

HAND DRYING:

AN
ASSESSMENT OF EFFICIENCY
AND
HYGIENE OF DIFFERENT METHODS

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SUMMARY

Observations of people's hand washing and drying habits under natural conditions have been carried out. These showed that disposable paper towels and cotton cabinet towels were much quicker and more efficient means of drying the hands than hot air driers. People rarely use hot air driers long enough to ensure more than 55-65% dryness and often complete drying by wiping hands on clothes, etc. Many women also use make-up and combs whilst hands are still damp. These activities could spread any bacteria left on the hands.

Microbiological studies revealed that using towels after washing the hands helps remove bacteria. Paper towels were slightly more efficient than cotton, both with respect to cleansing the finger tips and in between the fingers.

In contrast, hot air drying increased bacterial counts on the hands and in the local environment. Contamination of the face and inhalation could occur if hot air is used for drying the face. Bacterially contaminated air was emitted whenever a machine was running, even when not being used for hand drying.

INTRODUCTION

The choice of hand drying facilities in public and workplace washrooms is important, not just from a cost point of view but also with respect to ease and comfort of use and efficiency. Even more important are hygiene considerations, since the hands are one of the major ways in which bacteria can be passed from person to person (Sanderson & Weissler, 1992). Very careful washing can help remove transient surface bacteria and some residents from deeper skin layers (Meers & Yeo, 1978). Remaining transients can, however, be transferred between surfaces and people, increasing chances of cross-infection. This is especially important in sensitive locations such as toilets where levels of some pathogenic faecal bacteria can be high on surfaces (Mendes & Lynch, 1976) and in hospitals (Sanderson &

Weissler, 1992). These problems are recognised in legislation such as the Health & Safety at Work Act which places a duty on employers to provide hygienic washing facilities. However, careful washing is of little use if the hands aren't dried properly afterwards. Efficient drying helps remove bacteria, especially those rubbed off on dead skin cells (Meers & Yeo, 1978). It also removes water that could create warm moist conditions in which bacteria could thrive.

Sharing hand towels in public places can obviously increase the chances of transmitting bacteria, a problem that can be overcome by using disposable paper towels. Fabric towels dispensed in a loop from long rolls in wall cabinets offer a clean dry section to each user. However, they could become contaminated and people still have to handle them to pull down a clean section. Hot air driers don't involve contact but no bacteria are rubbed off on a towel and they appear to be slow in drying. They can therefore create warm moist conditions favouring bacteria, especially if hands aren't dried properly. It is also possible they can become internally contaminated and disperse and/or circulate bacteria in the air currents, including ones attached to dead skin cells and in minute droplets of water (aerosols). These could contaminate hands, clothes and surfaces that are touched.

There are conflicting views on the hygiene of hot air driers. The results of Blackmore (1989) support the hypothesis that hot air driers increase levels of bacterial contamination compared to towels, but those of Davis *et al.* (1969), Matthews & Newsome (1987) and Meers & Leong (1989) appear to show the reverse. Different methodologies may explain some of these conflicts.

This study was designed to compare the different drying methods under realistic conditions of use in relation to:-

1. People's hand washing and drying habits
2. The ease and efficiency of hand drying
3. Hygiene aspects of different methods

1. HAND WASHING AND DRYING BEHAVIOUR

How well people wash and dry their hands are key factors in personal hygiene. To assess these, males and females were observed using public washing facilities (e.g. in Euston Station and the University of Westminster). The results are shown in Tables 1a, b and c.

TABLE 1 Hand washing and drying behaviour (percentage of subjects using different methods) and average times (seconds) that people choose to take for different drying methods.

Table 1a. Using hot air driers¹
(23 males, 30 females)

	BEHAVIOUR	MALES	FEMALES
HAND WASHING	Soap used	56%	50%
	Average time (seconds)	11.5s	12.5s
BEFORE DRYING	Shake hands in bowl	69%	37%
	Shake hands/drip on floor	54%	50%
DRYING METHODS	Hands not dried	6%	10%
	Use cupping-turning method ²	56%	40%
	Rub hands vigorously	31%	37%
	Mixture of methods	7%	13%
	Average drying time (seconds)	19.6s	25.4s
SUBSEQUENT BEHAVIOUR	Wipe hands on clothes, hair, body	43%	39%
	Use comb, make-up, handbag or other case	0%	61%

Notes;

¹ Model A-548, World Drier Corp., average cycle length 30 seconds, air temperature 55°C at hand height

² 'cupping and turning' the hands over and over is carried out to help catch the hot air to dry the hands

Table 1b. Using cotton cabinet towels¹
(20 males, 23 females)

	BEHAVIOUR	MALES	FEMALES
HAND WASHING	Soap used	70%	100%
	Average time (seconds)	10.0s	12.7s
BEFORE DRYING	Shake hands in bowl	50%	61%
	Shake hands or drip on floor	45%	39%
DRYING METHODS	Hands not dried	0%	4%
	Average drying time (seconds)	7.9s	7.9s
SUBSEQUENT BEHAVIOUR	Wipe hands on clothes, hair, body	20%	4%
	Use comb, make-up, handbag or other case	0%	5%

Note; ¹ Initial Towel Services

1c. Using paper towels¹
(23 males, 20 females)

	BEHAVIOUR	MALES	FEMALES
HAND WASHING	Soap used	83%	80%
	Average time (seconds)	10.3s	8.9s
BEFORE DRYING	Shake hands in bowl	56%	35%
	Shake hands or drip on floor	39%	55%
DRYING METHODS	Hands not dried	0%	0%
	Average drying time (seconds)	11.6s	9.2s
SUBSEQUENT BEHAVIOUR	Wipe hands on clothes, hair or body	0%	5%
	Use comb, make-up, handbag or other case	0%	5%

Note; ¹ Equal numbers of Kleenex Premier, ScottFresh Pullman and Dixcel Professional paper towels

CONCLUSIONS; HAND WASHING AND DRYING BEHAVIOUR

The results reveal some interesting things about hand washing and drying behaviour;-

WASHING

- 1.1 The majority of people appear to wash (using soap) and dry their hands out of habit, taking as little time as possible. The average time spent washing the hands overall was 11.0 seconds, the differences between males and females being small. Such short and cursory washing is likely to leave residual bacteria on the skin .

BEFORE DRYING

- 1.2 Although many people shake their hands in the bowl before drying (more men than women), 35-50% shake or let them drip on the floor or clothing. The majority of people then use the available drying facilities, as follows;-

HOT AIR DRYING

- 1.3 Few people rub their hands, many just cup and turn them to catch the hot air and expose the palms and backs (56% of men, 40% of women observed).
- 1.4 Very few people use the full drying cycle time of 30 seconds set on most machines. Men on average leave after 19.6 seconds, women after 25.4 seconds.
- 1.5 Lack of rubbing and full drying could leave bacteria to multiply in warm moist conditions, especially between the fingers.

PAPER AND COTTON TOWEL DRYING

- 1.6 The majority of people rub their hands fairly vigorously and appear to dry their hands well. Differences between towels were small (the average drying time was 7.9 seconds (for both sexes) using cotton towels and 11.6 (men) and 9.6 seconds (women) using paper towels).

BEHAVIOUR AFTER DRYING

- 1.7 Many users of hot air driers appeared to still have wet hands and about 40% were seen to dry them further on clothing, handkerchiefs or hair - and the majority of women used make-up or touched-up their hair where hot air driers

were available. These actions could spread bacteria.

2. THE EASE AND EFFICIENCY OF HAND DRYING

An important question now needs answering - do people dry their hands properly in the time they allow themselves? To assess this, each drying method was tested on equal numbers of adult male and female volunteers. Each volunteer dipped their hands up to the wrists in warm water, shook them twice and dried them for 5 seconds using one of the three methods. All the water remaining on the surface of the hands was then carefully removed on a preweighed paper towel. The damp towel was reweighed and the amount of water removed from the hands calculated. The 5 second drying-full water removal operation was repeated twice again and the sequence repeated after 10, 15, 20 seconds and so on. To estimate the total amount of water on the hands immediately after washing, hands were dried thoroughly on a preweighed paper towel and the weight gain recorded. This was repeated twice more. It was then possible to calculate the mean percentage of the total water load removed by each method with time. Full dryness was difficult to achieve, therefore results of percentage dryness with time were plotted on a graph (see below) and the average time taken to achieve 95% dryness per method derived. Differences between males and females were small. The percentage dryness achieved in the average times actually spent using each method (as determined in the earlier study) was also calculated, as shown in Table 2 overleaf.

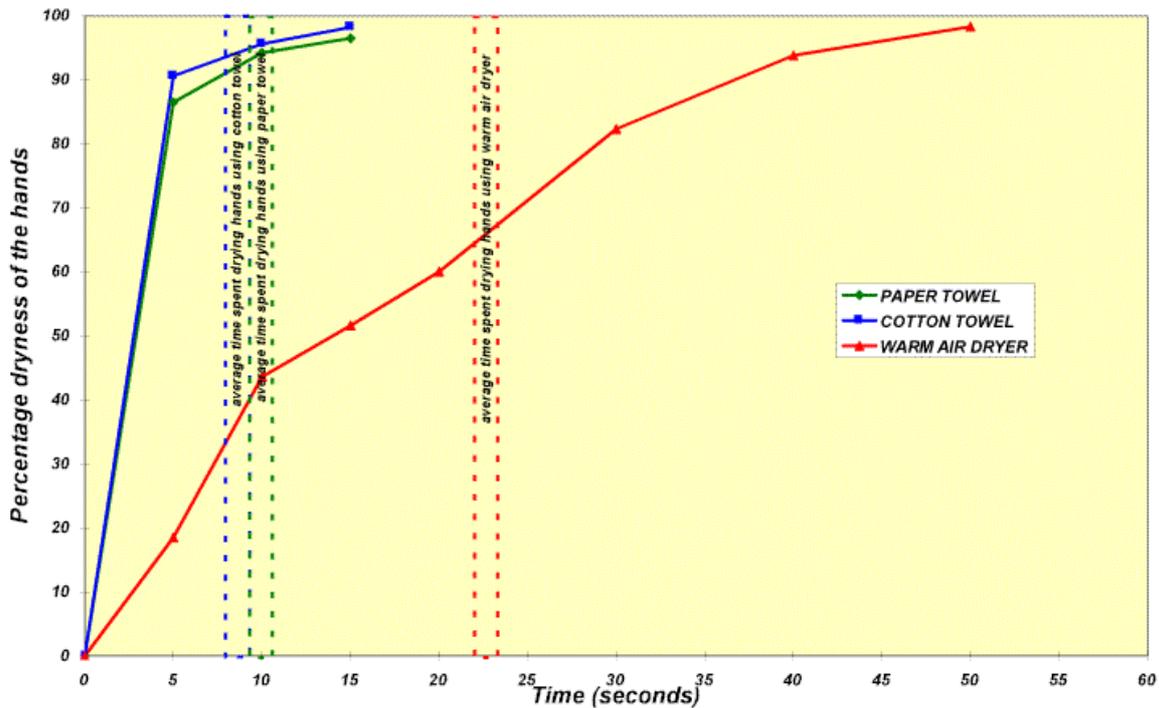
TABLE 2 Average times taken to achieve 95% dryness using

different drying methods and percentage dryness achieved in the drying times normally chosen.

Drying method ¹ (N = number of subjects)	Average time (seconds) taken to achieve 95% dryness	Average % dryness achieved in normal drying time	
		Men	Women
PAPER TOWELS (N = 28)	11.7 secs	95.5%	93.0%
COTTON TOWELS (N = 18)	9.8 secs	93.5%	93.5%
HOT AIR DRIERS (N = 14)	43.3 secs	55.0%	68.0%

Note:- ¹ Paper and cotton towels see Table 1, hot air drier Model HD1/T, Wandsworth Bunnie, average cycle length 30 seconds, air temperature 55°C at hand height

Figure 1: Drying efficiency of different hand drying methods as average percentage dryness of the hands against time



CONCLUSIONS; EASE AND EFFICIENCY OF HAND DRYING

2.1 Towels are quick and efficient, nearly all water on the hands is removed during normal drying times. The differences between paper and cotton towels are negligible in comparison with hot air drying which is much slower. Very few people remain long enough to dry their hands properly, men only achieving 55% dryness on average, women 68%. Subsequent wiping of damp hands on clothes and handling of combs, etc. could aid transmission of bacteria.

3. HAND HYGIENE

Bacteria, especially transients attached to the finger tips, would be expected to be rubbed off and left on towels for disposal or laundering (Blackmore, 1989). Bacteria from deeper cell layers will also be brought to the skin surface by friction and warm moist conditions. These should also be removed by rubbing off on towels. Finger tips are obviously the main route for bacterial transmission but some residual bacteria could remain between the fingers. Removing these will be difficult without very careful drying. Hot air driers would not be expected to be so efficient at removing bacteria - indeed, bacterial growth and spread might be encouraged because, as shown earlier, the hands are rarely rubbed and dried properly and are often wiped on clothes, etc. In particular, the areas between the fingers are not dried well using hot air by the cupping-and-turning method commonly used.

To test these hypotheses, experiments were carried out using the 'finger pad' method before and after hand washing and drying, using the standard times determined earlier. The pad method involves pressing finger tips onto Oxoid nutritive agar plates, growing up any transferred microorganisms overnight at 37°C and then counting the number of colony forming units (cfu's). This is a relatively quick method, suitably accurate for this type of study (Sanderson & Weissler, 1992).

Volunteers (equal numbers of men and women) were first asked to press the fingertips of one hand firmly onto an agar plate. They then used the finger tips of the other hand to stroke firmly between the fingers of the previously tested hand. In this way, any dead cells and bacteria between the fingers and in the webs were transferred to the finger tips. These were touched to another plate. Volunteers then washed their hands (using Sainbury's non-bactericidal Family bar hand soap) for 10-12 seconds, rinsed them and shook them twice. They then dried the hands using one of the drying methods for the length of time normally chosen according to previous observations (i.e. 10 seconds for towels and 20 seconds for men and 25 seconds for women using hot air driers). Clean sections of cotton towels and new paper towels were used for each test. The plate test

procedures were repeated, but this time reversing the hands for the finger tip/rub webs sequence.

Results of these tests are shown in Table 3 overleaf.

Table 3 Results for hand hygiene studies, showing bacteria

(cfu counts) on finger tips and on finger tips + webs before and after drying hands using different methods.

Drying method (N = no. of subjects) (F = finger tips, W = webs)	Mean (\pm SD) prewash cfu count	Mean (\pm SD) cfu count after drying	Mean percentage change ¹
PAPER TOWELS (N = 22)	F	45 \pm 43	- 42%
	W	24 \pm 22	+ 129%
COTTON TOWELS (N = 23)	F	30 \pm 19	- 10%
	W	33 \pm 33	+ 154%
HOT AIR DRIER ² (N = 21)	F	28 \pm 26	+ 504%
	W	52 \pm 42	+ 331%

Note; ¹ all differences significant at P>0.1, except for cfu's for finger tips with cotton towels

² Hot air drier Model HD1/T, Wandsworth Bunnie, average cycle length 30 seconds, air temperature 55°C at hand height

CONCLUSIONS; HAND HYGIENE

- 3.1 Results show that paper towels are effective, more so than cotton towels, in reducing bacterial counts on the hands after normal washing and drying.
- 3.2 Towels remove bacteria during drying. This would agree with the observations of Blackmore (1989) that cfu's on towels were very low before use but increased markedly after drying, especially on paper towels.
- 3.3 In contrast, using hot air driers markedly increases bacterial counts on the hands.
- 3.2 With regards to finger tips rubbed between the webs of the other hand, each method showed an increase in average cfu. This might be expected because people do not commonly rub and dry vigorously between the fingers. Such bacteria would be less easily transmitted than those on the finger tips. However, the smallest increases were seen when using paper towels. This is probably because it is easier to apply such towels between the fingers.
- 3.3 In contrast, the average increase in counts using hot air was about twice that obtained using towels. This is probably because of the lack of removal of bacteria by friction. Contamination by the air stream from the drier and the warm moist conditions engendered between the fingers are other potential causes.

4. ENVIRONMENTAL CONTAMINATION AND HYGIENE

Hot air driers could become internally contaminated with bacteria after prolonged use. They could also circulate dead cells and bacteria in warm moist air streams during drying, depositing them on hands and clothes. With paper and continuous cotton, any bacteria rubbed off would be expected to adhere to the towels and be disposed of or washed away during laundering.

To test these possibilities, agar plates were exposed next to the hands whilst using each drying method. Other plates were exposed below the hands at waist height to assess any contamination of the body and general environment during drying. For hot air driers, hands were held in the normal position, some 10 to 15cm below the nozzle. The appropriate average drying times determined in the earlier studies were used.

To check for general background levels of bacteria in room air, control plates were exposed at hand height in the normal hand drying positions for the appropriate standard times but when no-one was drying their hands. Control plates for hot air driers were also exposed for the standard drying time whilst the driers were operating and some when they were switched off.

All measurements were made in public facilities but only experimenters and subjects were allowed in during experiments to minimise disturbance and variations in background bacterial levels.

Results are shown in Table 4 overleaf.

Table 4 Results for environmental studies, showing bacteria (mean cfu counts \pm SD) on plates exposed for standard drying times next to the hands and at waist

height. Control plates were exposed at hand height for the same lengths of time, one set being exposed when hot air driers were switched on and another when they were not working.

Drying method (N = number of subjects)	Average cfu count at hand height	Average cfu count at waist height	Average cfu count for control plates
PAPER TOWELS (N = 20)	37 ± 56	32 ± 47	2 ± 2
COTTON TOWELS (N = 20)	25 ± 22	11 ± 16	6 ± 5
HOT AIR DRIER ¹ (N = 20)	166 ± 122	51 ± 38	Drier ON 117 ± 100 Drier OFF 4 ± 4

Note; ¹ Hot air drier Model HD1/T, Wandsworth Bunnie, average cycle length 30 seconds, air temperature 55°C at hand height

CONCLUSIONS; ENVIRONMENTAL STUDIES

- 4.1 Background control counts were low but counts increased significantly ($P > .01$) on plates held near hands and at waist height during drying with each method.
- 4.2 Average values for paper towels were slightly higher than those for cotton cabinet towels but the differences were not statistically significant. There is probably some shedding of skin cells and bacteria, together with contaminated towel fibres.
- 4.3 Counts at hand level obtained for hot air drying were four to six times those for towels. Counts at waist height were also up to five times higher.
- 4.4 The average control count at hand height when the hot air drier was switched on was not much smaller than when drying hands. This shows that hot air driers can release and circulate bacteria whenever they are running. Blackmore (1989) found relatively high levels of bacterial contamination on the inner surface of the nozzles of driers in public facilities. Subsequent dispersal and recirculation would help explain hand contamination after drying (Table 3).
- 4.5 The waist height plate counts also imply that some general contamination of the environment and of people in the vicinity of hot air driers can occur. Counts were, however, fairly low, implying effects are localised to just under the nozzle.

5. DISCUSSION AND CONCLUSIONS

DRYING BEHAVIOUR AND EFFICIENCY

- 5.1 The majority of men and women dry their hands efficiently using disposable paper or continuous cotton cabinet towels within 8-12 seconds.
- 5.2 The majority of people are too impatient to use hot air driers for long enough to ensure adequate dryness. Even with a drying cycle set to last 30 seconds, men on average leave after about 20 seconds (55% dryness achieved), women after about 25 seconds (68% dryness achieved).
- 5.3 Many more people (about 40% in total) using hot air driers subsequently wipe their hands dry on clothes, hair, etc. and many women use make-up or rearrange their hair. These actions can spread bacteria from incompletely dried and/or contaminated hands.

HYGIENE OF DIFFERENT DRYING METHODS

- 5.4 Microbiological studies show that bacteria are removed from the hands efficiently by normal washing with soap and drying with towels. Some residual bacteria are left between the webs of the fingers, slightly more on average with cotton towels compared to paper towels. This is possibly due to the greater ease of drying between the fingers when using paper towels. Blackmore (1989) found that cfu's on towels were very low before use but increased markedly after removing bacteria during drying. Paper towels were particularly effective in this respect.
- 5.6 In contrast, bacterial counts on the hands increase after standard washing and hot air drying times (by 500% on finger tips and 320% between the fingers on average). This is probably due to two main factors, (i) the lack of abrasion and removal of bacteria and (ii) the emission and recirculation of bacteria in air streams from contaminated driers.
- 5.7 The tendency for users of hot air driers to finish drying contaminated hands on clothes, etc. could increase chances of bacterial transmission and cross-infection.
- 5.8 Some bacteria are released into the environment near to the hands when using towels, probably attached to abraded dead skin cells and/or towel fibres.
- 5.9 In comparison, much larger bacterial numbers are

deposited by the air stream at hand height below hot air driers. Counts are also high even when hands are not being dried. This could be explained by internal contamination of driers and circulation of bacteria. This would also help to explain the relatively high levels of contamination of the hands after normal washing and drying.

- 5.10 The continuous release of bacteria even when hot air driers are running but not in use would increase general environmental contamination.
- 5.11 These conclusions about the hygiene of hot air driers are in broad agreement with those of Blackmore (1989). Furthermore, her studies of 48 driers in public washrooms revealed bacterial contamination of the nozzles, helping to explain the increases in cfu counts observed.
- 5.12 A number of other studies contradict the present findings and claim little difference in hygiene between hand drying methods. This is probably mainly due to differences in methodology which didn't take into account normal washing and drying habits and conditions. For example, Davis *et al.* (1969) used an unusually rigorous and long (31 seconds) washing protocol. Furthermore, drying involved using a paper towel for 8 seconds before finishing under hot air for 9 seconds. Matthews & Newsom (1987) also used a relatively long wash time (1 minute) and drying time (usually 1 minute). More importantly, the driers used were mounted for experiments in a room or cabinet supplied with microbiologically-filtered air. They therefore had little opportunity to become contaminated by bacteria through the normal usage expected in public facilities. Meers & Leong (1989) also used an experimental drier. Furthermore, they sampled air a relatively long way (60cm) from the nozzle, *i.e.* nearer to waist height rather than at the normal hand drying distance. It is therefore not surprising that they obtained relatively low counts.
- 5.13 A further concern arising from this study is the facility of many hot air driers for directing air onto the face. If they increase aerial contamination as suggested above, bacteria could not only be deposited on the face but could also be inhaled, increasing possible risks of infection.

REFERENCES

- Blackmore, M.A. (1989). A comparison of hand drying methods. *Catering & Health* **1**, 189-198.
- Davis, J.G., Blake, J.R., White, D.J. & Woodall, C.M. (1969). The types and numbers of bacteria left on hands after normal washing and drying by various methods. *The Medical Officer* Oct.1969, 235-238
- Matthews, J.A. & Newsom, S.W.B. (1987). Hot air driers compared with paper towels for potential spread of airborne bacteria. *J. Hospital Infection* **9**, 85-88.
- Meers, P.D. & Yeo, G.A. (1978). Shedding of bacteria and skin squames after hand washing. *J. Hygiene, Cambridge* **81**, 99
- Meers, P.D. & Leong, K.Y. (1989). Hot-air hand dryers. *J. Hospital Infection* **14**, 169-171.
- Mendes, M.F. & Lynch, D.J. (1976). A bacteriological survey of washrooms and toilets. *J. Hygiene, Cambridge* **76**, 183-190.
- Sanderson, P.J. & Weissler, S. (1992). Recovery of coliforms from the hands of nurses and patients; activities leading to contamination. *J. Hospital Infection* **21**, 85-93.