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Liberation of organisms from contaminated textiles

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INTRODUCTION

In an earlier study (Rubbo, Stratford & Dixson, 1962) it was shown that hospital blankets, artificially contaminated with a marker organism, *Staphylococcus citreus*, liberated more organisms in the ward environment when they were covered with laundry-clean counterpanes than when they were not. This curious 'counterpane effect' appeared to be due to the removal of bacteria-carrying particles from the contaminated surface by friction with the overlying counterpane.

In the present work this 'counterpane effect' has been further investigated. Apart from examining the mechanisms of liberation of organisms from contaminated textiles it was also possible to evaluate the degree of dispersion of organisms from different textiles carrying the same bacterial loading. The results support the view that friction between contaminated surfaces contributes heavily to the airborne dispersion of organisms and that cotton fabrics tend to yield a higher number of airborne organisms on agitation than woollen materials.

METHODS

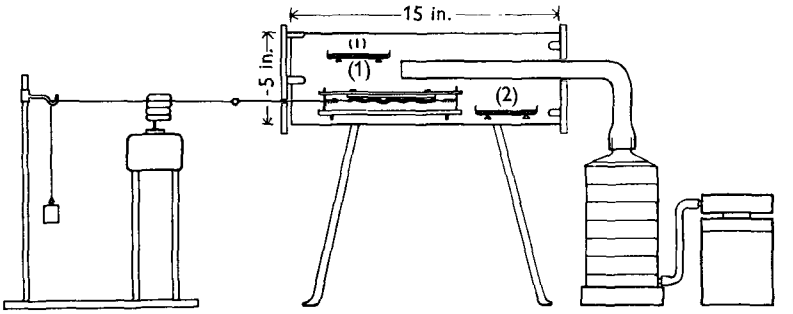
The general procedure used in this study was to contaminate a known area of sterile textile and then to determine the yield of airborne organisms on agitation in a specially designed apparatus (see Text-fig. 1 and Pl. 1B). The degree of surface contamination was measured by the contact plate method (Rubbo & Dixson, 1960) and airborne counts were made with an Andersen sampler (Andersen, 1958). In all cases Difco brain heart infusion agar containing 8% sodium chloride was used. The relevant details of this general procedure are as follows:

Textiles. New and used textiles consisting of pure wool, wool-cotton mixture, acrilan and cotton were tested. Each was cut into $6\frac{1}{4}$ in. $\times$ $3\frac{1}{4}$ in. samples and stapled at the corners. In addition, circles $3\frac{1}{2}$ in. in diameter were prepared for contact plating. All were dispensed in paper envelopes having cellophane-covered windows measuring $4\frac{1}{2}$ in. $\times$ 2 in. or 3 in. circles. The envelopes containing the textile samples were sterilized in 0·15% propylene oxide vapour at 56° C. for 24 hr. in a sealed container in an atmosphere of 70% relative humidity. The sterile samples were stored at room temperature for at least 48 hr. before use.

Contamination of textiles. The textiles were artificially contaminated by mounting the envelope on a copper frame, removing the cellophane window and placing the frame in a predetermined position in a desiccator jar (Pl. 1A). A suspension of

Staph. citreus, prepared by diluting a 24 hr. broth culture 1 in 10 in saline, was atomized into the sealed jar containing the exposed textiles. The time allowed for contamination was 7 min. consisting of 2 min. atomization period and a 5 min. fall-out time. The air pressure was regulated by a reducing valve to 15 lb. per sq.in.

Natural contamination of textiles in various wards was done by placing the envelopes, with their cellophane windows removed, on perforated metal trays mounted 3 and 6 ft. above floor level. The exposures were made in four bed surgical wards for 2 to 3 days.



Text-fig. 1. Drawing of apparatus illustrated in Pl. 1B showing position of settle plates (1) and (2).

Liberation of organisms from contaminated textiles. This was done under constant conditions using the apparatus shown in fig. 1 above and Pl. 1B. The method of using this apparatus might be briefly mentioned. The contaminated textile, mounted on springs (Pl. 2A), was shaken by the rotation of a spindle mounted off-centre on a small electric motor. The shaking was standardized to 1500 ½ in. oscillations per minute for 5 min. The shaking took place freely or in contact with a metal plate (aluminium) mounted above the textile or in contact with a second textile fixed to the metal plate (Pl. 2B). During the 5 min. period of agitation air was passed through the chamber into an Andersen sampler. The efficiency of this method of sampling airborne organisms was checked by exposing two settle plates in the chamber in every experiment. All air samplings recorded are for 5 cu.ft. of air collected at the rate of 1 cu.ft./min.

A typical experiment proceeded as follows. The interior of the collecting chamber and the removable Perspex end-plates were swabbed with 70% alcohol. The contaminated textile was mounted on the springs of the carrier and a paper clip attached to one end (Pl. 2A). Depending on the experiment, the metal plate, with or without the textile cover, was fixed to the carrier (Pl. 2B) so that contact between the spring-mounted textile and the plate was intermittently established during shaking. The carrier was then inserted in the chamber in a fixed position and two settle plates were placed in positions indicated in Text-fig. 1. The Perspex end-plates were mounted at either end of the collecting chamber; an air space, about ¼ in., was left at the end-plate nearest the shaker. Through a hole in this plate a wire loop was connected to the paper clip attached to the textile (Pl. 2B).

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Through the other end-plate a glass collecting tube (1 in. diameter) was inserted and connected to the Andersen sampler (Pl. 1B). Shaking the textile and air sampling were started simultaneously and continued for 5 min. The Andersen salt agar plates and the settle plates were then incubated for 48 hr. at 37° C. and counted. The Andersen plate counts were adjusted as recommended. The shaken fabric was sampled by the contact plate method and an unshaken control textile, similarly contaminated, was also sampled by contact plating.

RESULTS

In Table 1 the number of airborne organisms released on shaking artificially contaminated textiles is shown. It can be clearly seen that both woollen and cotton blankets release significantly more organisms when they are shaken in intermittent contact with a second textile, e.g. cotton sheet. On the other hand, shaking in contact with a smooth metal, such as aluminium, did not produce a higher yield of airborne particles from either material.

Table 1. *Release of airborne organisms on shaking artificially contaminated textiles*

Contamination: *Staph. citreus* (see text)

Textile	Condition of shaking (see text)	No. of expts.	Andersen sampler counts (av.) Stage 1	2	3	4	5	6	Total count
Woollen blanket	No contact	4	0	0	1	7	11	0	19
(75 % wool 25 % cotton)	Metal contact	4	2	2	2	6	4	0	16
	Sheet contact	4	1	2	7	29	22	9	70
Cotton blanket	No contact	4	1	1	1	12	18	1	34
(Terry towel)	Metal contact	4	1	1	2	14	23	1	42
	Sheet contact	4	1	4	7	62	56	0	130

Confirmation of these results was obtained by determining the extent of removal of organisms by contact plating textiles before and after shaking. Contact plates were made on separate samples of textiles contaminated at the same time as the sample to be tested, which, after shaking, was also contact plated. In every case the removal of organisms from the contaminated surface was significantly higher when shaken in contact with a second textile, Table 2. For example, the drop in surface count when a woollen blanket was shaken alone was 52 % but when shaken in contact with a cotton sheet the removal was 98 %. Similar differences are seen with other textiles as shown in Table 2.

By using the Andersen sampler it was possible to determine approximately the particle size distribution of the atomized suspension used for contaminating the textiles and the size of bacteria-carrying particles released when the textiles were shaken. The results are shown in Table 3. It is evident that the airborne organisms liberated from the textiles were of the same particle size as those which were used in contaminating the textiles.

Settle plate counts in all the above experiments and those reported later were negligible. Usually the plates were sterile or if growth occurred never more than two colonies were recovered. In short, the Andersen plate counts truly represent all the airborne organisms recoverable in the collecting chamber.

The results obtained with textiles contaminated by exposure to ward air reflect the same pattern as was found with the artificially contaminated samples, namely, an increased yield of airborne organisms when shaken in contact with a second textile (Table 4).

Table 2. *Removal of surface organisms on shaking artificially contaminated textiles*

Contamination: *Staph. citreus*

Textile	Condition of shaking	No. of expts.	Contact plate counts (av.) Before shaking	Contact plate counts (av.) After shaking	Removal of surface organisms (%)
Woollen blanket (75 % wool 25 % cotton)	No contact	7	220	105	52
	Sheet contact	8	183	7	98
Cotton blanket (Terry towel)	No contact	6	211	84	60
	Sheet contact	5	276	21	93
Acrilan blanket	No contact	4	399	230	42
	Sheet contact	7	282	7	98

Table 3. *Particle size distribution of airborne organisms released on shaking artificially contaminated textiles*

Contamination: *Staph. citreus*

Textile	Condition of shaking	No. of expts.	Andersen sampler count (av.) total $> 6\,\mu$ 1 2 3	Andersen sampler count (av.) total $< 3{\cdot}5\,\mu$ 4 5 6	Particle size distribution (%) $> 6\,\mu$	Particle size distribution (%) $< 3{\cdot}5\,\mu$
Woollen blanket (100 % wool)	No contact	5	2	24	8	92
	Sheet contact	5	6	42	11	89
Woollen blanket (75 % wool 25 % cotton)	No contact	4	1	18	6	94
	Sheet contact	4	10	60	14	86
Cotton blanket (Terry towel)	No contact	4	3	31	11	89
	Sheet contact	4	12	118	8	92
Staph. citreus (for comparison)	10^{-3} dilution atomized in 10 % broth	8	20 3 17	202 261 6	8	92

It is interesting to note that the natural contaminants in the ward air were delivered to the textiles on much larger particles than those used for artificial contamination (see Tables 3 and 4). When the particle size distribution of airborne organisms arising from the same textiles is considered, it is evident that textiles

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shed their contaminant flora on much the same size particles as those which were responsible for the contamination.

Table 5 confirms the findings listed in Table 4 by demonstrating that the most effective removal of surface organisms is seen when a textile is shaken in contact with another fabric.

Table 4. *Release of airborne organisms on shaking naturally contaminated textiles*

Contamination: exposure to ward air for 2–3 days

Textile	Condition of shaking	No. of expts.	Andersen sampler counts (av.) Stage > 6 μ 1	2	3	< 3·5 μ 4	5	6	Total count	Particle size distribution 90 particles (%) > 6 μ	< 3·5 μ
Woollen blanket (100 % wool)	No contact	5	8			1			9	89	11
	Sheet contact	5	21			1			22	95	5
Woollen blanket (75 % wool 25 % cotton)	No contact	4	6			1			7	86	14
	Sheet contact	4	11			3			14	79	21
Cotton blanket (Terry towel)	No contact	4	16			1			17	94	6
	Sheet contact	4	20			7			23	87	13
Acrilan blanket	No contact	3	4			1			5	80	20
	Sheet contact	4	10			1			11	91	9
Ward air for comparison		9	43	30	21	12	21	2	129	73	27

Table 5. *Removal of surface organisms on shaking naturally contaminated textiles*

Contamination: exposure to ward air for 2–3 days.

Textile	Condition of shaking	No. of expts.	Contact plate counts (av.) Before shaking	After shaking	Removal of surface organisms (%)
Woollen blanket (75 % wool 25 % cotton)	No contact	4	63	27	58
	Sheet contact	4	63	4	92
Cotton blanket (Terry towel)	No contact	4	70	21	70
	Sheet contact	4	70	3	96
Acrilan blanket	No contact	3	34	41	0
	Sheet contact	4	30	1	97

DISCUSSION

It is generally considered that agitation of a textile, e.g. a blanket, provides the principal mechanism for the airborne dispersion of its bacterial flora. The present study, and the one which preceded it (Rubbo *et al.* 1962), show that the yield of airborne organisms from a textile is greatly increased if the agitation is carried out in contact with a second textile (Tables 1 and 4). It would appear that the frictional contact between the two textile surfaces is a necessary prerequisite for

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the maximum liberation of organisms from these surfaces. The increase in aerial contamination due to friction is at least a twofold one and similarly the increased removal of organisms from a contaminated surface is of the same order. In contrast, shaking in contact with a smooth metal surface does not increase this yield of airborne organisms (Table 1).

These findings confirm previous conclusions which were drawn from the study of the spread of a marker organism in a hospital ward. The 'counterpane effect', as we previously termed it, described the increased dispersion of organisms when a contaminated blanket is covered by a laundry-clean counterpane (or quilt). In the light of these two parallel studies one can assume that one way of reducing aerial broadcast of organisms from contaminated blankets is to refrain from covering them with counterpanes and to expose only one side of the blanket during use.

In regard to the yield of airborne organisms produced by woollen and cotton blankets, it will be seen (Table 1) that when the two types of blanket are artificially contaminated and tested under the same conditions the cotton blankets always produce more airborne particles than the woollen types. Naturally contaminated woollen and cotton blankets yielded about the same number of organisms when shaken in contact with a sheet but shaken alone the cotton blankets gave higher counts (Table 4). Thus, from the point of view of airborne spread of infectious particles, one cannot claim any hygienic advantage in replacing woollen blankets with cotton ones.

This study provides no direct information on the nature of bacteria-carrying particles released from textiles. We have been able to show that there was no significant shift in the particle size distribution between airborne organisms contaminating a textile and those released when it was shaken. Since most bacteria found in the air of hospital wards are carried on particles about 10–20 μ in size, their origin is of theoretical as well as practical interest (Rubbo, 1963). We have suggested, on indirect evidence, that infectious airborne particles consist of minute cellulose fibres originating from dressings, sheets, pillow slips, etc., and contaminated by discharges and secretions of their users (Rubbo, Pressley, Stratford & Dixson, 1960). More recently Davies & Noble (1962) have suggested that airborne organisms dispersed from carriers and from their bedding are associated with desquamated skin. It would appear that the airborne particles released by textiles, for which we have used the term fibre nuclei, consist of both skin scales and fragmented cellulose fibres, the former arising from the clothing of skin carriers and the latter from contaminated dressings of patients. Whatever may be their true nature it is clear from the present study that the aerial dissemination of these particles will be determined to a large extent by the degree of friction between the contaminated textile surfaces from which they arise.

SUMMARY

By using a specially designed apparatus it was possible to study the yield of airborne organisms when various hospital textiles, artificially and naturally contaminated, were shaken under reproducible conditions. The results indicated that contaminant organisms are most effectively liberated when a textile is shaken in

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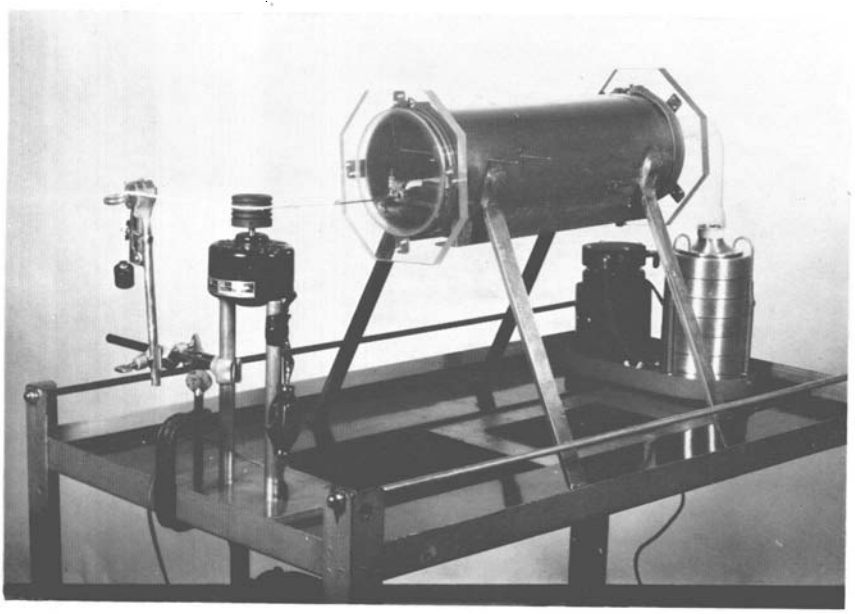

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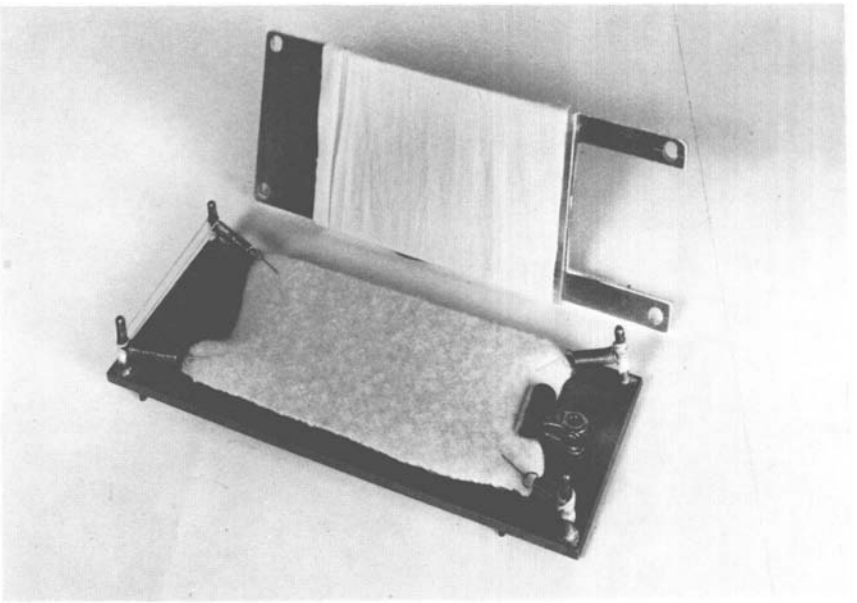

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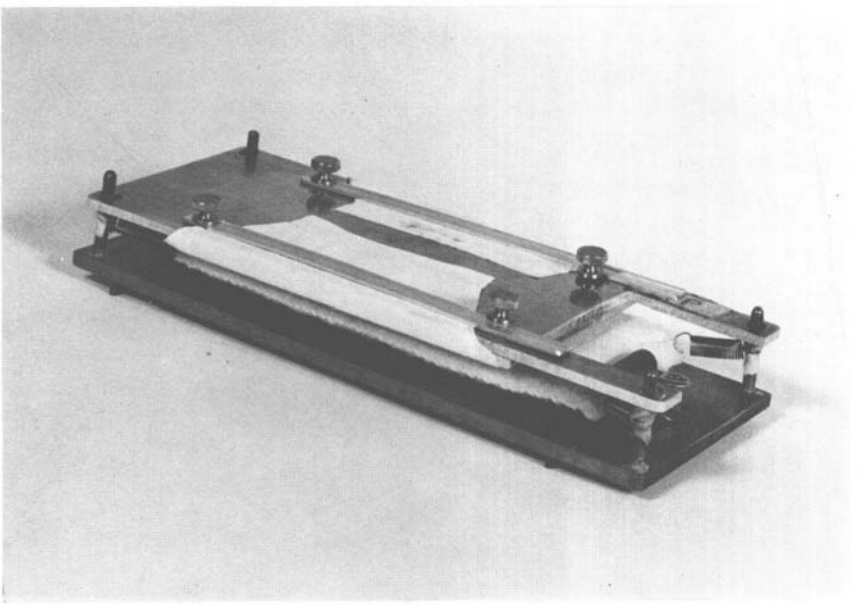

(B)

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contact with a second fabric. The yield of airborne organisms was approximately doubled under the conditions used. Similarly, a 95% removal of surface contaminants was also demonstrated by shaking in contact with a second textile, compared to 52% removal when the textile was shaken alone.

These findings confirm those described in an earlier study of the spread of airborne organisms in a ward environment. It is suggested that this increase in aerial spread of infectious particles, previously referred to as a 'counterpane effect', is due to friction between the contaminated textile and its covering material.

Other points which emerged in the course of this work were the demonstration that cotton blankets tended to yield higher airborne counts than woollen ones and that the size distribution of bacterial particles dispersed by textiles is the same as that of the particles which contaminate the textiles.

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EXPLANATION OF PLATES 1 AND 2

PLATE 1

A. Method of artificially contaminating a textile with atomized suspension of *Staph. citreus*.
B. The apparatus for collecting airborne organisms during shaking.

PLATE 2

A. Method of mounting contaminated textile on carrier and method of fixing second textile.
B. The two textiles mounted in position on the carrier.