

# Risk of Getting Nosocomial Water-borne Infections from the Main Water Systems in Hospitals

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**Summary:** Drinking water may be a risk factor for human infections if the water supply is contaminated with biofilm producing bacteria such as *Legionella pneumophila* or *Pseudomonas aeruginosa*. Several situations have to be considered when water supply to new buildings is planned. The aim of this paper is to review situations that have to be considered in new buildings and give an example on a new water supply contaminated with biofilm producing water bacteria and the precautions introduced to eliminate the contamination. When new buildings are planned, it should be considered where to get the water and what is the microbiological quality of the water. If the water is contaminated there will be troubles from the beginning. The material for the pipes should be considered as biofilm is produced in greater amounts and faster in PEG pipes than in stainless steel pipes. The choice of material depend on the expected lifetime of the building, the dimensions of the pipes, and the choice of forceps, how often the taps are used and thereby the flow in the system. The higher flow the less and slower biofilm formation. It is important to reduce the number of taps to a minimum to ovoid “dead ends” if they are not or only seldom used. Alternatively all taps could be opened automatically regularly. It is important to establish precautions to ovoid contamination of the water system in the period from it are established until the building is taken in use. The period can be several month where the system can act as a “dead end” if no precautions, such as regularly opening of all taps, are taken. The microbiological quality of the water in the system should be controlled before the building is taken in use. In a new building, where the water supply and the water in the building was not controlled before the building was taken in use, extremely high total and *Legionella* germ counts were found. The water was disinfected with low concentrations of chloride with very little effect. After disinfection with high concentrations of chloride for few hours and placing a sterile filter at the water entrance both the total and *Legionella* germ count decreased to an acceptable level.

**Key words:** Water supply, nosocomial infections, water contamination, *Legionella* spp, *Pseudomonas* spp.

## 1. Introduction

Drinking water may be a risk factor for human infections [1, 2]. The major focus has been on water supply contaminated with enteric bacteria, virus and parasites from animals and humans [3-9], which have caused several large and serious outbreaks of intestinal infections [3-9]. These outbreaks have mainly been caused by *Campylobacter* spp., *Escherichia coli*, Norwalk-like virus, *Giardia* spp. and *Cryptosporidium* spp. [1-14] These outbreaks has often been associated with recreational water (lakes, swimming pools etc.), contaminated surface water (lakes, rivers etc.), contaminated ground water

(flowing artesian wells, open reservoirs etc.) or they may be caused by break-down or over-floating in the water systems [1-3]. These problems are mainly a public health issue that cannot be handled by individual hospitals alone.

This paper will primary focus on the main water supply in the individual hospital, risk factors for water-borne infections and what can be done to prevent water-borne infections, for example *Legionella* spp, *Pseudomonas aeruginosa*. Even though the water supply to the hospital is of a high quality, the water system in a hospital is so complex and biofilm may occur in the system with an increased risk of water-borne infections especially in immunocompromised patients [2, 9]. The major central part of the water system is difficult to change

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in a building and should be taken in account during the planning of the construction of the building. The areas where interventions are easiest to do are the point of use such as taps, showers, instruments, drains etc.

The basic problem of nosocomial infections caused by water-borne bacteria is formation of biofilm in the water systems [2, 15-17]. Several factors promote the formation of biofilm in water systems: 1) The bacterial quality of the external water supply [2]. 2) The construction of the water pipes important [2, 18]. 3) The material used for pipes [19-24]. 4) The water flow. 5) The occurrence of dead ends [23].

The point-of-use sites, forceps, showers etc. and the apparatus such as ice cube machines, dental units that is connected to the water system as well as the waste water drains may be increased risk factors for biofilm formation causing a risk of infections [25-35]. Thus, it is an extremely complicated system that may lead to an increased risk of biofilm formation in the water system and thereby increases the risk for nosocomial water-borne infections in the health care system. The point-of use aspects will be described in separate papers.

One study found that more than 100 different bacteria was found in the same biofilm by genome sequencing [17]. Only few of these bacteria species causes infections in humans [36-44]. Most important are *Legionella pneumophila* and *Pseudomonas aeruginosa* which may cause severe infections, not only in ill patients but also in normal persons especially elderly. Some of the other water-bacteria like *Acinetobacter* spp. and *Stenotrophomonas maltophilia* and few others may cause infections in severe ill patients. Despite of the many different bacteria in biofilm only few are harmful for patients.

There are two main principles to prevent nosocomial water borne infections: either to make interventions central where the water comes to the building or at the point of use at taps, showers etc. The central intervention may be increased water

temperature, chlorination of water, ozone, UV irradiation or filtration. Increased water temperature is only useful for hot water but will as chlorination affect the whole water system. UV irradiation and filtration will only affect the incoming water and demands that all technical demands mentioned above are fulfilled. Point of use interventions are often filtration or UV irradiation, which may be useful when the bacterial count in the water is controlled regularly and increased number of bacteria only are found in few areas.

The aim of this paper is to give a review of the main water systems, the risk of biofilm formation, the risk of nosocomial water-borne infections and how the infections may be prevented. In addition a case with contaminated in a new building and precautions to reestablish the water supply is described.

## 2. Quality of External Water Supply

The external water supply differs considerable from country to country. In some areas the water supply comes from rivers or lakes. This water may be contaminated with bacteria from humans and animals and the water need to be boiled, chlorinated or otherwise disinfected before use as drinking water to prevent infections. In other areas open water reservoirs are used. Such reservoirs may be contaminated by intestinal bacteria from birds and other flying animals. Thus, boiling, chlorinated or otherwise disinfected of the water is also necessary in this case to prevent infections. In other areas deep ground water is pumped up and used for water supply. In this case contamination of the water from animals and humans is avoided and the bacterial count is usually low. Thus, the external water supply differs considerably from one area in the world to the other. The external water supply is important for the quality of tap water as a high bacterial count causes a high risk of biofilm formation in the water system and a high germ count in tap water. The control of water supplies by the authorities is also important for the

quality of delivered water as biofilm may be formed in the pipes before the water is delivered. In Denmark most water supplies is deep ground water and it is illegal to add chemicals to the water supply. The quality of the water is controlled by the authorities until the delivery to households and therefore, increased germ count in water is mainly caused by biofilm formation in the water system in buildings.

After knowing the quality of the supplied water, it is important to decide where to get the water supply. It can be from a new supply pipe which should always be the case in new buildings. It can also be taken from the supply of an existing building. In this case the bacterial quality of the water in the old building should be controlled and precautions should be taken to prevent the water in the new building to be contaminated from the beginning with i.e. *Legionella pneumophila* from the existing water supply which has been seen in some cases in Europe even though they have not been published (personal communication).

### **3. Construction of the Water System in Hospitals**

When water is running in strait pipes where the water flow is laminar the formation of biofilm formation is minimized. At bows, valves etc. in the pipes system the water flow will be turbulent which increases the biofilm formation. Bows, valves and other insertions in the water pipes cannot be avoided but the attention in the planning phase of the water system should be drawn to restrict of bow, valves etc. as much as possible.

Materials for the water system in hospitals: The material of the pipes is important for the biofilm formation in the pipes. Stainless steel and polyvinyl chloride (PVC) diminish biofilm formation to the greatest extent in the pipes. In some studies copper seem to diminish biofilm formation at the same level as stainless steel and PVC, whereas other studies find the risk of biofilm formation to be much higher using copper than stainless steel and PVC. The fastest and

greatest amount of biofilm formation is seen when zinc-coated steel or polyethylene are used for the pipes in the water system. Other materials such as chlorinated polyvinyl chloride and polybutylene cause biofilm formation in between these two extremes.

### **4. Water Flow in the Water System in Hospitals**

A sufficient high flow in the water system should be ensured as high water flow diminishes the biofilm formation in the pipes. The water flow can be regulated by decreasing the diameter of the pipes when the amount of water to the system is decreased. Most important for the water flow is that the use of water at the taps. When the taps are closed they act as dead ends with still water and a tremendous greater risk for biofilm formation. The tap water is used when necessary no matter what pipe system is used. Many new water-saving forceps and showers diminish the water flow dramatically with increased risk of biofilm formation in the water system and contamination of the water.

### **5. Dead-ends in the Water System in Hospitals**

Dead ends should be avoided. When sinks, showers and other water installations are closed down, the pipes should be careful handled to avoid blind end. Sinks and showers that are never or rarely used also act as dead ends and should be closed down. In some cases it may be preferable to have a sink if an accident is happening, but if the accidents are rare events the sink will be a dead end. It is preferable to have a program that ensures regularly opening of all forceps of the sinks to ensure a sufficient water flow and that unused taps acts as dead ends.

### **6. Preventing Nosocomial Infections with Water Borne Bacteria**

Many methods have been used for decontamination water systems [45]. The preferable decontamination

method is to increased water temperature, as no chemicals are used. This can be done by increasing the temperature in the output water or regulate the water temperature by shock absorbers. These methods can only be used on hot water line and if not very carefully there may an increase the risk of burn wounds in patients [46, 47]. Of chemical agents chlorination of the water system is most commonly used method. This can be done with either continuous low dose chloride or short time high dose chloride [48-50]. If the chlorine is not removed afterwards it may reduce the taste quality of the water and therefore the high dose, short time chlorination is preferable. Per acetic acid is an alternative to chlorination which is an oxidant that kills planktonic microorganisms and removes biofilm effectively. However, it may not be preferred in old water systems because of the risk for leakage when the biofilm is removed [51]. Electrolytic treatment of water can also remove biofilm and is commonly used in many formats [52, 53]. Decontamination of water with ultra violet light or large filters has been used on the incoming water supply to the building [54]. Filtration and ultra violet light are more often used at the point-of-use in water coolers and ice machines [55-57].

For the majority of these systems it is important that there is a sufficient water flow at all taps and that it is ensured that all taps in the building are open during the decontamination procedure to ensure that the effect of the decontamination reaches all parts of the water system.

## 7. Contaminated Drinking Water in a New Building

In our hospital a new temporary building in five stocks was built for the Infection Disease Department and Dialyze Unit. There was no control of the water before the building was taken in use. Three month after the departments have moved in, representative water samples were taken from 40 forceps and showers in patient rooms, forceps in kitchens and

waiting rooms. Twenty representative taps were selected to follow the decontamination procedure.

100 mL hot and cold water was sampled from each of the included taps. Water was filtrated and the filter re-suspended in 10 mL water. 100  $\mu$ L was grown on blood agar plates for total germ count and on MWY plates for *Legionella* germ count [58]. Blood agar plates were incubated at 37 °C for two days and MWY plates were incubated in a moistly chamber at 37 °C for 7 days. The colonies were counted and colony forming units (CFU) per liter was calculated.

The first intervention, continuous chlorination with 4 ppm  $\text{Cl}^-$  of the water system, was done for three month. Second intervention with high dose chlorine with 400 ppm  $\text{Cl}^-$  for short time and ensuring that all taps were open until the smell of chloride was clear. This was followed by pouring all taps, which were kept open, with plain water. The third intervention was to set up a central sterile filter at the water entrance to the building.

The result of the first 40 samples showed high *Legionella* germ count especially in hot water (Figures 1 and 2). Also the total germ count was increases in many taps (not shown). After three month with low dose chlorination (first arrow in the figures), total and *Legionella* germ counts decreased, but not sufficiently. Then high dose chlorination was initiated (second arrow in the figures) and within 2 weeks a central sterile filter was established (third arrow in the figures). In the following 2 years the *Legionella* germ counts have been at a sufficient acceptable level for the last 2 years (Figures 1 and 2). The total germ counts have also been acceptable the last two years (not shown).

## 8. Discussion

When planning a new building several things, that cannot be or are very difficult to change after the building is built, have to be considered. Where do you get the water supply? In the case of contaminated

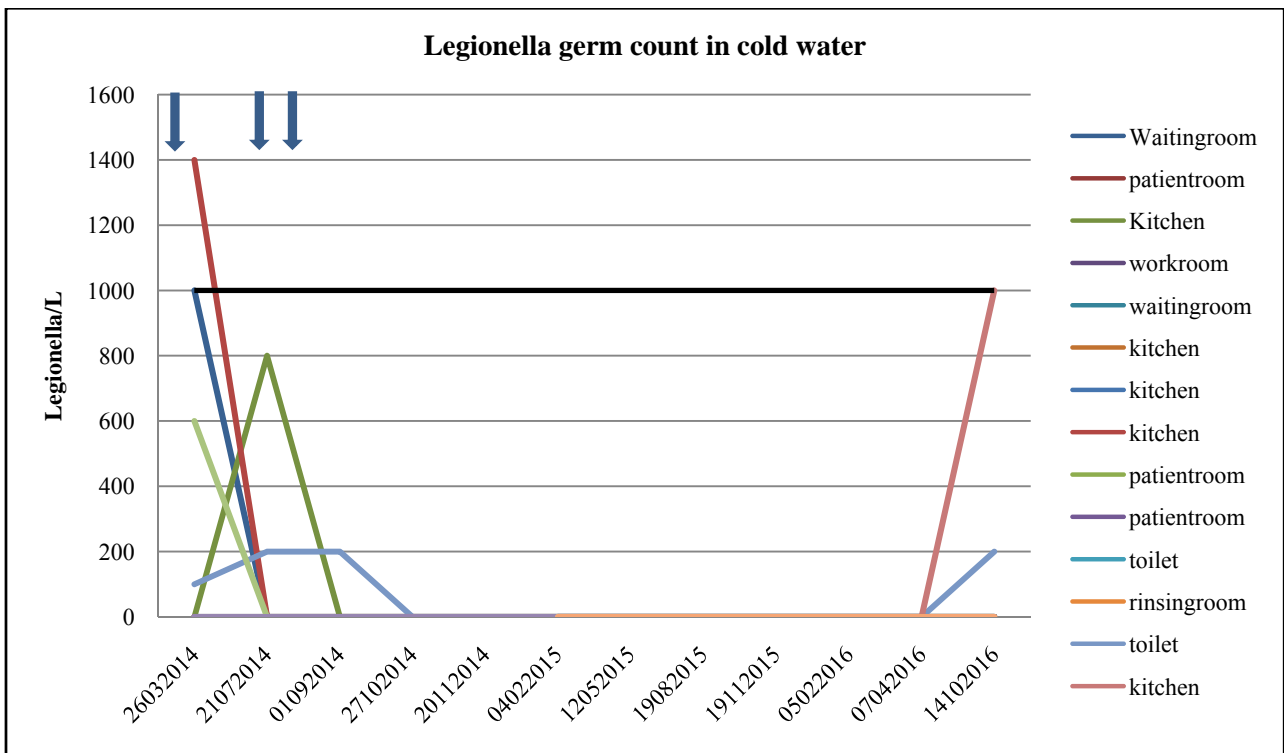


Fig. 1 Legionella germ counts in cold water are shown as CFU/Liter. The arrow to the left indicates the beginning of disinfection with low dose of 4 ppm chloride. The arrow in the middle indicates the disinfection with high dose of 400 ppm chloride. The arrow to the right indicates when the sterile filter at the water entrance was mounted.

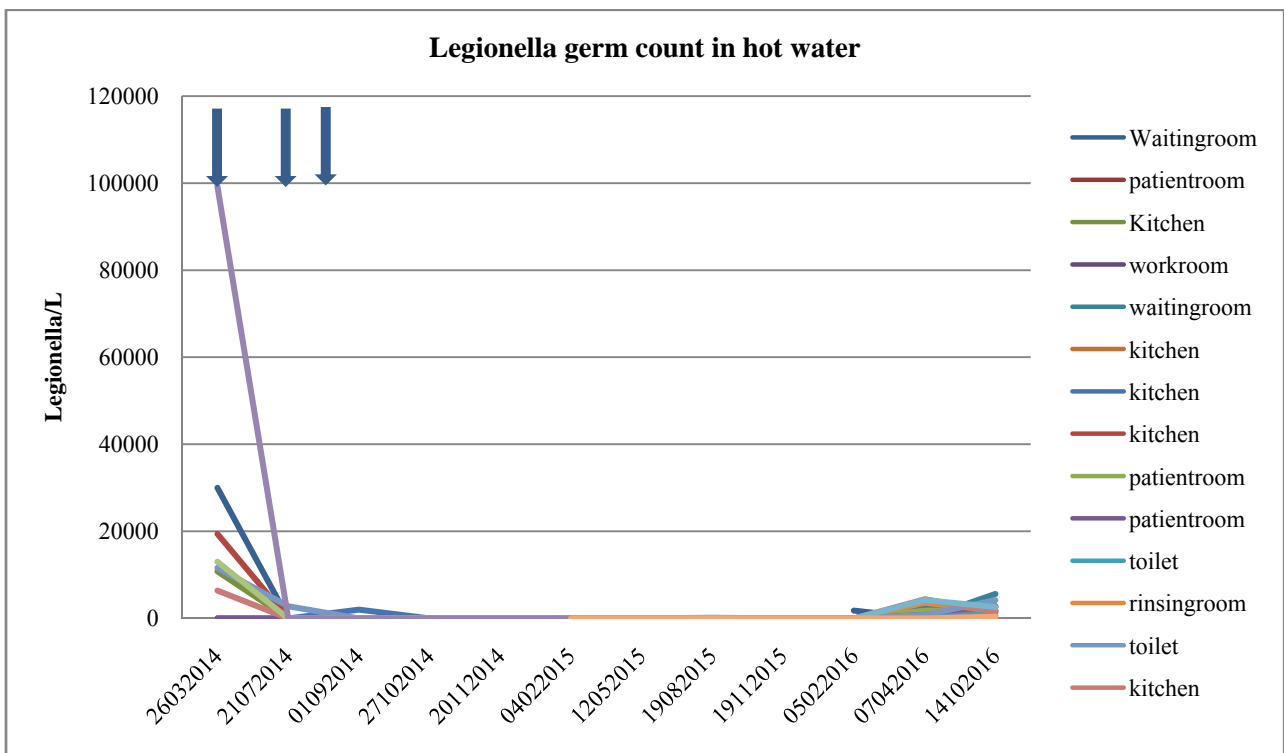


Fig. 2 Legionella germ counts in hot water are shown as CFU/Liter. The arrow to the left indicates the beginning of disinfection with low dose of 4 ppm chloride. The arrow in the middle indicates the disinfection with high dose of 400 ppm chloride. The arrow to the right indicates when the sterile filter at the water entrance was mounted.

water in a new building described above cold water was taken from the main entrance of water to existing buildings, which are known to be contaminated with *Legionella pneumophila* SG 1 and SG 6. In more than 20 samples *Legionella* has never been detected in this main entrance of cold water. Existing contamination of the buildings that are supplied from the main cold water entrance may indicate an increased risk of contamination of the water with *Legionella* in the new building. However, it was *Legionella pneumophila* SG 4 that constantly has been found in the new building. This may indicate that the water supply contains small amounts of several different *Legionella* serogroups which may contaminate the water and produce biofilm in the pipes in a randomly manner. The hot water supply was from an existing hot water supply to a building where water has never been investigated for *Legionella*. Later when the water was examined after the contamination of the new building the *Legionella* germ counts were found to be low (less than 1,000 CFU/L). The hot water supply should have been tested before it was planned to use this source for hot water.

What is the material for pipes? As described above pipes made of PEC increases the risk biofilm formation compared to stainless steel. In the new building all pipes were made of PEC because it is much cheaper than stainless steel. It has been argued that the flow of water in the pipes will increase when the diameter of the pipes is reduced, but no studies have shown how this affect the formation of *Legionella* biofilm in practice, as it will be affected by the taps and how often they are used.

What kinds of taps are used? Simple manual forceps where cold and hot water is separated seem to decrease the contamination of the tap water. All forceps in the new building were electronic with mixed cold and hot water. The electronic forceps save water, but also reduces the water flow in the system which has been argued to be compensated by reducing

the lumen of the pipes. This may be true if the forceps are open all time. It is thus necessary to keep the forceps open as long time as possible. In the new building the precaution of automatically opening all forceps for at least one minute per day was taken. Several forceps were used very little especially on the hot water site and thus acted as “dead-ends” and many taps were very little or never used and acted also as “dead-ends”, which increases the risk of biofilm formation considerable. It is, therefore, very important in the planning to decide where it is necessary to have taps and avoid taps that are rarely used and can be replaced by other taps.

In the case described above the water in the new buildings should be controlled before it was decided which sources should supply the cold and hot water to the building and the water should have been tested before the departments moved into the building. Precautions should have been taken in the time from the water supply was established and until the departments moved in. It could have been opening of all taps regularly or install a central sterile filter at the entrance of the water supply. However, the *Legionella* germ counts in cold water were not critical high (Figure 1) and the risk of infection from drinking water was low. The hot water is used for showers could be a risk in the Infection Disease Department, but no hospital acquired *Legionella* infections were observed in that period.

Precautions to eliminate the contamination of the water system were done in three steps. First the water system was disinfected with a continuous low dose of 4 ppm chloride for three month. The total germ count and the *Legionella* germ count decreased a little but not to an acceptable level (total germ count of 5,000 CFU/L and *Legionella* germ count of 1,000 CFU/L). The next precaution was to disinfect the water system with high dose of 400 ppm chloride with all forceps and taps opened until a clear smell of chloride was recognized. After disinfection the taps were opened and poured with plain water. After this disinfection

which was done within 8 h the total germ count as well as the Legionella germ count were reduced to levels below the acceptable levels. However, just before these measurements were done a large sterile filter was mounted at the entrance of water to the building which may have had a great influence on the low germ counts during the following two years. These precautions may have been successful as it was a new established water system and it may have been more difficult to decontaminate an old water system.

In the describe case of contaminated water in a new building should the water from the planned water supply to the building have been tested before it was decided to use and precautions should be taken in the time from establishing the water supply until the building is taken in use. The use of electronic forceps and the water flow at taps should have been discussed and precautions such as opening the taps regularly should have been considered.

It is important to test the water supplies to new buildings for bacteria before it is decided which source should be used for the water supply to a new building. It is important to make precautions to secure as high flow in the water system as possible in the time from it is established and until the building is taken in use. It is important to make precautions to secure a sufficient daily flow when taken in use. This include materials for pipes, kind of forceps, where and how many taps should there be in the building. It should be decided if there should be a regularly microbiological surveillance of the water.

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### Conflicts of Interest

The authors declare no conflicts of interest.

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