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Influence of the water temperature on the growth of *Legionella* in a test piping installation with different piping materials

Title
Influence of the water temperature on the growth of *Legionella* in a test piping installation with different piping materials

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Summary

In 2002, the influence of the piping material on the growth of Legionella bacteria was examined in a test piping installation (KWR report 02.090 February 2003). Water was run through piping of copper, stainless steel and cross-linked polyethylene (PE-Xa) according to a domestic tap usage pattern at a temperature of 37°C to create worst-case conditions. Under practical conditions, this temperature is almost only reached in mixed water systems. As a result of the old and current Legionella legislation in practice, many mixed water systems have been redesigned so that the relevance of this temperature has been further decreased. In this respect, it is important to examine the differences that can occur between the materials mentioned at the accepted normal temperatures in cold and hot water systems.

As a continuation of the research from 2002, research on the influence of water flows through piping of different materials (with a length of 15 metres) with water at different temperatures (25° C, 37° C, 55° C and 60° C) on the growth of Legionella was conducted in a newly designed and built test installation. The piping materials selected were: copper, stainless steel, chlorinated PVC (PVC-C) and a material based on cross-linked polyethylene (PEX). In the test piping installation, domestic water use is simulated according to NEN 5128 category 1 (basic pattern with one shower faucet).

The cultivation of Legionella bacteria in the new test piping installation required much time and effort, particularly in the copper piping. The inoculation of the copper piping needed to be repeated a number of times, in order to populate the installation in all cultivation phases. One of the important causes of this was the fact that circulation over a boiler system was not possible. This meant that after tapping, the optimal growth temperature of 37° C for Legionella could not be maintained.

During the research, it was established that relatively small “dead” piping parts (3 to 10 cm) in a water piping system near the sampling point could be responsible for an incorrect picture of the concentration of Legionella bacteria in the water piping system. The dead piping parts were located around the circulation pump that was used during the cultivation phases for the circulation of water over both test pipes of the same material. After the cultivation phase, the circulation pump was switched off and the valves were shut, which lead to the creation of dead-ends. Following discussion regarding dead-ends it was necessary to repeat parts of the research. After a cultivation phases, the dead-ends parts were completely removed.

In a general sense, there were few differences observed between the performances of the different materials in this research, with the exception of copper. During the whole study, the Legionella concentrations in the water phase and in the biofilm were lower with copper than with the other materials, with the exception of the research phase at 37° C.

A mixed water temperature of 25° C, in combination with a domestic tap pattern (including a shower faucet), over a period of nearly 100 days had little influence on the concentration of Legionella bacteria in the water phase. With stainless steel, PVC-C and PE-X, the Legionella bacteria could survive under these conditions in both the biofilm and in the water phase. At the end of the research period, Legionella was no longer detectable with copper (in the biofilm and in the water phase).

A mixed water temperature of 37° C, in combination with a domestic tap pattern (after a cultivation period), with the different materials resulted in the stabilisation of the Legionella concentrations in the water phase between $1*10^4$ and $1*10^5$ cfu/l.

A mixed water temperature of 55° C, in combination with a domestic tap pattern with stainless steel, PVC-C and PE-X, resulted in very little to no killing of Legionella bacteria in the water phase (maximum of 0.57 log reduction in 18 days). Under these circumstances, Legionella fully disappeared in the copper pipes researched. A mixed water temperature of 60°C, in combination with a domestic tap pattern with stainless steel, PVC-C and PE-X, also resulted in complete disinfection. The differences between the materials were very small here (2.8 log reduction in 6 days). The calculated log reductions at 55° C and 60° C show that the Legionella bacteria in the biofilm can (partly) recover in the periods between flow intervals. The longest period in which no water flow took place was 7 hours (night period). Water flow took place for a total of 36 minutes daily, the longest period being 13.3 minutes (shower faucet).

This research shows the accuracy of the generally formulated requirement in NEN 1006 which states that in a collective hot-water installation a temperature of at least 60° C must be reached at the draw-off points to achieve sufficient thermal disinfection in the piping of the installation. The type of piping material is then irrelevant. At the same time, this research shows that the comparable requirement of 55° C for hot water in domestic installations, with the exception of situations where copper is applied, probably results in insufficient thermal disinfection.

On the basis of this research, it is accordingly recommended to change the norm of 55° C introduced by NEN 1006 and the Bouwbesluit (Building Law) for domestic installations to 60° C.

13 Conclusions

The following conclusions are based on the research described in this report, where the development of Legionella bacteria was explored in a drinking water flow originating from PS Tull in ‘t Waal (Nieuwegein supply area) in a test piping installation with different piping materials. As a result of the complexity of this test piping installation and the sampling, to answer the research questions and draw up the below conclusions, particular attention was devoted to the trends in the results and not so much the separate results themselves.

1. The cultivation of Legionella bacteria in the new test piping installation required much time and effort, particularly in the copper piping. The inoculation of the copper piping needed to be repeated a number of times in order to populate the installation in all cultivation phases. This was probably attributable to the inability of recirculation over the boiler in this test piping installation.

2. A mixed water temperature of 37° C, in combination with a domestic tap pattern (after a cultivation period), with the different materials resulted in the stabilisation of the Legionella concentrations in the water phase between $1*10^4$ and $1*10^5$ cfu/l. These results can be influenced by the presence of ‘dead’ piping parts (see conclusion 4).

3. In a general sense, there were few differences observed between the performances of the different materials in this research, with the exception of copper. During the whole study, the Legionella concentrations in the water phase and in the biofilm were lower with copper than with the other materials, with the exception of the research phase at 37° C (research phase 1). Furthermore, thermal disinfection was only adequate with copper, when water was flowing through the copper piping at a temperature of 55° C, according to a domestic tap usage pattern.

4. Relatively small “dead” piping parts in the water piping system near the sampling point were responsible for an incorrect picture of the Legionella bacteria concentration in the water piping system. These piping parts (with a length of 3 to 10 centimetres) were located between the pipes being tested and the valves in the piping to the circulation pump. In the dead piping parts, the concentrations of Legionella bacteria were found to be $2*10^6$ cfu/l. In the continuation of the research, these dead piping parts were consistently removed after a cultivation phase. (The conclusions below are accordingly no longer influenced by this).

5. A mixed water temperature of 25° C, in combination with a domestic tap pattern (including a shower faucet), over a period of nearly 100 days had little influence on the concentration of Legionella bacteria in the water phase. With stainless steel, PVC-C and PE-X, the Legionella bacteria could survive under these conditions in both the biofilm and in the water phase. At the end of the research period, Legionella was no longer detectable with copper (in the biofilm and in the water phase).

6. A mixed water temperature of 55° C, in combination with a domestic tap usage pattern with stainless steel, PVC-C and PE-X, resulted in very little to no killing of Legionella bacteria in the water phase (maximum of 0.57 log reduction in 18 days). Under these circumstances, Legionella completely disappeared in the copper pipes researched. A mixed water temperature of 60°C, in combination with a domestic tap pattern with stainless steel, PVC-C and PE-X, also resulted in complete disinfection. The differences between the materials were very small here (2.8 log reduction in 6 days).

7. The calculated log reductions at 55° C and 60° C show that the Legionella bacteria in the biofilm can (partly) recover in the periods between flow intervals. The longest period in which no water flow took place was 7 hours (night period). Water flow took place for a total of 36 minutes daily, the longest period being 13.3 minutes.

8. This research shows the accuracy of the generally formulated requirement in NEN 1006 which states that in a collective hot-water installation a temperature of at least 60° C must be reached at the draw-off points to achieve sufficient thermal disinfection in the piping of the installation. The type of piping material is then irrelevant. At the same time, this research shows that the comparable requirement of 55° C for hot water in domestic installations ,with the exception of situations where copper is applied, probably results in insufficient thermal disinfection.

The hypothesis that “with regard to the presence of Legionnaire’s disease, it does not matter which material is applied in a water piping installation, as long as one abides by the thermal control concept” (see paragraph 1.3) is corroborated in this research to the extent that one assumes the maintaining of temperatures lower than 25° C and higher than 60° C. In this situation, the research in question has shown that the differences between the materials are relatively small. At 60° C (with a domestic tap pattern), Legionnaire’s disease cannot survive in the biofilm with any of the materials (and in the water phase). At 25° C, Legionnaire’s disease can indeed survive in all materials, except copper, but there is no longer any growth and the concentrations in the biofilm are low.

This observation applies to all collective water piping installations in the Netherlands in which the thermal control concept is successfully applied and NEN 1006 compliancy is met. Both aspects are required for optimal Legionella control. Therefore, for collective water piping installations, no change in policy is required based on this research.

For domestic installations with 55° C at the draw-off points, it does appear, from this research, that the choice of the piping material can be of relevance. For these small-scale water pipe installations there is, however, no specific policy for Legionella prevention because the government does not consider the Legionella risk in these installations to be great enough. However, in past years, Legionella bacteria have regularly been found in domestic installations (where, in a number of cases, they have also been identified as an infection source) and therefore it is recommended to change the norm of 55° C introduced by NEN 1006 and the Bouwbesluit (Building Law) for this category to 60° C.