THE TOXICITY OF SOME COMMON FUMIGANTS TO BODY LICE.

By J. R. Busvine, Ph.D., B.Sc.

Entomological Department, London School of Hygiene and Tropical Medicine.

Introduction.

Outbreaks of typhus or other diseases associated with body lice must be considered as a possible result of prolonged and widespread warfare. The soundest way of checking these diseases is by eliminating the lice, and there would be scope for several types of delousing measures. For example, two of the fumigants dealt with in this paper (hydrogen cyanide and sulphur dioxide) are not now considered satisfactory for fumigating infested clothes, if other methods are available. (The cyanide is too dangerous to be used in this way, and the sulphur dioxide is likely to damage the fabrics.) On the other hand both these gases could be used to fumigate houses contaminated by a case of typhus if their toxicity to lice could be established. But although both fumigants have been used against lice in outbreaks associated with the last war, there is little or no critical experimental work published on their toxicity and efficiency.

The bed-bug, on the other hand, has received much attention in recent years, both on a laboratory and a practical scale. Accordingly bed-bugs were included in many experiments in this paper in the hope that the comparison might be useful.

Laboratory Experiments.

Treatment of Insects.

The lice were taken from a stock reared in gauze-bottomed pill-boxes kept against the skin of the leg during the day as described by Buxton (1939).

Fifteen to thirty minutes before an experiment, lice or eggs were removed, placed in small muslin bags and kept at the fumigation temperature which was 20°C. After the exposure, they were aired for an hour at the same temperature. Then the lice were put back into breeding boxes, examined daily and the mortality estimated 3 days after fumigation. The eggs were incubated at 30°C. and 60 per cent. R.H. to determine the percentage hatch.

The bed-bugs were reared in muslin-topped glass tubes at 20°C. and allowed to feed weekly on the ears of a lop-eared rabbit. They were kept at the same temperature after fumigation, and the mortality estimated 7 to 10 days after exposure. The longer interval was necessary because they did not either die or recover so rapidly as the lice on the leg (approximately 30°C.).

Fumigation Methods.

Experiments with hydrogen cyanide, sulphur dioxide and trichlorethylene were done in 5-litre glass flasks kept in a constant-temperature chest at 20°C. Liquid hydrogen cyanide was introduced with a micro-pipette and the concentration estimated by a gas sample drawn in each test.

The sulphur dioxide was delivered from a gas burette and samples were taken requently to check the accuracy of delivery.

The trichlorethylene was added by a pipette, the quantities being sufficiently arge for reasonably accurate dosage in this way.

Exposures to saturated vapours of naphthalene, paradichlorbenzene, etc., were simply made by lowering dishes or bags of insects into bottles containing excess of the substances under test.

Reprinted from the Bulletin of Entomological Research, Vol. **34**, Part **1**, *April*, 1943.

TABLE I.

Statistics of Log Concentration/Probit kill Regression Lines.

Fumigant	Exposure (hours)	Insect	Stage	Average number used per test	Regression equation	Degrees of freedom		P * > ·05 ** < ·05 *** < 0·01
Hydrogen cyanide	1	*Pediculus*	Adults	13·7	y=3·1329x+08592	7	6·5358	*
,, ,,	,,	,,	III Nymphs	13·7	y=3·7886x−0·5651	4	1·6384	*
,, ,,	,,	,,	Eggs	81·0	y=4·2339x−0·3871	3	1·4974	*
,, ,,	2	,,	Adult	17·7	y=3·6740x+0·9665	7	4·6318	*
,, ,,	,,	,,	III Nymphs	14·9	y=2·9471x+1·4567	9	4·3861	*
,, ,,	1	*Cimex*	Adults	14·9	y=2·4373x+2·5987	8	6·1597	*
,, ,,	,,	,,	Eggs	45·0	Insufficient points	—	—	—
,, ,,	2	,,	Adults	20·0	y=3·7328x+3·2736	5	1·1331	*
Sulphur dioxide	1	*Pediculus*	Adults and III Nymphs	23·2	y=4·1158x+1·2481	8	14·5684	*
,, ,,	,,	,,	Eggs	58·3	y=7·7665x−5·6601	6	44·5374	* * *
,, ,,	,,	*Cimex*	Adults	21·2	y=4·8969x+1·1702	3	2·3359	*
,, ,,	,,	,,	Eggs	21·5	Insufficient points	—	—	—
Trichlorethylene	5	*Pediculus*	Adults and III Nymphs	39·0	y=8·1078x−8·8042	4	5·4342	*
,,	,,	,,	Eggs	62·5	y=11·3811x−16·2372	2	23·3768	* * *
,,	,,	*Cimex*	Adults	45·3	y=10·5441x−14·2792	2	0·6917	*
,,	,,	,,	Eggs	35·0	y=5·7237x−6·0017	3	4·2544	*

Results.

The critical doses of the fumigants were calculated by the methods described by Bliss (1935). Table I gives the regression line formulae and certain other statistics.

The relative toxicity of three fumigants to different stages of louse and bug is shown by the 50 per cent. and 99 per cent. lethal concentrations set out in Table 2. With respect to these three fumigants, the susceptibility of lice is rather similar to that of bed-bugs. The egg stage of both insects is more resistant to sulphur dioxide and trichlorethylene and less resistant to hydrogen cyanide than the other stages. The last nymphal stage of lice is slightly more resistant than the adult (which is often the case with the bed-bug). But the difference, although significant, is small and the two stages were pooled for experiments with sulphur dioxide and trichlorethylene.

TABLE II.

Lethal Concentrations in Milligrams per Litre of Fumigants for different Stages of Louse and Bug.

Fumigant	Exposure		Lethal concentrations to				
			Pediculus			*Cimex*	
			Egg	Nymph III	Adult	Egg	Adult
Hydrogen cyanide ...	1 hour	50% kill	1·87	2·9	2·1	0·4	0·97
,, ,, ...	,, ,,	99% ,,	6·6	12·1	11·6	1·2	8·7
,, ,, ...	2 hours	50% ,,	—	1·6	1·2	—	0·29
,, ,, ...	,, ,,	99% ,,	—	9·8	5·4	—	1·2
Sulphur dioxide ...	1 hour	50% ,,	23·6	8·1		13	6·8
,, ,, ...	,, ,,	99% ,,	47	30		40	21·8
Trichlorethylene ...	5 hours	50% ,,	73	50		84	67
,, ...	,, ,,	99% ,,	118	98		212	112

In Table III will be found the lethal exposures for lice and eggs to substances tested as saturated vapours. The eggs were more resistant than nymphs and adults to all of them.

It will be seen that the less volatile compounds require longer exposures but that their effect is achieved by proportionally very much lower concentrations in air. This conforms to the general rule that equitoxic concentrations decrease on ascending various homologous series but the volatility decreases even faster ; so the saturation concentrations of compound of lower molecular weight are generally most effective.

The practical importance of these facts is that non-volatile substances must be slow in action (unless they have some very unusual specific toxicity). Their advantage over more volatile fumigants is merely in economy ; so little is used in producing a saturated atmosphere.

The crude samples of naphthalene are clearly more toxic than the refined chemical owing to the presence of phenols, cresols, etc., which add to the toxicity. The higher toxicity of impure naphthalene was noted by Nuttall (1918), who advised the use of " unwhizzed " (*i.e.* not purified by centrifuging) naphthalene.

TABLE III.

Lethal Exposures, in Hours, to saturated Vapours at 20°C.

	Lethal exposures to				Saturation concentration (20°C.)
	Eggs		Nymph III & Adults		
	50%	99%	50%	99%	
Drained creosote salts* ...	—	—	1½ hours	3 hours	—
Whizzed naphthalene... ...	—	—	1¾ ,,	4 ,,	—
Pure flake naphthalene ...	24 hours	50 hours	4 ,,	12 ,,	0·6 mg./litre
Paradichlorbenzene	15 ,,	28 ,,	1 ,,	3 ,,	4·9 ,, ,,
Heavy naphtha	2 ,,	4 ,,	¾ ,,	1½ ,,	15 ,, ,,
Trichlorethylene	1 ,,	2½ ,,	⅛ ,,	½ ,,	410 ,, ,,

* " Drained creosote salts " are the crude source of naphthalene which can be partly purified of liquid impurities by centrifuging to " whizzed naphthalene." Further purification evolves the perfectly dry " flake naphthalene."

Field Trials.

House Fumigation.

It is well known that, in fumigating houses to eradicate bugs, the dose used in practice must be many times the concentration lethal in laboratory tests. This is to allow for leakage and absorption and to ensure a high concentration in the free space so that a lethal concentration may penetrate the crevices where the bugs hide.

Lice do not, properly speaking, infest a room ; but large numbers of them may be found in a room inhabited by a very lousy person. In a bedroom in which an infirm and heavily infested man had been living, the writer once found countless numbers on the bedding and several thousands upon each of two small woollen mats on the polished floor. There were also some upon the curtains but few elsewhere in the room. This is to be expected from the known habits of the body louse which clings to the fibres of clothing or fabric. This habit makes it extremely easy to pick up stray lice on the clothing when entering heavily infested premises. If a man has to disinfest a room previously occupied by a lousy typhus patient, he is exposed to considerable risk both of acquiring infected lice and from inhaling louse faeces carrying Rickettsia. The danger from lice would be eliminated if the room were effectively fumigated.

A number of practical fumigations were conducted to ascertain the effectiveness of sulphur dioxide and hydrogen cyanide in killing lice under various conditions. Louse adults and eggs, and sometimes bugs as well, were confined in small muslin bags and about a half dozen of these were placed about the rooms before fumigation. The penetrating powers of the fumigants were tested by covering the bags with 1 to 6 layers of ordinary grey blanket* or by secreting them among furniture.

The buildings were sealed in the usual manner by strips of gummed paper over the cracks in doors, windows or ventilators. In most trials a long thin glass tube was left running from the centre of a room to the exterior so that gas samples could be drawn at intervals during the exposure. After exposure, the bags of insects were collected and aired. The lice were then put into breeding boxes and their eggs and the bugs were put into appropriate incubators.

* As used in A.R.P. posts, etc.

TABLE IV.

Summary of practical Fumigation Tests.

Fumigant	Trial No.	Site	Dose of gas— oz. per 1,000 cu. ft.	Exposure (hrs.)	Weather: Air temperature (midday)	Weather: Wind	Concentration found (mgms/litre): 1 hr.	2 hrs.	4 hrs.	6 hrs.	12 hrs.	24 hrs.	Kill of insects: Exposed 0–1 layers of blanket	Intermediate 2–3 layers of blanket	Protected 3–6 layers of blanket
Sulphur dioxide	2	I	96	12	4°C.	Slight	35	—	—	18	—	—	a.e.b.	a.e.b.	—
,, ,,	6	I	48	12	3°C.	Slight	—	18	—	7·6	—	—	—	a.e.	a.
,, ,,	11	II	96	12	10°C.	Moderate	26	31	24	18	6·6	1·2	a.e.	a.e.	a.e.
,, ,,	14	II	64	12	20°C.	None	16	27	24	18	—	1·3	a.e.	a.e.	a.e.
,, ,,	12	II	64	12	17°C.	Fairly strong	13	21	7·5	2·2	0·3	0·2	a.e.	a.e.	A.E.
,, ,,	13	II	32	12	25°C.	None	6	10	9	8	—	1·1	a.	a.	a.
,, ,,	15	II	32	12	20°C.	Strong	5	8·6	3·2	0·6	—	·06	a.E.	a.E.	A.E.
Hydrogen cyanide	1	I	16	6	4°C.	Slight	9·8	9·7	—	3·5	—	—	a.e.b.	a.e.b.	—
,, ,,	5	I	16	5	3°C.	Slight	6·6	6·6	—	4·3	—	—	a.e.	—	a.e.
,, ,,	9	III	6	6	4°C.	Moderate							a.	a.	A.
,, ,,	4	IV	13	2	25°C.	—							a.e.b.	a.e.b.	a.e.b.
Chlorpicrin	8	I	21	5	3°C.	Slight							a.e.B.		a.e.B.

Key to kills—
- A Adult lice survived
- a Adult lice all killed.
- E Louse eggs survived.
- e Louse eggs all killed.
- B Bug adults survived.
- b Bug adults all killed.

Sites
- I Flats.
- II Top room.
- III Ship.
- IV Fumigation van.

The fumigations were done on various dates between January and August so that a variety of weather conditions was included.

Description of Sites fumigated.

(I) The use of an unoccupied block of three-roomed flats was obtained through the kindness of Dr. Fenton, M.O.H., Kensington. I also had the valuable cooperation of Mr. Walters, Chief Sanitary Inspector of the Borough, in the trials in this building, which were very kindly carried out for me by Messrs. Associated Fumigators, Ltd.

These small self-contained flats which amounted to about 3,000 cubic feet each contained beds and blankets and a few articles of furniture. There were no carpets or curtains.

(II) A room of about 1,500 cu. ft. on the top floor of the London School of Hygiene and Tropical Medicine was used for a number of the tests. This room has two windows and a skylight (the latter being far from gas tight). It was empty except for some stacks of wooden laths.

(III) On one occasion bags of lice were put at various points aboard a destroyer just before a cyanide fumigation for cockroaches.

(IV) Bags of lice and bugs were secreted among some furniture about to be fumigated for bugs in a heated steel van used for the purpose by the Borough of Kensington Health Department.

Results.

The results of relevant experiments are summarised in Table IV.

The curves of concentration of sulphur dioxide during the course of some of the trials have been plotted in fig. 1. It will be seen that the maximum concentration was attained about two hours after the sulphur candles had been lighted. The fall in concentration after that was dependent to a remarkable degree upon the strength of the wind.

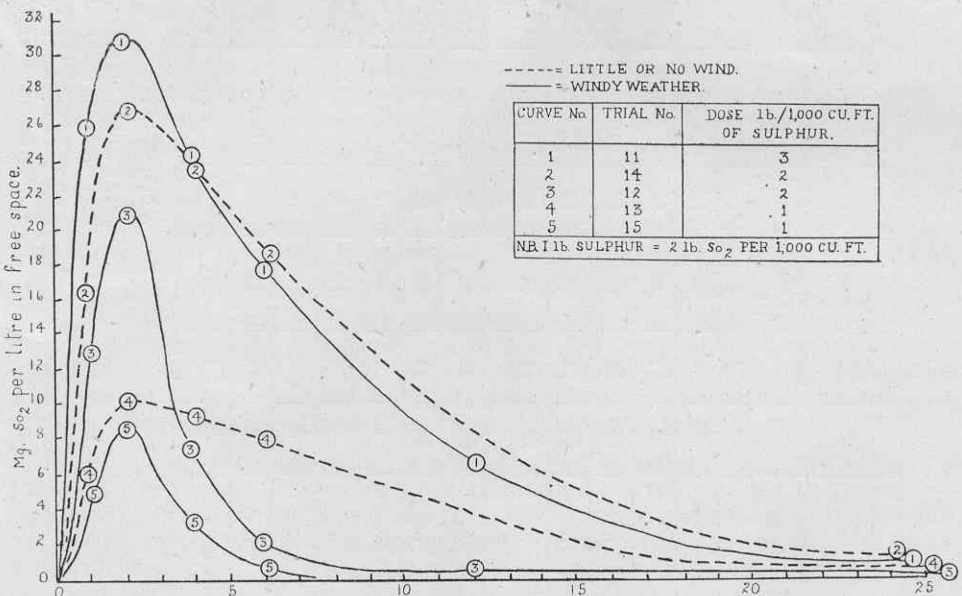

Fig. 1. Concentration curves of sulphur dioxide in fumigation trials (Site II).

Apart from revival of well protected lice after fumigations on windy days, sulphur dioxide proved quite effective. That the eggs revived in positions more exposed than the adults is not surprising in view of their greater resistance.

Although lice were found to be more resistant than bugs in the laboratory tests, the dose normally used to kill bugs in practice was sufficient to kill the lice too. The rather low dose used against cockroaches in the ship fumigation gave a fairly good kill of lice. The only revivals were in well protected places (in a closed drawer, in a suit-case, etc.).

The dosage in the single trial of chlorpicrin was based on recent Russian work with chlorpicrin as a delousing agent. Although it killed both lice and eggs, it does not appear suitable for house fumigation at this dosage, which was expensive and difficult to remove by airing. It will be noticed that bugs were not killed by this gas.

Bin Fumigation.

A very simple method of killing lice on garments is to put them into a dust-bin or a chest with a fumigant of low volatility such as naphthalene. Such substances

TABLE V.

Results of Bin Tests for disinfesting Garments.

Exposure	Test No.	Average temperature	Fumigant	Dose per bin	% kill of test insects	
					Lice	Eggs
20 hours	1	20°C.	Flake naphthalene... ...	Excess	24	50
,, ,,	2	,,	,, ,, ...	,,	17	—
,, ,,	8	,,	Whizzed naphthalene ...	,,	73	—
,, ,,	8	,,	Drained creosote salts ...	,,	100	—
,, ,,	1	,,	Paradichlorbenzene ...	,,	100	50
,, ,,	2	,,	,, ...	,,	81	—
,, ,,	3	,,	Heavy naphtha	32 cc.	100	70
,, ,,	4	,,	,, ,, ...	16 cc.	100	64
,, ,,	3	,,	Trichlorethylene	32 cc.	100	100
,, ,,	4	,,	,, ...	16 cc.	100	96
5½ ,,	9	16°C.	Whizzed naphtha	Excess	14	—
,, ,,	9	,,	Drained creosote salts ...	,,	36	—
,, ,,	5	15°C.	Heavy naphtha	32 cc.	100	36
,, ,,	6	17°C.	,, ,, ...	16 cc.	100	25
,, ,,	7	14°C.	,, ,, ...	,,	100	78
,, ,,	5	15°C.	Trichlorethylene	32 cc.	100	100
,, ,,	6	17°C.	,, ...	16 cc.	100	75
,, ,,	7	14°C.	,, ...	,,	96	90

NOTE (i) In test 1, naturally infested clothes were used: in other tests, overalls with bags of lice in pockets.

(ii) 32 cc. per bin corresponds to 2 gallons per 1,000 cubic feet; or ⅛ cc. per litre.

require a long exposure and are useless as general delousing methods in which the clothes must be rapidly returned to their owners. On the other hand, the clothes of people going into hospital or the protective clothing of individuals working among lousy people can be left in a bin overnight without disadvantage.

A number of tests were made with an ordinary dustbin without any special means of sealing on the lid. Garments, either naturally or artificially infested with lice, were placed inside and sprinkled with the fumigant under test, which was also scattered on the bottom of the bin. After the exposure, samples of lice were removed and put into breeding boxes for subsequent examination as usual. The results are summarised in Table V.

In these practical tests the substances show the same order of efficacy as in the laboratory experiments. The results indicate the unreliability of solid fumigants for destroying lice and their ineffectiveness against the eggs.

Complete kills of adult lice were obtained in $5\frac{1}{2}$ hours by heavy naphtha and trichlorethylene at suitable doses. Eggs were only killed by the higher dose of trichlorethylene.

It is likely that neither of these liquids are ideal fumigants for lice on garments, but they are evidently more reliable than the solid fumigants mentioned.

Summary.

An outbreak of body lice might require several control measures according to circumstances. Two types of fumigant action have been investigated in the laboratory and the field :—

(1) House fumigation for disinfesting typhus-contaminated premises.

Lice were fairly similar to bed-bugs in their resistance to the fumigants tested. In practice, 16 oz./1,000 cubic feet of hydrogen cyanide will kill lice and eggs : 2 lb. of sulphur/1,000 cubic feet is also successful if the wind is not strong.

(2) Bin fumigation of garments by saturated vapours.

The saturated vapours of solids such as naphthalene and paradichlorbenzene are extremely slow in action ; even with 20 hours exposure at 20°C. they are unreliable. Liquids such as heavy naphtha or trichlorethylene are much more promising.

For reading and criticising this paper I am grateful to Professor Buxton in whose department the work was done. My thanks are also due to the Medical Research Council for a grant.

References.

Bliss, C. I. (1935). The calculation of the dosage mortality curve.—Ann. appl. Biol., **22,** p. 134.

Buxton, P. A. (1939). The Louse.—London, E. Arnold & Co.

Nuttall, G. H. F. (1918). Combating lousiness among soldiers and civilians.—Parasitology, **10,** p. 411.

Printed under the authority of His Majesty's Stationery Office
by the South Essex Recorders, Ltd., Ilford

(564) Wt. P77/3730 100 5/43 S.E.R. Ltd. Gp. 432.