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# Evaluation of the effectiveness of the Pastormaster method for disinfection of legionella in a hospital water distribution system

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**Summary** The Pastormaster method consists of heating the water of hospital distribution systems at a specific point to a sufficient temperature for a minimum amount of time to eradicate legionella. The object of this study was to evaluate the effectiveness of the Pastormaster method for legionella disinfection in a hospital environment. A two-phase procedure was performed: hydraulic optimization of the water supply circuit, and implementation of the Pastormaster method. Water samples were taken at 10 representative points in the hospital hot-water system and cultured microbiologically. Other physical and chemical measurements were also determined. Implementation of the Pastormaster method and correction of the deficiencies identified during a hydraulic system audit confirmed the absence of legionella in the hospital water distribution system. The combination of implementation of the Pastormaster method and conduction of a hydraulic audit designed to identify and remedy any possible problems in water circulation is effective in minimizing the risk of legionella contamination in hospital water distribution systems.


## Introduction

The presence of legionella in hospital facilities, particularly in hot-water distribution systems and cooling towers, is an increasing problem,[1-3] and

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calls for the adoption of rigorous preventive measures. A recent publication on the findings of a study carried out in 20 hospitals[4] showed that over 80% of their water supplies were contaminated with *Legionella* spp.

Studies have shown an association between the presence of legionella in hospital hot-water systems and cases of legionellosis.[5-9] However, there are reports in which no cases of nosocomial legionellosis have been detected in spite of contamination of hospital hot-water systems over prolonged periods.[10] In contrast, however, other studies have shown that the contamination level of hospital water supplies with legionella is correlated with the incidence of nosocomial Legionnaires' disease.[11] It has been claimed that the number of points in the system testing positive for legionella is a better predictor of risk for Legionnaires' disease than the quantitative levels found at any given point.[7]

It is essential for hospitals to have an effective method of disinfection that guarantees the absence of legionella from their water distribution systems. A recently approved specific regulation in Spain establishes the sanitary and hygiene criteria for the prevention and control of legionellosis, and also stresses the need for an effective preventive tool. Various methods for disinfecting facilities are currently in use. They can be divided into localized methods, including ultraviolet light, ozonation and instantaneous heating systems, and systemic methods applied to the entire water supply, such as thermal eradication, hyperchlorination and copper–silver ionization. However, not all of these methods have proven to be consistently effective.[12-18] There is no ideal method for ensuring total disinfection, and it is accepted that eliminating legionella once it has colonized a water supply is extremely difficult.[19-21]

To guarantee the absence of legionella from a water system, three determining factors are usually considered to be important:

legionella must be prevented from entering the system;
hot-water systems must be kept at temperatures hot enough to prevent growth and multiplication; and
continuous circulation of hot-water supplies must be ensured, thus preventing any possible stagnation or dead-end areas.

Among the various methods available is a procedure known as Pastormaster, based on the continuous pasteurization of hospital hot water. Essentially, it consists of heating the water at a specific point in the distribution system to a sufficient temperature for a minimum amount of time (70 °C for a minimum of 3 min) to eliminate *Legionella* spp. In addition, it automatically maintains the water supply at a constant temperature high enough (over 50 °C) to guarantee the absence of legionella and other micro-organisms. From the time of installation, a period of two weeks is deemed necessary to disinfect the entire system and to prevent any possible re-infection at any point within the system.

We conducted an in-hospital study to evaluate the practical effectiveness of the method. The hospital was chosen on the verified presence of legionella in the return lines of the water distribution system. Although this does not pose a direct risk to hospitalized patients, the presence had persisted after several standard treatments using heat shock and chemical methods. The principal objective of this study was to evaluate the effectiveness of the Pastormaster method as a means of disinfecting the hot-water system of a hospital contaminated with *Legionella* spp.

## Operating principle of the Pastormaster method

The Pastormaster system is a global treatment intended to eradicate legionella from hot-water systems. To achieve this, a hydraulic diagnosis is first conducted on the water system to determine whether there are any areas of potential malfunction, dead-end sections or areas of risk. Afterwards, a physical, chemical and bacteriological examination of the water is carried out using water samples drawn from areas of risk in the water supply system. Initial results indicate whether there are legionella in the distribution system.

The hydraulic system is adapted and monitored to ensure good circulation of water to all parts of the system, and the Pastormaster unit is connected to the system's boiler. The hot-water system is then subjected to at least two weeks of remedial treatment, which involves pasteurizing the water at 70 °C while maintaining all sections of the system above 55 °C.

At the end of this phase, a repeat survey of the water is conducted. If legionella contamination is still present, a new and shorter remedial phase is initiated. If legionella has been eradicated successfully, the system is operated at a regular preventive level at a minimum temperature of 50 °C and the pasteurization temperature is reduced to 66 °C.

Water from the public distribution system (Figure 1) at approximately 15 °C is combined in a

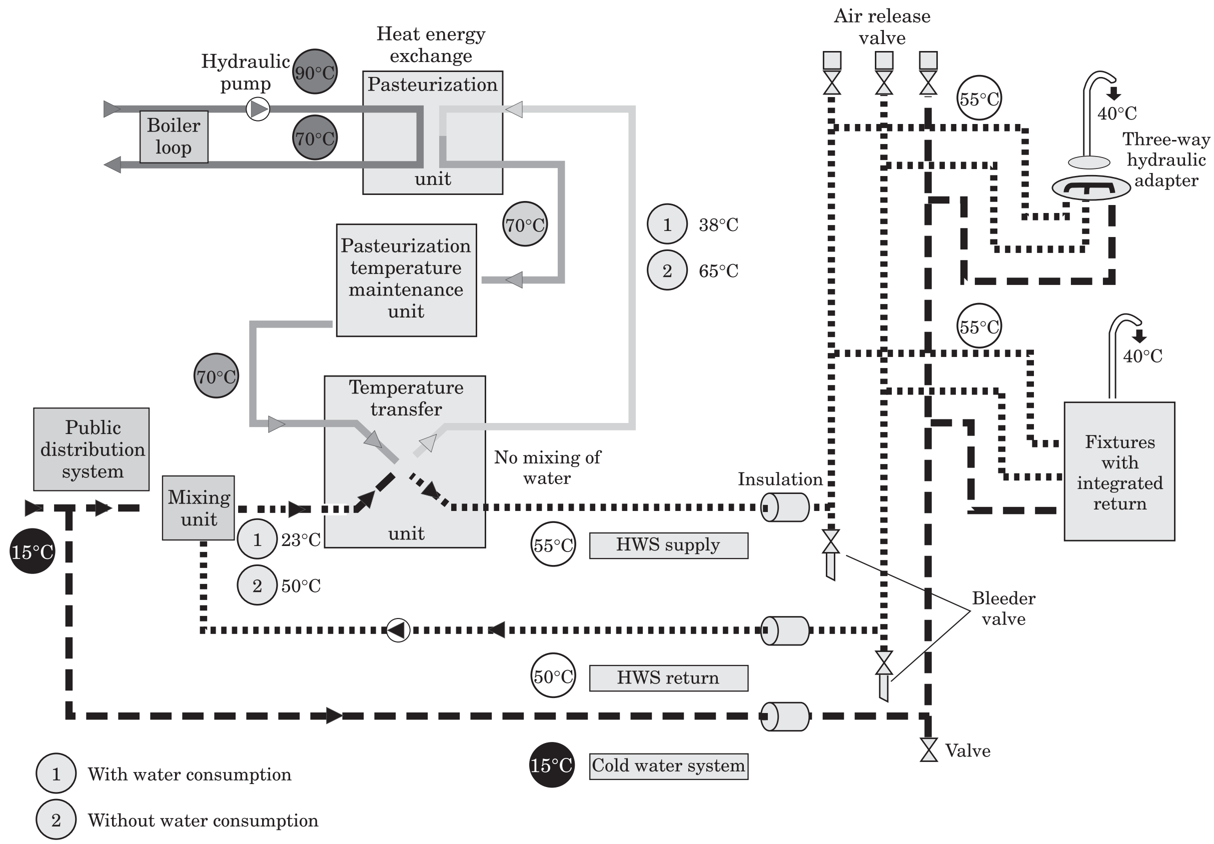


**Figure 1** Diagram of hospital hot-water system (HWS).

'mixing unit' with hot water from the return loop (50 °C). It is then heated in a cross-flow 'tempera-temperature transfer unit', taking advantage of the thermal energy produced by the pasteurized hot water, while at the same time preventing the temperature of the water in the distribution system supply loop from exceeding 60 °C. Unlike the mixing unit, there is no mixing of water in the temperature transfer unit, only heat exchange.

The heated water then enters a 'pasteurization unit', where it reaches a temperature of 70 °C through energy exchange (no mixing) with water from the primary boiler loop at a minimum temperature of 80 °C. After the water flows out of the pasteurization unit, it is kept at 70 °C in the 'pasteurization temperature maintenance unit' for a minimum of 3 min to ensure destruction of all vegetative bacteria.

After all the legionella and other vegetative bacteria present have been killed, the water runs back to the cross-flow temperature transfer unit, where it flows at 55 °C to the supply loop of the water distribution system. Thus there is a process of continuous hot-water pasteurization ensuring continual elimination of legionella and other micro-organisms.

## Scope of the study

Gorliz Hospital is a mid- to long-term-care facility for patients in need of recuperation or rehabilitation, in addition to general internal medicine healthcare services. The most common diagnoses of patients at Gorliz Hospital are: the sequelae of cerebral vascular accidents and head injuries; the sequelae of hip fractures; early rehabilitation following orthopaedic surgery; and any other functional deficiency that can be improved through rehabilitation. Since 1993, the hospital has also had a 23-bed palliative care unit.

The hospital facility comprises three buildings (Figure 2).

The main, three-storey building houses the patient care units, admissions areas, consulting rooms, gymnasium, etc.

The swimming pool structure consists of a seawater pool, patient changing rooms, gymnasia, physical therapy booths, etc.

The general services building houses the kitchen, the staff canteen, staff changing rooms and warehouses.

The hospital hot-water system of the main

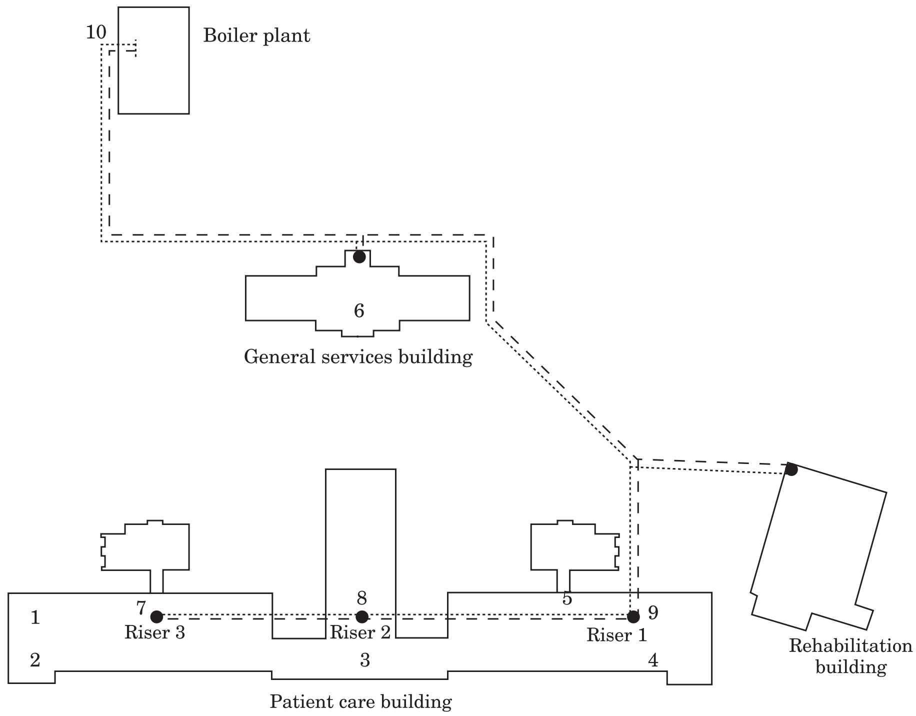


**Figure 2** Diagram of Gorliz Hospital. Sample collection points: 1, washbasin tap, room 326 (third floor, water riser 3, tail-end); 2, washbasin tap, room 226 (second floor, water riser 3, tail-end); 3, washbasin tap, office (third floor, water riser 2, central section); 4, washbasin tap, room 225 (third floor, water riser 1); 5, shower head in handicapped changing room, swimming pool; 6, most distal shower head, staff changing room; 7, water riser 3 (return); 8, water riser 2 (return); 9, water riser 1 (return); 10, general return loop.

patient care building has three water risers; for the purposes of this study, these have been numbered 1-3, beginning with the wing nearest to the accumulator (Figure 2). The boiler plant provides heating and hot water to the entire hospital facility. An underground circuit ensures proper distribution. Hot water is produced using heat exchangers with water supplied from the primary water loop of the hospital boiler plant and the general distribution system of the municipality of Gorliz. The general supply and return lines from the boiler plant to the patient care building are of stainless steel, while the pipes within the patient care building are made of copper.

## Methods

An experimental study was developed to assess a procedure performed on the hot-water distribution system of the hospital. The procedure had the following two phases.

### Hydraulic optimization of the water supply circuit

In this first phase, calculations were made of the total flow rate through the loop and the flow rates in each area of the hospital based on the number of water extraction points (i.e. taps). Differences in the supply and return water temperatures were measured at various points in the system, starting with the boiler plant and moving in the direction of water flow to the patient care building. The temperature of water drawn from the least effective taps and the amount of time it took to reach those temperatures was also recorded. Finally, a list was drawn up of all stagnant areas and dead-end sections in the system.

### Implementation of the Pastormaster method for legionella disinfection

In the second phase, the Pastormaster unit was installed in the heating system, replacing the existing storage heater, which was set aside as an emergency backup.

To evaluate the effectiveness of each of the phases involved in the procedure, hospital water samples were collected on the following four separate occasions.

Before initiating the procedure: preliminary system diagnosis.

After the implementation of any corrective measures determined during phase 1 of the hydraulic audit.
After installation of the Pastormaster unit.
One month after taking the third set of water samples to assess the circuit after stabilization.

A work group was created comprising representatives of the Hospital Management and Maintenance Service; the Microbiology Service at Basurto Hospital; the office of J.J. Boiffier (in charge of the hydraulic audit); Physics Development (Pastormaster marketing agents); and the Department of Architecture and Engineering, and the Department of Health Care, Osakidetza—Basque Health Service.

The water samples were taken from 10 previously selected points that were representative of the entire hospital hot-water supply system. Criteria for determining sample sites were based on representivity of the water distribution system and the potential risk of transmission to patients (Table I and Figure 2). These 10 samples were taken on each of the four sample collection dates at 8:00 a.m. and 10:30 a.m. in order to study the system during minimum (basal) and peak demand. The hot water was sampled at the predetermined points by collecting the first litre of water that came out of the tap when opened. Sterilized sample bottles were used, with sodium thiosulphate at a concentration of 0.5 cc of 0.1 N solution per litre of water. The samples were processed at the Basurto Hospital Microbiology Laboratory within 6 h of collection using the technique of Leoni and Legnani.[22] The lower limit for the detection of legionella was 50 cfu/L.

We also measured the chlorine level at each of the sample points (colorimetric method, DPD/phenol red, MERCK) and the time required for the hot-water system to reach 50 °C. To reduce variability to an absolute minimum, the same electronic thermometer was used to take all temperature measurements.

## Results

In November 2002, the work group conducted an initial tour of the hospital to study the characteristics of the water supply system and determine any legionella risks in the hot-water distribution circuits. The study included an analysis of the physical and chemical properties of the water, the level of corrosion in the system, the condition of water circulation in interior loops, and the water temperatures in four areas: hospital hot-water heater; general distribution system; interior loops; and water outlets in the various buildings.

An 11 °C loss between the supply temperature (59 °C) and the return temperature (48 °C) was found. This relatively significant loss may be due to the 350-m length of the system. It may also be due to the pipe insulation being faulty and inadequate. There was a difference between the water temperature in the patient care building return line and the general return loop. The temperature in the general loop, 48 °C, was greater than in the return lines from the three water risers in the patient care building, despite the greatest demand for hospital hot water being generated there. There was also a difference between the water temperature as it entered the patient care building (54 °C) and the supply temperatures at each of the three water risers located in the building (51 °C, 48 °C and 44 °C). Lastly, difficulties were observed in the water supply to the upper floors of the patient care building. It took more than 4 min for the hot water to reach 50 °C at the most distal water intakes, whereas the same temperature was reached more quickly at the initial part of the loop (the changing room and swimming pool facilities).

The conclusions of the initial study were as follows. (1) The temperature of the general return loop measured at the boiler plant (48 °C) was attributable to the return lines of the changing room and swimming pool facilities, not to the entire circuit, since the return flow in the water risers in the patient care building was weak. (2) The changing room and swimming pool facilities were overfed, while the patient care building, risers 1 and 3 in particular, were underfed. (3) The hot-water circulation on the second and third floors of the patient care building was very deficient. In summary, the condition of the patient care building

**Table I** Water sample collection points

| | Sample collection point |
|---|---|
| 1 | Washbasin tap, room 326 (3rd floor, water riser 3, tail-end) |
| 2 | Washbasin tap, room 226 (2nd floor, water riser 3, tail-end) |
| 3 | Washbasin tap, office (3rd floor, water riser 2, central section) |
| 4 | Washbasin tap, room 225 (3rd floor, water riser 1) |
| 5 | Shower head in handicapped changing room, swimming pool |
| 6 | Most distal shower head, staff changing room |
| 7 | Water riser 3 (return) |
| 8 | Water riser 2 (return) |
| 9 | Water riser 1 (return) |
| 10 | General return loop |

was considered to be conducive to the growth of legionella (low temperature and insufficient flow), especially in the upper stories.

On 18 December 2002, the first 20 water samples were collected from the 10 points previously chosen by the work group, and analysed for the presence of legionella prior to any action taken on the water supply system. The analysis (Table II) revealed legionella in the return lines of risers 1 and 3 and in the general return loop. The difference in temperature between the return in riser 3 and the third floor indicated faulty circulation, rendering effective legionella eradication treatment impossible. The findings showed that the return flow distribution was defective.

The hydraulics engineer calculated the theoretical flow rate for optimal water circulation in the different buildings, water risers, etc. The water system layout and the number of points where water could be drawn off (taps and showerheads) were taken into consideration as determinants of water demand in each area. These calculations demonstrated a significant surplus flow rate and a lack of power in the pump on the existing return loop. A large imbalance between supply flows and actual needs was also detected.

The existing return pump was therefore replaced with one better suited to this system, and 5-μm valves were installed on the return loop in each building and area of the hospital to control flow and distribution.

On 5 March 2003, the second set of 20 water samples was collected. The objective was to assess the effect of the first phase of the procedure, i.e. the hydraulic optimization of the water supply circuit, after installing the valves designed to adjust the flow in each area. Table III shows that this resulted in a significant reduction in legionella counts, although when there was minimum demand, contamination persisted in risers 1 and 3 (10 000 and 4500 cfu/L) and in the general return loop (7500 cfu/L); at peak demand, no legionella was detected in riser 1. There was an appreciable increase in temperatures reached at the different sampling points, with the exception of riser 3 and sample collection point 1.

After installing the Pastormaster unit, the temperature was maintained at 65 °C for eight days for remedial treatment. Following this period, efforts were made to keep the temperature of the supply water at 60 °C and the return water at a minimum of 50 °C.

On 24 April 2003, the third set of 20 water samples was collected as previously. The objective was to assess the effect of the second phase of the procedure, i.e. the implementation of the Pastormaster method for legionella disinfection. Table IV shows the absence of legionella in riser 3 at both minimum and peak demand. Legionella persisted in riser 1 and in the general return loop, although at peak demand, the count fell to 1950 cfu/L compared with 8350 cfu/L in the second sampling.

At this point, an area of possible stagnation was identified in a one-way supply loop in water riser 1 with the potential for recontamination. It was decided to eliminate the loop and to heat-and-flush all outlets fed by it for at least 30 min.

An area of stagnation was also found in a short

**Table II** Findings from samples taken on 18 December 2002. Prior to any action taken.

| Sample collection point | Minimum demand (7:45 a.m.) | | | Peak demand (10:30 a.m.) | | |
|---|---|---|---|---|---|---|
| | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) |
| 1 | 42°/2 min | <0.1 | <50 | 46°/2 min | - | <50 |
| 2 | 53°/1 min | <0.1 | 50 | 51.5°/1 min | - | <50 |
| 3 | 48°/1 min | <0.1 | <50 | 54°/30 s | 0.3 | <50 |
| 4 | 60°/1 min | <0.1 | <50 | 58°/1 min | 0.2 | <50 |
| 5 | 56°/30 s | 0.1 | <50 | 55.5°/30 s | 0.2 | <50 |
| 6 | 60°/1.5 min | - | <50 | 60°/1.5 min | - | <50 |
| 7 | 53°/-[a] | 0.1 | 18 000 | 51°/-[a] | - | >50 000[b] |
| 8 | 56°/-[a] | 0.2 | <50 | 56°/-[a] | 0.5 | <50 |
| 9 | 58°/-[a] | 0.3 | 15 000 | 55.5°/-[a] | 0.5 | 400 |
| 10 | 50°/-[a] | 'not measured' | <50 000 | 50°/-[a] | 'not measured' | 10 000 |

[a] The time it took to reach this temperature is not shown here since these readings were taken from external sensors which monitor temperatures continually.
[b] Approximate count due to converging growth.

**Table III** Findings from samples taken on 5 March 2003 after corrective measures

| Sample collection point | Minimum demand (7:45 a.m.) | | | Peak demand (10:30 a.m.) | | |
|---|---|---|---|---|---|---|
| | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) |
| 1 | 46°/2 min | 0.2 | <50 | 50°/2 min | 0.4 | <50 |
| 2 | 54°/1 min | 0.4 | <50 | 55°/30 s | 0.5 | <50 |
| 3 | 50°/1 min | 0.3 | <50 | 55°/30 s | 0.4 | <50 |
| 4 | 54°/2 min | 0.4 | <50 | 57.5°/30 s | 0.4 | <50 |
| 5 | 54.5°/30 s | 0.4 | <50 | 56.5°/30 s | 0.4 | <50 |
| 6 | 60°/1 min | 0.4 | <50 | 57°/1 min | 0.4 | <50 |
| 7 | 50°/-[a] | - | 4500 | 50°/-[a] | - | 2750 |
| 8 | 58°/-[a] | - | <50 | 58°/-[a] | - | <50 |
| 9 | 57°/-[a] | - | 10 000 | 53°/-[a] | - | <50 |
| 10 | 50°/-[a] | - | 7500 | 49°/-[a] | - | 8350 |

[a] The time it took to reach this temperature is not shown here since these readings were taken from external sensors which monitor temperatures continually.

section of pipe in the general return loop occluded by a valve no longer in use, which could explain the presence of legionella in the general return loop (sample collection point 10). The obsolete section of pipe was eliminated immediately.

On 3 June 2003, the fourth and final set of water samples was collected from the same points as before to determine whether the circuit had stabilized. Table V shows the elimination of legionella from riser 1 at both minimum and peak demand. The microbiological results from the water samples taken at both minimum and peak demand times (<50 cfu/L) revealed the total absence of legionella from the entire circuit.

## Discussion

Legionella contamination in a hospital hot-water distribution system is a potential risk for hospitalized patients, particularly those in high-risk groups.[6,23,24] Several studies have discussed legionella outbreaks in hospitals,[6,19,20,24-27] and it is likely that these form only part of the total number. Controlling an outbreak of nosocomial Legionnaires' disease calls for a rapid response, which in practice means either hyperchlorination or heat shock. Generally, these immediate disinfection methods reduce levels of legionella contamination significantly; however, they only provide a

**Table IV** Findings from samples taken on 24 April 2003 after installation of Pastormaster

| Sample collection point | Minimum demand (7:45 a.m.) | | | Peak demand (10:30 a.m.) | | |
|---|---|---|---|---|---|---|
| | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) |
| 1 | 50°/1 min 20 s | 0.1 | <50 | 50°/1 min 30 s | 0.2 | <50 |
| 2 | 50°/1 min 15 s | 0.1 | <50 | 50°/1 min | 0.2 | <50 |
| 3 | 50°/20 s | 0.1 | <50 | 50°/1 min | 0.2 | <50 |
| 4 | 50°/55 s | 0.1 | <50 | 50°/35 s | 0.2 | <50 |
| 5 | 50°/15 s | 0.1 | <50 | 50°/14 s | 0.2 | <50 |
| 6 | 50°/1 min 30 s | 0.1 | <50 | 50°/35 s | 0.2 | <50 |
| 7 | 48°/-[a] | - | <50 | 49°/-[a] | - | <50 |
| 8 | 51°/-[a] | - | <50 | 51°/-[a] | - | <50 |
| 9 | 51°/-[a] | - | 20 000[b] | 51°/-[a] | - | <50 |
| 10 | 53°/-[a] | - | 20 000[b] | 52°/-[a] | - | 1950 |

[a] The time it took to reach this temperature is not shown here since these readings were taken from external sensors which monitor temperatures continually.
[b] Approximate count due to converging growth.

**Table V** Findings from samples taken on 3 June 2003 one month after installation of Pastormaster

| Sample collection point | Minimum demand (7:45 a.m.) | | | Peak demand (10:30 a.m.) | | |
|---|---|---|---|---|---|---|
| | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) | Temperature/ time to reach this temperature | Cl (mg/L) | *Legionella* spp. (cfu/L) |
| 1 | 50°/1 min | 0.1 | <50 | 47°/1 min 15 s | 0.2 | <50 |
| 2 | 50'°/1 min | 0.1 | <50 | 50°/30 s | 0.2 | <50 |
| 3 | 50°/1 min 20 s | 0.1 | <50 | 50°/40 s | 0.2 | <50 |
| 4 | 50°/45 s | 0.1 | <50 | 50°/30 s | 0.2 | <50 |
| 5 | 50°/5 s | <0.1 | <50 | 50°/15 s | 0.2 | <50 |
| 6 | 50°/1 min 20 s | 0.2 | <50 | 50°/50 s | 0.2 | <50 |
| 7 | 51°/-[a] | - | <50 | 51°/-[a] | - | <50 |
| 8 | 52°/-[a] | - | <50 | 51°/-[a] | - | <50 |
| 9 | 52°/-[a] | - | <50 | 52°/-[a] | - | <50 |
| 10 | 55.5°/-[a] | - | <50 | 56.1°/-[a] | - | <50 |

[a] The time it took to reach this temperature is not shown here since these readings were taken from external sensors which monitor temperatures continually.

short-term solution since levels often rise again over time.[28]

Various disinfection methods are available including thermal eradication,[17,23,28,29] hyperchlorination[13,16] and copper-silver ionization.[12,16,17,30,31] Most experts agree that there is no one ideal method, and that sometimes a combination of different methods is needed to increase effectiveness and provide safeguards. In this respect, the Pastormaster method is of interest. Although the system is based on the traditional method of increasing the water temperature, it is new in that disinfection takes place continually at a specific point in the circuit where water enters and returns to the system, and in addition, it automatically maintains the water supply at a constant temperature that is hot enough to ensure the long-term elimination of legionella and other micro-organisms.

This experience suggests that every hospital should conduct a hydraulic audit to assess the quality of water circulation throughout the distribution system. The study should include the following: the time it takes for hot water to reach 50 °C at distal sites; calculation of the flow rates required for optimal water circulation in the different buildings, water risers, etc., taking into account the layout of the water system and the number of outlets; and the installation of any valves needed to adjust the flow to each area based on calculations made a priori. The aim of the audit is to optimize the water supply system. New pipes should be made of materials able to withstand temperatures over 70 °C, and in distal sites (e.g. taps), it is advisable to install return lines that guarantee continuous water circulation, thus preventing stagnant or dead-end areas.

After the Pastormaster method was implemented at Gorliz Hospital, there was a significant reduction in the number of areas contaminated with legionella, and after implementing all the remedial actions at the facility, all the water samples showed that legionella had been completely eradicated from the hospital's hot-water system.

The finding of an area of stagnation following the third sampling was illustrative in two respects. Firstly, that any part of the circuit with stagnant water, no matter how small, can be a source of infection, even when hot-water temperatures in the various points of the circuit are adequate. Secondly, that continuous pasteurization appears to be effective, since the microbiological cultures from the samples collected at distal sites and the supply loop were negative for legionella.

The microbiological analyses indicate that the implementation of this pasteurization method, combined with a hydraulic audit aimed at identifying and remedying any potential circulation problems, is effective in guaranteeing minimal risk of legionella contamination in a hospital hot-water system. Medium- and long-term follow-up on this method is essential to confirm the positive findings of the first experience of this type carried out in Spain. We should also bear in mind that in order for the Pastormaster method to be fully effective, any defects in the hydraulic system must first be corrected.

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