Pseudomonas aeruginosa Infections in the Intensive Care Unit

Facts and Control Measures
**Pseudomonas aeruginosa**

*P. aeruginosa* (PA) is a Gram-negative bacillus which is tolerant of a wide variety of physical conditions, has minimal nutrition requirements, and is a major opportunistic pathogen. PA appears sporadically in drinking water distribution systems, for example as a consequence of contamination during construction works, but seem to occur at a higher frequency in premise plumbing systems compared to water mains.

PA is one of the most common and most problematic bacteria in healthcare facilities and is responsible for approximately 10-20% of hospital-associated infections (HAI) (pneumonia, wound infections, blood stream infections and urinary tract infections) in intensive care units (ICUs). Length of stay, severity of underlying disease and exposure to invasive procedures, but also bacterial adherence, virulence factors, and antimicrobial drug resistance are associated with PA in ICUs. It has been shown that the incidence of HAI is 5-10 times higher in the ICU than in general wards.

Although endogenous origin was considered as the most relevant route of PA infections, in the last ten years a significant proportion of PA isolates have been shown to stem from the ICU environment and cross-transmission. Several studies have shown that up to 50% of hospital acquired PA infections may be derived from the in-premise water distribution system. Unlike patient and pathogen characteristics, environmental factors such as nursing workload or contamination of water taps could be managed and modified.

PA can colonise biofilms in water systems and be released from the tap. PA can colonise flow straighteners and aerators as well as bottled water.
PA colonises many types of fluids (even distilled water) and rapidly forms biofilms. Moreover, PA can be present in water taps including the tap body, connectors and flow straighteners, sinks, drains, toilets and showers. Sensor taps have been shown to be more likely to become contaminated than non-sensor taps.

PA has been observed to be present and growing within drinking water biofilms, thus becoming more difficult to eradicate than planktonic bacteria. PA is resistant to chlorine and other disinfectants used in water treatments and may survive in the ward environment even after disinfection, increasing the risk of acquisition by patients. PA living in biofilms exerts a higher resistance towards disinfectants due to the mechanical protection provided by the biofilm matrix. It has been shown that the use of sublethal concentrations of chlorine-based oxidising agents (sodiumhypochlorite, chlorine dioxide, electrochemically activated chlorine: continuous treatment with 0.15 ppm chlorine or shock treatment with 10 ppm chlorine for 6 hours) has led to a cyclical regrowth of biofilm after treatment end and the survival of PA living in the biofilm. Furthermore, under unfavourable operating conditions of a drinking water system PA has been shown to survive sequentially 24 h 50 parts per million (ppm) chlorine dioxide (ClO₂), 3 minutes (min) 70 °C and 24 h 50 ppm ClO₂.

In a large hospital in Taiwan, a comparative study on infection rates with and without continuous treatment with ClO₂ has been described. Building 1 was continuously treated (over 11 months) with ClO₂, whereas building 2 was not treated. In both cases infections have been monitored. Interestingly, the overall rate of non-fermentative Gram-negative bacilli nosocomial infections did not decline after ClO₂ disinfection. Furthermore PA infection rates increased in both buildings, showing no evidence for a relationship between ClO₂ treatment and PA infection rates.

PA is a major pathogen of cystic fibrosis patients with water being a major source of infection. Furthermore, PA is the organism that is most commonly detected in gastrointestinal endoscopy-related and bronchoscopy-associated outbreaks.

PA is rarely carried by healthy individuals (2–10 % of individuals, most likely aural) but can be recovered from 50–60 % of hospitalised patients. PA is a major cause of nosocomial infections.
of otitis externa (“swimmer’s ear”), with a magnitude of 2.4 million cases per year and an estimated outpatient cost of approximately $500 million (table 1)\(^{31}\). Moreover, PA is a frequent cause of skin infections such as folliculitis\(^{32}\). With the demographic change and patients being released early from the hospitals, PA is also increasingly recognized as a problematic water pathogen outside of hospital settings.

Due to the increasing numbers of immunocompromised patients and inherent resistance of PA to many antibiotics, hospitals are often facing the real problem of PA infection management as an important public health concern\(^{33}\).

<table>
<thead>
<tr>
<th>Number of annual non-hospitalised AOE visits</th>
<th>Mean cost per non-hospitalised AOE visit</th>
<th>Direct annual healthcare costs for AOE</th>
<th>Hours of clinicians’ time annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 Mio (8.1 visits / 1000 patients)</td>
<td>$200</td>
<td>$0.5 billion</td>
<td>600,000 hours</td>
</tr>
</tbody>
</table>

Table 1: Cost overview of Acute Otitis Externa (AOE) in the US, 2003-2007\(^{31}\).

Multi-Drug Resistant PA (MDR PA) in the ICU

MDR Gram-negative bacteria (MRGN) are defined as having 3 or more antimicrobial resistance mechanisms affecting different antibiotic classes\(^{25}\). The rise of antibiotic resistance in pathogenic bacteria is considered to be an emerging threat to human health and therefore of concern, being associated with increased mortality and limited treatment options\(^{10,34-36}\). In Europe, the European Antimicrobial Resistance Surveillance System (EARSS) reported that for Gram-negative bacteria the situation is especially worrying with high, increasing resistance percentages reported from many parts of Europe. For PA the weighted mean percentage for carbapenem resistance increased significantly between 2011 and 2014\(^{32}\). A post-antibiotic era – in which common infections and minor injuries can kill – is a very real possibility for the 21\(^{st}\) century\(^{37}\).

Opportunistic Gram-negative bacteria that present increasing resistance issues include Enterobacteriaceae (Escherichia coli, Klebsiella spp., Enterobacter spp., Seratia spp., Citrobacter spp.) and the non-fermenters, PA and Acinetobacter baumannii. Stenotrophomonas maltophilia is inherently MDR, but a less common reported cause of cross-infection\(^{25}\). PA strains have developed resistance against commonly used antibiotics, rendering effective treatment increasingly complicated and expensive\(^{2,38-40}\).

Data collected from MDR Krankenhaus-Infektionen-Surveillance-System (MDRO-KISS) from January 2013 through February 2014 identified 5,171 cases of MRGN from 341 ICUs of 247 hospitals in Germany; 848 of which were carbapenem-resistant organisms (CRO) (16 %)\(^{41}\). Infections with CRO are of particular concern, as only a few treatment options remain for patients and outcomes are poor\(^{42-43}\). 61 % of CRO were mainly Pseudomonas spp. (n = 516), mostly PA (n = 493, 58 %), followed by CRE (carbapenem-resistant Enterobacteriaceae) (n=212; 25 %) and Acinetocacter spp. (n = 120; 14 % dominated by Acinetobacter baumannii (n = 115, 14 %)\(^{41}\).

A German point prevalence study of 56 hospitals in 2011 showed that, overall, prevalence of resistance was highest in ICUs and higher on medical wards compared with
Bacteria living in water installation biofilms communicate and may exchange resistance genes.

MDR PA can be clinically manifested in the lung causing pneumonia, urinary tract, surgical site, bloodstream, cystic fibrosis lung and burns. In a neonatal ICU in Turkey a PA outbreak which involved 12 patients has been reported with electronic tap fittings being the likely source of the outbreak, with 8 of 12 invasive isolates being 4MRGN (4 Multi-Resistant Gram-Negative). In 2010 Inglis et al. described an increased incidence of MDR PA in the ICU and High Dependency Unit of an Australian hospital with contaminated aerators and the water system being the possible source. MDR PA is also a rare cause of community-acquired infections.

Transmission pathways of PA

Enterobacteriaceae, PA and Acinetobacter spp. can be transferred among vulnerable patients by staff vectors and contaminated equipment. PA and MDR PA are commonly transmitted by contact and aspiration, with the premise plumbing system being a likely infection source. In such epidemiology, a single clone or small number of clones causes infections in multiple patients in a unit or hospital, often without obvious links, over a prolonged period, sometimes extending over several years and with gaps of months between cases.

Patient exposure typically occurs while showering, bathing, drinking and through contact with medical equipment rinsed with contaminated tap water. During daily routines, tap water is used for personal hygiene. ICU patients often have multiple access devices such as catheters, drains and tracheal tubes. These portals represent potential entrance sites for bacteria. Droplets of contaminated tap water or contaminated hands of healthcare professionals can inadvertently come into contact with those entrance sites. Rogues et al. reported that 14% of ICU healthcare professionals hands were Pseudomonas positive, when washed with contaminated tap water and 12% were positive, when the last contact was with a Pseudomonas positive patient. Patient-to-patient transmission can occur
via air among patients with cystic fibrosis or via patient hand and environmental contamination. Contaminated bottled water or contaminated water from drinking water dispensers has also been described as a source of hospital-associated Pseudomonas infections in ICUs and Bone Marrow Transplantations (BMTs).

Waterborne bacteria including PA can cause infection by consumption via drinking, inhalation of aerosols and application via contact.

Water-associated PA infections

There are 4 main presentations of PA infections:

a) Bacteremia in immunocompromised individuals
b) Pneumonia in cystic fibrosis patients
c) Community-acquired ear and pneumonia infections
d) Hospital-acquired outbreaks, principally associated with contaminated solutions or medical devices used in general patients or those in intensive care units (ICUs).

In all 4 presentations, water containing PA may be an infection source.

Several studies have shown that clinical strains of environmental bacteria including PA and/or their modes of resistance often originate from the natural environment, including bacteria within soil and water. Multidrug-resistant bacteria have been detected from various water sources, including drinking water or tap water. Moreover, independent studies have demonstrated that antibiotic resistant bacteria, at least for some classes of antibiotics, may be more prevalent in tap water than in the water source. Vincenti et al. suggest that high resistance rates could develop in the case of infection, when the original environmental clone already had high rates of antibiotic resistance.

A cross-sectional study evaluating the recovery of Non-Fermenting Gram-Negative Bacteria (NFGNB) in water sources from the hospital environment was performed in different wards of a tertiary care centre and assessed the antibiotic resistance profile. Of 3268 water samples collected, 4.56% were positive for NFGNB with PA being the most represented strain (34.90 %) followed by P. fluorescens (17.45 %) and Stenotrophomonas maltophilia (10.74 %). More than half (55.56 %) of the isolated strains showed antibiotic resistance with up to 56 % of PA in the bronchoscopy unit being antibiotic resistant (48 % MDR and 8 % extensively drug-resistant (XDR), susceptible to only one or two categories of antimicrobial agents, categorization according to Magiorakos et al., 2012).
Ten patients were affected in a multiresistant PA outbreak in an adult ICU in the UK. Typing revealed that 2 of the 3 strains of PA detected in water samples matched the strains isolated from patients.

Cystic fibrosis (CF) patients become colonised with PA early in life, and the prevalence of colonisation increases with age. PA is a major pathogen of CF patients; 60–80% of CF patients are infected. Although a proportion of CF patients are infected with PA from other patients (cohabitating hospital wards), the recognised major source of infection is water.

Pseudomonas can persist in hospital water systems for expanded time periods and can result in outbreak situations. In a PA outbreak in a neonatal unit in Northern Ireland, where 4 neonates died, the typing data of the strains from 2 neonatal units linked the PA strains recovered from the biofilm on the tap surface and flow straightener, and/or the water from the tap to the clinical samples isolated from the patients affected.

Trautmann et al. have shown that on a 12-bed medical intensive care unit 42% of water samples were PA positive at various concentrations. At the same time period 9 patients had infections due to PA and 7 patients were colonised. Random amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) revealed strains of identical genotype in water and in patients in 8 of 16 (50%) infection or colonisation episodes.

In a review from different European ICUs a genomic identity between tap water and colonised/infected patients has been shown in 19.2%–50% of the reported cases.

A prospective multicenter study performed in 10 French ICUs evaluated the contributions of ICU environmental risk factors for PA acquisition and revealed previously contaminated tap water in the room and the cumulative ward level of nursing workload next to individual risk factors. In a Spanish NICU where PA outbreak has been described with 9 infections and 1 colonisation involved. PA had been detected in tap water, which had been used to warm up mothers’ milk. After introduction of sterile water instead of tap water, no further infection cases appeared.
Patients with chronic wounds are frequently colonised by multiple bacterial species including PA, thus delaying or even preventing the wound healing process. In a screening of patients with persisting venous leg ulcers Gjodsbol et al. showed that PA was found in 52.2% of the ulcers. Furthermore, ulcers with PA were found to be significantly larger than ulcers without the presence of PA (p<0.005). Kirketep-Moller et al. analysed wounds from 22 different patients by culture and Fluorescence-In-Situ-Hybridization using Peptide Nucleic Acid probes (PNA-FISH) and showed presence of both bacteria, but without correlation between results of both methods. PA was found to aggregate as microcolonies detected by PNA FISH.

Diabetic foot infections can process rapidly to irreversible septic gangrene necessitating amputation. An analysis of the polymicrobial nature of diabetic foot infections from 69 swabs and 73 tissues of 42 diabetic patients showed PA belonging to the most frequent aerobic bacteria cause with a 30.95% distribution. Moreover, antibiotic resistance is considered to be a major threat in the treatment of diabetic foot infections.

Infections are one of the most usual causal agents of morbidity and mortality for burn patients. In a study of 176 burn care centres in North America, Pseudomonas spp. was seen as the most life threatening infections in thermally injured patients. A 6 year antibiotics susceptibility study in a US Burn Centre to analyse MDR isolates prevalence revealed Acinetobacter baumannii being the most prevalent organism, followed by PA. Additionally, transmission of resistance genes between Pseudomonas species and from Pseudomonas spp. to other Gram-negative organisms has been demonstrated and recognised in the burn population. Zhang & Liu have analysed 84 patients with 134 burn related sepsis and wound infections, with multiresistant PA and Acinetobacter spp. being the most frequent.

Water provided for wound cleansing should be free of facultative pathogens. The European Practice Guidelines for burn care state that removal of slough, non vital tissue and necrosis should be by abundantly cleaning and cleansing the wound with tap water (filtered), saline solution or sterile water in combination with mechanical debridement in order to reduce the bacterial load. For the cleansing of wounds in immunocompromised patients, only sterile NaCl/ Ringer solution or 0.2 µm filtered water should be used in Germany.

By cleansing of wounds with unfiltered water, waterborne microorganisms can colonise wounds, leading to infections.
Chronic lung infections are associated with increased morbidity and mortality for individuals with underlying respiratory conditions such as cystic fibrosis (CF) and chronic obstructive pulmonary disease (COPD).\textsuperscript{49, 50, 53, 87} The process of chronic colonisation allows pathogens to adapt over time to cope with changing selection pressures, co-infecting species and antimicrobial therapies.\textsuperscript{88} COPD is a leading cause of mortality worldwide and is associated with an important morbidity related in large part to acute COPD exacerbations (AECOPD).\textsuperscript{69} COPD patients are more likely to be colonised or infected by PA than healthy individuals, with PA having been isolated from 4\% to 15\% of COPD sputum samples.\textsuperscript{89} It has been shown that PA could trigger AECOPD\textsuperscript{69} with PA antibiotic resistance being important for treatment determination and influencing clinical outcomes.\textsuperscript{89} Moreover, resistant PA affects patients with severe AECOPD and previous use of corticosteroids and antibiotics.\textsuperscript{87}

Clinical observations link respiratory virus infection and PA colonisation in chronic lung disease, including cystic fibrosis and chronic obstructive pulmonary (COPD) disease. The development of PA into highly antibiotic-resistant biofilm communities promotes airway colonisation and accounts for disease progression in patients.\textsuperscript{90}

Cystic fibrosis and COPD patients use nebulisers as an integral part of treatment regimens. Home nebulisers may become colonised with bacteria\textsuperscript{91} and are a potential source of bacterial infection as bacteria can colonise both plastic surfaces and human lungs via the formation of bacterial biofilms.\textsuperscript{91} Woodhouse et al. have shown that the use of sterilising grade filtered water for rinsing of repeatedly used nebulisers significantly reduces bacterial contamination.\textsuperscript{92} Moreover, several recommendations suggest the use of sterile water for rinsing of nebulisers, as tap water may harbour non-tuberculous mycobacteria, fungi or PA.\textsuperscript{93-95}

Cystic fibrosis patients often carry chronic PA colonisation.
PA infection prevention in the hospital ICU

Tap water has been demonstrated to be a common source of PA colonisation and infections using genotyping methods and comparing environmental with patients’ PA strains. Control of environmental PA transmission is critical, and the rise of antibiotic resistance in pathogenic bacteria including PA, is considered to be an emerging threat to human health and therefore of concern. The intensive use of antibiotics is creating selective pressure favouring the acquisition and spread of antibiotic resistance among bacteria. High awareness for attention to hand hygiene, especially with soap and water, is necessary.

Installation of Point-of-Use (POU) Water Filters has been shown to be an effective control measure in reducing waterborne PA infection rates as well as reducing critical PA contamination situations (table 3). A review which assessed the evidence that healthcare water systems are associated with PA infections has been performed by Loveday et al. From 196 relevant peer reviewed studies, only 25 met the criteria for data strength and only two studies provided plausible evidence for effective interventions. Both studies included Point-of-Use filters. Poor hand hygiene or compliance with contact precautions were identified as potential contributory factors, but there was no plausible evidence to confirm this.

Walker et al. suggest hospitals determine which patients are at risk in augmented units and undertake a review of not just the water system but also environmental cleaning practices and related best practice to assess possible tap contamination with patients’ bacteria, to evaluate patient contact with water in particular wards, and to assess other control measures that may be required in order to minimise risks to patients.

An increase of hot water temperature to 65 °C, eradication of multiresistant PA strains from the environment and use of terminal microfilters in burns and solid transplant organ patient rooms have been shown to be effective infection prevention measures in Swiss intensive care units as shown by a 10-year study.

In an Italian haemato-oncological unit a significant increase of PA positive blood cultures was observed. Environmental tests revealed contamination of > 50 % showerheads, taps, basins and taps on bidets. Whereas measures such as 5 minutes water flushing did not result in a decrease in infection rate, the installation of POU filters led to a significant reduction in septicemia rate.

In a surgical ICU endemic PA infections were observed for a period of > 24 months, with tap water being persistently colonised with a single PA clonotype. Different measures to reduce the rate of new PA infections cases, including a trial of selective digestive tract decontamination, enhanced hygiene measures and alcohol-based hand disinfection after handwashing did not prevent the occurrence of further cases. However, the installation of POU filters led to a significant reduction of colonisation and infection rates. The rate of PA positive patients reduced from 15.5 % in the non-filtration period to 4.3 % in the filter period (p ≤ 0.0001). Moreover, overall infections have been reduced by 22 % and PA infections by 56 %.

It can be argued that complete eradication of PA is not possible in an adult ICU, as already colonised patients can be admitted to the ICU or there is transmission between patients based on poor hygiene practice. However, providing hygienically controlled water at the ICU for infection prevention purposes should be prioritised.
A comparison of a 5-month period with POU filters installed at all taps, showers and ice machines in a subacute care unit with 29 beds showed a significant reduction in ventilator-associated pneumonia (VAP) cases ($p = 0.0087$), positive cultures for *Pseudomonas* ($p = 0.0004$) and upper respiratory colonisation with *Pseudomonas* ($p = 0.0179$) after implementation of POU filtration.\(^{103}\)

Barna *et al.* reported the reduction of PA infection rate to 0/100 ICU patient days during the filtration period of 4 weeks versus 2.7/100 patient days over 4 weeks without filters and 2 years before filter installation.\(^{98}\)

A reduction of nosocomial PA infections in burn patients from 10 % to 2.5 %\(^{99}\) and a 50 % reduction of Gram-negative bacteria infections in a bone marrow transplant unit have been reported after installation of POU filters. Furthermore, a prospective clinical study in a liver transplant unit comparing Gram-negative infection and colonisation rates before and after installation of POU filters reported a reduction of infection and colonisation rates of 47 % per 1,000 patient days during the filtration period.\(^{104}\)

<table>
<thead>
<tr>
<th>Country</th>
<th>Patient Unit</th>
<th>Effect of POU Filtration</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>Haematology</td>
<td>Reduction of PA positivity of blood cultures from 8 % and 18 % to 2.7 % respectively</td>
<td>Vianelli <em>et al.</em>, 2002 (^{96})</td>
</tr>
<tr>
<td>France</td>
<td>ICU</td>
<td>Reduction of PA infections from 8.7/1000 patient days to 3.9/1000 patient days</td>
<td>Van der Mee-Marquet, 2005 (^{105})</td>
</tr>
<tr>
<td>Germany</td>
<td>Surgical ICU</td>
<td>Reduction of PA colonisation by 85 % and infections by 56 %</td>
<td>Trautmann <em>et al.</em>, 2008 (^{97})</td>
</tr>
<tr>
<td>France</td>
<td>Burns Unit</td>
<td>Reduction of PA infections from 10 % to 2.5 %</td>
<td>Legrand <em>et al.</em>, 2009 (^{99})</td>
</tr>
<tr>
<td>US</td>
<td>BMT Unit</td>
<td>A 50 % reduction of Gram-negative bacteria infections</td>
<td>Cervia <em>et al.</em>, 2010 (^{100})</td>
</tr>
<tr>
<td>US</td>
<td>Subacute Care Unit</td>
<td>90.2 % reduction in VAP cases and 68.3 % and 58.6 % reduction of PA positivity in sputum and nasal samples</td>
<td>Holmes <em>et al.</em>, 2010 (^{103})</td>
</tr>
<tr>
<td>Hungary</td>
<td>ICU</td>
<td>Reduction of PA infections from 2.7/100 patient days to 0 patient days</td>
<td>Barna <em>et al.</em>, 2014 (^{98})</td>
</tr>
<tr>
<td>China</td>
<td>Liver Transplantant Unit</td>
<td>A 47 % reduction of Gram-negative infection and colonisation rates per 1,000 patient days</td>
<td>Zhou <em>et al.</em>, 2014 (^{104})</td>
</tr>
</tbody>
</table>

*Table 3: Reduction of infection / colonisation with Point-of-Use Water Filters.*
POU Water Filters are barriers against waterborne microorganisms and shown to reduce PA rates in high risk patient groups.

POU Water Filtration recommended as a control measure against waterborne bacteria

World Health Organisation (WHO) recommendations are generally recognised globally for drinking water quality requirements, and POU water filtration is listed as one suggested control measure for hospitals. In addition, there are national and regional drinking water guidelines, several of which have integrated POU filtration as one control method to prevent transmission of waterborne pathogens to patients and users.

Financial implications of PA infections and POU Water Filtration

Health care-associated infections (HAIs) can be associated with increased health care costs by prolonging hospitalisation in the range of $7,453 - $15,155 per infected patient as well as causing adverse effects on a patients’ psychological health. Gastmeier et al. estimated that 20 – 30 % of HAIs may be avoided by effective preventive programs, with potential cost savings of > €2 Mio per year for a major tertiary care medical centre, in addition to providing major clinical benefits for hospitalised patients. The use of POU filters was shown to prevent 7.6 infections per 100 patients staying ≥ 3 days in the ICU, and preventing 23 infection cases per year. Given a moderate estimate of the additional cost of any type of nosocomial infection in the range of $3,000, the POU filtration resulted in savings of $69,000 and a net saving of $64,000 when applied in the 12 bed ICU. A comparison of 5 month filtration period in a subacute care unit with 29 rooms versus 1 month non-filtration period showed a reduction in total patient costs of $248,136 with net cost savings of $231,036. After a PA outbreak affecting 17/67 patients, Bou et al. calculated €18,408 per case of PA infection, thus being 66 % higher than non-affected patients. Based on these figures a conservative estimate of the extra cost attributable to PA infection in the specific ICU reached €312,936. Additionally, the extra length of ICU stay attributable to PA infection was 70 days.
POU Water Filtration recommended as a control measure against waterborne bacteria.

Financial implications of PA infections and POU Water Filtration

<table>
<thead>
<tr>
<th>Year</th>
<th>Preventable Infections by Use of POU Water Filters</th>
<th>Costs due to Infections</th>
<th>Water Filter Costs</th>
<th>Net Cost Savings</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>23 per year</td>
<td>3,000 per infection per patient</td>
<td>5,000 pa for a 12 bed ICU</td>
<td>64,000 p.a.</td>
<td>Trautmann et al., 2008 97</td>
</tr>
<tr>
<td>2009</td>
<td>n.a.</td>
<td>Average increase of total ICU cost for € 18,408</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Bou et al., 2009 115</td>
</tr>
<tr>
<td>2010</td>
<td>16 in 5 months</td>
<td>n.d.</td>
<td>17,100 for 5 months for 25 POU</td>
<td>231,046 for 5 months</td>
<td>Holmes et al., 2010 103</td>
</tr>
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</table>

Table 4: Cost of nosocomial PA infections and net cost savings with use of POU Water Filters as the control measure. n.a. = not applicable; n.d. = not defined.

Conclusion

- PA is an opportunistic bacterium developing antimicrobial resistance and playing a major role in nosocomial infections
- Tap water is a common source of PA infections
- POU Water Filters interrupt the transmission pathway between tap water and patients and are recommended as an effective control measure against PA colonisation and infection
- Prevention of PA infections leads to cost savings

Typical medical applications of sterilising grade POU Water Filters.
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