ON THE USE OF A PRESSURE STEAM DISINFECTOR FOR DISINFESTATION AND DISINFECTION, BY DRY HEAT AND/OR GASEOUS DISINFECTANTS.

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Introduction.

It has long been felt that a great drawback exists in the very protracted time (*minimum* = 6 hours) required for the disinfection by gases of such articles as rubber, leather, furs, silks and woollens, which are damaged by steam and by high temperatures generally. True, such articles can alternatively be treated with liquid disinfectants, but, here again, much delay and inconvenience are occasioned by the subsequent necessary drying; while further, certain articles may thereby suffer some damage.

Therefore, it was thought that an investigation as to the possibilities of devising some method for accomplishing disinfection *in a more rapid manner and without injurious action* might yield practical results, especially if apparatus already existing—such as a steam disinfecting chamber—could be utilised for the purpose, thus economising in outlay.

At the same time, it was considered desirable to investigate the feasibility of using such an appliance for the destruction of vermin by means of dry heat or gaseous disinfectants, but more especially by the former, since only a relatively low temperature is required (see below).

The use of dry heat.

The insecticidal properties of dry heat in regard to lice and nits have been the subject of much work, especially in relation to louse-borne disease during the War of 1914–18. A very full account is given by Nuttall (1918)[1], with extensive references and bibliography. This worker lays stress on the fact that the nits have to be destroyed, and any method that falls short of killing them is bound to be ineffective. His conclusions may be summarised thus:

(*a*) adult lice and nits are killed by dry heat at 65°–70° C. acting for one minute;

(*b*) adult lice are killed by dry heat at 55° C. acting for five minutes;

(*c*) nits are killed by dry heat at 55°–61° C. acting for ten minutes;

(*d*) *in practice*, both lice and nits are killed by dry heat at 55° C. acting for thirty minutes.

This latter finding is taken as the basis for the destruction of vermin by dry heat in this investigation.

[1] *Parasitology*, **10**, pp. 1–42 (Bibliography), 411–586 (Combating Lousiness among Soldiers and Civilians).

As a *disinfectant*, dry heat is reliable only at temperatures that will damage delicate articles and fabrics (Nuttall, pp. 451, 480).

The use of gaseous disinfectants.

The bactericidal powers of sulphur dioxide and formaldehyde are well known, but their use in the past has been confined mainly to the disinfection of rooms, where prolonged exposure at atmospheric temperatures is required.

The insecticidal properties of these gases (and other chemicals) have been fully investigated—a full account with extensive references has also been published (*loc. cit.*). As a result of this work, the above-mentioned gases have been selected for the present investigation as being the most promising in action and the most suitable in use.

The combination of dry heat with a gaseous disinfectant.

The use of formaldehyde in a pressure-steam disinfector seems to be a well-established practice[1], but its combination with dry heat does not appear to have been exploited with a view to achieving the *rapid* disinfection of delicate articles; nor can any reference be found to research done in this direction.

OBJECTS.

To enquire as to whether:

1. Articles liable to damage by steam and high temperatures can be disinfected in a reasonable time by the action of a gaseous disinfectant in high concentration in a standard type Pressure Steam Disinfector

(*a*) at room temperature; or,

(*b*) following exposure to dry heat;

without injury to the articles themselves and without fixing blood-stains.

2. The destruction of vermin can also be secured by such a method.

APPARATUS.

The apparatus in which this investigation was carried out is a standard "Velox" steam disinfecting chamber, which was kindly placed at my disposal by The Grampian Engineering Co., Causewayhead, Stirling, to whom I am also further extremely indebted for facilities and help.

Attached to the disinfector is a powerful electrically driven suction pump capable of exhausting the chamber to the very high degree of 25 in. of vacuum.

In order to provide for the generation of a disinfectant gas, such as sulphur dioxide or formaldehyde, and to furnish means for its introduction into the

[1] Jameson and Parkinson (1930). *Synopsis of Hygiene.* 3rd ed.—Kenwood and Kerr (1929). *Hygiene and Public Health.* 8th ed.—Nankivell (1926). *Synopsis of Hygiene and Public Health.*—Park (1928). *Public Health and Hygiene.* 2nd ed.—Rideal (1900). Methods employed for generating formaldehyde for disinfecting purposes (and discussion). *J. Sanit. Inst.* **20**, Part iv.—Rosenau (1925). *Preventive Medicine and Hygiene.* 4th ed.

chamber (following vacuumisation), there is also attached a "generator" consisting of a vertical cylindrical copper container of suitable size for holding either a "Hydralformant" lamp or a sulphur candle in a small tray of water, and connected to the chamber by a copper pipe with shut-off valve. Provision is also made for fitting to the end of this pipe where it leaves the generator an inlet nipple of desired internal diameter so as to regulate the time taken for admission of gas to the chamber.

Generation of gas.

Sulphur dioxide was generated by the burning of a sulphur candle, and formaldehyde by the vaporising of "Paraform" tablets, in the generator.

An important point was the adjusting of the period taken in reducing the vacuum to zero in relation to the amount of gas which it was desired to introduce. For this purpose, several trials were made of the length of time required—incidentally by no means constant—for the vaporising of 10 "Paraform" tablets, and then a nipple of suitable diameter was fitted to the generator extremity of the inlet pipe. In the case of sulphur greater difficulty was experienced, as will be noted in the remarks following group A of the experiments.

Recording of temperatures within the chamber.

In addition to the fitting of a mercurial thermometer through the top of the chamber, two thermocouples were employed in the interior, their leads passing through special airtight nipples in the casing. By means of these thermocouples the temperature changes could be closely followed. As a check, "temperature control-tubes" (containing chemicals of known melting-points) were inserted before each experiment, but, of course, could not be "read" until after the close. In the earlier experiments with sulphur dioxide and formaldehyde at room temperature a wet-bulb thermometer was also passed through the casing of the chamber.

Procedure.

Exposure of objects.

Test bacterial cultures and tuberculous sputum used were emulsified in sterile normal saline and taken up separately on pieces of sterilised lint which were then placed in separate sterilised pill-boxes (with lids removed) and wrapped in further sterilised lint. Lice and bugs were similarly placed in pill-boxes with the lids removed and secured by wrapping in lint. All were then placed at the site selected. Conditions were thus more severe than would be the case in actual practice.

Preliminary heating of chamber.

Except in the experiments at room temperature, the chamber itself was pre-heated to about 80° C., as recorded by the thermometer at the top of the chamber, by the admission of steam both to the heating coils and to the

interior: it was then opened and loaded, the objects being placed in the desired situations. By thus quickly warming up all metallic parts a great saving in both steam and time is subsequently effected.

Sampling of gas.

This was done only in the case of sulphur dioxide, the gas being withdrawn by means of a suction pump through a rubber tube having its inner end in proximity with the test objects, while its outer extremity was connected to a "Clayton" burette. A special nipple was inserted in the casing for this purpose.

THE EXPERIMENTS.

A complete protocol of the experiments is not presented, since such would prove needlessly long. It will suffice, therefore, to give a summary only, dividing the tests into appropriate groups.

Group A.

As to the effects of the products of the combustion of sulphur at room temperature on lice, bugs and B. typhosus, *both embedded in flock mattress and in exposed situations.*

A piece of flock mattress, about 15 inches square, was wrapped in two layers of blanket, while the test objects were inserted into its centre. This was the method adopted in all experiments with mattress in order to obtain the maximum difficulty normally liable to be met. Inside the chamber the temperature was 65° to 66° F. and relative humidity 90 per cent.

Results.

(i) The sulphur gases penetrated to the interior of the piece of flock mattress, attaining a concentration which approached very closely to the theoretical as computed from the amount of sulphur consumed.

(ii) Exposure, for four hours, to the gases at a concentration of sulphur dioxide falling from 4 per cent. at the beginning of the test to 0·75 per cent. at its close, both killed lice and sterilised *B. typhosus* in exposed situations: but, while killing lice embedded in the mattress did not sterilise *B. typhosus* at that site.

(iii) Exposure to 1 per cent. sulphur dioxide maintained for four hours destroyed bugs, but was ineffective against lice and *B. typhosus*.

Remarks.

It is obvious that sulphur gases are unreliable for use in this connection. In any case, the length of time that would be occupied by this process definitely places it beyond the bounds of practical application. There are, too, further objections to their use.

In the first place, it is not always possible to secure that the sulphur will remain alight. Constant watch must be maintained, so that, should it become extinguished, the shut-off valve on the inlet pipe can be closed immediately.

Again, the rate of burning is very variable, as is evidenced by the subjoined table:

Sulphur consumed in ounces	Time taken in min.	Rate of burning per min. in ounces
0·42	14	0·03
1·05	23	0·04
1·25	18	0·08
4·37	32	0·14

It was noted that an unused candle burned more freely than one partially used, and that one of relatively large cross-section burned more rapidly than a narrower. Finally, burning sulphur is a very disagreeable object to handle: it must be removed from the generator and taken outside the building, for it is difficult to extinguish in the generator when once well alight.

Group B.

As to the effects of formaldehyde in theoretical concentrations of $3\frac{1}{2}$ *per cent. for* 30 *minutes, and* 7 *per cent. for one hour, at room temperature, on* B. typhosus, *where embedded in a piece of flock mattress and where fully exposed.*

The Hydralformant lamp was lit some time before the addition of the "Paraform" tablets so as to get the water well heated.

The temperature inside the chamber rose to 80° F., with relative humidity 86 per cent., and at the conclusion was 72·5° F. with relative humidity 93 per cent.

Results.

There was no sterilisation of *B. typhosus*, even where fully exposed.

Remarks.

This method is obviously of no practical value. No similar experiment was done to ascertain the effect on lice, since this gas is known not to be reliable for the purpose.

Group C.

As to the penetration of dry heat into

(i) *a piece of flock mattress wrapped in two layers of blanket;*

(ii) *a whole mattress, the chamber being loaded with the equivalent of a full set of bedding.*

This group was designed to ascertain whether it were possible to attain a temperature of 55° C. within a mass, such as a mattress, and if so, the length of time required. Obviously, if this temperature could not be attained, or if it occupied an unduly long time in attainment, no useful purpose would be served by proceeding further along these lines.

The method employed was alternately to exhaust the chamber to 15 in. of vacuum and then to destroy the vacuum by admitting hot air until the required temperature was registered.

In (i) the piece of mattress was placed at the level of the centre of the chamber.

Results.

(i) In this series, at the expiration of almost exactly one hour, 55° C. was reached in the centre of the piece of mattress, while in the open centre

of the chamber 75° C. was attained, and at the top 90° C. This was encouraging, and subsequently in the course of later experiments it was found that this period might be materially reduced, while, in the case of loosely suspended articles, penetration was still more rapid.

(ii) Here, a very much longer time was required—so prolonged, in fact, that the method is impracticable for such bulky articles.

Remarks.

It was noted that, after the discontinuance of the heating process, the temperature within a bulky article continued to rise for about 45 min., reaching some 3° C. higher. This would lead to economy in that steam could be shut off from the heating coils (or jacket) during the period of contact.

It was further noted that, as would be expected, a longer time was occupied in attaining a given temperature amongst articles placed at the bottom of the chamber than amongst those at a higher level. Except where stated, the attainment of the desired temperature at this point was the criterion adopted in all later experiments.

Group D.

As to the effects of dry heat on lice and certain micro-organisms, and the fixation of blood-stains.

The following micro-organisms were used: *B. typhosus, B. diphtheriae* and *Strept. haemolyticus.*

Heating was continued until the thermocouple showed a temperature of 55° C. within a piece of flock mattress wrapped in two layers of blanket and placed at the centre of the chamber.

Results.

Lice were killed by 30 minutes' exposure, but the effect on micro-organisms was unreliable, in that while such were in some instances sterilised in the more exposed situations (and hence higher temperatures), they were unaffected where embedded in the piece of mattress, even after exposure for one hour. Incidentally, it was also shown that *Strept. haemolyticus* is much more resistant to dry heat than either *B. typhosus* or *B. diphtheriae.*

Blood-stains were not fixed.

Remarks.

It can be concluded from the above that, while dry heat at 55° C. can be so applied satisfactorily for the destruction of lice, it is quite useless for the sterilisation of micro-organisms—thus, of course, merely confirming previous work.

Group E.

As to the effects of dry heat combined with formaldehyde, on lice and certain micro-organisms: the possibility of injury to rubber, leather, imitation leather furs, silks and woollens: and as to the fixation of blood-stains.

In addition to the micro-organisms used in the former experiments, tuberculous sputum (virulence proved) was, in the later experiments in this group, also subjected to this process.

The test objects were placed in the pockets of coats and amongst the folds of clothing loosely suspended, as well as being embedded in a piece of flock mattress.

The temperature within the articles was first brought up to 50°–55° C. by admission of hot air, after which the required number of "Paraform" tablets were vaporised into the chamber to give the desired theoretical concentration of formaldehyde. In the earlier experiments one dose (= 4–5 per cent.) was given and 30 minutes' contact allowed: in the later ones the dosing was repeated and the period of contact doubled. The repetition of dose increases the concentration of formaldehyde by 50 per cent. at the most, since, theoretically, of the volume of gas previously admitted one half should be withdrawn by the subsequent vacuumisation to 15 in. The total time taken varied from two to two and a half hours when dosing twice and giving one hour's contact.

Results.

(i) *Loosely suspended articles.* With the chamber fully loaded in this manner, complete success was attained in the disinfection of *B. typhosus*, *B. diphtheriae* and *Strept. haemolyticus*—even at the lowest point of the chamber—with a concentration of formaldehyde of 4–5 per cent. (theoretical) following on penetration of dry heat to 50°–55° C. and contact for one hour. Actually, 30 minutes' contact sufficed, but in practice it would be desirable to give the longer exposure, while the repetition of dosage with formaldehyde is a further safeguard. As regards tuberculous sputum, this was disinfected by exposure to formaldehyde 4–7 per cent. following on similar penetration of dry heat, with contact for one hour. No test was made with a shorter period of contact.

(ii) *Bulky articles.* All the above-mentioned infective objects, embedded inside a flock mattress, were disinfected by exposure for one hour to a concentration of formaldehyde, 5 per cent. (theoretical), following on penetration of dry heat to 50° C. A shorter period of contact was not tested.

Owing to the length of time taken to obtain the penetration of dry heat with the chamber fully loaded (*vide* also under Group C), the method is scarcely practicable for the disinfection of the interior of such objects as mattresses, which contain relatively large volumes of entangled air.

Lice were, of course, readily killed.

As to the effects on rubber, etc., articles, no injurious effects whatever were noted, even where such were exposed to the maximum temperature obtainable, *i.e.* close to the top of the chamber.

Blood-stains were, as would be expected, fixed by the action of the formaldehyde.

Remarks.

A further rise of temperature within the articles was again noted following on the introduction of the hot gas, the rise being from 3° to 5° C., while in one instance it was as much as 8° C. amongst the folds of clothing resting on the bottom of the cradle. This rise of temperature will take place even when steam is cut off from the heating coils.

Residual formaldehyde can be neutralised by vaporising liq. ammon. fort. into the chamber on conclusion of exposure; but this is not essential and is, further, liable to cause dampness of the articles.

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SUMMARY AND CONCLUSIONS.

1. An investigation has been carried out, with a view to determining (*a*) whether articles liable to damage by steam can be disinfected and/or disinfested in a standard steam pressure disinfector by the action of dry heat and/or gaseous disinfectants; (*b*) the economic practicability of the method.

2. Lice and bugs can be thus easily destroyed in loosely suspended articles by dry heat at 55° C. acting for 30 min., the total time occupied being one to one and a half hours, depending on the size of the charge.

3. Infective material (non-sporing organisms), including tuberculous sputum, in loose articles, can be disinfected by penetration of dry heat at 50° C. followed by formaldehyde, 5 per cent. (approximately), allowed to act for one hour, the total time not exceeding two and a half hours. Organisms, other than tuberculous sputum, can be disinfected by exposure for 30 min.

4. (*a*) Rubber, leather, imitation leather, furs, silks and woollens are not injured by this method.

(*b*) Blood-stains are fixed by the action of the formaldehyde, but not by dry heat alone.

5. The method is not suited for the disinfection of large bulky articles containing much entangled air.

6. Infective material cannot be rendered sterile, and lice are not killed, by exposure to formaldehyde, 7 per cent. (approximately), for one hour at room temperature.

7. It required an exposure of four hours at room temperature to a concentration of sulphur dioxide beginning at 4 per cent. and falling to 0·75 per cent., in order to kill lice and bugs and to sterilise *B. typhosus* in exposed situations; but even this was ineffective where such were embedded in a piece of flock mattress.

8. Contact with dry heat at 55° C. for one hour cannot be relied upon to sterilise infective material.

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