



Elimination of Legionella support factors in plastic pipes

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ABSTRACT:

The main aim of this paper is to present the results of the influence comparison of biocides on hot water polypropylene pipes as a part of a longtime investigation on the sustainable and safety of buildings. There are a lot of guidelines that have linked water distribution systems as an infection source and methods on how to eliminate Legionella from water systems. The presence of bacteria in the technical systems of buildings causes contamination, which may be very dangerous if there are good conditions for multiplication. The basic point is the occurrence of biofilms on the walls of distribution pipes as well as material impact. The investigation in the targeted hospital brings together interesting results from a combination of technical solutions and the dosing of biocides and their effect on the inner surface of pipes.

KEYWORDS:

Legionella contamination; pipe material; water systems; technical solutions; biocide

1. Introduction

One of the pillars of creating healthy and sustainable buildings points to the need to hygienically ensure water and air distribution so that it does not become a threat to people. Microbiological contamination of water [1] and air and health risks caused by germs that colonize technical systems cause various problems and illnesses. Among these conditions is Legionnaires' disease. Legionellosis, which is caused by the ubiquitous water bacteria Legionella pneumophila, having a diameter of 0.2 to 0.7 microns, contamination can occur by inhalation of aerosols formed, for example, through showering. There are a lot of guidelines that have linked water distribution systems to the infection source [2-4] and methods on how to eliminate Legionella from water systems [5]. At least 5,000 to 6,000 people in Europe every year are infected and approximately 450 people die. The 29 countries reported a total of 30,532 diseases, 2.6 times more in males than in women, with 70% of the infections being community-based, 20% of travel-related and 10% of those in health care facilities [6, 7]. In Slovakia, the incidence is not high, but during 2017, 16 cases were reported, per. 0.29/100,000, an increase of more than double that in 2016. Only 3 cases were travel infections. Healthcare facilities represent a high-risk environment for legionellosis transmission in patients through the inhalation of contaminated aerosols [8, 9].

2. Legionella in water distribution systems

In water supply systems, Legionella bacteria colonize, in particular, on corroding surfaces, rubber seals as well as components of plastic materials. Biofilm formation with more than 50%

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share of *Legionella* was maximal at a water temperature 40°C and was minimal at 20°C on the plastic materials. Conversely copper surfaces inhibit adherence of *Legionella* and the formation of biofilms [10, 11]. Experiments have already shown that after a week, *Legionella* germs have been found on all surfaces. Within three weeks, biofilms start to form. *Legionella* bacteria live in the biofilms in correlation with atypical microbacteria, algae and amoeba. The main reason why it is virtually impossible to eliminate *Legionella* bacteria from the water mains completely, together with higher resistance of *Legionella* to chlorine, is the effectiveness of the shelter in microbacteria communities as well as their exploitation of mineral deposits on the inner walls of pipes [12]. The occurrence of the bacteria in the technical systems of buildings causes contamination, which may be systemic or local. Local colonization affects end parts of the system, such as faucets, discharges, showerheads, etc. and usually do not result in outbreaks. The reduction comes immediately by the removal of stagnant water and cleaning aerators or showerheads. Systematic colonization occurs if the whole distribution system of hot and cold water is evenly colonized. Here the chemical or thermal disinfection and risk management plan is needed for monitoring and control. Systemic contamination affects 48% of large buildings and installations and out of them, 56% reports an amount 104 colonies forming units (CFU)/L and 36% out of 102 to 104 CFU/L *Legionella* [2, 13]. To control *Legionella* colonization in hot water, firstly, the knowledge of the whole technical water service system is needed. Operation of the pipeline network should be provided not only by designers but also by installers and operators in direct relation to the results of microbiological examination and comparison with other parameters of hot water. Following the identification of types of material that is used for the pipelines and whole distribution systems, not only in terms of lifespan, appropriate hydraulic design, measurement and regulation, as well as the quality of potable cold water used for hot water heating. We prepared a study of the hospital distribution network comparing the influence of biocides on hot water polypropylene pipes (PPR pipes). The main goal was to define the relative role of pipe material as a risk factor and to suggest possible remediation, supported by case studies. The basic technical measures for the elimination of *Legionella* bacteria include physical treatment (thermal disinfection, use of UV emitters, ionization using Ag-Cu) and chemical treatment (use of bioconics based on hypochlorite solution, chlorine-containing anolyte, biocides based on other halogens, chlorine dioxide dosing, use of chlorine dioxide in the form of a stabilized solution and chlorine dioxide [14] produced in situ from chemicals by a generator, hydrogen peroxide with silver, peracetic acid and use of non-oxidizing biocides, etc. [15, 16]. For hygienic safety, there are also other possibilities in fighting against *Legionella*. While for hospitals with immunosuppressed patients (e.g. ARO, transplantation clinics) the presence of *legionella* bacteria must be permanently at zero, for other accommodation facilities, according to the Decree of the Ministry of Agriculture of the Czech Republic No. 252/2004 Coll., Annex 2, „A recommended value of 100 KTJ per 100 ml” is allowed. In the Slovak Republic, a permanent level of zero must be maintained in all cases [3].

3. Discussion and results

The investigation in studied hospital brings together interesting results from a combination of technical solutions and dosing of biocide and its effect on the inner surface of the pipes. The hot water system consisted of two storage heaters and a distribution system of an internal water supply provided through a polypropylene pipeline. Due to the microbiological problems of the hospital, hygienic safety was realized by producing chlorine dioxide „in situ” by a generator. After about three years, problems with the overall system occurred. The microbiological quality of the hot water was not fully ensured despite the fact that the doses according to the water meter were increased up to several times the limit according to the Decree of the Ministry of Health. No. 252/2004 Coll. as amended (the limit for chlorine dioxide is 0.80 mg per litre, and the dose of 3.5 mg per litre was used). So, the response was the gradual degradation of the inner surface of the plastic pipeline and the start of emergency situations. In 2011, samples from broken pipes were submitted for an electron microscope examination. The results of the

examinations are documented below (Figures 1, 2a and 2b): PPR DN 32 pipes after 40 months of operation - hot water was hygienically treated with chlorine dioxide produced “in situ”. As shown in Figure 1, the inner surface of the pipeline has no “protective” mineral deposit. Operating problems with frequent pipeline accidents had to be solved. On the basis of discussions held, a proposal for the transition to a method of hygienic safety using stabilized chlorine dioxide (sCHD 100L) was prepared. One litre of this liquid biocidal agent contains approximately 110 g of active ingredient.

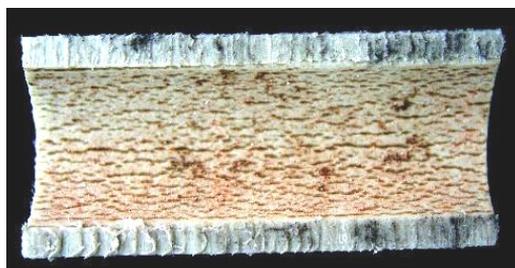


Fig. 1. View of inner surface of the pipe after examination - PPR DN 32 pipes after 40 months of operation

The liquid is supplied in canisters, and is safe to use and therefore, also safe to operate (which is a fundamental difference from the chlorine dioxide generator where the gas can escape into the atmosphere).

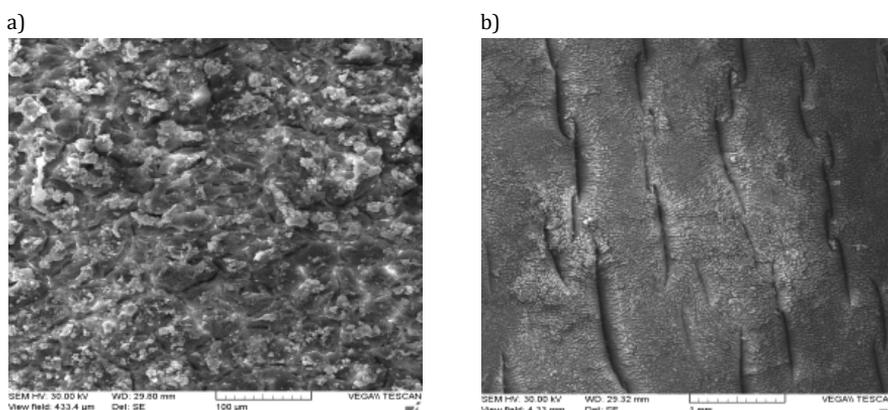


Fig. 2. PPR DN 32 pipes after 40 months of operation - hot water was hygienically treated with chlorine dioxide produced „in situ”: a) enlargement 500x; b) enlargement 50x

The dosing pump delivers to the hot water, according to the requirement and microbiological verification, between 10÷15 mL of sCHD 100L per 1,000 litres. Therefore, a biocide concentration limit of 0.8 mg of chlorine dioxide in a litre of hot water is in accordance to the Decree of the Czech Republic Ministry of Health No. 252/2004 Coll., and the microbiological quality of this hot water - i.e. the elimination of legionella bacteria and other bacteria - is permanently ensured. For information and comparison, the dose of sCHD 100L for the hygienic provision of cold drinking water is 3 mL per 1,000 litres.

In order to improve the hot water preparation and to ensure the sufficiency and stabilization of the hot water temperature, a proposal to change the connection of two hot water storage heaters, each with a volume of 1,000 litres (with a daily preparation of about 10 m³) per cascade was recommended. This, to the satisfaction of the operator, meant a stable hot water temperature was permanently ensured. The required temperature on both heaters was

the same. Consequently, this method of heating clearly demonstrates the benefits of using sCHD 100L biocide and its impact or influence on the inner surface of the PPR pipeline. It was assumed that after a longer period of time, the same analysis (EDA - Electron Spectrum Analysis on the Electron Microscope) would be performed on the samples of PPR pipelines behind the first and the second heaters and the cumulative hot water status will be different for each of the two heaters (even if the temperature is the same) and thus have a different impact on the internal surface of the PPR piping. This is because only the cold drinking water heated without the chemical influence comes to the first heater so that the PPR pipeline will be in the normal state. In the other heater, where hot water is supplied from the first heater, water is also supplied from the circulation of the hot water distribution system to which the sCHD 100L is dosed near the junction of this circulating pipe into the heater. The heater volume is mixed, then the hot water that is treated with sCHD 100L is discharged from the second heater into the distribution system. So, behind the first heater, the inner surface of the pipeline is affected only by the temperature and deposits from the heating, while behind the second heater the chemistry of hot water is influenced, at the same temperature, by the dosed biocide and the deposits are different. It is also necessary to take into account the total flow rates in each of the heaters. Thus, a specimen was taken out behind the first heater and three months later, (postponed from the point of view of operation), another specimen from behind the second heater.

Deposits on the inner surface of the pipes behind the first and the second heaters were different. It is important to note the fact that while, at the time of the test, about 15 thousand m³ of hot water passed through the pipe behind the heater one, the same volume of water passed through the pipeline behind heater two as well as, due to the circulation, an additional six times more water or about 90 thousand cubic meters. While the deposits behind heater one were minimal, behind heater two was a layer of about 0.8 mm thickness. The deposit layer protected the surface of the pipeline itself, and after its removal, the surface was found to be practically intact, so undoubtedly, the mineral deposits protect the surface of the pipeline resulting in hot water dosed with oxidizing biocide not reaching the surface of the pipeline. The surface behind heater two was in a much better condition than behind heater one where only the same temperature was applied. The inner surface of the PPR pipeline behind heater two was comparable to the outer surface condition of this pipeline.

4. Conclusions

Hygienic water audits should help hospitals to control the risk of legionella and choose the best solution in their case. The advantage of using ozone or chlorine dioxide is the high microbiological efficiency at low concentrations without affecting the sensory properties of the water. Even in their longer-term use, bacteria cannot be adapted and decontamination of the distribution system is possible without interrupting normal operation. The advantage of these systems is also the long service life and low maintenance costs.

Targeted measures, in this case, efforts to eliminate bacterial colonization where the internal water pipes are made of polypropylene pipelines, must be complex and not only vigorously eliminate bacteria, but also result in the whole, long life and trouble-free operation of the internal water supply system. PPR pipelines were discussed, but similar emergency situations are shown in copper piping where chlorine dioxide dosing „in situ” also leads to a decrease in the pH of the treated hot water and the requirement for the pH of water for copper pipes to be above 7.5 is usually not considered. A multi-year operating test of the impact on PPR pipes when using a biocide (a stabilized solution of chlorine dioxide where one litre has a content of 110 grams CO₂) has shown several aspects of the option. In particular, operational results are essential and it is important that the elimination of bacteria takes place completely and there is no damage to the piping, thus shortening its service life. In 2018 we started long term monitoring of legionella elimination through the combination of technical solutions and dosing with biocide in Slovak and Czech hospitals.

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Eliminacja czynników sprzyjających występowaniu bakterii *Legionella* w rurach z tworzyw sztucznych

STRESZCZENIE:

Głównym celem pracy jest przedstawienie wyników badań porównawczych wpływu biocydów na rury polipropylenowe używane do transportu gorącej wody. Badania przeprowadzono podczas długoletniego projektu, który polegał na określeniu zrównowazenia i bezpieczeństwa budynków. Istnieje wiele opraco-

wań, które traktują systemy dystrybucji wody jako źródło infekcji, przedstawiając jednocześnie metody eliminacji *Legionelli* z systemów wodnych. Obecność bakterii w systemach technicznych budynków powoduje zanieczyszczenie, które może być bardzo niebezpieczne, jeśli występują dobre warunki do namnażania. Główną przyczyną namnażania jest występowanie biofilmów na ścianach rur, a także wpływ materiału. Badania w wybranym szpitalu pozwoliły uzyskać interesujące rezultaty wpływu na wewnętrzną powierzchnię rur przy zastosowaniu połączenia rozwiązań technicznych oraz dozowania biocydów.

SŁOWA KLUCZOWE:

zanieczyszczenie bakteriami *Legionella*; materiał rury; systemy wodne; rozwiązania techniczne; biocyd