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Legionella disinfection by solar concentrator system

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ABSTRACT

The current study concerns the fundamental problems of Legionnaires disease. Four decades after Legionnaires' bacteria was first identified there is still a low level of clinical awareness. Humans are infected by inhalation of aerosolized water and/or soil contaminated with the bacteria. Several control methods are available for water disinfection: biocide, ultraviolet light sterilization, copper-silver ionization, ozonation etc. but only thermal treatment can completely eliminate *Legionella*, which is killed almost instantly at 70 °C. The current paper describes *Legionella* disinfection by a solar concentrator combined with a heat recovery system that reduces the heat demand. Though this study is made for a small system (160 l of hot water per day) the system can be enlarged (more hot water and more solar collector area) and the results are thus valid also for such larger systems. Here experiments of water treatment by a solar concentrator are summarized and analyzed where the temperature exceeds 80 °C at the outlet of the heat exchanger.

1. Introduction

Legionnaires' disease, or legionellosis, is a potentially fatal form of lung infection (pneumonia) caused by the bacterium *Legionella pneumophila*. The disease was first identified in 1976 when a group of American Legionnaires contracted it at a convention in Philadelphia, during which 34 of 221 infected persons died. It is estimated that there are 200 cases of the disease in the UK each year with about 20% of these being fatal. In the United States between 8000 and 18,000 people contract the disease each year. The largest ever single outbreak of Legionnaires' disease was in Murcia Spain, July 2001 with 650 cases and 4 deaths.

Legionella pneumophila belongs to the Legionellaceae family which includes 48 species, half of which are capable of infecting humans. *Legionella* spp. live in aquatic environments with rare cases being recorded from soil [1].

The bacteria will multiply if the conditions in a water system are favourable, dramatically increasing the chances of people becoming infected. It is therefore essential that all water systems are maintained at non-favourable conditions for *Legionella*.

The bacterium has been found in water with temperatures ranging from 6°C to 60 °C (Fig. 1). It will not multiply below 20 °C and dies above 63 °C [2]. *Legionella* bacteria are more infectious at 37 °C than at 25 °C but will readily multiply in any water maintained between 20 °C and 45 °C.

Places that *Legionella* can multiply include: hot and cold water tanks, pipes with little or no water flow, slime (biofilms) and dirt on pipe and tank surfaces, rubber and natural fibres in washers and seals, showers and taps. Major sources of legionellosis are the water distribution systems of large buildings including hotels and hospitals. *Legionella* also requires a source of nutrients to multiply, many of which readily occur in aquatic environment, such as algae, amoebae and other bacteria. Within a water system the presence of sediment, sludge, scale and biofilms also provide ideal habitats for *Legionella* multiplication [3].

Several studies in the existing literature have been done to eradicate the *Legionella* bacteria:

- Nguyen et al. [4], Miuetzner et al. [5], Stout and Yu [6]: thermal disinfection is a common practice for water distribution systems in hospitals, hotels, and other institutional buildings. The hot water temperature is elevated to above 70 °C.
- Borella et al. [2], Bates et al. [8] and Roggers et al. [7]: *Legionella* spp. have been isolated from water with a temperature as high as 63 °C.
- McCoy [9]: *Legionella* is killed instantly at 70 °C.
- Ontario Agency for Health Protection and Promotion (Public Health Ontario) [10]: *Legionella* can withstand temperatures of up to 50 °C for several hours, but are destroyed within a few minutes at 60 °C.
- *Legionella* have been isolated from hot-water systems up to 66 °C; however, at temperatures above 70 °C they are destroyed almost instantly (Dennis et al. [11]; Dennis [12]; Bartram et al. [13]).

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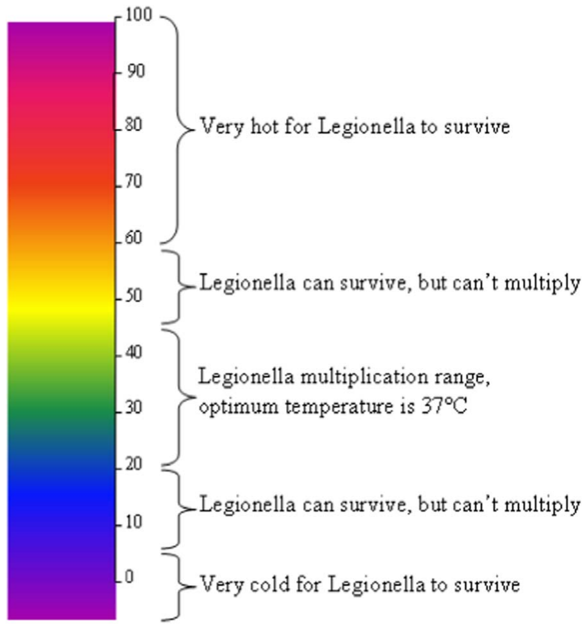

Fig. 1. *Legionella* bacteria live [16].

In this engineering study, we are not dealing with the bacteria itself but trust the existing scientific literature which specifies the required water temperature and the necessary time to eradicate the bacteria.

Remedying the problem of legionellosis continues to be a topical issue. Recent, important information on laboratory testing, microbiology and prevention methods have been published within the last several years. In this paper, we will touch upon some of the highlights that contribute to eliminate *Legionella* bacteria for medical applications. Ensuring safe water in hospitals and hostels is particularly important because of the public's frequent exposure to hot water outlets. (Table 1) and can reach 160 l/day. Furthermore, thermal water treatment can also be used for drinking water disinfection and sterilization in addition to providing protection against *Legionella* and other micro-organisms in the bath and kitchen sectors.

2. Objectives

Solar energy has been harvested by various methods for many centuries. Different types of solar collectors producing hot water at temperatures between 30°C and 90 °C are commonly used. Large areas of mirrors are employed to obtain higher temperature with solar power concentration in order to drive boilers and turbines for the production of electricity. The other main development is water treatment for reducing risks and liabilities due to the presence of pathogens.

The overall objective is to develop the Anti-Bacterial Heat Exchanger (ABHE) for various disinfection applications, flow rates and fluids. A more distant aim is to develop the ABHE to a point where it, if possible, becomes a generally accepted water treatment method using renewable heat sources. Examples are fire wood and solar (light) collectors from which the visible light is concentrated in the focus. Here concentrating solar collectors (Fig. 2) are tested as a heat source for the ABHE.

Table 1
Hot water consumption per occupant or person in common types of buildings [14].

Type of building	Consumption per occupant l/day	Peak demand per occupant l/h	Storage per occupant liter
Factories (no process)	22–45	9	5
Hospitals, general	160	30	27
Hospitals, mental	110	22	27
Hostels	90	45	30
Hotels	100–180	45	30
Houses and flats	90–160	45	30
Offices	22	9	5
Boarding Schools	115	20	25
Day Schools	15	9	5
Playschools	100	30	9
Barracks	60–80	10	7
Restaurants	20–120	20	5

Fig. 2. A SOLUX collector without the protecting acrylic dome [15].

3. System description of water treatment

Nature has by evolution developed environmentally friendly systems in plants and animals.

Fig. 3 shows how a bird can stand comfortably warm on the cold ice. The heat loss is very small because the blood circulating through its

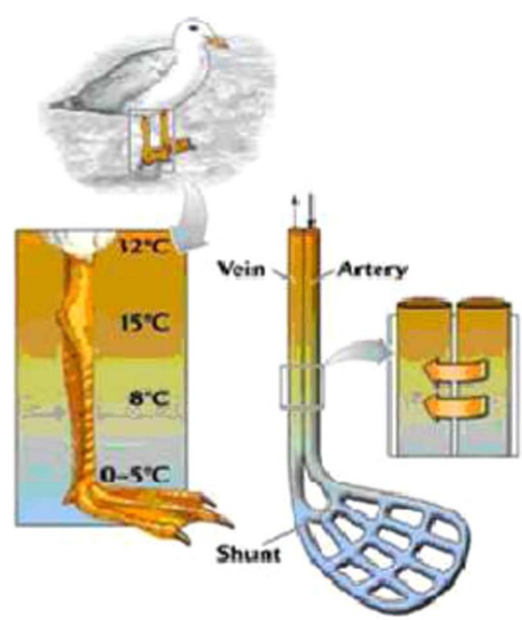

Fig. 3. A bird stands warm on ice due to – the efficient heat exchanger system in the birds' legs [16].