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APPLICATION OF DDT, BHC, AND CYANOGAS IN THE CONTROL OF PLAGUE IN INDIA

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SYNOPSIS

A comparison is made of the results obtained in various parts of India since 1945 with DDT, BHC, and Cyanogas in the control of plague.

Antiplague campaigns involving the use of Cyanogas (calcium cyanide) have shown this pulicide to be effective in many cases in keeping down the flea index and in restricting the spread of the disease, although Cyanogas fumigation alone will not stop the annual recrudescence of epidemics. Comparative trials in Madras State showed that insufflation of rat-holes and harbourages with 10% DDT dusting-powder was effective in keeping the flea index below 1 in several villages, while repeated Cyanogas fumigation in the town of Coonoor did not greatly reduce the index there. In another series of experiments, the toxic action of both DDT and BHC (Gammexane) was still evident 84-90 days after dusting, but the DDT was the more powerful pulicide. Cyanogas dusting had no effect in reducing the flea index in these experiments.

In their conclusions, the authors consider that DDT, despite a number of instances of its failure, is the most valuable pulicide, followed by BHC and Cyanogas, in that order. A successful antiplague operation, however, depends on the methods used, the dosage of pulicide, and the time and intensity of its application. In addition, to eradicate plague in endemic areas, it is, of course, necessary to continue control efforts during the interepidemic periods.

Until 1947, the routine antiplague measures in the different States of India consisted of Cyanogas (calcium cyanide) fumigation of rat burrows, total Cyanogas fumigation of the infected and the surrounding houses, single-dose mass inoculation of the population with Haffkine plague-vaccine, and, occasionally, evacuation of houses or villages during an actual epidemic out-

break. Mass destruction of rats by baiting and trapping was undertaken as an interepidemic measure in certain States, while in a few towns, such as Bijapur and Pandharpur in Bombay State, and Ootacamund, Coonoor, and Kotagiri in Madras State, systematic Cyanogas fumigation of burrows, grain godowns, and market-places was done during interepidemic periods or as a matter of routine every 3 or 4 months. Rat-proofing of dwelling houses, godowns, and other places has not received adequate attention in India except perhaps in very large cities, such as the city of Bombay.

Cyanogas Fumigation

Madras State

Cyanogas fumigation as a plague-control measure was tried in the Salem and Nilgiris districts of Madras State between 1945 and 1949. In 1945-6, Cyanogas fumigation of rat-holes and other rat harbourages in all the villages of Hosur (Salem district) [1] gave good results in preventing or suppressing plague outbreaks, i.e., in villages in which Cyanogas fumigation was done soon after the detection of rat plague, no further rat-falls or human cases occurred, and in villages where it was adopted after the occurrence of human cases, the epidemic stopped immediately or continued only in a very mild form.

Similar results were obtained in Nilgiris district in 1947.[2-5] In this campaign, infected dwellings were fumigated in toto, while in the surrounding buildings only rat burrows, cracks in the walls, and other obvious rat harbourages were fumigated. In 19 villages fumigated after the rat-fall, no human case occurred after fumigation and rat plague also aborted quickly, while in 38 villages fumigated after the occurrence of human cases, fresh human cases occurred only in two of them. In the municipal towns of Ootacamund, Coonoor, and Kotagiri, the market-stalls, grain godowns, grocery shops, potato stores, and congested residential areas were fumigated every 2-3 months with the result that no plague infection has occurred in any of these towns since adoption of the above procedure. Following this experience, the Madras Public Health Department organized Cyanogas fumigation of the villages in the following manner :

(1) villages with no history of plague were left alone;

(2) in villages with a history of infection in previous years, fumigation of rat burrows and harbourages was undertaken every 3 months;

(3) in villages threatened with plague owing to rat-fall, fumigation of rat burrows and harbourages was done immediately, irrespective of the usual quarterly fumigation programme;

(4) in villages in which human or rodent plague had been reported, block fumigation covering all houses was arranged immediately;

(5) in villages with a history of repeated plague infection or of infection in the immediately previous years, block and house-to-house fumigation was organized every month until the plague season was over.

The results of the above procedures for the years 1948-9 are given in table I.

TABLE I. RESULTS OF CYANOGAS FUMIGATION AFTER RAT-FALL

Year of operation	Number of villages under treatment	Number of villages fumigated after rat-fall	Number of villages reporting human cases after fumigation	Total number of plague cases	Total number of plague deaths
1948	?	35	16	33	6
1949	468	18	11*	23	8

* Only 2 villages reported human cases of plague after Cyanogas refumigation.

Bombay State

As in Madras State, Cyanogas fumigation was resorted to as a routine measure in any area of Bombay State after the report of a rat-fall or human case, and fumigation of the whole village was completed quickly. It has been the experience of the Bombay Public Health Department that if the infection was localized to a small village or to one part of a large village, Cyanogas fumigation of all the burrows in the area and total fumigation of infected houses and the surrounding houses and huts usually aborted the infection promptly or delayed the spread considerably. In bigger infected villages and towns, Cyanogas fumigation of all the burrows in the houses and their surroundings, and total fumigation of the infected and adjoining houses in the lanes, usually brought down the extent and tempo of the outbreak but failed to eradicate it completely from the town. In such cases, the people evacuated the houses and lived in the nearby fields; whenever possible, fumigation of all personal effects was done before the villagers re-occupied the evacuated huts.

It is evident from these reports that although Cyanogas fumigation was able to control the epidemic to a great extent in different places, it was not able to eradicate it completely except in the case of three towns in Madras State—Ootacamund, Coonoor, and Kotagiri—where plague infection has been absent since the programme of systematic fumigation of these towns was regularly adopted.

Use of DDT and BHC as Pulicides

The first successful field application of DDT in the control of plague was made by the US Army in occupation at Dakar (West Africa) in 1944.

The floors and walls were strewn with 10% DDT dust, leading to the stoppage of plague infection in two weeks. In laboratory experiments carried out in jars in the Haffkine Institute by Sharif,[8,9] it was found that when DDT dust was mixed with sand in a dilution of 1:200,000 it still gave a residual effect for as long as 230 days, while the residual effect of BHC (Gammexane) when used in a concentration of 1:5,000 was found to last only 48 days.

Similarly, an experiment carried out in artificial burrows, by insufflating them with either DDT dust or Gammexane dust by blowing the powder with a Baby Cyanogas 'A' Dust Pump until it appeared at the other end of the burrow, showed long residual effect though not uniformly distributed over the whole length of the burrows. In this experiment, DDT was found to be much superior to Gammexane.

Experimental work to study the pulicidal effect of DDT in natural rat-holes in the field was carried out by Madras workers in 1947, when DDT was used in 5% concentration in kerosene. The results obtained are given in table II.

TABLE II. PULICIDAL EFFECT OF INSUFFLATION OF DDT INTO NATURAL RAT-HOLES

Number of rat-holes treated	Interval between insufflation and opening of rat-holes (weeks)	Number of rat-holes showing nests	Number of nests showing fleas	Number of fleas discovered per nest
39	2	10	3	26, 16, 2
20	3	5	2	9, 5
43	4	9	3	15, 7, 3
35	6	8	3	10, 7, 3
45	8	12	3	11, 8, 2
Total 182		44	14	

It will be seen that, in 182 rat-holes excavated at intervals of 2 to 8 weeks after DDT insufflation, live fleas were found in 14 of the 44 rat nests discovered. DDT solution was, however, detected in only the first few inches of the tortuous burrows and did not reach the actual site of the nest.

This control work was then extended to two villages 2 miles (3 km) apart and each containing 500 houses. Here, the rat burrows were insufflated with 10% DDT (Neocid) dusting powder until it was seen coming out at the other end. Outlets were then closed by packing with mud, and more powder was blown in, followed by air, to ensure uniform distribution. Finally, the mud packings were removed and the burrows left open.

All rat burrows, cracks in the walls, heaps of firewood or stones, and collections of sundry articles were dusted with Neocid dusting powder. As a result of this, the initial flea-indices in the experimental villages, which were 3.1 and 3.6 before insufflation, were found to have come down to 0.65 and 0.3 respectively, as against 3.6 and 5.6 in the control villages. These lower flea-indices in the two treated villages remained low for a period of one year. The results thus being encouraging, 60 villages were dusted once with DDT powder in 1948, and all remained free from plague infection.

A further indication of the efficacy of DDT in controlling plague in India through its pulicidal action came from Viswanathan [10] and Viswanathan & Rao,[11-13] who recorded evidence of prevention of plague as a collateral benefit during malaria-control operations carried out with DDT in 1946 in 1,131 villages of Dharwar and Kanara districts, and Belgaum and Khanapur taluks,[a] with a total population of 913,298. Here each village was sprayed only twice a year during the malaria season at intervals of 4 to 6 weeks, with 5% DDT emulsion in medium kerosene extract and soap, on roofs and walls of the houses in a dosage of 56 mg per square foot (603 mg per m^2) and at a per capita cost of 8 annas. There was not a single case of human plague in any of the sprayed villages in this epidemic area for the 4-year period (1947-50) of the antimalaria operations, although there were rat-falls due to plague infection. However, plague infection occurred in 10 out of the 900 unsprayed villages, and not less than 65 human plague cases were recorded. In 1949, although there was a fairly severe epidemic of plague in villages of Mysore State adjoining Kod taluk in Dharwar district, which was a sprayed area, no case of plague occurred in this taluk.

A flea survey was carried out by Viswanathan in 1949, 6 months after the last DDT spraying operation, in 12 sprayed and 12 unsprayed villages in Dharwar district, 500 rats being included in the examination from each group. The flea-indices were found to be 0.6 and 2.4 respectively. A human plague case occurred subsequently in one of the unsprayed villages, but the spread of infection was brought under control by spraying with 5% DDT-Aromex-soap emulsion.

Since 1949, Patel & Rodde [6] have carried out fairly extensive plague-control measures with various DDT formulations in 105 villages and 2 towns reporting human plague, 29 villages with rat-fall, and 46 threatened villages in 5 districts of Bombay State (T. B. Patel—personal communication, 1952). The following four methods of treatment with DDT were tried in addition to a single-dose plague vaccine inoculation :

Treatment method 1. Indoor residual spray of all houses and huts with 10% aqueous suspension or 3% oil emulsion of DDT, an average

a A taluk is an administrative subdivision of a district.

dose used being 65-75 mg per square foot (about 670-800 mg per m^2). This operation was carried out in 182 villages of which 81 reported human plague and 27 rat-falls only, while 44 were threatened with plague owing to cases in the neighbouring villages.

Treatment method 2. Combined method of DDT indoor-spraying of all houses and insufflation of burrows in the whole village with 10% DDT powder. Only 18 villages were included in this operation.

Treatment method 3. Combined method of indoor residual spraying of DDT in the houses of the infected locality only, and insufflation of rat burrows of the whole village with 10% DDT powder. Only 7 villages, which reported plague cases, were given this treatment.

Treatment method 4. Insufflation of the rat burrows in the whole village. This treatment was given only in three villages reporting rat-falls or considered threatened.

The approximate cost of spraying a whole village, with an average population of 1,000, ranged from Rs 350 to Rs 400 [b] for labour and materials, excluding the cost of supervisory and other staff and of the special transport and equipment. The results of the above treatment methods are summarized in table III.

The results show that, allowing the cases which occurred within 72 hours of the DDT spraying to be due to infection in the incubation period, there were 28 attacks and 2 deaths with treatment 1 ; only 2 attacks and 1 death with treatment 2 ; 4 attacks and no death with treatment 3 ; and 13 attacks and 2 deaths with treatment 4. The incidence per 1,000 of population was 0.4, 0.14, 0.16, and 8.0 respectively with the four methods of treatment. Thus, out of the 180 villages which were given treatment under different forms, 27 reported infection after the operations and 153 escaped infection altogether.

The flea-indices in the above villages before and after treatment with DDT are given in table IV. It will be seen that a considerable reduction in flea-indices was obtained by an indoor residual spray alone or in combination with insufflation of rat burrows (treatments 1 and 2).

Instances of Failure of DDT

In some villages, however, infection in rats and human beings did not come to an end as quickly as in the majority of cases ; after the disinfestation of the burrows in each house, and of all infected houses, with 10% DDT powder and 1% aqueous suspension, respectively, the infection continued to occur for about a month after the spraying had been completed.

[b] Rs 4-12-0 = US $1.00

TABLE III. EFFECTS OF VARIOUS METHODS OF DDT INDOOR-SPRAYING AND INSUFFLATION OF RAT BURROWS ON PLAGUE INCIDENCE IN VILLAGES OF BOMBAY STATE

Method of treatment	Number of villages treated	Type of plague manifestation	Total population	Before DDT treatment		After DDT treatment												Number of villages with no plague after DDT treatment
						within 3 days			after 3-10 days			after 10 days			total			
				plague attacks	plague deaths	number of villages affected	plague attacks	plague deaths	number of villages affected	plague attacks	plague deaths	number of villages affected	plague attacks	plague deaths	number of villages affected	plague attacks	plague deaths	
1	81	human plague	71,053	588	242	9	45	9	3	19	2	3	9	0	15	73	11	66
1	27	rat-fall	19,750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
1	44	threatened	36,504	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44
2	18	human plague	14,348	91	25	4	7	1	2	2	0	0	0	0	6	9	1	12
3	7	human plague	24,642	77	34	1	2	0	1	2	0	1*	2	0	3	6	0	4
4	3	rat-fall	1,633	0	0	—	—	—	—	—	—	—	—	—	3	13	2	—

* Cow-dung was applied to the walls some 3-7 days after DDT spraying.

TABLE IV. EFFECTS OF VARIOUS METHODS OF DDT TREATMENT ON FLEA-INDICES OF DIFFERENT VILLAGES AT VARIOUS INTERVALS AFTER SPRAYING

Method of treatment	Village	Flea-indices							
		before treatment	time after treatment						
			7 days	10 days	15 days	1 month	2 months	3 months	5 months
1	1	3.6	—	—	0.0	—	—	0.0	—
	2	8.0	—	4.0	—	0.4	—	—	—
	3	8.4	—	—	—	0.8	—	—	—
	4	6.6	—	—	—	—	0.0	—	—
	5	4.75	—	—	1.0	—	—	—	—
	6	7.6	—	—	—	—	—	—	—
	7	9.7	0.6	—	0.5	—	—	—	—
	8	2.42	2.2	0.47	—	—	—	—	0.45
2	1	3.0	—	—	—	0.15	—	0.0	—
	2	4.42	—	0.42	—	—	—	—	—
	3	3.51	—	—	—	—	—	—	0.6
	4	6.84	—	1.39	0.07	—	0.25	—	—
	5	2.0	0.0	—	—	—	0.77	—	—
3	1	17.1	—	2.8	—	—	—	—	—
	2	8.3	—	3.08	—	—	—	0.2	—
	3	1.7	—	—	—	—	—	—	1.4
	4	2.0	—	—	—	—	—	0.26	1.2
	5	—	—	—	—	—	0.2	—	—

Mysore State

As in the other States, Cyanogas " A " dust fumigation was the usual method employed for control of plague in Mysore State. Usually, 1 pound (0.45 kg) of dust was used for the fumigation of 60 rat burrows and one fumigation was done in each village when the infection was on, but in special cases where the infection persisted Cyanogas fumigation was repeated. The results achieved in the 4 districts by this method during the period 1948-9 are summarized in table V.

DDT operations were started in 1948 in Krishnarajanagar taluk. The upper and lower halves of the wall surfaces of houses were sprayed with a dose of 200 mg per square foot (2,153 mg per m^2) of Geigy's DDT 50% water-dispersible powder or of a 5% DDT emulsion, prepared locally. Between 1942 and 1948 there were 111 infected villages in this taluk, with a total of 469 deaths. However, between 1949 and 1951 (after DDT treatment)

TABLE V. PLAGUE ATTACKS AND DEATHS BEFORE AND AFTER CYANOGAS FUMIGATION IN FOUR DISTRICTS OF MYSORE STATE, 1948-9

District	Number of localities fumigated	Before Cyanogas fumigation		After Cyanogas fumigation *	
		plague attacks	plague deaths	plague attacks	plague deaths
Hassan	1	1	0	—	—
Kolar	2	15	8	5	3
Mysore	7	49	31	59	26
Chitaldurg	13	21	16	223	102
Total	23	86	55	287	131

* Cases occurring within 1 day to 5 months after Cyanogas fumigation

no sprayed villages became infected, while infection did occur in 20 unsprayed villages, with 49 attacks of plague and 20 deaths.

This evidence is favourable to the use of DDT, as no plague occurred in the sprayed villages over a continuous three-year period. Similar results were obtained in the town of Chiknayakanhalli.

Punjab State

Plague was absent from the Punjab for some years after 1937. It again made its appearance there in 1944, starting with 137 cases and 61 deaths, and the peak was reached in 1947 with 4,247 cases and 1,905 deaths. During these years, the following antiplague measures were adopted :

(1) All rat-holes, cracks, and crevices were fumigated with Cyanogas " A " dust.

(2) Pyrethrum-kerosene mixture was sprayed in infected houses following fumigation of the rooms with cresol at the rate of 10 ounces per 1,000 cubic feet (100 g per 10 m^3).

(3) Floors and walls of infected houses were singed up to a height of 2 feet (60 cm) to destroy the fleas resting there.

(4) During the interepidemic period, rat burrows were fumigated with Cyanogas " A " dust, and poison baits with barium carbonate were laid to destroy the rats.

In spite of these operations, the incidence of bubonic plague showed no sign of abatement but rather increased progressively. Early in 1948, therefore, indoor residual spraying of the infected houses with DDT up to a height of 5 feet (1.5 m) was introduced to supplement the cyanogassing of rat burrows, and an experiment was set up in an endemic area to study

the comparative value of DDT, BHC, and Cyanogas " A " dust in the control of plague. In these investigations, DDT was found to be superior to Cyanogas " A " dust in keeping down the flea-index. The policy in regard to control of plague was therefore revised in 1949-50. The chief methods adopted were the treatment of all rat-holes, cracks, and crevices with 10% DDT or Gammexane followed by Cyanogas " A " dust fumigation, which was later discontinued. The localities affected during 1948 and 1949, and areas within 2 miles of these places, were sprayed with DDT once every 4 months, with very encouraging results, as is evident from the records of incidence of plague in the Punjab for the years 1947-52, given below :

Year	*Cases*	*Deaths*
1947	4,247	1,905
1948	700	211
1949	877	241
1950	none	
1951	none	
1952 (until June)	none	

Hyderabad State

Until 1945, measures adopted with a view to controlling plague epidemics in Hyderabad State consisted of evacuation of infected localities, antiplague inoculation, and disinfestation of houses with kerosene-soap emulsion as a pulicide. After 1945, Cyanogas fumigation of rat burrows in infected towns and villages and in the neighbourhood of infected centres was introduced to avoid the risk of further spread of infection. This, however, could not cover all the endemic areas or the towns subjected to periodical epidemics, with the result that plague infection continued unabated in this State. In 1949, the number of units carrying out the fumigation of endemic areas was increased, but for various reasons the fumigation had to be discontinued. From 1950 onwards, the number of units carrying out antiplague measures was increased considerably, and this enabled the units to work not only in the endemic zone but also in some of the districts where epidemics had broken out before. DDT was also introduced as a routine antiplague measure, particularly for the disinfestation of houses. Cyanogas " A " dust was used for disinfestation of burrows, and 2.5% DDT solution prepared from water-dispersible DDT powder (Geigy) was used for disinfestation of houses. From the records of the incidence of plague deaths in Hyderabad State for the last quarter of a century, it is clear that in spite of antiplague measures, which included Cyanogas fumigation of rat burrows and rat harbourages, there has been practically no reduction in the incidence of plague. The intensity of the measures adopted in 1949 slightly improved the situation. But it was not until the introduction of DDT in 1950 [7] that a satisfactory response was obtained.

The cases and deaths recorded from 1944 to 1951 are given in the following tabulation, which shows that with the use of DDT the incidence of plague in Hyderabad State has very largely been brought under control :

Year	*Cases*	*Deaths*
1944	5,904	3,895
1945	9,734	6,567
1946	8,681	5,474
1947	5,613	2,390
1948	2,784	883
1948-9	6,101	2,289
1949-50	7,779	2,395
1950-1	1,870	670
1951 (plague season)	85	18

Comparative Value of DDT, BHC, and Cyanogas as Pulicides

Madras State

A comparative study of DDT insufflation and Cyanogas fumigation was made in Nilgiris district under the Director of Public Health, Madras, during the period 1948-9.

Four villages and one town were selected. All the rat-holes and rat harbourages of Wellington village were insufflated with 10% DDT powder in the third week of June 1947, and similar treatment was applied in the villages of Ketty and Hullada between 17 March and 23 March 1948. Aruvankadu, having the same general flea-index, was selected as the control village. Monthly rat-flea surveys were done in these villages for a period of 28 months. Cyanogas fumigation was regularly carried out in Coonoor town from September 1948, and a monthly flea survey was begun in October 1948. The results of the flea surveys carried out in the three experimental villages, in Coonoor town, and in the control villages are given in table VI.

The results show that DDT was very effective in keeping the general flea-index below 1 for nearly 16 months after a single application, whereas with repeated Cyanogas fumigation the monthly flea-index in Coonoor town remained quite high. Again, while plague occurred in 45 out of 460 village units regularly fumigated with Cyanogas once every 3 or 4 months, all the 90 village units treated with DDT escaped infection during the same period.

To test the value of Gammexane as an insecticide for the control of plague, a small field experiment was arranged by the Madras workers. The village of Mukkatty was selected for Gammexane treatment with Edappally and Elithorai as controls. Gammexane dust was insufflated into all the rat burrows (160) and dusted in the rat runs of 36 houses and 8 cattlesheds in an isolated part of Mukkatty village on 19-20 January 1949. Smoke bombs were used only in those houses which could be rendered

TABLE VI. MONTHLY GENERAL FLEA-INDICES OF DDT-DUSTED VILLAGES, CYANOGAS-FUMIGATED TOWN, AND CONTROL VILLAGE

Date	Control village (Arunvankadu)	DDT-dusted villages			Cyanogas-fumigated town (Coonoor ††)
		Wellington *	Ketty **	Hullada †	
1947					
January	—	2.7			
February	—	3.2			
March	5.3	4.3			
April	3.6	3.1			
May	—	—			
June	—	—			
July	3.6	0.65			
August	4.0	—			
September	5.6	0.3			
October	6.0	0.1			
November	6.6	0.1			
December	7.8	0.4			
1948					
January	2.3	0.1			
February	2.2	—	3.8		
March	5.7	0.7	—	1.8	
April	—	0.2	0.3	—	
May	—	0.3	—	—	
June	—	0.3	—	—	
July	1.3	0.1	0.1	—	
August	3.0	0.6	0.2	—	
September	2.0	0.5	—	0.1	
October	—	0.7	—	—	1.3
November	—	1.0	—	—	0.83
December	1.8	1.0	—	—	1.8
1949					
January	5.0	1.2	—	—	4.5
February	3.4	2.6	—	—	2.2
March	3.4	1.7	—	—	3.4
April	—	—	1.7	—	—
May	3.4	1.1	—	1.7	4.0
June	—	—	0.8	—	5.7
July	5.2	3.0	—	—	6.6
August	4.6	1.5	1.0	1.4	4.1
September	—	—	1.1	1.7	—
October	2.4	1.6	—	—	3.4

*** DDT insufflation carried out between 16 June and 21 June 1947**
**** DDT insufflation carried out between 16 February and 25 February 1948**
† DDT insufflation carried out between 17 March and 23 March 1948
†† Cyanogas fumigation carried out at intervals of two months from September 1948

more or less air-tight. The experimental villages had not been subjected to any other control measures for about six months previously, nor were they further treated subsequent to the Gammexane treatment until October 1949 at the earliest. The results of rat-flea surveys in the treated and control villages are given in table VII.

TABLE VII. MONTHLY RAT-FLEA INDICES OF GAMMEXANE-TREATED VILLAGE AND CONTROL VILLAGES

Date	Gammexane-treated village * (Mukkatty)		Control villages	
	before treatment	after treatment	Edappally	Elithorai
1948				
October	1.0	—	0.5	0.9
November	—	—	0.5	0.9
December	3.7	—	1.8	1.9
1949				
January	—	—	—	1.6
February	—	0.9	—	—
March	—	0.9	2.7	2.0
April	—	—	—	—
May	—	0.5	2.4	3.0
June	—	—	—	—
July	—	0.7	2.6	7.6
August	—	—	—	—
September	—	0.55	2.0	1.6
October	—	—	—	—

* Treated with Gammexane on 19-20 January 1949

As may be seen from table VII, the general rat-flea index is lower in the treated village than the indices in the control villages, but the reduction is not so marked as that resulting from DDT treatment. However, in view of the smallness of the experiment, the workers could not arrive at a definite conclusion.

Bombay State

In 1947, there was a severe plague infection in 103 villages and 7 towns in Bombay State. In all these, Cyanogas fumigation was resorted to as an antiplague measure. The average period for which plague infection continued was 35 days in the villages and more than 90 days in the towns. In 57 affected villages in the same district in 1949, where DDT treatment

alone was used, plague infection persisted on an average for a period of 10 days after the treatment.

Punjab State

A flea survey was carried out immediately prior to experimental operations in five selected villages, namely, Barnala, Janetpur, Kakru, Dhrukara, and Panjokhra. Barnala was then treated with 10% DDT dusting-powder (Geigy 310), Janetpur with Gammexane D .025, Kakru with 10% DDT dusting-powder (Geigy 310) and Cyanogas "A" dust, and Dhrukara with Cyanogas "A" dust alone, during May 1949. Panjokhra was left untreated to act as a control.

Each rat burrow was insufflated with 1 ounce (approximately 28 g) of 10% DDT or BHC dusting-powder and left unsealed. For the combined operation, 10% DDT dusting-powder was first insufflated into rat burrows, immediately followed by fumigation with Cyanogas "A" dust, then all entrances to the burrows were sealed with mud. Cyanogas "A" dust was used according to the approved method. Rat-flea surveys were done 3 weeks after the treatment and twice more, once between 84 and 90 days after treatment and again after 184-193 days. The results are given in table VIII.

TABLE VIII. EFFECT OF TREATMENT OF RAT BURROWS WITH DDT, BHC, AND CYANOGAS "A" DUST IN VILLAGES OF BOMBAY STATE

Village	Pulicide	Before treatment			Date of treatment	3 weeks after treatment	
		date of examination	number of rats examined	flea-index		number of rats examined	flea-index
Barnala	10% DDT dust	29 April 1949-1 May 1949	43	5.8	3 May 1949	25	1.1
Janetpur	BHC *	2-4 May 1949	81	6.9	4 May 1949	63	0.5
Kakru	10% DDT dust with Cyanogas "A" dust	5 May 1949	44	9.7	5 May 1949	32	2.2
Dhrukara	Cyanogas "A" dust	6 May 1949	43	4.9	6 May 1949	38	5.0
Paniokhra	none (control)	9 May 1949-11 May 1949	39	3.6	—	59	2.8

* The BHC used was Gammexane D .025.

The residual action of both DDT and BHC was still evident 84-90 days after the treatment, as the flea-indices remained at practically the same level as that obtained 3 weeks after treatment. The final rat-flea survey conducted 184-193 days after treatment, however, showed that the residual effect

had disappeared. On the whole, the toxic action of DDT was considered by the worker to be more persistent than that of BHC.

It was therefore concluded that both 10% DDT dusting-powder and 10% BHC (Gammexane D .025) dust showed evidence of residual action for at least 3 months, under the environmental conditions obtaining in Ambala district. Cyanogas " A " dust had no effect in reducing the rat-flea index under the conditions of the experiment.

Uttar Pradesh State

To judge the relative pulicidal values of DDT and Cyanogas a small-scale experiment was carried out in 1950 in the three villages of Raibha, Sahai, and Nagla Laldas, situated 1½-2 miles apart from one another, in the district of Agra. All of them had a history of rat-falls and of some cases of human plague in March 1949. In Raibha, rat-holes were insufflated with 10% DDT dust, and in Sahai with Cyanogas dust, while Nagla Laldas served as a control. Flea surveys were carried out once before the operation in September 1950 and then at intervals of 30, 60, and 90 days after treatment. The results, as summarized in table IX, show that the lower flea-indices were maintained during the entire period of observation in the case of DDT, while in the case of Cyanogas dust the effect deteriorated after 60 days.

TABLE IX. RELATIVE PULICIDAL VALUE OF DDT AND CYANOGAS DUST AS TESTED IN 3 VILLAGES OF AGRA DISTRICT, UTTAR PRADESH, IN 1950

Village	Pulicide	Before treatment		30 days after treatment		60 days after treatment		90 days after treatment	
		number of rats examined	flea-index	number of rats examined	flea-index	number of rats examined	flea-index	number of rats examined	flea-index
Raibha	DDT	52	9.9	50	4.5	31	2.8	30	3.6
Sahai	Cyanogas dust	50	8.1	52	4.8	32	5.6	40	8.5
Nagla Laldas	none (control)	51	10.2	50	8.5	29	9.0	40	7.3

Conclusions

From the above observations it is clear that, although systematic studies to compare the value of Cyanogas fumigation with that of DDT indoor residual spraying and insufflation of rat burrows in the field have been comparatively few in India, sufficient data are now available for

drawing certain conclusions concerning their respective merits in the control of plague.

Cyanogas fumigation of rat burrows, rat harbourages, and infected houses has long been recognized as being of value in the control of plague on the basis of the results of laboratory and field experiments. But it is clear that Cyanogas fumigation does not materially prevent the annual recrudescence of plague in endemic areas, although intensive operations keep down the incidence to a great extent and delay the spread of infection to fresh areas. The most encouraging results with Cyanogas fumigation were those obtained by the Madras workers in the Nilgiris district, where they were able to control plague infection to a considerable extent and even were able to eliminate it from at least 2 towns; however, results in other States have not been so encouraging. Comparative studies of the pulicidal value of Cyanogas, DDT, and BHC have shown that DDT is the most efficient insecticide, with BHC next, and Cyanogas last. The value of DDT and BHC is higher because they have a prolonged residual action which Cyanogas has not. Most public-health workers agree that DDT has been able to keep plague infection in their States under control since its introduction on a reasonably large scale, and they feel that the results obtained point to the possibility of eradicating plague through concerted action in its use. It should, however, be noted that unrestricted success has not been obtained by the use of DDT, and that instances are known where in spite of DDT treatment infection has continued in some villages.

It is further known that the success of the treatment depends upon the method used, the dose of the insecticide, and the time and intensity of application. The method of DDT indoor residual spraying in all houses in a village and the combined method of indoor residual spraying for a whole village and insufflation of the burrows in and around the houses in a village have both given equally good results in about 8-10 days in the majority of instances. This experience is in great contrast with the results obtained with Cyanogas fumigation, where infection has usually continued for as long as one month or more after the treatment. Although disinfestation of houses and rat burrows with DDT during a plague epidemic will cause the epidemic to subside, the rats may escape and the plague infection persist in them. For complete eradication of plague from endemic areas it would seem to be necessary to control the rat population and rat infection; and it would therefore appear that efforts to control the rat population must be continued during the interepidemic period. For economic reasons, the method of choice for control of plague would appear to be disinfestation of houses with DDT-Aromex-soap solution during an epidemic, supplemented by insufflation of rat burrows with 10% DDT dusting-powder during interepidemic periods. But if economic reasons are not of great importance, then disinfestation of both houses and rat burrows would give the best results.

It would, however, be necessary to use a proper formulation and a proper dose for effective action. The Bombay public-health workers prefer the use of DDT-Aromex-soap solution to a suspension of water-dispersible DDT for disinfestation of houses. Better results have been obtained with the use of DDT in a dosage of 70-75 mg per square foot (754-807 mg per m^2) than with smaller doses, such as 50 mg per square foot (538 mg per m^2). It need not be mentioned that the use of DDT is found to be comparatively cheaper than Cyanogas fumigation.

In Madras State, for instance, 2,000 pounds (907 kg) of 10% DDT dusting-powder were required to fumigate 90 village units once a year; at 14 annas per pound of powder, this cost Rs 1,750. In order to carry out Cyanogas fumigation of the same 90 village units, about 1,000 pounds (approximately 450 kg) of Cyanogas dust would be needed. But in order to obtain the same results as with DDT, the operation would have to be carried out three times a year, demanding some 3,000 pounds (1,360 kg) of Cyanogas dust. At Rs 1-8-0 per pound, the total cost would be Rs 4,500 against Rs 1,750 for DDT.

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RÉSUMÉ

Jusqu'en 1947, on a lutté de deux façons contre la peste, dans l'Inde : par les fumigations de Cyanogas (cyanure de calcium) dans les terriers de rats ainsi que les habitations voisines, et par la vaccination de la population au moyen du vaccin de Haffkine. La construction de bâtiments à l'épreuve des rats n'avait guère été prise en considération, si ce n'est dans de grandes villes, telles que Bombay.

Les auteurs passent en revue les résultats obtenus grâce aux fumigations, de 1945-49, dans les Etats de Madras et de Bombay. Si le Cyanogas a permis de limiter les épidémies dans une large mesure, il n'a pu assurer la suppression de la peste, sauf dans trois villes de l'Etat de Madras, où la maladie a disparu depuis l'application systématique des fumigations.

En 1947, des essais furent entrepris dans l'Etat de Madras avec les insecticides à effet rémanent. A la suite de l'insufflation de poudre de DDT dans les terriers dont l'issue avait été obturée, dans les fissures des murs, dans les tas de bois ou de pierres, l'indice des puces passa, dans certain village, de 3,6 à 0,3 et se maintint tel durant une année. Tous les villages traités de la sorte en 1948 restèrent indemnes de peste. Toutefois des échecs ont été observés dans divers cas, qui sont décrits dans l'article.

Après avoir exposé les diverses méthodes d'application des insecticides, les auteurs évaluent les avantages respectifs du DDT, du HCH et du Cyanogas, d'après les expériences faites dans divers Etats. Ils formulent les conclusions suivantes : Le Cyanogas

est la moins efficace des trois substances ; le DDT est la plus active. Les fumigations au Cyanogas n'empêchent pas la recrudescence annuelle de la peste dans les régions d'endémie, bien qu'elles aient diminué considérablement la fréquence de l'infection et empêché sa propagation à des régions indemnes. La plupart des services de santé reconnaissent que l'application du DDT sur une vaste échelle a permis de limiter l'infection pesteuse. Les résultats obtenus laissent espérer même qu'une action concertée permettrait de supprimer la peste. Il faut cependant tenir compte des échecs et en chercher les causes.

Le succès dépend de la méthode d'application, de la dose d'insecticide, de l'époque et de l'intensité du traitement. En combinant le traitement, par les insecticides à effet rémanent, de toutes les maisons d'un village et l'insufflation de poudre insecticide dans les terriers et autour des maisons on a obtenu de bons résultats au bout de 8-10 jours, alors qu'après traitement au Cyanogas l'infection a persisté durant un mois et plus. La suppression de la peste cependant exigerait la lutte contre les rats et l'infection des rongeurs. Les efforts devraient être poursuivis, dans ce sens, au cours des périodes interépidémiques.

Une méthode économique de lutte consisterait à désinfecter les maisons avec la solution savonneuse de DDT-Aromex pendant les épidémies et à insuffler de la poudre de DDT dans les terriers en période interépidémique. Si les conditions financières le permettent, il faudrait procéder à la désinfestation des terriers et des maisons. En terminant, les auteurs indiquent les préparations de DDT qui ont donné satisfaction dans divers Etats, la quantité à utiliser et le prix de revient du traitement.

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