatives.

First alternative is classical solution, using gas fired boiler.

DHW production temperature is 80/60°C, Storage tank is 1000l, with insulated shell with external heat exchanger. Water in tank is stored at 60°C. The fresh water is heated up by a heat exchanger, that has got proper size to heat up 2,1/s flow rate at desired temperature. This can ensure to rebuild Domestic Hot Water stocks within 15 minutes, while using it.

Each tap in bathrooms is equipped with thermostatic mixing taps, ensuring proper use of temperature mixture for users. All outlets are equipped with safety mixing valves if temperature at tap could be over 45C. Peak flow is 2,1l/s for hot water, main distribution pipe is copper pipe 42x1.5mm with insulation shell of 9mm thickness, EF type insulation. Return pipe for recirculation we will consider a pipe of 28x1 mm overall pipe length is 200m for main distribution + 200m return pipe. *Figure 3* is showing a typical schematic of the above described system.

Second alternative is to use Gas fired boiler and to implement a secondary controller, that is heating up boiler for 65°C during night time, so it ensures extra energy availability at morning peak time also.

Third alternative will be the use of Heat Pump system combined with electric heater. In this case, the heating up of Legionella heat treatment is done during night time.

Solution number 4 and 5 does involve the presence of chemical treatment, so no Heat treatment is needed. Consequently, it is not needed either the use of the mixing protective valves, that could cut cost in case of new system.

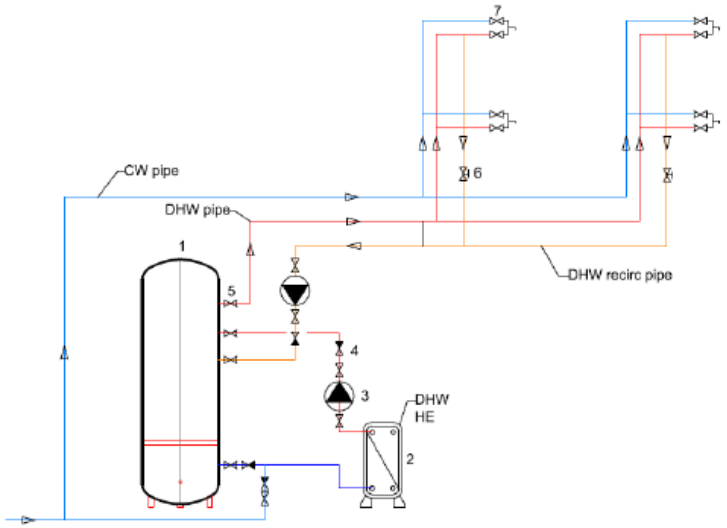

Figure 3 – Domestic Hot Water Distribution scheme with recirculation
1 – Domestic Hot Water Storage tank; 2 – DHW production Heat Exchanger; 3 –Circulating Pump; 4 – Non Return Valve; 5 – Closing Valve; 6 – Balancing Valve; CW Pipe – Cold water pipe from main supply; DHW Pipe – Domestic Hot Water distribution pipe; DHW recirc pipe – Domestic Hot water recirculation Pipe

Table nr.1 does show the comparison of the systems, and also daily average water use, and energy demand, as well as the yearly energy consumption. Since calculation is a theoretical calculation, heat generator systems efficiency has been considered fixed for full time.

Calculation does reflect only the energy demand for temperature rise, circulating pumps and recirculation losses are not included.

If we look on the 5 alternatives, we can see, that heat treatment as described above is effective against Legionella, but best solution could be to use scheduled heat treatment during night time. If we apply this solution, we can get as result a better energy consumption per year.

If we have a system where use of gas fired boiler is not possible we can see, that energy costs by using combined Heat Pump and electric solution will be very high. An another possibility could be the use of wood fired boiler as sources. Having that said in all cases the system will get extra investment price. If we plan to use Heat Pump System, we could also consider if possible the use of Gas Fired Boiler to cover peaks. In this case, we can overall reduce somehow the yearly consumptions.

Reflecting on a period of 10-15 years might change the point of view, using combined systems could be better.

We have to be aware anyhow, that using Heat treatment will only kill Legionella, but other germs and bacterias might still remain in water (like Pseudomonas).

Another important fact to consider, that in case of Heat Treatment against Legionella, the Biofilm on the pipe walls will remain. This is a very thin layer, that are remaining parts of bacterias and germs. If we apply the heat treatment solution for existing old system, prior chemical treatment could be considered.

Table 1

Domestic Hot Water system cost calculations – heating and Legionella Treatment

Solution	nr.1	nr.2	nr.3	nr.4	nr.5
DHW storage temperature [°C]	65	45	45	45	45
Night time heat up limit [°C]	-	65	65	-	-
Time to heat up [min]	-	20	20	-	-
Heating system	Gas Boiler	Gas Boiler	Heat pump	Gas Boiler	Heat pump
Auxiliar heating for heating up to 65	-	Gas Boiler	electric	-	-
Legionella treatment	heating	heating	heating	chemical	chemical
Cold water temp [°C]	10	10	10	10	10
Peak Load [l/s]	2,1	2,1	2,1	2,1	2,1
Energy needed for peak load	133,98	85,26	85,26	85,26	85,26
Energy dem. For	0	48,72	48,72	0	0
Solution	**nr.1**	**nr.2**	**nr.3**	**nr.4**	**nr.5**
Legionella prot.					
Gas boiler efficiency	95%	95%	0	95%	0%
Heat pump efficiency (COP)	0	0	3,5	0	3,5
Electric heater efficiency	0	0	1	0	0
Daily av. DHW water use [m3/day]	3	3	3	3	3
Daily average en. Use for DHW heat. [kW]	191,4	121,8	121,8	121,8	121,8
Daily av. Energy use for Legionella heat. tr. [kW]	0	57,42	57,42	0	0
Energy Consumption gas					
Row en. Consumption gas (applied eff. Factor)	201,47	128,21	0,00	128,21	0,00
Row en. Cons. For Legionella heat tr.	0,00	60,44	0,00	0,00	0,00
Energy Consumption electric					
Row en. Consumption gas (applied eff. Factor)	0	0	34,8	0	34,8
Row en. Cons. For Legionella heat tr.	0	0	57,42	0	0
Annual energy consumption					
Gas [kWh]	73537,8	68858,2	0,00	46796,84	0,00
Electric [kWh]	0,00	0,00	33660,3	0,00	12702,00

Energy Prices

Gas EUR/MWh	24,28
Electircity EUR/kWh	0,1

Annual Costs

Total cost for DHW heating + Legionella heat. Tr.	**1 785,50** EUR	**1 671,88** EUR	**3 366,03** EUR	**1 136,23** EUR	**1 270,20** EUR

4. Chemical Treatment

When it comes as alternative to this, chemical treatment could be considered for Antibacterial treatment.

Most common version is the pure Chlorine use, but this solution it could be also dangerous for health in case of overdosing.

An another solution that can be considered is using a combination of 2 components, that will result Chlorine Dioxide (ClO_2). This is a result of mixing Sodium Chlorite ($NaClO_2$ – 7,5% concentration) and Hydrocloric Acid (HCl – 9%). With the combination and reaction of these 2 components we will get as result the formula of Chlorine Dioxide.

Advantage of this Chlorine Dioxid use is that is effective against most of the germs and against Biofilm, as well as it does not change the taste of water like in case of pure Chlorine use and it also looks to be more effective than Hypochlorous acid. Figure nr.4 shows a comparison chart between the use of these 2 chemical agents for cleaning.

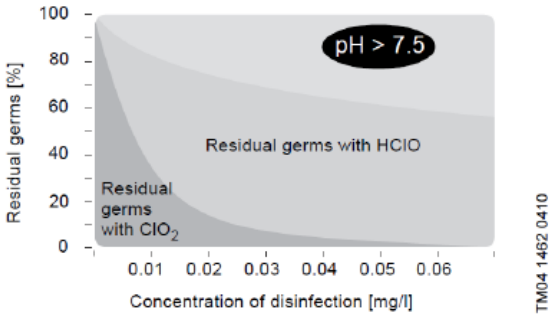

Figure 4 – Hypochlorous Acid effectivenes vs. Chlorine Dioxid

Using similar solutions does allow system cleaning and disinfection of the entire DHW system. Depending on where it is injected, the Chemical water treatment could threat only the DHW used row water, or it could be also threat the Cold Water as well.

According to specific manufacturer (Grundfos) datasheet, Chlorine Dioxide treatment system can inject the disinfection material of 0,4mg/l directly in the pipe, where it needs certain length for homogenisation in water, before it enters to consumer or to heat exchanger.

Using the solution it also eliminates the use of heat treatment of water. Finally this leads to reduction of energy demand. Cons for using the water treatment is, that needs extra space for storing and also needs periodic testing of concentration and water probes.

However, if we reflect on the costs of this system, it is about 9500 EUR including installation costs, and yearly cost of the Chlorine Dioxide is around 400 EUR including maintenance costs of service specialist.

If considered these costs, Return of investment would be around 4-6 years if we consider Heat Pump solution, where no extra heating is needed.

5. Conclusions

Legionella treatment is important for ensuring not only Ambiental Comfort, but also a full wellbeing, including healthy conditions.

German standard DVGW-W 551 clearly states how to design and build large DHW storage and distribution systems. It also states that as long as your water content is less than 3l until tap, it could be used without recirculation. Concluded calculations shows, that a large amount of energy is needed to treate against Legionella, but a good treatment algorithm, can also save large amount of energies.

If we consider to use renewable energy systems, our costs of heat treatment could be fearly high.

While using a chemical treatment against bacterias for example Chlorine Dioxide, we will face a larger investment (can compensate extra cost for auxiliar heating system) and in this case our energy consumption will be much lower, while not only Legionella is killed, but also other bacterias.

Ambiental Comfort not only includes daily cleaning and hygienisation, but also includes the fact that we are living in a healthy condition, we have comfortable DHW condtions.

No matter wich solution is used, we need to consider one of the solutions, so we can ensure healthy conditions.

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