



Sink area contamination during hand washing

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Research Report

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Sink contamination during handwashing has been linked to healthcare-associated infections and has implications for laboratory-associated infection. When handwashing protocols are designed for high infection risk workplaces, the extent to which performing the handwashing protocol would create contamination around the sink area is not considered.

This study aimed to identify whether the distribution of the splash around the sink area, after a common handwashing method, differed when compared with that seen when the handwashing method was modified.

Trials were conducted using a semi-quantitative approach. The sink area was split into areas and a presence or absence of contamination system used to indicate sink area contamination. Volunteers, after covering their hands with a fluorescent marker, washed them using either an NHS handwashing method or a modified version. After washing, the sink area was visualised under ultraviolet light and areas of contamination recorded. The modified handwashing method showed a statistically significant reduction in sink area contamination.

The method has been incorporated into the revised World Health Organization's Laboratory Biosafety Manual and a video has been produced which could be used as a training tool to highlight visually the benefits of handwashing as well as how to reduce sink area contamination.

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Sink area contamination during hand washing

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Research ethics statement

Ethical approval for this study was given by the University of Sheffield Medical School Research Ethics Committee [HSL19, approved 20 July 2019].

Key Messages

Sink contamination during handwashing has been linked to healthcare-associated infections and has implications for laboratory-associated infections. The NHS have developed handwashing protocols to ensure healthcare workers hands are clean but the amount of splash and other contamination in and around the sink has not been considered in any depth. This has infection control implications if the extent of the sink contamination is not understood or regularly removed during routine cleaning. It is possible for individuals to unknowingly leave contamination for the next user and re-contaminate their hands after washing, potentially passing on pathogens and subsequently cause infection.

The aim of this study was to identify the distribution of the splash around the sink area after a common handwashing method used in healthcare, and then to establish if this could be reduced by modifying the handwashing method.

Preliminary observations identified the first two steps of the handwashing method had the potential to result in significant splash on and around the sink area. It was hypothesised that modifying the initial part of the handwashing process could reduce splash and therefore sink contamination. The proposed modification included collecting soap with one hand, wetting the other hand and then bringing them together to lather in the sink.

A semi-quantitative approach was taken, where the sink area was split into areas and a presence or absence of contamination system used to indicate sink area contamination. Thirty volunteers, recruited from HSE's Science Division, were asked to cover their hands with a fluorescent marker and then wash their hands using an NHS handwashing method and a modified version. After handwashing, the sink area was visualised under Ultraviolet (UV) light and areas of contamination recorded on a sink map. Volunteers' hands were also visualised to see if the handwashing techniques were effective.

The modified handwashing method showed a statistically significant reduction in sink area contamination whether the soap was located above the sink or located further away (both $p < 0.01$).

A short film has been produced which could be used to raise awareness of the minor modification that can be made to reduce splash during handwashing.

The modified method has been incorporated into the revised World Health Organization's Laboratory Biosafety Manual and will be used by HSE inspectors to advise on best practice where appropriate. Further study employing a harmless bacterial contaminant would allow for a more sensitive and quantitative assessment of contamination differences between handwashing methods.

Executive Summary

Background

Sink contamination has been linked to healthcare-associated infections. The benefits of careful handwashing are widely known, and several similar handwashing methods have been devised that clean an individual's hands effectively. However, while handwashing protocols used in healthcare settings have been extensively studied, the amount of splash and other contamination in and around the sink has not been considered in any depth. This has infection control implications if the extent of the sink contamination is not understood or regularly removed during routine cleaning. It is possible for individuals to unknowingly leave contamination for the next user and re-contaminate their hands after washing, potentially passing on pathogens and subsequently cause infection.

Whilst handwashing protocols are usually designed for use within healthcare and laboratory sectors, they apply to all industries and the public more generally as good practice. The research outlined in this report aimed to identify the distribution of the splash around the sink area, after a common handwashing method, and then to establish if this could be reduced by modifying the handwashing method. The study's main objectives were:

- To undertake a small-scale study using fluorescence to observe contamination of the sink area during the performance of a modified handwashing method with soap positioned in different locations.
- To identify whether contamination of different parts of the hands alters the level of observed contamination around the sink area.
- To produce a short film demonstrating the modified handwashing technique for use by HSE inspectors, World Health Organization's (WHO) officials and others to demonstrate good hand hygiene practice.

Methods

A semi-quantitative approach was taken, where the sink area was split into areas and a presence or absence of contamination system used to indicate sink area contamination. Volunteers were asked to cover their hands with a fluorescent marker and then wash their hands using an NHS handwashing method and a modified version. Training on the handwashing methods was given before the trial and a flip chart used to ensure that all the handwashing steps were completed. After handwashing, the sink area was visualised under Ultraviolet (UV) light and areas of contamination recorded on a sink map. Volunteers' hands were also visualised to see if the handwashing techniques were effective.

A modified method was devised from initial observations whereby the individual collected soap with one hand, wetted the other hand and then brought them together to lather in the sink.

The number of contamination events for the different handwashing methods were recorded and compared to determine statistical significance.

Findings

The modified handwashing method showed a statistically significant reduction in sink area contamination whether the soap was located above the sink or located further away ($p < 0.01$). The biggest impact of the modification was seen volunteers had to reach further for the soap. Here, the number of contamination events dropped from 10 contamination events out of a possible 10 to 0.

Conclusions

A slight change to the first steps in the handwashing method significantly reduced the distribution of contamination within the sink areas. A semi-quantitative analysis noted the presence or absence of fluorescence contamination in pre-specified areas around the sink. Further study employing a harmless bacterial contaminant would allow for a more sensitive and quantitative assessment of contamination differences between handwashing methods.

The modified method has been incorporated into the revised WHO Laboratory Biosafety Manual and will be used by HSE inspectors to advise on best practice where appropriate. The HSE film has been produced which could be used as a training tool by inspectors, employers and workers alike to highlight visually the benefits of handwashing as well as how to reduce sink area contamination. This modified handwashing method could reduced potential infection rates in laboratories and hospitals by decreasing transference of microbial contamination.

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1 Introduction

1.1 Background

Hand hygiene, particularly handwashing is renowned for its importance in preventing infections and controlling infectious disease outbreaks (Vally et al., 2019; Wong and Lee, 2019). There are a large number of studies looking at the effectiveness of handwashing methods and many have been shown to effectively clean hands (Martos-Cabrera et al., 2019; Kitsanapun and Yamarat, 2019). Current handwashing techniques used by healthcare and laboratory workers can however create a lot of splash around the sink area (Yui et al., 2019), which will contain microorganisms if they are present on the skin of the individual washing their hands. This moist environment can encourage ubiquitous microorganisms e.g. Pseudomonads, present in the local environment to grow and multiply where there is sufficient food source such as components of soap and skin squames, and some dusts (Cloutman-Green et al., 2014). These microorganisms can be transferred from the sink area to other fomites (surfaces and objects, Dandalides et al., 1984), which are more likely to be touched by individuals e.g. paper towel dispensers, bins, door handles. Healthcare worker, patient and laboratory personnel exposure to these microorganisms poses an infection risk for both the person(s) exposed and subsequent transference to others (Feng et al., 2019). For example, burns patients are susceptible to infection due to the loss of skin integrity, i.e. their primary infection barrier. Infections of such patients caused by Pseudomonas species have been associated with contaminated sinks (Lalancette, 2017). Other areas of sink contamination such as the P-drain (Kotay et al., 2017; Livingston, 2018) and soap bottles (Archibald et al., 1997) have been implicated in infections of hospital patients, such as paediatric patients or the elderly. The infection mechanism has not been fully elucidated, however, bioaerosols have been generated when taps are being run in a sink where the drain is contaminated with pathogenic bacteria (Cole and Talmadge, 2019). Work has been undertaken to understand how sink design and their placement within hospital and laboratory facilities can be used to reduce pathogen transfer (Cloutman-Green, 2014; Hota et al., 2009); however, evidence that handwashing methods have been designed to effectively wash hands and minimise sink splash was not found.

Occupational infections of laboratory and healthcare workers are an ongoing regulatory concern as specialist inspectors in the Health and Safety Executive's (HSE's) Microbiology and Biotechnology Unit (MBU) continue to receive reports under the Reporting of Incidents, Diseases and Dangerous Occurrences Regulations (RIDDOR) related to laboratory-associated infection. Therefore, improving the knowledge on the type of handwashing techniques that are effective as well as reducing the amount of splash around the sink area could potentially reduce the incidence of such occupation-associated infections. In addition, improving the evidence base around handwashing is not only

important for informing HSE as the regulator, but also contributes to cross-government advice and response to public healthcare emergencies.

Preliminary observations identified the first two steps of a handwashing method commonly used in the NHS, laboratory settings and currently advised as good practice by the WHO (NHS, 2019; WHO, 2009), had the potential to result in significant splash on and around the sink area.

Water from wet hands dripped on and around the sink area prior to soap collection. As such, any contamination on the hands could also drip on and around the sink area, providing a reservoir of bacteria and increased risk of others being exposed and potentially infected.

It was hypothesised that modifications to this initial part of the handwashing process could reduce splash. The proposed modification was applying soap to one hand followed by wetting the other and bringing them together. This simple modification could reduce splash in and around the sink area, reduce the presence and proliferation of microorganisms around the sink area and subsequently reduce transference onto more readily contactable fomites and ergo reduce the incidence of healthcare- and laboratory-associated infection.

1.2 Research aim

The purpose of the work described in this report was to provide evidence for or against a revised handwashing technique that could potentially reduce the distribution of splash from contaminated hands around the sink area. If successful, this could reduce the likelihood of transference onto other fomites, other individuals' hands and subsequently help to reduce the incidence of occupational- and healthcare-associated infections.

The work was divided into three objectives:

Objective 1. Undertake a small-scale study using fluorescence visualisation techniques to observe contamination of the sink area during the performance of a current and modified handwashing method with soap positioned in different locations.

Objective 2. Identify whether deliberate contamination of different parts of the hands e.g. full hands versus fingertips using a fluorescent marker alters the level of observed contamination around the sink area.

Objective 3. Produce a short 3-5-minute film demonstrating the modified handwashing technique for use by HSE inspectors, WHO officials and others to demonstrate good hand hygiene practice. HSE's Infections at Work microsite will broadcast this film.

2 Methods

2.1 Objective 1: Contamination of sink area during different handwashing techniques

This study looked at the potential difference in sink area contamination by comparing a handwashing method commonly used in the NHS, laboratory settings and currently advised as good practice by the WHO (NHS, 2019; WHO, 2009) with the modified version of the handwashing method.

Soap dispenser positioning can differ between handwashing stations. Some are located above the sink while others can be located further away, e.g. between two sinks or on an adjacent unit. This is likely to have an impact on the level and location of contamination dripped from wet hands during soap collection when using the current commonly used handwashing technique. Based on this consideration, the study included two locations for soap dispensers: above the sink and on a small cupboard adjacent to the sink.

Harmless fluorescent markers are often used as surrogate contaminants that are applied to the hands of personnel during training on correct handwashing techniques and during studies on handwashing. Fluorescent markers have been used successfully to indicate areas of potential contamination (Crook et al., 2019) when they are visualised under ultraviolet light (UV). Ordinarily, during such trials and training sessions entire hands are contaminated with the fluorescent marker to provide the greatest challenge for removal from the hands and to identify maximum possible contamination levels of the local environment. For the main part of the study HSE SD scientists used this same maximum fluorescent contamination challenge where hands were completely coated in a fluorescent marker as a worse-case scenario for visualising contamination around the sink to compare different handwashing methods with two different soap locations as noted in Table 1.

Table 1 Handwashing methods and soap locations

Test	Handwashing method	Soap location
1	Current NHS method	On cupboard next to sink
1	Modified NHS method	On cupboard next to sink
2	Current NHS method	Above sink
2	Modified NHS method	Above sink
3	Volunteers' own methods	Above sink
3	Modified volunteers' own methods	Above sink

2.1.1 Handwashing methods

Several handwashing techniques exist, but all follow a similar regime. For this study we selected the one currently promoted by the NHS, WHO and the CDC (NHS, 2019, WHO, 2009; CDC, 2020). It should be noted that the efficacy of the handwashing regime is not being investigated by this study, but rather the distribution of splash generated around the sink area.

Prior to the testing, volunteers were taught the NHS handwashing technique (NHS, 2019, see Figure 1), and the modification suggested by HSE SD scientists (see Figure 2).

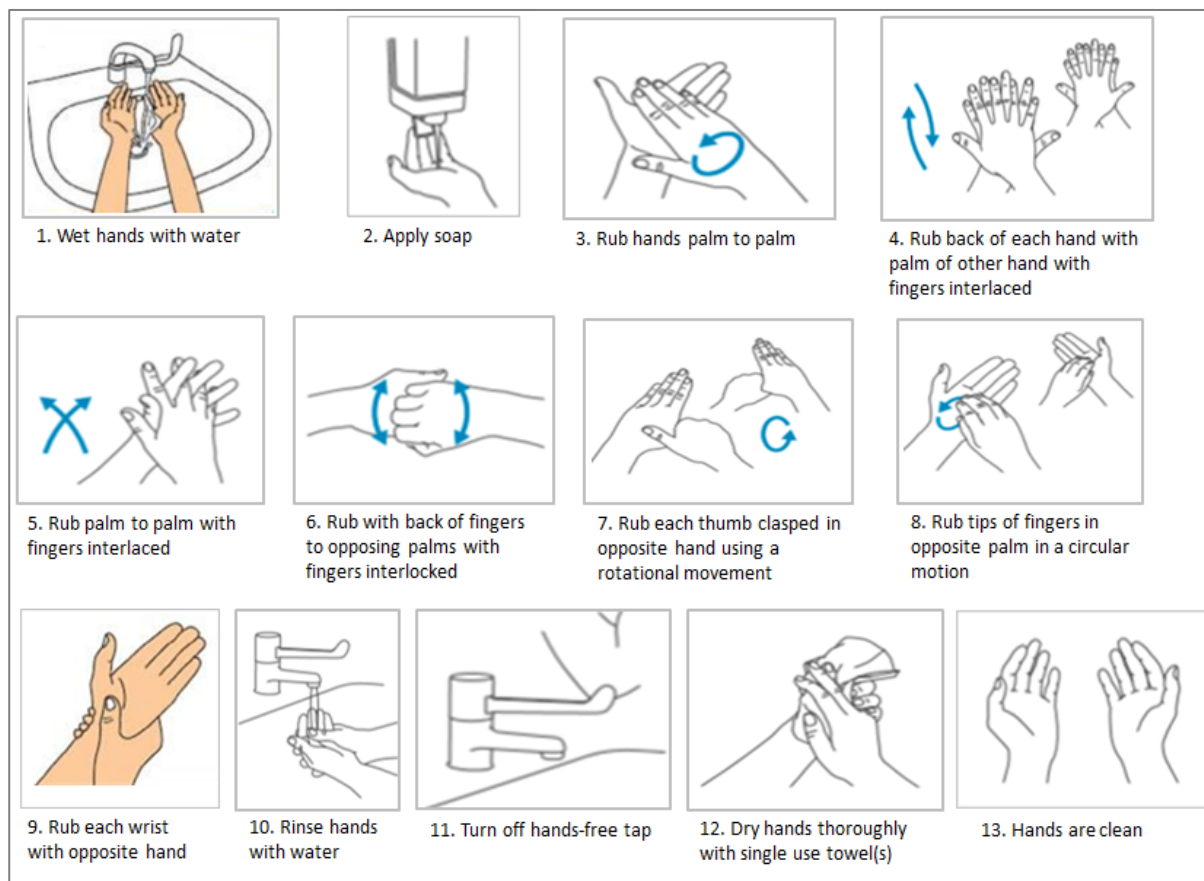


Figure 1 Current NHS handwashing technique. (WHO, 2009) Steps 1 and 2 shows where the modification occurs (see Figure 2)

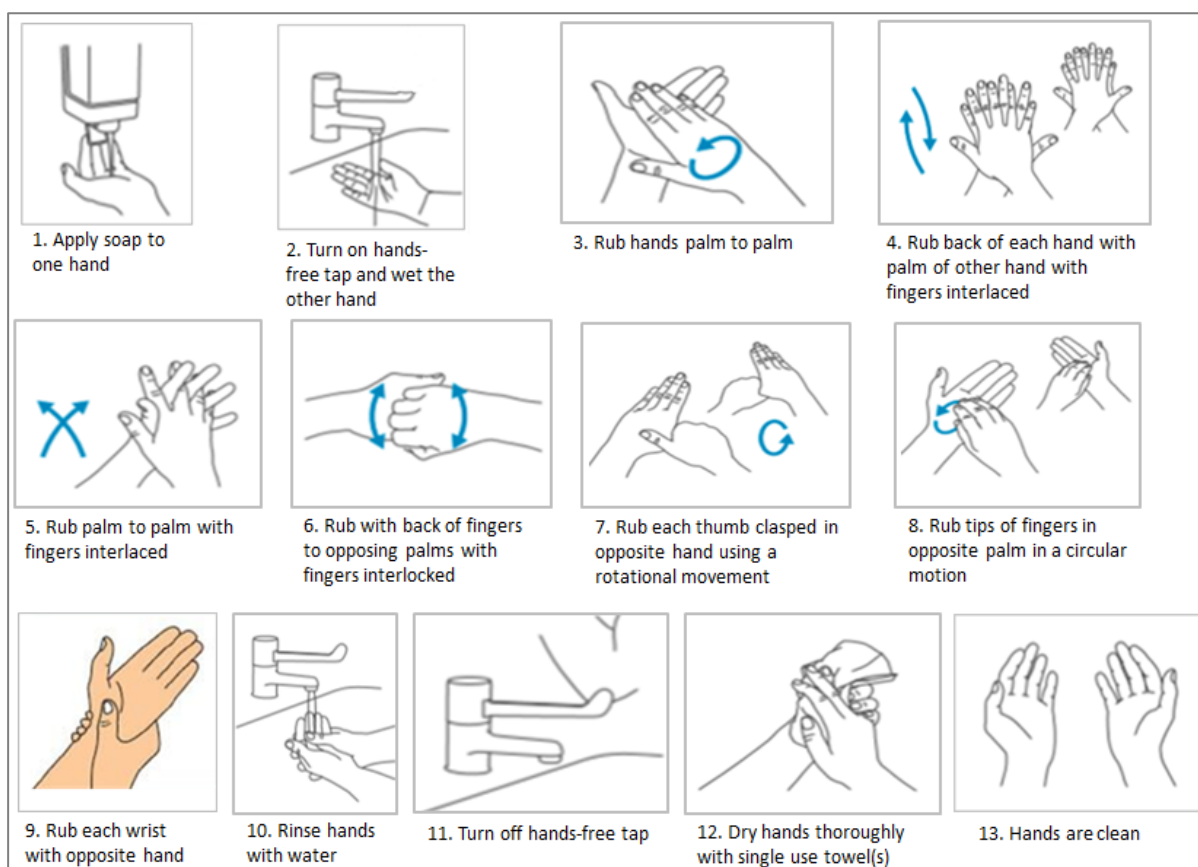


Figure 2 Modified NHS handwashing technique with the modified steps 1 and 2. Adapted from WHO, 2009)

It was thought that the level of splash may differ between volunteers taking part in this study and those more experienced (e.g. ex-nursing staff, laboratory personnel) in the technique. As such, volunteers new to the handwashing technique would wash their hands more slowly and considerately. Therefore, volunteers' own handwashing techniques were also employed to observe any differences in environmental contamination of the sink area. Volunteers were directed to wet both hands and then get the soap before using their own hand washing method for the duration of the test, until they felt they had clean hands. They then repeated the process, but with the modified front end and their own handwashing method thereafter. Notes were taken of the handwashing technique each volunteer used.

2.1.2 Soap locations

Two soap locations were used during the study to determine the impact on the location of contamination dripped from wet hands during soap collection. The soap was positioned above the sink, or on a small cupboard adjacent to the sink (see Figure 3).



Figure 3 Soap locations (highlighted by the circles)

2.1.3 Volunteer involvement

A call for volunteers was sent to the SD volunteer pool, of those 20 responded positively. Another 10 volunteers were obtained by opportunistic sampling i.e., they were not part of the volunteer pool, but were happy to participate on request. The 30 volunteers were all SD staff and comprised 20 science and engineering personnel, nine administrators and one photographer. Groups of 10 volunteers were randomly selected to perform one of the handwashing tests indicated in Table 1. Only one volunteer was present at any one time for the handwashing tests to avoid copying and bias.

2.1.4 Test procedures

Volunteers selected to carry out handwashing exercises in tests 1 and 2 were given a visual demonstration of the common and modified handwashing methods from experienced instructors. To avoid any confusion, a flipchart with each step of the handwashing methods (noted in Figures 1 and 2) were shown to the volunteers during the handwashing tests. To avoid bias through practise of the hand washing method, half of the volunteers proceeded with the common handwashing method first and the other half carried out the modified method first. For test 3 whereby volunteers used their own handwashing methods, an explanation of the modification of collecting soap in one hand and wetting the other before bringing them together to lather was discussed prior to performing the modified method. Notes were taken of the volunteers' own handwashing techniques to identify the likely cause of splashing around the sink area.

Approximately equal amounts of blue/white fluorescent marker (GloGerm gel, two pumps of the dispenser) were applied to the volunteers' hands. The volunteers then rubbed the gel into their hands akin to the application of hand cream ensuring an even and complete distribution across both hands up to the wrists. This was checked visually using a UV light. Prior to starting each handwashing method, the sink was cleaned, and a UV lamp was used to check for any fluorescence from previous handwashing methods. Notes were

taken of the height of the volunteers' hands above the sink bowl during the handwashing method as it was thought that this could have an impact on the amount and location of splash generated (Figure 4).



Figure 4 Height zones of volunteers' hands during handwashing. Zone 1: within the bowl; Zone 2: 0 to 30cm above the bowl; Zone 3: >30cm above the bowl

A photograph of the volunteers' hands was taken after the first handwashing method. A photograph was not taken after the second handwashing as it was deemed unreasonable as remnants could be present (e.g. in fingernails) from the first handwashing method. Photographs of the sink area were taken after each handwashing method to capture any visual contamination.

2.1.5 Contamination mapping

In addition to taking photographs of the sink area after each handwashing method, the contamination was mapped on a diagram of the sink area (Figures 5 and 6). The sink area was segregated into locations which included the taps and soap dispenser. The number of locations varied depending on the position of the soap dispenser (17 when the soap was located above the sink and 18 areas when the soap was located on a small cupboard adjacent to the sink) (Table 2). A semi-quantitative presence-absence system was adopted for assessing and comparing the distribution of splash from handwashing due to the difficulties of quantifying the amount of contamination in each of the mapped locations.

Sink area contamination during hand washing

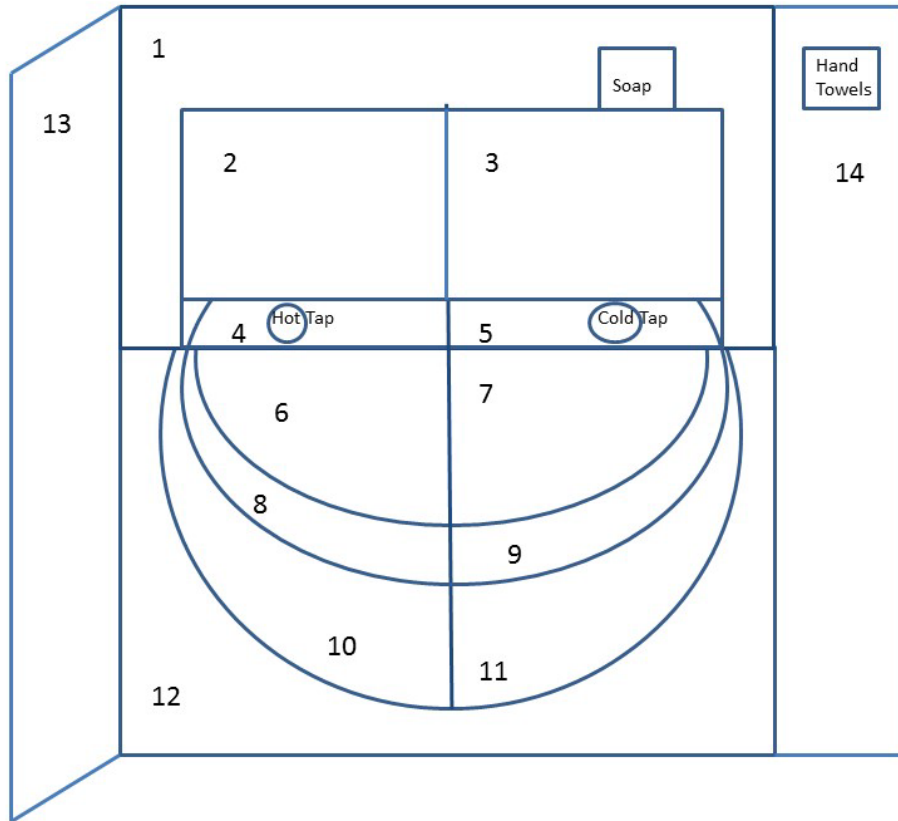


Figure 5 Diagram of the sink areas and location numbers when the soap dispenser was located above the sink

Sink area contamination during hand washing

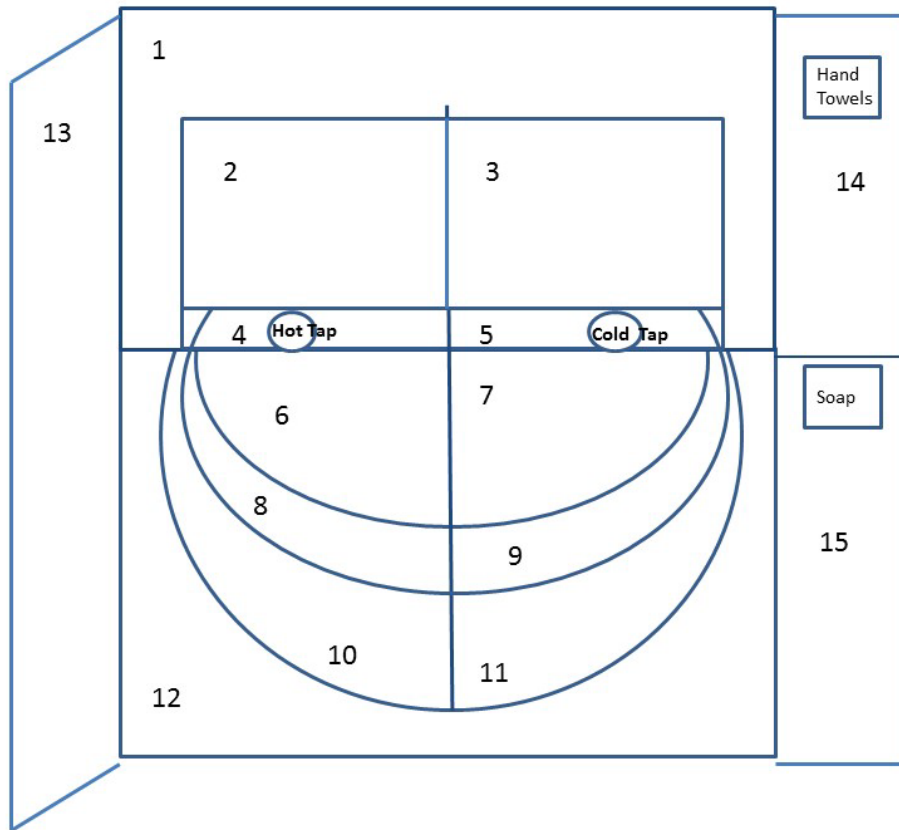


Figure 6 Diagram of the sink areas and location numbers when the soap dispenser was located on a small cupboard adjacent to the sink

Table 2 Segregated locations around the sink for contamination mapping

Sink area location	Description
1	Wall around tiled backsplash
2	Tiled backsplash (left-hand side)
3	Tiled backsplash (right-hand side)
4	Top back of sink (left-hand side)
5	Top back of sink (right-hand side)
6	In the basin (left-hand side)
7	In the basin (right-hand side)
8	Rim of the basin (left-hand side)
9	Rim of the basin (right-hand side)
10	Outer side of the basin (left-hand side)
11	Outer side of the basin (right-hand side)
12	Floor around the sink
13	Adjacent wall (90°) to the left of the sink
14	Wall to the right of the sink
15^a	Cupboard top where soap dispenser is located
Hot tap	Left-hand side
Cold tap	Right-hand side
Soap dispenser	Above or adjacent to the sink

^a not used when the soap dispenser was located above the sink

2.1.6 Contamination Analysis

Ten volunteers were involved in each test, with 17 locations (including taps and soap dispenser) assessed for contamination if the volunteer did not need to reach for the soap and 18 locations if volunteers needed to reach for the soap on the small cupboard. Overall, contamination of the sink area by a volunteer was quantified using the percentage of locations contaminated by that volunteer. For example, if a volunteer contaminated five of the 17 locations, then the percentage of locations contaminated by that volunteer would be 29%. The percentage of locations contaminated by the two methods was then compared using a paired t-test.

Contamination at specific sink locations was compared by identifying the number of volunteers that contaminated a particular location. The number of contamination events per location, when using the original or modified method, were not statistically compared.

This is because, due to the relatively small number of volunteers involved, a statistically significant difference would only be observed if the difference was extreme – i.e. if a specific location was contaminated by all volunteers using one method, but never contaminated using another. Results were presented for each test separately on diagrams to highlight the number of volunteers that contaminated specific locations for the two handwashing methods. Diagrams were colour-coded according to the number of the volunteers that contaminated a particular location enabling more frequently contaminated areas to be readily observed by a darker hue.

2.1.7 Observational analysis

Contextual analysis was carried out whilst volunteers were washing their hands. This included the area in which individuals washed their hands (see Figure 4) and any changes to method such as flicking excess water from hands before collecting soap during the current NHS method. Notes were also taken of any action that looked to cause a lot of dripping, splashing or contamination of a specific area. Each volunteer's occupation and height were compared with other volunteers to identify whether either of these factors affected the extent of sink area contamination.

2.1.8 Questionnaire and analysis

Each volunteer was asked to fill in a short questionnaire (appendix A) on completion of the handwashing methods for the test in which they were participating. This was used to ascertain volunteers' perception of handwashing, if the potential for contamination was deemed a concern, and whether they would change how they washed their hands in the future. All responses were analysed using content analysis. Content analysis is a systematic way of analysing an individual's responses to questions and the underlying context. Every sentence is carefully analysed to see what themes it encompasses, such as knowledge of health, personal habit and whether it suggests a positive or negative attitude to change. For example, "I don't see sink contamination as a problem" is a negative personal attitude to change.

2.1.9 Use of different fluorescent markers

A commercially available and commonly used blue/white fluorescent gel (GloGerm™, Hygienic Solutions UK, Omega) was used to contaminate hands before washing (Tests 1-3). The gel forms a creamy consistency and is difficult to see in normal light when applied to hands. An alternative orange fluorescent formulation is available (GloGerm™, Hygienic Solutions UK, Omega), which is an oil rather than a gel and is easier to discern under UV light, which can be useful given that some cleaning products and other materials can fluoresce blue/white under UV light. The orange fluorescent marker is visible when applied to volunteers' hands, which can be advantageous to ensure full coverage of the hands but

can cause bias during washing as people will wash more thoroughly than they ordinarily would due to the visibility of this marker. A test (Test 4) was set up that employed the orange fluorescent marker to identify any differences in the number of contamination events between the two fluorescent markers. One group were asked to perform two tests, one with the orange fluorescent marker and a second test with blue/white fluorescent marker. Photographs were taken of the sink pre and post handwashing under UV light, contamination events recorded on the sink maps and statistical analysis carried out as described in section 2.1.

2.2 Objective 2: Contamination of different parts of the hands

Whilst coating the whole area of the hands with the fluorescent marker provides a worst-case scenario for identifying remaining contamination on hands post handwashing as well as local environmental contamination, in practice contamination of the whole hands is unlikely during various laboratory and healthcare methods. It was considered that reducing the amount of contamination on the hands would lower the volume of contamination and number of contamination events of the various areas noted in Figure 6 and Table 2. To investigate this, a small experiment was carried out by an SD scientist. The current NHS and modified handwashing methods were carried out with three distinctive extents of hand contamination: whole hands including wrists; whole fingers and thumbs; and finger and thumb-tips only. Photographs were taken of the sink pre and post handwashing under UV light and contamination events were recorded on the sink maps as described in section 2.1. Statistical analysis was not carried out on these data as only a single handwashing trial was undertaken for each of the different levels of hand contamination for each handwashing method. The results were considered indicative.

2.3 Objective 3: Film production

Pre-production, production and post-production stages of the film making including shot lists and script editing were undertaken by HSE's Advanced Imaging Solutions (AIS) team. HSE scientists aided this process by carrying out the handwashing methods and preparing the initial script. Imaging techniques were employed including use of the fluorescent marker to enhance the visual experience and to highlight the spread of contamination from hands to the local environment between handwashing methods. A combination of film footage of a HSE scientist performing the different handwashing techniques augmented by voiceover was considered most useful for the audience. Collectively, this made sure that the key message of reducing contamination of the local environment during handwashing to prevent occupationally associated infections would be understood clearly. To ensure a consistent HSE message the film script and draft visuals were checked and approved by a representative specialist inspector from MBU to ensure that the film would support their role in reducing infections in laboratories and the healthcare sector.

3 Results

3.1 Objective 1: Contamination of sink area during different handwashing techniques

The blue/white fluorescent marker was applied to full hands for maximum contamination to compare different hand washing methods with two different soap locations. The summary results are presented below, followed by the contamination mapping of the individual tests.

3.1.1 Handwashing methods and soap location

Table 3 summarises the percentage of locations contaminated during each trial, by test (i.e. different soap locations) and method (i.e. NHS and volunteers' own handwashing methods versus the modified version). Hence a greater percentage means a greater distribution of contamination around the sink.

All tests observed a reduction in the distribution of sink contamination when the modified method was used, but this was not always a statistically significant result. The largest reduction in the distribution of contamination was observed when reaching for the soap that was located on a small cupboard next to the sink (Test 1), with a fall in the percentage from 62% to 42%; a statistically significant reduction ($p=0.001$). The next largest reduction in distribution of contamination was observed when using the current NHS method without reaching for the soap i.e. where the soap was located above the sink (Test 2), which saw the percentage fall from 56% to 42%; again, a statistically significant reduction ($p<0.001$).

Table 3 Summary of the percentage of locations contaminated during each trial by handwashing method for tests 1, 2 and 3 using blue/white fluorescent marker

Method	Number of trials	Mean % of contaminated locations ^a	Standard deviation	Minimum	Maximum	Paired t-test comparing methods within groups
<i>Test 1: NHS method, soap adjacent to sink</i>	10					$p=0.001$
NHS		62.2	17.7	38.9	88.9	
NHS - Modified		41.7	14.2	22.2	61.1	
<i>Test 2: NHS method, soap above sink</i>	10 ^b					$p<0.001$
NHS		55.9	6.4	47.1	70.6	

NHS - Modified		41.8	9.4	29.4	52.9	
Test 3: Own method, soap above sink	10 ^b					<i>p</i> =0.100
Own method		51.8	12.9	23.5	70.6	
Own - modified		43.5	13.9	17.6	64.7	

^a 18 locations for test 1, and 17 locations for test 2 and test 3.

^b same group of volunteers conducted tests 2 and 3.

3.1.2 Contamination mapping Test 1: Current and modified NHS handwashing methods, soap on cupboard away from the sink

Figure 7 shows the results of the contamination mapping for test 1, which compared the commonly used current NHS method with the modified method that changed the front-end of the method. This was undertaken with the soap located on a small cupboard adjacent to the sink necessitating the volunteers to reach for the soap. The biggest impact was seen on the top of the cupboard where the soap was located (location 15), which observed the level of contamination in this area drop from 10 contamination events (all volunteers) to 0 (no volunteers). Relatively large differences were also observed between the number of contamination events on the floor (location 12) from *n*=6 to *n*=2, the back of the sink by the cold tap (location 5) from *n*=9 to *n*=6 and the soap dispenser from *n*=7 to *n*=4, when using the modified NHS method. Changes were not observed for the left-hand side of the basin (location 6) or the right-hand rim of the bowl (location 9), which were contaminated by all volunteers irrespective of the method used.

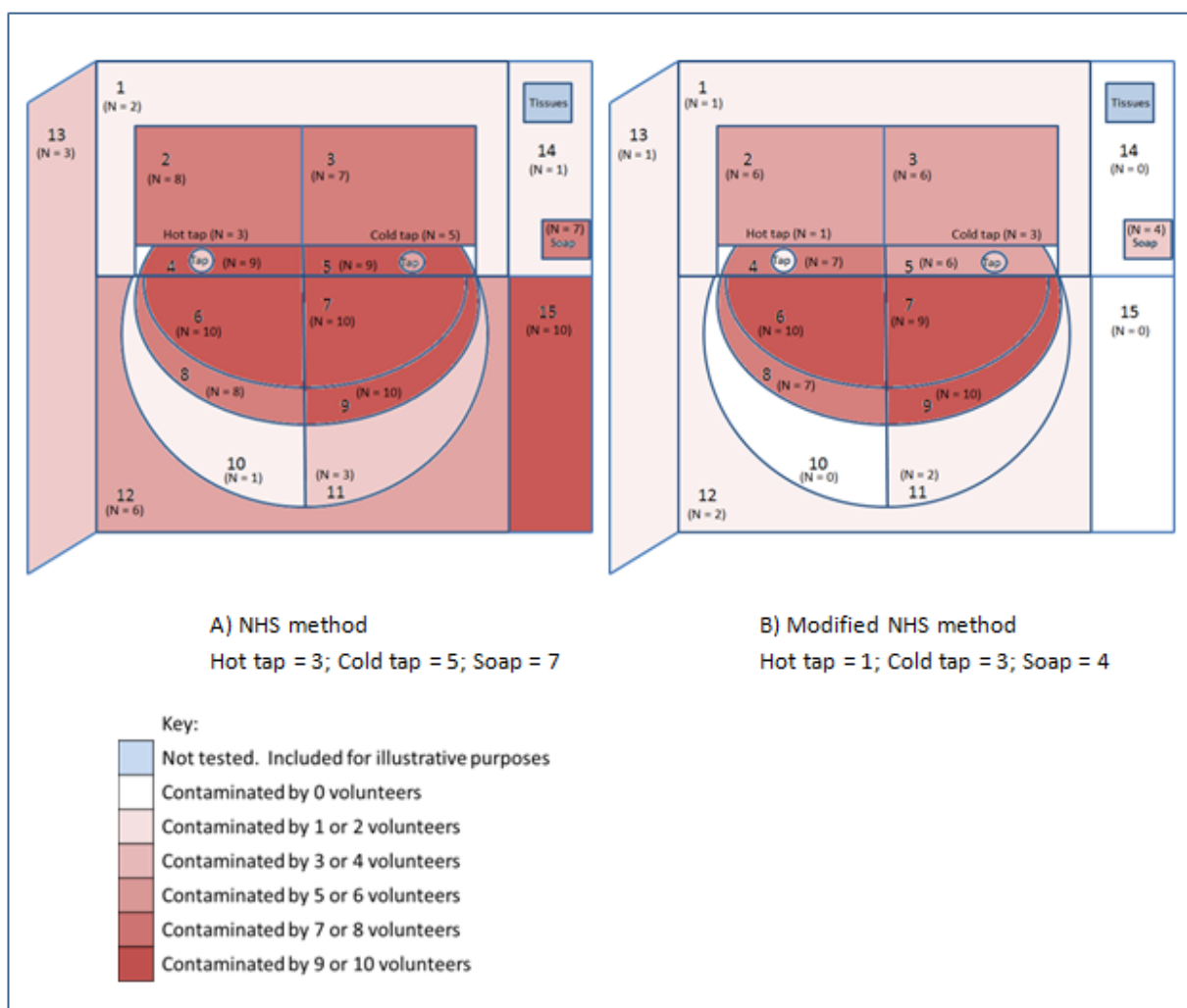


Figure 7 Number of contamination events by 10 volunteers using the current NHS handwashing method (A) and the modified version (B) when the soap was located adjacent to the sink

The number in each area is the location reference from Table 2 and 'N=x' is the number of volunteers who contaminated that location.

3.1.3 Contamination mapping for Test 2: Current and modified NHS handwashing methods, soap above sink

Figure 8 shows the results of the contamination mapping for test 2, where the current NHS handwashing method and the modified method were compared when the soap was located above the sink. The largest change in terms of numbers of contamination events was on the cold tap, whereby seven volunteers contaminated the cold tap when using the current NHS handwashing method compared with two contamination events when the modified method was employed. A relatively large reduction was observed on the right-hand-side tiled area behind the sink (location 3). Here the number of volunteers that contaminated this area reduced from eight with the current NHS method to four with the

modified method. Both sides of the basin (locations 6 and 7) and the right-hand rim of the bowl (location 9) observed no change in contamination events between the methods. The wall to the right of the sink (location 14) never became contaminated by any of the volunteers for either method.

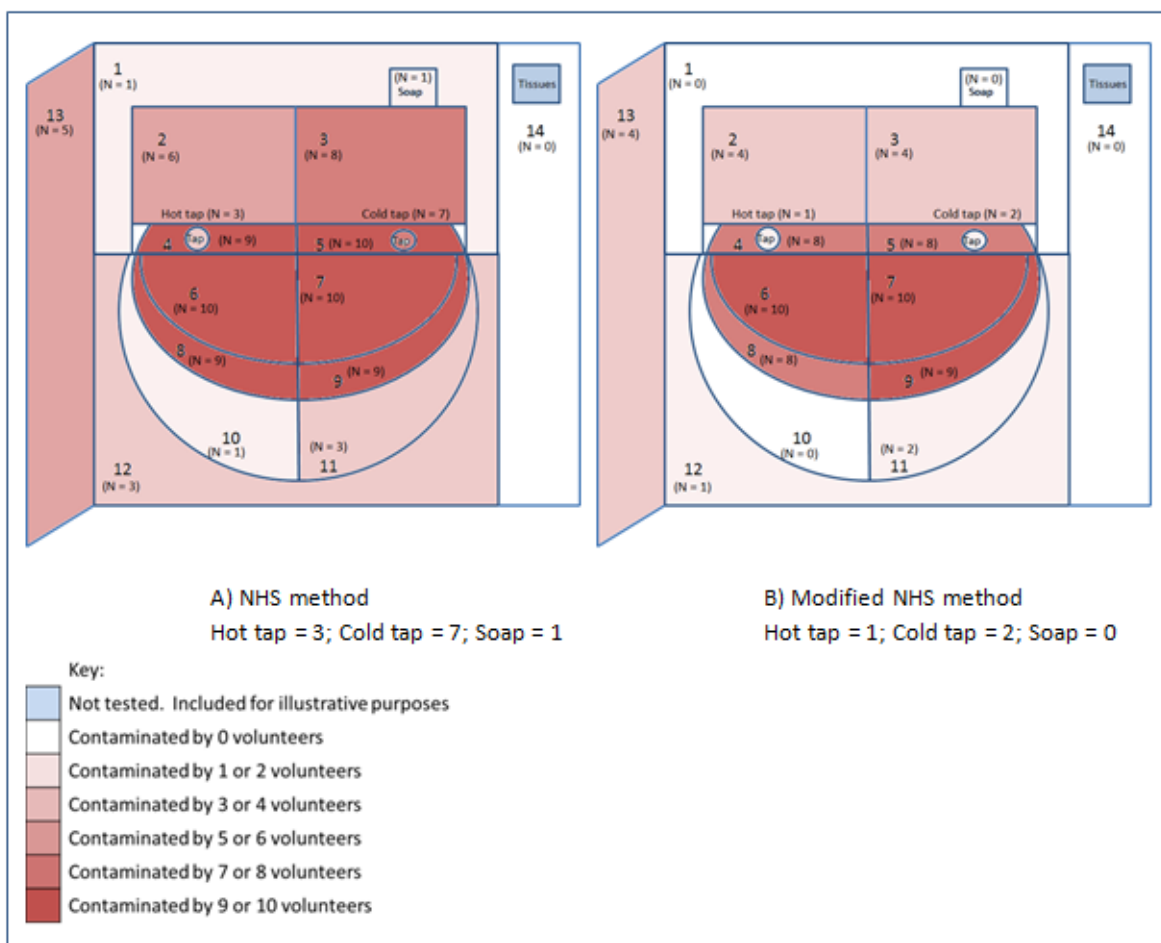


Figure 8 Number of contamination events by 10 volunteers using the current NHS handwashing method (A) and the modified version (B) when the soap was located above the sink

The number in each area is the location reference from Table 2 and 'N=x' is the number of volunteers who contaminated that location.

3.1.4 Contamination mapping of Test 3: Current and modified own handwashing methods, soap above sink

Figure 9 shows the results of the contamination mapping for test 3, which compares the volunteers' wetting their hands, collecting the soap and then using their own handwashing method or their own method with the modified front-end with the soap located above the sink. The greatest change was observed on the floor (location 12) and the wall to the left of the sink (location 13), where the number of volunteers who contaminated these areas

reduced from four using the volunteers' own method to one using the volunteers' own method with the modified front-end. There was no change for both sides of the basin (locations 6 and 7) and both sides of the back of the sink (locations 4 and 5), where contamination either always occurred or nearly always occurred for both methods. There was also no change for the wall to the right of the sink (location 14), which was never contaminated during this test.

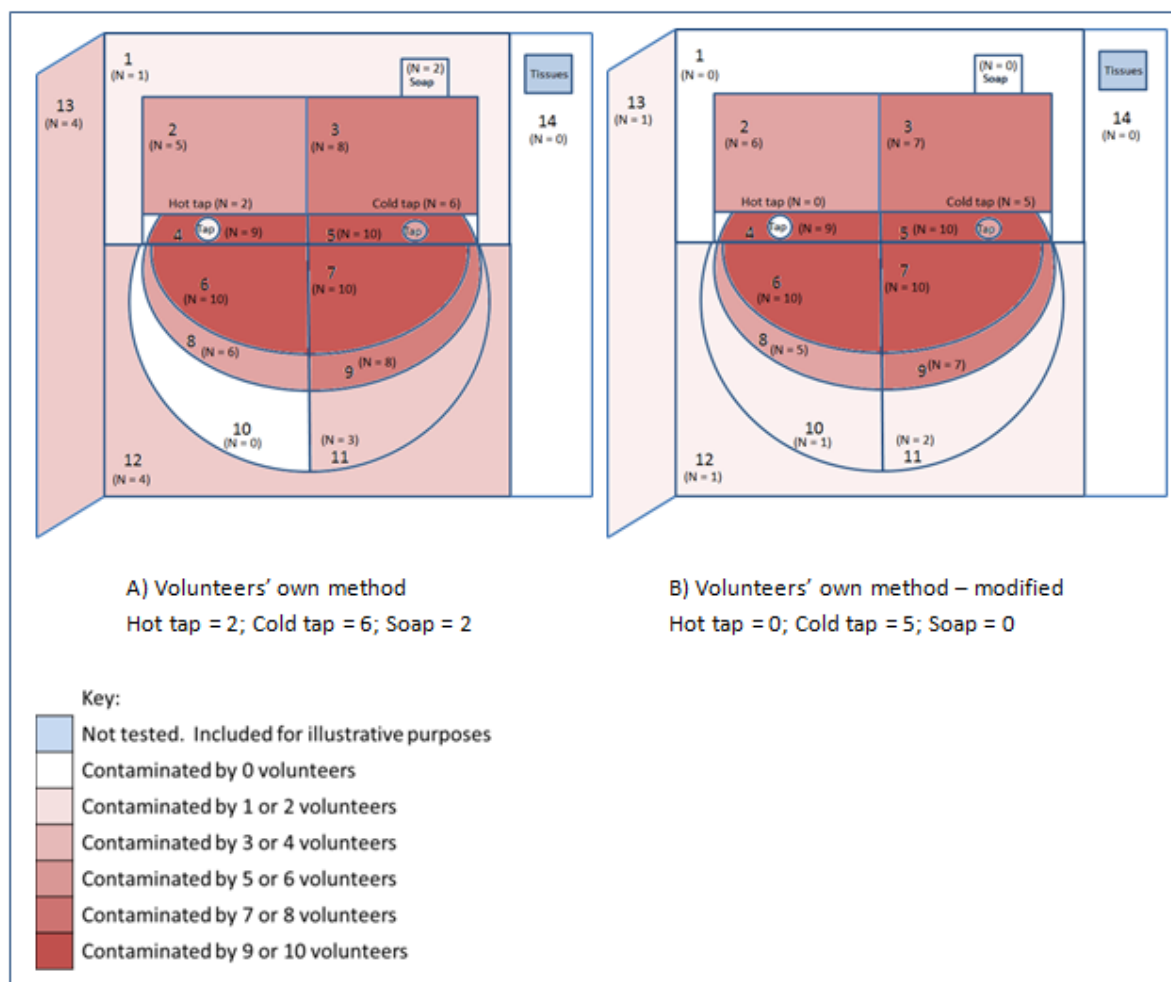


Figure 9 Number of contamination events by 10 volunteers using their own handwashing method (A) and their own method with modified front end (B) when the soap was located above the sink

The number in each area is the location reference from Table 2 and 'N=x' is the number of volunteers who contaminated that location.

3.1.5 Use of different Fluorescent markers

Table 3.2 shows the results of the trials for test 4. This test employed the current NHS method and the modified NHS method where the soap was located above the sink using an orange fluorescent marker (GloGerm™, Hygienic Solutions UK, Omega). Overall, the difference between the two methods was not statistically significant (Table 4).

Table 4 Summary of the percentage of locations contaminated during each trial, by handwashing method for test 4

Method	Number of trials	Mean % of contaminated locations ^a	Standard deviation	Minimum	Maximum	Paired t-test comparing methods within groups
<i>Test 4: NHS method, soap above sink, fluorescent orange oil</i>	10					$p=0.096$
NHS		40.0	7.2	29.4	52.9	
NHS-Modified		31.2	15.7	5.9	58.8	

^a 17 locations for test 4.

Figure 10 shows the contamination mapping for test 4. The biggest impact was seen at the back of the sink, which saw the numbers of contamination events reduce from eight (current NHS method) to five (modified method) on the left-hand side (location 4) and from 10 (current NHS method) to seven (modified method) on the right-hand side (location 5). There was no change in the number of contamination events for either side of the outside of the bowl (locations 10 and 11), the floor (location 12), the wall behind the sink (location 1) and the wall to the left of the sink (location 13), where contamination either never occurred or was rare. There was also no change to the left tiled area (location 2), which was contaminated by four volunteers for both methods.

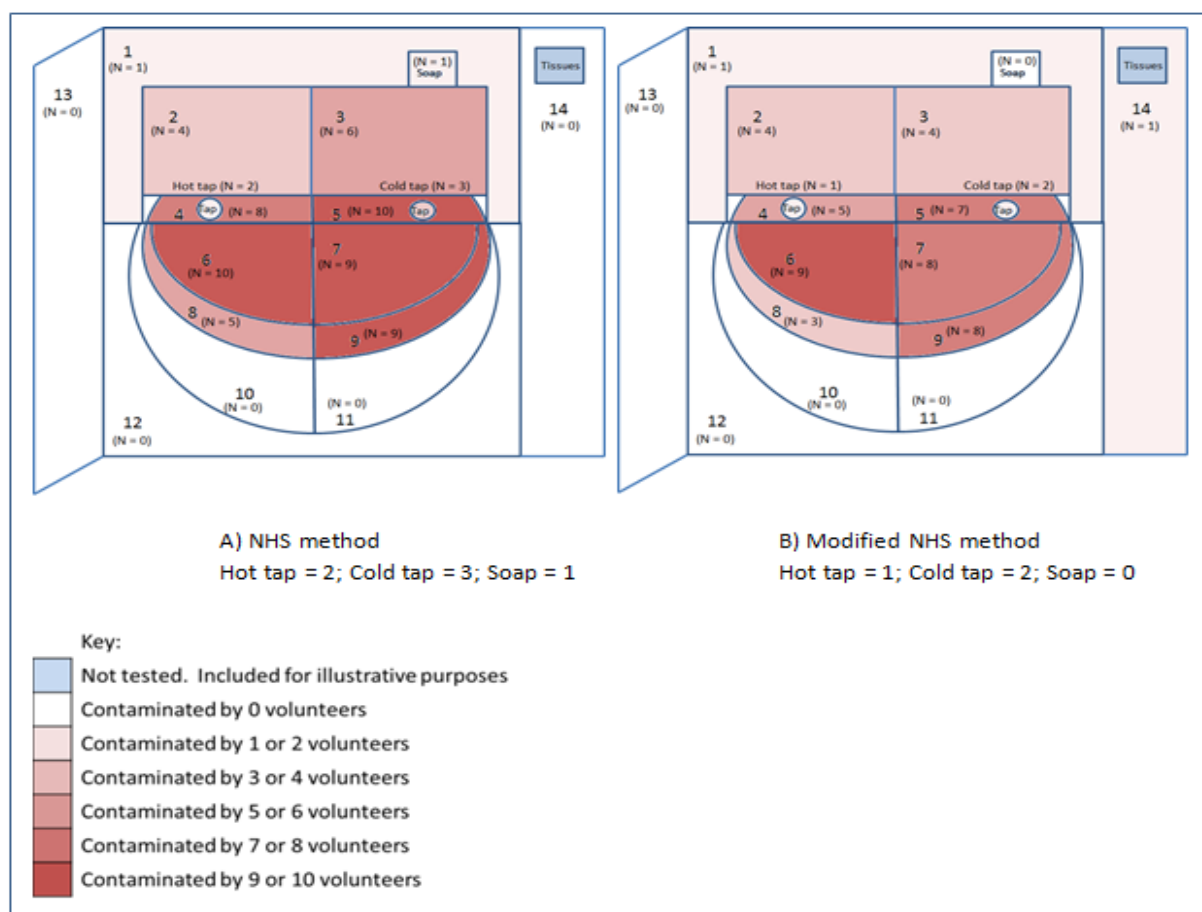


Figure 10 Number of contamination events by 10 volunteers using the current NHS handwashing method (A) and the modified version (B) when soap was located above the sink using the orange fluorescent oil

The number in each area is the location reference from Table 2 and 'N=x' is the number of volunteers who contaminated that location.

During the study, the investigators thought that the orange fluorescent marker (oil) did not seem to be washing off as well as the blue/white fluorescent marker (gel) used in the previous tests despite the robust handwashing method used. The results of this test when using the NHS method were therefore compared with the data from test 2 (Table 4) i.e. the current NHS method with soap located above the sink using blue/white fluorescent marker. The distribution of contamination was lower when using the orange fluorescent marker (mean = 40%, Table 3.2) compared with the blue/white fluorescent marker (mean = 56%, Table 3.1), and this was a statistically significant difference (unpaired t-test assuming unequal variance, $p < 0.001$). This supports the investigators' observation of less fluorescent marker being washed off the hands of volunteers using the orange fluorescent marker.

3.1.6 Observational analysis

It was thought that different occupations of the volunteers e.g. microbiologists and engineers might impact how individuals washed their hands, however the number of participants was not sufficient and number of different occupations too varied to analyse this.

It was thought that an individual's height might influence where they washed their hands in relation to the bowl of the sink. Most volunteers washed their hands just above the bowl with only two volunteers washing their hands within the bowl and one that washed their hands close to the top of the area above the bowl, slightly above 30 cm. It was determined that the numbers of volunteers that washed their hands either in the bowl or much higher than the sink would not provide enough information to be able to statistically analyse the data. Further testing would be needed to determine if height and where an individual washed their hands in relation to the sink significantly affected sink contamination.

During all the handwashing trials the volunteers rinsed their hands and then flicked excess water off into the bowl. The hands should be clean at this point due to the handwashing method, however in everyday life this might not be the case and as such microorganisms and dirt remaining on the hands and within the excess water could contribute to contamination of the sink.

When volunteers performed the handwashing steps after soap collection using their own method, many used three or four similar hand movements. Most volunteers had clean hands at the end of the test, although there was some contamination seen around the nailbed and around the wrist and some with more extensive contamination (see Figure 11). Contamination was also seen in the skin crease around the thumb on a small number of volunteers. The details of the handwashing movements used by volunteers during their own handwashing methods are shown in Table 5. They all washed the top of their hands, palm to palm and round the wrist and hands. One volunteer used the interlocking hands as part of their handwashing regime. When asked they mentioned that their mother was a trained nurse and had taught them how to wash their hands. That individual was the only volunteer to use this action. No individual washed their nails against the palm of the hands as prescribed by the NHS method. Eight volunteers washed their hands just above the sink bowl and two washed their hands within the bowl. All volunteers contaminated the sink area.

Table 5 How the volunteers washed their hands when using their own handwashing technique. (N.B. the volunteer number does not relate to the number of volunteers, it is simply an identifier used to distinguish one from another)

Volunteer	Handwashing method
Volunteer 7	<ul style="list-style-type: none"> • Tap turned on with the elbow; hands wetted before soap application; hands rubbed together palm to palm; • rubbed the backs of hands;

Volunteer	Handwashing method
	<ul style="list-style-type: none"> • rinsed hands while rubbing the backs of hands; flicked water when rinsed.
Volunteer 25	<ul style="list-style-type: none"> • Wet hands and the flicked excess water off before going for the soap; • palm to palm rubbing; • interlocked fingers; • palm to palm rubbing repeated; • round the back and the wrists before rinsing; • flicked excess water off again and then dried.
Volunteer 34	<ul style="list-style-type: none"> • Palm to palm rubbing; • rubbed backs of hands in circular motion and between fingers; • knuckles clasped together and rubbing; • palm to palm again; • rinsed and flicked dry.
Volunteer 30	<ul style="list-style-type: none"> • Rubbing lots of palm to palm and then round thumbs; • flicked water from hands after rinsing.
Volunteer 13	<ul style="list-style-type: none"> • Very quick palm to palm and then rinsed.
Volunteer 40	<ul style="list-style-type: none"> • Palm to palm rubbing; • around wrists and back of hands; • interlocking fingers; • rinse right up to the wrists.
Volunteer 5	<ul style="list-style-type: none"> • Palm to palm rubbing; • around the hands and rubbing the backs of hands; • palm to palm rubbing with interlocking fingers; • around the thumbs; • rinsed and flicked off excess water in the sink.
Volunteer 42	<ul style="list-style-type: none"> • Palm to palm rubbing; • interlocking fingers; • around the hands; • backs of hands and around the wrists; • rinsed while rubbing hands; • dried well.
Volunteer 41	<ul style="list-style-type: none"> • No method recorded due to researchers' error
Volunteer 36	<ul style="list-style-type: none"> • Palm to palm rubbing; • interlocking fingers; • around the hands; • rinsed while rubbing hands.



Figure 11 An example of contaminated hands after handwashing with volunteer's own method

3.1.7 Volunteer deliberations

Before the trial, many volunteers stated that they did not think about the contamination round the sink. After the trial volunteers were asked for their thoughts about handwashing and sink contamination and if this would change the way they washed their hands in the future. Many stated they were surprised at the extent of the contamination around the sink with comments such as “I was surprised how much residue and splash was left” and that “it is quite easy to contaminate without much activity”. One volunteer stated that the level of contamination was “a little surprising, but as it's in the sink, not of great concern”. Other volunteers did not view this in the same way, stating they “would take more care to clean the sink and surrounding area”.

When asked if participating in the trial would affect their future handwashing behaviour the responses were mixed. Half of the respondents reported that they would carry on as they had done before and the other half saying they would pay more attention of the areas of the hands that they did not wash very well, such as the wrists and the nail beds. None of the volunteers mentioned using the modified front end to reduce sink contamination, despite most volunteers stating that such contamination did appear to be reduced. Two of the volunteers stated that they could see more dripping and sink contamination when they wet both their hands before getting the soap.

Volunteers thought the NHS handwashing method was involved, but easy to perform and effective, although remembering it would be “a matter of continual practise”. A few volunteers did state that they were unlikely to follow the method and would be very likely to take short cuts if they were expected to wash their hands with this method regularly. This may mean that their hands are not as clean as they could or should be. One volunteer noted that the modified method would “take getting used to and breaking the habit of

reaching for the water first”. This is an acknowledgement that handwashing is generally performed out of habit and to use a specific method with or without the modified front end requires training and conscious effort.

The majority of volunteers thought that changing the front-end to wetting one hand and getting the soap with the other hand “made sense”, with the majority of the volunteers seeing less contamination around the sink. Several volunteers stated that to do this they would “need to overcome their habit of wetting both hands first” and several volunteers also stated that they thought they “needed more soap as it did not bubble as much as they expected”, but this was mainly due to the one hand not being wetted enough rather than the method itself. All volunteers agreed that the change to the front end did not affect the efficacy of the handwashing method, as many of the steps had not changed, but the modified method did reduce the amount of contamination around the sink.

3.2 Objective 2: Contamination of different parts of the hands

A small experiment was performed by the researchers where the hands were contaminated with different amounts of the blue/white fluorescent marker to see if small amounts of contamination would result in sink contamination. The sink area was contaminated in all tests performed irrespective of whether the whole hands, parts of hands or fingers were contaminated as noted in Figures 12 and 13. Significant amounts of splash were seen in and around the sink area even where just the fingertips were contaminated.

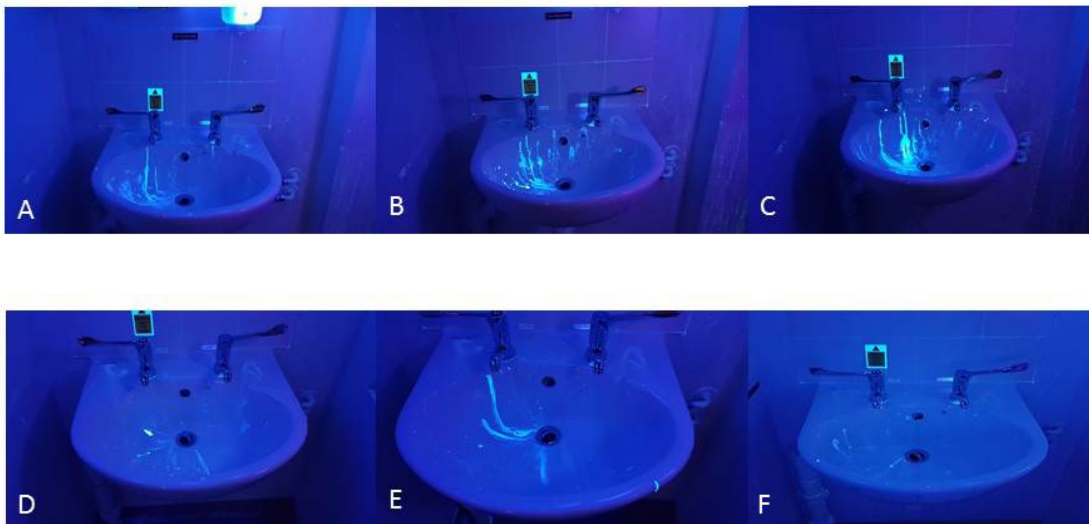


Figure 12 Comparison of contamination events following standard method reaching for the soap (A-C) for fingertips (A), fingers (B) and full hands (C) contamination and modified method (D-F) for fingertips (D), fingers (E) and full hands (F) contamination

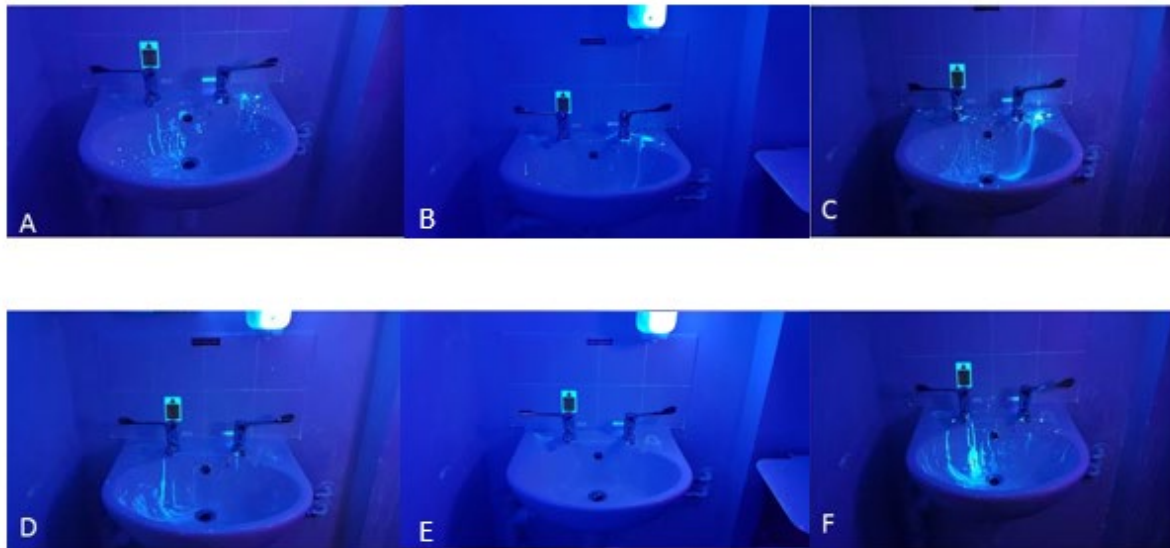


Figure 13 Comparison of contamination events following standard method with soap above the sink (A-C) for fingertips (A), fingers (B) and full hands (C) contamination and modified method (D-F) for fingertips (D), fingers (E) and full hands (F) contamination

3.3 Objective 3: Film production

The film is available on the [HSE Infections at Work microsite](#).

4 Discussion

This small-scale study showed that by slightly modifying a commonly used handwashing method i.e. wetting one hand and collecting the soap with the other before bringing them together for washing, the amount of sink contamination is reduced significantly. This was observed irrespective of whether the soap was positioned close to the sink or further away. When volunteers used their own handwashing method a reduction in splash was observed both with and without the modified front end compared with the current NHS method, but this was not statistically significant. The volunteers' own handwashing methods tended to contain fewer steps. Therefore, it may be that the volunteers' own handwashing methods generated less splash from being less complex and/or were carried out over a shorter timeframe such that the modification at the front end of the protocol had less impact. This did not mean that hands were cleaned as well when volunteers' own handwashing methods were employed compared with the NHS method.

While the presence or absence of fluorescent contamination worked well as a visual tool to indicate the spread of contamination within a specific location around the sink area, the volume of fluid or amount of fluorescence was not measured. This meant that the presence/absence check did not distinguish between heavily contaminated areas and those areas showing only light contamination. Much of the contamination seen near the soap in the unmodified method could have been classed as heavy contamination as there was a high volume of fluid containing the fluorescent marker present at that location, compared with other areas that might have had only a few droplets.

Fluorescent oils (orange GloGerm oil in this study) used widely in the training of good handwashing practices behaved differently to the more water-soluble gels (blue/white GloGerm gel in this study). In addition to the orange oil being visible on application compared with the more invisible gel, it was found that even with vigorous rubbing, the orange oil was difficult to remove compared with the blue gel. This impacts on training as individuals that wash their hands correctly are likely to have large amounts of oil-based fluorescent markers remaining on their hands compared with the gel-based fluorescent markers. Additionally, there was less contamination of the sink area with the orange oil, given it didn't wash off readily, which could give a false indication of the typical level of contamination known to be generated during handwashing. Based on this, the type of fluorescent marker should be noted when comparing studies on hand hygiene practices.

Volunteers employed in this study were HSE colleagues rather than healthcare workers and most were not microbiologists. The survey completed by volunteers participating in this trial (see Appendix) showed that changing peoples' habits may be difficult, as many did not think they would use either the standard NHS handwashing method or the modified version in the future. This was despite visualising the contamination around the sink. However, this is based on the presumption that volunteers based this thinking on risk to themselves rather than risk to others. In order to change peoples' handwashing habits, it

may be necessary to use behavioural interventions to emphasise the importance of good hand hygiene practices. If behaviour change was brought about, it would be possible to help reduce the potential infection risks associated with sink area contamination and possibly occupational- and healthcare-associated infections.

A short handwashing film was produced showing the slight modification to the front end of the NHS handwashing protocol and how effective it is at reducing sink area contamination. This film is available on the HSE Infections at Work microsite. It will be used to highlight the benefit of employing the modified handwashing method to workers in the healthcare and laboratory sectors.

In addition, HSE SD scientists have contributed to the revision of the World Health Organization's (WHO) Laboratory Biosafety Manual (LBM) and a series of seven associated monographs, which will be used to identify and implement best practices and methods including hand hygiene techniques (https://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/, accessed 05/05/20). Based on this experiment, HSE scientists alerted the WHO lead for the revision of the LBM to this modified technique, who agreed with the preliminary evidence-base for the modified handwashing method. As such, the modified method has been included in the LBM as best practice. HSE inspectors will use the WHO LBM and the results from this study to advise duty holders of best practise within the laboratory area, specifically around handwashing.

5 Conclusion

This small-scale study modified a commonly used handwashing method by wetting one hand and collecting the soap with the other before bringing them together for washing. This minor modification made to the front end of the commonly used NHS handwashing method significantly reduced the extent of contamination around the sink area particularly where the soap dispenser was located some distance from the sink. The resultant film demonstrates this clearly and could be used by employers as a training tool for staff. Infection control is essential in many settings but especially within healthcare. As such, any small change that can reduce environmental contamination and therefore the potential for infection is important. Whilst this small-scale study noted the presence or absence of contamination resulting from handwashing methods, it was not possible to differentiate between heavy and light contamination. Further research could be carried out with non-pathogenic bacterial species to determine the presence, absence and concentration of contamination as well as survivability thereafter.

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NHS handwashing poster: <https://www.uhb.nhs.uk/Downloads/pdf/HandHygienePoster.pdf>

7 Appendix A – Handwashing Questionnaire

Volunteer number..... Date

Researcher.....

1. How did the visual evidence of splash around the sink area affect your thoughts on both handwashing and contamination of the sink area?
2. What do you think of the NHS handwashing method?
3. How easy did you find the NHS handwashing method?
4. What do you think of the modified handwashing method?
5. How easy did you find the modified method?
6. How will participating in this trial affect the way you wash your hands?

Sink area contamination during hand washing

Sink contamination during handwashing has been linked to healthcare-associated infections and has implications for laboratory-associated infection. When handwashing protocols are designed for high infection risk workplaces, the extent to which performing the handwashing protocol would create contamination around the sink area is not considered.

This study aimed to identify whether the distribution of the splash around the sink area, after a common handwashing method, differed when compared with that seen when the handwashing method was modified.

Trials were conducted using a semi-quantitative approach. The sink area was split into areas and a presence or absence of contamination system used to indicate sink area contamination. Volunteers, after covering their hands with a fluorescent marker, washed them using either an NHS handwashing method or a modified version. After washing, the sink area was visualised under ultraviolet light and areas of contamination recorded. The modified handwashing method showed a statistically significant reduction in sink area contamination.

The method has been incorporated into the revised World Health Organization's Laboratory Biosafety Manual and a video has been produced which could be used as a training tool to highlight visually the benefits of handwashing as well as how to reduce sink area contamination.

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