A.L. 63, THE ORIGINAL BRITISH ARMY LOUSE POWDER

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(With 3 Figures in the Text)

1. INTRODUCTION

A paper written by us entitled 'The control of the body louse, *Pediculus humanus corporis* de Geer, during wartime' was accepted for publication in this *Journal* in May 1940, but was withdrawn for reasons of security. Since that time great advances have been made with new insecticides, such as D.D.T., and in the methods of louse control. It is felt, however, that some of the original work done by us retains its scientific value. A.L. 63 was the official British army louse powder from 1940 until the introduction of the D.D.T. louse powder in 1944, so that there is also a considerable historical value which warrants publication. This paper is a condensation of the original, written by one of us (H.J.C.-B.) without consultation with the second author (J.McL.), as the latter is still on active service 'somewhere in the Far East'. The original paper is lodged with the Editor of the *Journal of Hygiene*, where it can be seen by anyone who is interested.

2. HISTORY OF A.L. 63

The work began in 1939 with the object of producing a louse powder which could be applied by each individual to his own clothing in order to kill lice and prevent reinfestation. It was also intended that the powder could be used as a prophylactic to protect clean troops against lice, and further that the ingredients of the powder should be readily available in Great Britain or the British Empire. A.L. 63, the product of the research, contained derris. When Japan entered the war and seized Malaya, Dutch East Indies and the Philippine Islands the supplies of derris ceased and so A.L. 63 became obsolete. Some work by one of us in 1943 (H.J.C.-B.) showed that cube root from South America could be used in place of the derris, and A.L. 63 Mark II became a temporary louse powder for the army pending the introduction of D.D.T. louse powder in 1944.

During the period 1940–4, A.L. 63 or A.L. 63 Mark II was used exclusively by the British army in all theatres of war, where it proved its value not only for the prevention and cure of body-louse infestations, but also as a general insect powder. Finally, in the Naples typhus epidemic of 1943–4 it was the only louse powder used by the British troops and the civilians employed by the British army. Its value was shown in that only two cases of typhus occurred amongst the British troops, both of them as a result of the soldiers disregarding orders, and entering air-raid shelters, failing to use the powder and becoming louse infected, and that no cases of typhus occurred amongst the 25,000 civilians employed by the British and treated regularly at fortnightly intervals.

The work reported here is also of interest for two other reasons. It is believed that this is the first time that practical trials of insecticides were conducted with naturally louse-infested persons, a special clinic in the East End of London being established for the purpose. The methods used were later adopted by other workers. Secondly, the principle of activation of derris by high-boiling tar acids, discovered in the course of this work, led to much research by our colleagues of the Cooper Technical Bureau. Much chemical as well as biological work was done but had to remain secret for reasons of security.

3. CHEMICAL DATA

It was decided that one inert dust, or 'filler', should be used with any insecticide to obviate physical differences in the dusts due to different inerts. China clay was selected as being the easiest, cheapest and the one most likely to be obtainable in large quantities throughout the war. Tests of the adhesive properties of various dusts on two types of material, (*a*) cotton print and (*b*) flannelette, showed that china clay was the best all-round filler. Some dusts were better on one type of material and less adhesive on another, and vice versa. The general formula of all preparations was as follows:

Insecticide A	x %
Insecticide B (if any)	y %
China clay	$100-(x+y)$ %

For brevity each preparation was given a reference number (e.g. A.L. 63), and this number or the principle contained in the preparation is used in the text.

(*a*) *Naphthalene*

The material referred to in our experiments as 'pure' was 'refined Flake Naphthalene'. 'Coarse-

https://doi.org/10.1017/S0022172400013553 Published online by Cambridge University Press

ground' refers to naphthalene ground in a small laboratory mortar and the particle size varied considerably. 'Fine-ground' means that all the naphthalene was ground twice through a Christie and Norris mill, using a 60-mesh sieve. The term 'premix' (see A.L. 59, 61, 68) denotes that the naphthalene was melted, china clay added and the mixture stirred. On cooling, the solid mixture was ground to pass a 60-mesh sieve.

(b) High-boiling tar acids

Creosote was tested in one series of our laboratory experiments, but was not used in the field because of its carcinogenetic properties. Cresylic acid is free from this objection. The characteristics of the material used were as follows: a commercial product, obtained by extracting high-temperature coal-tar creosote and then fractionating by distillation; the phenol content was 95–97%, and it boiled substantially between 210 and 300° C.

(c) Pyrethrum

Pyrethrum flowers were used exclusively, and the concentration of pyrethrum is given as the percentage of ground flowers in the preparation. In all the pyrethrum preparations tested, except for a proprietary insecticide, which was used as bought, the flowers contained 0·9% total pyrethrins (I and II).

(d) Derris

One sample of derris root was used, containing 21% of total ether extract, the pure rotenone content being 32% calculated on the extract. The rotenone content of the root was thus 6·72%. Compounded derris preparations are referred to by the rotenone content, i.e. a 1% rotenone product prepared with the particular sample of derris root used in these experiments was a product containing 14·3% of the ground root which gave to the mixture a content of 3% of total ether extract and 1% of rotenone. The root was in the fine state of division customary in horticultural and insecticidal powders.

4. CELL TESTS

(a) Methods

We are indebted to Prof. P. A. Buxton for supplying us with the original lice for rearing a colony.

The lice were reared in small metal cells similar to the boxes described by Downing (1936). The top and bottom of each cell was sealed with no. 1 or no. 6 mesh bolting silk obtained from Messrs J. Harrison Carter and Co. Ltd., Dunstable. The silk was fixed with an alcoholic solution of shellac.

For the insecticide tests twenty or twenty-five lice were used in each cell with any one preparation. Large nymphs and young adults were used exclusively. Bolduirev (1931) and Arakawa (1932) stated that the larvae of *P. humanus corporis* are more resistant to insecticides than the adults. Our findings were in agreement with this, except that the young or first stage nymphs were the most susceptible of all stages.

Each batch of twenty or twenty-five lice was placed in a cell, into which some of the insecticide powder was introduced. The cell and lice were then shaken so as to cover the lice with the dust and remove the surplus dust. Two pieces of flannelette, measuring approximately $\frac{3}{4}$ in. sq., were dusted with the preparation, the dust being spread over the whole surface by lightly rubbing with the fingers, and finally the excess dust removed by one quick flick of the material. The pieces of cloth were then placed in the cell with the treated lice, the top of the cell placed in position and fixed with a piece of adhesive tape. The flannelette material used throughout these tests was cut from one piece of cloth.

After treatment, the cell, with the lice and flannelette, was placed on the leg of a volunteer for the lice to feed. The cells were removed only at night (11 p.m.–8 a.m. approximately). The contents of each cell were examined each day for 6 days.

The number of dead and living lice were counted each day, and the result expressed as the percentage of lice killed. Table 1 gives the average percentage kill for each preparation, the percentages being corrected to allow for the death of lice in the control (untreated) groups.

An untreated control group of insects was included with each series of tests. In addition, groups of lice were treated with the standard inert, china clay, to demonstrate that this dust was truly inert and had no insecticidal value (see Table 1). Further, two tests were made to ascertain the starvation mortality rate in cell tests. For this purpose two groups of lice were confined in cells in the normal test technique, but the basal bolting silk was sealed with adhesive paper so that the lice were unable to feed. The cell was worn on the leg in the usual manner, and the daily mortality observed.

(b) Results of cell tests

(i) *Pyrethrum.* There was a marked effect in 24 hr., the quick paralysing action being comparable to the 'knock-down' effect observed with pyrethrum fly sprays; the paralysing effect appeared to pass off in some cases, but the majority of lice failed to recover and died. It is possible that the paralysing action of the pyrethrum prevented the lice from feeding, so that ultimately many of the lice died from starvation. This explanation may account for the variable results reported by other workers, and is supported by the observations in the field trials.

(ii) *Derris.* Ground derris root, at all concen-

Table 1. *Cell tests. Average percentage kill for each preparation tested*

Prep. no.	Active principles	No. of tests	No. of lice	No. of days after treatment 1	2	3	4	5	6
Control tests:									
	China clay only	1	20	0	0	0	10·5	10·5	10·5
	Starvation	2	40	2·7	78	100	—	—	—
I. Vegetable insecticides:									
1.	6·7 % rotenone-derris root	2	40	0	15·4	28·6	62·8	77·1	85·3
5.	2 % rotenone-derris root	2	40	0	5	10·3	20·5	38·5	50
11.	1 % rotenone-derris root	3	60	0	6·8	14·3	30·4	35·9	38·9
13.	50 % pyrethrum	2	40	7·5	45	84·6	86·9	94·9	97·4
14.	100 % pyrethrum	1	20	0	5	65	90	90	95
12.	1 % rotenone-derris root + 50 % pyrethrum	2	40	0	50	89·8	97·4	100	—
II. High-boiling tar acids:									
17.	5 % H.B.T.A.	3	60	83·7	93·3	96·7	96·7	98·3	100
27.	2 % H.B.T.A.	2	40	2·5	10	15	17·5	17·5	20
26.	1 % H.B.T.A.	1	20	0	5	5	5	5	5
18.	2 % creosote (27 % tar acids)	2	40	15	62·5	67·5	67·5	67·5	67·5
III. Activated derris:									
15.	5 % H.B.T.A. + 1 % rotenone-derris root	2	40	32·5	65	80	90	100	—
16.	2 % H.B.T.A. + 1 % rotenone-derris root	5	105	7·6	28·6	70·5	85·3	89·9	95
47.	2 % H.B.T.A. + 1 % rotenone-derris root	2	45	2·2	36·4	74·9	93·2	100	—
28.	1 % H.B.T.A. + 1 % rotenone-derris root	2	40	5	22·6	38·4	48·7	71·8	86·7
50.	2 % H.B.T.A. + 2 % rotenone-derris root	2	45	4·4	13·6	56·8	72·6	88·6	97·5
24.	10 % paraffin (medicinal)	2	40	5·1	13·2	13·2	13·2	15·8	16·2
25.	10 % paraffin (medicinal) + 1 % rotenone-derris root	1	20	5	30	60	80	90	95
IV. Naphthalene:									
36.	5 % crude coarse naphthalene	1	20	20	45	65	65	70	70
35.	5 % pure coarse naphthalene	1	20	25	60	65	65	70	70
55.	10 % pure coarse naphthalene	2	40	100	—	—	—	—	—
54.	25 % pure coarse naphthalene	2	45	93·3	100	—	—	—	—
53.	50 % pure coarse naphthalene	2	45	95·5	100	—	—	—	—
30.	100 % pure coarse naphthalene	1	20	100	—	—	—	—	—
29.	100 % crude coarse naphthalene	1	20	100	—	—	—	—	—
60.	5 % tetralin	2	40	100	—	—	—	—	—
57.	10 % tetralin	3	65	100	—	—	—	—	—
V. Miscellaneous:									
49.	20 % paradichlorbenzene	2	45	?	84·1	88·6	93·2	93·2	93·2
19.	50 % boric acid	1	20	0	35	50	50	50	50
20.	5 % phenothiazine	1	20	0	5	10	15	15	15
21.	5 % diphenylamine	1	20	0	45	85	90	90	90
22.	5 % pseudo-cumene	1	20	0	10	15	15	15	15
32.	5 % parachlormetaxylenol	1	20	0	10	10	15	15	15
34.	5 % dibrometacresol	2	40	0	2·5	2·5	7·7	12·8	12·8
72.	Neosyl	2	40	90	100	—	—	—	—
73.	100 % balloon sulphur	2	40	2·5	7·7	13·2	13·2	13·2	16·2
VI. Activated derris + other insecticides:									
51.	25 % naphthalene pure coarse*	2	45	100	—	—	—	—	—
59.	29 % naphthalene pure pre-mix*	2	40	100	—	—	—	—	—
52.	50 % naphthalene pure coarse*	2	45	97·7	100	—	—	—	—
58.	10 % tetralin*	2	45	97·7	100	—	—	—	—
56.	10 % tetralin†	2	45	100	—	—	—	—	—
46.	50 % pyrethrum*	2	45	4·4	40	88·6	100	—	—
48.	20 % paradichlorbenzene*	2	45	71·1	81·8	100	—	—	—

* Including 2 % H.B.T.A. + 1 % rotenone-derris root. † Derris extract in place of root.

https://doi.org/10.1017/S0022172400013553 Published online by Cambridge University Press

trations, showed a slow rate of killing, the maximum effect appearing by the fourth day (Fig. 1).

(iii) *High-boiling tar acid.* Three concentrations of H.B.T.A. were used. 5% H.B.T.A. (A.L. 17) gave a high kill (83·7%) in 24 hr., but some of the lice which survived the first 24 hr. appeared to recover from the initial 'shock' before finally dying (see Fig. 1). 2% H.B.T.A. (A.L. 27) was almost ineffective, with a maximum effect in the first 48 hr. Some of the lice which were obviously affected in the first 24 hr. recovered and survived

(iv) '*Activated*' *derris.* In an endeavour to improve upon the effect obtained by derris alone, H.B.T.A. was added, since this had given over 90% kill in 48 hr. when used alone at 5% strength. The results were interesting and unexpected. They are illustrated in Fig. 1.

The 1% H.B.T.A. + 1% rotenone-derris root mixture (A.L. 28) gave a toxicity curve similar to the 6·7% rotenone-derris root (A.L. 1). The 2% H.B.T.A. + 1% rotenone-derris root mixture (A.L. 16) showed a higher toxicity than A.L. 28 but

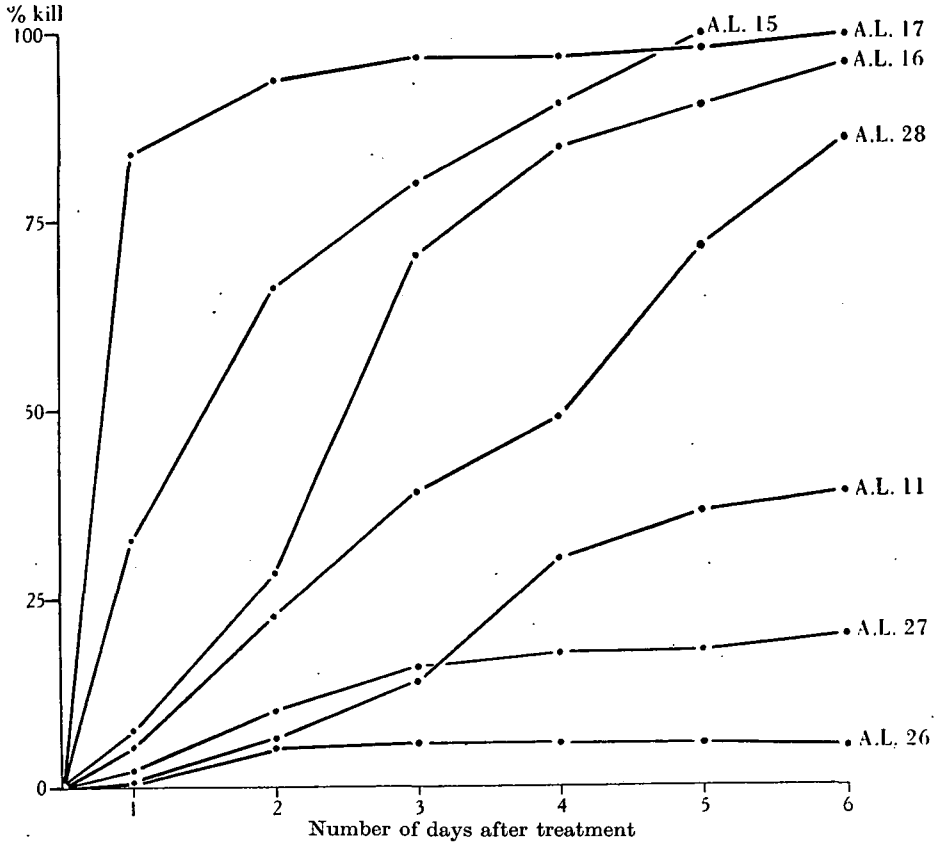

Fig. 1. Cell tests. Group 2. Activated derris. Comparison of rate of kill of activator, activated substance, and mixtures of both together.

the experiments. 1% H.B.T.A. (A.L. 26) killed 1 louse out of 20 in 6 days, but it affected a few lice in the first 24 hr., and these lice recovered. It seemed, therefore, that H.B.T.A. was a *quick-acting poison*, and that the minimum lethal concentration (termed in this report the threshold of toxicity) was approximately 2%.

2% creosote (A.L. 18) was compared with H.B.T.A. mixtures and, weight for weight, was more toxic. As the creosote contained only 27% tar acids it is apparent that the neutral tar oils and tar bases must have insecticidal properties.

a lower toxicity than 5% H.B.T.A. + 1% rotenone-derris root mixture (A.L. 15). The A.L. 15 curve lies below the toxicity curve of 5% H.B.T.A. alone (A.L. 17) and much higher than the 1% rotenone-derris root alone (A.L. 11).

These results show that when 5% H.B.T.A. was mixed with 1% rotenone derris root the H.B.T.A. effect was depressed, but when 1 or 2% H.B.T.A. was mixed with the same quantity of derris root the H.B.T.A. effect was apparently enhanced. In all three cases the derris effect was increased. The apparent non-toxicity of 1 or 2% H.B.T.A. alone

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shows that when 1 or 2% H.B.T.A. is added to derris root the resultant toxicity is considerably greater than could be expected if the result were purely the summation effect, suggested by Hartzell (1930) as one explanation of activation. The absence of a simple summation effect was most clearly demonstrated by the reduction of the 5% H.B.T.A. effect. Thus one ingredient had 'activated' the other. It was clear that the derris root could not have activated the H.B.T.A. because by gradually increasing the H.B.T.A. concentration a reversal of action was obtained. On the other hand, the H.B.T.A. could have activated the derris root because in all three cases the insecticidal action of the derris had been gradually increased without any relation to the insecticidal action of H.B.T.A. In other words, H.B.T.A., even at concentrations below its own threshold of toxicity, was able to activate derris.

The results for A.L. 24 and A.L. 25 in Table 1 showed that an activation effect could be accounted for by a straightforward summation effect.

A powder (A.L. 47) of the same formula as the 2% H.B.T.A. + 1% rotenone-derris root mixture (A.L. 16) was prepared by mixing the H.B.T.A. with the derris root before the addition of china clay. The resulting tests showed no significant difference in toxicity between this and A.L. 16, and further tests (Table 1) showed that a 1% rotenone-activated derris root mixture (A.L. 16) was equal in toxicity to a 2% rotenone-activated derris root mixture (A.L. 50). Thus the method of mixing the ingredients did not affect the activation of the derris, and 1% rotenone-derris root was the maximum concentration of derris root that need be activated, where 2% of H.B.T.A. was used.

It was considered inadvisable to use 5% H.B.T.A. in a dusting powder for human use for fear of causing burning of sensitive skins; the minimum amount of derris root mixed with 2% H.B.T.A. to produce the same insecticidal effect as that of A.L. 16 was not established.

(v) *Naphthalene.* All concentrations of pure naphthalene, from 10 to 100%, gave a 100% kill of lice in 48 hr. (see Table 1). 5% pure or crude whizzed naphthalene failed to give a 100% kill, and there appeared to be no difference in insecticidal power between the pure and crude chemical. This observation is in contrast to the findings of Kinloch (1916).

Tetralin (tetrahydronaphthalene) (A.L. 57 and 60) was tested as a possible alternative activator for derris. The tests showed that it was highly toxic to body lice, and that, weight for weight, it was more toxic than naphthalene (see Table 1). No activation effect was shown with tetralin and derris in cell tests (see A.L. 56) and (A.L. 58) because of the invariable 100% kill of tetralin alone in 24 hr.

(vi) *Miscellaneous.* A variety of chemicals were tested in a search for a quick-killing insecticide. Many of these substances, at the concentrations tested, were valueless. 20% paradichlorbenzene (A.L. 49) appeared promising, particularly because of its quick paralysing action, but it had an unpleasant smell and evaporated rapidly when stored. 5% diphenylamine (A.L. 21) showed a slow action: it was not tested at higher concentrations. A proprietary silica dust (A.L. 72) was rejected in spite of its amazing toxicity because of the necessity of wetting the dust to prevent the powder 'flying', a dangerous characteristic for a preparation that might cause silicosis.

The sulphur used was a very fine dust, and the tests show that it was of no practical value for the control of lice.

(vii) '*Activated' derris and other insecticide.* This series of tests gave little information on the effect of combining a quick-killing agent with activated derris, but was of importance in connecting the relative values of cell tests and field trials. This is discussed later.

5. FIELD TRIALS

It has been our experience in many fields of research to find that insecticide tests on insects confined in small areas on the host, or tests on insects off their normal host, are often very misleading. For this reason it was obvious that trials for the control of human lice must include tests of insecticides on verminous persons.

(*a*) *Methods*

In December 1939, a 'clinic' was established in East London where verminous persons could be examined and treated. The patients were selected from among the inhabitants of common lodging houses and hostels in the area, and from 'down-and-outs' in the streets.

For the insecticide tests the innermost garments of each patient were examined and treated. The shirt, vest and pants were divided into areas, and the numbers of lice in each area were counted and recorded daily. The pure biological results of these examinations were published by MacLeod & Craufurd-Benson (1941). The garments to be treated were dusted on the inner surface only, the dust being applied liberally to the seams and more lightly to the general surface areas. When it had been applied the dust was rubbed into the garment by one firm sweep of the hand over the treated area. One worker treated all the garments in order to ensure uniform treatment. An excess of dust was applied to the garments to eliminate variations in the physical properties of the dust and to ensure that there was no loss of effect through lack of powder.

(b) *Types of field trials*

It was found that the ideals of a good louse powder were (*a*) to kill lice quickly and (*b*) to prevent infestation of clean persons or reinfestation of previously louse-infested persons. Our experience in the cell tests and early field trials showed that these two ideals were, in reality, independent. Thus the work of the field trials was divided into two sections, referred to in this paper as (*a*) 'the rate of kill of lice' or 'quick-killing powers of an insecticide' and (*b*) protection tests, introducing a time factor measured in days, for the period during which a given preparation remained insecticidally active.

The technique for the two types of tests was the same. For the rate of kill tests the patient's clothing was examined for three consecutive days, and for the protection tests nine consecutive days after treatment. All preparations were tested by the first method, and the more promising powders used in the second series.

The protection tests were continued for 9 days after treatment, in order to observe the rate of recovery of the louse population. It was considered that if a patient could be kept louse-free for 9 days the rate of reinfestation would vary considerably in individual cases, because (*a*) the main source of reinfestation would have been removed as all the eggs would have hatched in 9 days; (*b*) the second source of reinfestation, i.e. immigration of lice from the outer clothing, would have taken place within 9 days, and the lice be killed or repelled; and (*c*) the third source of reinfestation, i.e. immigration of lice from outside (not outer clothing), was slow and haphazard.

A third type of test was used in special experiments discussed in the section entitled 'Prophylaxis' and full details are given there.

(c) *Interpretation of results*

The results of each field trial are recorded as the number of live lice, adults or nymphs, observed on the treated garments. Several methods of assessment, incorporating correction factors, can be used to express the results mathematically, but, in our opinion, the most reasonable method is to express all the daily numbers of lice observed as a percentage of the total number of lice recorded on the day of treatment.

In the tests of the rate of kill of lice the percentage assessment is reasonably accurate. In the protection tests, where the reinfestation factor was in full operation, the results are less reliable, as the rate of reinfestation was not necessarily in direct proportion to the original number of lice. Furthermore, many uncontrollable factors influenced the results such as (*a*) the density of the original louse population before treatment, (*b*) the type of infestation, normal or otherwise (see Macleod & Craufurd-Benson, 1941), (*c*) the standards of personal hygiene of each experimental subject, (*d*) the physical properties of the dust, more particularly its adhesion to fabrics, and (*e*) the type of material of which the garments were made.

It will be clear that while the tables and figures give a reasonable indication of the results, it is essential that the individual protocols should be carefully studied and the various factors taken into account if a true interpretation of the tests is to be made.

(d) *Results of field trials*

The combined results of all tests are given in Table 2.

(i) *Pyrethrum.* The quick paralysing action of the pyrethrum was very noticeable. The reduction in the numbers of lice was due to the paralysed lice failing to maintain their hold on the clothing and falling off. Further, the tests with this preparation were conducted in two series at an interval of a fortnight with different batches (A.L. 83 and 107), and the results were very different, suggesting that the action of pyrethrum was uncertain.

(ii) *Derris.* The results with two of the derris dusts, A.L. 1 and 11, were poorly assessed, but sufficient evidence was obtained by personal observation to show that the slow action of the derris permitted the lice to migrate away from the treated areas.

The derris and pyrethrum mixture A.L. 12 was also poorly assessed, but the tests showed that the derris did not inhibit the paralysing action of the pyrethrum.

(iii) *High-boiling tar acid.* The 5% (A.L. 17) and 2% (A.L. 27) H.B.T.A. mixtures both showed the same comparative results as in the cell tests, the maximum effect being produced in the first 24 hr.; there was no persistent effect.

(iv) *Activated derris.* The effect of adding 5 or 2% of H.B.T.A. to 1% rotenone-derris root (A.L. 15 and 16) was carefully tested, and again an activation effect was obtained. The lowest concentration of H.B.T.A. that would activate 1% rotenone-derris root was not established, but it is clear that the 2% H.B.T.A. mixture gave as good results as the 5% mixture.

(v) *Naphthalene.* The results show that the full effect of the naphthalene is obtained within 24 hr., so this substance is a quick-killing insecticide.

(vi) *Miscellaneous.* These substances were tested in the protection tests and are only included in Table 2 for interest. They are discussed later.

(vii) *Activated derris + other insecticides.* In this group, 2% H.B.T.A. + 1% rotenone-derris root were incorporated in each preparation.

The series show the precise value of (*a*) the concentration and (*b*) the physical state of the

https://doi.org/10.1017/S0022172400013553 Published online by Cambridge University Press

naphthalene. Table 2 shows that the coarse-ground naphthalene mixtures (A.L. 51 and 52) are slightly less effective than either the fine-ground or pre-mix preparation ('pre-mix', see § 3, 'Chemical data'). There appeared to be little difference between the fine and pre-mix preparations, so the fine-ground mixture was selected as being easier to manufacture.

efficient louse powder. The results (see Table 2) did not support this theory, and it appears that quick-killing actions of activated derris and pyrethrum are very similar, that their actions are not enhanced by mixing the two insecticides, and that the individual actions of activated derris and pyrethrum are not inhibited by the presence of the other.

Table 2. *Field trials. Rate of kill of lice*

Number of lice observed after treatment expressed as average percentage of original infestation.

Group	Prep. no.	Active principles	No. of cases	Total lice in all cases	Days after treatment 1	2	3
Vegetable insecticide	1	6·7 % rotenone-derris root	2	58	54·5	24	20
	11	1 % rotenone-derris root	2	?*	?	?	?
	83	Proprietary insecticide batch 1. 64 % pyrethrum	6	1918	11·8	9·2	18·2
	107	Proprietary insecticide batch 2. 64 % pyrethrum	6	405	34·8	35·8	48·7
	83 + 107	Average of proprietary insecticide	12	2323	23·3	22·5	33·5
	12	1 % rotenone-derris root + 50 % pyrethrum	4	?	?	?	?
H.B.T.A.	17	5 % H.B.T.A.	2	117	41·4	87·5	96·2
	27	2 % H.B.T.A.	2	48	64·4	123	126·5
Activated derris	15	5 % H.B.T.A. + 1 % rotenone-derris root	2	342	42·5	23·6	9·2
	16	2 % H.B.T.A. + 1 % rotenone-derris root	15	1919	32	15·7	15·5
	25	10 % paraffin (medicinal) + 1 % rotenone-derris root	2	69	27·7	26·4	47·3
Naphthalene	36	5 % crude coarse naphthalene	2	55	102	143	185
	54	25 % pure coarse naphthalene	2	134	111	109·5	114·2
	66	25 % pure fine naphthalene	1	16	—	56·3	56·3
	69	50 % pure fine naphthalene	3	137	35·2	29·5	43·2
	57	10 % tetralin	3	177	71·3	93·9	127
Miscellaneous	70	50 % naphthalene + 14·3 % derris root A + 35·7 % china clay	3	403	29·4	22·9	26·1
	N.C.I.	96 % naphthalene pure + 2 % creosote + 2 % iodoform	3	2674	7·2	8·4	15·4
	82	2 % H.B.T.A. + 1 % rotenone-derris root + 10 % Seekay wax	6	1226	6·3	2·7	2·3
Activated derris + naphthalene	51	25 % naphthalene pure coarse	3	475	12·9	24	15·9
	62	25 % naphthalene pure fine	3	279	4·7	7·5	11·9
	68	25 % naphthalene pure pre-mix	3	453	8·1	5·1	6·2
	52	50 % naphthalene pure coarse	2	94	10·7	7·5	—
	63	50 % naphthalene pure fine	9	759	4·1	13	13·4
	61	50 % naphthalene pure pre-mix	3	106	5·6	12	5·4
	58	10 % tetralin	3	681	52·3	38·8	37·6
Activated derris + pyrethrum	85	25 % pyrethrum	5	284	16·1	10·2	19·2
	46	50 % pyrethrum	5	549	15·8	13·8	22·2
	106	50 % pyrethrum (proprietary insecticide)	4	441	21·8	9	10·8

* ? = accurate data not available.

The 10 % tetralin-activated derris mixture (A.L. 58) gave unsatisfactory results, due, in our opinion, to the bad physical state of the powder.

It was thought that the slow certain action of the activated derris might ensure that all lice paralysed by the action of the pyrethrum would die, and so the combined actions would produce a highly

6. PROTECTION TESTS

The consolidated results are given in Table 3, and the four most important results illustrated in Fig. 2.

N.C.I., the preparation devised during the 1914–18 War, gave a very quick kill in 24 hr., but after a delay of a further 48 hr. the louse populations increased rapidly, showing that there was no pro-

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Table 3. *Duration of protection against reinfestation after treatment of verminous persons*

Daily infestation expressed as a percentage of the original infestation.

Reference no.	Formula	No. of cases	Total no. of lice	Average percentage of original infestation—days after treatment								
				1	2	3	4	5	6	7	8	9
N.C.I.	97 % naphthalene 2 % creosote 1 % iodoform	3	2684	7·2	8·4	15·4	32·5	59	100	—	—	—
A.L. 69	50 % naphthalene 50 % china clay	3	137	35·2	29·5	43·2	58	57·9	61·1	66·7	—	—
A.L. 70	50·0 % naphthalene 14·3 % derris root (1 % rotenone) 35·7 % china clay	2	169	38·4	30·6	35·8	40	68·7	100	—	—	—
Proprietary insecticide A.L. 83 and 107	65 % pyrethrum approximately	12	3176	23·3	22·5	33·5	33·4	31·2	42·7	49·2	63·5	79·9*
A.L. 85	58·7 % china clay 14·3 % derris root (1 % rotenone) 2·0 % high-boiling tar acid 25·0 % pyrethrum	5	674	14·1	10·2	19·1	17·5	32·8	53·7	60·4	57·7	56·3
A.L. 46	33·7 % china clay 14·3 % derris root (1 % rotenone) 2·0 % high-boiling tar acid 50·0 % pyrethrum	5	649	15·8	13·8	22·2	20·6	22·1	42†	29·9†	48·1†	39·4†
A.L. 16	83·0 % china clay 15·0 % derris root (1 % rotenone) 2·0 % high-boiling tar acid	13	1589	28·9	16·7	15·7	12·8	21	26·4	45·6	43·1	38·1
A.L. 82	73·7 % china clay 14·3 % derris root (1 % rotenone) 2·0 % high-boiling tar acid 10·0 % Seekay wax	6	1226	6·3	2·7	2·3	3·8	17·6	13·9*	15·4*	8·4*	8·3*
A.L. 63	50·0 % naphthalene 14·3 % derris root (1 % rotenone) 2·0 % high-boiling tar acid 33·7 % china clay	6	482	2·9	5	5·4	5·4	8·4	13·4	24·7	31·1	28·2

* Five cases only.

† Four cases only.

tective value. A.L. 69, 50% naphthalene, had less quick action in 24 hr., but in other respects was similar to N.C.I. A.L. 70, 50% naphthalene and 1% rotenone-derris root, was similar to A.L. 69 and N.C.I., showing that the action of the derris root, if any, was too slow to enhance the value of the naphthalene.

Two sets of tests were made with pyrethrum powder, A.L. 83 and 107, with different results, though in both tests the maximum period of protection was very short; the quick action was also very poor. When pyrethrum was incorporated with activated derris root, A.L. 85 and 46, the results were better than those obtained with pyrethrum alone but inferior to those obtained with A.L. 16, an activated derris root powder. The results suggest, as in the cell tests, that the quick-killing actions of pyrethrum and activated derris were very similar, and that the effect of the mixture was no better than activated derris alone.

The activated derris root dust, A.L. 16, had a slow action which required 3–4 days to attain its maximum effect. The slow rate of increase of lice after the fourth day suggested that the powder was exerting a good protective action. When naphthalene was added to the activated derris root A.L. 63, the good quick-killing action of the naphthalene was obtained and the long protective value of the activated derris successfully prevented reinfestation for 7–8 days.

A.L. 82, a preparation containing 10% Seekay wax and activated derris root, was very successful and was equal in effect to A.L. 63. The Seekay wax had to be abandoned because of the risks of dermatitis, etc. (Browning, 1937).

7. PROPHYLAXIS

Preparation A.L. 63 was selected for the prophylactic trials. These tests were conducted by giving each of twenty-one men a new army-pattern shirt, and the men, wearing the shirts next to their skin, without washing them until given permission to do so, and wearing their own clothes over the shirts, were examined daily. Nearly all the men came from the same lodging-house, so that the possibilities of infestation were to that extent fairly uniform. Each man's louse history was known from previous work, so that the patients were classified into three classes: (*a*) clean type, never having lice; (*b*) average type, usually with 40–70 lice each; (*c*) dirty type, usually with over 100 lice. Three of these men were exceptionally dirty and placed in a special category. Thus in each group, as described below, there were two class *a*, two class *b*, two class *c* and one exceptional case.

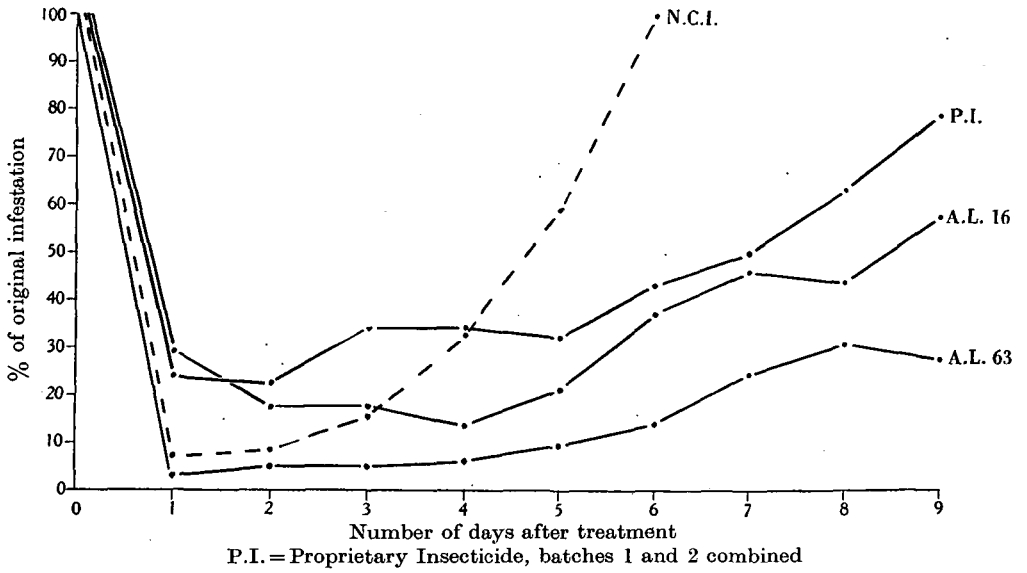

Fig. 2. Duration of protection after treatment of verminous persons. Average results of all treatments with each preparation.

The twenty-one men were divided into three groups:

Group A. Issued with a new army shirt, untreated, to observe the natural infestation rate.

Group B. Issued with a new army shirt, treated with A.L. 63, on the inner surface only, at the time of issue, to observe the protection value of this preparation against infestation of a clean garment.

Group C. Issued with a new army shirt, treated with A.L. 63, on the inner surface only, at the time

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of issue, and retreated twice on the inner surface only, at 8-day intervals, to observe the effect of serial treatment in preventing reinfestation of a clean shirt.

Table 4 and Fig. 3 show that group A, the untreated shirts, became increasingly lousy at a steady rate, the infestations averaging 70·8 lice per man in 10 days. In group B, shirts treated at the time of issue only, the men remained almost free of lice for 5 days. It would be impossible to prevent some degree of infestation, as the lice must reach the treated surface of the shirt before they can become affected. Hence an average of 1–2 lice per man was, for practical purposes, complete protection. On the 6th day the curve of the number of lice observed rose, showing that the maximum protection period had been passed. From the 6th to 15th day the number of lice fluctuated about a higher level (five lice), until on the 16th day the curve began to rise steeply, showing that all effect of the treatment had been lost. In individual cases the length of maximum protection varied from 5 to 11 days, average 7–8 days, and the maximum + partial protection varied from 14 to over 19 days, the average being approximately 16 days.

In group C, the serially treated shirts, the same increase in degree of infestation on the 6th day was observed as in group B. Then the lice that were becoming established and forming the nucleus of a colony were destroyed at the second treatment 8 days after the first treatment. A third treatment was given 8 days after the second, but from the 9th day after the commencement of the experiment until the observations ceased 19 days later (28 days from commencement) the lice never became established. This proved the value of serial treatments in preventing infestation of clean shirts, even when exposed to verminous conditions.

The three exceptionally heavily infested cases are shown separately in Table 4. The general results were the same, though the periods of protection were substantially shorter, due probably to the large reservoir of lice and eggs in the outer garments which brought about a greater rate of reinfestation.

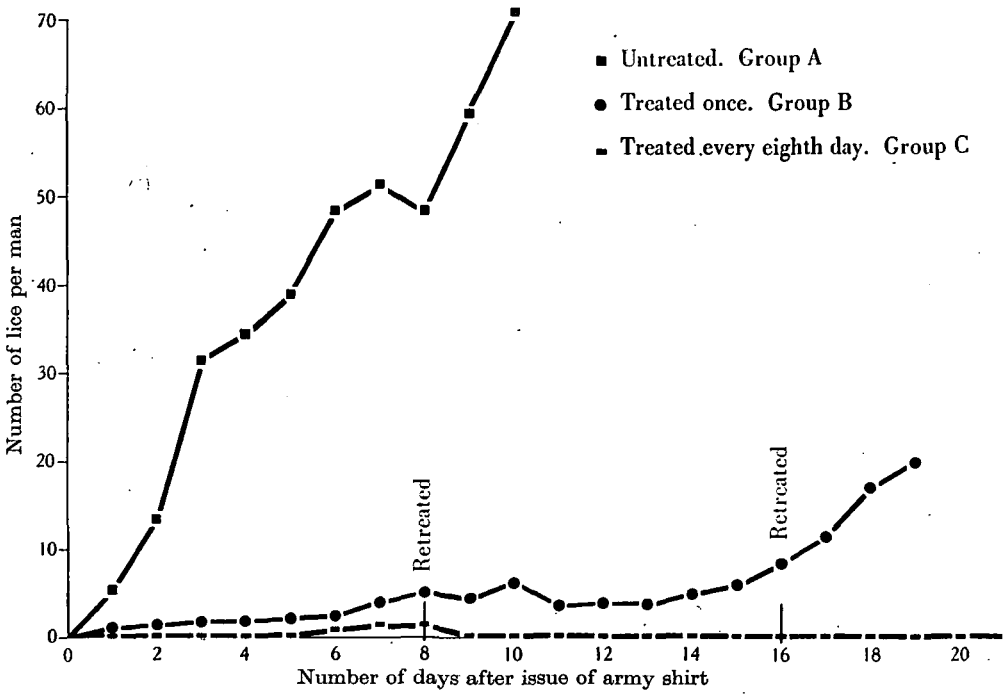

Fig. 3. Protection against infestation of clean army shirts under verminous conditions.

The results of the trial show that (*a*) one treatment of a clean shirt afforded complete protection against infestation for an average of 7–8 days, and a minimum of 5 days, even in the most verminous cases; (*b*) lice were prevented from seriously infesting a man for an average of 16 days after treatment, this period being shorter in very verminous cases; (*c*) serial treatment of the inside only of the shirt at 8-day intervals prevented a person becoming infested with lice, for a period of 1 month's continuous wearing of the garment.

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Table 4. *Duration of protection against infestation of clean army shirts under verminous conditions*

(*a*) Normal infestations.

Case no.	No. of days after treatment: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28
Controls: group A, untreated																								
80	2/0	0/3	1/7	2/3	3/3	2/4	3/4	5/3	2/0	6/1														
81	0/0	2/0	5/1	4/4	4/3	4/5	6/11	4/12	8/22	7/26														
82	0/0	3/1	4/7	3/4	4/11	4/12	8/18	4/17	16/7	18/8														
83	9/5	16/21	20/24	17/25	20/41	21/50	21/39	31/45	33/62	40/63														
84	2/0	1/14	0/28	5/32	4/31	8/34	8/39	6/44	11/52	30/63														
85	8/5	4/17	11/81	8/100	7/105	15/132	18/146	10/141	30/115	30/133														
No. of lice per man	5·2	13·7	31·5	34·5	29·3	48·5	51·8	48·5	59·7	70·8														
Treated once, group B																								
87	1/0	0/0	0/0	1/0	0/1	0/1	1/1	1/4	1/2	1/1	0/0	0/0	0/0	1/0	0/0	0/3	1/3	2/6	3/6					
88	1/1	1/0	2/1	1/1	2/0	6/0	9/3	8/4	4/9	8/9	7/4	3/7	4/4	4/6	0/10	3/14	2/19	9/19	10/32					
89	1/1	0/0	1/0	1/0	0/1	0/0	1/2	1/0	1/0	0/4	2/4	Called up under Armed Forces Act												
90	0/0	0/0	0/0	0/0	0/0	1/0	0/0	1/0	0/0	0/0	1/0	3/0	3/0	6/3	4/10	1/10	3/16	8/24	5/25					
92	0/0	1/0	0/0	0/0	3/0	6/3	7/2	7/1	3/1	4/2	5/4	Shirt washed												
93	0/0	0/0	1/0	0/2	0/2	0/3	1/2	1/1	1/1	4/1	2/0	1/1	2/1	2/0	0/0	2/2	1/1	0/0	1/0					
No. of lice per man	0·8	0·3	0·8	1	1·5	3·3	4·8	4·8	3·8	5·7	4·8	3·75	3·5	5·5	6	8·75	11·5	17	20·35					
Treated serially, group C																								
94	0/0	0/0	0/0	0/0	0/0	0/0	0/2	0/0	0/0	0/0	0/0	1/0	0/0	0/0	0/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/0
95	0/0	0/0	0/0	0/0	1/0	0/0	1/3	1/0	1/0	0/0	0/0	1/0	0/0	0/0	1/0	0/0	0/0	0/0	0/1	0/0	0/1	0/0	1/1	0/1
96	0/0	0/0	3/0	0/1	0/0	0/0	0/0	1/0	0/0	1/0	0/0	1/0	1/0	0/0	0/0	0/0	0/0	0/0	0/0	0/1	0/0	1/0	0/0	0/1
97	0/1	1/1	2/0	1/0	1/2	2/1	0/0	1/1	1/0	1/0	0/0	0/0	0/0	1/0	0/0	2/1	0/0	2/0	0/0	0/0	1/0	0/0	0/0	0/0
98	0/0	0/0	0/0	0/0	1/0	0/0	0/1	0/1	0/0	0/0	0/1	0/1	0/0	0/2	0/0	0/0	0/0	1/0	0/0	—	0/0	0/0	1/1	0/2
100	0/1	1/0	0/0	1/1	0/1	0/3	1/2	0/6	0/0	0/0	1/2	0/0	0/1	0/1	2/1	1/1	0/0	0/1	0/0	—	0/0	0/0	1/1	0/1
No. of lice per man	0·3	0·5	0·8	0·6	1	1	1·7	1·8	0·3	0·3	0·6	0·6	0·3	0·6	0·8	0·8	0	0·6	0·15	0·5	0·3	0·15	1	1

(*b*) Exceptionally heavy infestations.

Group A																								
86	35/724	30/807	40/920	32/686	28/401	23/228	70/326	116/384	76/277	84/299														
Group B																								
91	12/12	10/13	8/32	12/19	14/28	13/37	35/74	37/74	45/75	95/118														
Group C																								
99	25/82	11/51	17/43	12/23	13/24	11/56	6/93	15/134	3/9	3/10	1/7	1/12	0/8	0/13	1/36	4/45	0/3	0/1	0/0	0/2	0/0	1/0	2/0	1/1

8. DISCUSSION

It was stated earlier in this report that previous experience in other fields of research had shown that the reactions of external parasites of domestic animals were considerably influenced when these parasites were prevented from leading a normal life, either by being confined in certain areas on their natural host or when maintained under conditions comparable with their natural habitat but actually off their host.

This fact is substantiated once more by the present research work. In the cell tests the precise insecticidal value of a preparation could be obtained because the lice were unable to avoid the treatment, and the complicated variable factors encountered in field trials were eliminated. In the field trials, the insecticidal value of a preparation was only a part of its true value as a preparation for controlling lice. In spite of the wide difference of the cell tests and field trials, the general results from each and any preparation were relatively the same. There was, however, a distinct difference in (*a*) the minimum concentration required to give a small percentage kill, and (*b*) the actual insecticidal value because the variable factors in the field trials were sufficiently strong to prevent a preparation developing its full effect.

The higher concentrations required to give a small percentage kill in the field trials compared with that in the cell tests is illustrated by comparing any of the preparations containing 10% or more of naphthalene, which in cell tests gave 100% kill in 48 hr., and sometimes in 24 hr., but in the field failed to do so. Further, 10% tetralin and 5% tetralin in cell tests gave 100% kill in 24 hr., yet 20% tetralin appeared to have very little effect in the field. 5% H.B.T.A. alone had a marked effect (average 83·7% kill) in 24 hr. in cell tests, but had no effects in the field.

It may be argued that the field trials were so influenced by the various uncontrollable factors that the insecticides were not given a fair chance. This is true, in spite of the fact that the insecticides were liberally applied to prevent some of these variable factors from influencing the result. There is also the undeniable fact that in the field trials the lice were living normally, so having the best chance to avoid or resist the action of any insecticide.

Both the cell tests and the field trials show the value of activating derris root to enhance the toxicity of the derris root.

Several theories have been advanced to explain a similar phenomenon observed in other fields of research. Inman (1929) and Dills & Menusan (1935) suggest that it is due to an increased contact between the insect and the insecticide. This theory could explain the activation effect of H.B.T.A. because derris extract is soluble in this. It could also explain the action of the medicinal paraffin, although here the paraffin is not a solvent for derris extract and, in any case, a simpler explanation can be found in Hartzell's (1930) summation effect. Another theory suggests that a chemical change is produced by the activator, and support is lent to this by the work of McGovran (1929) on the activation of nicotine. Hurst (1940) has suggested that activation occurs when a non-polar substance is combined with a polar substance, because the non-polar substance is able to penetrate the thin outer lipoid layer covering an insect. The activator H.B.T.A. is polar, so that Hurst's theory cannot explain the H.B.T.A. derris root activation effect. Yet another explanation might be found in the theory that the so-called activator merely operates by affecting the insect sufficiently for the slow action of the so-called activated substance to be quickened.

The mechanism of the activation recorded here has been studied by our colleagues; a satisfactory explanation of the phenomenon has not yet been established.

9. SUMMARY

1. The problem of louse control by powders has been shown to be twofold, namely (*a*) to kill the lice present on a verminous person at the time of treatment, and (*b*) to prevent reinfestation of a deloused person or infestation of a clean person. In these experiments no single insecticide was found that would fulfil both functions.

2. The work shows the necessity of using laboratory tests ('cell tests') in conjunction with insecticide tests on the parasite living under natural conditions ('field trials').

3. The technique and results of the cell tests and the field trials are described in detail. In the field trials naturally louse-infested persons living in verminous surroundings were treated and examined daily to observe the true insecticidal value of each preparation.

4. Naphthalene was found to be the most effective insecticide for killing body lice quickly. It failed to give any protection against reinfestation.

5. The vegetable insecticides, derris and pyrethrum, were found to be toxic to *Pediculus humanus corporis*, but either alone or in combination with each other they were inferior to other combinations of insecticides.

6. The combination of high-boiling tar acids and derris resulted in the combined chemicals being more toxic to lice than either alone. This proved an activation effect, and the theory of activation is discussed.

7. Activated derris, while slow in killing lice, was

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shown to be the best preparation which gave protection against reinfestation.

8. The preparation referred to as A.L. 63 was outstanding as the best preparation that controlled body lice and which fulfilled the original conditions stipulated for a successful louse powder for human use. The formula is:

H.B.T.A.	2 %
Derris root	14·3 % giving 1 % rotenone and a minimum of 3 % extract in the final product
Naphthalene	50·0 %
China clay	33·7 %

The nature of each chemical in this formula is defined.

9. A.L. 63, when applied to the clothing of a verminous person, killed 95 % of all lice on the treated garment in 24 hr., and gave complete protection against reinfestation for an average of 5 days, and partial protection for 8 days. When applied to clean garments as a prophylactic measure, A.L. 63 gave complete protection for an average of 7–8 days, and partial protection for approximately 16 days.

10. Patients living in a verminous environment were made to wear one shirt continuously for a month without washing it. Even under these conditions they were protected from infestation by treatment of the inside of the shirt, at 8-day intervals, with A.L. 63.

11. A short history is given of the use of A.L. 63 in the British army from 1940 to 1944.

During this work we have had much help and sympathy from many people, but we would like to place on record our especial thanks to the following: Prof. P. A. Buxton, of the London School of Hygiene and Tropical Medicine, for supplying us with the original material for establishing a louse colony, and for his great interest and encouragement during the work; Dr W. E. Parry, the Divisional Police Surgeon at Spitalfields, for his kindness in describing the best areas to search for suitable patients, and his assistance in finding suitable accommodation for establishing the 'clinic'; those numerous volunteers, within the Cooper, McDougall and Robertson organization, who offered to feed lice when the colony was being maintained at the Research Station, and suffered much discomfort while doing so.

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(*MS. accepted for publication* x. 1940 *under the title* '*The control of the body louse,* Pediculus humanus corporis *de Geer, during wartime*', *but withdrawn for security reasons. The present MS. received for publication* 22. VIII. 45.—Ed.)