Table 3: *Drying Method and Microbial Translocation, Dispersion and Environmental Contamination*

Publication Details	**Principal Study Objective**	**Context**	**Hand Drying Device(s)**	**Study Design**	**Summary of Findings**
Ali Alharbi etal, 2016. Saudi Arabia.	Identify and count the bacterial contamination of hand air dryers used in washrooms.	15 air dryers in the washroom of an academic institution in the Kingdom of Saudi Arabia were used to assess the bacterial contamination.	Warm air dryer.	The warm air dryers were turned on for 30 s and the air was played on to nutrient agar medium in petri dishes. The petri dishes were then incubated at 37° C for 48 h. Following incubation, a total count of bacteria was calculated. Bacterial contamination of the surface was evaluated by placing petri dishes containing nutrient agar medium in a washroom for a period of ten minutes, followed by incubation at 37° C for 48 h.	Warm air dryers can deposit pathogenic bacteria onto the hands and the body users. Bacteria are distributed into the general environment whenever dryers are running and could be inhaled by both users and non-users. The results offer an evidence base for the development and enhancement of hygienic hand drying practices.
Ansari etal, 1991. Canada.	To compare the efficiency of paper, cloth and warm air drying in eliminating	The authors did not incorporate any friction in hand drying because of the difficulties in standardising	Paper towels, cloth towels and warm air dryer.	The contaminated area on the finger pads of a volunteer was exposed to the hand washing agent for	Irrespective of the hand washing agent used, warm air drying produced the highest and cloth drying the lowest reduction in the numbers of test organisms.

	rotaviruses and Escherichia coli remaining on finger pads washed with 70% isopropanol, a medicated liquid soap, an unmedicated liquid soap, or tap water alone.	and accurately representing field conditions.		10 s and then rinsed in 40°C tap water. The washed areas were dried for 10 s by one of the three methods.	
Best, Parnell & Wilcox, 2014. UK.	To compare the propensity of three hand drying methods to contaminate the environment, users and bystanders.	All tests were carried out in a room measuring 65m3 with the door closed throughout experiments. Room air was maintained by standard ventilation without air-conditioning or negative or positive pressure ventilation. Experiments were carried out over a period of six weeks.	Paper towels, warm air dryer and jet air dryer.	Hands were coated in lactobacilli to simulate poorly washed, contaminated hands, and dried. The investigation comprised 120 air-sampling tests (60 tests and 60 controls), divided into close and 1m proximity from the drying process. Separate tests used hands coated in paint to visualise droplet dispersal.	Jet air and warm air dryers result in increased aerosolisation when drying hands. These results suggest that air dryers may be unsuitable for use in healthcare settings, as they may facilitate microbial cross-contamination via airborne dissemination to the environment or bathroom visitors.

Best & Redway, 2015. UK.	To assess the potential for airborne microbial dispersion during hand drying by 4 methods using 3 different models.	All hand-drying methods are in use in public / National Health Service toilet facilities. Hand drying was undertaken in a standardised manner (to simulate normal use) for each method, with a 10 s drying time (20 s for warm air dryer).	Paper towels, roller towels, warm air dryer and jet air dryer.	Before use, the drying devices were decontaminated and control tests were performed before each run. In the acid indicator model, gloved hands were washed in 50 ml of lemon juice for 10 s and dried with one of the four methods. The transmission distance was assessed using circular filter paper discs, soaked in universal indicator and air dried, placed next to and 0.25, 0.5, 0.75 and 1 m away from the hand drying units; discs were also placed at different angles (0°, 30° and 90°) to the hand drying units. Sheets of indicator paper were affixed to a vertical board (1.8 x 0.6 m) positioned 0.4 m to the left of each drying unit. Following drying,	Jet air dryer dispersed liquid from users' hands further and over a greater range (up to 1.5 M) than the other drying methods (up to 0.75 M). Thus demonstrating the differing potential risks for airborne microbial dissemination, especially if handwashing is suboptimal.

				spots on the filter papers were counted. For the yeast model, a similar experimental set up was used, except that gloved hands were washed in a suspension of Sacchromyces cerevisiae, and agar plates containing Sabouraud dextrose agar were used for detection. To determine if actual bacterial contamination could be transferred, experiments were repeated using volunteers who had previously used toilet facilities and washed their hands without soap, then dried them using one of the four methods. Agar plates containing blood agar were used for the detection of colonies.	

Gustafson etal, 2000. US.	To evaluate the effects of 4 different drying methods to remove bacteria from washed hands.	Potential recruits for the study were excluded if they had acute or chronic nail or skin disorders, including eczema, or were considered by an examining physician to have compromised immunity. One hundred healthy adults older than 18 years were enrolled in the study. This number was chosen following the results of a pilot study. Of the 100 people recruited to participate in the study, 1 failed to complete the experiment under all 4 hand drying conditions and was removed from the data set, leaving 99 subjects available for analysis.	Paper towels, cloth towels, warm air dryer and room air evaporation.	One hundred adult volunteers participated in this randomised prospective study. All bacterial counts were determined using a modified glove-juice sampling procedure. The difference was determined between the amounts of bacteria on hands artificially contaminated with the bacterium Micrococcus luteus before washing with a nonantibacterial soap and after drying by 4 different methods. The results were analysed using a nonparametric analysis (the Friedman test). By this method, changes in bacterial colony forming unit values for each drying method were ranked for each subject.	No statistically significant differences in the efficiency of 4 different hand-drying methods for removing wetness or bacteria from washed hands.

Hanna, Richardson & Marshall, 1996. Australia.	To investigate the cleaning efficiency of three hand drying techniques.	Comparison of the number of bacteria remaining on hands after drying. Bacteria samples were taken from the hands onto contact plates.	Paper towels, linen towels and warm air dryer.	A tracer bacterium (Serratia marcescens) was inoculated onto the hands of volunteers. Bacterial removal from the hands after washing and drying was analysed.	Warm air dryers appeared to be the least effective method of removing bacteria from the hands and further resulted in substantial numbers of airborne bacteria in the vicinity of the user. Paper towels and linen towels produced negligible contamination of the surrounding environment.
Huesca-Espitia etal, 2018. US.	Screening of hot air hand dryers for their deposition on plates of: A: Total bacteria B: A kanamycin resistant *Bacillus subtilis* strain, PS533.	Hot-air hand dryers in multiple men's and women's bathrooms in 3 buildings in the basic science research areas of the University of Connecticut were screened.	Hot air dryer.	36 hot-air Xlerator hand dryers without HEPA filters were surveyed in 18 men's and 18 women's bathrooms in or adjacent to two basic science research areas in the University of Connecticut and in areas above the academic building.	Results indicate that many different kinds of bacteria, including pathogens and spores, can be deposited on hands exposed to bathroom hand dryers and that spores can be dispersed throughout buildings and deposited on hands by hand dryers.
Kimmitt & Redway, 2015. UK.	The use of a MS2 bacteriophage to compare three hand drying methods for their potential to disperse viruses and contaminate the	MS2 bacteriophage (ATCC 15597-B1) was propagated at 37°C overnight in log phase tryptone soya broth cultures of Escherichia coli to yield a mean count in the range of 1010 plaque-	Paper towels, warm air dryer and jet air dryer.	Participants rinsed their gloved hands in 50 ml of the phage suspension for 10 s and simulated the process of washing during this period followed by shaking three times and then drying	Use of the jet air dryer led to significantly greater and further dispersal of MS2 bacteriophage from artificially contaminated hands when compared to the warm air dryer and paper towel.

	immediate environment during use.	forming units (PFU) per mL. Following infection, nonlysed bacteria were removed by centrifugation (3000 g, 10 min) and the supernatant phage suspension generated was used in subsequent experiments. All experimental work took place in a university teaching laboratory.		them using one of the 3 hand-drying devices. The quantity of MS2 present in the areas around each device was determined using a plaque assay. Samples were collected from plates containing the indicator strain, placed at varying heights and distances and also from the air.	
Margas etal, 2013. UK.	To compare for the potential of cross contamination of the surrounding environment resulting from two different hand drying methods.	Hand-drying systems were placed alternatively in the centre of the back wall of a controlled atmosphere test room. In the trials using paper towels, the paper towel dispenser containing paper towels was mounted on the wall 120 cm from the floor. The accompanying open mouth bin was placed	Paper towels and jet air dryer.	One hundred volunteers (70% of the participants were female) for each method washed their hands and dried them using one of the two methods. Bacterial contamination of the surrounding environment was measured using settle plates placed on the floor in a grid pattern, air sampling and surface swabs.	Both drying methods led to different patterns of ballistic droplets and levels of microbial contamination under heavy use conditions. The jet air dryer produced a greater number of droplets dispersed over a larger area and more microbial contamination of the immediate environment than paper towels.

		directly below the dispenser.			
Matthews & Newsom, 1987. UK.	Comparison of the release of bacteria into the air when drying hands with a range of warm air dryers with numbers released using paper towels. To measure the residual bacteria after drying with each method.	Four different warm air hand dryers were examined by comparing the bacterial aerosols released from hands during use by sets of twelve participants with those released by paper towels. Tests on two units also included hand imprints on agar plates for detection of residual bacteria.	Paper towel and warm air dryers.	Twelve participants were enlisted to wash and dry hands by the two methods. One hand of the participants was covered with a sterile plastic glove and the other washed and dried by a paper towel. The process was repeated for the warm air dryers.	No significant difference between aerosols liberated by towels and warm air dryers were observed for two units, while the other two generated significantly fewer aerosols than towels. Impression plates revealed similar numbers of bacteria on the hands after drying by either method. Warm air dryers appeared safe from a bacteriological viewpoint.
Ngeow, Ong & Tan, 1989. Malaysia.	To investigate the potential risk of a warm air dryer contributing to airborne infection in a hospital using a strain of Serratia marcescens and a strain of coagulase-negative, streptomycin-resistant Staphylococcus.	All tests were carried out in a hospital side room.	Paper towel and warm air dryer.	Procedure 1: The investigator immersed both hands in a suspension of marker bacteria contained in a beaker, allowed his hands to drip dry for around 1 m then held them beneath the air dryer and gently rubbed them until they were completely dry.	Dispersal of marker bacteria by the air dryer was demonstrated within a radius of about 3 feet from the dryer and to the investigator's laboratory coat. When paper towels were used for hand drying, no dispersal of marker bacteria was demonstrated. The authors therefore claim that hot air dryers are unsuitable for use in critical care areas as they may contribute to cross-infection either via airborne dissemination or via contaminated personnel.

				Procedure 2: After immersing his hands in the bacterial suspension, the investigator washed his hands in the sink with soap and water for around 1 m in the manner of a routine hand wash by a nursing staff, before holding up his hands to drip dry and to dry under the air dryer. Procedure 3: This is the same as for procedure 1 except that a paper towel was used for hand drying. Procedure 4: This is the same as for procedure 2 except that a paper towel was used for hand drying. At the end of each hand drying 3 settle plates were immediately incubated at 37° C. Following incubation, plates were	

				examined for the growth of the marker bacteria by standard bacteriological methods.	
Redway & Fawdar, 2008. UK.	Measure the drying efficiency of paper towel, warm air dryer and jet air dryer. Assess any potential contamination of users and the washroom environment caused by the use of paper towel, warm air dryer and jet air dryer.	The experimental protocol used in this study attempted to reproduce the public's usual hand washing and drying practices as closely as possible.	Paper towel, warm air dryer and jet air dryer.	Sets of 5 paper towels were placed in sterile plastic bags and weighed prior to use. Two volunteers were asked to dip their hands up to the wrists in warm water for 10 seconds, shake them thrice, and then dry them for 10 seconds using one of the 7 hand drying methods. All the water remaining on the surface of the hands was then carefully removed by the investigator with one of the sets of 5 pre-weighed paper towels using a standardised protocol for 40 seconds. The damp towels were returned to their plastic bag, re-weighed and the amount of water	Paper towels are likely to cause considerably less contamination of other users and of the washroom environment than jet air dryers; which were found to disperse artificial hand contamination to a distance of at least 2 metres. Paper towels and warm air dryers produced more positive results than jet air dryers regarding contamination of the washroom environment. Paper towels created less contamination at 0 metres (directly below the device) than warm air dryers, although there was no significant difference at greater distances. In environments with jet air dryers such as public washrooms, noise levels could constitute a potential risk to those people exposed to it for long periods of time.

				removed from the hands calculated. The operation was repeated using increasing drying times at 10-second intervals: 20, 30, 40, 50 and 60 seconds. The order of drying times and the drying methods were randomised to minimise any possible effect of external factors such as variations in room temperature, relative humidity or human behaviour.	
Taylor etal, 2000. UK.	To evaluate the performance of warm air dryers, in comparison with paper towels, to examine a number of issues.	Experiments were undertaken using a containment cabinet. 15 volunteers were asked to wash and dry their hands using warm air hand dryers. The following day the same people were asked to use paper towels.	Paper towel and warm air dryer.	The hand dryer was situated outside a containment cabinet with an extension tube on the nozzle passing through a porthole into the centre of the cabinet. The air inlet of the dryer was open to a laboratory. The opposite port was used for	A finger rinse technique for counting microorganisms on hands showed no significant difference in the level of recovered microorganisms following hand drying using either warm air dryer or paper towels. Drying of hands warm air dryers was no more likely to generate airborne microorganisms than drying with paper towels. Levels of microorganisms on external surfaces of warm air dryers were not significantly different to those on other washroom surfaces.

				participants to place their hands for drying and the adjacent port was used to take air samples from the cabinet during the drying procedure. After each participant, the cabinet was purged with filtered air for 4 m. Hand drying with paper towels was also done in the cabinet and after drying, the towel was retained for microbiological testing.	
Yamamoto, Ugai & Takahashi, 2005. Japan.	Evaluate warm air and paper towel drying for removing bacteria from washed hands.	Each drying method was performed as a randomised trial using 30 hands.	Paper towel and warm air dryer.	After hands were washed with non-antibacterial soap, they were dried using warm air with and without ultraviolet light, while being rubbed or held stationary, or paper towels.	Holding hands stationary and not rubbing them was desirable for removing bacteria. Ultraviolet light reinforced the removal of bacteria during warm air drying. Paper towels were useful for removing bacteria from fingertips but not palms and fingers.