HAND DRYING: A STUDY OF BACTERIAL TYPES ASSOCIATED WITH DIFFERENT HAND DRYING METHODS AND WITH HOT AIR DRIERS

CONTENTS

HAND DRYING: A STUDY OF BACTERIAL TYPES ASSOCIATED WITH DIFFERENT HAND DRYING METHODS AND WITH HOT AIR DRIERS

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SUMMARY

A study of the bacterial numbers and types on subjects' finger tips before washing and drying and after washing and drying using three different drying methods (paper towels, cotton towels and hot air driers) was carried out. The results showed that both paper and cotton towels reduce the numbers of most types of bacteria monitored. Hot air driers increased by significant amounts the numbers of all the types of bacteria monitored in this study.

The types of bacteria identified included intestinal and skin organisms. Some were relatively harmless commensals of the skin and intestine (indicators of faecal contamination) whilst others were potential pathogens.

In a second study counts were made of the numbers of bacteria isolated from the air flow, nozzle and air inlet of hot air driers in various locations including hospitals, railway stations, public houses, clubs, colleges, shops, and eating places.

Some of these bacteria were faecal in origin, some skin commensals and some potential pathogens.

Due to the widespread contamination of hot air driers by bacteria, some of which are potential pathogens, their use should be carefully considered particularly in areas such as hospitals and catering establishments where hygiene is especially important.

INTRODUCTION

A previous study carried out by the Applied Ecology Research Group of the University of Westminster for the Association of Makers of Soft Tissue Papers (Knights et al., 1993), had shown that hot air driers substantially increase the number of bacteria on the hands. Compared to the number present on subjects' hands before washing and drying, the mean percentage increase after using a hot air drier was found to be 504% for finger tips and 331% for webs.

Paper towels and continuous cotton towels were shown to reduce the mean number of bacteria on fingertips by 42% and 10% respectively. Both types of towel produced a mean increase in bacteria from webs (129% for paper and 154% for cotton). This was thought to be due to the fact that most people do not dry this area of the hands as thoroughly as the finger tips and removal of bacteria by friction was not so pronounced.

Another study by Blackmore (1989) had also shown that hot air driers increase the number of bacteria that can be isolated from the finger tips after drying. She also recorded decreases in the bacterial numbers on finger tips when paper towels and continuous cotton towels were used for hand drying. In addition she isolated and counted bacteria blown out in the air from hot air driers and present inside the nozzle.

However, neither of the studies mentioned above made any attempt to identify the types of bacteria present on hands before and after washing and drying or those isolated from hot air driers. Therefore, the present study was begun in an attempt to not only count the numbers of bacteria present on hands before and after washing and drying but also to identify some of the types isolated. Likewise, it was hoped that some of the bacteria isolated from hot air driers could be identified and their significance appraised.

Study 1: A study of bacterial types and relative numbers on hands using wash-dry protocols as in previous survey of efficiency and hygiene.

Two previous studies (Blackmore, 1989; Knight et al., 1993) used the 'finger pad' method to assess changes in the number of bacteria present on the hands before and after washing and drying. Both of these studies compared the use of paper towels, continuous cotton towels and hot air driers for hand drying and found that towels decrease the numbers of bacteria on finger tips whereas hot air driers increase them. The method involves pressing the finger tips onto nutritive agar plates, growing any transferred bacteria at 37°C overnight and then counting the number of colonies (colony-forming units [cfu's]) present. The method is relatively quick, and accurate enough for this type of study (Sanderson & Weissler, 1992).

Using the same protocol as in the previous study carried out by the University of Westminster (Knights et al., 1993), volunteers (approximately equal numbers of men and women) were asked to use the toilet and then press the finger tips of their dominant hand onto three different types of growth medium in turn. The volunteers were then asked to wash their hands (using a bar of ordinary white hand soap) for 10-12 seconds and dry them using one of the following methods and times:

Paper towel (Dixcel Professional):

10 seconds (both sexes)

Cotton towel (supplied by Initial Towelcare Services):

10 seconds (both sexes)

Hot air drier (Wandsworth Bunnie, Model HD1/T):

20 seconds (men)
25 seconds (women)

Volunteers were then asked to press the finger tips of the same hand onto fresh plates of the same three growth media in turn.

New paper towels and clean sections of cotton towel were used for each test.

The times used for washing and drying the hands were those shown by the previous study (Knights et al., 1993) to be the averages for men and women using the three different drying methods under 'normal', ie. non-laboratory conditions.
This protocol was chosen in an attempt to reproduce people's usual hand washing and drying practices as closely as possible.

The growth media used in turn were:

1. Nutrient Agar (Oxoid)

   A non-selective, general purpose growth medium which would be expected to grow most non-fastidious types of bacteria.

2. MacConkey Agar (Oxoid)

   A differential growth medium used for the detection, isolation and enumeration of coliforms and intestinal pathogens. It is able to support the growth of pathogenic, Gram-positive cocci (eg. staphylococci and enterococci) as well as Enterobacteriaceae (Gram-negative, fermentative rods). Potential pathogens may be presumptively identified on this medium by their colonial appearance but further tests are required for confirmation. Lactose fermenters (LF's) produce pink or red colonies due to acid production from lactose, eg. relatively harmless, commensal coliform enterobacteriaceae. Non-lactose fermenters (NLF's) produce colourless colonies, eg. pathogenic enterobacteriaceae - salmonellas and shigellas (causes of food poisoning and dysentery).

3. Mannitol Salt Agar (Oxoid)

   A selective growth medium used for the isolation of presumptive pathogenic staphylococci. Most other bacteria are inhibited by the high salt content. Presumptive pathogenic, coagulase-positive staphylococci produce colonies surrounded by yellow zones (due to acid production from mannitol) whilst non-pathogenic staphylococci produce colonies with reddish purple zones. Confirmation of coagulase activity can be carried out by subculture in a medium not containing excess salt followed by the coagulase test using rabbit plasma.

Using these three media it was hoped to enumerate most of the types of bacteria present on subjects' hands before and after washing and drying. In addition, it was also hoped that information would be obtained about the incidence of the following types of bacteria:

1. Lactose fermenters (LF's)

   These were differentiated on MacConkey agar and include coliform bacteria such as *Escherichia coli* (*E. coli*). These are generally normal commensal inhabitants of the human gut and not pathogenic (although this does depend on the serotype and location in the body). However, such coliforms can serve as useful indicators of faecal contamination. In other words, if coliforms such as *Escherichia coli* are detected in a specimen, then there is a potential for more dangerous pathogenic enteric bacteria to be present as well.

   Some types of staphylococci and micrococci found on the skin are also lactose fermenters.

2. Non-lactose fermenters (NLF's)

These potential food poisoning and dysentery pathogens were differentiated on MacConkey agar and selected colonies Gram stained and examined under the microscope. Any Gram negative rods found were then further tested using the catalase and oxidase tests. If the results showed Gram negative rods, catalase positive, oxidase negative, then identification was attempted using Analytical Profile Index (API) 20E strips.

Gram staining and examination also served to identify non-lactose fermenting staphylococci and micrococci present as they are easily distinguishable from enterobacteriaceae by being Gram positive and spherical in shape.

3. Mannitol-negative staphylococci and micrococci

These were differentiated on mannitol salt agar and are normal commensal inhabitants of human skin and nostrils. They are not usually pathogenic. No further tests were performed on this type although any changes in number before and after washing and drying helped to assess the efficacy of the hand drying method.

4. Mannitol-positive staphylococci

These were differentiated on mannitol salt agar by the production of yellow zones around colonies. Selected colonies of this type were tested further using Gram staining and examination under the microscope. Any Gram positive cocci found were tested for coagulase activity by observing the clotting of rabbit plasma (coagulase slide test).

Positive coagulase activity indicates *Staphylococcus aureus*. This organism can be found on the skin and in the nostrils of healthy people but it is a potential pathogen causing a toxigenic food poisoning, abscesses, boils and other problems. However, pathogenicity and antibiotic resistance vary greatly between different strains. Its presence on the hands of a worker in the food industry or medical field should be taken seriously as should any increase in its numbers caused by particular hand drying methods.

The results of Study 1 are shown in Tables 1 and 2 and Figures 1 - 3 overleaf.

Table 1 Results for three different growth media showing bacterial numbers (colony-forming unit counts) and types on finger tips as sampled before washing and after drying hands using three different drying methods (paper towel, cotton towel and hot-air drier).

MEDIUM	COLONY TYPE	HAND DRYING METHOD	MEAN (" SD) BEFORE WASH CFU COUNT	MEAN (" SD) AFTER DRY CFU COUNT	MEAN CHANGE (%)
NA	*ALL*	*PAPER*	*84 (" 27)*	*35 (" 7)*	*- 58* [2]
NA	ALL	COTTON	97 (" 24)	53 (" 17)	- 45 [1]
NA	**ALL**	**DRIER**	**83 (" 26)**	**295 (" 47)**	**+ 255** [4]
MAC	*LFs*	*PAPER*	*44 (" 14)*	*32 (" 12)*	*- 27*
MAC	LFs	COTTON	73 (" 18)	45 (" 15)	- 38
MAC	**LFs**	**DRIER**	**40 (" 11)**	**198 (" 42)**	**+ 395** [4]
MAC	*NLFs*	*PAPER*	*7 (" 2)*	*14 (" 6)*	*+ 100*
MAC	NLFs	COTTON	11 (" 2)	7 (" 2)	- 36 [1]
MAC	**NLFs**	**DRIER**	**9 (" 3)**	**70 (" 22)**	**+ 678** [3]
MAC	*ALL*	*PAPER*	*59 (" 17)*	*46 (" 13)*	*- 22*
MAC	ALL	COTTON	84 (" 18)	52 (" 15)	- 38 [1]
MAC	**ALL**	**DRIER**	**50 (" 13)**	**269 (" 44)**	**+ 438** [4]
MSA	*MAN -*	*PAPER*	*40 (" 14)*	*17 (" 4)*	*- 58* [1]
MSA	MAN -	COTTON	71 (" 18)	52 (" 18)	- 27
MSA	**MAN -**	**DRIER**	**30 (" 8)**	**92 (" 21)**	**+ 207** [3]
MSA	*MAN +*	*PAPER*	*14 (" 5)*	*30 (" 13)*	*+ 114*
MSA	MAN +	COTTON	18 (" 4)	19 (" 7)	+ 6
MSA	**MAN +**	**DRIER**	**57 (" 35)**	**143 (" 40)**	**+ 151** [1]
MSA	*ALL*	*PAPER*	*53 (" 15)*	*46 (" 14)*	*- 13*
MSA	ALL	COTTON	89 (" 22)	75 (" 23)	- 16
MSA	**ALL**	**DRIER**	**88 (" 36)**	**237 (" 40)**	**+ 169** [3]

Key: CFU = colony-forming unit, NA = nutrient agar, MAC = MacConkey agar, MSA = mannitol salt agar.

ALL = total number of cfu's (all types of colony), LFs = lactose fermenters, NLFs = non lactose fermenters, MAN - = acid from mannitol negative, MAN + = acid from mannitol positive. Mean % change: + = increase, - = decrease in cfu's.

Number of subjects (N) = 24 (PAPER TOWELS), 25 (COTTON TOWELS), 26 (HOT-AIR DRIERS)

Difference between before wash/dry and after dry counts significant at:

[1] $p>0.2$, [2] $p>0.1$, [3] $p>0.01$, [4] $p>0.001$

Table 2: Summary of mean percentage change in different bacterial types before and after wash/dry.

MEDIUM	COLONY TYPE	PAPER TOWEL	COTTON TOWEL	HOT-AIR DRIER
NA	ALL	- 58 9	- 45 9	+ 255 8
MAC	LFs	- 27 9 *	- 38 9 *	+ 395 8
MAC	NLFs	+ 100 8 *	- 36 9	+ 678 8
MAC	ALL	- 22 9 *	- 38 9	+ 438 8
MSA	MAN -	- 58 9	- 27 9 *	+ 207 8
MSA	MAN +	+ 114 8 *	+ 6 8 *	+ 151 8
MSA	ALL	- 13 9 *	- 16 9 *	+ 169 8
ALL THREE	ALL	- 35 9	- 34 9	+ 264 8

Key: NA = nutrient agar, MAC = MacConkey agar, MSA = mannitol salt agar.

ALL = total number of cfu's (all types of colony), LFs = lactose fermenters, NLFs = non lactose fermenters, MAN - = acid from mannitol negative, MAN + = acid from mannitol positive.

8 = increase in cfu count after wash/dry
9 = decrease in cfu count after wash/dry

* = change not significant at the limit of probability used ($p>0.2$). All other changes are significant at this limit or greater.

The data in the above Table are presented graphically in Figure 1 overleaf.

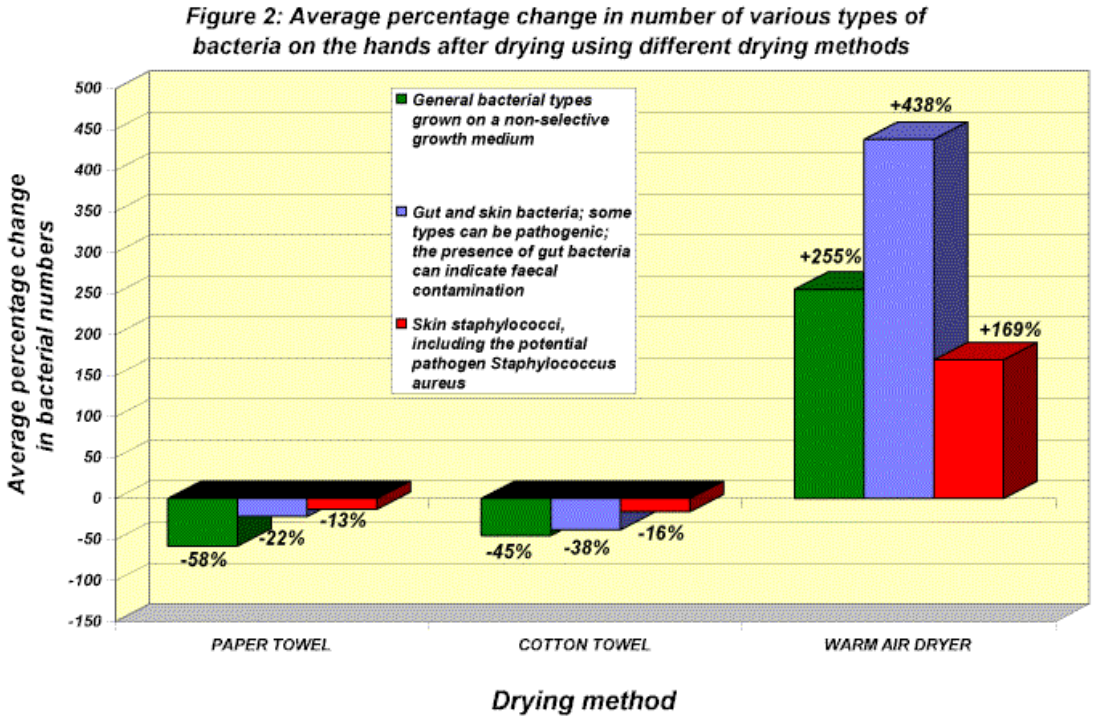

Figure 1 Showing the mean percentage change in all types of colony-forming unit isolated from hands on three different growth media before and after washing and drying using different drying methods.

Key: CFU = colony-forming unit.
NA = nutrient agar, MAC = MacConkey agar,
MSA = mannitol salt agar.

ALL = total number of cfu's (all types of colony),
LFs = lactose fermenters, NLFs = non lactose fermenters,
MAN - = acid from mannitol negative,
MAN + = acid from mannitol positive.

COMMENTS

Potentially pathogenic coagulase-positive staphylococci were identified from over 50% (21/40) of MSA plates showing mannitol-positive colonies. No enteric pathogens were identified using API 20E strips from any of the samples used in Study 1. Most of the non-lactose fermenting bacteria isolated on MacConkey agar were Gram positive cocci (staphylococci and micrococci). Other bacteria identified as being present on the hands after washing and drying included *Bacillus* species (often found as contaminants in various samples but not usually pathogenic) and *Proteus* species (the source of these is often the gut so, like *Escherichia coli*, they can serve as indicators of faecal contamination).
There was no demonstrable correlation between the types of bacteria identified on the hands and the method of hand drying.

CONCLUSIONS

1.1 Results of Study 1 show that the numbers of most types of bacteria decrease after hand washing followed by drying using paper towels or cotton towels. Decreases were observed for the total number of bacteria growing on all three growth media using paper and cotton towels for hand drying. Some of these decreases were significant at the limits of probability used.

1.2 Increases in all types of bacteria on all three growth media were observed when hot air driers were used. All of these increases were significant at the limits of probability used. Therefore, hot air driers significantly increase the numbers of all types of bacteria on the finger tips monitored in this study. This is possibly due to the warm, moist conditions produced on the hands by hot air driers and/or lack of removal of bacteria by friction as occurs with towels. Another possible explanation is the addition of bacteria to the hands from the contaminated air flow emanating from most hot air driers (see Study 2). Further work is required to establish which of these possibilities is the most likely.

1.3 The increase in the number of non-lactose fermenting bacteria isolated on MacConkey agar after using paper towels was not significant at the limits of probability used. This type of colony was found to be mainly Gram-positive cocci which were also isolated on mannitol salt agar. Non-lactose fermenting bacteria are less numerous than lactose fermenting bacteria on the hands before washing so the reduction in the latter is probably more pertinent.
Also, increases in the number of mannitol-positive staphylococci observed after washing and drying with both paper and cotton towels were not significant at the limits of probability used.

1.4 Towels remove most types of bacteria during drying. This agrees with the observations of Blackmore (1989) that bacterial numbers on towels were very low before use but markedly increased after being used for hand drying. This was especially true for paper towels.

1.5 The most significant decrease ($p > 0.1$) in bacterial numbers after washing and drying was obtained for bacteria growing on nutrient agar after paper towels had been used.

1.6 The failure to identify any enteric pathogens from the MacConkey plates in Study 1 is not surprising as this would require the subject to be infected with such, be a carrier or be contaminated by matter from another person who was infected. Most of the non-lactose fermenting bacteria isolated on MacConkey agar were identified as Gram positive cocci and, therefore, probably skin organisms (which could be further differentiated on mannitol salt agar).

1.7 Although there was no obvious correlation between the types of bacteria identified on the hands of subjects and the hand drying method used it should be noted that in all cases hot air driers increased the numbers of all types of bacteria (including pathogenic types) whereas towels reduced the numbers of most types of bacteria. Without further work it is impossible to say if hot air driers add to the bacterial flora of the hands significantly. They may simply increase the numbers of all types of bacteria already present on the hands. (However, Study 2 shows that bacteria are blown out from hot air driers and so contamination of the hands by bacteria not previously present is possible.)

Study 2: A study of bacterial types and relative numbers in air currents from selected hot air driers and contamination in nozzles.

Blackmore (1989) isolated numbers of bacteria from the air flow and outlet nozzles of hot air driers. For air flow sampling she used nutrient agar plates held 6 inches from the nozzle for one cycle of the drier. Nozzles were sampled using a moist swab rubbed over the inside of the nozzle followed by transport and dilution in 10 ml of ¾ st. Ringers solution. 1 ml of the Ringers was then used to inoculate molten nutrient agar for the preparation of pour plates. The numbers of colony-forming units blown out in the air flow and also transferred to the swab from the nozzle were counted but no attempt was made to identify the bacterial types.

It was decided that for the present study a similar protocol would be used to sample hot air driers from various locations in the central London area. However, different growth media, including some selective types, were used and samples also taken from the air inlets of hot air driers. The type and model of hot air drier was noted and also its cycle time (a minority of driers are automatic and operate as long as the hands are in position).

Plates of five different growth media were in turn held 6 inches away from the nozzles of hot air driers and their lids removed for 25 seconds. The distance and time used were chosen because they reflect the average behaviour of persons using hot air driers under 'real' conditions (Knights et al., 1993). Control plates of nutrient agar were exposed to air in the same locations as the driers and for the same standard time as the flow sample plates.

Sterile swabs were moistened in ¾ st. Ringers solution and used to sample the inside of nozzles and the air inlet of hot air driers by wiping them over the surfaces. Using gloves, the ends of the swabs were transferred to 10 ml of Ringers solution and vortexed to release bacteria adhering to the cotton wool of the swab. 1 ml aliquots were then transferred to the surface of plates of the five different growth media and spread using a sterile glass spreader. All plates were incubated at 37EC and examined after 1 and 2 days.

The growth media used were as follows:

1. Nutrient agar (Oxoid)

   As used in Study 1. NA is a general purpose growth medium.

2. MacConkey agar (Oxoid)

   Also used in Study 1. Used for the isolation and enumeration of coliforms and intestinal pathogens. Staphylococci and micrococci form the skin will also grow on this medium. Lactose fermenters (LF's) can be distinguished from non-lactose fermenters (NLF's) by the colour of the colony.

3. Desoxycholate Citrate Agar (Hynes) (Oxoid)

   A selective medium used for the isolation of salmonellas (a major cause of food poisoning) and shigellas (a cause of dysentery) which can be distinguished by their

colonial differences (salmonellas usually produce colonies with a central grey or black dot). Most strains of *Escherichia coli* will not grow on this medium.

4. XLD Medium (Difco)

Used for the isolation and identification of salmonellas and shigellas which produce red colonies. Coliforms and some other types of enteric bacteria are inhibited by this medium but may still produce yellow colonies.

5. Mannitol salt agar (Oxoid)

As used in Study 1. Will support the growth of staphylococci and micrococci from the skin and distinguish potentially pathogenic types by the production of yellow zones around colonies due to acid production from mannitol.

Attempts at identifying the bacteria isolated from hot air driers were concentrated on colonies derived from air flow samples.

Colonies growing on DCA or XLD medium were further tested by Gram staining and examination under the microscope. If this showed the presence of Gram negative rods, then the catalase and oxidase tests were performed. If the bacteria were catalase positive, oxidase negative, an API 20E identification strip was set up and incubated in an attempt to identify any enterobacteriaceae present. Selected colonies on the MacConkey agar plates were also treated in the same way and API 20E strips used where appropriate.

The results of Study 2 are shown in Tables 3 - 6 overleaf.

Table 3 Results of mean colony-forming unit counts on five different growth media for plates exposed to the air flow of hot air driers for 25 seconds (cfu's per plate), and for swabs used to sample the nozzles and air inlets of hot air driers (cfu's per swab).

MEDIUM	COLONY TYPE	MEAN CFU COUNT (" SD) FLOW	N	MEAN CFU COUNT (" SD) NOZZLE	N	MEAN CFU COUNT (" SD) INLET	N
NA	ALL	153 (" 32)	23	540 (" 120)	21	1980 (" 430)	21
MAC	LFs	58 (" 10)	32	120 (" 20)	30	190 (" 30)	28
MAC	NLFs	19 (" 3)	32	20 (" 10)	30	100 (" 20)	28
MAC	ALL	77 (" 13)	32	140 (" 30)	30	290 (" 50)	28
DCA	-	38 (" 8)	23	1270 (" 260)	23	170 (" 40)	23
DCA	+	0	23	0	23	0	23
DCA	ALL	38 (" 8)	23	1270 (" 260)	23	170 (" 40)	23
XLD	YELLOW	0	23	0 **	23	0	23
XLD	RED	0 *	23	10 (" 0)	23	180 (" 40)	23
XLD	ALL	0 *	23	10 (" 0)	23	180 (" 40)	23
MSA	MAN -	41 (" 8)	23	100 (" 20)	23	370 (" 80)	23
MSA	MAN +	27 (" 6)	23	250 (" 50)	23	310 (" 60)	23
MSA	ALL	68 (" 14)	23	350 (" 70)	23	680 (" 140)	23
RANGES FOR CFU COUNTS ON NA		6 - 1016		0 - 6980		0 - 6970	
MEAN COUNT FOR NA CONTROL PLATES WITH DRIER OFF		4 (" 5)					

* 1 colony found, ** 3 colonies found (means are calculated to nearest whole number)

Key: CFU = colony-forming unit, N = number of driers sampled.

ALL = all types of colony.
NA = nutrient agar, MAC = MacConkey agar, DCA = desoxycholate citrate agar,
XLD = XLD medium, MSA = mannitol salt agar.

LFs = lactose fermenters, NLFs = non-lactose fermenters,
DCA -/+ = colonies not having/having the appearance of salmonellas or shigellas,
XLD YELLOW = yellow colonies (includes coliforms),
XLD RED = possible salmonella or shigella colonies.

Table 4 Table showing the types of location of toilets and number of driers sampled.

# LOCATIONS	NUMBER OF DRIERS SAMPLED
1. FAST FOOD OUTLETS & BURGER BARS	8
2. UNIVERSITIES & COLLEGES	7
3. HOSPITALS & CLINICS	5
4. RAILWAY STATIONS	5
5. DEPARTMENT STORES	3
6. PUBLIC HOUSES & BARS	3
7. SPORTS CLUBS	2
8. SUPERMARKET	1
9. THEATRE	1
TOTAL NUMBER OF DRIERS SAMPLED	35

Table 5 Table showing the identifications of some of the bacteria isolated from the air flows of hot air driers and the types of location.

IDENTIFICATION	TYPES OF LOCATION OF HOT AIR DRIER	N
Staphylococcus aureus	1 - 9	22
Other staphylococci and micrococci	1 - 9	21
Bacillus species	1, 4, 5	5
Enterobacteriaceae (inhabitants of human gut):		
Citrobacter freundii	1	1
Serratia species	2	1
Enterobacter species	2, 6	2
Proteus species	1 - 5, 7, 8	16
Hafnia alvei	6	1
Yersinia species	1	1
Aeromonas salmonicida	1, 2	2

N = number of isolates identified.

Table 6

MEAN CYCLE TIME (N = 29)	37 seconds
RANGE	25 - 60 seconds

6 of the driers in the study were automatic and operated as long as hands were held beneath them.

CONCLUSIONS

2.1 Bacteria were isolated from the air flows of all 35 hot air driers sampled and from swabs used to sample the air inlets. Swabs from the nozzles of hot air driers produced bacterial growth for all but one of the driers sampled.

2.2 The mean numbers of bacteria isolated on nutrient agar from the air flow of hot air driers in this study were very close to the results obtained in a previous study carried out by the University of Westminster (Knights et al., 1993). Control plate counts were also similar to this previous study. However, air flow counts and counts from the nozzles of hot air driers were higher in this study than those found by Blackmore (1989). This may be explained by differences in the frequency of use of hot air driers depending on their location. This study sampled 35 driers from toilets in the central London area. Most of the locations chosen (eg. mainline railway stations, public houses, department stores) would have a high frequency of use. There was some indication in this study that, as might be expected, bacteria were isolated in greater numbers from hot air driers in busy locations than from ones having light use but more work would have to be done to establish this.

2.3 The bacteria most frequently isolated from hot air driers in this study were those commonly found on human skin and hair, ie. staphylococci and micrococci. These types of bacteria were isolated from all 35 hot air driers sampled but particularly from air flows. All but one of the driers blew out staphylococci which produced colonies with yellow zones on mannitol salt agar (indicating acid production from mannitol). This character indicates the presence of coagulase-positive staphylococci (*Staphylococcus aureus*) - a potential pathogen which can cause toxigenic food poisoning, boils, abscesses, and other problems. Antibiotic resistant strains of this organism can be a serious hazard in the hospital environment. Mannitol-positive, Gram-positive cocci were detected in the air flows of hot air driers in 4 out of 5 of the hospitals sampled in this study. However, due to time constraints confirmation of identity using the coagulase test was not carried out, nor was antibiotic resistance tested. Nevertheless it is a cause of concern that *Staphylococcus aureus* may be blown out in the air flow from hot air driers leading to possible contamination of the hands and inhalation of the bacteria, especially as the organism is a cause of broncho-pneumonia.

2.4 The *Bacillus* species isolated from 5 of the hot air driers sampled in this study almost

certainly have no significance with respect to human health. *Bacillus* species are commonly found in soil and the general environment. They are common air-borne contaminants of agar plates. There are only two pathogens in this group (one causing anthrax and the other a toxigenic food poisoning) but they are unlikely to have been isolated from the locations sampled in this study.
The highest incidence of these bacteria was recorded with nozzle and air inlet samples.

2.5 Enterobacteriaceae were isolated from the air flows of 22 of the 35 driers sampled. The most frequent group found was *Proteus* species which occurred in 16 of the driers sampled and in 7 out of 9 of the types off location sampled.
Enterobacteriaceae are inhabitants of the human and animal gut but can also be found in water and other samples where they may indicate faecal contamination. However, their presence in the air flow from hot air driers situated in toilets does suggest that their source is probably faecal matter from persons previously using hot air driers. The detection of their presence in the air flow from hot air driers is another cause for concern as it indicates the potential for hot air driers to disseminate other more pathogenic types of enterobacteriaceae (eg. salmonellas and shigellas).

2.6 *Aeromonas salmonicida* was isolated from the air flow of 2 hot air driers from 2 different locations. This organism is a pathogen of fish but presents little threat to human health.

2.7 In addition to contaminated air flows, the nozzles and air inlets of most hot air driers sampled showed considerable bacterial contamination. In many cases it was obvious to the eye that nozzles and air inlets were very dirty and had not been cleaned recently.

2.8 In summary, Study 2 showed that the main causes of concern in the use of hot air driers in public toilets were that pathogenic staphylococci and faecal bacteria may be blown out in the air flow leading to possible contamination of the hands and inhalation of microorganisms. Both types of microorganism present a risk to human health.

3 DISCUSSION AND CONCLUSIONS

3.1 There are conflicting reports on the hygiene of hot air driers for hand drying. The results of Blackmore (1989) and Knights et al. (1993) support the hypothesis that hot air driers significantly increase the levels of bacteria on the hands. However, the results of Davis et al. (1969), Matthews & Newsom (1987) and Meers and Leong (1989) show the reverse. The different methodologies employed may explain some of these differences. In this study and the previous one undertaken by the University of Westminster (Knights et al., 1993) conditions of sampling were used that reproduced the normal use of hot air driers as closely as possible, eg. times of drying used were based on observations of people's normal behaviour and driers were not used in a laboratory situation but in actual toilets. This present study suggests that hot air driers do increase the numbers of all types of bacteria (including pathogenic types) on the hands.

3.2 Paper towels and continuous cotton towels reduce the numbers of most types of bacteria on the hands. Increases were observed with some types of bacteria but were not significant. Towels help remove bacteria partly by producing more efficient drying of the hands under normal conditions of use and partly by removal of dead skin cells (Meers & Yeo, 1978).

3.3 Blackmore (1989) isolated numbers of bacteria from the air flow and nozzles of hot air driers. This study confirms her results and also demonstrates that bacteria can be isolated from the air inlets of driers. The study also shows that some of the types of bacteria blown out from hot air driers are potential pathogens. The main pathogens isolated in this study were staphylococci whose source was probably the skin of previous persons using the drier. Different intestinal bacteria were also isolated from the air flows of hot air driers. These indicate the potential for pathogenic bacteria in faecal matter to be disseminated by hot air driers. Mendes & Lynch (1976) showed in a previous study that levels of pathogenic faecal bacteria can be high on surfaces in washrooms and toilets.

3.4 The two studies suggest that the use of hot air driers for hand drying is not to be recommended for three reasons because:

1. They significantly increase the numbers of bacteria already present on the hands before washing and drying.

2. They may contribute to the bacterial load on the hands and have the potential to add pathogenic types of bacteria.

3. Some of the bacteria blown out from hot air driers are likely to be inhaled.

Paper and cotton towels would appear to be more hygienic than hot air driers and their use should be preferred particularly in locations where hygiene is especially important, eg. hospitals and catering establishments.

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