10th International Symposium on District Heating and Cooling

September 3-5, 2006

Tuesday, 5 September 2006

Sektion 8 b

Heat metering and water quality

Ecology and control of Legionella and Pseudomonas bacteria in drinking water systems

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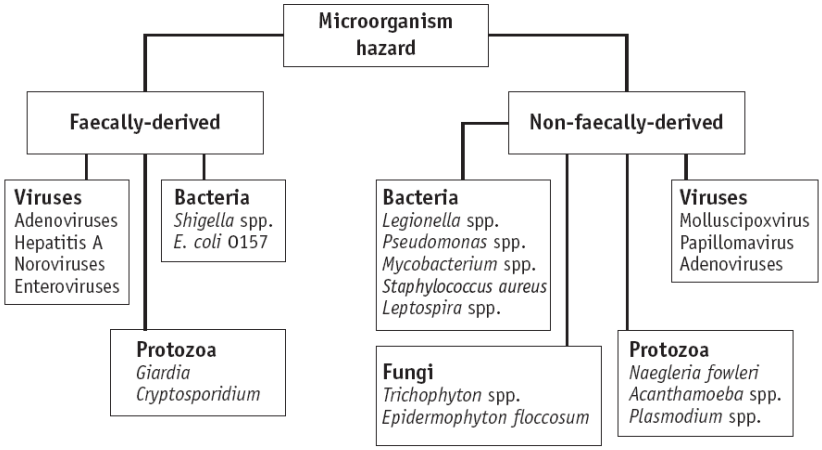
A variety of microorganisms can be found in water environments, which may be introduced in a number of ways. The risk of illness or infection linked to faecal contamination of the water is a rare event in industrialised countries. Many of the single cases, clusters or even outbreaks related to water supplies would have been prevented or reduced if the water treatment had been well managed. The traditional role of indicator parameters is to show the presence or absence of faecal pollution in water supplies.

On the other site many most notably non-faecally-derived bacteria may accumulate in biofilms and present an infection hazard. In addition, certain free-living aquatic bacteria and amoebae can grow in water supply tubes, natural spa or pool facilities, heating, ventilation and air-conditioning systems as well as on other wet surfaces. This kind of contamination cannot be completely avoided by properly water treatment. Some of these bacteria may cause a variety of respiratory, dermal or central nervous system infections or diseases. Some of these so called opportunistic pathogens' can also be shed from users and transmitted via surfaces and contaminated water.

This short overview describes illness and infection associated with Pseudomonas and Legionella contamination of water supply systems.

Potential microbial hazards in water

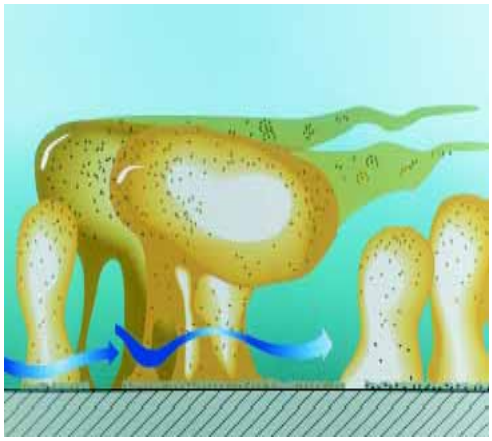


Guidelines for safe recreational waters, WHO 2006

Pseudomonas aeruginosa

Pseudomonas aeruginosa is an aerobic, non-spore-forming, motile, Gram-negative, bacterium. P. aeruginosa is ubiquitous in water, vegetation and soil. Although shedding from infected humans is the predominant source of P. aeruginosa in pools and hot tubs the surrounding environment can be a source of contamination. The warm, moist environment on decks, drains, benches and floors provided by pools and similar environments is ideal for the growth of Pseudomonas, and it can grow well up to temperatures of 41 °C. Pseudomonas tends to accumulate in biofilms in filters or in tap and shower outlets that are poorly maintained.

Biofilm



- **Intracellular Matrix (EPS =** intracellular, polymeric Substances)
- Diffusions barrier (desinfectants)

- Reaction chamber
  - Immobilization of Exoenzymes
  - enhances exchange of substrates

It is also possible that people pick up the organisms on their feet and hands and transfer them to the water and vice versa.

P. aeruginosa can be isolated from all kinds of stagnant water in hospitals and domestic water supplies, usually in concentrations ranged from 10^2 to 10^5 per ml.

It can metabolize a variety of organic compounds and can therefore grow on very limited nutrition resources. In addition it is resistant to a wide range of antibiotics and disinfectants.

Susceptibility of planktonic and biofilm-associated Bacteria against antibiotics

organism	Antibiotic	MIC / MBC planktonic Flora (µg/ml)	MIC / MBC biofilm-associated (µg/ml)
S. aureus NCTC 8325-4	Vancomycin	2 (MBC)	20
Pseudomonas aeruginosa ATCC 27853	Imipenem	1 (MIC)	>1,024
E. coli ATCC 25922	Ampicillin	2 (MIC)	512
P. pseudomallei	Ceftazidime	8 (MBC)	800
Streptococcus sanguis 804	Doxycycline	0.063 (MIC)	3.15

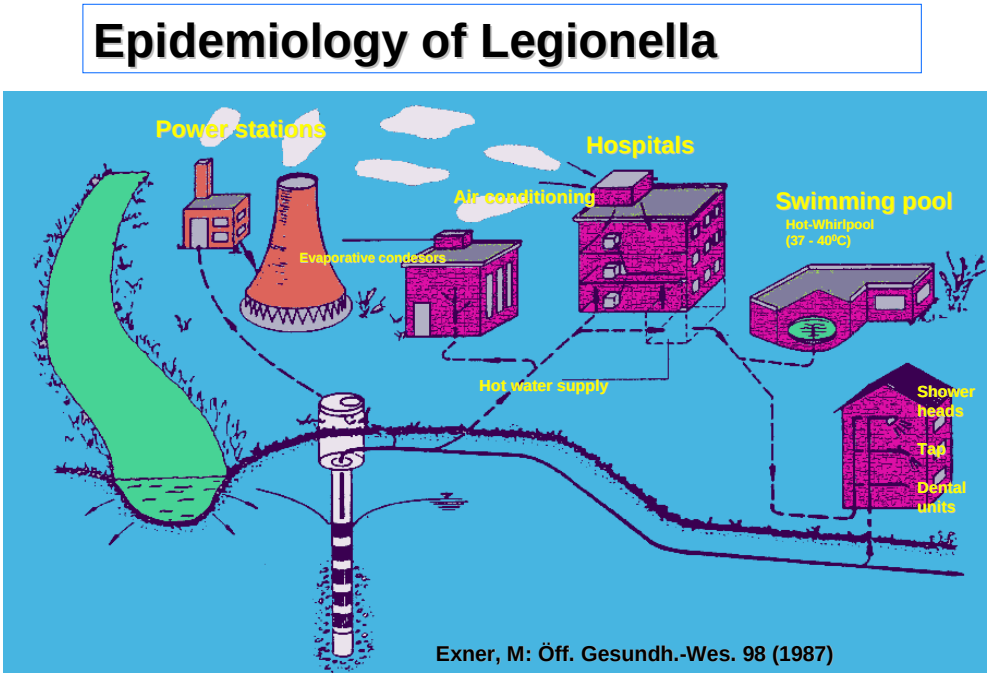
The primary health effect associated with the presence of P. aeruginosa is folliculitis, otitis externa or swimmer's ear. Repeated exposure to water is thought to remove the protective wax coating of the external ear canal, predisposing it to infection. Further more, infections of the urinary tract, respiratory tract, wounds and cornea might be caused by P. aeruginosa. Infection of hair follicles in the skin with P. aeruginosa produces a pustular rash, which may appear under surfaces covered with swimwear or may be more intense in these areas. The rash appears 48 h (range 8 h to 5 days) after exposure and usually resolves spontaneously within 5 days. It has been suggested long term immersion in warm facilitates the invasion by P. aeruginosa. There are some indications that extracellular enzymes produced by P. aeruginosa may damage skin and contribute to the bacteria's colonization: Other symptoms, such as headache, muscular aches, burning eyes and fever, have been reported. Some of these secondary symptoms resemble humidifer fever and therefore could be caused by the inhalation of P. aeruginosa endotoxins. Investigations have indicated that duration or frequency of exposure, bather loads, bather age and using the facility later in the day can be significant risk factors for folliculitis. It has been suggested that the infective dose for healthy individuals is greater than 1000 organisms per ml but these figure are not supported by experimental data.

In ambulant settings or at home the true incidence of illnesses associated with P. aeruginosa in pools and similar environments is difficult to determine. Since the symptoms are primarily mild and self-limiting, most patients do not seek medical attention.

Routine, thorough cleaning of surrounding surfaces will help to reduce infections with P. aeruginosa. In addition, swimming pool, hot tub and natural spa operators should strongly maintain recommended control and prevention measures.

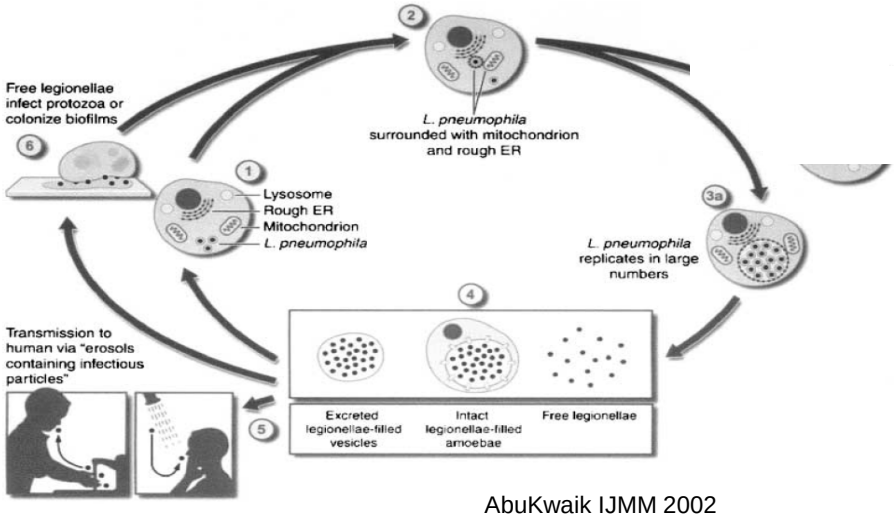
Legionella.

Legionella spp. are heterotrophic bacteria found in a wide range of water environments and can proliferate at temperatures above 25 °C. They may be present in high numbers in water supplies, and they can also grow in poorly maintained hot tubs, associated equipment and HVAC systems.



Legionella are Gram-negative, non-spore-forming, motile, aerobic bacilli, which may be living within amoebae and other protozoa or within biofilms. Legionella spp. can also multiply on filter materials, namely granular activated carbon.

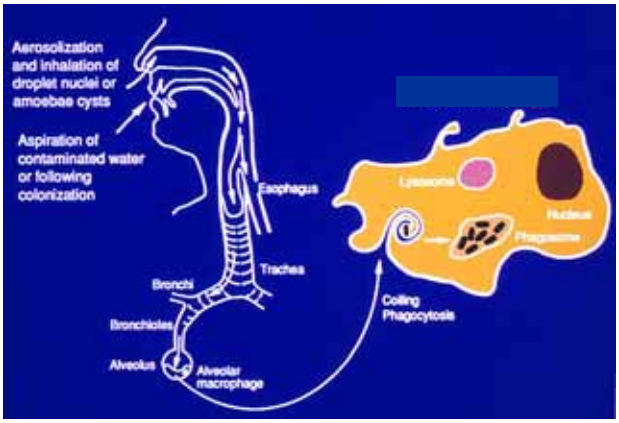
Ecology of Legionella

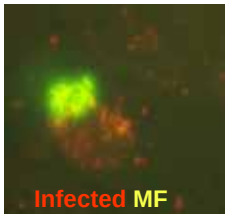


AbuKwaik IJMM 2002

Legionella spp. can cause legionellosis, a range of pneumonic and non-pneumonic disease.

Legionella-Infection





No transmission from men to men

Although the attack rate of Legionella pneumonia is often less than 1%, mortality among hospitalized cases ranges widely up to 50%. It has been estimated that about 15-30 000 cases occur in Germany each year. Pontiac fever is a non-pneumonic, no transmissible, non-fatal, influenza-like illness. The attack rate can be as high as 95% in the total exposed

population. Patients with no underlying illness or condition recover in 2–5 days without treatment.

Clinical forms of legionellosis

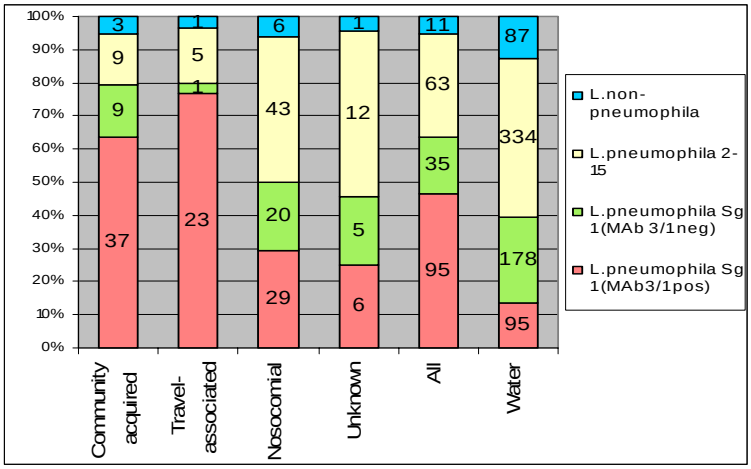
	Pneumonia	Pontiac-Fever	Extrarespirat. Manifestation	Inapparent Sero-konversion
Frequency	**1 - 5 (10%)**	**10 x as pneumonia**	**?**	**100 x as pneumonia**
Manifestation rate	**1 - 5 %**	**90 - 98 %**	**?**	**?**
Incubation period	**4 - 10 (20 d)**	**1 - 2 days**	**?**	**?**
Illness	**2 - 3 Weeks**	**2 - 5 days**	**2 - 3 weeks**	**-**
Clinical presentation	**Pneumonia with systematic symptoms** **Pleuritis, ZNS- u. a. extrapulmonal Symptoms**	**Influenza-like**	**Wound infection** **Proctitis** **Endocarditis**	**-**
Mortality	**2 - 20 % (80 %)**	**0**	**as pneumonia**	**-**

Ninety per cent of cases of legionellosis are caused by L. pneumophila. Legionnaires' disease is characterized as a form of pneumonia. General risk factors for the illness include gender (males are roughly three times more likely than females to contract Legionnaires' disease), age (50 or older), chronic lung disease, cigarette smoking and excess consumption of alcohol. Specific risk factors, in relation to pools and hot tubs, include frequency of hot tub use and length of time spent in or around hot tubs.

Certain clones (L. pneumophila Serogroup 1, Mab 3-1 positive) possess higher virulence potential than other strains. Currently the reason for this phenomenon is not understood completely.

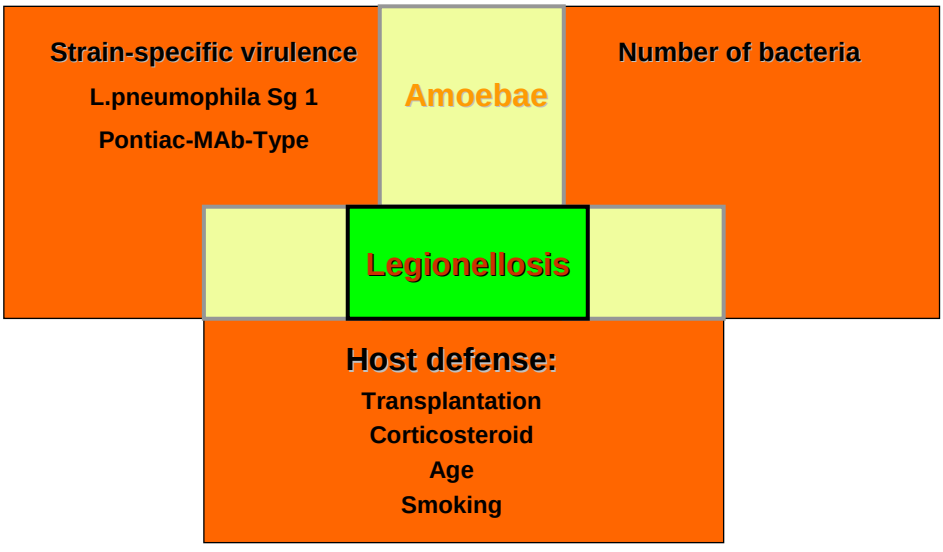
Serological Typing of Clinical Legionella-Isolates

(classified by the origin of infection)



The risk of infection following exposure to Legionella is difficult to assess and remains a matter of some debate. Due to its prevalence in both natural and artificial environments, it must be considered that people are frequently exposed (at least to low numbers). Generally, there is no reaction to such exposure, asymptomatic production of antibodies or development of a mild flu-like illness, which may not be attributed to Legionella infection.

Prerequisites for the development of *Legionella* infections



Risk of legionellosis is associated with proliferation of Legionella water systems and HVAC systems. However, the exact infectious dose for humans is not known and is strain depended. Furthermore, since infected amoeba is the transmissible form of Legionella it is difficult to make any correlation between the number of legionellae in a water sample and the risk for infection. From reported outbreaks and documented single cases that inhalation of bacteria or aspiration following ingestion is the route of transmission. Noteworthy, an aerosol is not a mist that can be easily seen by eye. Thermal spring waters may be a source of high numbers of Legionella spp. and they have been rarely implicated in cases of Legionnaires' disease. Besides piped drinking-water distribution systems, household hot and cold water maintained between 25 °C and 50 °C, cooling towers, evaporative condensers of air-conditioning devices, water fountains and mist-generating machines are also potential sources of exposure to Legionella.

Control of Legionella follows similar general principles to water safety plans applied to drinking-water supplies although, in this instance, the principal responsibility will not lie with the water supplier. Important control measures include appropriate design of the water system, to minimize the available surface area to reduce the area for possible bacterial colonization.

In order to control the growth of Legionella in cooling towers physical cleaning of surfaces and the appropriate use of disinfectants are critical.

High-risk individuals such as those with chronic lung disease or after transplantation should be cautioned about the risks of exposure to Legionella. In hospitals end stage filters on all water outlets reduce the risk for Legionella Infection.

Increased risk of Legionella in drinking-water has been associated with systems operating within the temperature range 25–50 °C. Therefore, the most important measures to reduce the risk are:

- Coldwater must be cold (<20°C)
- Warm water must be hot (>55-60 °C)

- Water must not be stagnant
-

In most cases, monitoring for potential microbial hazards is done using indicator microorganisms (rather than specific microbial pathogens), which are easy to enumerate and would be expected to be present in greater numbers than pathogens. This approach is applicable to faecal microorganisms but on not to microbes that are grow in close association with biofilm and / or protozoa.