# CASE STUDY: MANAGING THE LEGIONELLA OVERGROWTH OF CORRODED WATER SYSTEM IN PUBLIC FACILITY.

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Safe, high quality drinking water is an invaluable good. It is essential in our daily life, not just for drinking and food preparation, but also for many other purposes, such as hygiene. The quality of the drinking water does not only depend on the state of the distribution system, but the maintenance of the water systems in buildings can also play a crucial role in this regard. A case study of a five-year long colonialization with Legionella in the internal water system of a public facility is presented. Periodically the numbers of Legionella were tested according to ISO standards. In addition, adenosine triphosphate (ATP) measurements were made. High numbers of bacteria were a result of damaged pipelines, unfit thermostatic mixing valves (TMV) and an insufficient temperature of the hot water distribution system. All these factors contributed to the formation of biofilm. Defects were excluded step by step and the number of bacteria declined.

**Key words:** Legionella spp, water system, public facility

## Introduction

The case of improper management of a problematic water system is presented. The issues mainly occurred due to economic reasons.

Ten years ago the Health Inspectorate of Republic of Slovenia started stricter supervision of internal water systems in public buildings. Legionella was a hot topic, especially because of the affair that occur in our main hospital. [1]

Legionella's natural habitats are fresh waters worldwide, but they can enormously multiply inside water systems. Legionella is a causative agent for Legionnaires disease and Pontiac fever. Legionnaires disease is atypical pneumonia caused by Legionella spp., mostly Legionella pneumophila. Humans are infected by inhalation of contaminated aerosols. Typical symptoms, such as shortness of breath, cough, high fever, muscle pains, headaches, start two to ten days after exposure. Cases of Legionnaires disease are mostly reported in older males.

Pontiac fever is an acute, mild upper respiratory disease. Symptoms such as mild fever and muscle ache start one to three days after exposure and usually go away after few days without any treatment.

In 2014, 6941 cases were reported in Europe. The overall notification rate was 1.35 per 100,000 inhabitants and the reported fatality rate was 8%. In Slovenia 59 cases were reported. Notification rate was 2.86 per 100,000 inhabitants, which places Slovenia on the top of notification rates in Europe. [2]

Legionellae have been isolated from hot water systems up to 66℃, however, at temperatures above 70℃ they are destroyed almost immediately. Legionellae can multiply in environments at temperatures between 25℃ and 45℃ with optimal range 32-42℃. Therefore, to prevent Legionella infection, the recommended temperatures of cold water are below 20℃ and hot water more than 55℃. Legionella will survive for long periods in cold environment and then proliferate when the temperature increases. [2]

Some simple methods for internal surveillance of multiplying bacteria in systems are available. In parallel we used ATP testing to make some conclusion on applicability.

## Methodology

For enumeration of Legionella the standard ISO 11731-2:2004, direct membrane filtration method was used.

Additionally ATP measures and Heterotrophic plate count according to ISO 6222:1999 were made. Application of these methods for internal controls and better surveillance of water systems was tested in parallel.

Method ISO 11731-2:2004: 1 liter of sample was divided. 0.1 ml, 1 ml, 10 ml, 100 ml and 900 ml were filtered. Media used for isolation were GVPC (Biomerieux). For confirmation of Legionella spp. BCYE with cisteine (Biomerieux) and Columbia blood agar (Biomerieux) were used. For confirmation of Legionella pneumophila serotyping was performed with Legionella Latex test (Oxoid).

ATP measures were made using Quench-gone$^{TM}$ aqueous (QGA) kit. Method quantifies intracellular adenosine triphosphate (ATP): ATP is an important biological molecule – coenzyme. It is a special carrier of energy in all living organisms. The principle of ATP measurement is based on bioluminescence technique, in which one photon of light is produced. Intensity of the light is measured with luminometer. The quantity of the produced light is directly proportional to the active biomass present in the sample.

Heterotrophic plate count was tested according to ISO 6222:1999. 1ml of sample was poured with PCA agar (Oxoid). Samples were incubated for 48 h at 37℃ and for 72 h at 22℃. It is estimated that only 0,1-1 percent of all living microorganisms in samples are detected with this method.[3]

**Actions taken to minimize Legionella contamination in public building and results of testing**

The Slovenian National laboratory started to test *Legionellae* in samples from this facility in 2009. Before this, drinking water was routinely tested on microorganisms, specified in the European Drinking Water Directive and the Slovenian drinking water policy, namely Coliforms, *Escherichia coli*, Intestinal enterococci and Total number of microorganisms at 37℃ and 22℃. [4] The results of the samples from this facility were consistent with the legislation. None of the problems were identified in these routine samples. However, tested parameters are only indicators of fecal pollution. They are not adequate basis for making conclusions on hygiene and Legionella presence in pipelines. It should be noted that in the Slovenian legislation Legionella testing is not defined exactly.

From 2009 until 2013 Legionellae were tested in cold water samples from the facility and all were negative. Cold water temperatures were below 20℃. In 2013 a health inspector prescribed hot water testing, because the temperatures were lower than 45℃. It was presumed that this could be proper env ironment for Legionellae multiplication.

First positive samples were observed in September 2013. 2,4x$10^4$cfu/1l. Legionellae in hot water sample and 55cfu/l Legionellae in cold water from the distal site were found. The plan of action was prepared and partially implemented.

Firstly water installation system examination was performed. The system was more than 30 years old at this time and it was made of galvanized pipes. Thermostatic mixing valves (TMV) were not functioning properly. The temperature of the water could not be regulated and was not adequate to prevent the multiplication of bacteria. The hydrant and the pipelines in storage area ended as dead legs. In addition, the water in a distant part of the facility did not circulate in the system.

After the first positive samples, flushing of the whole system was implemented and samples were taken immediately after this procedure. The results showed reduced numbers in hot water from the distal site for approximately 1log (7x$10^3$cfu/l). Also in the sample from the kitchen, the proximal part of the system, Legionellae were found (6x$10^2$cfu/l).

The reduction in numbers was not satisfactory; therefore other actions had to be taken. The first assumptions were that the renovated TMVs would enable higher temperatures at the end point of use to prevent multiplication of bacteria. The TMVs were changed in November 2013. After the replacement the temperatures were still below 50℃.

In this period extensive flushings were repeated. Legionellae were still present in high numbers. First wet spots after extensive flushing were noticed in the kitchen area. The ceramics were removed and the system was checked. The pipes were installed between different layers of waterproof materials, such as polyvinyl and Styrofoam (Figure 1). The hot water pipes were not properly isolated (Figure 2), and were extensively corroded. (Figure 3).

**Figure 1: Water system installation between layers of waterproof material**

**Figure 2: Missing parts of the hot water pipes isolation**

**Figure 3: Damaged pipes in the kitchen area**

Some pipes showed extensive perforation. The water probably leaked out for a long period of time. The walls were also soaked wet, and after removing the upper layers of the walls moulds were found.

After these findings the whole problematic area was restored. The examination of other parts showed that the water system could still be used. An urgent intervention was not necessary, but the renovation plan, phase 2, was implemented.

After the restoration of the kitchen area, the removal of one of the death legs and new TMVs, samples for Legionellae testing were taken.

The results from the proximal part of the building showed low numbers of Legionellae, but the distal part was still heavily contaminated and new critical points were found.

Special attention was paid to the heating system because the hot water temperatures were low, even though the system was completely renewed in 2012. A new hot storage water tank and a heater were installed in 2011. They were oversized and the water level was stagnating. In addition, the expansion tank was inadequate. The water was not heated over weekends. The overheating was done only twice per year and hot water did not go through the whole system.

Firstly, the storage tank was cleaned and disinfected. The results were not satisfying. Also the water from expansion tank was checked, because it was assumed that this site is the niche for the multiplication of Legionellae. Legionellae were not found, but Heterotrophic plate count was over $10^5$ cfu/ml. Samples were taken before and after removing the tank and flushing the system. In distal part the number of Legionellae was even higher than before. In samples from the proximal part the number was a bit lower.

Because of the constantly high number of Legionellae in the distal part, the reconstruction of the pipeline was done and an additional heating device was implemented to achieve target temperature over 60℃ in the boiler and over 55℃ at distant sites.

The work plan was prepared in April 2014 and the reconstruction ended in October 2014. A pipeline (MEPLA PE-Xb/Al/PE-HD pipes) was installed under the ceiling in protected channel. A pump with flow rate between 0.3-0.5 m/s enables circulation, which is regulated by heating device.

A sanitation boiler of appropriate size and pipelines in the boiler room were installed. A heating pump with integrated electric heater, which would enable thermal disinfection, was connected to the heating substation. The exposed parts of the installation were isolated with polyethylene material with $\lambda < 0.04$ W/mK at 0℃.

After the reconstruction, 60 cfu/l Legionellae were found in the sample from the distal part. The number of bacteria finally dropped to a satisfactory level.

In January 2015 control sampling was made. In samples from the proximal and the distal parts high numbers of Legionellae repeated ($2,4x10^3$ cfu/l and $1,15x10^4$ cfu/l). The reason for the high numbers of bacteria was that the water from old and the new part of the installation were mixing. A proper thermo disinfection was not applied in this period, even though the disinfection was possible with new heating system.

Immediately after the first results the plan for disinfection was implemented and results were satisfactory. The numbers of Legionella were below 100 cfu/l.

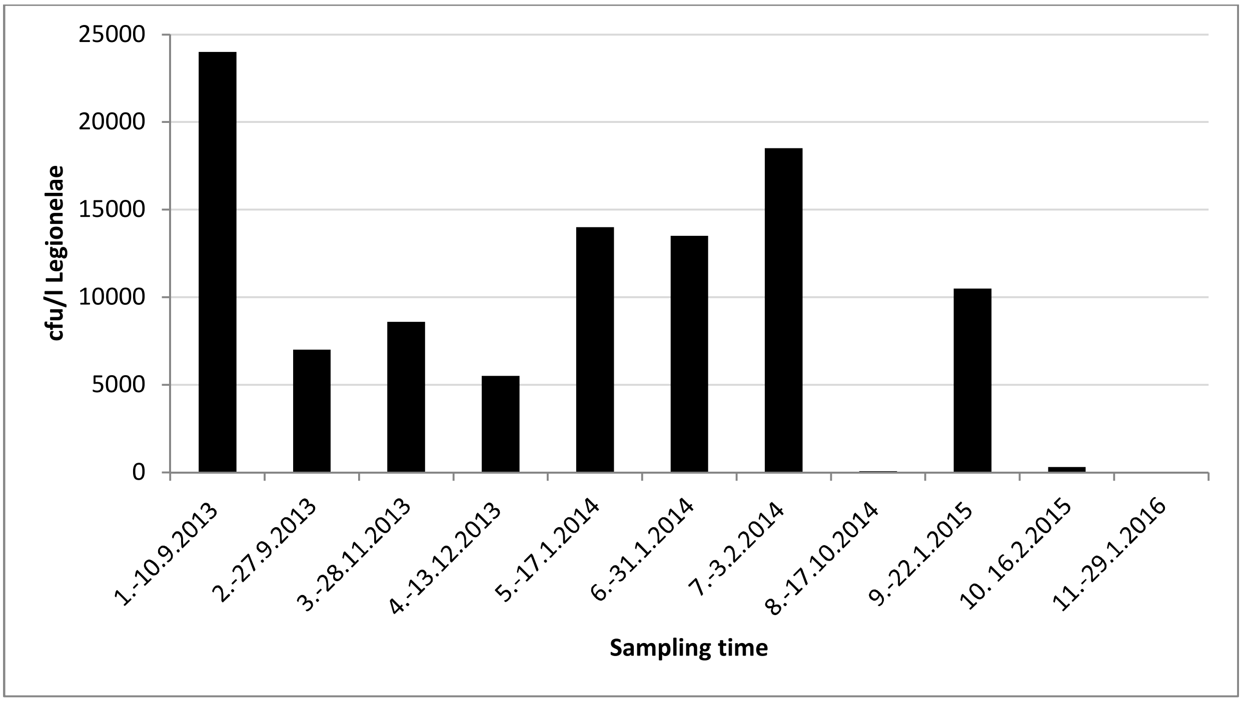
All actions are summarized in Table 1.

**Table 1: Time schedule of the action plan:**

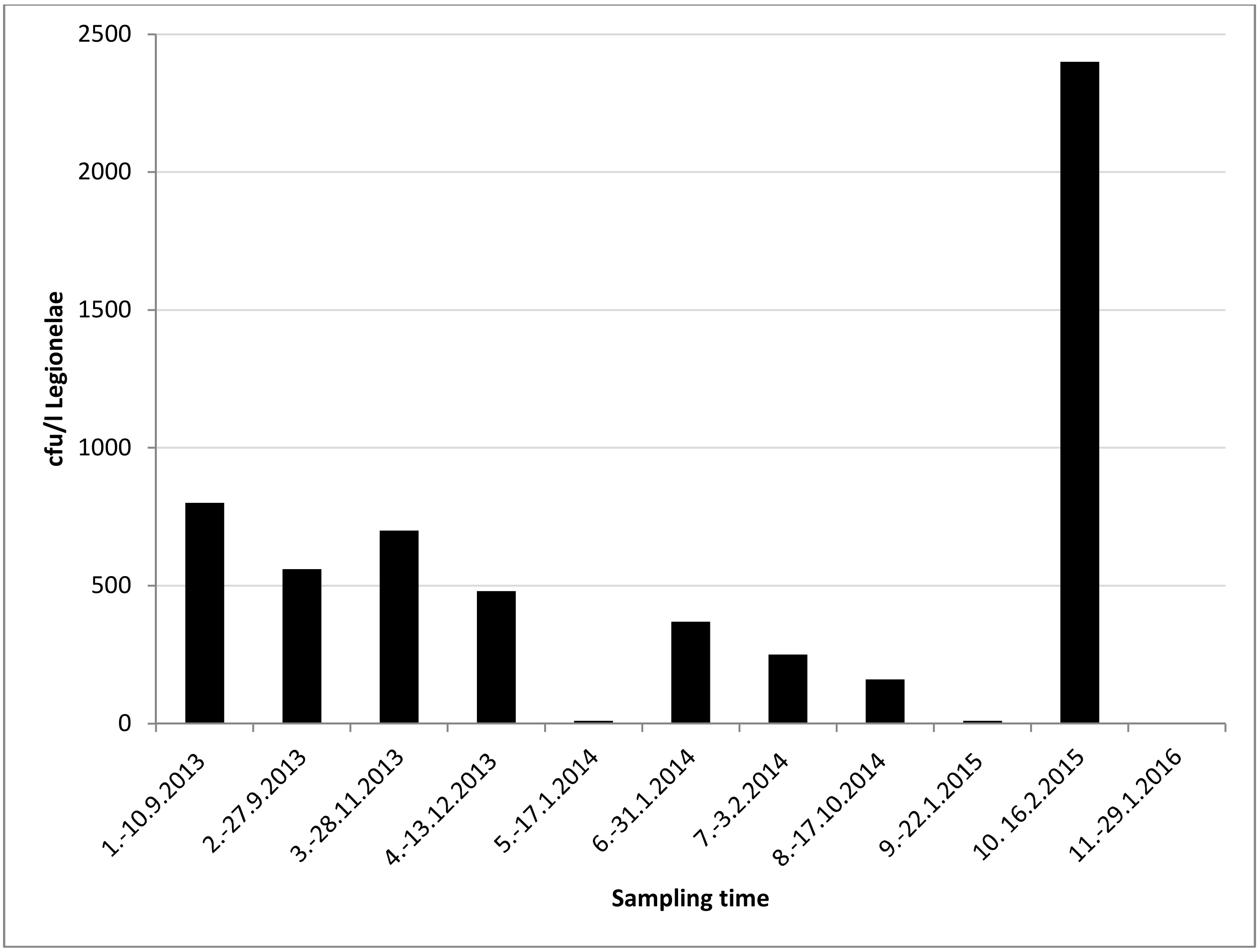
1.- 10.9.2013 - first hot water sampling
2.- 27.9.2013 - samples taken after flushing and new TMV installation
3.- 28.11.2013 - beginning of kitchen adaptation
4.- 13.12.2013 - end of kitchen adaptation
5.- 17.01.2014 - disinfection of boiler and removing expansion tank
6.- 31.01.2014 - before extensive flushing
7.- 03.02.2014 - end of flushing
8.-17.10.2014 - sampling after installation of new circulated pipelines and adaptation of heating substation
9.- 22.01.2015 - control sampling
10. 16.02.2015 - sampling after chemical disinfection
11.-29.01.2016 - control sampling

The results of distal sampling site are presented in Graph 1.

**Graph 1: Number of Legionellae in samples from distal site**

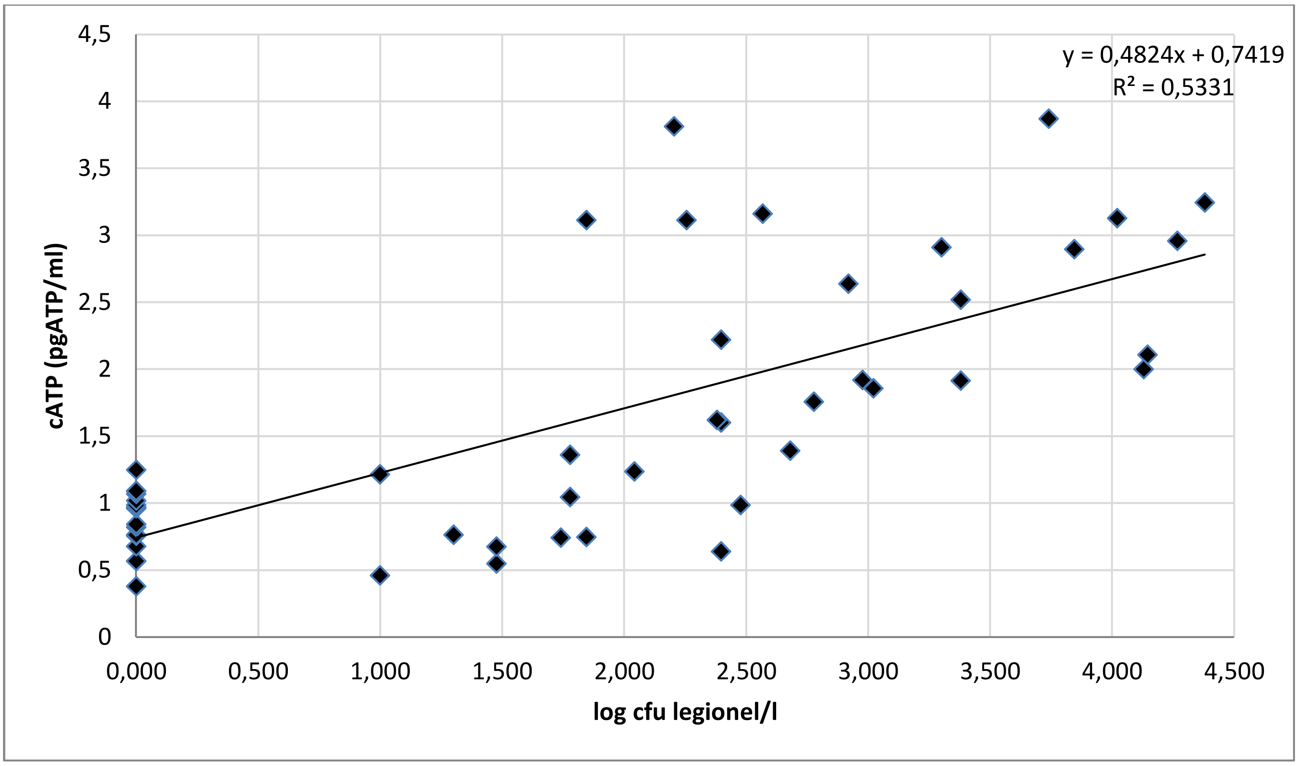



**Graph 2: Number of Legionellae in samples form proximal site**



All the samples were tested with the ATP method in parallel.

**Graph 3: Correlation of Legionella number and ATP results**




## Discussion and conclusions

One of the main responsibilities of managers in public buildings is to provide healthy environment, which includes safe drinking water. This is mostly a technological challenge. Monitoring is one of the sources of data about the quality of water. As these case shown some problems could be overlooked, also because of the fact that there are lack of data on the materials used, especially if they are old more than 30 years. Materials and procedure of installation and their maintenance have enormous effect on the quality of the water. If there are no statutory regulated methodology of determining the effects of materials on the quality of drinking water these problem could raised. In some cases managers continually encounter problems because of inadequate water systems in the buildings. The systems are old, corroded, and lack adequate maintenance. In some cases, when the samples of water do not comply with the microbiological criteria, disinfection with chemicals is the only possible corrective action. Disinfection is just a temporary solution and it works only for a short period of time. It can worsen the situation in the long run, because of the aggressive affect on the galvanized pipes, which were mostly used in past.

ATP method is suitable for field testing. Results are available in 5 minutes. The action can be made in real time. It is a good indicator of disinfection efficiency and to control critical points where microbial proliferation is possible (water stagnation, corrosion, pollution). If the system is thoroughly checked, ATP can serve as a good predictive tool to implement preventive and corrective actions, but for verification purposes the isolation and enumeration of Legionella should be conducted.

Testing of heterotrophic plate count has no predictive value for Legionella contamination, because they do not grow on PCA agar. For example in the expansion tank there were over $10^5$ cfu/ml heterotrophic bacteria due to the stagnant water, but we could not detect any Legionella.

This case is presented especially to highlight the importance of cooperation between different specialists, engineers, project managers and also microbiologists to solve very complex problems quickly and efficiently. The examination of the system must be done extensively. A proper action plan that includes a cost analysis must be done to protect the population, especially the elderly. Such findings are one of the bases for the elaboration of a uniform approach to the protection of the quality of water. The collection of data locally for individuals must lead to another very important basis for the drawing up of the strategy “Water Safety Plan”.

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