A practical approach to safe management of water systems in healthcare premises

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Waterborne disease is the generic term for all infections arising from water use

- The agents of disease may be:
  - chemical e.g. Cu, Pb
  - or microbial- various opportunistic pathogens e.g. Pseudomonads, legionellae, mycobacterium etc

- The ability of waterborne agents to cause disease depends on various factors including
  - The dose required to cause infection
  - The susceptibility of the individual,
  - The ability to survive in the environment
  - The potential for increase within the water system

- For chemicals increases may be due to corrosion e.g. Cu, Pb, Ni etc
- For potential pathogens due to increases due to growth within the system
Water in buildings: a recognised source of waterborne disease

Agents of disease have the potential to increase from the point of supply to the point of use.

- Levels increase due to corrosion; leaching; microbial growth e.g. Cu, Ni, Pb, PVC etc and opportunistic pathogens.
- No or Low levels in the supply.

Infectious dose + susceptible persons = CASES.
The presence of a microorganism or toxic chemical constitutes a **HAZARD**.

The probability of an injury, disease, or death occurring under specific circumstances (WHO) is a **RISK**.
In the context of today  The hazard =
A plume of volcanic ash from Iceland has led to flights across the UK being grounded. The events around one British Airways flight in 1982 reveal the potential dangers of this sort of dust.

When all four engines on the Boeing 747 being flown by Captain Eric Moody shut down at 37,000ft, he hadn't a clue why.

It wasn't until later, when Capt Moody, his crew and the 247 passengers on board the flight, were safely back on the ground, that he discovered the cause of the narrowly averted catastrophe - volcanic ash.

Airports are being closed across the UK after dust which spewed from a volcano in Iceland, began drifting southwards. The experience of Capt Moody, almost 30 years ago, shows the potential danger clouds of volcanic ash present to modern jet aircraft.

There had been no hint of trouble when flight BA 009 took off from
Hazards associated with water in buildings: -
common waterborne microbial contaminants: -

• Usually from exogenous sources
  – e.g. sewage contamination; backflow; animal and/or insect ingress
  – Faecal-oral transmitted pathogens including enteric aquatic bacteria
    • eg: *Salmonella*, *Shigella*, *E.coli* 0157

• Persistence depends on various parameters including presence of nutrients, temperature etc

• Preventable in modern well designed and well managed water systems
Hazards associated with water in buildings:- indigenous infectious agents

- Survive and grow in water (usually associated with biofilms)
- Opportunistic pathogens particularly of the immunocompromised include—
  - *Pseudomonads*
  - *Legionella* spp
  - *Mycobacterium* spp.
  - *Aspergillus* spp.
  - *Stenotrophomonas (Pseudomonas) maltophilia*
  - *Acinetobacter* spp. (e.g. *Acinetobacter baumannii*)
  - *Achromobacter* spp.
  - *Aeromonas* spp.
  - *Ochrobacter anthropi* (syn. CDC gp Vd)
  - *Chryseobacterium meningosepticum*
  - *Serratia marcescens*
Routes of exposure

The type and nature of exposure will vary. Examples include:-

- **Direct ingestion** of drinking water or through consumption of food and beverages prepared at restaurants, food outlets, cafés, etc.
- **Ingestion /contact with water** from bathing including the use of pools, such as swimming, spa, whirlpool baths.
- **Aerosol inhalation** from cooling towers, hot and cold water outlets such as showers, taps, water closets, spa pools, decorative fountains, irrigation systems, misting devices, medical nebulizers etc.
Pseudomonas aeruginosa = Most problematic

- leading cause of illness in immunocompromised individuals
  (Mena KD, Gerba CP. Rev Environ Contam Toxicol. 2009;201:71-115)
  - Extremely widespread in nature
  - Are tolerant to a wide variety of physical conditions, including temperature and biocides
  - capable of growth in very low nutrient environments,
  - can grow in distilled water scavenging nutrients from the air
  - can utilise wide range of compounds including some disinfectants / plasticisers
  - often antibiotic resistant
  - Some evidence of ozone and chlorine resistance (isolated from whirlpool bath with 3.00ppm residual chlorine)
**Pseudomonas aeruginosa outbreaks**

- Estimate of 1400 deaths /year USA as a result of waterborne nosocomial pneumonias caused by *Pseudomonas aeruginosa*
  
  Review by Anaissie, et al 2002; Archives of Internal Medicine. 162(13):1483-1492,

Problems with *P. aeruginosa*

Estimate of 1400 deaths /year USA as a result of waterborne nosocomial pneumonias caused by *P. aeruginosa*

Review by Anaissie, et al 2002; Archives of Internal Medicine. 162(13):1483-1492,

- Trautmann *et al*, showed between 1998 and 2005 9.7%-68.1% of randomly taken tap water samples on different types of ICUs were positive for *P. aeruginosa*,
  - 14.2%-50% of infection/colonization episodes in patients were due to genotypes found in ICU water.
    *American Journal of Infection Control*, Volume 33, Issue 5, Pages S41-S49

- **Germany 2008** contaminated still bottled water 19 ICU patients-15 infections and four colonisations due to in 6 intensive care units.
Whirlpool baths and hydrotherapy pools

- Can cause infections due to *Pseudomonas aeruginosa* e.g. folliculitis
- Not yet shown to be a cause of legionnaires’ disease but have isolated *Legionella* from a free standing pumped whirlpool system
- Disinfection and cleaning a problem
Pseudomonas hydrotherapy pools

• Microbiologically confirmed infections with P. aeruginosa of identical antibiotic sensitivity patterns arose in one week in wounds of 4/24 residents who used a whirlpool bath from which *P. aeruginosa was also isolated.*


• Nosocomial outbreak of *Pseudomonas aeruginosa* folliculitis associated with a physiotherapy pool. Hospital staff and patients using a swimming pool in a newly constructed physiotherapy unit. 5/11 (45%) physiotherapists who had used the pool, as compared with 0 / 17 who had not (p less than 0 005).

Schlech et al, CMAJ 1986 Apr 15;134(8):909-13
Pseudomonas risk factors

- Stagnation
- Low / no biocides
- Lack of cleaning regime
- Presence of nutrients (including plastic plumbing components / plastic bottles)
- Low water temperatures
- UV treatment
  - Hospital hydrotherapy pools treated with ultra violet light: bad bacteriological quality and presence of thermophilic Naegleria, De Jonckheere ;Hyg (Lond) 1982 Apr;88(2):205-14
Mycobacterium spp.

- Includes relatively heat and biocide resistant NTMs, associated with biofilms and protozoa
- *Includes* *M.* *fortuim*, *M.* *chelomae*, *M.* *Kansaasii*, *Mycobacterium avium* complex (MAC) which consists of two species— *M. avium* and *M. intracellulare*. 
Risk factors

- automatic taps, low chlorine levels, low hot water temperatures, plastic pipework, biofilms
- Can survive and grow in distilled water

- Aids Patients at increased risk from *M. Avium* colonised hospital water systems

- Temperature relationship
  - *M. avium* and *M. xenopi* frequently isolated from hospital hot water systems and *M. kansasii* from cold water systems
Outbreaks

• Wallace et al; J.Clin Micro, 31:10:2697-2701
  – Describe several outbreaks due to poor endoscope / bronchoscope washer processes and hygiene e.g. *M.cheloneae /M.Abscessus*
  – And an outbreak of *M.Abscessus* due to contaminated haemodialysis process water,

  – 5 paediatric –oncology patients with *M. mucogenicum* linked to automatic taps and low CL₂ levels and failure to cover CVC sites.
Fungi including *Aspergillus* spp.

- 3 year study by 2003 Anaissie et al (Blood, 101:7: 2542-46) in a hospital with air filtration in place but
  - Low residual chlorine levels <0.5ppm in water
  - *Aspergillus* present in incoming water supply; hospital water tanks; sinks and showers, biofilms
  - Older systems at risk but also linked to new systems
  - Immunocompromised patients at higher risk
Outbreaks

- **A. fumigatus** a frequent problem
  - 8 patients with invasive aspergillosis - clinical isolates
    *A. fumigatus* recovered from patients matched those recovered from water sources
  - Nosocomial aspergillosis due to the hospital water system. *Aspergillus fumigatus* recovered from a patient with aspergillosis - genotypically identical to an isolate recovered from the shower wall in the patient's room.
Polymicrobial infections from cool water used in burns first aid treatment

- Three cases of severe invasive and necrotizing infection in patients who used or immersed themselves in cool water to limit soft tissue damage following acute major burns. Wound cultures from all patients yielded *Aeromonas hydrophila* and two yielded *Bacillus cereus*. One patient had a complex polymicrobial infection, including zygomycosis with *Rhizomucor variabilis*. 
How to manage the problem? WHO Framework for Safe Water

Public Health context and health outcome

Health based targets

Water safety plans

Surveillance

System assessment

Monitoring

Management & communication
The UK Legal Framework for prevention of waterborne infections

- **Act of Parliament / EU Directive**
  
  (Law = must be done)

  ↓

- **Implemented by Regulations**
  
  (Law = must be done)

  ↓

- **Approved Code of Practice**
  
  (managerial procedures to follow to comply with Law)

  ↓

- **Technical Guidance**
  
  Best technical practice that if followed will ensure compliance with law. Alternatives are permissible provided they can be shown to be at least equally effective
Additional Guidance for Health Care Buildings

Water systems
Health Technical Memorandum 04-01: The control of Legionella, hygiene, “safe” hot water, cold water and drinking water systems

Part B: Operational

‘Safe’ hot water and surface temperatures
Health Guidance Note
The Health and Safety at Work Act 1974
(as amended and associated legislation)

- leaves employers freedom to decide how to control the risks that they identify – that is, to look at what the risks are and to take sensible (reasonable and practicable) measures to tackle them.

- The Act is part of criminal law, enforcement is by the UK Health & Safety Executive.

- Successful prosecution can result in fines or imprisonment.
Reasonable and Practicable?

• What is reasonable and practicable?
  - Has to be decided in court

• What is an acceptable risk?
  • Who decides what is acceptable?
Acceptable Risk / Risk Appetite

If high levels of *Legionella* in a building?
Do you accept the risk if:-

- the cost of reducing the risk of legionellosis is greater than the building / equipment value
  - *e.g. When the building / equipment has a short life*
- the cost of reducing the risk would exceed the costs saved
  - *e.g. Compensation costs would be less than remedial work*
- There are other, more pressing public health problems
- The cost of control is greater than the cost resulting from litigation
- There are no cases
It could be an expensive gamble!
Corporate manslaughter and Corporate homicide Act 2007

- Large fines possible and / or imprisonment
- Statutory offence of corporate manslaughter in England and Wales (Corporate homicide in Scotland)

Fine for Legionnaires' cider firm

Cider maker HP Bulmer and its water treatment contractor Nalco have each been fined £300,000 over a fatal outbreak of Legionnaires' disease.

Two people died and more than 20 others fell ill in Hereford in 2003, the city’s crown court heard.

Judge Alistair McCrea thought a failure to clean two cooling towers adequately at Bulmer’s mill in Plough Lane in 2003 was "almost beyond belief".

The two firms had admitted breaching the Health and Safety at Work Act.

Legionella 'flourishing'

They were also ordered to pay more than £50,000 each in prosecution costs.

Nalco, based in Northwich, Cheshire, and the cider firm pleaded guilty
Acceptable limits – various applicable legislation and guidelines
Examples of Health based targets for *Legionella* in piped water systems (WHO 2007)

<table>
<thead>
<tr>
<th>Country</th>
<th>Cfu/L</th>
<th>Comment</th>
<th>refs</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>&lt;1000</td>
<td>Target for general public facilities</td>
<td>Ministere de Sante et des Solidarites (2005)</td>
</tr>
<tr>
<td></td>
<td>&lt;100</td>
<td>Target for prevention of nosocomial infections</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;50</td>
<td>Target where “At Risk “ patients hospitalized</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>1000</td>
<td></td>
<td>DVGW (2004)</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>100</td>
<td>Guideline target</td>
<td>VROM (2002)</td>
</tr>
<tr>
<td>UK</td>
<td>&lt;100</td>
<td>Guideline Target</td>
<td>HSE (2004)</td>
</tr>
</tbody>
</table>
### German hospital guidelines (2004)

**target = 0 cfu/L**

<table>
<thead>
<tr>
<th>Art der Einrichtung, in der sich die Wasserversorgungsanlage befindet</th>
<th>Werte für Legionellen (KBE/100 ml)</th>
<th>Maßnahmen</th>
<th>Weitergehende Untersuchung</th>
<th>Untersuchungsintervall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krankenhäuser sowie andere medizinische und Pflegeeinrichtungen (entspr. 2.1–2.2) – Hochrisikobereiche</td>
<td>• Zielwert 0&lt;br&gt;• Gefahrenwert ≥1</td>
<td>Nutzungs Einschränkung oder endständige Filtration</td>
<td>unverzüglich(^b)</td>
<td>nach einem halben Jahr(^a)</td>
</tr>
<tr>
<td>Krankenhäuser sowie andere medizinische und Pflegeeinrichtungen (entspr. 2.1–2.2) – Normalbereiche</td>
<td>• Zielwert &lt;100&lt;br&gt;• Prüfwert ≥100&lt;br&gt;• Maßnahmewert &gt;1000&lt;br&gt;• Gefahrenwert &gt;10.000</td>
<td>keine&lt;br&gt;keine&lt;br&gt;Sanierungsmaßnahmen umgehend, Umfang in Abhängigkeit von weitergehenden Untersuchungen&lt;br&gt;Gefahrenabwehr unverzüglich Meldung an das Gesundheitsamt(^b,c)</td>
<td>keine&lt;br&gt;keine&lt;br&gt;Sanierungsmaßnahmen umgehend</td>
<td>keine innerhalb von 4 Wochen umgehend&lt;br&gt;1 Jahr</td>
</tr>
<tr>
<td>Übrige Bereiche (entspr. 2.3–2.7)</td>
<td>• Zielwert &lt;100&lt;br&gt;• Prüfwert ≥100&lt;br&gt;• Maßnahmewert &gt;1000&lt;br&gt;• Gefahrenwert &gt;10.000</td>
<td>keine&lt;br&gt;keine&lt;br&gt;Sanierungserfordernis in Abhängigkeit von weitergehenden Untersuchungen&lt;br&gt;Gefahrenabwehr unverzüglich</td>
<td>keine&lt;br&gt;keine&lt;br&gt;Sanierungserfordernis in Abhängigkeit von weitergehenden Untersuchungen</td>
<td>keine innerhalb von 4 Wochen umgehend&lt;br&gt;1 Jahr(^d)</td>
</tr>
</tbody>
</table>

\(^a\) Richtlinie für Krankenhausthygiene und Infektionsprävention des Robert Koch-Institutes [10].

\(^b\) Maßnahmen unter Information des zuständigen Gesundheitsamtes und in Abstimmung mit einem vom Gesundheitsamt empfohlenen Hygiene-Institut (siehe 5).
In Sweden

- No legislation but
- Building guidelines
  - No levels for Legionella
  - Guidelines for management of buildings
  - Disinfection
  - Heat management
Who has the responsibility?

- **Building legislation**
- The person who constructs or has someone to construct i.e. works, is responsible
- for meeting the demands of laws and regulations.
- *The owner of the building is responsible for maintaining the building and its installations*
- *The local Building Committee is the supervisory authority there you can get information* on what rules apply in each case. The Committee may intervene if the mandatory provisions in the building regulations are not met.
- *The Swedish Board of Housing, Building and Planning, Boverket is responsible for* the general supervision of planning and building activities and controls the application of the building legislation. The Board has the right to issue technical requirement for constructions works and installations.
Other legislation

- Legal action can be taken with the support of several laws against persons responsible and also as a result of binding agreements.

- Examples: the Land Law, the Criminal Law, Law on Damages, contract agreements
How to manage the problem? WHO Framework for Safe Water

Health based targets

Public Health context and health outcome

Water safety plans

- System assessment
- Monitoring
- Management & communication

Surveillance
The Risk Assessment Process

Hazard Identification (Legionella)

Exposure Assessment (who? how?)

Toxicity Assessment (how much?)

Risk Characterization

(80/1107/EC; 88/642/EC; WHO, 2001)

Over 50 Male Smokers immunosuppressed

>10^5 in cooling towers
If you ask Google what is risk?
= 66,600,000 hits!!

World Health Organisation definition:-

• the probability of injury, disease, or death under specific circumstances (WHO)
Ask Google What is a risk assessment = only 131,000,000 hits!!!

• The overall process of using available information to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences
The WHO water safety plan (WSP)

1. A 10 step process, that fits within the three main areas of system assessment, monitoring and management and communication

2. Health-based targets: targets normally set a national level by a competent authority

3. System specific plans developed and implemented by the operator of the system (such plans may be building specific, may be developed and implemented by the building operator).

4. Surveillance - system of independent checking
Steps in System assessment

1-Document and describe the existing system

2-Assess hazards and prioritise risks. Undertake a hazard analysis and risk characterisation to understand how hazards can enter and grow within the water system

3-Assess the system Assess the existing system, including a description of the system and a water flow diagram

Assemble the team
e.g. people with knowledge of: the particular water system, specific health risks, system design and management, control measures
Assessment of risk requires understanding of the:

- Potential hazards
- Design features
- Sources of contamination
- Conditions necessary for amplification
- Modes of transmission
- Routes of exposure
- Population susceptibility
- Control strategies
An understanding of the Chain of events leading to infection e.g. For *Legionella*

<table>
<thead>
<tr>
<th>Environmental reservoir</th>
<th>(with a virulent organism)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplication</td>
<td>(stagnation, temperature, nutrients)</td>
</tr>
<tr>
<td>Dissemination</td>
<td>(aerosol generating outlets)</td>
</tr>
<tr>
<td>Inhalation</td>
<td>(infectious dose)</td>
</tr>
<tr>
<td>Susceptible host</td>
<td>(age, sex, underlying disease)</td>
</tr>
</tbody>
</table>
Selection of Assessors
Complex buildings may need specialist assessors

- If you consider all the potential systems in healthcare premises
  - Cooling towers /air conditioning units
  - Hot and cold water systems
  - Pools (hydrotherapy; whirlpool baths)
  - Dental chairs and equipment
  - Birthing pools
  - Specialist equipment (e.g. Audiology, dermatology, podiatry, tissue debridement etc)
  - Construction equipment – concrete batchers, pressure washers etc
If we take legionellae as an example:-
the hazard is the presence of legionellae

34 years since the 1st recognised outbreak of “legionnaires’ disease 58th state convention of the American Legion Dept. of Pennsylvania July 1976

• Type species *Legionella pneumophila*
• At least 52 species described to date
• At least 20 species associated with disease in man

• Worldwide *L. pneumophila* (except some parts of Australia where *L. longbeachae* is most common cause) of one particular subtype (serogroup 1 monoclonal subtype 3/1 [synonyms Pontiac / mAb2 reactive])
most common cause of outbreaks of legionnaires’ disease

In hospitals a wider range of species has been found to cause disease
### Isolates by species 1995-2008

<table>
<thead>
<tr>
<th>Species</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. pneumophila</td>
<td>5,399</td>
</tr>
<tr>
<td>L. anisa</td>
<td>5</td>
</tr>
<tr>
<td>L. bozemanii</td>
<td>25</td>
</tr>
<tr>
<td>L. brunensis</td>
<td>1</td>
</tr>
<tr>
<td>L. cincinatensis</td>
<td>1</td>
</tr>
<tr>
<td>L. dumoffii</td>
<td>5</td>
</tr>
<tr>
<td>L. feelii</td>
<td>1</td>
</tr>
<tr>
<td>L. gormanii</td>
<td>4</td>
</tr>
<tr>
<td>L. jordanis</td>
<td>1</td>
</tr>
<tr>
<td>L. longbeachae</td>
<td>29</td>
</tr>
<tr>
<td>L. macaechernii</td>
<td>1</td>
</tr>
<tr>
<td>L. micdadei</td>
<td>26</td>
</tr>
<tr>
<td>L. parisiensis</td>
<td>1</td>
</tr>
<tr>
<td>L. saint helensi</td>
<td>1</td>
</tr>
<tr>
<td>L. wadsworthii</td>
<td>1</td>
</tr>
<tr>
<td>Legionella spp</td>
<td>134</td>
</tr>
</tbody>
</table>

Total 5,635
The WHO /UK approach to the control of legionellosis

• PREVENTATIVE

• Requirement for a Water Safety Plan / Risk Assessment (RA) and written scheme of control

• To do this need to know:-
  – Susceptible population
  – Current knowledge of ecology
  – Knowledge of system design and operation
  – Good operational and management practice

• Use RA to prepare a scheme to control risks

• Enshrined within legislation and guidance
Risk factors for nosocomial pneumonia : (WHO 2006)

- The most susceptible hosts are immunocompromised patients, including solid organ transplant recipients and those receiving corticosteroid treatments (Arnow et al., 1982; Strebel et al., 1988).

- Other risk factors
  - recent surgery
  - intubation and mechanical ventilation
  - presence of foreign matter in the lung (aspiration)
  - presence of nasogastric tubes
  - use of respiratory therapy equipment.

- Smoking is a significant risk factor
Nosocomial cases by patients’ underlying medical conditions England and Wales 1980 – 2007  
(data from Dr Carol Joseph HPA CFI)

<table>
<thead>
<tr>
<th>Clinical conditions</th>
<th>Cases</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transplant patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>renal</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>cardiac</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>liver</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>other</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Other immunosuppressed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>leukaemia</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>lymphoma</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>carcinoma</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>diabetes</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>other</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Other medical/surgical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cardiac</td>
<td>39</td>
<td>18</td>
</tr>
<tr>
<td>Not known</td>
<td>181</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>315</td>
<td>106</td>
</tr>
</tbody>
</table>
### Cases associated with occupational nosocomial infection 1980 – 2007

data from Dr Carol Joseph (HPA CFI)

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurses</td>
<td>13</td>
</tr>
<tr>
<td>Doctors</td>
<td>6</td>
</tr>
<tr>
<td>Dentists</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory staff/engineer</td>
<td>2</td>
</tr>
<tr>
<td>Cleaner/porter</td>
<td>3</td>
</tr>
<tr>
<td>Ancillary staff</td>
<td>10</td>
</tr>
<tr>
<td>Other/not known</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42</strong></td>
</tr>
</tbody>
</table>
Route of infection—aerosol formation

- Inhalation of air containing the Legionella bacteria (aerosol)
- Rarely by aspiration (water going down the “wrong way”) of water containing Legionella bacteria
- NEVER from someone else
Sources of Aerosol formation

- Water drops falling onto a hard surface
- Bubbles rising to the water surface and bursting
- Rain
- Running a tap
- Running shower
- Flushing a toilet
- Spraying plants
- Humidifiers
- Water running over pack of cooling towers
- Wave formation
The scale of the problem
Legionnaires’ disease in Europe 1995 - 2008

Average 30 reporting countries

51,091 reported cases

3778 reported deaths

Average annual population 446 million

European Working Group for Legionella Infections
Total European cases: country of report 2008

N = 5960
European Working Group for Legionella Infections

European outbreaks by type 2008

N = 132

Travel abroad 36%

Travel home 23%

Spa pools 2%

Nosocomial 11%

Community 28%
### Legionnaires’ disease in residents of England and Wales

#### Age, sex and deaths 2000-2007

<table>
<thead>
<tr>
<th>Age range</th>
<th>Nosocomial</th>
<th>Travel</th>
<th>Community</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age range</td>
<td>22-95y</td>
<td>17-91y</td>
<td>4-103y</td>
<td>4-103y</td>
</tr>
<tr>
<td>Mean</td>
<td>62y</td>
<td>59y</td>
<td>58y</td>
<td>58.5y</td>
</tr>
<tr>
<td>Median</td>
<td>64y</td>
<td>59y</td>
<td>58y</td>
<td>58y</td>
</tr>
<tr>
<td>Mode</td>
<td>53y</td>
<td>55y</td>
<td>53y</td>
<td>53y</td>
</tr>
<tr>
<td>M to F ratio</td>
<td>2.4:1</td>
<td>2.9:1</td>
<td>4.1:1</td>
<td>3.0:1</td>
</tr>
<tr>
<td>Deaths</td>
<td>41.2%</td>
<td>9.1%</td>
<td>10.7%</td>
<td>10.7%</td>
</tr>
</tbody>
</table>

(European average 12%)
In England & Wales approx 400 cases reported /y

What is the real number?

- **Estimate 1.**
  - Countries with best surveillance report 20 cases / 10^6 p.a.
  - This suggests in England & Wales a total of 52 x 20 = 1040 cases p.a.

- **Estimate 2**
  - 2000/2001 - 192,565 cases of pneumonia in England in 1 year
  - Agent identified in <5%
  - Estimates of true incidence of LD based on intensive studies of patients in hospital with pneumonia caught in the community suggest 2% – 3% of all community acquired pneumonias are legionnaires’ disease
  - This suggests in England & Wales there are about 5500 cases p.a.
Where are the bugs?

1981-4 DoH survey

- Hospitals - 70%
- Hotels - 53%
- Businesses - 75%

Lower Saxony study 1985-7
(Habicht 1988) 1241 samples

- Hospitals - 70%
- Hotels - 18%
Problems with control in large buildings eg hospitals and hotels

**HOSPITALS**
- Complex water systems
  - Many outlets
  - Long pipe runs
  - Numerous wash hand basins
- Thermostatic mixer valves to control outlet temperatures
- Often old plumbing following unknown routes leading to dead-legs & blind ends
- Highly susceptible patients
- New builds / PFIs – tenders not specific enough, difficult to manage
- Management conflicts - hospital estates / PFI managers
- Phased occupation of new buildings
- Change of use / misuse e.g. Bathrooms used as storerooms

**HOTELS**
- Complex water systems
  - Many outlets
  - Long pipe runs
  - Numerous wash hand basins
- Variable water demand
- Variable occupancy (seasonality)
- Variable (mobile) staff (training)
- Variable water supply
- Extensions (design and capacity)
- Energy saving - solar heating
- Spa pools
water in healthcare premises - potential sources of infection

Drinking water
- Tap
- Bottled
- Plumbed dispenser
- Drinks vending machines
- Ice

Food preparation

Domestic hot & cold water
- Bathing
- Dish washing
- Toilet flushing

Equipment
- Endoscope washers
- Water baths
- Nebulisers

Clinical humidifiers
- Nebulisers
- Dental chairs
- Dialysis

Pools
- Hydrotherapy
- Birthing
- Whirlpool footbaths

Building services
- Cooling towers
- Humidifiers
- Fountains
The WHO /UK approach to the control of legionellosis

- PREVENTATIVE
- Requirement for a Water Safety Plan / Risk Assessment (RA) and written scheme of control
- To do this need to know:-
  - Susceptible population
  - Current knowledge of ecology
    - Knowledge of system design and operation
    - Good operational and management practice
- Use RA to prepare a scheme to control risks
- Enshrined within legislation and guidance
Current knowledge of ecology – key facts

• Widespread in natural aquatic environment
  – Thermal springs, rivers, lakes, streams, soils, sediments, groundwater, tropical rainforest canopy
• Legionellae survive prolonged periods / indefinitely in water provided physico-chemical conditions are not adverse (applies to other opportunistic pathogens e.g. Pseudomonads /Mycobacteria)
• Seasonal incidence in temperate zones
• Require other aquatic organisms for growth
• Grows in biofilms
• Growth at 20 - 45°C
• Optimum growth at 32 - 42°C
• Most commonly isolated from water at 35 – 45°C
Legionella and temperature

- Detectable in waters up to ~55°C
- Killed in seconds at 70 °C
- 90% killed every 2 minutes at 60°C - (but can have millions in a system which is causing cases)
- No observable growth below 20 °C

- Basis of control in hot and cold water systems
- Keep hot water **hot** to reach outlets at a minimum of 50 °C
- Cold should be **less than 20°C** within 2 minutes of turning on tap
Water temperature, growth rate and risk

L. pneumophila growth rate

Temp °C

Risk

Minimal
Max
Low

10 15 20 25 30 35 40 45 50 55

0% 100%

= growth rate
Lack of insulation
Nutritional characteristics – affecting survival

- Utilises amino acids as carbon and energy sources
- Some bacteria eg *Flavobacterium* spp. produce extracellular cysteine which will support growth of legionellae.
- Can be seen on medium without cysteine
- Growth Factors also include iron-so corrosion products can increase risk
Nutrients from materials

- Increased use of polymeric materials in plumbing which can leach organic compounds from surfaces

- These may provide nutrients to support microbial growth e.g. polyvinyl chloride

- Bezanson (1991) showed PVC significantly more susceptible to colonisation than copper or brass

- Habicht (1988) showed copper had an inhibitory effect in the first 5 years; no significant reduction in isolation rates after
Growth on different plumbing materials relative to glass (=1)

- Legionella and supporting flora were grown in continuous culture model systems.
- Counts are expressed as a ratio relative to the counts on glass (=1).
- e.g. there was approximately 10 X the growth of aerobic heterotrophs on cPVC as there was on glass.
Materials – UK hospital outbreak

- Parker bath showing different types of plastic hose

- The white hose feeding the shower head contained very much higher counts of *L. pneumophila* than did the black.
Legionellae and protozoa

• Rowbotham 1980 *J. Clin. Path.* 33: 1179-83 first reported association of legionellae and amoebae

• Subsequently shown to be associated with several protozoans e.g. *Acanthamoebae* spp; *Hartmanella vermiformis; Tetrahymena pyriformis; Naegleria* spp

• Intra-amoebal growth patterns different from those grown *in vitro* – modifications of lipopolysaccharide and fatty acid content of the cell envelope.
Protozoa protect legionellae

- Trophozoites often more resistant to chlorine and other biocides than legionellae
- *L. pneumophila* have been shown to survive inside amoebal cysts treated with 50ppm chlorine overnight (Kilvington & Price 1990 J Appl Bact 68: 519 - 525).
- Cysts are especially protective and can also protect against drying and heat

- *L. pneumophila* inside a cyst of *Hartmanella*
Virulence is important for its ability to infect amoebae and human monocytes and macrophages

- To replicate inside the host virulent *L. pneumophila* resists / evades the hosts’ natural defence mechanism at warm temperatures
  - At 35 ºC legionellae proliferate inside suitable host
  - At 22 ºC amoebae digest legionellae

- Protozoan host specificity- if legionellae ingested by unsuitable amoebal host then either egested or digested
Growth in Biofilms

= consortia of micro-organisms growing on surfaces

planktonic

Grazing protozoa

Shear stresses
(some species more susceptible)

Attachment

Bacterial; Monolayer

Conditioning layer

Cell division

Biofilm

Biofilm sloughing off

biofilm
Biofilm features

- Rougher surfaces preferentially colonised forms microniches
- Protection from shear stresses; turbulent flow and biocide activity
- Different physiological state & Nutritional advantage
- Glycocalyx – hydrated poly-anionic polysaccharide matrix
- Benefits of growth in biofilms
  - Niches for bacteria with differing metabolic needs - Eg aerobic and anaerobic bacteria can be isolated from the same biofilm
  - Ionic exchange-metal ions and nutrients transported by permeases into cells
  - Biocide resistance - Can take up to 1000 x greater exposure to a given biocide concentration to kill an organism in a biofilm as it would to kill the same organism in water
Overview of factors encouraging biofilm growth

**Presence of Nutrients**
- Poor quality supply water,
- Accumulation of dirt and debris in system
- Corrosion and scale

**Poor design**
- eg Difficult to clean - not possible to remove biofilms
- High surface to volume ratio

**Stagnation**
- Areas of low or no flow,
- Storage vessels too large,
- Pressure vessels,
- Dead / blind ends,

**Water above 20 ºC**
Where are the biofilms?

- Outlets, washers, seals, flexible hoses, plastic shower heads, thermostatic mixer valves
- Areas of stagnation
  - eg oversized header tank
- Dead legs / blind ends
- Interfaces in aquatic systems
  - eg cutting oil/ water
Flexible hoses (electron micrographs with permission of Dr T Makin)
What is a potential source of legionella infection?

- Any system / device where the temperature of some or all of the water in it can be between 20°C – 45°C. - in practice anything that doesn’t have sterile water in it
- AND there is a possibility of the water being aerosolised and inhaled or in rare cases aspirated during normal operation or maintenance
- NB history has shown that systems that have been perceived as potential risks usually are eventually shown to be responsible for an outbreak e.g. air scrubbers; vehicle washes; jet washes
Potential sources

- Recognised sources
  - Wet cooling systems
  - Domestic hot and cold water systems
  - Spa pools
  - Humidified display cabinets for meat and vegetables
  - Indoor fountains
  - Natural spas / hot springs
  - Humidifiers
  - Respiratory therapy equipment
  - Effluent (sewage) plant
  - Compost
  - Air scrubbers
  - Water pressure jet cleaners
  - Vehicle washes
  - Cutting fluids

- Other potential sources
  - Irrigation equipment
  - Whirlpool baths and therapy pools
  - Whirlpool footbaths
  - Sprinklers and outdoor water features
  - Carpet cleaners
  - Solar / geothermal heating

- And so on
potential sources
Modified systems

Looks like you have some non-standard plumbing here!!
Outbreaks by source 1995 - 2008

Wet Cooling Systems

Hot or cold water systems

Spa water

Not known

European Working Group for Legionella Infections
WHERE A RISK IS IDENTIFIED LOOK AT PRACTICALITIES OF REMOVING THE RISK
Calorifier / storage water heaters/buffer vessels = higher risk

Temperature gradient

Vertical calorifier

Hot return

Hot out

Cold inlet

Vent

High

Low

Horizontal calorifiers

Should be cleaned & disinfected regularly (usually annually)
Deposits flushed out regularly
Prevent stratification operating anti-stratification pumps when there is low demand (usually at night for 2 – 3 hours)
Consider replacing with non-storage water heaters – low risk

Angeleri type

Gas fired

Plate heat exchangers
WSP step 2- Monitoring

• Three steps
  – Identify control measures
  – Monitor control measures
  – Validate effectiveness of WSP
Identify Control Measures:-
Basis of control in hot and cold water systems

- Clean supply of water- source water quality
- Keep system clean to prevent build-up of nutrients
- Do not use construction materials that support growth
- Keep at temperature that limits growth or treat with biocide
  - Avoid temperatures between 25 °C and 45 °C
  - Cold below 20°C
  - Hot at 60°C from the heat source
- Keep water moving – do not allow stagnation
  - Storage in tanks should not exceed 24 hours
  - No dead legs or blind ends
Monitor Control Measures
Temperature monitoring is the most powerful tool
NB to check representative outlets on all loops of the system
Validation and verification of WSP

- **Validation** - Developing procedures to ensure WSP effective
- **Verification** - Uses methods, procedures tests, in addition to those used for operational monitoring, to determine if health based targets met - e.g.
  - Preferably by independent surveillance
Validation of a water treatment regimes

• Especially if recent changes in:-
  • The system
  • The treatment regime
    • E.g. Biocide used, dosing levels / intervals
  • The sampling points
  • Key personnel
  • Service providers / samplers etc
  • Recent monitoring results
    • Temperature, pH, Biocide levels, microbiological
Surveillance

- Surveillance is the systematic collection, consolidation, and analysis of data to verify the health of its targets, system assessments, and control measures operating properly. This may include:
  - Internal and external audit, to confirm that operational monitoring and corrective actions have been undertaken as stated in the WSP.
  - Heterotroph counts to track trends and changes, rather than as an absolute indicator, to be undertaken by an accredited laboratory.
  - Sampling for *Legionella*, where indicated.
Risk communication

- The person involved in implementing the WSP should be responsible for risk communication and developing the risk management plan. This should include:
  - Modes of communication to be used and stakeholders to be informed (e.g., building owners, public health authorities)
  - Background information on the risk posed by microorganisms from the risk assessment and system assessment.
  - The goals of the WSP in addressing the risk posed.
  - Content and target audiences for communication
  - Sources of further information about the water system and microbial contamination
WHO Building (environmental) risk factors (2007)

- Poor design or maintenance of cooling water systems
- Complex water distribution systems
- Long pipe runs
- Poor water temperature control
- Low water flow rates/stagnation
- Inadequate staff training
New builds are not problem free!

- Brand new 1200 bed hospital with 3 blocks. Block 1 finished early 2005 and blocks 2 and 3 still under construction to be finished and occupied in 2006.
- Ground floor and 2\textsuperscript{nd} floor occupied. 3\textsuperscript{rd} floors planned to be occupied soon with haematology patients.
- All plastic plumbing, conforms to UK Water Fittings Regulations
- Hot water no legionellae but cold water already colonised a few months after occupation
- Cause partial occupancy and therefore poor flow?
What happens when it all goes wrong?
Case study hospital A

- New build for high risk patients
- Complex management regime
- Disinfected prior to handover in June,
- Handed over August
- Not fully occupied until October
- Supposedly built to “Standard Design” and supposedly with approved materials
- 5 months later positive *Legionella* tests followed by chlorination and “negative tests”
- + 1 month later first nosocomial case (patient recovered)
Basic system design

Ambient temp >34 °C

Roof tank
Over capacity

Plant room >34 °C

40K storage tank

UV

Incoming mains

Riser steam + HCW

Potable
Findings

- Hot and cold pipes in same conduit with insufficient insulation to prevent heat/loss gain (riser 36 °C).

- Excessive build-up of heat - builder rectification shaft mechanically ventilated

- Mechanical Services in riser i.e. steam, condensate, MTHW, DCWS, DHWS flow and returns, drinking water and pipe medical gas services
Solar reflective cover fitted over mechanical service pipes

- Designers had assumed mains intake @ 8-12 °C in fact nearer to 18-20 °C
- Fitted after first incident
UV on supply as it enters building before storage?

- No control downstream
If a building is designed well should it need a disinfection system?

- Chlorine dioxide specified in original specification
- Not installed until after the first incident
Cold Water Storage

- Domestic water holding tank oversized
- Level reduced on two separate occasions
- Drinking water tank un-insulated
- Tank was later insulated and a by-pass facility provided, the water level was dropped and the float control mechanism was changed to a copper type.
Overall failures

- Presence of deadlegs (specification changed during build)
- Cold water at >30°C!
- Storage tanks in plant room
- Chlorine dioxide plant specified in design but not installed
- Tanks oversized (trust asked for more basins)
- Duplicate facilities in theatres, anaesthetic rooms etc
Actions

- Showers descaled and chlorinated
- Chlorine dioxide installed (but dosed at <0.5mg/l)
- Extra insulation
- Flushing and descaling and more sampling.
- “Deadlegs removed”.

• Stated that now compliant with ACoP
Hospital A part 2

- + 4 months - a second nosocomial case-patient died (had been in hospital for several weeks)
- *L. pneumophila* 1 from hot water matches patient isolate
  - *Legionella* found in H&CW outlets & drinking water fountains
  - Further testing revealed 42% outlets Lp +ve (>10 cfu/L)
  - 31% of outlets $10^2$ - $10^4$ Lp cfu/L
  - System pasteurised, ClO$_2$ increased to 3mg/l,
  - Point of use filters installed
Further investigations into patient’s death

- Patients room empty for 2.5 weeks before used
- UV not working properly
- Nebulizers ? rinsed with tap water
- Chlorine dioxide levels inadequate
- Flexible fittings to outlets were not approved
  >1200 required replacement

- Imported not as in building specification -
Flexible hoses

- Flexible hoses
- Non-compliance hoses removed
- Example of damage sustained to hose during installation
- Damage/distortion was only identified after the hoses were removed
Further actions

• Chlorine dioxide levels raised to 2-3 ppm & monitored at the outlets

• Temperature profiling of whole system

• Risk based sampling programme

• Deadleg removal

• Sterile water used for nebulisers

• Flushing programme maintained

• Point of use filters installed in all high risk areas
Conclusions

- This should never have happened!!
- *Legionella* control not inherent in design
- Build was not sufficiently monitored to ensure that the specified materials were used
- A well designed system should not need additional treatment
- UV on incoming water has no residual effect downstream
- Too many outlets- and tanks oversized
- Patients high risk and very ill so outlets not used for some time even when rooms occupied
- When chlorine dioxide installed the system should have been hyperchlorinated and a high level maintained until system under control
Conclusions
Benefits of the water safety plan approach

• Systematic and detailed assessment.
  – Determination of whether the water quality, at the point (s) of potential exposure or use meets the health-based target based on a risk assessment for the population likely to be exposed

• Prioritised hazards and risks-control water systems with the potential to cause legionnaires disease (biological, chemical or physical)

• Operational monitoring of barriers and control measures

• Good Management and communication in place
  – to document the system assessment and monitoring
  – The describe actions to be taken during normal operation, and after outbreaks and incidents.
  – Including documentation and communication (e.g. a planned remedial action after adverse monitoring results such as low biocide levels; listing those to be informed of an event)
The incidence of health-care--associated waterborne infections can be minimized by

1. **Having an up to date risk assessment**
2. **A control plan in place**

   1. Recognition of high risk patients and appropriate management
   2. Appropriate maintenance, cleaning and disinfection regimes for water systems and medical equipment (e.g., Endoscope/bronchoscope washers; hydrotherapy equipment)
   3. Adherence to water-quality standards for special purposes e.g. hemodialysis units
Legionnaire's case at hospital

Earlier this year the Trust was fined for failing to control a bug which can cause Legionnaire's disease, after the death of a patient in 2002.

At the time, the Trust carried out £50,000 worth of tests on the hot water systems in the building, which can harbour the bacteria.

But following the diagnosis of this new case at Basildon Hospital, tests revealed the problem has returned.

Patients with suspected pneumonia are being tested for the bacteria, and work is being done to get rid of the contamination.

It is not possible to eradicate the bacteria and we did, and have continued to do, everything that was recommended to manage the risk.

Legionnaires' hunt focuses on factory

Legionnaires' disease inquest opens

Cooling systems are being checked for a disease source.

Health officials are testing water samples from a chemical factory to see if it is connected to a Legionnaires' Disease outbreak.

Killer bug strikes fear into thousands

Britain's worst outbreak of Legionnaires' disease grips town

Rita Spencer, 58, of Ashcott, Somerset, and the same age, died.
Thank you for listening

Are there any questions?