Journal of Water Process Engineering 13 (2016) 196–205

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

Efficacy of copper-silver ionisation in controlling *Legionella* in complex water distribution systems and a cooling tower: Over 5 years of practical experience

Nikolaj Walraven[a,*], Wiebe Pool[b], Conrad Chapman[b]

[a] GeoConnect, Meester Dekkerstraat 4, 1901 PV, Castricum, The Netherlands
[b] Holland Water, Nijendal 52, 3972 KC Driebergen, The Netherlands

ARTICLE INFO

Article history:
Received 9 May 2016
Received in revised form
15 September 2016
Accepted 22 September 2016

Keywords:
Copper
Silver
Ionisation
Efficacy
Legionella
Water
Treatment
Complex
Distribution
Systems
Cooling
Towers

ABSTRACT

Control of *Legionella* bacteria in water distribution systems and cooling towers is an increasing priority for health authorities world wide. Treatment of *Legionella* contaminated water is essential, and a well-recognized method to control *Legionella* is copper-silver ionisation. In this study the efficacy of copper-silver ionisation in 4 complex drinking water distribution systems (1 juvenile institution, 2 hotels and 1 penitentiary) and 1 cooling tower was studied over a period of at least 5 years. Dosing of 400 ± 200 μg/l copper and 40 ± 20 μg/l silver proved to be effective to control, abate and eradicate *Legionella* bacteria at all 5 treated locations. *Legionella* reoccurred only incidentally and temporarily (in 3.8% of the measurements; 27 out of 718), most likely due to insufficient flushing of the water distribution systems; in the case of the cooling tower technical malfunction of the tower itself and non-optimal positioning of the copper-silver ionisation system in the cooling tower. There was no evidence that pH (7.8–8.6) and hardness (1.4–2.3 mmol/l) of treated drinking and cooling water influenced the efficacy of copper-silver ionisation.

1. Introduction

Legionella bacteria, usually *L. pneumophila* serogroup 1, can cause Legionnaires' disease. This disease was first described in the 1970s [1]. *Legionella* bacteria were identified as the cause of a pneumonia outbreak at the 1976 American Legion Convention in Philadelphia. 221 of those attending the Convention became ill with pneumonia and 34 of those affected died [2]. The responsible bacterium was named *Legionella pneumophila* to honour the stricken legionnaires and pneumophila from the Greek word meaning 'lung loving'. The pneumonia contracted was named Legionnaires' disease [3].

An estimated 8000 to 18,000 people get Legionnaires' disease in the United States each year [4]. However, many infections are not diagnosed or reported, so this number may be higher [5,6]. Legionnaires' disease can be very serious and can cause death in up to 5%–30% of cases [6–8]. People most at risk of getting sick from the bacteria are older people (usually 50 years of age or older), as well as people who are current or former smokers, or those who have a chronic lung disease (like emphysema) [9].

In the period of 10 years, between 1995 and 2005, around 32,000 cases of Legionnaires' disease and around 600 outbreaks were reported to the European Working Group for Legionella Infections [10]. The 35 Countries participating in EWGLI reported in the period of 1 year, 2005–2006, a total of 11,980 cases, therefore, showing a continued increase in reported cases compared with earlier years [10]. 377 cases of these 11,980 reported cases were fatal, giving a case fatality rate of 6.6% [10].

Legionella contamination can, amongst others, occur in distribution systems of drinking water, cooling water (e.g., in cooling towers), fountains and swimming pools. In particular, aerosolised water droplets from such contaminated water systems pose significant health risks to people [11]. Because *Legionella* can cause devastating disease in humans, it is important to prevent water systems from becoming contaminated and to control the risk of exposure [1]. The control of hazardous pathogens, such as *Legionella*

* Corresponding author.
E-mail address: n.walraven@geoconnect.nl (N. Walraven).

http://dx.doi.org/10.1016/j.jwpe.2016.09.005
2214-7144/

in water distribution systems and cooling towers, is therefore a priority for health authorities world wide and leading to increasingly onerous legionella risk assessments and control requirements being placed on owners and operators of water distribution systems.

Treatment: of contaminated water is essential, and a number of approaches are commonly used such as superheat-and-flush, (hyper)chlorination, point-of-use filtration and treatment with ultraviolet (UV) light.

A well-recognized method to control *Legionella* is copper-silver ionisation [e.g.,12–15]. The method is based on channelling the water through a device that applies a DC current through copper and silver electrodes. The positively charged copper and silver ions thus released, form electrostatic bonds with negatively charged sites on bacterial cell walls. These electrostatic bonds create stresses leading to distorted cell wall permeability which, coupled with protein denaturation, leads to cell lysis and cell death [1,16]. Importantly, some authors have demonstrated that these ions are able to penetrate and break up the biofilms in which other bacteria, algae, protozoans, and fungi, cohabit with *Legionella* species in water pipes [17,18].

The amount of copper and silver dosed must remain within a certain range for efficacy and at the same time remain below the WHO and other guidelines. Studies carried out *in-vitro* demonstrated that effective copper and silver concentrations (to inactivate *L. Pneumophila*) are 400 μg/l for copper and 40 μg/l for silver [e.g.,19–21]. A residual effect of copper and silver throughout the treated systems was also observed [12,17]. As with other water treatment approaches to be effective, the treated water must be flushed through the system regularly, in particular through infrequently used tap points, showers and other parts of the system.

Studies have been conducted on the efficacy of copper-silver ionisation against *Legionella,* but have primarily focused on water distribution systems in hospitals [1,22–24]. Little evidence of its efficacy is available from routine monitoring data outside hospitals. Therefore, the aim of this study was to:

- determine the efficacy of copper-silver ionisation in controlling *Legionella* contaminations in 4 complex water distribution systems in different (non-hospital) buildings (1 juvenile institution, 2 hotels, 1 penitentiary) and 1 cooling tower,
- determine the efficacy in accordance with the test criteria as issued by the Dutch Board for the Authorisation of Plant Protection Products and Biocides (CTGB) and to
- monitor the water quality and efficacy using data collected over a period of more than 5 years.

2. Background information: legislation on *Legionella* control in the Netherlands

This study was carried out in the Netherlands and performed in compliance with Dutch legislation on *Legionella* control. In the Netherlands, copper-silver ionisation may only be used for drinking water in so-called 'priority locations' and for cooling water in wet cooling towers with a maximum capacity of 4 MW discharging to a surface water treatment plant. Priority locations are locations (buildings) with collective drinking water installations where people have a great(er) risk to get infected with *Legionella*. Priority locations include, amongst others, hospitals, care facilities, hotels and detention centres. It is only allowed to use copper-silver ionisation when total *Legionella* concentrations are higher than 100 cfu/l and when the contamination cannot be controlled with thermal (e.g., heat-and-flush) and/or physical (e.g., UV or ultrafiltration) treatment, unless there is a good motivation to directly place a copper-silver ionisation system. In cooling towers copper-silver ionisation is allowed when total *Legionella* concentrations are higher than 1000 cfu/l. There are no further restrictions for cooling towers.

Legionella control legislation has large variations within Europe. In some countries copper-silver ionisation may be used for both prevention and abatement of *Legionella* contaminations in drinking water (e.g., Belgium and Italy). In others it is not feasible e.g., Germany; due to a maximum allowable silver concentration in drinking water of 10 μg/l [25]. Companies in all Member States of the European Union selling copper-silver ionisation systems must 'register' copper and silver as biocides within the European Biocidal Products Directive. Currently, discussions are held about harmonisation of *Legionella* legislation within the European Union. The restrictive use of copper-silver ionisation for priority locations in the Netherlands, might be changed into the unrestricted use of copper-silver ionisation for all locations with *Legionella* contaminated (drinking) water.

3. Methods and materials

3.1. Study sites

This study used data collected from 5 sites:

1. Four complex collective drinking water distribution systems with a minimum of 100 operational tap points per system (Table 1).
2. One wet cooling tower (Table 1).

At the start of the water treatment with copper-silver ionisation, the cooling tower and all complex collective water distribution systems were contaminated with *Legionella* (>100 cfu/l in drinking water and >1000 cfu/l in cooling water). Several other techniques (e.g. heat-and-flush, filtration, UV and flushing with chemicals like dilute sodium hypochlorite) had been used in the past to abate the *Legionella* contaminations at these sites, but had all failed. For this reason, these sites were selected to test the efficacy of copper-silver ionisation.

The sites are spread across the Netherlands, which enabled us to study the efficacy of copper-silver ionisation in drinking water with varying chemical compositions (e.g., hardness and acidity). The relevant general water quality data (pH, hardness, Cu and Ag concentration) of the drinking and cooling water at the sites were obtained from the relevant water supply companies (Table 1).

3.2. Installation and setup of the copper-silver ionisation systems

In the four complex collective drinking water distribution systems, the copper-silver ionisation systems (Bifipro® system; Holland Water, the Netherlands) were connected via a bypass to the water distribution system: downstream of the meter of the water supply company and upstream of the hydrant boosters (when present). In other words, the systems were installed at the point of entry so that all water, both cold and hot, was treated. In the cooling tower, the copper-silver ionisation system was placed in the circulation system of the cooling water (Fig. 1).

The studied cooling tower consisted of several in parallel connected cooling units. The cooling tower worked continuously, but since more cooling power was needed in summer, more water was used during this period. Make-up water consists of partially softened drinking water. Copper and silver was dosed to the softened recirculation water. Blow-down of the evaporated cooling water was controlled by electrical conductivity measurements of the cooling water. After a blown-down, the cooling system is refilled with softened make-up water.