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# SOME OBSERVATIONS ON HOSPITAL DUST

## WITH SPECIAL REFERENCE TO LIGHT AS A HYGIENIC SAFEGUARD

BY

LAWRENCE P. GARROD, M.D., F.R.C.P.

*Professor of Bacteriology in the University of London; Bacteriologist to St. Bartholomew's Hospital; Pathologist to an E.M.S. Hospital*

Dust has been recognized as a vehicle of infection for many years, but preoccupation with "droplet" spread has obscured its true importance until recent times. The first of a series of modern studies revealing the actual infectivity of dust was that of Cruickshank (1935), who found that haemolytic streptococci could readily be cultivated from the air and dust in the burn wards of the Glasgow Royal Infirmary, where most of the patients were infected by these organisms. Elizabeth White (1936), working with Colebrook at Queen Charlotte's Hospital, showed that dust in single rooms used for patients with streptococcal puerperal fever contained the same streptococcus, and that sweeping and bed-making increased the numbers recoverable in plates exposed to the air. In one such room these proceedings were carried on for experimental purposes after the patient had left it, and the sweeper developed a throat infection due to the same type of streptococcus. It was also shown that streptococci in artificially infected dust will survive for 10 weeks, and that their mouse virulence is undiminished after 25 days. The infectivity of dust is also evident from the observations made by Brown and Allison (1937) in scarlet-fever wards. Diphtheria bacilli may also exist in floor dust in large numbers in the neighbourhood of infected patients; Crosbie and Wright (1941), who demonstrated this, also found that this organism can survive in stored dust, retaining its virulence, for as long as 102 days.

Cross-infection, by dust or otherwise, is particularly liable to occur in wards where there are many open wounds, and the war therefore concentrated attention on its mechanisms. The observations of Miles *et al.* (1940), Hare (1941), and Thomas (1941) have confirmed and extended our knowledge of dust-borne streptococcal infection, and the precautions necessary to prevent it are described in M.R.C. War Memorandum No. 6. The oiling of floors (van den Ende, Lush, and Edward, 1940; Thomas, 1941) and of bed-clothes (van den Ende and Spooner, 1941; Thomas and van den Ende, 1941; van den Ende and Thomas, 1941) is now recognized as a valuable safeguard in diminishing the amount of atmospheric dust, and thus the chances of cross-infection by this means.

The original purpose of the work described in this paper was to determine how far dust is responsible for cross-infection in surgical wards, and how much cross-infection is to be ascribed to other causes. This aim was not reached, except in showing that, under the conditions existing in some of the wards studied, dust is so infective that, without the aid of any other vehicle, it could well have caused all the accidental infections observed. Owing to novel and unexpected features in the results obtained, a study was then made of the conditions governing the survival of haemolytic streptococci in dust.

### Methods

An ordinary sample of dust can easily be obtained by rubbing the dusty surface with a swab as used for throats or wounds: a large amount of dust, particularly of the fluffy variety, readily adheres to the cotton-wool. A few drops of sterile water were added to the tube containing such a swab, and a suspension of the dust was obtained by vigorously rotating the swab in this fluid. A loopful of this thick suspension was then sown on a 1 in 500,000 gentian-violet blood-agar plate (Garrod, 1942). The growth of almost all indifferent bacteria in dust, including all species of *Bacillus*, staphylococci, micrococci, *Sarcina*, diphtheroids, moulds, and yeasts, is inhibited on this medium, while *Str. pyogenes* grows freely and characteristically. So selective is the medium for this organism that almost pure cultures are sometimes obtained from an inoculum which on plain media would yield a confluent growth of bacteria classed in other circumstances as contaminants. That a thick suspension of what is really dirt should give either a nearly pure growth of a pathogen or an almost sterile plate is surprising, but it is a constant finding. *Viridans* streptococci (not usually of a type found in the mouth) and occasionally coliforms are the only other organisms commonly encountered. All haemolytic streptococci were grouped, and disregarded if not found to be of Group A; in some cases, when their precise identity was of interest they were typed. I am greatly indebted for this typing to the kindness of Dr. S. D. Elliott and to Dr. Dora Colebrook, of the Research Laboratory for Streptococcal Infections, Medical Research Council. For some purposes, to be described later, dust was collected by other methods, and studied quantitatively.

### Distribution of Streptococci in Dust

Most of the observations hitherto made on dust-borne streptococcal infection have reference to floor dust. That this may be heavily contaminated with haemolytic streptococci, particularly under and around the bed of an infected patient, was amply confirmed in the present study. On one occasion a heavy throat carrier, whose condition was entirely unsuspected, was detected in the first instance by the discovery of very large numbers of haemolytic streptococci in the floor dust near her bed in an isolated corner of the ward. This was an 18-bed ward in which there had been a case of scarlet fever, while four other patients were known to be infected, either in a wound or in the throat. The floor was swabbed in the neighbourhood of each occupied bed, and while at least a few haemolytic streptococci were found in nearly every specimen (one exception being the floor beneath the bed previously occupied by the case of scarlet fever: this proved on inquiry to have been treated with dettol), the numbers were much greater in the neighbourhood of known infected cases and of the unsuspected carrier mentioned above.

This grossly infected ward was on the ground floor. Windows on the ground floor of this (E.M.S.) hospital are protected by brick blast walls built up to within 34 in. of the top of the

window at a distance of only 7 in. from it, thus shutting off the lower 4 ft. of the window completely. These wards are therefore very badly lighted, whereas wards on the first floor have no such protection and are well lit. Multiple specimens of floor dust were collected at various times from three ground-floor and three first-floor wards where cases of haemolytic streptococcal infection had occurred, usually in circumstances suggesting cross-infection, and there was a very marked difference between them in the frequency of positive findings (Table I):

TABLE I.—*Number of Specimens of Floor Dust containing (+) and not containing (–) Haemolytic Streptococci*

| | – | + | % + |
|---|---|---|---|
| Ground floor .. .. | 21 | 55 | 72 |
| First floor .. .. | 27 | 6 | 18 |

The two groups of wards were not strictly comparable, either in the circumstances prompting the investigation, which naturally varied, or in the type of case treated; but the difference between them was so evident as to suggest the overriding operation of one factor, and one possible factor appeared to be light.

Evidence capable of the same interpretation was being obtained at the same time in a different way. Dust was collected not only from the floors but from other surfaces on which it accumulated. The thickest dust (neglect of which is explained by shortage of domestic labour and lack of vacuum-cleaning facilities) was to be found on the black-out screens. Each window was obscured at night by lowering four hinged screens placed one above the other, and made of fibre board in a light wooden frame; by day these were hoisted and held by cords at an angle of about 70 degrees to the window. The sloping surface thus facing the ward, enclosed in a wooden frame over half an inch in depth, readily collected dust. Samples obtained from these screens and from parts of the windows themselves (e.g., upper surface of lower sash) form the first category in Table II. The second is a smaller category of sites intermediate in level between the window and the floor (skirtings and low shelves); the third consists of floor-dust specimens only. The figures refer to specimens from both ground-floor and first-floor wards.

TABLE II.—*Number of Specimens of Dust containing (+) and not containing (–) Haemolytic Streptococci*

| Source | – | + | % + |
|---|---|---|---|
| Screens and windows | 42 | 0 | 0 |
| Skirtings, etc. .. .. | 13 | 9 | 41 |
| Floors .. .. .. | 48 | 61 | 56 |

The difference in distribution here is clearly significant, and could be interpreted in the same way. Dust on or close to windows, and hence much more exposed to light than anything else in the ward, is, so far as these observations go, consistently free from haemolytic streptococci. It does not appear to differ in nature from floor dust, being composed mainly of blanket fluff, although it is lighter in colour owing to relative freedom from admixed dirt of various other kinds. It is possible, however, that a closer analysis of dust deposited at various levels might reveal unsuspected differences in composition.

In all the ground-floor and one only of the first-floor wards studied the floors were treated with spindle oil. This is known not to disinfect dust, but merely to prevent its diffusion. There is no apparent reason, on the other hand, why it should encourage the longer survival of streptococci, or otherwise so act as to complicate the interpretation of these findings.

### Action of Light on Haemolytic Streptococci

Dust is an inconstant and difficult material to work with, and it seemed better to get further information about the action of daylight on streptococci by using some other medium. Buchbinder *et al.* (1942) obtained data on this subject by spraying organisms into the air, whence they settled on filter papers in Petri dishes; after exposure to various types of light these were cultivated. *Str. pyogenes* survived only 65 hours in the dark under these conditions, which therefore seem too unfavourable to the organism. Exposure to daylight (not sunlight), sterilized these preparations in about four hours. C. R. Smith (1942), studying the survival of tubercle bacilli, after failing to detect them in dust from rooms occupied by sputum-positive cases, dried either culture suspensions or actual sputum on cover-slips, and exposed these in an unglazed north window. He found that the bacilli in these films were usually dead within four days, whereas in a drawer in the same room they survived for two or three months, and in a refrigerator for over six months. Survival was longer in films made from sputum. The use of natural material is clearly preferable, and Smith's method was adopted with modifications for the present purpose.

*Experiments with Films of Dried Pus.*—Pus containing haemolytic streptococci was diluted with sterile glass-distilled water (1 in 2 000 in the first experiment; 1 in 20 and 1 in 5 in later experiments), and a loopful of this dilution was spread over an area about 1.5 cm. in diameter on a sterile slide and allowed to dry. These slides, of which as many as 60 were made for each experiment, were placed film upwards in Petri dishes, and sets were kept in each of three or four situations: (1) the ledge immediately inside a first-floor laboratory window facing south; (2) the ledge inside a window on the opposite side of the same laboratory—i.e., facing north and never exposed to direct sunlight; (3) a dark cupboard in the same laboratory; (4) a refrigerator at about 4° C. Cultures were made, at lengthening intervals, by adding enough blood agar (about 4 c.cm.) at 46° C. to form an adequate layer over the slide. A confluent haemolytic growth from the area of the film was succeeded later, as the number of survivors fell, by diminishing numbers of discrete colonies and eventually by total sterility. The results of four such experiments are given in Table III.

TABLE III.—*Survival of Str. pyogenes in Dried Films of Pus*

| Date of Start of Experiment | Dilution of Pus | Number of Days of Survival* | | | |
|---|---|---|---|---|---|
| | | South Window | North Window | Cupboard | Refrigerator |
| Sept. 7, 1942 .. | 1 in 2,000 | <1 | 6–8 | >18 | |
| „ 11, „ .. | 1 in 20 | 3–4 | 7–11 | 31–45 | |
| Nov. 13, „ .. | 1 in 5 | 10–13 | 13–17 | 75–92 | >92 |
| Mar. 6, 1943 .. | 1 in 5 | 6–9 | 13–19 | 103–110 | 41–52 |

* The first figure given is the day of the last positive culture, the second that of the first negative: > means all films used before a negative was obtained.

The increasing concentrations of pus were used, as it was found that these thicker films were sterilized by exposure to ultra-violet light, and were thus suitable objects for testing the bactericidal action of other kinds of light. (For exposing these films and other materials to measured doses of ultra-violet light I am indebted to Dr. L. D. Bailey and Miss Greenhill of the physiotherapy department of this hospital.)

These observations tally with those of C. R. Smith. The streptococci died most rapidly in a position exposed to sunlight, in spite of this having to traverse two layers of ordinary glass (the window and the Petri dish); survival was naturally longest in the experiment begun in November. Diffuse daylight in the north window was also lethal within 13 days or less, whereas in a dark cupboard in the same room, and hence under identical conditions apart from light, survival was prolonged for many weeks. Survival was longest in the refrigerator in one of the two experiments employing this site; in the second, sterility after 52 days is unexplained, but may possibly have been due to the action of some noxious vapour.

### Action of Light on Infected Dust in Vitro

Two attempts were made to assess the bactericidal action of natural light on haemolytic streptococci in dust. This was obtained by vacuum-cleaner from floors known to be infected and weighed in tubes, the contents of which were subsequently scattered in Petri dishes, and placed either on the north window-ledge or in the cupboard already mentioned. Counts of colonies in pour-plates of gentian-violet blood agar from a measured inoculum of volumetric suspensions showed little change in the cupboard dust and a fall of the order of 98% in the window dust within a few days; but duplicate counts

varied, owing evidently to lack of homogeneity in the material. This experiment was done in July. A much more elaborate repetition was begun in January, when heavily infected dust was obtained by passing a vacuum-cleaner over the bed-clothes of four patients known to have haemolytic streptococcal infections. This dust was filtered through gauze to remove coarse particles, yielding a dense fine grey powder, of which 20 mg. was kept in each of many tubes either in the dark or exposed to north daylight, and cultivated quantitatively from time to time. Neither in tubes nor in Petri dishes in which their contents were subsequently spread out as far as possible did this dust cease to yield haemolytic streptococci in culture until April 2, the experiment having been begun on Jan. 18. Winter conditions may have accounted partly for this long survival, but a more important reason was probably the nature of the material itself; ultra-violet light failed repeatedly under various conditions to kill more than a proportion of the streptococci in it, and it may be that dust in this artificially concentrated form is more protective to contained bacteria than the looser aggregations of natural dust.

The main interest of this experiment was the survival period in the dark. The original number of living haemolytic streptococci per gramme of dust was 204,000; succeeding counts were 176,000 on Jan. 25; 5,900 on March 19; 8,700 on April 2; 2,700 on May 4; 700 on June 4; and 300 on August 2, when the last available tube was cultivated. The three colonies in this last culture were all of Group A, and that sent to Dr. Elliott proved, as did a subculture from the plate of June 4, to be of Type 11. This type was responsible for the epidemic in progress in the ward when the dust was collected six and a half months earlier (195 days). This is the longest survival on record.

## Discussion

These imperfect observations are placed on record in order to draw attention to the possible importance of good natural illumination as a hygienic safeguard, and in the hope that they may lead to further study of this subject. Although good lighting is universally recognized as desirable, it has never, so far as I am aware, been insisted on as a prime necessity in wards for septic surgical cases. This study suggests that in such wards it has an important part to play, particularly if no special measures (such as the oiling of bed-clothes and vacuum dust extraction) are taken to prevent the atmospheric diffusion of dust. It has been shown that haemolytic streptococci naturally present in dust will survive for over six months in the dark. It was noticeable that dark corners on the floors of infected wards were always more liable to yield dust containing haemolytic streptococci than more open situations; one dark recess beneath a bookcase was repeatedly sampled, and never failed to yield them. Prolonged ward epidemics with long intervals between fresh cases are readily explicable in such conditions. It was also found that dust on or close to windows never contained haemolytic streptococci, whether exposed to direct sunlight or not. Whether this is an effect of light, or is partly or wholly explicable on other grounds, can only be settled by further observations.

The quantitative study of bacteria in natural dust *in vitro* is beset by difficulties, and it is not claimed that direct proof of the disinfectant action of light on this material has been obtained. Of the action of light on haemolytic streptococci in another natural medium there can be no question; dried films of pus are of the same nature as infected dry particles liberated from a wound dressing, and form an unexceptionable test object. These are sterilized within a few days by diffuse north daylight passing through two layers of glass, whereas in the dark the streptococci in them remain viable for weeks. My observations on this point differ from those of C. R. Smith, since no glass was interposed between his cover-slip films and the northern sky of California. Preoccupation with the ultra-violet part of the spectrum has led to a common belief that only direct sunlight is usefully bactericidal; it must now be recognized that ordinary diffuse daylight, even on a cloudy day and even in winter in England, can be lethal to bacteria, and that glass is no absolute bar to this effect. The conditions governing this type of light effect would evidently repay further investigation from several points of view.


## Summary

In wards where there are patients with haemolytic streptococcal infections dust may contain these organisms in large numbers, particularly near infected patients' beds.

Haemolytic streptococci were found to be most numerous in floor dust, and were absent from many specimens of dust in the same wards collected from sites on or close to the windows. They were more often found in dust from exceptionally dark wards than in comparable specimens from normally lit wards.

Haemolytic streptococci of Group A, Type 11, in naturally infected dust survived in small numbers in the dark at room temperature for 195 days.

Ordinary diffuse daylight is bactericidal to haemolytic streptococci. The interposition of glass does not prevent this effect, and it occurs even under winter conditions in England.

These facts suggest the possibility that good natural lighting may be a factor in preventing the atmospheric spread of infection in surgical wards and elsewhere.


I am indebted for valuable technical assistance in this work to Miss P. M. Waterworth. Her services and the equipment of the laboratory in which most of the work was done were made available by the generosity of "Bundles for Britain," which organization provided a fund under the control of Mr. Rainsford Mowlem for laboratory work in connexion with his surgical unit. I am also indebted to the medical superintendent of the hospital for permission to publish these findings, and to Mr. Mowlem and other members of the surgical staff for allowing me to refer to cases and conditions in their wards.

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# A NOTE ON THE TRANSMISSIBILITY OF HAEMOLYTIC STREPTOCOCCAL INFECTION BY FLIES


BY

**R. A. SHOOTER, M.B., B.Ch.**

AND

**PAMELA M. WATERWORTH**

*(From the Pathology Department of an E.M.S. Hospital)*


During the investigations described in the preceding paper by Prof. L. P. Garrod, when explanations were being sought for cross-infections in surgical wards, attention was directed to the possibility that these might be conveyed by flies. Wounds and septic dressings attract flies, and in some circumstances cannot altogether be protected from them.

In Sept., 1942, when flies abounded in this hospital, it was decided to catch some and cultivate them. They were trapped actually in a Petri dish containing blood agar, one half of the plate being spread with three drops of 1 in 3,000 gentian violet, as recommended by Fleming, and simply incubated in the plates, their busy wanderings on the surface of the medium being relied on to inoculate it with whatever bacteria might be on their feet. After overnight incubation the flies were found dead.

The flies were caught in two surgical wards where there were cases with streptococcal infections; a control series was caught in the laboratory. Of 27 flies caught in these wards 3 gave sterile plates, 9 gave cultures containing haemolytic streptococci, three of which proved to be of Group A, while the remainder grew a variety of other organisms, including coagulase-positive staphylococci and coliform bacilli; 2 plates were overgrown with *Proteus*. Of cultures from 22 flies caught in the laboratory 5 were sterile, 2 overgrown with *Proteus*, and the remainder grew a variety of unidentified organisms; there were no haemolytic streptococci in any culture.