**A Laboratory-Based Pilot Study Investigating contaminant residence time in water trap seals in clinical settings: Comparing bottle-traps, S-traps, and P-traps**

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**Executive Summary**

Hand-wash sink traps are a growing concern in healthcare facilities globally. These plumbing fixtures are increasingly being identified as reservoirs for pathogenic microorganisms that can lead to nosocomial infections. A method was developed to benchmark the ability of a water trap seal to clear a water-borne contaminant. A dye test was used to establish the relative timings of flushing of the contaminant for different water trap seal types: a Bottle-Trap, and a P-Trap. The bottle trap was that specified by NHSScotland Assure for use in en-suite bathrooms.

The residence time of water in the Bottle-Trap was compared to a commercially available P-Trap. The ratio of standing water in the traps was 344:164 respectively, or approximately 2:1, for the Bottle-trap and P-Trap. The study used dye dilution in consecutive 20 ml flushes measured by spectrophotometry to represent water wash-through from sink use. The residence time calculated from the dye concentration during consecutive 20 ml flushes (or by the point at which no detectable dye remained) was 1,320 ml for the Bottle-Trap compared to 580 ml for the P-Trap (a ratio of approximately 2.3:1). This is very close to the ratio of standing water volume in the two trap types. The excess water volume in the Bottle-Trap promotes longer residence time and therefore contamination. For this pilot-study a simple flush technique was used, so the impact of biofilm fouling was not considered. Biofilms will reduce the free volume and increase surface roughness according to type and age and would contribute to continuing contamination beyond any flush period. It would therefore be recommended that further work consider the presence of biofilm from engineering performance and microbiology contamination perspectives.

In addition to the dye contamination test we considered the design of the traps from a blockage risk potential. We established maximum size of object that could enter the trap and the maximum size that could exit the trap. These were taken as the maximum dimension of the object. For the P-Trap, the entry and exit size was the same as the internal diameter of the trap – in this case 32 mm nominal. For the Bottle-Trap, the entry size is 32 mm, however, the exit is just 10 mm, meaning the maximum size of object that could exit the device is <10 mm. This can mean that objects are more likely to get trapped in the Bottle-Trap than the P-Trap. If the Bottle-Trap is contaminated, with bacteria for example, any object stuck within it could promote growth and thus compound the problems of a longer residence time and contamination risk. Using small pieces of hand towel to represent normal material that can enter a trap, we found that the Bottle-Trap required 4 flushes to clear the material, compared to 2 flushes for the ‘P-Trap. Paper recovery was approximately 94% of the original samples giving confidence in the results.

1. **Introduction**

Hand-wash sink traps are increasingly being reported as the source of hospital-acquired infections worldwide [1-7]. Whilst sink traps are designed to safeguard the building from the ingress of foul contaminated air from the wastewater system, the warm water in the sink trap provides favourable conditions for opportunistic pathogens [8]. In reality, sink traps in patient care areas could serve as open breeding media for highly antimicrobial-resistant bacteria that cannot be easily cleaned or removed, greatly increasing nosocomial infections [6,9].

Sink traps traditionally take the form of a P-Trap or S-Trap, and as specified in SHTM 64, Bottle-Traps [10], with each name relating generally to the shape the pipework takes in its design to hold the water within, see Figure 1.

(a) (b) (c)

  

**Figure 1: Sink trap types: (a) P-Trap, (b) S-Trap, and (c) Bottle-Trap**

Bottle-Traps are now commonly installed in hospitals and healthcare buildings due to their relative ease in recovering lost items such as earrings and rings that may drop into the sink. However, their bottle-shape design with larger water volume and asymmetric outflow, means that they could harbour pathogens for prolonged periods due to inefficient flushing, encouraging increased growth and transmission risk, compared to traditional P- and S-Traps.

The experiments described in this report tests the hypothesis that the residence time for pathogens in sink traps is greater in Bottle-Traps than it is in P-Traps and S-Traps. If this is the case, the use of Bottle-Traps would, therefore, could increase the risk of nosocomial outbreaks.

## **Existing Evidence**

Often located in patient care areas, sink traps act as reservoirs for long-term transmission of multidrug resistant pathogens [1,2,6,11,12]. Many reports have shown genetic association between pathogens found in sink traps and those found in patients [13-15], with sinks in intensive care units (ICUs) even being associated with increased rates of hospital-acquired infection [16, 17]. Little work has been undertaken to investigate the impact of different sink trap types on transmission risk.

1. **Trap residence time investigation**
   1. **Equipment and Materials**

The spectrophotometer used was the SPECTRONIC 200E manufactured by Thermo Fisher Scientific (Shanghai) Instruments Co. Ltd., which measures light absorbance of test samples at the selected wavelengths. Absorbance is measured in absorbance units (Au or A), which is a dimensionless ratio inversely proportional to transmittance. For example, 1.0A is equal to 10% transmittance, 2.0A is equal to 1% transmittance, and so on in a logarithmic trend.

* 1. **Dyes**

Two different dyes were used: (i) E133 (aniline blue, acid blue); and (ii) Rhodamine-b. Both dyes are safe for use in public spaces and are readily water soluble. They are both suitable for use as a tracer dye within water to determine the rate and direction of flow, transport and mixing, and both give good results with common spectrophotometers. Rhodamine-b is also fluorescent, but tests were conducted by light absorption for this investigation.

E133 has an absorption peak at 635 nm and a molecular mass of 783 gMol-1. A stock solution of 5 L at 0.05 mol in water was prepared for creating a range of dilutions.

Rhodamine-b has an absorption peak at 559 nm and a molecular mass of 479 gMol-1. A stock solution of 5 L at 0.05 mol in water was prepared for creating a range of dilutions.

* 1. **Water Traps**

Three water trap types were tested: (i) the standard 32 mm Bottle-Trap (as currently used by the NHS); (ii) a 32 mm P-Trap; and (iii) a 32 mm S-Trap. The tests of the Bottle-Trap and P-Trap are compared in this report since the hydraulic performance characteristics of the P-Trap and S-Trap are identical. The Bottle-Trap standing volume is 344 ml, compared to 164 ml for the P-Trap; a ratio of roughly 2:1.

* 1. **Calibration and Operation**
     1. *Absorption Sensitivity*

Although dye absorptions are available in the public domain, a frequency sweep in 5 nm steps was performed with each dye to find the peak for the spectrophotometer used – see Figure 2. All testing was performed at the appropriate wavelength for each dye.

**Figure 2: Dye Frequency Sensitivity Comparison**

* + 1. *Dilution Accuracy*

Dilution response calibration curves were prepared for each dye by identifying the highest concentration at which the meter began to start recording light transmission, then using dye solutions of decreasing concentration until the spectrophotometer was out of range. The respective calibration curves are shown in Figure 3.

**Figure 3: Dye Dilution Calibration Comparison**

* + 1. *Errors*

Dye dilutions were performed with graduated auto-pipettes with selectable volumes of between 1ml ±0.1ml and 50ml ±0.1ml. The dyes in original powder form were weighed on a 200g range scale with an accuracy of 0.01g or 10mg. The spectrophotometer has a Manufacturer-published error in absorbance of ±0.05 out of a range 2.5, or ±1%. These errors were neglected as they were small in comparison to the results obtained.

* 1. **Procedure**
     1. *Establishing Trap Residence Time*

The general procedure involved clamping each trap to a test stand in the correct orientation, and starting the test with the trap filled to capacity (i.e. until it overflowed through the outlet) with dye solution at the maximum practical concentration. Clean water was dropped into the inlet in 20ml steps by syringe, and the outflow was sampled and measured in the spectroscope for each step. This was repeated for each trap.

* + 1. *Establishing General Initial Concentration.*

Dye dilutions were achieved in sequential steps of roughly 1:10 dilutions to simplify the process and allow the maximum practical concentration for each dye to be established within the range limit of the spectrophotometer. Once the maximum practical concentration was established, all subsequent dilutions below this were achieved by adding small quantities of dye to a 50 ml beaker, topping up to 50 ml via the preset pippette, then dispensing 3 ml of each dilution into the sample vials (cuvettes) via preset pippette to be placed into the spectrophotometer to be measured.

This process was completed for both dyes, with the maximum practical concentration for E133 being 2.00x10-5molL-1 compared to 2.51molL-1 for Rhodamine-b. For E133 this process required 19 dilutions to be below the measurable range, compared to Rhodamine-b which required 15 dilutions. E133 was selected for the trap comparison tests because it had greater range sensitivity, allowing greater resolution.

* 1. **Results and Discussion**

The wavelength absorbance peak sweep (Figure 2) for both dyes compared well to published values and produced very predictable results well within the capabilities of the spectrophotometer.

The dilution calibration tests (Figure 3) also produced very straightforward results with the E133 dye giving marginally greater resolution through requiring a slightly greater dilution to reach the lowest resolution of the spectrophotometer, compared to Rhodamine-b. Hence, E133 was used for these tests although either dye would produce acceptable results.

Figure 4 Shows the concentration reduction of E133 in the P-Trap compared to the Bottle-Trap. The point where the spectrophotometer was below the measurable range for the P-Trap was approximately 560ml, compared to approximately 1,320 ml for the Bottle-Trap. This indicates that the residence time for the Bottle-Trap is approximately 2.3 times greater than that of the P-Trap, measured either by the end points or the half-life.

**Figure 4: Trap residence time curves**

The test is a measure of non-microbial evacuation and does not account for potential growth of micro-organisms, however, the time taken to discharge the contaminant can be considered a proxy for the time available for a micro-organism to grow, wand thus perpetuate contamination.

1. **Solid Flush Efficiency by Trap type**
   1. **Equipment and Materials**
      1. *Water Traps*

The same water traps were used in these experiments as those in the water residence tests, see section 2.3 above. The entry and exit dimensions of both traps were measured. For the P-Trap, the entry and exit size was the same as the internal diameter of the trap: 32 mm nominal. For the Bottle-Trap, the entry size is 32 mm, however, the exit was just 10 mm, see Figure 5.

* + 1. *Scales*

Scientific balance Kern PCB10000-1 manufactured by Kern& Sohn GmbH, Germany was used.

* + 1. *Paper Hand Towels*

Paper towels were Tork Advanced H3 White Flushable Single-Fold Paper Towel Pack as used by some NHS Trusts. Paper towels had dimensions of 225mm x 225mm. By weighing ten towels, the weight of each towel was calculated to be 2.24g.

* 1. **Procedure**
     1. *Establishing Towel Discharge*

The general procedure involved clamping each trap to a test stand in the correct attitude, and starting the test with trap filled to capacity (i.e. until it overflowed through the outlet: Bottle-Trap was 344 ml, 'P'-trap was 164 ml), Then paper towel samples were flushed through both trap types with water in 800ml increments (roughly equivalent to a 10 second hand wash) and the output from each increment was retained until no more paper towel appeared.

The samples of paper towel were prepared by cutting 2cm x 11.2cm strips with a tolerance of +/- 1 mm, with five strips being used for each test, See Figure 6. The weight of five strips was calculated to be 4.96mg. The strips were cut to represent random pieces of hand towel found in traps. The strips were placed in a 1L beaker which was filled to 800 ml with cold water, then stirred. The paper towel strips could be seen to break up into randomly sized pieces ranging from a few millimetres to a few centimetres.

The water and paper towel fragments were then poured into the pre-filled traps, then flushed through with the sequential 800 ml flushes, with the output of each flush being retained.

|  |  |
| --- | --- |
| (a) | (b) |
| A white plastic container with a circular object inside  Description automatically generated | **A close up of a white container  Description automatically generated** |

**Figure 5: Inside of bottle trap (a) and a P trap (b). Note the limited exit space on (a) compared to (b) – arrows show maximum exit size. (not to scale)**

A ruler and strips of white tape

Description automatically generated

**Figure 6: Paper strips used for blockage test**

* + 1. *Towel Capture*

The towel output was captured with a metal sieve of pore size 1.0 mm2. By rotating the sieve between flushes, it was found possible to collect five distinct samples which took the form of a small mound of clumped paper fibres. These were removed with plastic forceps and stored with labels.

* + 1. *Towel Weights*

Each sample was seen to leak water over several minutes, so the dry weights were used and compared to the 4.96 mg starting weights. Drying was achieved by placing each sample on labelled filter paper and drying for 17 hours in a non-fan oven at 50˚C.

* 1. **Results and Discussion**

The number of flushes required to clear the Bottle-Trap is double the number required to clear the P-Trap. The total dry paper towel weight recovered from the Bottle-Trap was 4.50 mg, after 4 washes. The total dry paper towel weight recovered from the P-Trap was 4.80 mg, after 2 washes. The total dry paper towel weight recovered from the Bottle-Trap was 91%, after 4 washes. The total dry paper towel weight recovered from the P-Trap was 96%, after 2 washes.

The relatively consistent and high recovery fraction from both traps is much smaller than the difference in required flushes giving confidence that the flush number ratio of 2:1 required to clear the Bottle-Trap compared to that of the P=Trap is accurate.

1. **Conclusions**

The equipment used was suitable for the task and produced clear results well within operational parameters. Measured by water body dilution in 20 ml increments, the residence time of the Bottle-Trap is approximately 2.3 times greater than that of the P-Trap. Based on a straightforward paper towel load test with consecutive flushes, the Bottle-Trap performance in terms of clearing the test load required double the number of flushes compared to the P-Trap, approximately in proportion to the ratio between their standing volumes.

Given the differences in performance of the different traps with respect to both residence time and propensity to blockage (which would contribute to bacterial growth in a real situation), it is highly recommended that the same type of investigation be carried out using bacteria as the contaminant as longer residence times and ability to ‘self-cleanse’ are likely to be important indicators of prolonged bacterial growth with the potential for re-entry back into the basin [18].

Both the dye dilution residence time test and the solid flush efficiency tests are both suitable benchmark tests for water trap seal product selection with respect to safe water and wastewater systems within hospitals. These are first stage- ‘look see’ benchmark tests which could be built upon in order to ensure patient and staff safety in the future.

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