THE SURVIVAL OF BACTERIA IN DUST

III. THE EFFECT OF LIGHT ON THE SURVIVAL OF BACTERIA IN DUST

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(With 1 Figure in the Text)

Sterilization of air by ultra-violet radiation is effective when the organisms are dispersed in droplet nuclei, the smallest particles being the most vulnerable (Wells & Wells, 1936; Bourdillon & Lidwell, 1948). Airborne bacteria, however, are also carried on dust particles shaken from textiles or swept from the floor, and against these ultra-violet radiation at intensities higher than those normally used for sterilizing air is found to be ineffective (see Dumbell, Lovelock & Lowbury, 1948). It does not follow, however, that continued ultra-violet irradiation is without effect against the bacteria of settled dust, which may persist in a room for long periods (Lowbury, 1950). Garrod (1944) has shown that the floor dust of infectious wards receiving normal daylight contains fewer streptococci, even in winter, than dust in similar wards which are poorly daylit. Hollaender, du Buy, Ingraham & Wheeler (1944) have advocated ultra-violet irradiation of floors, which they claim reduces the numbers of bacteria in the air significantly more than ceiling irradiation.

The sterilizing action of daylight, originally described by Downes & Blunt (1877), has been quantitatively studied on pure cultures by Buchbinder, Solowey & Phelps (1941). Buchbinder (1942) also reports germicidal action by fluorescent lamps equal per unit of illumination to that of daylight.

The purpose of our experiments, described in this paper, was to measure the effect of daylight, fluorescent and tungsten lighting, and an intensity of ultra-violet radiation comparable with that reflected from irradiated ceilings, on the death-rate of bacteria in dust. Limited studies on the effect of varying atmospheric humidity on the lethal action of ultra-violet radiation are also described.

METHODS

The sources of dust and the technique of extraction, culture and counting used in these experiments have been described (Lidwell & Lowbury, 1950*a*).

Exposure of specimens

In a preliminary trial of method (Exp. 1) pooled sweepings from living rooms (dust no. 1) were mixed by sifting and turning, and 10 mg. samples were weighed out and spread as evenly as possible on sterile glass slides, two portions per slide.

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Six-inch aluminium Petri dishes, each containing five slides, were covered with sheets of cellophane clipped to the outside of the dishes by metal hoops. Vaseline was applied to the contact edge between the dish and the cellophane cover.

Dishes were exposed in each of the following positions: (1) A dark cupboard in the laboratory. (2) On a table 12 in. high, never in direct sunlight in a room facing east. The computed daylight factor was 1·2 %. (3) In a blacked-out room containing a 40 W. tungsten light. (4) In a similar room with an 80 W. fluorescent lighting tube, Osram (G.E.C.) 'daylight'. (5) In a similar room with a 15 W. low-pressure ultra-violet lamp. The lamps were alight throughout the experiment, and dust specimens were exposed on the floor directly under the lamps, at a distance of 8 ft.

In Exps. 2 and 3, pooled sweepings from two fever hospitals (dusts nos. 6 and 9) were selected for their high content of β-haemolytic streptococci. Sifted dust was spread out on paper and divided into five equal heaps. Weighed portions of dust were spread out in 6 in. aluminium Petri dishes, five dishes for each site of exposure. Portions of dust were selected from the five heaps, using a table of random numbers. The quantities taken were 0·3 g. per dish in Exp. 2, and 1·0 g. (spread on a glass disk) per dish in Exp. 3. The dishes were covered with cellophane and exposed at the sites chosen for Exp. 1. A 100 W. tungsten bulb replaced the 40 W. bulb used in Exp. 1.

Bacterial sampling

Dust specimens were not disturbed until the time of sampling. In Exp. 1, five portions of 10 mg. each were extracted and plated out on the day when exposure of the dust began; on the 1st, 6th and 30th days sampling was repeated, ten portions per exposure on the 1st day, and eight portions per exposure on the other occasions. Extracts, undiluted and at a dilution of 1/10, were spread on serum-agar plates, and counts of total organisms and of *Staphylococcus aureus* were done after incubation.

In Exps. 2 and 3, twenty portions of 10 mg. each were extracted at the sampling periods, one dish of dust being available for each sampling. Samples were taken at intervals up to $2\frac{1}{2}$ months. Extracts were cultured, undiluted and at 1/20 dilution, on serum agar and, undiluted only, on 10^{-6} crystal-violet blood agar.

Effect of turning dust

Since dust particles shield from the light a proportion of the bacteria that they carry, turning the dust might be expected to increase the death roll of its flora. To test this point we re-exposed to ultra-violet radiation and fluorescent light three of the plates which had been turned and sampled on the 4th, 8th and 32nd days in Exp. 3, and sampled them again on the 35th, 71st and 75th days respectively.

The intensity of illumination

Daylight is a variable factor, and no attempt was made to keep a detailed record of intensity during the experiments. On a uniformly clouded day the illumination level at the exposure site was about 1 % that at a point outside which had an

unobstructed illumination from the whole sky. Exp. 1 was done between 16 March and 16 April, Exp. 2 between 19 April and 3 July 1948, and Exp. 3 between 10 November 1948 and 20 January 1949.

The cellophane sheet used as a covering to the dishes was found to have an overall transmission, measured with a barrier layer photocell, of about 90 % for the light from the tungsten filament and fluorescent lamps. The ultra-violet transmission at 2537 A. was approximately 55 %.

Measurements were made of the irradiation intensities under the cellophane covering at the sites of exposure. These were as follows: under a 100 W. tungsten-filament lamp, 5·5 equivalent foot-candles; under the 80 W. fluorescent lamp, 18 equivalent foot-candles; under the 15 W. low-pressure mercury discharge lamp, 2·6 μW./cm.^{2} at 2537 A. The intensity of ultra-violet irradiation was measured by exposing uranyl oxalate solutions in 6 in. glass Petri dishes and estimating the radiation as described by Leighton & Forbes (1930).

Except during the first experiment, daily records of humidity were kept throughout the course of the experiments.

RESULTS

Tables 1, 2 and 3 give the values of the log-median counts after various periods of illumination and the general pattern they reveal is illustrated in figure 1. The values of the log-medians and of the standard deviations of the log-counts, which are also given in the tables, have been estimated graphically as described in the first paper of this series (Lidwell & Lowbury, 1950*a*). Several points call for comment. First, all the radiations, except tungsten-filament lighting, have a definite effect in reducing the numbers of all three groups of organisms. Secondly, this effect does not appear to proceed indefinitely but reaches its full extent

Table 1. *Log-median counts after exposure to various radiations. Dust no.* 1. *Daylight: mid-March to mid-April*

Species and dilution	Radiation	Days exposure: 0 and 1	6	30
Total organisms 1/10	Dark	2·26 (0·22)	2·22 (0·15)	2·38 (0·31)
	Daylight	—	1·73 (0·40)	1·00 (0·49)
	Tungsten filament	—	2·28 (0·25)	2·26 (0·59)
	Fluorescent	—	1·92 (0·39)	1·28 (0·23)
	Ultra-violet	—	1·60 (0·41)	1·75 (0·34)
Styphylococcus aureus undiluted	Dark	1·06 (0·67)	0·70 (1·13)	0·35 (0·97)
	Daylight	—	0·90 (0·65)	—
	Tungsten filament	—	0·45 (0·80)	0·86 (0·70)
	Fluorescent	—	1·75 (0·85)	[2·0]
	Ultra-violet	—	0·15 (0·46)	0·00 (1·25)

In brackets ( ), the standard deviation of the log-counts. In this experiment the dust was dispersed in 10 ml. of physiological saline instead of in 5 ml. as in the other experiments. The 1/10 dilution is therefore equivalent to the 1/20 dilution elsewhere, while the undiluted dispersion is only one-half the usual concentration. In square brackets [ ], on this occasion too few positive plates were obtained for any direct estimate of the log-median or the standard deviation of the log counts to be made. Approximate values for the log-median have been estimated as described in a preceding paper (Lidwell & Lowbury, 1950*b*).

Table 2. *Log-median counts after exposure to various radiations. Dust no.* 6. *Daylight: late April to beginning of July*

Species and dilution	Radiation	Days exposure: 0	2	7	9	14	43	49–51	57	69–73	78
Total organisms 1/20 dilution	Dark	2·21 (0·40)	—	1·91 (0·42)	—	1·80 (0·26)	—	1·21 (0·60)	0·83 (0·41)	0·28 (0·33)	—
	Daylight	—	1·86 (0·45)	—	**0·80 (0·48)**	—	—	**$\bar{1}$·46 (0·58)**	—	$\bar{1}$·46 (0·58)	—
	Tungsten filament	—	—	1·50 (0·32)	—	1·60 (0·43)	—	**0·44 (0·53)**	—	—	$\bar{1}$·78 (0·58)
	Fluorescent	—	1·63 (0·54)	—	1·17 (0·50)	—	**0·23 (0·51)**	—	—	$\bar{1}$·80 (0·66)	—
	Ultra-violet	—	1·34 (0·54)	—	**0·97 (0·52)**	—	**$\bar{1}$·94 (0·58)**	—	—	$\bar{1}$·85 (1·00)	—
β-haemolytic streptococci undiluted	Dark	0·85 (1·42)	—	0·42 (1·12)	—	0·57 (1·23)	—	$\bar{1}$·10 (1·60)	$\bar{2}$·95 (2·00)	[$\bar{3}$·5]	—
	Daylight	—	$\bar{1}$·60 (2·80)	—	$\bar{1}$·70 (1·93)	—	—	[$<\bar{4}$·0]	—	[$<\bar{4}$·0]	—
	Tungsten filament	—	—	0·05 (0·98)	—	0·70 (1·12)	—	[$\bar{4}$·0]	—	—	[$<\bar{4}$·0]
	Fluorescent	—	$\bar{1}$·75 (2·10)	—	$\bar{1}$·60 (1·90)	—	$\bar{1}$·25 (1·30)	—	—	[$<\bar{4}$·0]	—
	Ultra-violet	—	0·29 (0·92)	—	$\bar{1}$·45 (0·72)	—	[$\bar{4}$·5]	—	—	[$\bar{3}$·5]	—
Staph. aureus undiluted	Dark	1·00 (1·00)	—	0·88 (0·97)	—	1·19 (0·87)	—	$\bar{1}$·35 (1·04)	$\bar{1}$·54 (1·58)	[$\bar{3}$·0]	—
	Daylight	—	1·40 (0·58)	—	$\bar{2}$·80 (2·20)	—	—	[$\bar{4}$·0]	—	[$\bar{4}$·0]	—
	Tungsten filament	—	—	0·70 (1·12)	—	0·85 (0·90)	—	$\bar{2}$·00 (2·40)	—	—	[$\bar{4}$·5]
	Fluorescent	—	0·85 (0·88)	—	0·47 (0·91)	—	$\bar{2}$·40 (1·60)	—	—	[$\bar{4}$·5]	—
	Ultra-violet	—	0·35 (0·86)	—	$\bar{1}$·52 (1·17)	—	[$\bar{2}$·0]	—	—	[$<\bar{4}$·0]	—

Symbols in this table are used as described in Table 1. The values in heavy type have been obtained from plate counts on the undiluted suspension, dividing these by 20.

Table 3. *Log-median counts after exposure of dust to various radiations. Dust no.* 9. *Daylight: mid-November to end of January*

Species and dilution	Radiation	Days exposure: 0	1	4	7 and 8	21	32	35 and 36	65	71 and 75
Total organisms 1/20 dilution	Dark	1·89 (0·45)	—	—	1·58 (0·51)	1·19 (0·45)	—	1·43 (0·47)	—	**0·56 (0·52)**
	Daylight	—	1·60 (0·46)	1·83 (0·45)	1·53 (0·55)	—	**0·88 (0·52)**	—	**0·31 (0·44)**	—
	Tungsten filament	—	1·93 (0·48)	1·85 (0·50)	1·65 (0·58)	—	**0·88 (0·51)**	—	**0·47 (0·42)**	—
	Fluorescent	—	1·85 (0·50)	1·40 (0·76)	**1·27 (0·64)**	—	**1·00 (0·65)**	**0·57 (0·75)***	**0·46 (0·57)**	**$\bar{1}$·95 (0·63)***
	Ultra-violet	—	1·63 (0·38)	**0·68 (0·55)**	**0·85 (0·51)**	—	**0·33 (0·72)**	—	**0·04 (0·54)**	**$\bar{1}$·63 (0·78)***
β-haemolytic streptococci undiluted	Dark	1·00 (0·79)	—	—	1·20 (1·60)	0·72 (1·50)	—	$\bar{1}$·95 (1·70)	—	$\bar{1}$·44 (0·60)
	Daylight	—	0·78 (1·10)	1·58 (0·77)	1·04 (0·95)	—	$\bar{1}$·65 (1·00)	—	$\bar{1}$·50 (0·85)	—
	Tungsten filament	—	1·62 (0·73)	1·18 (0·85)	1·58 (0·62)	—	0·45 (1·38)	—	$\bar{2}$·70 (1·60)	—
	Fluorescent	—	0·80 (0·92)	0·92 (0·95)	0·48 (1·70)	—	0·25 (1·05)	$\bar{2}$·60 (1·90)*	$\bar{2}$·60 (2·00)	[$<\bar{4}$·0]*
	Ultra-violet	—	1·25 (0·76)	0·00 (1·90)	$\bar{2}$·90 (2·10)	—	$\bar{2}$·20 (2·30)	—	[$\bar{3}$·5]	[$<\bar{4}$·0]*
Staph. aureus undiluted	Dark	0·52 (1·00)	—	—	0·94 (0·85)	0·40 (0·81)	—	$\bar{1}$·35 (1·36)	—	[$\bar{4}$·5]
	Daylight	—	0·86 (1·15)	1·46 (1·20)	0·60 (1·12)	—	[$\bar{3}$·5]	—	[$\bar{3}$·0]	—
	Tungsten filament	—	1·14 (1·02)	0·20 (1·43)	0·76 (1·90)	—	0·20 (1·24)	—	[$\bar{4}$·5]	—
	Fluorescent	—	1·15 (0·83)	0·35 (1·10)	$\bar{1}$·75 (1·55)	—	$\bar{1}$·20 (1·75)	[$\bar{2}$·0]*	[$\bar{4}$·0]	[$<\bar{4}$·0]*
	Ultra-violet	—	1·02 (0·71)	$\bar{1}$·87 (1·07)	$\bar{1}$·50 (1·55)	—	$\bar{1}$·45 (0·95)	—	[$\bar{4}$·5]	[$<\bar{4}$·0]*

The symbols in this table are used as described for the preceding tables.

* The dust sampled on these occasions had been turned over. The 35-day sample after 4 days' exposure and the 71- and 75-day samples after 32 and 8 days' exposure to fluorescent lighting and ultra-violet irradiation respectively.

Table 4. *Log-median counts after exposure of dust to various radiations in a dry atmosphere. Dust no.* 13

Species and dilution	Radiation	Days exposure 0	2	5	11	14	26	31	46
Total organisms 1/20 dilution	Dark	2·26 (0·30)	—	—	—	2·25 (0·40)	2·18 (0·38)	—	1·85 (0·41)
	Tungsten filament	—	2·26 (0·38)	2·22 (0·27)	2·33 (0·29)	—	—	2·23 (0·34)	—
	Fluorescent	—	2·24 (0·30)	2·35 (0·32)	2·29 (0·40)	—	—	2·06 (0·26)	—
	Fluorescent (turned)	—	2·41 (0·23)	2·38 (0·30)	2·26 (0·30)	—	—	2·07 (0·37)	—
	Ultra-violet*	—	2·19 (0·39)	1·98 (0·25)	1·82 (0·41)	—	—	1·45 (0·48)	—
β-haemolytic streptococci undiluted	Dark	1·30 (0·63)	—	—	—	1·58 (0·45)	1·15 (0·83)	—	0·86 (0·82)
	Tungsten filament	—	1·12 (1·04)	1·32 (1·00)	1·57 (0·82)	—	—	0·91 (0·99)	—
	Fluorescent	—	1·07 (0·76)	1·10 (1·06)	1·50 (0·72)	—	—	0·70 (0·78)	—
	Fluorescent (turned)	—	1·50 (0·79)	1·30 (0·64)	1·02 (0·58)	—	—	0·50 (0·95)	—
	Ultra-violet*	—	1·00 (0·91)	0·90 (1·00)	0·80 (1·20)	—	—	0·07 (1·02)	—
Staph. aureus undiluted	Dark	0·65 (1·10)	—	—	—	0·30 (1·18)	$\bar{1}$·80 (0·71)	—	0·24 (0·94)
	Tungsten filament	—	1·09 (1·29)	0·55 (1·31)	0·37 (1·00)	—	—	$\bar{1}$·48 (1·28)	—
	Fluorescent	—	1·00 (0·67)	0·17 (1·50)	0·63 (1·08)	—	—	$\bar{1}$·40 (1·20)	—
	Fluorescent (turned)	—	0·80 (1·06)	0·53 (0·62)	0·41 (0·78)	—	—	$\bar{1}$·46 (1·12)	—
	Ultra-violet*	—	$\bar{1}$·38 (1·33)	0·14 (1·48)	$\bar{1}$·87 (0·52)	—	—	$\bar{2}$·96 (1·10)	—

The symbols in this table are used as described for the previous tables.

* Dust for this experiment was taken on the 14th day from that kept in the dark; 14 days should therefore be added to the number of days exposure in order to find the corresponding sample in the 'dark' rows.

The 'fluorescent turned' dust was turned over daily with a spatula.

somewhere between the 7th and 14th days. There is a suggestion, particularly in the results obtained for total organisms, of a subsequent convergence of the log-median counts, but the data do not permit of any definite conclusion as to the reality of this phenomenon. The presence of a fraction of the organisms more resistant than the main body to the effect of radiation is paralleled by the behaviour of organisms under mechanical stress (King & Alexander, 1948) and the effects of ultra-violet radiation on dried films of streptococcal cultures (Lidwell & Lowbury,

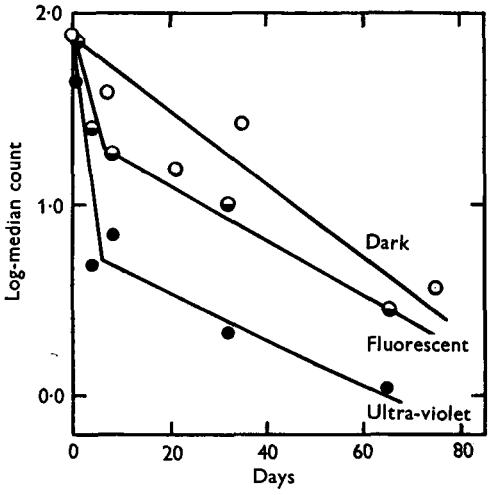

Fig. 1. The changes in the log-median count of 'total organisms' when dust no. 9 was exposed, (*a*) in the dark, (*b*) to fluorescent lighting, (*c*) to low-intensity ultra-violet irradiation.

Table 5. *Maximum reduction of the log-median counts of* 10 *mg. dust portions after exposure to various radiations*

	Total organisms				*β*-haemolytic streptococci				*Staph. aureus*			
Radiation	I	II	III	IV	I	II	III	IV	I	II	III	IV
Daylight	1·1	1·25	0·3	—	—	1·0	0·5	—	—	2·0	0·6	—
Tungsten filament	0·0	0·4	0·2	0·0	—	0·1	0·0	0·0	(0·0)	0·3	(0·0)	(0·0)
Fluorescent tube	0·8	0·8	0·5	0·0	—	1·0	0·9	0·5	1·7	1·0	1·1	0·5
Ultra violet	0·6	1·0	1·0	0·5	—	1·0	2·2	0·8	0·6	1·6	1·3	0·8

The numbering on the columns refers to the tables containing the data on which these estimates are made. I, II and III refer to experiments carried out at the prevailing humidity, 50–60 %. IV refers to the experiment under dry conditions, over calcium chloride. In I the tungsten filament lamp was only 40 W. as against 100 W. in II and III.

In I, II and III the reductions are estimated at or about the 10th day, in IV after 30 days. Bracketed figures ( ) are of less accuracy.

1950*c*). Under these circumstances it was not found practicable to assess bacterial death-rates attributable to the various radiations. The death-rates in the dark can be, and have been, assessed as described in a preceding paper (Lidwell & Lowbury, 1950*b*) and are quoted in that place. In Table 5 the differences between the log-median counts of the dust samples kept in the dark and those exposed to the various radiations are given. The values have been obtained by interpolation of the

observed data at a time when the difference had reached its full extent, i.e. about the 10th day. A rough idea of the bacterial death-rates can be obtained from these figures by multiplying by 0·23 to obtain the death-rates per day. For the experiments under dry conditions, which are described below, the corresponding multiplying factor is 0·07, the reductions being estimated after 30 days' exposure. Daylight, ultra-violet irradiation and fluorescent lighting all produce a significant reduction in the log-median count of all the three groups of organisms. The small reduction sometimes recorded for tungsten-filament illumination is not significant, and, indeed, no reduction would be anticipated in view of the spectral distribution of the light from this source and of previously reported data on the variation of the bactericidal efficiency of radiation with wave-length (Duggar, 1936). The duration and brilliance of the daylight in Exp. III, begun in the late autumn, was markedly less than in the two previous experiments in the spring and summer, and this seems to be reflected in a diminished bactericidal action. Any differences there may be in the sensitivity of the three groups of organisms to radiation are not significantly revealed by the figures in the table. Taking together all the results of all the experiments for ultra-violet irradiation and fluorescent lighting, the mean reduction in the log-median counts at or about the 10th day is 1·2 for the ultra-violet radiation and 1·0 for fluorescent lighting, i.e. the log-median counts are respectively reduced to about one-sixteenth and one-tenth of the values in the absence of radiation. These figures may be compared with a mean reduction of 1·3, or to one twentieth, for the spring and summer daylight. It should be remembered in making this comparison that the lamps were kept on throughout the full 24 hr., whereas the daylight was intermittent and the room chosen not particularly well lit. Bearing this in mind the comparative results of daylight and fluorescent lighting do not conflict with Buchbinder's findings (Buchbinder, 1942).

Table 6. *The reduction of the log-median count of* 10 *mg. dust portions after exposure to various radiations for several periods*

	Duration of exposure		
Radiation	1–5 days	6–10 days	over 10 days
Tungsten filament	0·11 (0·11) **6**	0·23 (0·12) **8**	0·13 (0·11) **13**
Fluorescent lighting	0·47 (0·10) **9**	0·76 (0·11) **8**	0·64 (0·15) **11**
Ultra-violet	0·71 (0·16) **9**	1·20 (0·14) **8**	1·12 (0·20) **11**

The figures given are the mean values of the differences in the log-median counts, followed in brackets by the standard error of these means. The number of observations on which the means are based are inserted in heavy type.

An alternative method of assessing the results which allows a better estimate of their significance is shown in Table 6. Values for the log-median counts of the samples kept in the dark have been interpolated by drawing the best straight lines through the data, and the differences between these and the observed log-median counts of the samples exposed to the various radiations evaluated. As has also been inferred from Table 5, there is no significant distinction between the three groups of organisms in respect of the effects of the radiations, although there

is some suggestion that 'total organisms' are more resistant, so the values for the three groups have been combined and the mean value of the differences in the log-median counts, together with the standard deviation of this mean value, calculated over three time intervals for the three artificial radiations. The figures for daylight have been omitted since this was not constant in the three experiments. It will be seen from Table 6 that there is no doubt as to the significance of the effects of fluorescent lighting or ultra-violet irradiation, and that the mean values of the differences in the log-median counts over the period 6–10 days agree quite well with those already given for the mean maximum differences. It would, of course, be reasonable for them to be somewhat smaller.

The few experiments in which the dust was turned over suggested that a further killing effect resulted from this procedure and this point is taken up in the following section.

The effect of light on dust flora in dry atmospheres

Quantitative assessment of the sterilizing power of the various radiations is complicated by the natural dieaway of bacteria as observed in the dark. This is greatly retarded in a dry atmosphere (Lidwell & Lowbury, 1950*b*). We therefore exposed dust to different kinds of radiation in cellophane-covered boxes containing anhydrous calcium (Exp. 4) in the hope that the shape of the killing curve and the effect of turning dust would be clarified by this procedure.

METHODS

Sifted floor sweepings from a scarlet-fever ward were tested to confirm the abundance of β-haemolytic streptococci.

Three aluminium baking trays, 12 by 20 and $4\frac{1}{2}$ in. in depth, were fitted with cellophane covers which could be sealed down with adhesive tape on to a level rim on the trays. The trays were fitted with wire grids on which the 6 in. aluminium Petri dishes containing the dust samples were supported above a layer of anhydrous calcium chloride which covered the floor of the trays. Experiments showed that a dry atmosphere was in fact maintained by this arrangement.

There were four dishes in one of the trays, which were exposed to an 80 W. fluorescent lighting tube at a distance of 8 ft. The dust in two of the Petri dishes of this container was mixed and spread out again daily. The other trays each contained two dishes of dust, and were exposed at a similar distance, one to the 15 W. ultra-violet lamp and the other to a 100 W. tungsten light. Two portions of the same dust were exposed in the dark over anhydrous calcium chloride. As the tray exposed to fluorescent light was opened daily to turn the dust, all the trays were opened momentarily every day.

Sampling of dust was done in the usual way at intervals up to the 46th day.

RESULTS

The log-median counts after various periods of exposure are given in Table 4. The most striking fact is the much reduced effect of all the radiations at the low humidity. It would have been desirable to continue the observations over a longer

period, but after the earlier samples had been taken insufficient dust remained for this purpose.

The ultra-violet radiation produced a definite effect on all three groups of organisms, the reductions in the log-medians after 30 days' exposure, as compared with the dust kept in the dark, being about 0·5, 0·8 and 0·8 for total organisms, β-haemolytic streptococci and *Staph. aureus* respectively. There is no evidence as to whether the reduction was continuing beyond this point.

No significant difference could be detected between the two samples, one left undisturbed and the other turned over daily, exposed to radiation from the fluorescent lamp, and these may be considered together. No significant effect of exposure to this radiation for 30 days could be observed with total organisms. With β-haemolytic streptococci and *Staph. aureus* a similar, though smaller, effect to that found with ultra-violet radiation was observed. The reduction in the log-medians after 30 days' exposure appeared to be about 0·5 with no evidence as to the continuance of the effect beyond this point.

No evidence of any effect from illumination with the tungsten filament lamp could be detected.

DISCUSSION

The results obtained in these experiments confirm previous observations of the bactericidal influence of illumination. The process, however, is much slower with dust than with cultures spread on slides or Petri plates and appears to proceed to a limited extent only in the dusts we have examined. In most environments, however, there is a continual turnover of dust, and the average life of any given dust particle, except for those hidden in crevices, etc., where in any case they are out of reach of illumination, will not usually be as long as 10 days (Lowbury, 1950). At the room humidities studied, around 60 % relative humidity, low-intensity ultra-violet irradiation (2·6 μW./cm.^{2}) and fluorescent lighting of good intensity (18 equivalent foot-candles) appeared to destroy the various organisms about five times as fast as their natural death-rates in the dark. This observation with respect to fluorescent lighting, if it is adequately confirmed over a useful range of humidity, may be of appreciable hygienic significance, particularly in sites where there are no external windows.

The fraction of dust resistant to the effects of illumination may be so because of shadowing by opaque dust particles, but other experiments with dried films of streptococcal cultures (Lidwell & Lowbury, 1950*c*) suggest that a more general phenomenon may also be involved.

The marked reduction in the effects of fluorescent light, and ultra-violet irradiation under dry conditions was quite unexpected and contrary to the generally observed behaviour of airborne bacteria (Bourdillon & Lidwell, 1948), but it has since been found possible to parallel the effect in films of some types of streptococcal cultures (Lidwell & Lowbury, 1950*c*). The extent of this effect over different ranges of humidity is at present unknown and calls attention once again to the importance of this factor in relation to bacterial viability. In the absence of direct information it would seem likely to be similar in form to that shown by

films of *Strep. pyogenes* grown in serum broth-dust extract (Lidwell & Lowbury, 1950*c*). Considering both this and the greater persistence of viable organisms in dust at low humidities (Lidwell & Lowbury, 1950*b*), it seems possible that the survival of pathogenic organisms in the dust of ordinary room environments might be considerably enhanced by a fall in humidity over a comparatively narrow range, e.g. from 60 to 40 % relative humidity, which in turn might have some bearing on the seasonal incidence of some types of infection.

SUMMARY

The effects of daylight, low-intensity ultra-violet radiation, fluorescent lighting, and tungsten-filament lighting on the survival of dust flora have been studied, at room humidities of about 60 % and under dry conditions. The first three radiations all cause a significantly enhanced death-rate at room humidities for all the groups of organisms studied. The effect appears to be limited in extent and to be complete in about 10 days. The action of the radiations is much slower under dry conditions.

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