Plague Control with DDT and "1080"

Results Achieved in a Plague Epidemic at Tumbes, Peru, 1945 *

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THE certain, rapid, and persistent action of DDT (dichlorodiphenyltrichloroethane) as a pulicide, and the high effectiveness as a raticide of sodium fluoroacetate (" 1080 "), justify an extension from the rather limited sphere of laboratory experiment to application in the field of these new measures, with the view of eradicating bubonic plague by the elimination, or at least the control, of the reservoirs and vectors of *Pasteurella pestis*. The value of the simultaneous use of these chemical substances in plague prevention will be the subject of a separate report. The present paper deals exclusively with the control, under emergency conditions, of an epidemic of bubonic plague at the height of its evolution.

ANTECEDENTS

The National Anti-Plague Service of the Peruvian Ministry of Health, through an arrangement with the Pan American Sanitary Bureau, assigned to the author the technical direction of an anti-plague campaign in the city of Tumbes, Peru, with the object of impeding the extension of an outbreak of bubonic plague which appeared in that locality during the last trimester of 1945. It was agreed to use only DDT and 1080 in accordance with a previously developed plan. The theoretical bases of this plan may be summarized as follows:

1. Elimination of the flea vector potentially capable of attacking man, which we assumed could be accomplished by the application of DDT in powder form to the floors of human habitations. This procedure we termed " surface application " of DDT.
2. Elimination of the flea vector from rats and rat nests by a second application of DDT to the spaces beneath floors, between double walls and roofs, to dead spaces in general, and to rat burrows and places habitually frequented by rats. We termed this the " subsurface application " of DDT.
3. Extensive application of sodium fluoroacetate (" 1080 ") in poisoned bait to eliminate the murine population once it had been freed from fleas.

MATERIALS AND METHODS

The application of DDT was accomplished by using a " dust " composed of 10 per cent DDT in talc or pyrophyllite, as well as DDT diluted to 5 per cent and to 2 per cent in refined wheat flour; the following dusting apparatuses were used: (a) The Cyanogas Foot-Pump made by the American Cyanamid and Chemical Company; (b) the Cyanogas Citrus Duster, manufactured

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by the same company; (c) the Degesch Powder Duster, Type 6, used formerly for applying calcium cyanide; (d) the Root "Giant Spot Duster," Model F-4, made by the Root Manufacturing Company. These were the only dusters at our disposal, although other good types are on the market. The foot-pump was used for dusting rat burrows; the spot duster for persons, vehicles, etc.; and the Degesch centrifuge for treating floors and other large surfaces.

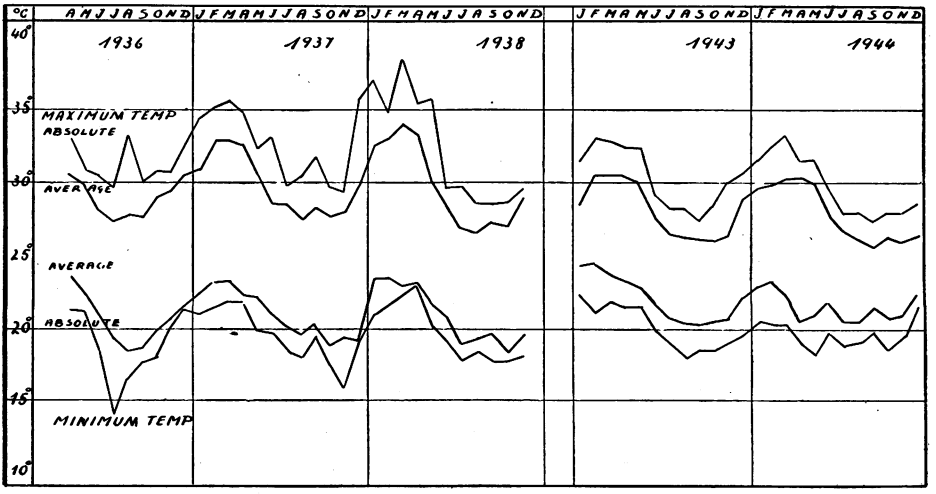
The 1080 (sodium fluoroacetate) was obtained through the Pan American Sanitary Bureau from Mr. Richard A. Ormsbee, Technical Aide, ICC Coördinator Center, Rodent Control Subcommittee, National Research Council. It was used in three kinds of bait or vehicles: (a) water, in 1/1,000 solution; (b) small cakes (using 5 parts of 1080 per 1,000) made with toasted wheat flour, 10 kg.; evaporated milk, 800 ml.; Parmesan cheese, 1 kg.; lard, 1 kg.; and salt, 30 gm. The poison was dissolved in water before adding it to the mixture. The dough was rolled out on metal sheets, dried and browned in the oven, and cut into small square cakes of about 1.0 gm. weight; (c) rolled oats, mixed with poison in the proportion 5 parts of 1080 per 1,000.

For placing the poisoned baits the city was divided into 9 sectors (see map), and the baits were applied so that two contiguous sectors received, in each of three consecutive poisonings, different baits.

Personnel consisted of 1 technical director, 1 assistant director, 1 clinician to care for the sick, 1 physician in charge of sanitating the city, 6 brigades (later 3) for applying DDT, each brigade composed of 1 inspector and 2 laborers, 3 inspectors for applying 1080, and 1 technician and 1 servant for laboratory work. Isolation facilities for patients of both sexes were provided; and a central office and laboratory were set up, the latter with minimal equipment for bacteriological and investigative work.

DESCRIPTION OF TUMBES

The city of Tumbes is the capital of the Department of the same name, in the Republic of Peru; Tumbes Department forms part of the border with the



GRAPH 1—Absolute and Average Maximum and Minimum Temperatures. Meteorological Observatory at Zorritos, Department of Tumbes, 1936–1938; 1943–1944.
COURTESY OF DR. G. PETERSEN

Republic of Ecuador. The city is situated at 3°34'16" South latitude, and at 80°28'01" longitude West of Greenwich, at 33 meters above sea level; it is a few kilometers from the Pacific coast, and lies on the banks of the Tumbes River. The population is about 10,000, and there are 1,600 dwellings, nearly all of primitive construction, chiefly bamboo, wood, or adobe. There are no sewers, nor is there a public water system. On account of the rains (December to May) the houses are elevated, leaving spaces beneath which are rat harborages. Climatic data do not exist; but in Graph 1 appear a few figures from the petroleum port of Zorritos, about 30 kilometers to the south. During our stay the temperature varied between 26° and 34° C., and the humidity between 75 and 94 per cent. An imperfect census of the population, not including about 2,000 members of the Army and police, nor the suburban sectors not included in our campaign, gave the following figures: dwellings, 1,357; individual rooms in these dwellings, 3,820; inhabitants of these, 7,388; males, 49.2 per cent (male children, 24.1 per cent); females, 50.2 per cent (female children, 21.9 per cent). The average number of rooms per house was 2.8, and the average number of inhabitants per house was 5.4.

EPIDEMIOLOGICAL FACTS AND FACTORS

Bubonic plague has occurred in Tumbes in 1909, 1915, 1922, and 1940; in the 1940 outbreak, 18 cases were recognized officially.

Rats: *R. rattus alexandrinus,* 95 per cent; *R. r. rattus,* 5 per cent; *R. norvegicus,* so common in other localities in the country, does not exist. The rats live in the spaces beneath floors, between double walls and ceilings, in straw roofs, etc. The number of burrows in the ground is small, and these generally are found in the pit privies; their scarcity may be explained by the sandy constitution of the soil.

Rat fleas: At the beginning of the work, 172 fleas were collected from 38 rats, the general flea index for the rats of the city being 4.5; but the index was 11.3 for the rats trapped in the epizoötic foci, and 2.1 for the rest of the town—97 per cent of the fleas were *X. cheopis.*

Fleas in rat nests: From 31 rat nests the total number of fleas collected was 156, with an average of 5.03 fleas per nest. Thirteen nests had no fleas, which elevated the figure of fleas per nest with ectoparasites to 8.6. Of all the fleas, 6 were *P. irritans,* taken from a single nest in a bedroom, and the rest were *X. cheopis.*

Free-living fleas: There were many *P. irritans* on the floors of the houses; on the earth floors, especially in patios (yards), *Ct. canis* predominated. There were a few *X. cheopis* found on the floors of warehouses, and on the clothing of persons working in the epizoötic foci. One of our laborers contracted plague in one of these foci.

Rainfall: When the plague appeared the rains had not yet commenced. The first rains began at the end of December, and they became torrential in the following months. There was fear that the rain would dislodge the rats and fleas from the spaces beneath the floors, which in part of the city were totally covered with water, into the domiciles themselves.

The epizoötic: The most probable source of the infection in Tumbes was plague-infected fleas transported in sacks of merchandise from the zone of Villa de Eten and Monsefú, in the Department of Lambayeque, about 600 kilometers to the south, where to date human and rodent plague persists. The merchandise was received in the Public Market of Tumbes in July or August, 1945—that is to say, during the "non-plague" season. At the beginning the

epizoötic was slow in developing, reaching its height in September, by which time secondary foci of murine plague had already been formed in different parts of the city. The initial focus of the Market began to produce human cases of plague in October. During this month and the one following at least 21 secondary plague foci were formed, the chief one being that of the house of S. M., which was surrounded by the warehouses and storerooms of the State Tobacco Monopoly, the State Salt Monopoly, the State Department of Warehouses and Shipments. In all of these places dead rats were found almost daily, the carcasses being located behind piles of thousands of sacks of merchandise, stacked in such a way that it was almost impossible to make adequate inspections, since the warehouses were so completely filled. In order to collect the dead rats it was necessary to open passageways between the sacks, a job which took several days. The epizoötic focus in the house of S. M. was beneath a cement floor which on the surface appeared to be in perfect condition; but the ground beneath was honeycombed with rat galleries and burrows. These, beginning at the earth borders, reached various depths and distances beneath the cement slabs, and the floor had to be destroyed to disclose these facts. The peculiar location of this focus explains its slight human repercussions.

Of the 21 epizoötic foci mentioned—scattered about the city as shown on the map—10 were inactive when we arrived; abundant mummified rat carcasses were found in the burrows and in the double walls. In 3 of these foci the epizoötic was followed by 1 or more human cases. The single focus of the Public Market, which was extinguished by demolishing the building, produced 9 cases of plague.

The 11 active epizoötic foci were confirmed as shown in Table 1. In designating these foci as being active, only those rats found dead or captured alive are considered which were proved in the laboratory to be infected with plague; the same applies to the fleas from rats or nests. The relation of the infected rats and fleas with the human cases is evident.

Of 139 rats examined, 38 (27.3 per cent) were positive for plague. Of the total examined 17 were found dead in the house of S. M. (10 of these with plague), and 15 were trapped in the same place (5 with plague) during the first five days of our work in Tumbes. Of the remaining active foci, four were of importance, producing between 30 and 70 per cent of the plague rats. The

TABLE 1

Flea or Murine Plague Foci, Active at the Beginning of the Antiplague Campaign, Tumbes, November 30, 1945

	Location	*Dead Rats*	*Plague Infected Rats (Trapped)*	*Plague Fleas from Rats*	*Rat Nests with Plague Fleas*	*Human Cases of Plague*
1.	Huáscar 324 and 326	+	+	..	..	..
2.	Huáscar 412	+	+	..	..	..
3.	Bolívar 231 (Mr. Maceda)	+	+	+	+	+
	State Tobacco Monopoly	+	+	..	..	..
	State Rice Monopoly	+	..	..	..	..
	Cinema	..	..	..	+	..
	State Salt Monopoly	+	..	..	+	..
4.	Ugarte 119, 159 and 161	+	..	..	+	+
5.	Piura 210, 220 and 230	+	+	+	+	+
6.	Piura 231 and w/n	+	..	+	..	+
7.	Cementerio 129–131	+	+	..	..	+
8.	Jaén 204	..	+	+	+	+
9.	Hospital	..	..	+	..	..
10.	Teniente Vásquez w/n	+	..	..	..	+

majority of the active secondary foci were developing when we arrived.

FLEAS INFECTED WITH PLAGUE

Of 29 lots of rat fleas classified, 13 were inoculated into guinea pigs, 7 proving positive. Of 12 lots of fleas taken from 18 rat nests, 7 were positive for plague on guinea pig inoculation.

THE EPIDEMIC

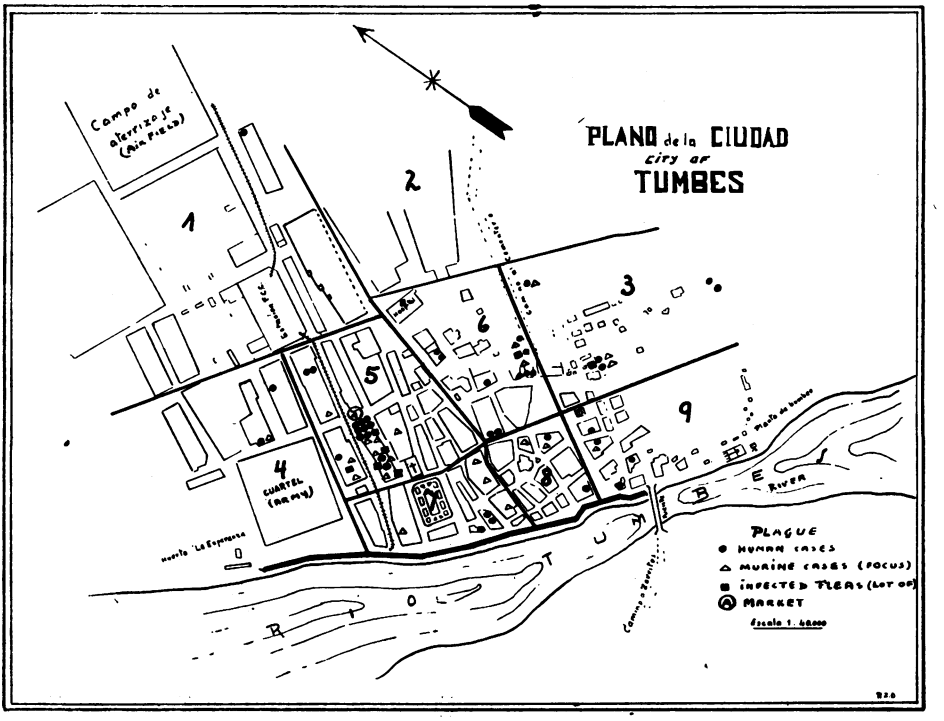
It is probable, though not certain, that there were cases of human plague toward the end of September, 1945. In October there were at least 6 cases, none of which was diagnosed as plague. In November, before the first case was diagnosed, there were at least 10 more cases. The first case diagnosed was that of a child 2½ years old, the son of the Government physician. Since the cases which occurred in November were still in evolution, it was possible to hospitalize them and to confirm the diagnoses by laboratory examinations. From October, 1945, to February, 1946, cases occurred as shown in Table 2.

TABLE 2

Weeks	*Cases*
Oct. 7–13	1(?)
Oct. 14–20	1(?)
Oct. 21–27	2(?)
Oct. 28–Nov. 3	2(?)
Nov. 4–10	5
Nov. 11–17	5
Nov. 18–24	11
Nov. 25–Dec. 1	3
Dec. 2– 8	8
Dec. 9–15	1
Dec. 16–22	0
Dec. 23–29	0
Dec. 30–Jan. 5	0
Jan. 6–12	0
Jan. 13–19	0
Jan. 20–26	1
	40 *

* Eight cases confirmed only clinically by private practitioners and accepted by us after epidemiological investigation of each case

The distribution of the cases in the city, and their relation with the epizoötic foci, may be seen on the map, Of the 40 cases accepted by us, 14 (35



per cent) died. Twelve of the patients were children of 10 years of age or less; 13 were young persons from 11 to 25 years old; 12 were adults from 26 to 55; and 3 were over 55 years of age. Age limits were from 2½ to 95 years. Twenty-six of the cases occurred in males, and 14 in females. Two cases were ambulatory; 4 were mild; 8 were rapidly fatal, with an average duration of 3 days; 3 had a longer, though fatal, course, with an average duration of 31 days, and with death due possibly to inadequate treatment; and there were 3 fulminating cases, death occurring within 12 hours. The different degrees of gravity of the cases were due, in our opinion, to the progressive diminution in virulence of *Pasteurella pestis* in the fleas, in accordance with the period of extrinsic incubation of the infection, more than to variations in individual resistance. The bubos were localized as follows: Twenty-nine inguino-crural (5 double); 5 cervical; 1 axillary; 1 axillary and cervical; 4 with uncertain or unknown localization. In 2 cases, plague "carbuncle" occurred on the dorsum of the foot, 1 and 3 days, respectively, before the development of the corresponding bubo. The chief symptoms were: bubo, fever, chills, dizziness, headache, vomiting, and in the grave cases, unconsciousness and coma.

The treatment instituted prior to our intervention was excessive. Serum in small doses was given, and sulfathiazole in enormous doses, such as: 42 and 50.5 gm. (in a boy of 9); 52.5 gm. (in a boy of 14); 72, 72, and 73 gm., etc. Secondary manifestations included cutaneous eruptions, edema, oliguria, and incontinence of urine. Apparently sulfathiazole did not influence the evolution of the disease, although the writer has proved its beneficial effects in guinea pigs, which agree with the results already established in the literature.

Of the cases in which the site of infection was known, 9 pertained to the focus in the Public Market; 2 to the house of S. M.; 3 to Alfonso Ugarte Street; 4 were related to the sacks in the warehouses where rats had died; and the rest to diverse foci (see map).

APPLICATION OF DDT

From November 30 to December 10, 1945, 10 per cent DDT powder (Neocid) was applied with mechanical dusters to the floors of 1,357 dwellings, with a total of 3,820 rooms; and also to 47 public offices, churches, barracks, moving picture houses, schools, warehouses, etc. Also treated were the houses, clothing, household goods, furniture, etc., of 30 plague patients, including the clothing of contacts. With special equipment, DDT was applied to 7,000 bales of tobacco and sacks of cereals, and to several thousand empty sacks.

The average area treated per room was 15 square meters. Using 203 kilos of 10 per cent DDT, a total area of 81,000 sq. m. was covered, giving an average of 2.5 gm. of 10 per cent DDT per sq. m. The inhabitants were told not to sweep out the houses for at least a week. This method of using DDT we term "surface application" of DDT.

From the 11th to the 19th of December, 1945, the "subsurface application" of DDT was carried out; that is, the use of 5 per cent DDT (2 per cent in cement buildings) in the spaces between ceilings and roofs, double walls, double boundary walls, beneath floors, in corridors and passageways used by rats, and in general in all "dead" and empty spaces which could be considered as accessible to rats or fleas. In all, 1,006 houses, with 2,643 rooms, were treated with 170 kilos of 5 per cent DDT and 74 kilos of 2 per cent DDT. DDT mixed with flour in strengths of 5 per cent and 2 per cent

proved to be an excellent insecticide against flies and other diptera, except mosquitoes.

From December 20, 1945, to January 19, 1946, the application of DDT was repeated in 1,295 dwellings having a total of 4,026 rooms, using 230 kilos of 5 per cent DDT. In this treatment were included governmental and public buildings of all kinds, and dwellings located in the central part of the city. In all applications, special attention was given to rat burrows and harborages.

Results obtained may be best appreciated by examining Table 3, and may be summed up as follows:

1. The next to the last case of plague occurred 4 days after the termination of the "surface application" of DDT. It had its origin from a sack of rice in the Government warehouse of the Department of Warehouses and Shipments, a site in which rats, coming from the adjoining house of S. M., were repeatedly found dead of plague. Rats which died among the stacked sacks left their infected fleas there. The Rice Monopoly distributed these sacks among local stores, and the case in question, a woman, proprietress of one of these stores, slept beside the spot where a sack of cereal had been left. The final case, which occurred more than a month after the penultimate, was related to the house of S. M., which has been mentioned as the focus of an intense epizoötic. The sick person, before falling ill, had purchased and carried to his house all the wood in a storeroom of S. M. which was located beside the epizoötic focus, and which had been kept closed up to that time. We wish to point out that both the rice warehouse and the storeroom for wood

TABLE 3

Results of the Application of DDT against the Development of a Plague Outbreak, Tumbes, 1945, Judged by the Evolution of Flea-rat Index and the Incidence of Murine and Human Plague

	Before the Application of DDT	*After the 1st Application of DDT*	*After the 2nd Application of DDT*
I. *Rat Fleas:*			
Rats examined	38	36	49
Fleas collected	172	30	37
Global Flea Index	4.5	0.83	0.755
Flea index, epizoötic areas	11.3	5.3	0.86
Flea index, other areas of the city	2.1	0.39	0.66
Per cent of *X. cheopis*	97.0%	100.0%	100.0%
Total reduction of rat fleas		81.6%	83.3%
Bis, epizoötic areas		50.5%	92.4%
II. *Rat burrow fleas:*			
Number of burrows examined	31	13	
Bis, without fleas	13	8	
Fleas collected	156	8	
X. cheopis	150	8	
Average number of fleas per burrow	5.03	0.61	
Bis, per burrow with fleas	6.66	1.6	
Reduction of fleas in burrows		87.9%	
III. *Free living fleas:*			
Free living fleas	Abundant	Very scarce	Very scarce
X. cheopis living free on the floor of the houses	Scarce	None	None
X. cheopis on the clothing of persons	Scarce	None	None
IV. *Rats examined:*			
Rats examined	139	45	49
Plague positive	38	3	0
Per cent of plague rats	27.3%	6.66%	0%
V. *Fleas from rats and rat burrows:*			
Lots of inoculated fleas	25	7	
Plague lots	14	0	
Per cent of plague positive lots	56%	0%	
VI. *Human plague cases:*			
Before application of DDT	29		
During application of DDT		9	
Bis, 2nd application of DDT		1	
After 2nd application of DDT			1

had received as thorough as possible a treatment with DDT; and we reiterate that both instances prove that the application of DDT without the prior removal of stacked sacks and similar merchandise is ineffective, since DDT acts solely as a contact poison. In the tobacco warehouse a direct proof of the existence of infected fleas was the infection with plague of one of our laborers, whose job it was to apply DDT to several thousand bales of tobacco. In this instance, each bale was individually treated—baled leaf tobacco apparently does not repel fleas from the outside of the bales—and no additional cases occurred. To sum up, the two final cases of the outbreak were due to defective treatment of the respective foci, the warehouses, in that only the surfaces of the stacks of baled merchandise were treated with DDT. It is obvious that the cost of a correct application of DDT in warehouses filled with piled merchandise may be beyond the financial resources of the sanitary services; also, an excessive amount of DDT may be required.

2. There was an 81.6 per cent reduction in the flea infestation of rats after the first application of DDT, and an 83.3 per cent reduction after the second. In the epizoötic foci this reduction was in the order of 50.5 per cent and 92.4 per cent respectively.

3. After the first application of DDT there was an 87.9 per cent reduction in the flea population of rat nests and burrows; in the epizoötic foci the reduction was 81.5 per cent.

4. Rat plague was reduced by 76.3 per cent after the first application of DDT, and by 100 per cent after the second.

APPLICATION OF SODIUM FLUOROACETATE (1080) AS A RATICIDE

The city was divided into 9 sectors (see map), and the poisoned baits were placed in the dwellings in 5 localities: floors, rat burrows, "high interiors" (including ceilings, spaces between ceilings and roofs, attics, rafters, flat roofs, etc.); "low interiors" (including spaces beneath floors, spaces between boundary walls, in double walls, and in "dead" and empty spaces of all sorts within the houses); and exteriors, especially in pit privies.

The poisoned baits—cakes, rolled oats, or water—were made up so that a dose was 10 ml. of water poisoned with 1080, or 3 or 4 gm. of rolled oats poisoned with 1080 in the proportion of 5 parts of poison per 1,000, or one cake weighing approximately 1 gm., with the same concentration of the poison as in the rolled oats bait. The baits were carefully placed in an endeavor to keep them out of the reach of children and domestic animals. The rolled oats were handled with spoons; the poisoned water and the cakes were handled with bare hands, but the inspectors were warned not to smoke, and to avoid putting their hands to their mouths. Not more than 5 baits were placed in any one house. No accidents occurred, in placing the poisoned baits, among human beings, nor were there any complaints about the killing of domestic animals, except a few cats.

RESULTS

Due to the shortage of personnel the control of the poisoning was deficient. In Table 4 can be seen the number of doses of each type of bait placed in 1,200 dwellings. The poisoned water was the most difficult to handle, and only 481 domiciles were treated with this method, in which 713 doses (1.4 baits per house) were placed. Nevertheless the results with the water were the most satisfactory, since 151 dead rats were recovered, or 21.1 per each 100 baits, 0.31 per domicile. The 1,648 doses of rolled oats placed in 796 dwellings killed 113 rats, or 6.9 rats per 100 baits, and 0.142 per dwelling. The 2,247 cake baits, placed in 809 houses, killed 51 rats, or 2.3 rats per 100 baits, or 0.063 rats per house. In all, 4,608 baits deposited in 1,200 dwellings (2,086 dwellings, considering independently the dwellings treated in each poisoning) killed 315 rats, a relatively small figure which does not represent the true results, since dead rats were collected and examined only when their presence was reported by the householders. These figures are mentioned only for the purpose of comparing the

TABLE 4

Total Number of Baits Poisoned with Sodium Fluoracetate (1080), Distributed at Tumbes, 1945

(See the text for a detailed description of the different types of poisoned baits used—cakes, rolled oats, or water solution—and also for the exact meaning of the different locations where they were placed)

Type of Bait	Cumulative Number of Houses Treated with Poison	Average Number of Poisoned Baits per House	Total Doses Distributed	Location of Poisoned Baits in the Houses					Control of Poison Activity		
				Floor	Rat Burrows	Low Interiors	High Interiors	Exterior	Dead Rats	Dead Rats per 100 Poisoned Baits	Dead Rats per House
Water solution	481	1.4	713	178	16	153	320	46	151	21.1	0.31
Cake	809	2.7	2,247	339	393	643	551	321	51	2.3	0.063
Rolled oats	796	2.1	1,648	627	182	211	505	123	113	6.9	0.142
	2,086 *		4,608	1,144	591	1,007	1,376	490	315		

* Includes 1,200 different houses

relative activity of the three types of baits used, and not as a demonstration of the raticidal effectiveness of the poison itself. Indeed, in a sector controlled by the inspectors it was observed that the proven murine mortality was 40.4 rats per 100 baits, and 1.204 rats per treated domicile. In another sector checked by the inspectors during only one afternoon the proven murine mortality from "1080" was 13.8 rats per 100 baits, and 0.453 rats per dwelling.

On the other hand, complaints of bad odors (from putrefying rat carcasses) were uniform throughout the city, which suggests that the results considered as not so favorable, from certain sectors, were due only to lack of adequate checkup. The entire population was in agreement in eulogizing the action of the poison and in declaring that there were now neither rats nor fleas in their homes.

In a rural area not included in our experiment, 150 baits were distributed on a banana plantation, and 23 dead rats were recovered in a single afternoon.

Precise data on the raticidal power of the poison will be presented in a future report dealing with studies carried out in the city of Huacho, Peru.

DISCUSSION

The epidemiological situation in Tumbes at the beginning of the plague epidemic of 1945 may be characterized thus: a city in a deplorable sanitary condition, with a climate propitious for bubonic plague, and with a heavy murine population of *R. alexandrinus* exhibiting very high flea indices, the fleas nearly all *X. cheopis*. The infectious agent — *Pasteurella pestis* — imported from an endemic plague zone, encountered a medium favorable for its propagation in a rat population completely susceptible. The epizoötic developed slowly in a single focus—the Public Market—during the season of the year not favorable for the spread of the disease, and then developed rapidly with the beginning of the plague season. Human plague cases occurred in relation to this focus, which was eradicated by the destruction of the Market. The murine infection spread to over 20 successive foci, half of which died out *in situ* due to the scarcity of available murine population. Up to November of 1945 there persisted an

intense epizoötic focus with various others of lesser intensity; and in relation to these foci a total of 40 human cases of plague occurred.

The "surface application" of DDT wiped out the pulicine vectors living "free" in the dwellings, thus protecting the inhabitants. During the first application of DDT about 10 human plague cases developed which had been in the incubation stage at the time dusting was started. Four days after finishing this first application, one case appeared. After the second "subsurface" application, there was a significant diminution in the number of plague rats, infected fleas on rats, and infected fleas in rat nests. There occurred the late development of one benign human case of plague due to the persistence of the infection in a site which was insufficiently treated—a place in which an intense epizoötic had occurred.

It is evident that DDT was surprisingly rapid and effective in controlling the plague outbreak, especially when it is considered that the epidemic occurred in a medium highly unfavorable for the application of eradicative measures, and where the outbreak was just developing. The poison 1080 completed the work of the DDT, destroying the rodent population in a high degree. The rat-flea indices, and those of plague infection, were profoundly influenced by our measures, all being very favorable at the termination of the campaign.

The plan for the work done in Tumbes followed a logical order of reasoning taking into consideration the quality of the medium, the zoölogical situation, and the murine and human infection. We believe that the campaign carried out can serve as an example to be followed in places where plague epizoötics and epidemics are in full swing, and where *R. alexandrinus* (or *R. rattus*) and *X. cheopis* are involved. Preventive measures, or the presence of *R. norvegicus*, would have required other methods of approach, as will be described elsewhere.

Previous laboratory experiments showed that a dilution of DDT mixed with inert powders in a proportion of 0.002 per cent is the minimum dose effective as a pulicide when spread so as to cover uniformly the treated surface. On the other hand, 0.05 gm. of DDT per sq. m., in any dilution, was an effective pulicide in our experience. In Tumbes we applied approximately 2.5 gm. of 10 per cent DDT (0.25 gm. of pure DDT) per sq. m. The higher dilutions require more time to eliminate the fleas. Mixtures of 2 per cent DDT in flour, applied at the rate of 10 to 15 gm. of the mixture per sq. m., are equally effective as the use of 2.5 to 3.0 gm. of 10 per cent DDT in the same area. Three gm. of 2 per cent DDT per sq. m. had the same activity as the previously mentioned mixtures; but the time required for the effect was four times greater. The mixtures of DDT and flour are attractive to flies (which is not the case with the pyrophyllite or talc mixtures), killing them in not over 12 hours. Wasps and horse-flies were also susceptible to this mixture. However, mosquitoes were not eliminated by any of the mixtures in the percentages used, due possibly to the fact that they do not rest on the floors.

Ten per cent DDT was effective against *X. cheopis* embedded in the fur of rats: but it was not lethal to *E. gallinacea*. Rats covered with a heavy dose of DDT, for example, one or two gm. of a 10 per cent mixture, may die from DDT intoxication, as they lick their fur. The application of DDT to floors was effective in eliminating *P. irritans*, *Ct. canis*, and *T. penetrans*. Free-living *E. gallinacea* resisted the action of DDT no better than the other fleas, so that the resistance of this species when embedded in the fur of

rats may possibly be due to the circumstance that, when so embedded, they leave exposed to the action of DDT only those abdominal segments which are protected by a thick coating of chitin. Similar observations have been reported by Davis.[1]

The residual effect of DDT was demonstrated in the persistence of its activity after the first rains had dislodged the flea population from the spaces beneath the floors of the houses.

The initial cost of the DDT application in this campaign was S/.0.03 per sq. m., (or less than $0.005 US). An average of 140 gm. of 10 per cent DDT were used per house, the average amount per room being 50 gm. Costs per house were S/.1.80 (approximately $0.27 US). In using 5 per cent DDT, an average of 193.8 gm. of insecticide was used per house, and 75.3 gm. per room, with a corresponding diminution in costs to S/.0.15 per sq. m. ($0.0023 US), and S/.0.60 ($0.098 US) per house.

We wish to emphasize that DDT is effective against fleas only in the places where it has been applied—it is strictly a contact poison—so that its uniform spread must be meticulously carried out. Rats may transport particles of DDT adhering to their fur; but usually only to their own burrows. Flea breeding places which are not also rat harborages (and thus more liable to treatment) persist in their infestation if they are not directly treated with DDT.

As regards 1080, we recognize that it is the best poison that we have used against rats, and we have proved to our own satisfaction its qualities as summed up by Ormsbee,[2] a high degree of toxicity for rodents, excellent acceptance in different baits, rapid lethal effect, absence of taste and odor, chemical stability, non-volatility, not toxic or irritating to the skin, no tolerance on ingestion of sublethal doses, easy incorporation in baits, and low cost of production. Poisoned baits may be avoided by rats when they learn to recognize them; but this may be nullified by changing the type of bait. There are few inconveniences in using this poison, if it is carefully handled.

Three inspectors, personally placing the baits, carried out three poisonings of the city of Tumbes, using three different types of poisoned baits, in 25 working days, depositing 4,608 baits in 1,200 houses, in 2,086 visits. In other words, each inspector covered 28 houses daily, placing therein 61.4 baits. The cost of the poison per bait (per dose) was high, nearly $0.02 US; but the total cost of the poisonings was less than $76.00 US. The high cost per bait applied was due to the care taken in placing each bait. For reasons given earlier, figures on the cost of the poison per rat killed will not be calculated; they would give a false idea of the cost involved, since we did not find anywhere near the total number of rats poisoned.

In studies now in progress we have found that 1080 is a secondary poison for the fleas which suck the blood of poisoned rats. Even *E. gallinacea* are killed, as well as *P. irritans, X. cheopis, H. suarezi, Ct. canis, Cediopsylla inequalis, R. cavicola,* etc. The rapidity with which the fleas succumb depends on the level of circulating poison in the blood stream of the rats. It will be comprehended that the confirmation of this finding would be of transcendental importance in anti-plague work.

SUMMARY AND CONCLUSIONS

In the city of Tumbes, Peru, which has a tropical climate, 10,000 inhabitants, the majority of the houses constructed of bamboo or wattle (mud and sticks), and which has no public water supply or sewerage systems, an epizoötic

of murine plague, followed by a human epidemic, broke out in the last trimester of 1945. Among the epidemiological factors of importance were the intense murine over-population with *R. alexandrinus,* with a flea index of 4.5 per rat (11.3 in the epizoötic zone), the fleas being chiefly *X. cheopis;* an abundance of rat fleas in the rat nests, with an average of 5.03 fleas per nest (8.6 in the epizoötic zone), practically all *X. cheopis;* an abundance of free-living fleas on the floors of houses, predominately *Ct. canis, P. irritans,* and *T. penetrans;* and the presence of *X. cheopis* on floors, and in the clothing of plague cases. Other important factors in the outbreak were the proximity of the rainy season, which began in December, a temperature fluctuating between 26° C. and 34° C., and a relative humidity between 75 and 94 per cent. The plague epizoötic may have begun in July or August (which are not in the plague season) and progressed slowly until the beginning of the plague season at the end of September. A total of 21 foci were formed, of which 2 were intense, the first of these being in the Public Market. In these plague foci 27.3 per cent of rats found were plague-infected, as were 56 per cent of the fleas found on rats or in rat nests. The epidemic caused a total of 40 human cases, and it was not diagnosed until the middle of November, by which time more than a dozen cases had occurred. All of the cases were bubonic in type, and the case fatality was 35 per cent.

The only control methods used were DDT in powder form (diluted to 10 per cent in talc or pyrophyllite, and diluted to 5 and 2 per cent in refined wheat flour), followed by the application of sodium fluoroacetate (1080) as a raticide. The DDT was applied first to the floors of all houses (1,357, with 3,820 rooms and 7,388 inhabitants), using an average of 2.5 to 3 gm. of 10 per cent DDT per sq. m. (140 gm. per house, 50 gm. per room), to prevent the biting of the populace by infected fleas. The second application was made to the spaces between ceilings and roofs, on the flat roofs, beneath floors, between double walls, etc., using 5 per cent DDT powder. The first method we term "surface application," and the second "subsurface application." A third application of DDT was similar to the two preceding. Simultaneously with the third application of DDT, the raticide "1080" was brought into use, three types of poisoned baits being employed: A 1/1,000 solution in water, a 5/1,000 mixture in rolled oats, and a similar concentration in small dried cakes. In placing the baits, 1,200 domiciles received a total of 2,086 visits, with 4,608 baits being set out, locating them in both upper and lower parts of the houses, outside as well as inside, and also in rat burrows.

The effectiveness of the application of DDT can be appreciated by: (a) the stopping of the epidemic 4 days after finishing the first application of DDT (the one case occurring over a month later was due to the incomplete treatment of a known focus); (b) the 81.6 per cent lowering of the flea infestation of the rats, and the 87.9 per cent diminution in the numbers of fleas found in rat nests, after the first application of DDT. There was a final reduction in the number of fleas in the epizoötic foci of over 90 per cent. Rat plague was reduced 75.6 per cent after the first application of DDT, and 100 per cent after the second.

The results of the use of sodium fluoroacetate (1080) were excellent, as could be judged by partial controls. In one district of the city 40.4 rats per 100 baits were killed, and 1.2 rats per house succumbed to the effects of 1080. In other sectors fewer dead rats were found, but the checking of this factor was deficient and irregular. The popu-

lation was well satisfied with the results of the poisoning.

Only mentioned here, and to be discussed in later papers, are the toxicity of 10 per cent DDT for rats (which regularly and carefully lick their fur) in dosages of 1.0 to 2.0 gm. of the powder applied to the body surfaces of the rat; and the toxicity of sodium fluoroacetate (1080) for rat fleas, which die by secondary poisoning from ingesting the blood of poisoned rats.

The application of DDT, followed by poisoning with 1080, promises to be the procedure of choice in the control of epidemics of bubonic plague.

REFERENCES

1. Davis, David E. The Control of Rat Fleas (*Xenopsylla cheopis*) by DDT. *Pub. Health Rep.*, 60, 18:485–489 (May 4), 1945. *Reprint No.* 2626.

2. Ormsbee, Richard A. A Summary of Field Reports on 1080. NRC, ICC Rodent Control Subcommittee, October 26, 1945 (Mimeograph).

Western Reserve Expands Teaching Staff in Preventive Medicine

A series of appointments have been announced at Western Reserve University School of Medicine and University Hospitals, Cleveland, Ohio, looking toward the development of an important center for the study of disease prevention. Five physicians from the U. S. Army staff will join the university and hospital staffs during the coming summer.

John H. Dingle, M.D., will occupy the Elizabeth Severance Prentiss chair as Professor of Preventive Medicine to succeed James A. Doull, M.D., Dr.P.H., who has joined the staff of the U. S. Public Health Service. Dr. Dingle is director of the Commission on Acute Respiratory Diseases of the U. S. Army Epidemiological Board. Dr. Dingle, a native of North Dakota, has a Doctor of Science degree from Johns Hopkins and a medical degree from Harvard.

Other appointments include George F. Badger, M.P.H., M.D., as Associate Professor of Biostatistics. Dr. Badger, formerly Assistant Professor of Biostatistics at Johns Hopkins University School of Hygiene and Public Health, was from 1942–1946 consultant to the Secretary of War in biostatistics. He is presently a Major in the Army Medical Corps.

C. H. Rammelkamp, M.D., is a graduate in medicine from the University of Chicago and also was consultant to the Secretary of War from 1943–1946.

A. E. Feller, M.D., is a graduate in medicine from the State University of Iowa. He was formely instructor in the New York University College of Medicine and a fellow in medical science with the National Research Council at the Harvard Medical School.

R. G. Hodges, M.D., is a graduate in medicine from Harvard in 1936. He was formerly instructor in pediatrics at the College of Physicians and Surgeons, New York City.