Legionella control program for cooling and process water systems in an industrial plant

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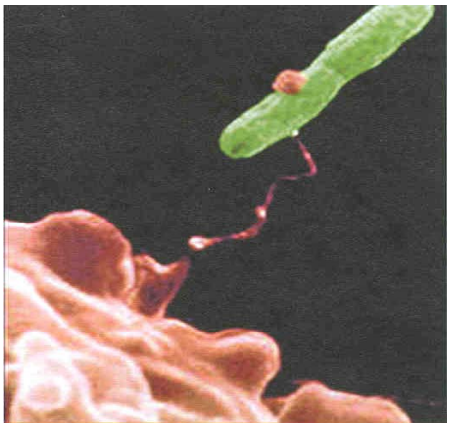
Summary
Spring 1999 231 cases of Legionnaires disease and 29 deaths were reported following a Legionella outbreak at a large flower exhibition near Amsterdam. This was the immediate cause to start an extensive investigation to the possible presence of Legionella bacteria in water systems and ways to prevent growth of these bacteria at the Corus site in IJmuiden.
Legionella bacteria where found in both domestic water systems like emergency showers and industrial water systems like cooling towers. Particularly cooling water of two plants (the continuous caster in the steel plant and at the cooling of the stands and product in the hot strip mill) appeared to be very sensitive for infection by these bacteria. Through carrying out especially for this purpose developed risk assessment procedures specific control programs were developed including immediate actions that had to be taken at the installations.
January 2004 the Dutch Health and Safety Act was extended with a special chapter about Legionella prevention in industrial surroundings. Through this legislation Legionella control programs are made compulsory for all companies.

1. Introduction

Legionella bacteria are widespread in the environment. Both man made and natural water sources provide habitat. In nature these bacteria exist at low concentrations in slime and biofilms. The bacteria are not completely eliminated by the traditional chlorination as used in some countries to purify domestic water supplies. In the industrial environment and in health care facilities, bacteria present in purified water sources can increase dramatically under the right conditions. There are approximately 35 Legionella species known to produce the disease.
Outbreaks of Legionnaires' disease have occurred frequently in or near large building complexes such as hotels, hospitals, offices and factories and sporadically at cooling towers. There is no evidence that water systems in domestic homes present any risk.



Legionella bacteria

So Legionella bacteria can be found in many places, especially in water sources such as rivers, streams and ponds, and in many (recirculating) man-made water systems such as:
- Cooling towers, evaporative condensers and fluid coolers that use evaporation to reject heat. These include many cooling systems used in industrial processes like the iron and steel industry
- Domestic hot and cold water systems (hot water heaters, showers, whirlpool spas, drinking fountains, etc.)
- Humidifiers and decorative fountains
- Fire sprinkler systems, emergency eye washers and safety showers
- Parts washers as used in industry
- Spray systems used for cooling down hot (steel) products

The risk of legionellosis can be reduced by the proper implementation of a thorough assessment of all water systems present. This will identify potential hazardous places and circumstances and appropriate control measures that have to be taken.

2. Corus IJmuiden and Legionella control

The Dutch Corus-plant belongs to a multinational operating company with headquarters in London. In the integrated iron- and steel plant at the IJmuiden site from iron-ore and coke a variety of half-finished products

like slabs, tinplate and other coated steel is produced. On the site about 10.000 people are working in more than 50 different factories, workshops and offices. The high process temperatures in an iron and steel plant require emergency showers on several places to protect workers and cooling water systems to reject the heat that is released in blast furnaces, steel plants and rolling mills.
Since 2000 at the Corus-plant in IJmuiden the procedures as described in the Approved Code of Practice *) (already in use in the UK for several years) are applied to control and prevent the growth of Legionella bacteria in domestic and industrial water systems.
Starting point of the Legionella control plan was making an inventory of all the water systems with special attention for factors that promote the growth of Legionella like:

- water reservoirs and pipe work where water that is allowed to stand undisturbed for long periods;
- reservoirs that are not well covered to prevent entry of dirt and debris, and that are not periodically inspected, cleaned and disinfected;
- water temperatures between 20 - 45°C that should be avoided by insulation of cold water tanks and piping in warm spaces and by storing and recirculating hot water at 60 °C

On the basis of the inventory risk assessments were carried out followed by action plans containing corrective measures that have been taken in the short and longer term. After that a monitoring program for day to day operation was developed. This program includes routine sampling and testing to establish the presence both general (aerobic) bacterial species and Legionella bacteria.
Finally appropriate records are kept of the findings of the risk assessment, the results of any monitoring, inspection, test or check carried out.

What is Legionaires' disease?
Legionaires' disease is a potentially fatal form of pneumonia caused by bacteria. Initial symptoms include fever, headaches, muscle pains, a dry cough and breathing difficulties. Some patients also develop diarrhea, vomiting and may become delirious. It is caught by breathing in droplets of water infected with the bacteria that cause Legionnaires disease. It is thought that only about 1 in 100 people who are exposed to an infection source actually contract the disease, of these is fatal in around 12 % of cases depending on the susceptibility of the population. For example in hospitals or retirement homes some people will be more at risk due to age or illness.
The disease was first recognized following an outbreak in the US amongst a convention of the American Legion in 1976. 221 people attending the convention or working at the hotel caught Legionnaires disease and 34 died. The source of the infection was traced to the air conditioning system and eventually the bacteria responsible was isolated and named "Legionella Pneumophila". Although this was the first time it was identified it is not a new bacteria. Since it was identified it became clear that the bacteria has been present in cases previously thought to be pneumonia as far back as 1943. In the UK a major outbreak occurred in 1985 at Stafford Hospital where 101 people contracted the disease and 28 died. An other high profile incident is the outbreak from a cooling tower on top of the BBC offices in central London.
The total number of people who catch Legionnaires disease is not known. In the UK around 150 - 200 cases are reported annually but an estimate of actual cases is given as 1.100. Some estimates for the US alone suggest that between 10.000 and 15.000 people catch Legionnaires disease each year.
The same bacteria have also been found to be responsible for outbreaks of a non-fatal flu like illness called "Pontiac Fever".

How is it caught?
Evidence of person-to-person transmission has not been found. Infection is attributed to people inhaling Legionella present in water droplets, which are small enough to penetrate deeply into the lung. However for this to happen a series of events needs to occur and this includes:

1. *Conditions present that are suitable for the multiplication of the organism, i.e. water temperature in the range of 20 - 50 °C.*
2. *The presence of sludge, scale, rust, algae and organic matter to provide nutrient for the bacteria.*
3. *A means of creating breathable droplets, for example at industrial and comfort cooling towers. These towers are considered a particular hazard because they generate large amounts of fine droplets, usually at rooftop level where there is potential for air currents to carry the droplets over a relatively large area.*
4. *Inhalation of the contaminated droplets by a person or people.*

Antibiotics can cure when the disease is diagnosed properly in an early stage the illness. Many of them are highly effective against Legionella bacteria.

3. Legionella at the Corus site

After the water systems have been systematically evaluated and control actions have been taken some water systems were sampled under the guidance of an accredited lab. In the laboratory the concentration of Legionella bacteria is analyzed using the Dutch NEN6265 standard, which is more or less equal with ISO11731 from the UK. Legionella contamination is expressed in number of colony forming units per liter of water (CFU/l).

Legionella analysis according to NEN 6265/ISO11731

From several places at the Corus-site, which were considered to have a higher risk for growth of Legionella bacteria, about 2000 samples are collected every year since 2001. In a major part of the samples (app. 40 %) the Legionella concentrations appeared to be (too) high.
According to temporary legislation in the Netherlands systems in the years 2001 and 2002 the Legionella concentration in drinking water systems should always be less than 50 CFU/l, the detection limit in this type of water. For cooling water actions are required at levels of 1.000 or 10.000 CFU/l. In the mean time new legislation for drinking water systems is composed that probably come into effect in 2004. The accepted level in this new law will be 100 CFU/l for drinking water.

In the Corus samples of emergency showers and eyewash stations in particular, the observed concentrations were much higher than allowed. In cooling water levels of even higher than 100.000 CFU/l were analyzed. Through a combination of arrangements like cleaning, flushing and applying thermoshocks (water temperatures above 60 °C during a certain period of time) on a regular basis the problems with infected showers and eye washers were overcome. In some cases in addition complete renovation of the water system was necessary and in other cases it was unavoidable to install desinfection units where growth of Legionella bacteria is prevented through UV-radiation, ozonisation, chlorination or peroxide treatment.

3. Dutch legislation for industrial water systems

January 2004 new regulations became effective in the Netherlands concerning industrial water systems. As part of the Health and Safety Act every company should now have a control program in operation for all industrial water systems on their premises, or to be more precise for all non-tap water systems. So all the air conditioning and comfort cooling installations not using drinking water, emergency showers and eye washers, rinse and wash installations, spray systems, gas scrubbers and waste water treatment plants should be part of this control program.

In the new regulations much attention is given to cooling water systems. Especially cooling towers and their associated water systems need to be well designed, maintained and operated. It is important that drift eliminators are fitted to prevent the escape of fine water droplets. These cooling systems should be cleaned and disinfected on a regular basis (for example every six months). Furthermore cooling water should be treated to prevent scale, corrosion and microbial growth.
According to the European BAT-Cooling **) consideration should be given, when practicable, to replacing cooling towers with dry cooling systems.
Cooling water systems generally operate at of 25 - 45 °C, temperature levels favorable for growth of Legionella bacteria. Water is sprayed in the cooling tower causing the formation of aerosols (small water droplets) which are released into the surrounding environment by the air coming out of the tower through natural draft or by mechanical means like ventilators.

For open recirculating cooling water systems with cooling towers the following starting points should be taken into consideration by the owner of the installation during developing a control program:

- the risk for employees and people living nearby should be known
- the installation should be designed properly
- regularly the installation should be inspected on:
  - right treatment of the water circulating in the system
  - prevention of aerosol release as far as possible
  - proper functioning of all parts of the system
- regular maintenance and inspection should be part of the control program

Taking water samples from a cooling tower

In the design phase of a cooling water system one should bear in mind that:

- stagnant water zones should be prevented (no dead ends, water velocity > 1 m/sec, flushing spare pumps and other parts of the installation regularly, etc),
- spraying of droplets should be limited to a minimum (installing high efficiency and easy to clean drift eliminators at top of the tower, clean inlet louvres at bottom of the tower),
- materials should be used that slow down growth of biofilms in all parts of the installation (smooth surfaces, if possible apply coatings) and
- dosing systems for adding chemicals should be applied (if possible automatic dosing systems).

Also water temperatures (in and outlet), water qualities and possibilities to inspect the system should be part of the design.

According to the European BAT-Cooling in cooling towers can be dived in 4 categories each with his own risk level and frequency of controlling on the presence of Legionella bacteria:

Category	Location	Control on Legionella
1	Nearby (< 200 m) a hospital or health related institution	At least every month
2	Nearby (< 200 m) homes for the elderly, hotels or buildings with a lot of people present	At least every quarter
3	Industrial cooling tower near homes (< 600 m)	1 – 4 times a year
4	Industrial cooling towers in an industrial environment (> 600 m from homes)	At least once a year

The intention of water treatment is not only to prevent corrosion and scaling (corrosion products and scaling deposits act like nutrient for bacteria) but also to decrease the development of biofilms. From literature is known that biofilms provide an environment in which microorganisms like Legionella bacteria can proliferate very fast. Sometimes more than 90 % of the Legionella present is found in these layers of microorganisms.

4. Desinfection of cooling water systems

Once higher concentrations of Legionella bacteria are found in a cooling water system immediate actions are necessary. Depending on the Legionella level and the location of the tower different actions should be taken:

Category 1,2,3	Approach	Category 4	Approach
< 100 CFU/l	A	< 1.000 CFU/l	A
100 – 1.000 CFU/l	B	1.000 – 10.000 CFU/l	B
1.000 – 10.000 CFU/l	C	10.000 – 100.000 CFU/l	C
10.000 – 100.000 CFU/l	D, E	100.000 – 1.000.000 CFU/l	D, E
> 100.000 CFU/l	F, E	> 1.000.000 CFU/l	F, E

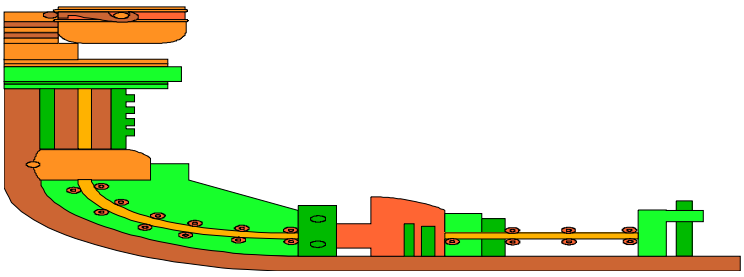
A: System is under control, no further action required
B: Check treatment program, there is no cause for concern
C: Check treatment program and add extra biocide. If bleach is used the FO-concentration (Free Oxidant) in return water from the tower has to be 2 – 4 mg/l for two hours. The discharge valve should be closed during this operation. The remaining FO can be neutralized with sodium bisulphite (normally 5 g per m^3 water per mg FO is sufficient). The discharge valve can be opened again when the FO-concentration is < 0,5 mg/l. Afterwards an extra Legionella sample should be taken. If there are still Legionella bacteria present procedure C must be repeated.
D: On line desinfection and cleaning. The system is contaminated and direct action is needed. Before starting with adding extra biocide the discharge out of system should be increased for some hours, lowering the concentration factor of the system. All pumps, heat exchangers etc have to be flushed. If bleach is used the FO-concentration in return water from the tower has to be 5 mg/l for five hours. It can be necessary to add biodispersant and anti foam also. The discharge valve should be closed during this operation. The remaining FO can be neutralized with sodium bisulphite (normally 5 g per m^3 water per mg FO is sufficient). The discharge valve can be opened again when the FO-concentration is < 0,5 mg/l. If the water still contains Legionella bacteria procedure D must be repeated.
E: Check if any employees or visitors possible have been in contact with the aerosols coming from the system. Local and regional health authorities should be informed.
F: Off line desinfection and cleaning. The system should be taken out of operation as soon as possible. Information about the situation should be passed on to the local and regional health authorities. Procedure D should be performed twice. Sometimes it can be necessary to inspect the internal of the system to be sure that it is clean. When people have to enter the cooling tower for inspection proper safety measures should have been taken.

5. Cooling water of the continuous caster

In cooling towers at a steel plant where cooling water is used for product cooling also, solving the Legionella problem is very complex. At the Corus site in IJmuiden in one of the cooling water systems of the continuous caster at the steel plant and the spray system of the hot mill in almost every sample Legionella bacteria are present. The circumstances in these systems are favorable for the growth of Legionella-bacteria: right temperature levels, stagnant water zones (spare pumps etc.) and the presence of biofilms, scale and rust particles. In the past three years tests were carried out especially at the cooling system of the caster to remove the biofilms and to find a more effective desinfection program.

Continuous casting machine

hot steel in



cold steel out

At the continuous caster cooling of the hot steel takes place through three separate systems. Besides closed systems for indirect cooling of the mold and parts of the machine, the main direct circuit is responsible for cooling the slabs produced. In this so-called primary cooling system water is sprayed on the slabs through nozzles, the water contaminated with suspended solids, oil and grease is treated in settling basins and sand filters. Before recirculation the treated water is passing a cooling tower.
As in most cooling water systems dosing sodium hypochlorite is used to keep microbiological growth in the spray cooling under control. In this way the aerobic count based on dip slide can be consistently low. Sampling every two weeks over a period of years shows that aerobic counts at the caster are always less than 10^4 CFU/ml at 30 °C (at minimum 48 hours incubation).
Nevertheless Legionella bacteria are found at high levels (up to 100.000 CFU/l) frequently. According to AcoP and legislation in other countries desinfection should be carried out at levels > 10.000 CFU/l. Best practice is considered to be maintenance of a continuous minimum residual of 5 mg/l free chlorine for a minimum period of 5 hours. Under normal conditions the free chlorine concentration is app. 0,2 mg/l. Through these desinfection procedures the amount of bleach added is increased dramatically over the years:

year	biocide	ton/year
1995	shock dosing NaOCl	147
1996	shock dosing NaOCl	131
1997	continuous addition NaOCl	80
1998	continuous addition NaOCl [1])	57
1999	continuous addition NaOCl + NaBr [2])	100
2000	continuous addition NaOCl + NaBr	40
2001	continuous addition NaOCl + NaBr	170
2002	continuous addition NaOCl + NaBr + biodispersant	149

[1]) Jan - Jun NaOCl + NaBr, Jul - Dec NaOCl
[2]) Limit bacterial count from < 10^5 to < 10^4 per ml

Despite these high amounts of biocides added still Legionella bacteria from time to time are detected in the system. A first test with a combined dosage with bromide resulted in a remarkable lower consumption of hypochlorite. But again, Legionella bacteria were found in the samples. It may very well be possible that through chlorination and bromination only, bacteria in biofilms are not affected. The last test so far, adding a biodispersant, a chemical that is penetrating and together with bleach breaking down the biofilms, gave fairly good results. The growth of Legionella is now more or less under control. However, the discharge of chlorinated halogens in the present situation is far from environmentally acceptable. The search for an alternative method is continued.
One of the alternatives, the application of non-oxidizing biocides, is under Dutch rules and regulations almost impossible. Methods like UV-radiation, ozone-treatment, Ag/Cu-ionization and mechanical systems like membrane filtration are economically not achievable in the current situation.

In other countries and other industries chlorine dioxide addition has proven to be very promising. This product is a friendlier oxidant because no by-products are formed. Tests with chlorine dioxide are carried out starting last autumn..

Measuring the Legionella concentrations directly in the aerosols or droplets coming from the top of the cooling tower is another approach. Through addition of hypochlorite directly into the inlet of the tower it could be possible that after a thorough cleaning no Legionella bacteria are emitted anymore. At this moment a method to measure Legionella concentrations under these circumstances is developed.

Conclusions

- *Carrying out risk assessments and taking the proper actions at places where according to the assessment the risk is higher, minimizes the risk of getting infected by Legionella bacteria. A monitoring program including actions like flushing and carrying out thermoshocks, should control situations where Legionella bacteria is able to grow. Confirmation should be established by taking samples on a regular basis for both general (aerobic) bacterial species and Legionella bacteria.*
- *Regularly maintenance and cleaning cooling towers at least once a year is essentially to prevent growth of Legionella. A well designed system is the only reliable basis.*
- *A seriously infected cooling system should be treated with extra sodium hypochlorite. Depending on location of the tower and the analyzed concentration of Legionella bacteria it can be necessary to add bleach to a level of 4 - 5 mg/l free oxidant. This level should be maintained for at least five hours. Detailed operation and maintenance records should be kept.*
- *Cooling water should be treated constantly. Ideally, an automatic water treatment system should be used that continuously controls the quality of the circulating water.*
- *Because of its specific nature cooling water systems in iron and steel industry are very sensitive for infection by Legionella bacteria. Standard solutions used in other industries to prevent the growth of Legionella bacteria are not always applicable for cooling water systems like the ones at continuous casters. The main reason for this is he way cooling water systems are used: products are cooled down also resulting in contamination of the cooling water with nutrients for Legionella bacteria*
- *The most common way nowadays to prevent Legionella growth is adding sodium hypochlorite to the recirculating water. This can result in not environmentally acceptable discharges of chlorinated byproducts. Further research in alternative methods is necessary.*

*) "Legionaires' disease – The control of Legionella bacteria in water systems. Approved Code of Practice", Health and Safety Commission, UK, Nov 2000

**) "Reference Document on the application of Best Available Techniques to Industrial Cooling Systems", European Commission, European IPPC Bureau, Seville, Spain, Nov 2000