Handwashing and hospital wastewater systems

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Hungarian obstetrician Ignác Fülöp Semmelweis is considered to be the father of hand hygiene: in 1847, he demonstrated that the mortality rate among mothers giving birth at the First Obstetrics Clinic at the General Hospital of Vienna fell dramatically when staff washed their hands with a chlorinated lime solution (Martini and Lippi, 2021). They also cite Florence Nightingale, the founder of modern nursing, who wrote in 1860: 'Every nurse ought to be careful to wash her hands very frequently during the day' (Martini and Lippi, 2021).

Almost two centuries after the work of Semmelweis and Nightingale the challenge of poor hand hygiene in healthcare premises remains, with Ijaz et al (2021) citing studies documenting the isolation of pathogens from healthcare workers.

For example, Ijaz et al (2021) reported that one investigation found that, when gloves were not worn by healthcare staff, 15% of nurses working in an isolation unit had a median count of 10 000 colony-forming units of *Staphylococcus aureus* on their hands. Another study found that 21% of doctors and 5% of nurses carried over 1000 colony-forming units of *S. aureus* on their hands. And yet, despite 'the potential for healthcare workers to disseminate pathogens via contaminated hands, it has been estimated that these professionals practice hand hygiene fewer [sic] than half the time that they should' (Ijaz et al, 2021).

The main routes of infection transmission are well established: it is 'known that 80% of common infections are spread by hands and washing hands at least five times a day has been shown to significantly decrease the frequency of acquiring colds, influenza, and other infections' (Ijaz et al, 2021). But to what extent might sinks and wastewater systems on healthcare premises play a role in cross-infection and the development of antimicrobial resistance (AMR)?

Sinks

Despite reports implicating micro-organisms in carrying drug resistance genes from colonised sink traps to vulnerable hospitalised patients, the mechanism of transmission from the wastewater of the P-trap under the sink to patients is poorly understood.

This was noted by Kotay et al (2017), who investigated whether a green fluorescent protein (GFP)-expressing *Escherichia coli* surrogate organism could migrate upwards from the P-trap water to the sink strainer in the plug hole. They also looked at whether the organism could spread from one sink to another along the internal surfaces of pipes with a shared drainage system, and which portion of a colonised drain pipe results in dispersion into the sink during handwashing.

Kotay et al (2017) found that when GFP-expressing *E.coli* was allowed to mature in the P-trap under hospital environment-type conditions, a biofilm grew upward over 7 days to reach the sink strainer, resulting in droplet dispersal to the surrounding areas (around a 30-inch (75 cm) radius), when the tap was being used. They also 'demonstrated that P-trap colonisation could occur by retrograde transmission along a common pipe' (Kotay et al, 2017).

Feng et al (2020) noted how carbapenem-resistant *Klebsiella pneumoniae* (CRKP) has emerged globally as a severe challenge for clinical management. It has been described by the World Health Organization as a 'critical priority' pathogen, posing the greatest threat to human health.

Describing how CRKP isolates caused hospital-acquired bloodstream infection or gut colonisation in two patients in an intensive care unit (ICU), Feng et al (2020) hypothesised that handwashing sinks were the source. All ICU handwashing sinks were sampled and genome sequencing and analysis revealed that 'one sink was the source of CRKP colonisation/infection in both patients, instead of direct transmission of a common clone between the patients'. The authors suggested that their study indicated that handwashing sinks are an important source of multi-drug-resistant organisms; they reported that sink management, which included the 'prohibition of disposal of body fluids and daily disinfection with chlorine, curbed the transmission' (Feng et al, 2020).

Hospital wastewater

The history of AMR reflects the natural response of bacteria to the presence of antibiotics, which are now widespread in the environment. For example, in the first study of its kind, Rodriguez-Mozaz et al (2020) analysed the final effluent of wastewater treatment plants (WWTPs) in seven European countries (Portugal, Spain, Ireland, Cyprus, Germany, Finland, and Norway) in 2015 and 2016.

Of 53 antibiotics monitored, 17 were detected at least once in the final effluent of the WWTPs. Ireland, and the southern countries Portugal and Spain, were found to have the highest effluent average concentrations of antibiotics (Rodriquez-Mozaz et al, 2020).

Given this context, the increasing awareness of antibiotic-resistant bacteria and their related antimicrobial resistance genes (ARGs) in the hospital environment – and its associated wastewater – raises potential cross-infection threats in hospital and community settings.

As observed by Kelly et al (2023): 'The clinical setting has a number of ecological niches, including patient-facing wastewater apparatus, which have the potential to act as reservoirs of ARGs and pathogenic bacteria due to their physical design and human activities associated with their use.' Indeed, the authors cited examples of studies implicating not only the hospital environment – especially sanitaryware – in causing outbreaks of infection, but also of hospital effluent and its subsequent treatment, usually in wastewater

plants, contributing to the spread of ARGs in community settings.

Affirming this observation are the results of a recent collaboration between the University of Limerick School of Medicine (ULSM) in partnership with University Hospital Limerick (UHL) and Queen's University Belfast. In the first large-scale study of its kind, Kelly et al (2023) identified multidrug-resistant bacteria in UHL's wastewater system and correlated their presence with clinical isolates from patients who became infected while hospitalised.

A UHL medical ward had been the focus of persistent harmful bacterial infections since 2009, with UHL recorded as the site of the first carbapenemase-producing *Enterobacterales* (CPE) bacteria detection in Ireland. Kelly et al (2023) noted that, as a result, the incidence of CPE at UHL 'has been among the highest in Ireland'. During the ward's refurbishment, samples for microbial analysis were taken from the wastewater drains of ten sinks, four showers, and the U-bends of six toilets.

The report's corresponding author Colum Dunne, Head of School, Foundation Chair and Director of Research at ULSM, told *BJN* that all the bacterial DNA present in the samples were analysed, with the entire metagenome, or complete collection, undergoing genetic sequencing, which was then subjected to bioinformatic analysis. 'These analyses,' Professor Dunne explained, 'provided a picture of all of the bacteria there and also included profiles of ARGs that were present'.

This process was further applied to those bacteria isolated from patients who had become infected at least 48 hours post-admission to the ward… and there were matches between bacteria detected in wastewater and bacteria isolated from patients. As a result, the genomes of five antibiotic-resistant bacterial isolates from patients, when analysed, showed that they harboured several ARGs, with the respective profiles of the clinical and wastewater isolates revealing a high degree of similarity with many shared ARGs.

These findings invite the inference that the patients became infected while they were in hospital, and Kelly et al (2023) noted that the 'highest numbers of ARGs observed were those encoding resistance to significant clinically and commonly used antibiotic classes'. Interestingly, no significant differences were found between the genomic analyses of patient and staff wastewater outlets, 'which may indicate that the microbiological wastewater highway may be multi-directional and that there is substantial scope for contamination exposure throughout this system' (Kelly et al, 2023).

Waste water and its management

Given the findings of Kelly et al (2023), what are the implications for the management of hospital wastewater systems, and what mitigation measures might be appropriate? 'Studies such as ours add insight,' Professor Dunne explained, 'and we now understand the complexity of the microbial communities present in the wastewater systems, and what ARGs and traits they possess.'

Stewardship of antibiotic use is essential, and, similarly, effective and targeted cleaning and hygiene systems, together with innovative cleaning solutions and infection prevention products, will prove important.

In relation to design aspects, Professor Dunne suggested that there are opportunities to assess whether current numbers and placement of sinks and showers are appropriate. 'Both retrofitting of existing facilities and a focus on this aspect for future new builds should consider this. However,' he added, 'a further implication of our work is that wastewater effluent should be monitored as it exits hospital or clinical sites, checking for both problematic microbes and antibiotic residues.'

He also addressed the potential concerns of those preparing for a stay in hospital: 'It is recognised internationally that hospital-acquired infections can occur, but infection prevention and control teams in hospitals work hard to protect patients and staff alike. While patients should be aware, they can also be confident that safety measures are in place.'

He emphasised that these risks 'are not being ignored. Indeed, we are continuing to build on this work and, through collaborations like this, between Limerick and Belfast, we have increased the scale and accuracy of our analyses'.

It is apparent that the rise of such molecular-based epidemiology will occupy an important place in the infection control landscape, from influencing hospital architecture to determining the design of wastewater systems adjacent to patient-occupied areas.

Kelly et al's work (2023) further cited evidence suggesting that wastewater-based epidemiology could also have a role to play in the detection of novel antibiotic-resistant pathogens and assist public health surveillance. However, they acknowledged that, although it is difficult to 'conclude definitively whether these isolates were transmitted from wastewater pipes to patients or vice versa, these data emphasise very clearly the potential for hospital wastewater systems to act as reservoirs of clinically relevant bacteria and ARGs' (Kelly et al, 2023).

Hand drying

Just as important as handwashing is hand drying. For example, Ijaz et al (2021) highlighted evidence that micro-organisms are transmitted more effectively in wet environments than dry environments. They also pointed out that, although hand drying using electronic touch-free dryers is often favoured for the touch-free advantages conferred, the 'use of hot-air dryers also may lead to dry, rough, and red hands'.

By contrast, patting the skin's surface with a clean paper towel contributes to the removal function of handwashing, and contamination of the washroom environment is lessened 'because hot-air hand dryers can disperse pathogens into the air if the handwashing itself has been improperly practised' (Ijaz et al, 2021).

Conclusion

It appears that the basic tenets of handwashing promoted by Semmelweis and Nightingale (Martini and Lippi, 2021) are the most effective means of infection control. However, maximising patient care, together with a need for a heightened awareness of the spectre of AMR, demand that healthcare workers must exercise constant vigilance in relation to hand hygiene. **BJN**

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