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EFFECTIVENESS OF DDT DUSTING IN CONTROLLING RAT ECTOPARASITES AND TYPHUS INFECTION IN RATS

Newell E. Good
Scientist (R)

The effectiveness of DDT dusting operations in reducing the hazard of transmission of murine typhus to man is measured by two methods: (1) the reduction in rat ectoparasites and (2) the reduction in typhus infection in rats. The effect of this work in reducing human typhus can be measured of course only in the reduction occasioned in the number of reported human cases. Reduction in rat ectoparasites usually takes place within 1 or 2 days after dusting, whereas a year or more may elapse before the full import of the reduction in human typhus is apparent. Typhus in this country is a disease of rats which man acquires by accident. During the period 1945-49 approximately 18 percent of all rats tested proved positive for typhus. During these same years, an average of 2,485 human cases was reported per year in the nine Southeastern States (including and south of North Carolina and Tennessee, plus Louisiana and Texas), for an over-all average case rate of 92 per 10,000 or 0.009 percent. Thus it is observed that typhus is approximately 2,000 times more prevalent in rats than in man. This comparison is justified if one considers that rats probably live only about 1 year in nature and that most infections therefore are more or less recent. Since infection rates in rats are so much higher, they are considered to be much more significant statistically in measuring present typhus reduction and also in indicating probable future typhus incidence in man.

Eight species of ectoparasites commonly infest rats in the Southern States. These include three species of nonsticktight fleas, *Xenopsylla cheopis*, *Leptopsylla segnis*, and *Nosopsyllus fasciatus;* the sticktight flea, *Echidnophaga gallinacea;* three species of mites, *Liponyssus bacoti*, *Laelaps echidninus*, and *Laelaps nuttalli;* and the rat louse, *Polyplax spinulosa*. Other species, such as the cat flea, *Ctenocephalides felis*, also may be taken on rats. Any or all of these species of ectoparasites possibly may be involved in the transmission of typhus from rat to rat. However, only the oriental rat flea, *X. cheopis*, appears to be of any great importance in transmitting murine typhus to man; at least control of *X. cheopis* is correlated directly with a lowered typhus case rate in man. The degree of control obtained of this flea, therefore, is of particular significance in any evaluation of the effectiveness of typhus control operations.

THE CONTROL OF RAT ECTOPARASITES BY DDT DUSTING

Ten percent DDT dust in pyrophyllite, applied to rat runs and burrows, has been used on a large scale since the latter part of 1945 for the control of rat ectoparasites. During all of this period of more than 4 years, rats have been trapped systematically in both dusted and nondusted premises in each of the Southeastern States, and their ectoparasites removed and identified. Data on rats examined during the period from September 1945 through September 1949 are now available.

There is considerable variation in the effectiveness of DDT dust against the different species of rat ectoparasites. Fortunately, the ectoparasites which are the most important vectors of murine typhus (*X. cheopis* and the other nonsticktight rat fleas) are the ones against which DDT dust is most effective. In general terms it may be stated that 10 percent DDT dust, as applied for reduction of human typhus, gives very good control of each of the nonsticktight rat fleas, *X. cheopis*, *L. segnis*, and *N. fasciatus*; poor to fair control of the sticktight flea, *E. gallinacea*; good control of the mite, *L. nuttalli*; but only fair control of the other rat mites, *L. bacoti* and *L. echidninus*; and very poor results against the rat louse, *P. spinulosa*. Cat and dog fleas are affected little by ordinary typhus control dusting methods but can be controlled if the dust is concentrated in the places frequented by dogs and cats. Control of the sticktight flea, likewise, might be improved by the dusting of chicken houses, which are the most common habitat of this flea.

The natural abundance of rat ectoparasites depends largely upon the season and the type of weather. Thus we find an increase of *X. cheopis* during the warm season and a decrease during the colder part of the year. The abundance of rat ectoparasites likewise varies from year to year. *X. cheopis* did not become as numerous in the summers of 1947 and 1948, each of which was preceded by a cold winter, as in the summer of 1946. On the other hand, there was an unusual increase in the abundance of this species, and of other fleas, in the latter part of the warm 1948-49 winter. The yearly and seasonal trends in both dusted and nondusted areas are shown in figure 1.

Figure 1 shows that marked reduction was obtained for the first 6 months after dusting at all seasons of the year during each of these 4 years. Data on individual months, however, show that in 1 month in each of the years 1945 through 1948 the average number of *X. cheopis* per rat commonly referred to as the "*X. cheopis* index," exceeded 0.9 but was in no instance higher than 1.3. During 1949 the highest *cheopis* level was more satisfactory, being 0.5 per rat.

Averages for the entire year for the years 1946 through 1948, and for the first 9 months of 1949 are as follows:

Application of dust	1946	1947	1948	1949 (9 months)
Nondusted	2.8	2.1	2.3	2.7
Dusted within 6 months	0.4	0.4	0.3	0.2
Dusted more than 6 months previously	1.1	1.1	0.5	0.7

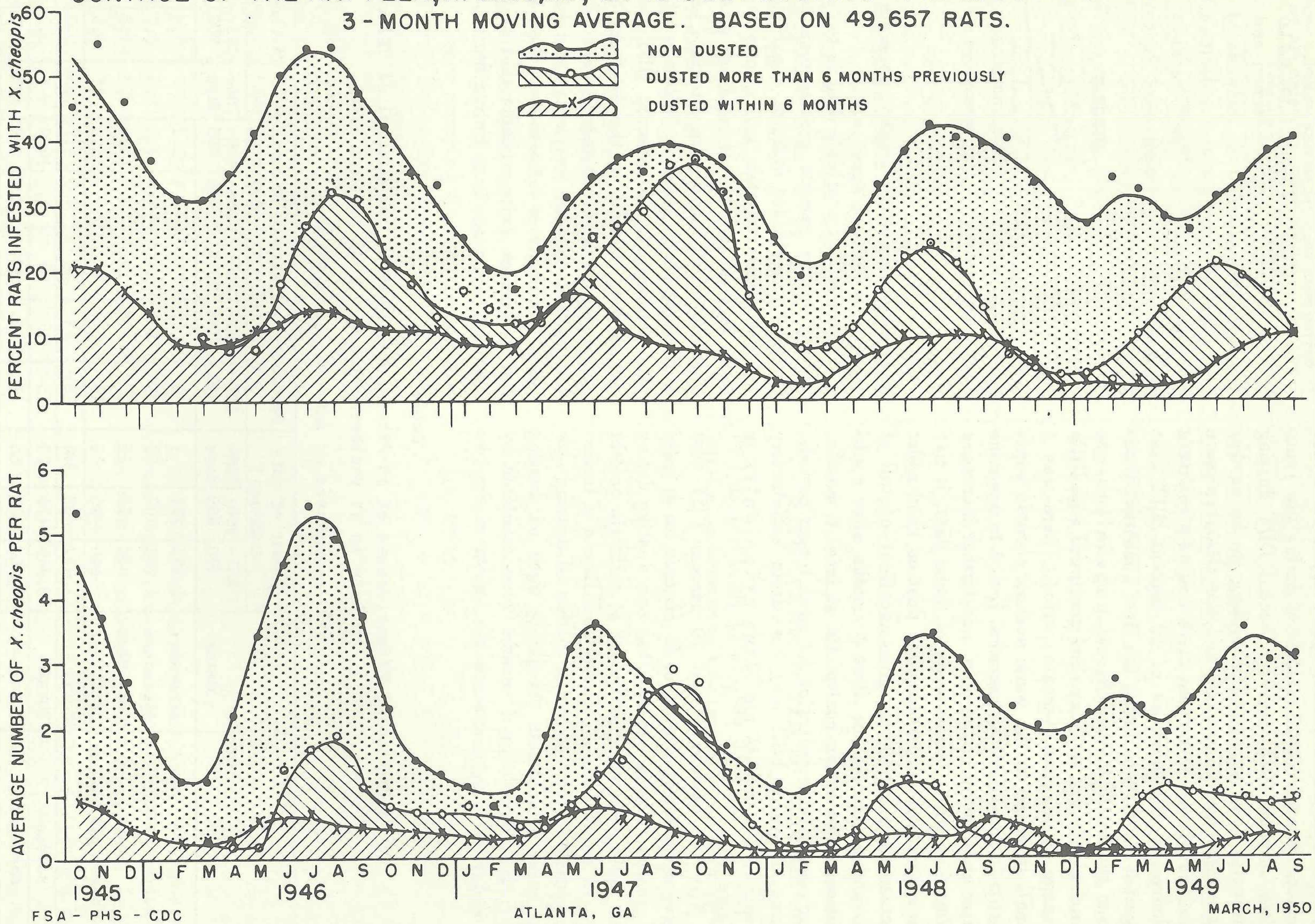
In percentages, these figures represent reductions for the first 6 months after dusting of 84, 79, 87, and 94 percent respectively for these 4 years. It is encouraging to note that the degree of control improved in both 1948 and 1949. This would appear to indicate either increased skill in dust application or a cumulative effect from repeated applications. It appears to indicate also that any development of resistance to DDT by *X. cheopis* under field conditions, which may have occurred, is not a factor of importance, as yet.

The duration of effectiveness of 10 percent DDT dust is of great practical significance, since upon this point, together with the associated factor of duration of reduction of typhus infection in rats, depends the frequency of dusting or the number of

FIGURE I

CONTROL OF THE RAT FLEA, *X. cheopis*, BY 10% DDT DUSTING IN NINE SOUTHERN STATES

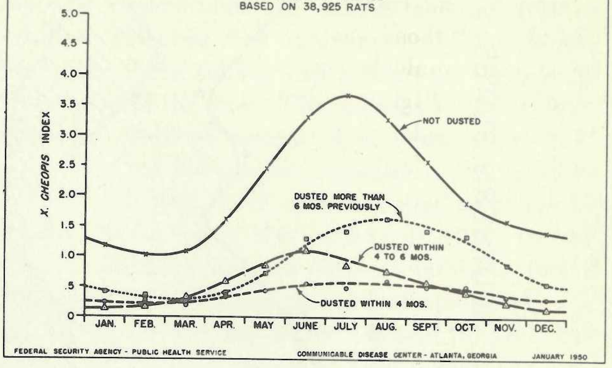
3-MONTH MOVING AVERAGE. BASED ON 49,657 RATS.



cycles of dusting necessary per year, or per 2-year period. Data on 38,925 rats, taken during the years 1946 through 1948 from 10 percent DDT dusting projects, were separated according to the number of months after dusting and the results were analyzed. It was found that there was no significant change in effectiveness of 10 percent DDT dust against *X. cheopis* during the first 4 months. Maximum reduction in the *cheopis* population was reached in from 1 to 7 days and continued with little change during this 4-month period. There was a small increase in the warm season *cheopis* population in the following 2 months, i. e. 4 to 6 months after application of the dust, and further increases after 6 months. On the basis of these data, it may be stated that 10 percent DDT dust as used under actual field conditions gives excellent control of *X. cheopis* during the first 4 months after application, satisfactory control for at least 6 months, and considerable reduction for much longer periods, some of which still may constitute satisfactory control. These data are shown graphically in figure 2.

With the assurance that 10 percent DDT dust gave satisfactory control of *X. cheopis* for at least 6 months, it was evident that one dusting during the spring would be sufficient to maintain control for an entire season. The possibility of a further reduction in the number of cycles of dusting now is being considered. Available data on dusting periods greater than 6 months were tabulated by 100-day periods, and since the habits of the two

FIGURE 2
DURATION OF CONTROL OF THE RAT FLEA, *XENOPSYLLA CHEOPIS* BY DDT DUST
AVERAGE NUMBER OF *X. CHEOPIS* PER RAT
NINE SOUTHERN STATES - 1946 THROUGH 1948
3-MONTH MOVING AVERAGE
BASED ON 38,925 RATS



species of rats differ greatly, separate tabulations were made for each species.

The amount of available data is too small, particularly in the periods greater than 400 days, to provide a basis for definite conclusions on this subject. However, the indications would appear to be that (1) in areas or buildings where roof rats only are found, dusting in alternate years may be sufficient; (2) in areas or buildings where Norway rats predominate, 10 percent DDT dusting gives satisfactory control in the Southern States as a whole up to approximately 1 year after dusting. Insufficient data are available for a further breakdown by climate or temperature zones at this time, but it appears quite probable that in the northern portions of the southern United States, i. e. above

Table 1

Duration of Effectiveness of 10 Percent DDT Dust in the Control of "X. cheopis" on Rats in 11 Southern States,* 1946 through 1949

Based on data on 4,835 rats

Rat	Month	Number of rats examined			Percentage of rats infested			Av. no. per infested rat			Av. no. per rat examined		
		181-399	400-699	700+ days	181-399	400-699	700+ days	181-399	400-699	700+ days	181-399	400-699	700+ days
Rattus rattus and *Rattus norvegicus*	Jan.-Mar.	1,203	277	1	8	8	**	4.4	2.2	**	0.4	0.2	**
	Apr.-June	1,298	107	72	15	14	44	5.0	4.9	8.5	0.7	0.7	3.8
	July-Sept.	901	173	55	23	12	29	4.5	12.3	6.3	1.0	1.5	1.8
	Oct.-Dec.	640	96	12	15	27	**	3.6	16.6	**	0.6	4.5	**
	Total	4,042	653	140	15	13	36	4.5	9.7	7.5	0.7	1.2	2.7
R. rattus	Total	2,989	476	75	15	15	31	4.9	10.8	6.6	0.7	1.6	2.0
R. norvegicus	Total	1,053	177	65	15	6	42	3.3	2.9	8.2	0.5	0.2	3.4

*Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia.

**Number of rats examined is too small to determine percentage and average.

Table 2

Control of "X. cheopis" by 5 Percent DDT Dust (and Comparison with 10 Percent DDT Dust Results)

Quarter	No. of rats examined	Percentage of Rats infested			Av. no. of "X. cheopis" per infested rat			Av. no. of "X. cheopis" per rat examined		
		Non-dusted	Dusted 1-180 days	Dusted 181-600 days**	Non-dusted	Dusted 1-180 days	Dusted 181-600 days**	Non-dusted	Dusted 1-180 days	Dusted 181-600 days**
1948										
Jan.-Mar.	761	6	5	0*	2.1	2.0	0*	0.1	1.1	0*
Apr.-June	1,199	22	12	18	8.4	4.1	9.2	1.9	0.5	0.6
July-Sept.	1,689	37	15	9	6.4	5.0	1.7	2.4	0.7	0.2
Oct.-Dec.	1,581	29	8	11	3.7	2.7	6.1	1.1	0.2	0.7
1949										
Jan.-Mar.	2,387	19	5	4	3.8	2.4	1.5	0.7	0.1	0.1
Apr.-June	1,183	31	15	12	5.6	5.8	5.3	1.7	0.9	0.6
July-Sept.	1,818	27	15	33	8.0	6.2	6.1	2.2	0.9	2.0
Total or Average	10,618	25	11	9	5.6	4.8	5.3	1.4	0.5	0.5
Average for 10% DDT dust for same period	17,154	33	7	12**	6.6	3.5	4.1**	2.2	0.3	0.5**

*Based on only 47 rats. Other figures are based on examinations of from 74 to 1,660 rats. The total number of rats examined by dusting periods is: nondusted - 3,312; dusted 1-180 days - 6,131; dusted 181-600 days - 1,175.

**Ten percent DDT dust data include records on rats from premises dusted 6 months to 3 years.

33° north latitude, dusting in alternate years may be sufficient. A condensed tabulation of these data is given in table 1.

The possibility of reducing the cost of dusting operations by the use of 5 percent instead of 10 percent DDT dust prompted its experimental use in 1946 and 1947. These comparatively small-scale tests appeared to indicate that 5 percent DDT dust was as effective as 10 percent dust for periods up to 3 or 4 months. Accordingly, large-scale use of 5 percent DDT dust was started, particularly in Georgia and Alabama, at the beginning of the 1948 season. During the early part of 1949, field observations indicated that unsatisfactory results were being obtained with 5 percent dust, and a swing back to 10 percent DDT dust took place. Data on examinations of 10,618 rats taken in 5 percent DDT dust areas over a period of nearly 2 years are given in table 2.

In premises dusted with 5 percent DDT the average number of *X. cheopis* per rat for the first 6 months after dusting, based on data from 1,789 rats, averaged 0.9 during the months of April through September 1949. The corresponding figures for 10 percent dust areas, based on data from 1,915 rats, is only 0.3 per rat.

It should be noted also that control appeared to be much poorer during the second year of dusting with 5 percent DDT than during the first year. This suggests the possibility that the use of dust with a low percentage of DDT may have permitted the development of a minor amount of resistance to DDT by *X. cheopis*.

A direct comparison of the amount of reduction in the *X. cheopis* population obtained by 5 percent and 10 percent DDT dust shows that poorer reduction was obtained by 5 percent than by 10 percent DDT dust during the first 6 months after dusting, both in the percentage of rats infested and in the average number of fleas per infested rat (table 3).

A comparison of these two dusts for the groups dusted more than 6 months previously, which are not entirely comparable since the data for 10 percent dust include many rats from premises not dusted for more than 600 days, shows that there was no difference in the percentage of rats infested but that 5 percent dust gave poorer results in regard to the average number of *cheopis* per infested rat and also, therefore, in the average number per rat examined.

Table 3

Percentage of Original Infestation of "X. cheopis" Found after Dusting
Comparison of 10 Percent and 5 Percent DDT Dust, Based on 27,772 Rats

Period or Quarter	Percentage of rats infested				Av. no. of "X. cheopis" per infested rat				Av. no. of "X. cheopis" per rat examined			
	1-180 days		181+ days		1-180 days		181+ days		1-180 days		181+ days	
	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%
1948												
Jan.-Mar.	17	78	37	0*	37	96	46	0*	6	Inc.	17	0*
Apr.-June	23	53	53	84	92	49	Inc.	Inc.	22	26	73	32
July-Sept.	24	41	52	26	35	78	44	27	9	31	23	7
Oct.-Dec.	20	29	16	37	Inc.	73	39	Inc.	26	21	6	61
1949												
Jan.-Mar.	9	26	9	21	15	63	23	38	1½	16	21	8
Apr.-June	16	49	42	37	14	Inc.	32	94	22	51	14	3
July-Sept.	24	57	41	Inc.	55	77	72	77	13	44	29	93
Average for 21 months	21.7	44.6	37.1	37.0	53.6	85.7	62.2	94.4	11.6	38.2	23.1	34.9

*Based on only 47 rats.

REDUCTION IN TYPHUS INFECTION IN RATS BY DDT DUSTING

The rat is by far the most important animal reservoir of murine typhus and, therefore, any reduction in the percentage of rats infected would result in the infection of a smaller percentage of fleas with the rickettsia and should be reflected in a reduction in human typhus. Thus the determination of the percentage of rats showing typhus antibodies in the blood can be used as a second method of measuring the effectiveness of DDT dusting operations for the control of transmission of murine typhus to man (table 4).

In the preliminary analyses made to date, a complement fixation test of 1:4 has been considered positive. However, there is considerable doubt regarding the significance of titers of 1:4 or even of 1:8, and a reconsideration of what constitutes a positive titer may be necessary. This test, of course, shows past infection and cannot be evaluated correctly when using the same periods after dusting as for ectoparasite infestation. Typhus antibodies do not begin to appear in the blood until the 12th to 18th day after exposure but, after appearing, are present at least for several months. Reduction by DDT dusting, in the percentage of typhus infection in rats is not as striking as the reduction of ectoparasites. Many factors in addition to the reaction factor just discussed must be segregated before definite conclusions can be drawn. The following table is of a preliminary nature and the important factors, such as age of rat, have not been considered. Nevertheless, a fair reduction in the percentage of rats infected is shown. Data on rats caught within 30 days after dusting have not been considered because of the probability that most of the rats found positive for typhus in this group acquired the infection before the time of dusting.

The data on typhus infection in rats presented above are rather variable and hardly can be interpreted satisfactorily without further break-down of the contributing factors. However, they do show a steady decrease in the natural typhus infection in rats, some of which may be due to natural factors such as weather conditions, but a large part of which undoubtedly is due to actual interchange of rats between dusted and nondusted premises, and to a systematic and successful reduction in typhus in the areas of highest endemicity.

A good percentage of reduction of typhus infection in rats, 50 percent, is shown for 10 percent DDT dust areas, and a somewhat smaller percentage of reduction, 41 percent, for 5 percent dust areas during the period 1 to 6 months after dusting in 1948 and 1949. However, for periods greater than 6 months after dusting, no such consistency was evident; results show almost no reduction, 1 percent, in the 10 percent dust areas but a good reduction, 52 percent, in the 5 percent dust areas. No

Table 4
Effect of 10 Percent and 5 Percent DDT Dusting Operations
on the Percentage of Rats with Typhus-Positive Complement Fixation Titers
11 Southern States - Based on 41,170 Rats

Year	Quarter	10 percent DDT dust			5 percent DDT dust		
		Nondusted	Days after dusting		Nondusted	Days after dusting	
			31-180	181+		31-180	181+
1945	Oct.-Dec.	51	31	-			
1946	Jan.-Mar.	33	34	0*	No data		
	Apr.-June	30	21	5**			
	July-Sept.	35	21	30			
	Oct.-Dec.	29	18	28			
	Total 1946	32	23	27			
1947	Jan.-Mar.	23	24	27	No data		
	Apr.-June	22	18	21			
	July-Sept.	15	14	25			
	Oct.-Dec.	22	13	16			
	Total 1947	21	18	23			
1948	Jan.-Mar.	18	8	30	15	11	40**
	Apr.-June	16	8	17	18	15	20
	July-Sept.	15	8	10	19	9	8
	Oct.-Dec.	14	7	10	18	9	6
	Total 1948	16	8	18	18	10	17
1949	Jan.-Mar.	10	2	10	15	4	2
	Apr.-June	11	12	10	16	9	7
	July-Sept.	16	6	8	9	11	9
	Total Jan.-Sept. 1949	13	7	9	14	8	4
4-year Total		22.4	16.2	18.3	-	-	-
Total 1948-1949		15.1	7.6	14.9	15.6	9.1	7.5
Percentage of reduction 1948-1949***		-	50%	1%	-	41%	52%

*Based on less than 20 rats.

**Based on 20-49 rats.

***Based on 20,239 rats as follows: 10 percent dust areas: nondusted - 6,215; dusted 1-180 days - 4,298; dusted 181+ days - 2,213. 5 percent dust areas: nondusted - 2,839; dusted 1-180 days - 3,684; dusted 181+ days - 990.

explanation for this sharp reversal in trend is offered. It is hoped that additional data and more critical analyses may give a clearer picture of the effect of DDT dusting on typhus infection in rats.

CONCLUSIONS

1. Ten percent DDT dust applied to rat runs and burrows is very effective in controlling the oriental rat flea, *Xenopsylla cheopis*, the principal vector of murine typhus to man.

2. The effectiveness of DDT has not decreased during the 4 years it has been used for this purpose.

3. The residual effect of DDT or the duration of its effectiveness against *X. cheopis* appears to be as follows: very effective for 4 months, satisfactory for 1 year, and probably satisfactory for 2 years on roof rats and, in the northern parts of the typhus area, on Norway rats also.

4. Five percent DDT dust has been definitely less satisfactory than 10 percent dust in the control of *X. cheopis*.

5. Analyses of, and interpretations of the importance of, reductions in typhus infection in rats to date are preliminary only. A fair percentage of reduction in typhus infection in rats is shown for both 10 percent and 5 percent DDT dusted areas during the 6 months after dusting. For longer periods, the data at hand appear to be too inconsistent to permit valid interpretations.