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Elimination of biofilm and microbial contamination reservoirs in hospital washbasin U-bends by automated cleaning and disinfection with electrochemically activated solutions

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Background: Washbasin U-bends are reservoirs of microbial contamination in healthcare environments. U-Bends are constantly full of water and harbour microbial biofilm.
Aim: To develop an effective automated cleaning and disinfection system for U-bends using two solutions generated by electrochemical activation of brine including the disinfectant anolyte (predominantly hypochlorous acid) and catholyte (predominantly sodium hydroxide) with detergent properties.
Methods: Initially three washbasin U-bends were manually filled with catholyte followed by anolyte for 5 min each once weekly for five weeks. A programmable system was then developed with one washbasin that automated this process. This U-bend had three cycles of 5 min catholyte followed by 5 min anolyte treatment per week for three months. Quantitative bacterial counts from treated and control U-bends were determined on blood agar (CBA), R2A, PAS, and PA agars following automated treatment and on CBA and R2A following manual treatment.
Findings: The average bacterial density from untreated U-bends throughout the study was $>1\times10^5$ cfu/swab on all media with *Pseudomonas aeruginosa* accounting for $\sim$50% of counts. Manual U-bend electrochemically activated (ECA) solution treatment reduced counts significantly (<100 cfu/swab) ($P<0.01$ for CBA; $P<0.005$ for R2A). Similarly, counts from the automated ECA-treatment U-bend were significantly reduced with average counts for 35 cycles on CBA, R2A, PAS, and PA of 2.1 ± 4.5 ($P<0.0001$), 13.1 ± 30.1 ($P<0.05$), 0.7 ± 2.8 ($P<0.001$), and 0 ($P<0.05$) cfu/swab, respectively. *P. aeruginosa* was eliminated from all treated U-bends.

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Conclusion: Automated ECA treatment of washbasin U-bends consistently minimizes microbial contamination.

Introduction

Hospital water systems and associated fixtures and fittings have been identified as significant reservoirs of microbial contamination responsible for nosocomial infections, especially among immunocompromised patients and in intensive care units (ICUs).[1–3] Microbial biofilms readily form within washbasins and sinks and their wastewater outlets and associated pipework.[4] These include the U-bend, which retains water to provide a barrier preventing sewer gas from wastewater pipes entering buildings. Furthermore, U-bends collect hair and other debris, and are frequently stagnant. U-bend biofilms may act as reservoirs and disseminators of infection by a range of bacteria, many of which harbour antimicrobial resistance elements.[1,2,5,6] Often these bacteria are motile, especially *Pseudomonas aeruginosa* and other Gram-negative species, which along with water flow, splashing, and aerosolization facilitate retro-contamination of washbasins, sinks, and taps.[1,3,5,7,8]

Biofilm present in wastewater pipework is difficult to eradicate by conventional disinfection. Several approaches have been investigated to reduce the microbial bioburden in hospital washbasin and sink drains including fixture replacement, regular manual disinfection and the use of thermal disinfection by installing a heating element into U-bends.[2,4,8] Fixture replacement is not effective in the long term as new washbasins and pipework rapidly become colonized with micro-organisms.[2] Disinfectants have diminished efficacy against dense biofilms present in U-bends and associated pipework, and, whereas they may temporarily reduce bioburden, they must be applied regularly due to frequent water stagnation in U-bends.[2,4] Thermal disinfection of U-bends has been shown to be effective but is not in widespread use.[8]

Previously we used the pH-neutral electrochemically activated solution Ecasol as a residual disinfectant to effectively minimize microbial contamination of dental unit waterline output and washbasin tap water in long-term studies.[9–11] Electrochemically activated (ECA) solution generators produce two solutions during electrochemical activation of dilute salt solutions; an oxidant solution capable of penetrating biofilm termed anolyte such as Ecasol [predominantly hypochlorous acid (HOCl)] and a catholyte with detergent properties [predominantly sodium hydroxide (NaOH)].[9] The purpose of this study was to investigate whether automated filling of a hospital washbasin U-bend for short periods of time with catholyte as a cleaning agent followed by automated filling with anolyte as a disinfectant would be effective at eradicating biofilm and minimizing microbial contamination.

Methods

Chemicals

All chemicals and reagents used were of analytical or molecular biology grade and were purchased from Sigma–Aldrich (Arklow, Ireland).

Anolyte and catholyte solutions

Anolyte and catholyte were produced by electrochemical activation (ECA) of a 0.2% (w/v) NaCl solution using an Ultra-Lyte Mini-UL-75a ECA generator (Clarentis Technologies, FL, USA). The generator was configured to produce anolyte with 450 ppm free available chlorine (FAC) at pH 7.0 and catholyte with 400 ppm NaOH. For U-bend treatment, freshly generated anolyte and catholyte were used undiluted and diluted 1:10 with mains water, respectively.

Measurement of free available chlorine

Free available chlorine levels in anolyte were measured using a Hach Pocket Colorimeter II (Hach Company, Ames, IA, USA) according to the manufacturer's instructions.

Test and control washbasins

Six identical ceramic washbasins (Armitage Shanks, Rugeley, UK) located in adjacent staff bathrooms at the Dublin Dental University Hospital were included in the pilot study. All bathrooms are in frequent use Monday to Friday. Three months prior to the study, washbasins were equipped with new Multikwik polypropylene U-bends (Marley Plumbing and Drainage, Maidstone, UK) with a cleaning port above the U-bend water line. The washbasin wastewater outlets were located underneath the tap water flow. One test washbasin was selected for automated ECA treatment studies, with a second used as a control.

Pilot study of ECA treatment of U-bends

Preliminary experiments were undertaken with three washbasins to investigate the efficacy of ECA solutions to minimize U-bend contamination with three additional washbasins used as controls. A manual valve was fitted to the wastewater pipe downstream of each washbasin U-bend to seal the wastewater outflow. The volume of liquid required to completely fill the U-bends and the wastewater pipe as far as the valve was determined empirically. For the test washbasins the valve was closed and the required volume ($\sim$1 L) of catholyte was poured slowly into the washbasin, filling it several centimetres above the wastewater outlet. Then the valve was partially opened to allow catholyte to completely fill the U-bend and outflow pipe as far as the valve while ensuring that sufficient catholyte remained in the washbasin to cover the wastewater outlet. Catholyte was left *in situ* for 5 min and the valve was then opened to void the solution to waste. The process was repeated with freshly generated anolyte. The same process was repeated for the control washbasins using mains water instead of ECA solutions. An area of the internal part of the U-bends was swab-sampled through the cleaning