From the data collected in this study it is clear that paper towels have substantially fewer viable bacteria on them than cloth towels of the continuous type dispensed mechanically. Paper towels are superior to cloth towels both from public health and esthetic standpoints.

A STUDY OF BACTERIAL CONTAMINANTS OF CLOTH AND PAPER TOWELS

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General

HISTORY has credited Semmelweiss[1] with the discovery that hands may be a mode of transmission of pathogenic bacteria. Many studies, some of considerable breadth and depth, have centered around the microbial flora of the skin,[2] of soap,[3] and the role of soap as a transmitting agent of disease-producing microorganisms,[4] as well as the effects of disinfectants as degerming agents of hands.[5] Relatively few investigations have analyzed the part that hand drying agents and processes play in the cause of human disease.

Recent reports from Western Germany and the British Isles have indicated clearly the health hazards associated with communal or roller towels.[6-8] One investigator in London, after a thorough study of the bacterial contamination of cloth hand towels of the individual, continuous, and roller types and of paper towels, concluded that "only paper and efficiently laundered and unused cloth towels can be regarded as hygienically safe beyond doubt" and that "for all practical purposes, paper towels can be regarded as absolutely safe."[9] This report and the supporting data suggest that, while paper and efficiently laundered and unused cloth towels can be regarded as acceptable from the public health viewpoint, they also imply that paper towels are more acceptable than efficiently laundered and unused cloth towels.

These findings pose the following two questions: (1) If paper towels are superior to cloth towels for health and sanitation reasons, should the use of cloth towels be allowed in areas where the hazards of disease transmission are great, as in hospitals, or where the population at risk is large, as in public eating establishments? (2) Are the findings of this microbiologist in London reproducible in the United States?

In an attempt to develop answers to these and other questions, a study was undertaken to collect the required data.

Collection of Data

The study was conducted in two phases. The purpose of the initial phase was to obtain quantitative data of the microbiology of paper and unused cloth towels or so-called "clean towels." It was conducted during the summer of 1966 in two metropolitan areas, with similar climatic conditions, one in the northeast and the other in the north

central areas of the United States. The second phase was conducted during the summer of 1967 and included a continuation of the quantitative data-collecting, but used two metropolitan areas with different climates. The same northeastern metropolitan area was used in the second phase of the study, as in the initial phase, but the second metropolitan area was located in the south where the climate was warm and humid. The purpose of using two different areas, where data were collected in each phase, and the changing of one area in the second phase, was to obtain an evaluation of the magnitude of differing results that might be attributed to geographical or regional differences and to climate.

The sites where samples were collected to determine the microbial population of unused cloth and paper towels were those places readily accessible to, and used extensively by, the public. These were public washroom facilities in gasoline stations, restaurants, airports, bus and railroad stations, and similar establishments. The locations were chosen at random. It was hoped that an equal number of samples from unused cloth and paper towels would be collected. While the numbers of samples of each type of towel are approximately equal, more samples from paper towels were collected because of their apparent greater use and popularity.

To reduce the possibility that the organisms recovered from the towels were transient, i.e., had been deposited by the immediate previous user of the dispenser by an act such as sneezing, and to get a sample that would be representative of the average towel dispensed, the initial paper towel in the container was discarded. Thus, the sample was collected from the second towel. As for the continuous cloth towels, clean portions were withdrawn from the dispenser twice and the sample collected from an area of the second withdrawal. Where the cloth towel was an individual towel, the first one obtained was used to dry the investigator's hands and a second towel was then requested from the attendant. The sample was collected from the second towel.

The procedure of collecting the sample from the second towel dispensed may have yielded results that show less microbial contamination than if collected from the first towel. However, this course of action was deemed necessary to eliminate some of the variables that might otherwise have been introduced. If the sample were collected from the initial towel, it might be possible that the organisms recovered from the towel were inadvertently placed upon the towel by prior use of the towel dispenser. The results of samples collected from the second towel, or second portion of the towel, are deemed to be more representative of the average.

The basic technic of collecting both quantitative and qualitative data employed the use of the Rodac contact plate[9] containing trypticase soy agar (BBL). The use of this device provided data on the number and types of bacteria that are readily removable from cloth and paper towels by contact.

To obtain a sample from a towel for recoverable microorganisms the procedures previously described were employed. Care was taken to handle the towel only by the outer edges and to avoid any contact with the areas from which the samples would be collected. A portion of the towel was wrapped around the back of the left hand of the person collecting the sample and held in a firm position by the fingers. The contact plate was taken by the right hand; then, with a pressure of about one pound, the agar surface was pressed on the towel surface with a slight rocking action to insure good contact of the agar and the towel surfaces. The flat, smooth area of the back of the hand provided good support for the towel. Special caution was exercised not to let

the contact plate slip or slide on the towel surface.

Laboratory Procedures

During the initial phase of the study (the 1966 series of samples), laboratory procedures were limited to incubation of the plates at 35° C for 48 hours. This was followed by counting the number of colonies which had developed on each Rodac plate, using a standard Quebec Colony Counter. All counts were recorded as observed, except that, if the number of colonies exceeded 300, the count was recorded as TNTC (Too Numerous To Count).

For the second phase (the 1967 series of samples), when qualitative evaluations were desired, the procedure was as follows:

Rodac plates following incubation were counted with the aid of a stereomicroscope, using a 10X ocular and low power objective. Each colony was then picked and transferred to a trypticase soy agar slant and incubated. An exception to this procedure was made for those plates containing TNTC colonies. In these cases, a representative number of each morphological type colony was picked and transferred to trypticase soy agar slants. Following incubation, cultures were refrigerated at 4° C until all isolations had been completed.

After all cultures had been received, transplants were made on trypticase soy agar slants. These cultures were used for identification studies. Gram stains were made and tubes of glucose, sucrose, and lactose broth (with 0.04 per cent bromothymol blue indicator) for fermentation tests and trypticase soy broth for catalase and motility tests were inoculated. All cultures were incubated at room temperature and the carbohydrate broths observed for fermentation at 24-hour intervals. All negative tests were held for 14 days before discarding. Catalase was determined by the addition of 1.0 ml of 3 per cent hydrogen peroxide to each tube and observed for the evolution of gas.

To differentiate bacteria of genus Micrococcus from those of genus Staphylococcus the so-called OF (oxidative-fermentation) method of Hugh and Leifson, as recommended by Cowan and Steel,[10] was followed. Those organisms found to be members of the genus Staphylococcus were further cultured on Staphylococcus Medium No. 110 agar (Difco) and tested for mannitol fermentation and gelatin liquefaction. These organisms also were grown on mannitol salt agar (Difco). All cultures that fermented mannitol were tested for coagulase production. Only those organisms which were mannitol-coagulase-positive were considered to be Staph. aureus and all other organisms of this genus were classified as Staph. epidermidis.

Organisms, which on initial staining were gram-positive and were diphtheroid-like rods, were identified as corynebacteria. These organisms were not studied further.

Results

The results of the 1966 and 1967 quantitative tests are presented in Tables 1 and 2 for each of the three areas where samples were collected. Table 1 is a compilation of data for unused paper towels and Table 2 for unused cloth towels. Sixty-five per cent of all samples collected from paper towels, within the three different metropolitan areas, had no microbial growth on Rodac contact plates in contrast to only 28 per cent for cloth towels. None of the results from paper towels showed counts in excess of 100 colonies per Rodac contact plate, but 15 per cent of samples from cloth towels had more than 100 colonies per Rodac contact plate. Seven per cent of the samples from cloth towels had more than 300 colonies per plate.

If the data for each metropolitan area

are compared individually, the results of samples collected from paper towels are consistently lower than for cloth towels. The difference is the least for the north central metropolitan area; nonetheless, the results of samples collected from paper towels in this area are lower than the results of samples from cloth towels.

The results of data of the qualitative analyses of bacteria recovered from paper and cloth towels are presented in Table 3. The most common bacterial contaminants of paper towels were members of the genus Bacillus. Of all samples collected, 21.7 per cent from paper towels had one or more colonies of this genus. Bacteria of the genus Bacillus were also the organisms most frequently isolated on samples from cloth towels; from these samples 37.7 per cent had one or more colonies of this genus. However, unlike samples from paper towels, from which no other organism was isolated in more than 10 per cent of the samples, specimens from cloth towels yielded organisms of the following types and frequency: Staph. epider-

Table 1—Summary tabulation of Rodac contact plate tests collected from unused paper towels within three metropolitan areas, 1966 and 1967

No. of bacterial colonies per Rodac contact plate	Number and per cent of observations made in each metropolitan area						No. and % of all observations made	
	Northeast metropolitan area (1966–1967)		North central metropolitan area (1966)		Southern metropolitan area (1967)			
	No.	%	No.	%	No.	%	No.	%
0	90	67.7	21	52.5	21	72.4	132	65.3
1–9	34	25.6	18	45.0	8	27.6	60	29.7
10–99	9	6.7	1	2.5	0	0.0	10	5.0
100–299	0	0.0	0	0.0	0	0.0	0	0.0
300 and over	0	0.0	0	0.0	0	0.0	0	0.0
Total	133	100.0	40	100.0	29	100.0	202	100.0

Table 2—Summary tabulation of Rodac contact plate tests collected from unused cloth towels within three metropolitan areas, 1966 and 1967

No. of bacterial colonies per Rodac contact plate	Number and per cent of observations made in each metropolitan area						No. and % of all observations made	
	Northeast metropolitan area (1966–1967)		North central metropolitan area (1966)		Southern metropolitan area (1967)			
	No.	%	No.	%	No.	%	No.	%
0	13	26.6	15	37.5	7	25.9	35	28.7
1–9	21	38.2	21	52.5	10	37.1	52	42.6
10–99	11	20.0	4	10.0	1	3.7	16	13.1
100–299	4	7.2	0	0.0	6	22.2	10	8.2
300 and over	6	10.9	0	0.0	3	11.1	9	7.4
Total	55	100.0	40	100.0	27	100.0	122	100.0

Table 3A—A summary tabulation of the number of samples collected from paper and cloth towels by the Rodac contact plate method for each of two metropolitan areas studied with specific types of bacteria identified

Species of bacteria recovered from towels	No. of samples collected from northeastern metropolitan area		No. of samples collected from southern metropolitan area		No. of samples collected from both metropolitan areas	
	Paper towels	Cloth towels	Paper towels	Cloth towels	Paper towels	Cloth towels
Staph. epidermidis	3	7	1	7	4	14
Staph. aureus	0	1	0	1	0	2
Micrococci	2	3	1	5	3	8
Unidentified cocci	1	6	1	3	2	9
Corynebacteria	2	5	0	7	2	12
Unidentified gram negative bacilli	0	0	1	0	1	0
Bacillus (Sp)	10	10	5	13	15	23
Other microorganisms	0	2	1	1	1	3
Number of samples with one or more colonies per Rodac contact plate	15	21	8	20	23	41
Number of samples with no growth on Rodac plates	25	13	21	7	46	20
Total number of samples collected for qualitative analyses	40	34	29	27	69	61

Table 3B—A summary tabulation of the per cent of samples collected from paper and cloth towels by the Rodac contact plate method for each of the two metropolitan areas studied with specific types of bacteria identified

Species of bacteria recovered from towels	% of samples collected from northeastern metropolitan area		% of samples collected from southern metropolitan area		% of samples collected from both metropolitan areas	
	Paper towels	Cloth towels	Paper towels	Cloth towels	Paper towels	Cloth towels
Staph. epidermidis	7.5	20.6	3.4	25.9	5.8	22.9
Staph. aureus	0.0	2.9	0.0	3.7	0.0	3.3
Micrococci	5.0	8.8	3.4	18.5	4.3	13.1
Unidentified cocci	2.5	17.6	3.4	11.1	2.9	14.8
Corynebacteria	5.0	14.7	0.0	25.9	2.9	19.7
Unidentified gram negative bacilli	0.0	0.0	3.4	0.0	1.4	0.0
Bacillus (Sp)	25.0	29.4	17.2	48.1	21.7	37.7
Other microorganisms	0.0	5.9	3.4	3.7	1.4	4.9
Per cent of samples with one or more colonies per Rodac plate	37.5	61.8	27.6	74.1	33.3	67.2
Per cent of samples with no growth on Rodac contact plates	62.5	38.2	72.4	25.9	66.7	32.8
Total per cent of samples collected for qualitative analyses	100.0	100.0	100.0	100.0	100.0	100.0

midis, 23 per cent; corynebacteria, 19 per cent; micrococci, 13 per cent, and unidentified cocci, 14 per cent.

Pathogenic staphylococci, i.e, Staphylococcus aureus, were isolated on two samples from cloth towels, but were not isolated on any samples from paper towels.

Discussion

The data seem to clearly indicate that there is a distinct difference in the microbial cleanliness of cloth and paper towels, available for use in public washrooms. While many samples collected from cloth towels were free of microorganisms, an appreciably greater percentage of samples from paper towels had no bacterial growth on Rodac contact plates. Also, a significant percentage of samples from cloth towels had more than 100 bacterial colonies per Rodac contact plate, but not a single sample from a paper towel had a colony count greater than 75 per Rodac contact plate.

There seems to be no demonstrable difference in the quantitative data collected within each of the three metropolitan areas for paper towels. Geographic or climatic variables seem to exert little or no effect on the numbers of microbes readily recoverable from paper towels, as dispensed to the public. However, this relationship does not seem to exist for cloth towels. These data suggest that there are geographic and/or climatic differences which affect the number of bacteria that may be recovered from cloth towels. Of the samples from cloth towels, collected within the southern metropolitan area, 33 per cent had more than 100 recoverable bacteria per Rodac contact plate in contrast to 18.1 per cent and 0.0 per cent of the samples collected within the northeastern and the north central metropolitan areas, respectively. The higher humidity in the southern metropolitan area may permit longer survival of microorganisms on cloth towels, but this is conjecture. The difference may be in reality related to such factors as laundering procedures, methods of delivery, and storage of laundered cloth towels, procedures of servicing towel dispensers, and the like.

Explanation and interpretation of the qualitative data of the microorganisms recovered from paper and cloth towels must be limited to generalities. The data do not permit detailed analyses. The presence of predominantly Bacillus species on paper towels suggests that the contamination is of nonhuman origin. Organisms of this genus are found readily everywhere, for in the spore state these bacteria may survive heat, cold, and drying. These organisms denote environmental contamination, such as dust, and their presence alone on towels does not suggest the existence of a public health hazard.

Strains of the genus Bacillus also were recovered from samples of cloth towels, but at a much greater frequency. Apparently, the same sources of environmental contamination that affect paper towels also applies to cloth towels. The increased frequency can not be explained by these data.

The isolation of Staph. epidermidis and corynebacteria from a significant number of samples of cloth towels suggest human contamination. These organisms are indigenous to man and are easily and readily recoverable in large numbers from the body surfaces. Several theories may be advanced concerning the origin of these bacteria. They may be survivors of the laundering process, if performed inadequately or improperly, or may come from the dispenser because of faulty design. Again, the person servicing the dispenser may be guilty of handling the laundered towel improperly. These and other suppositions may be made cocerning the origin of Staph. epidermidis and corynebacteria that were recovered from con-

tinuous cloth towels, made available for use through a dispensing unit.

Less conjecture is necessary in hypothesizing the source of these bacteria recovered from individual cloth towels. The practice of a washroom attendant handing an individual cloth towel to a patron for use can be interpreted as a mechanical transfer of bacteria from person to person. However, not all individual cloth towels in the sample showed evidence of bacterial contamination; nor was the recovery of Staph. epidermidis and corynebacteria limited to individual cloth towels. The latter apparently are no better or worse than continuous cloth towels from a dispensing unit.

The practice in "posh" places, where an attendant hands a patron an individual cloth towel, can not be considered in the best interest of public health. This practice should be discontinued. The data presented here imply that the use of paper towels from a dispenser would be preferable.

The finding of viable Staph. aureus on samples from two cloth towels, but not on paper towels, suggests again that from the public health point of view paper towels are hygienically superior to cloth ones. This does not imply that a disease hazard is probable, but it points to the possibility. Staph. aureus is a relatively common contaminant in and on many items in the environment, but these organisms are related to human contamination to some degree.

To some public health people, the failure to isolate bacteria of the coliform group may be a surprise finding. However, Williams reports that several investigators, who have searched extensively and carefully, failed to find these organisms in appreciable numbers on the skin of normal adults.[11] If an important source of bacteria, other than those of the genus Bacillus, found on paper and cloth towels is the hands, then coliform organisms should not be found to any great extent on paper and cloth towels.

Conclusions

From the data collected during this study, the following general conclusions have been formulated concerning paper and cloth towels made available for use in public washrooms in the United States today:

1. Paper towels have substantially fewer, recoverable, viable bacteria on them than cloth towels of the continuous type and dispensed by mechanical means and individual cloth towels.
2. The number of bacteria found on paper towels does not seem to be a variable appreciably influenced by geographic and/or climatic differences, but the number of bacteria found on cloth towels seems to be significantly influenced by variables associated with geographical and/or climatic differences.
3. The most common bacterial contaminants of paper towels are bacteria of the genus Bacillus, suggesting environmental contamination.
4. The most common bacterial contaminants of cloth towels are also bacteria of the genus Bacillus.
5. Staph. epidermidis and corynebacteria are common contaminants of cloth towels, but these organisms are only occasionally found on paper towels. These bacteria denote probable human contamination of the cloth towels.
6. Staph. aureus is not a common contaminant of cloth towels, but it may be found on them from time to time, posing a potential health hazard.
7. From public health and esthetic standpoints, paper towels are superior to cloth towels, as dispensed or made available for use in the United States today.

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Collaboration Between the Health Professions and Other Specialties

The health fields now depend so heavily on complex technical procedures and relate to so many different social activities that they can no longer be the monopoly of the health professions; they require the services of many other specialized skills. Collaboration between the health professions and other specialties will grow more urgent and more intimate as our society demands that steps be taken not only to treat its diseases but also to protect its health against the dangers created by technological innovations.

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