environmental hygiene

By Richard Dixon and David Koenig, PhD

Healthcare Sinks as a Source of Pathogens and a Potential Solution

Authors' note

The purpose of this article is to stimulate a discussion on an innovative concept to clean and disinfect healthcare sink drains, which are a common source of pathogens.

It is not intended to claim any outcomes.

Antimicrobial resistance (AMR) is among the World Health Organization (WHO)'s top 10 threats for global health. The rise of AMR was initially driven by the misuse of antimicrobials in livestock, crops, and humans. The rise in AMR microbes has reduced or eliminated the effectiveness of many antibiotics used to treat infections such there are limited alternatives. Lack of treatment is predicted to lead to a tenfold increase in AMR associated deaths by 2050. AMR microbes and associated health impacts are expected to become burden on the global economy leading to a rise in poverty.

Prevention is at the core for stopping AMR emergence. It is well known that the environment plays a key role in the development and transmission of AMR microbes. Conversely, the environment is a key area for active prevention of AMR. In the hospitals, the sink has been shown to contribute to the rise of AMR. Not only is the sink a source of hospital-acquired infections (HAIs) but is also a source for dispersal of AMR microbes into the community. Therefore, eliminating the sink as a source of HAIs and AMR microbes will greatly help in the quest for controlling AMR globally.

Sinks and Drains

Researchers all over the world have been investigating sinks and drains as a source of HAI microorganisms, especially carbapenem-resistant Enterobacteriaceae (CRE). CRE infections are of particular concern because of their ability to transfer their AMR genetic elements from one bacterial species to another, for example from carbapenem-resistant *Klebsiella pneumoniae* to *Escherichia coli*. In 2000, a paper in *Current Opinions in Microbiology* posed the question, "Is the emergence of carbapenemase a problem waiting to happen?" Almost 20 years on, the problem is here.

Reports that suspected sinks and drains could be the source of CRE that caused HAIs began to emerge in 2003. In a 2017 review, The Hospital Water Environment as a Reservoir for CRE Causing Hospital-Acquired Infections, 17 studies identified sinks as a potential source of microorganisms causing HAI outbreaks, often in the Intensive Care Unit (ICU). Additionally, AMR microbes can colonize sinks and associated plumbing allowing for the transmission of AMR genes to non-AMR microbes, increasing the AMR problem exponentially. In that the waste stream from a sink ultimately reaches the municipal wastewater facilities, AMR microbes and other pathogens can be released into the community.

Figure 1: Carbapenem-Resistant Enterobacteriaceae (CRE). Courtesy of NIAID

Sink design directly drives the environmental conditions that favor microbial growth on plumbing line surfaces and ultimately favor AMR development. To prevent sewer gases being released into the room, sinks use water traps. These traps were first invented by Alexander Cumming in 1775, the S-bend trap. Eventually, P-trap (Figure 2) design was adopted that added a 90-degree fitting on the outlet side of a U-bend. The P-trap was popularized by Thomas Crapper in the 1880s and remains in use today. By design the P-trap allows for the sink lines to remain wet, but as was probably underappreciated in 1880 these conditions allow for the rapid growth of biofilms that will harbor pathogens and AMR microbes.

Figure 2: The P-trap of a sink. Courtesy of Adobe Stock

AMR microbes can spread along waste lines connecting sinks and colonize the P-trap. Once there, they form a biofilm which can grow upwards to reach the sink strainer at a rate of up to 2.5 cm a day. When the water from the faucet hits the sink strainer there is splashing that carries pathogens (HAI) and AMR microbes in droplets onto surrounding counters and the floor up to 1 meter away. Patient-care and personal items left around the sink can become contaminated, increasing the chance of transmission of pathogens to patients. Additionally, superbugs contained in sink biofilms can be flushed out of the sink into the municipal water treatment system contaminating the outside world, leading to community AMR infections. Sink design has been virtually unchanged for more than 140 years, going back to the days of Alexander Cumming and Thomas Crapper. It is time to change this plumbing.

To date, healthcare facilities have tried a wide range of interventions to stop outbreaks associated with sinks. A few of these are listed here:

- Replacing the entire contaminated sink or replacing the downpipes and p-traps.
    - Still using the Crapper design, problem reoccurs soon after replacement.
- Correct defective conditions in water systems such as dead ends, low water use areas, temperature, and pressure fluctuations.
    - Helpful in simplifying water flow but the P-trap is still there, maintaining the primary driver for biofilm development.
- Placement of an offset sink drain in hand hygiene sinks.
    - Will reduce splashing from the sink strainer.
    - P-trap is still in place allowing for biofilm growth.
- Changing to deeper sink basins to prevent cross-contamination of hands and adjacent surfaces.
    - Does not eliminate splashing or biofilm growth.
- Regularly pouring disinfectants such as sodium hypochlorite, hypochlorous acid, hydrogen peroxide, acetic acid, octanoic acid, or peroxyacetic acid down sink
    - Significantly decreases bioburden, but regrowth happens within a few days.
- Blocking the drain line and allowing the disinfectant to sit in the P-trap.
    - More successful than just pouring disinfectant down drain.
    - Regrowth will still occur.
- A device that heats and/or subjects the downpipe to ultrasound to kill and remove the biofilm.
    - There will be biofilm regrowth after treatment.
    - Units require a power source near the sink.
- Unit on sink that generates ozonated water via the faucet to disinfect the P-trap and drain at each use.
    - Shown to be effective at decreasing Pseudomonas aeruginosa and Candida auris contamination.
    - Due to rapid decomposition of ozone, water left to sit for long period of time in P-trap will become contaminated and form biofilms.
    - Units require a power source near the sink.
    - Ozone generators require engineering controls to ensure no release of ozone into occupied spaces.

It seems clear that there is no silver bullet that will eliminate the risk of pathogen (HAI), and particularly CRE transmission (AMR microbes) due to ancient design of sink P-traps and drains. Some interventions resulted in the end of outbreaks but didn't fully eliminate CRE from the P-trap or drain and the potential of a CRE infection occurring. Others were not successful at eliminating the outbreak at all. We therefore propose a very different plumbing configuration to address sink biofilms and splash transmission of HAI and AMR microbes to the hospital-built environment.

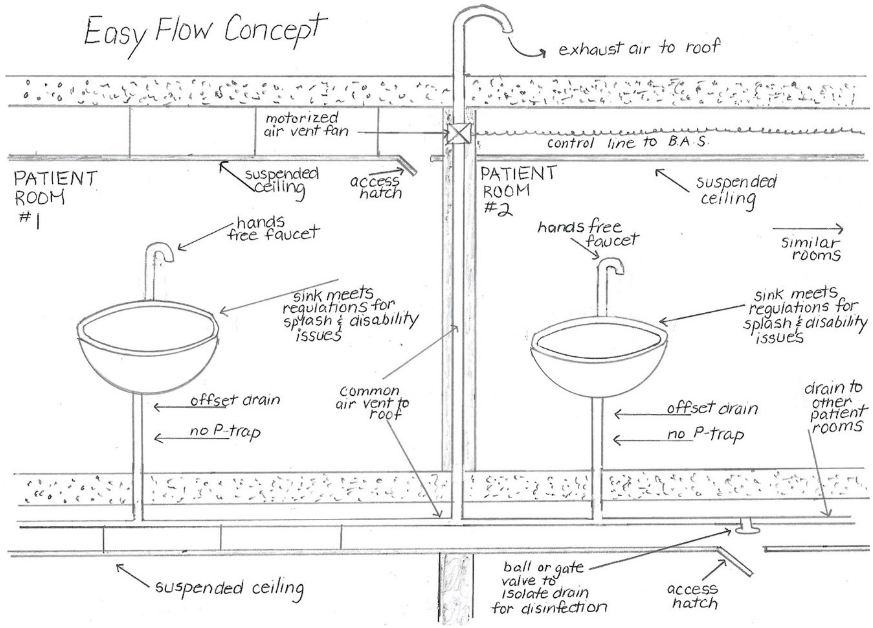

Figure 3: EasyFlow concept. Courtesy of the authors

EasyFlow Concept

All the interventions to date have missed the obvious, the ancient P-traps drain design is the key to biofilm development. Thus, the necessity of the immense problem lies in a new radical approach to the design called EasyFlow (Figure 3). This design eliminates the P-trap. The P-trap encourages biofilm growth by simply providing the water needed to build luxurious biofilms that will harbor AMR microbes and pathogens (HAIs) in conditions that are hard to treat and remove. The water in the P-trap furthermore provides the necessary water of activity (a_w) conditions in the waste lines from the P-trap to the sink strainer allowing growth of biofilm on all surfaces. Ultimately providing the source of microbes to be splashed into the hospital-built environment. Removal of the P-trap allows for reducing the a_w in the sink lines such that luxurious biofilms will not form, significantly reducing the risk of splashing microbes into the hospital-built environment.

The key to EasyFlow is eliminating the P-trap. To do this an offset sink drain line is routed straight down or at any angle equal or less then 45 degrees from the bottom of the sink. After which the drain line is routed 90° or less to the discharge line (Figure 3). Sewage odors are mitigated by installing a negative pressure fan on the vent pipe to pull the air gases continually out of the entire system. Negative pressure

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fans will have the ability to adapt flow rate to ensure appropriate operation in concert with room fluctuations of the heating, ventilation, and air conditioning (HVAC) systems air flow and pressures. All fans are connected via a low voltage control wire to the healthcare facility Building Automation System (BAS) so that if a fan fails, the engineering department can receive the failure signal and repair or replace the fan/motor immediately. A hatch is required for access by engineering. The advantage of this system is that unlike the "Crapper" design this system will substantially reduce the moisture in the waste system lines thereby minimizing dangerous wet biofilms. Dry biofilms are still expected to persist but will be treated using disinfectant applications.

A horizontal drain line will be installed at an applicable distance away from the sink or varying number of sinks on the front end of the drain system. These lines will have a closure gate or ball valve that can isolate the drain for short periods of time (Figure 3). This allows for completely filling the system with the appropriate disinfectant. The goal of this procedure is to remove any dry biofilm that may propagate in the waste lines. The valve should be placed such that there is an easy to locate access hatch that is appropriately marked as such. Conversely, a remote-control valve can be used to allow for energization of the circuit without manual interventions. It is also possible to install a remotely controlled ice plug device at the point required for fluid restriction as a redundant feature. It is also possible to use these valves to close off the drain line in the case of a negative pressure fan failure stopping sewer gas escaping into the room, during fan repair.

To ensure appropriate function of the system regular auditing of the drain lines via ATP tests, protein tests, or microbial culture are recommended to ensure there is no or very little dry biofilm in the section of the drain line closest to the sink(s). Remember a dead biofilm that is still on the surfaces will enhance the regrowth of new biofilm.

The advantage of the EasyFlow concept over the "Crapper" design is:

1. Proactive biofilm through engineered infection prevention
2. Continuous drying of waste drain lines
3. Efficient removal of dry biofilms
4. Redundancy
5. Process control monitors
6. Active reduction of AMR bacterial dispersal to the hospital-built environment and community

Summary

For 140 years the same design for sinks has been used that enhances the growth biofilms. These biofilms will harbor bacteria and fungi. The microbes in the biofilms will share genetic elements allowing for transfer of AMR between divergent species and enhance the growth of HAI microbes. Sink biofilms drive the transfer of HAI and AMR microbes into the hospital-built environment through splashing as well as dispersal into the community by release into the municipal waste stream.

The EasyFlow concept removes the P-trap greatly reducing the ability of biofilms to form by lowing the a_w on the surfaces of associated sink and drain lines. This will reduce the ability of microbes to transfer AMR elements to others and eliminate the biofilm on the sink strainer abolishing dispersion of pathogens into the hospital-built environment. Ultimately enhancing the lives and wellbeing of both patients and care givers.

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