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APPLICATION OF RISK ANALYSIS IN HOT WATER SUPPLY SYSTEMS

ZASTOSOWANIE ANALIZY RYZYKA W SYSTEMACH ZAOPATRZENIA W CWU

Odpowiedzialność za poprawność językową ponoszą autorzy

A b s t r a c t

The core of the article consists in our investigation of Legionella contamination of hot water in a cross-sectional survey in Kosice, the Slovak Republic. Bacteria Legionella in water systems, especially in hot water distribution system, in terms of health protection of inhabitants, is a crucial problem which must not be neglected.

Keywords: hot water system, hot water, Legionella pneumophila, disinfection

S t r e s z c z e n i e

Celem artykułu jest opracowanie dotyczące skażenia bakterią Legionella systemów zaopatrzenia ciepłej wody na podstawie badań przekrojowych wykonanych w Koszycach na Słowacji. Skażenie bakterią Legionella w systemach wodnych, zwłaszcza w systemach dystrybucji CWU, stanowi z punktu widzenia ochrony zdrowia mieszkańców podstawowy problem, którego nie można bagatelizować.

Słowa kluczowe: system CWU, ciepła woda, Legionella pneumophila, dezynfekcja

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Denotations

PWH – potable water hot
PWC – potable water cold
WH – water heating
H – heating

1. Risk analysis

A number of colonies forming units of Legionella bacteria in portable water distribution systems depends on numerous factors and can undergo changes over time and place. Microorganisms occurring in water distribution systems affect their growth and multiplication, and therefore it is important to reduce and monitor them. Risk analysis is one of the methodological procedures to identify possible contamination threats by Legionella pneumophila in water distribution systems. It is an analysis of problems based on the latest scientific – technical knowledge to make basis and inferences for effective decisions. The goal is to estimate necessary precautionary measures since specific risk assessment is essential for their successful implementation. Risk analysis evaluates specific conditions on the ground of information about current contamination that comprises the assessment of possible ways of proliferation, exposure risk, and the target group risk in each situation. Risk analysis involves risk assessment and risk management.

Building owners, landlords and managers are responsible for assessing sources of risk in water distribution systems. Risk analysis includes four parts: system assessment – identification of risk sources and groups, risk assessment, risk management, conclusions of risk analysis. As a part of the risk assessment, it is significant to determine level of risk from the exposure to Legionella bacteria. It is a tool for choosing the proper preventive measures in order to reduce the risk to acceptable level.

Risk management is an activity directed towards implementation of control and precautionary measures based not only on the estimated risk but also in a technically competent [1].

1.1. System and Risk assessment

It is essential to identify factors and critical points which contribute to contamination of water distribution system (Fig. 1). Risk of Legionella infection is not equally detrimental to inhabitants. We consider the most commonly affected group; people with weakened immunity, after organ transplantations, suffering from chronic Bronchitis, Diabetes, and lung tumors. Fatality rate significantly increases by age. The latest researches also prove various death rates by sex. About 20% of infected men in contrast to 15% of infected women die from contracting the Legionnaires disease. People at greater risk are mainly smokers with weakened immunity. Due to the fact that Legionnaires` disease is difficult to diagnose the death rate is constantly increased. To get a complex approach it is essential to identify the level of risk.

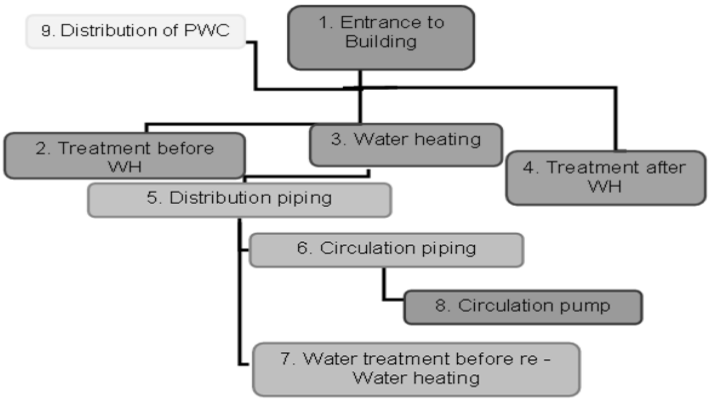

Fig. 1. Critical points of the system [2]

Rys. 1. Krytyczne punkty systemu [2]

Table 1

Level of the Risk

	Level of risk	Measures
0	No risk	No measures
1	Low risk with rare changes in operation	Preventive sampling
2	Medium risk without changes in operation	Preventive sampling, periodical increment of temperature in the water systems
3	Serious risk	Technical measures, thermal disinfection
4	Acute risk	System's shutdown and implementation of a package of measures

1.2. Risk management and conclusion of Risk analysis

The next step is risk management – a package of remedial regulations, appointment of a person to be managerially responsible, and preparation of a scheme for preventing or controlling a risk to eliminate sources of pollution. It is inevitable to set the data for repeated hygiene monitoring. In addition it is required to analyze individual variants of remedial measures. Also control points for regular monitoring of cold and hot water, and concentration of biocide – if it is dosed, are necessary to determine. Keeping system records so called logbooks is an inseparable part of management policy. As a result of risk management is a document that ensures safe and correct operation of hot water at the end of distribution systems for users. All the above items stem from constant diagnoses, proved findings and implemented requirements [1]. Conclusions of risk analysis involve summary of risk assessment together with risk management as well as a scheme of precautionary measures to reduce risk.

2. Risk analysis in experimental boiler room P1

2.1. Experimental research – Boiler room P1

The experimental research was aimed to Boiler room P1 at Lomnicka Street. The P1 boiler room together with secondary networks and new connections with P2 provides heating and hot water preparation for Residential houses in Kosice.

Characteristics of boiler room:

– Water temperature: 45° to 51°C
– Water heater tank capacity: 2 x 10 000 l, 1 x 6 300 liters
– Boilers: 3
– Thermal insulation: partially damaged
– Positive samples:
  - Legionella pneumophila, sampling IX/2006: 3733 KTJ/100ml
  - Legionella pneumophila, repeated sampling after TD X/2006: 450 KTJ/100ml.

Firstly, we have collected all accessible information about the contaminated system (project, technical reports) P1. Than we start with the monitoring plan. It was divided in two parts:

1) **capacity analyse**: dataloger, volumes,
2) **microbiological analyse**: to collect samples, identify factors and critical points of system.

To get a complex approach we have to identify the level of risk: it was Level 3 – Serious risk, technical measures, thermal disinfection were recommended. Our measures have proved that the thermal disinfection is not a suitable system treatment therefore it is inevitable to search for a new complex solution. Therefore we decided to simulate an existing water heater tank with boundary conditions in the boiler room.

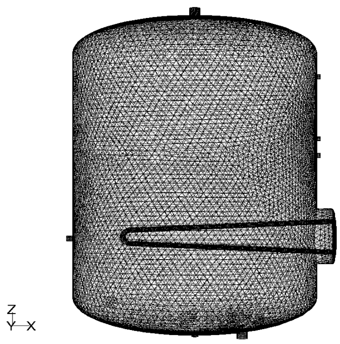


Fig. 2. Experimental storage model

Rys. 2. Model pojemnika badawczego

2.2. Minimizing of microbiological hot water risk in the boiler by using the simulation methods

Low temperature in the boiler, as well as the possible stagnation of water, are among the factors that caused the microbiological contamination of water in the boiler room P1. There is a question in which layer the temperature is insufficient, and where the water stagnation occurs. We have simulated two conditions. Situation A in standard operation and situation B for thermal disinfection. To verify the simulations, we used images from the infrared camera.

2.2.1. A Situation – standard operation

The first operating condition is defined by boundary conditions:

– flow rate: 0.08 kg/s,
– inlet temperature: 10°C,
– storage insulation 10 cm: λ: 0.04 $Wm^{-1}\cdot K^{-1}$,
– boiler room temperature: 15°C,
– heating pads temperature: 80°C,
– outlet temperature: 51°C.

Temperature (or temperature stratification) and the stagnation of water in the tank are factors that we decided to explore. Based on the temperature stratification of the first simulation in Figure 3, exactly the bottom of the water heater tank belongs to the range of temperatures from 35°C to 45°C, which are risky. For simulation control, we used a thermovision camera. After removing the insulation, we scanned the bottom of the tank during standard operation (Fig. 4).

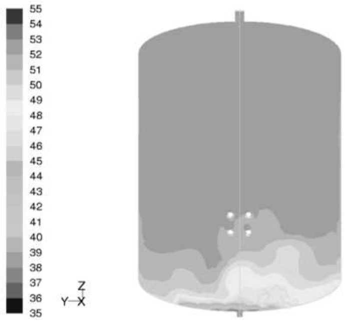

Fig. 3. Temperature stratification – situation A

Rys. 3. Pola temperatur – sytuacja A

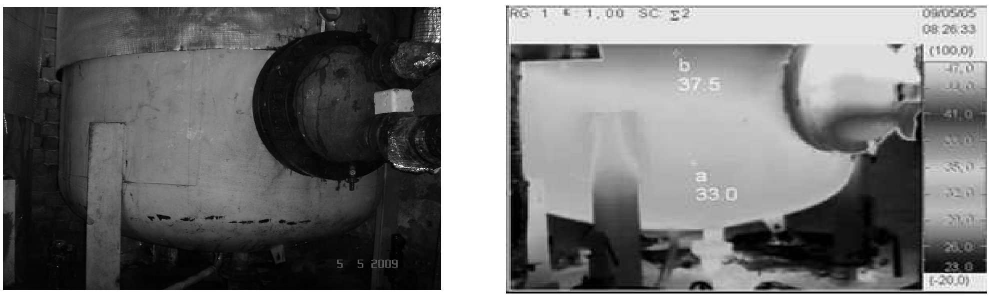

Fig. 4. The bottom of tank without insulation and Standard operation – A

Rys. 4. Spód zbiornika bez izolacji i standardowa operacja A

Figure 3 shows the appropriate conditions for the growth of bacteria of the genus Legionella, directly Legionella pneumophila.

In connection with the sediments, and inlay, which are located at the bottom of the storage, the riskiest places become sludge blow off and surrounding areas of drinking water supply.

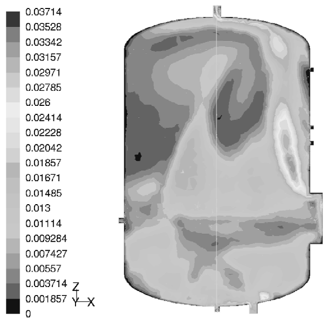

Fig. 5. Water stagnation and the affects of storage bottom

Rys. 5. Wpływ efektu zastoju wody na pojemność cieplną zbiornika

In Figure 5 we can see that the problem of water stagnation also affects storage bottom. Simulations show the stagnation of water in blind junctions (one left, three right and one on the axis of symmetry) due to almost zero speed. Eliminating of death legs and the unused outlets can prevent stagnation. Simulated temperatures are consistent with the actual condition. The simulated model can be used as a general model (tolerance ±2°C) of temperature layering for vertical type of water heater tank (boundary conditions can be changed if necessary).

2.2.2. B Situation – thermal disinfection

The second condition of the thermal disinfection is defined by the following boundary conditions. The required temperature in the storage is 75°C measured in all side blind junctions (right and left):

– flow rate: 0.008 kg/s,
– storage insulation th.10 cm: λ: 0.04 $Wm^{-1}\cdot K^{-1}$,
– boiler room temperature: 15°C,
– heating pads temperature: 80°C,
– control temperature sensor: 75°C.

The simulation of B condition shows that layering has changed, but the risky places did not change. The temperature in a closed sludge blow off is approximately from 3 to 4 K lower than the temperature in the tank (Fig. 7). This means that bacteria can survive and colonize the whole system.

Stagnation of water in B situation occurs in the same places as with A situation (due to almost zero flow speed, and water circulation) (Fig. 6). Figure 7 shows a detail of sludge blow off, where almost zero flow speed is – ideal conditions for bacterial growth.

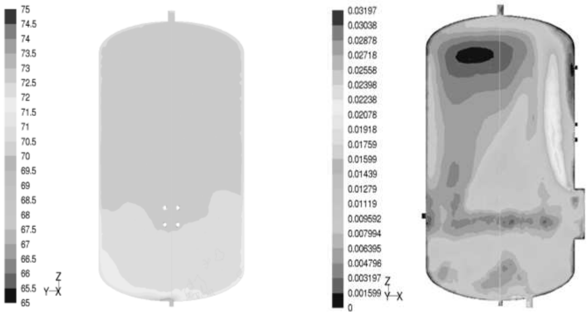

Fig. 6. Temperature layering – B situation and water velocity – B situation

Rys. 6. Warstwy temperatury – sytuacja B i prędkość wody – sytuacja B

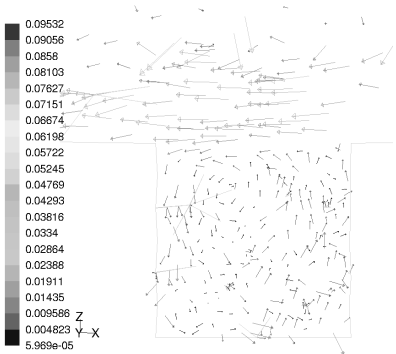

Fig. 7. Detail of water flow in closed sludge blow off

Rys. 7. Szczegół przepływów wody w przedmuchiwanym zamkniętym osadniku

Definitely do not go through blind connections, where the flow is very slow about: 0.004823 m/s [3].

3. Discussion

By the outcomes of Risk analysis and simulations, the following are recommendations and sound practices to help manage and reduce the incidence of Legionella contamination within experimental plumbing (hot and cold) water systems:

- Reduce dead legs (stagnant lines and stubs) in the system,
- Clean and inspect hot water tanks regularly – annually as a minimum,
- Continually run hot water circulation pumps – avoid recycling to mixing valves only,
- Store hot water at a minimum temperature of 60°C and deliver to the taps at a minimum temperature of 50°C,
- Store and distribute the cold domestic water below 20°C – if not possible, then consider monitoring for Legionella and using a disinfection system if Legionella are not under control,

– Flush the entire water system on a regular basis,
– Consider routine potable water treatments – including the use of approved biocides [4].

4. Conclusions

Achievements of simulations operating conditions offer insight into the flow of water and heat transfer in a standing container to assess temperature and water stagnation. Due to stagnation of very slow water flow and also low overheating of thermal disinfection the point of highest risk is clearly bottom of the tank – called sludge blow off. Here maintain suitable conditions for growth of Legionella bacteria, and if temperatures drop in the tank, may colonize the entire system. The proposed general model of temperature distribution of the water heater tank can be applied to all similar types of tanks. Risk analysis helps the managers reduce the Legionella infection and gives a well arranged summary of risk assessment together with risk management as well as a scheme of precautionary measures to reduce risk.

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