

THE CONTROL OF PHLEBOTOMUS IN PERU WITH DDT¹

MARSHALL HERTIG² AND G. B. FAIRCHILD¹

INTRODUCTION

Before the advent of DDT there was no satisfactory control method against *Phlebotomus* sandflies. At best, temporary protection was afforded by repellents, bednets and the treatment of rooms with pyrethrum sprays or aerosols. Weekly spraying of fuel oil on the outer walls greatly decreased sandflies within houses (1) but this method was of limited application on account of its obviously disagreeable features.

Our interest in the control of *Phlebotomus* with DDT began in January 1944. Although primarily engaged in testing repellents in the sandfly-bartonellosis zone of the Rimac Valley in Peru (2, 3) we made two trials of residual DDT. The walls of two adobe huts with an abundant sandfly population were sprayed inside and out with DDT in kerosene. Although unforeseen circumstances put an early end to these experiments, in both cases sandflies were not seen nor were bites received for about a week.

Work with DDT was continued when one of us (M. H.) went to the Mediterranean in July 1944 in connection with *Phlebotomus* and sandfly fever (4). There were a number of small local outbreaks of sandfly fever among American troops in the Naples area associated with *Phlebotomus papatasi*. At that time residual DDT was being employed on an increasing scale in Italy and it became the practice to spray the interiors of quarters generally, and in any case, wherever sandfly fever occurred. In all cases which came under observation, it was noted that whenever the spraying was adequately done, *i.e.*, complete coverage with 5 per cent DDT in kerosene at the rate of at least one gallon per 1000 square feet, there were no further cases of sandfly fever and usually no sandflies at all could be found in the sprayed quarters. On investigating the unsatisfactory results in the case of one extremely large building with very high ceilings, it was found that inexperienced personnel had applied irregularly only a fraction of the DDT needed. A subsequent spraying reduced the sandflies to negligible numbers. In the area south of the Arno River, a number of buildings, particularly stables, had been sprayed with DDT in connection with malaria control. It was unusual to find any sandflies at all in such cases, whereas unsprayed stables frequently contained numerous sandflies, mostly *P. perfliewi* and *P. perniciosus*.

It was not feasible to undertake controlled experiments in human habitations in Italy, but several small-scale tests were carried out in stables in Bagnoli, near

¹ This work was initiated under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development (the contract having been assumed later by the Office of the Surgeon General) and the Gorgas Memorial Laboratory.

² Major, Sanitary Corps, Army of the United States.

³ Medical Entomologist, Gorgas Memorial Laboratory, Panama, R. de P.

Naples. The buildings were of stone, frequently with bomb rubble nearby. Sandfly catches were of the order of 10 to 20 at one visit, mostly *P. perniciosus* with some *P. papatasi*. It had already been observed that buildings sprayed inside could usually be expected to harbor no sandflies. It was desired to determine whether or not a barrier to the entry of sandflies could be created by outside spraying. Accordingly, only the outer walls, together with any immediately adjacent rubble, were sprayed. Sandfly catches were greatly reduced. They were frequently zero and rarely exceeded three or four. An untreated stable maintained its normal sandfly level.

A few preliminary laboratory tests of the toxicity to sandflies of residual DDT were also made at this time (4). Sandflies were exposed to DDT in glass jars which had been rinsed with a kerosene solution, drained and allowed to dry several weeks previously. Exposures of 6 to 15 minutes gave knockdown without recovery in the case of *P. perniciosus* and *P. parroti* var. *italicus*, while *P. papatasi* required 15 to 40 minutes. In all cases, however, agitation began within about three minutes, and after about six minutes fluttering of the wings and lack of coordination were common. At this stage there was frequently noted a characteristic "stumbling" on alighting, the sandfly going down on one side and then quickly recovering its normal position. The behavior as to feeding, oviposition or other functions of those sandflies which recovered, was not followed.

The duration of the effect of the DDT in the Italian work could not be determined. The longest period of observation was a scant two months from the time of application to the decline of the sandfly season in October. In no case was there evidence of the effect wearing off.

Controlled experiments in Palestine with *P. papatasi* (4) showed that spraying the inner walls of houses gave practically complete protection from the bites of sandflies and constituted the most effective single method of house spraying. DDT applied outside gave roughly 75 per cent control. It was recommended that in practice living quarters be sprayed inside, and in addition the outside of doors, windows and other openings, together with a little of the surrounding outer wall.

The work in Italy and Palestine established the effectiveness of "house-control" and pointed to the possibility of achieving area-control by applying DDT to those outdoor structures or objects which serve as sandfly breeding and resting places. It was felt at that time that several features of the habits and life-cycle of *Phlebotomus* would operate in favor of control by this method, namely, the limited flight range from breeding places; the characteristic short flights with relatively long pauses both at shelters and near a blood meal; the long life-cycle with a correspondingly slow replacement rate.

We returned to Peru in 1945 at the invitation of the Peruvian Ministry of Public Health to study further the possibilities of area-control (5). Peru offered a number of advantages for this work. There was an abundant sandfly population the year round which had been under more or less continuous study from 1937 to 1942 by one of us (6) and later by an associate, Dr. Aristides Herrero. Furthermore, we had the active interest and generous cooperation of various

Government agencies and private individuals and groups who have been much concerned with sandfly-borne diseases as a public health problem⁴. We were in Peru from June to September 1945. The experimental areas were revisited in March and April 1947.

Several small-scale preliminary experiments were carried out at Surco, a village in the Rimac Valley about 40 miles from Lima at an altitude of 2013 meters. Sandflies, mostly *P. verrucarum* with a few *P. peruensis*, are abundant in most of the houses scattered around the periphery. We have sandfly data for some houses covering several years.

Field headquarters and laboratory were established in a railway coach⁴. We had the able and enthusiastic assistance of Doctor Herrer and Señores Caballero and Puertas⁴, all with years of experience in sandfly work in that region. When abroad at night we protected ourselves with Army insect repellent. Our three associates had had bartonellosis and used repellent only occasionally when sandflies were particularly annoying. The coach was sprayed with DDT. So far as we are aware we have never been bitten by *Phlebotomus* in any of our Peruvian work.

Criteria for sandfly abundance. For the purpose of estimating sandfly abundance as accurately as possible to check the results of our experimental work, we made use of a number of different methods, alone or in combination. While from a statistical point of view it might have been better to employ but one standard method, the time at our disposal and other circumstances beyond our control made it seem advisable to employ whichever method promised the most information in any given case.

(1) *Indoors. a. House catches.* The simplest method is to make catches in houses and associated animal shelters during the day, with the aid of tobacco smoke and a flashlight. However, the number of sandflies which remain in a house after the night's activity depends partly on the construction. A dark house of adobe or masonry, with few openings, particularly between the walls and roof, will harbor more sandflies than one made of cane, sheet metal or boards with many openings. Where cooking is done over an open fire very few sand-

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flies remain, even though they may enter and feed in great numbers at night.

b. The characteristic bites of *Phlebotomus* give a rough index of sandfly activity during the previous night. On sensitive individuals, particularly children, the bites are red spots, two or three millimeters in diameter, distributed on face, neck and forearms. They are distinct in the morning but may fade by noon.

c. *Bites reported.* The people are thoroughly familiar with sandfly bites and distinguish them with accuracy from those of other insects. Once friendly relations have been established, considerable confidence can be placed in the reports of intelligent individuals. In the areas where we worked there are practically no mosquitoes of any sort which might lead to confusion.

For our experimental work we selected houses known to yield consistently good catches, *i.e.*, of the order of 60 to 80, rarely falling below 40, and at times totaling 100 to 150 or even more sandflies at one time. However, even in "good sandfly houses" the catches may vary a great deal from day to day depending on weather and other conditions. A rainy or windy night checks sandfly activity and may be reflected in reduced catches the following day.

(2) *Outdoors.* a. *Domestic animal shelters.* Those animal shelters which have a roof are comparable to houses as daytime resting places for sandflies. This category, however, includes only poultry houses and hutches for guinea-pigs or rabbits. In Peru cattle, horses and burros are kept in open corrals, not stables. Piggens are usually small enclosures of loose-laid stone. Daytime searches of the walls of corrals or piggens reveal very few sandflies, which is true of outdoor stone walls in general. While smoke which penetrates the inner recesses may cause the sandflies to move, the irregular and intercommunicating spaces permit them to avoid the daylight and they can rarely be seen even with a flashlight⁵. However, beginning at five or six o'clock in the evening, sandflies come out of hiding and may be seen resting in the interstices or actually on the surface of the wall preparatory to taking flight. Smoke hastens the process of emerging from the inner recesses. Piggens are especially profitable for night observation since attractive hosts, resting places and probably also breeding places are closely associated and sandflies can easily be found throughout the night.

b. *Stone walls, caves and other shelters not associated with hosts.* Stone boundary and retaining walls laid without cement were the principal outdoor sandfly shelters in our experimental areas. Especially favorable were thick walls with many dark recesses free of air currents, and with year-round sources of moisture, such as nearby irrigation ditches, or in the case of retaining walls, irrigated ter-

⁵ We have observed in the case of various Panamanian species of *Phlebotomus* that while collecting with smoke a number will fly out, even into bright sunlight, from hiding places in masonry recesses, tree buttresses or animal burrows, a phenomenon which is rare with Peruvian species. It may be noted for sandflies in general that while their resting places are usually dark, it is in many cases a matter of choosing a spot away from the source of light rather than seeking the lowest possible light intensity. Sandflies often penetrate small crevices but many seem to prefer to rest on an open surface rather than avail themselves of nearby crevices. As a result, it often happens that sandflies may easily be seen on the far side of rooms or shallow caves without the aid of artificial light.

racés. As indicated in the preceding paragraph it is only in the evening that sandflies can be demonstrated in stone walls. Certain stretches of wall consistently harbored more sandflies than others and thus served as convenient observation points.

In our present work we regarded stone walls merely as shelters and identified no particular spots as breeding places. Nevertheless these walls undoubtedly included breeding places and most stone walls may be considered potential breeding places. Crevices in steep rocky slopes and the spaces beneath large boulders would fall into the same category as stone walls from the standpoint of sandfly shelters and potential breeding places, but actually we had to deal with very few such situations. Several dry, uninhabited caves were consistently good sandfly shelters, readily checked in the daytime.

c. Outdoor biting rate. Quiescent or sleeping persons and animals may be bitten in the open throughout the night, except when rainy or windy. We believe that the only really satisfactory method of determining the outdoor sandfly population is an animal-baited trap which would measure the sandfly activity of the entire night⁶. In the absence of suitable traps, the most feasible method was to observe the biting rate on burros during early evening. We found these animals quite attractive to sandflies. A tethered burro was examined with a flashlight at frequent intervals and the number of sandflies biting or merely resting on the animal were noted. Most of them would alight on the udder or male genitalia, with a few on the front legs and occasionally also on the face. As many as 15 or 20 were counted at one time. Feeding takes three to six minutes, but sandflies may remain without changing position even longer, whether they feed or not. The light causes little disturbance. At each inspection those sandflies which were judged to be new arrivals were counted. In general, burros are more attractive than man, the ratio being of the order of twenty to one as between burro and observer. A wave of outdoor biting begins between five-thirty and six o'clock and continues until about seven or at times until eight o'clock, after which there are usually very few bites, even in the absence of wind or rain. We have few data for the period after midnight. In previous work we have observed or had reports of a sudden increase of bites indoors after two or three o'clock in the morning. Biting rates tend to be highest near houses or particular portions of stone walls where sandflies are known to emerge nightly, and are lowest in open fields or away from normal hosts and good resting places.

In house catches there are considerable variations in the proportions of freshly fed females, *i.e.*, those with red blood and those which fed one or two nights previously and have black intestinal contents. We have taken this as a rough index to the preceding night's activity and as an aid in distinguishing isolated wave of sandflies. A low proportion of females with red blood would indicate that relatively few had entered the previous night, while the others would rep-

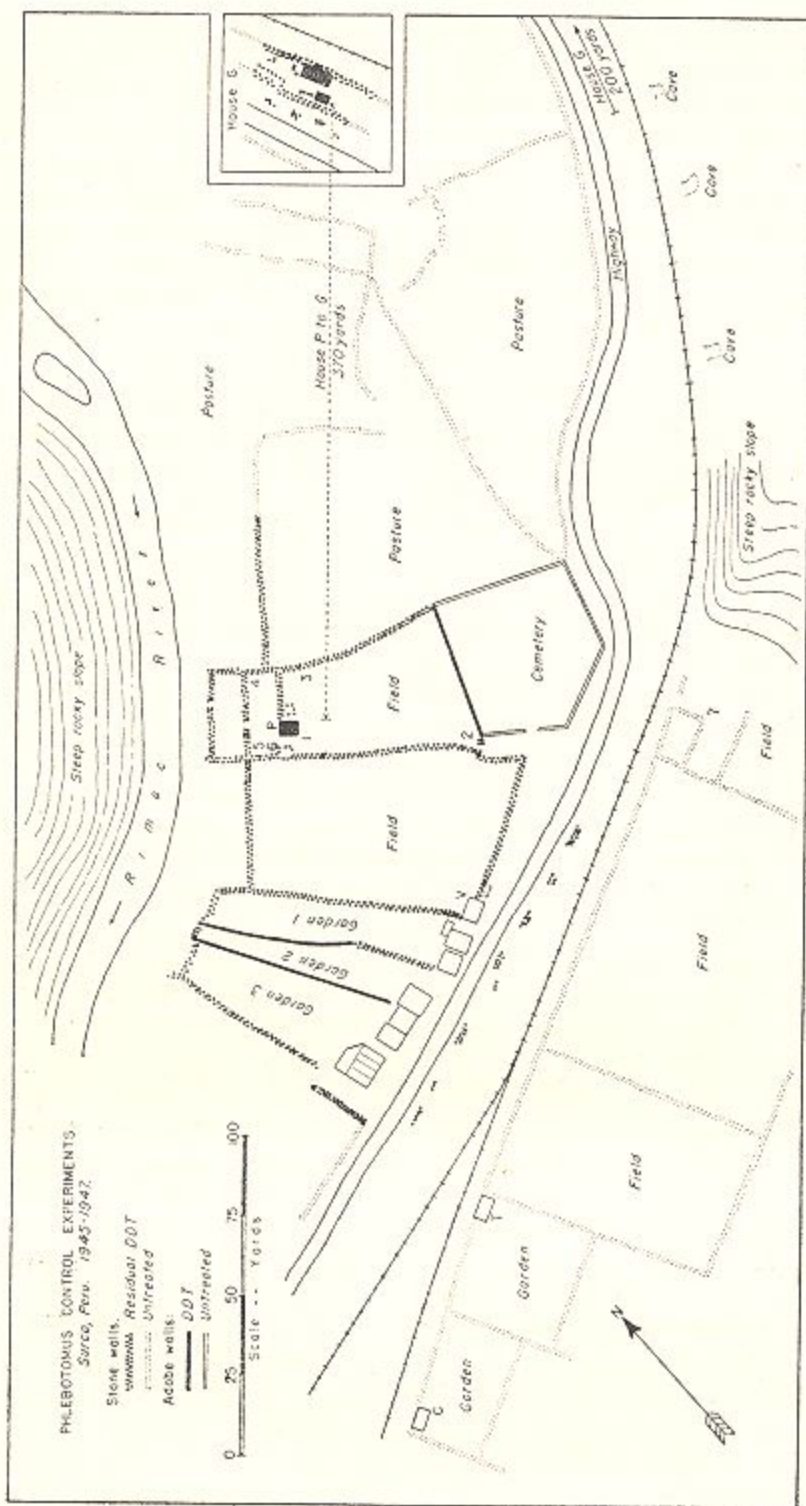
⁶ In Panama horse-baited traps operated in connection with mosquito studies frequently catch large numbers of *Phlebotomus* (as many as 200, mostly *P. panamensis* and *P. suis*). Even though sandflies can easily escape through the wire screening, they may be found on the lower wooden panels.

resent females which had remained for several days after feeding. It is unusual to find one with both red and black blood. In previous studies in the general region (6) a total of over 13,000 sandflies from daytime house catches consisted of 54 per cent fed females, 28 per cent unfed, and 18 per cent males. The proportion of those freshly fed was not recorded, but in our present work we have noted that in houses not disturbed by collecting for several days, about one-third of the fed females show red blood. The proportions of unfed females and males to the total are extremely variable and are apparently greatest when breeding places are immediately associated. We have included both unfed females and males in our totals but have been unable to extract from their proportions any particular significance for these experiments. Unfed females varied from less than 1 per cent to about 20 per cent of the total, while males rarely exceeded 3 per cent. Although we have only scanty information on the relative activity of sandflies which have fed and those which have not, it has been noted that unfed females make up the great majority of those seen leaving a house or outdoor shelter early in the evening and of those found abroad during the night. From our present work there are indications that engorged sandflies may remain continuously for two or three days, but probably not longer, in the house where they have fed, before seeking outdoor shelters or breeding places.

EXPERIMENTAL WORK

Our first experimental work was done in and around Surco in June and July 1945. Here we used more or less isolated houses or groups of houses to test the degree of control obtainable by applying DDT to the surroundings of the houses, to their outside walls, or to their interiors, in various combinations. Since we were "feeling our way" as it were, we modified the tests in various ways to give additional information and answer specific questions which arose during the course of the work. For this and the additional reason that this work illustrates problems which arise in dealing with sandflies, a group unfamiliar to most American entomologists, we have thought it advisable to record these experiments in considerable detail.

In all cases DDT was applied as a 5 per cent solution by weight in kerosene (5.6 ounces or 160 grams of Technical Grade DDT to the gallon). In getting the DDT into solution compressed air, when available, liberated at the bottom of the mixing tank was the most convenient way of securing continuous agitation. A wet spray was delivered by 4-gallon cylindrical pressure sprayers of conventional type, the disk nozzles having a 60-wire-gauge aperture (Figure 3). The rate of movement of the nozzle and its distance from the surface, about 18 inches, were roughly regulated to give coverage of at least one gallon per 1000 square feet. In practice the spraying was done so that the surface was seen to be wet without an excess running down, with an actual coverage approaching an average of 1.5 gallons per 1000 square feet. All surfaces, whatever their nature, were sprayed as nearly as possible at the same rate and as though they were flat and unbroken. In the case of stone walls no account was taken of irregularly projecting stones and no special treatment was given to openings in the wall. Thus



the outer surface of any individual stone would be wet while the spray might not be obvious on the rounded sides leading into the wall.

Area control, isolated houses at Surco (see sketch map; Figures 1, 2).

I. *House P* (Figure 2). A small adobe house, surrounded by nearly level cultivated fields with stone boundary walls, had been known for some time to have a good sandfly population. The adobe walls were smoothly finished and whitewashed inside and on two sides outside. There were two stories of one room each occupied by two families totaling six or eight persons. The only domestic animals were a dog and a few guinea-pigs and chickens which shared the lower floor with the family.

Preliminary observations, 30 May to 25 June 1945. This house had served as a catching station in the Institute's work since May 1945. On the basis of partial catches (34 to 70 sandflies, average 54) together with estimates on seven occasions between 30 May and 22 June, the sandflies were rated as abundant. A careful estimate on 23 June gave a total of over 170 sandflies, and on 25 June, over 160.

We made no thorough nighttime exploration of the 250 yards of stone wall near this house, but there was found one small stretch (Station 2) about three yards in length with a small irrigation ditch at its base, 60 yards from the house, which on several inspections never failed to show sandflies emerging in the evening. No estimate was made of the nightly total from this piece of wall. Three or four sandflies could be seen at any one time beginning about five-thirty, with an increase shortly thereafter, so that 10 to 20 could be seen at one inspection up to about eight-thirty, which was the latest for which we have data.

20-24 June. Beginning 20 June, evening biting rates were taken with one or two burros during successive periods of 15 minutes at six stations within the experimental area. Two stations were near the house; the most distant one (Station 2, 60 yards) was near the stone wall known to harbor many sandflies. Most of the observations were under way by six o'clock and were over before eight. The distribution of bites as between the different stations was thoroughly capricious, with no one station consistently attracting its proportion of the total. For example, the extremes for the entire series occurred on the same evening with two burros attracting 112 and 32 sandflies in 15 minutes at Station 1, and not a single sandfly at Station 4, while on the following evening these two stations were equal with 51 each. For the five evenings before spraying the averages for the different stations ranged from 17 to 40, with an overall average of 26 sandflies per station per 15-minute period.

25 June. DDT. All the stone walls in the area around the house were sprayed with DDT for a maximum distance of about 30 yards. The walls were mostly between three and four feet high. Both sides as well as the top were sprayed. The house was left untreated to serve as an index of the results. The sprayed boundary walls were the sole barriers to any sandflies entering the area. (Actually, this first spraying left an open approach from

PLATE I

EXPERIMENTAL AREAS, SURCO, PERU

These two overlapping views (note corner of cemetery with gate) include part of the area shown in the sketch map.

FIGURE 1. House V is the nearest one of the row along the highway. Station 7 is in the lower left foreground.

FIGURE 2. House P, middle distance; Station 2, under trees near corner of cemetery, left. After treatment of house and surrounding stone walls with DDT, House P remained virtually free of sandflies, while in House V, 75 yards away across an open field, they continued to be abundant.

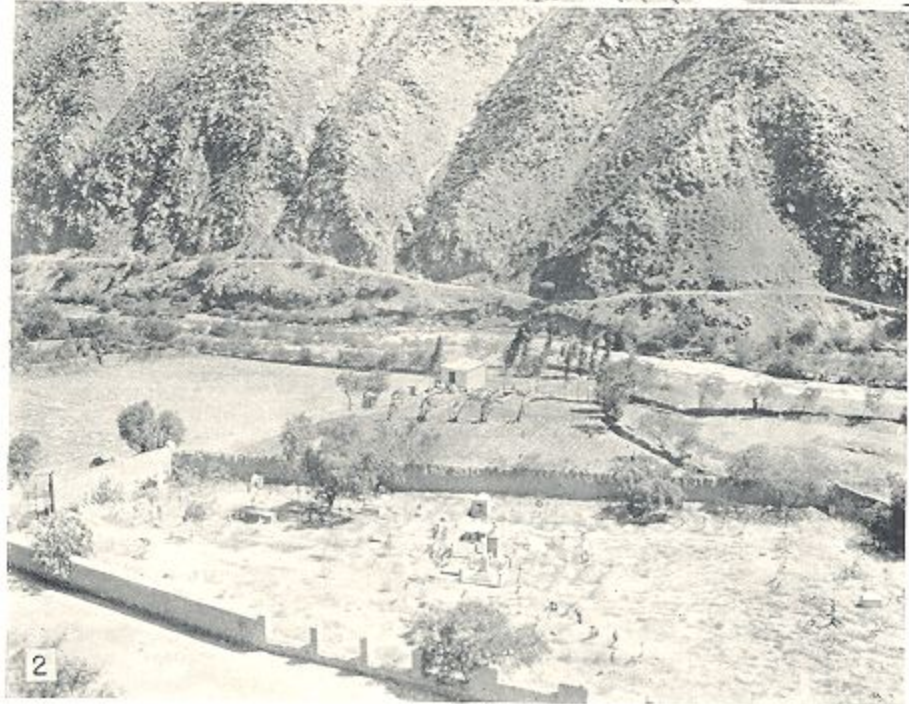


PLATE I

the sandfly shelter at Station 2.) Any sandflies already within the area which managed to avoid a sprayed surface, or were already in the house itself, were free to carry on their normal activities.

25 June to 1 July. House catches. On the first six days after spraying two or more of our group made complete house catches amounting to 120, 73, 18, 14, 21 and 4 respectively. These catches comprised all the sandflies which could be made to reveal themselves by means of tobacco smoke in diligent searches repeated several times, a process which required from thirty minutes to an hour. A "complete" catch does not mean that there are no more sandflies hiding in a house. This is particularly true when the sandflies are very abundant, since the more sandflies there are the more there will be in the inaccessible hiding places. Further, the greater the time spent in making captures, the more smoke is employed, with the result that some sandflies become narcotized and remain immobilized or fall, but recover later. The catches on the first three days included only 5 females with red blood compared with 184 with black intestinal contents and 17 unfed, and probably represented chiefly sandflies which were already in the house before the spraying. On the next three days there were a total of 7 with red blood, 10 with black and 20 unfed.

25 June to 1 July. Sandflies continued to emerge in customary numbers from the stone wall at Station 2, which was 30 yards outside the sprayed area. *Burro rates* dropped sharply beginning with the night of the spraying, with the exception of the unsprayed Station 2. On five nights between 25 June and 1 July this station averaged 23 sandflies in its 15-minute period (21 for the preceding five nights) while the other five stations in the sprayed area averaged only 2.5. A spot (Station 7) 130 yards from the house, where on 19 June a grazing burro was being bitten by many sandflies, gave a biting rate of 14 on 25 June. One burro at three stations in an orchard-garden (Garden 1) 50 to 75 yards from the house, on 26 June attracted over 60 sandflies in one hour.

Control houses. A number of houses within 200 yards were known in former years and on the basis of recent work by the Institute to have many sandflies. They continued abundant during this period by the report of the occupants, with characteristic bites obvious. One house in particular, House V (Figure 1), was located 75 yards across an open field from House P and about 50 yards from the nearest sprayed wall. Our first actual catches were made on 4 July when over 100 were caught, and on the following day when 67 were caught and at least 50 more seen, at a time when sandflies in House P had dropped to a very low level. A house on the other side of the village on 27 June yielded 65 sandflies. The weather was consistently favorable for sandfly activity during the whole period before and after spraying and our data indicate that sandflies continued to be normally abundant immediately outside the sprayed area.

3 July. Sprayed area extended. 25 sandflies were caught in House P. While there had been a marked drop after spraying, it was obvious that an appreciable number of sandflies still had free access to the house. In view of the extremely limited area which had been sprayed and the open approach on one side from a known sandfly shelter, the spraying was extended on 3 July on all walls up to a maximum of 65 yards from the house. This closed the open approach and included the wall at Station 2. At the latter point the spraying on one side had just been completed a little after five o'clock. A number of sandflies were seen to emerge suddenly from the other side showing considerable agitation but no other symptoms. No sandflies at all were found later in the evening. (Various evening inspections during the next two months always gave completely negative results.) The burro rate for that evening was zero at the four stations tested, while it averaged 15 in Garden 1, 50 to 75 yards away.

4-14 July. House catches on 4, 5, 6, 10 and 14 July were 7, 9, 3, 3, 7 respectively.

18 July to 13 August. There was a sudden increase of sandflies in House P, with catches on 18 and 24 July amounting to 75 and 92. Half the fed females on the first date showed red blood and on the second, only about one-seventh. On 27 July the catch had declined to 30, two-thirds with red blood, and on 31 July, 18 with none freshly fed, and reached a level which averaged 9 sandflies in six catches in the first two weeks of August.

Burro rates during the July rise averaged only 4 sandflies on each of two evenings, 23 and 31 July. On 3 and 8 August the rates averaged 3.

We have no explanation for the sudden rise in the house catches nor for their subsequent decline. The nearest dwelling, House V, which by that time had entered into a second spraying experiment (see Experiment II), also showed a slight rise but reached a level only half that of House P. Burro rates in orchards and gardens in this second experiment also showed a slight corresponding rise. We considered the possibility that sandflies were breeding in the foundations of the house itself, but the composition of the catches did not support this view. Our associates who made the observations during this period informed us that there had been considerable wind at night, even though the customary calm of early evening had prevailed during the burro observations. While sandflies ordinarily do not fly at all when it is windy, in previous work they have been seen to alight in numbers on buildings at speeds approaching violence, apparently blown there by the wind which was sufficient to move the wings of those at rest. Wind-borne waves of sandflies could easily be carried over low walls on which they would normally alight if left to their own devices. During the July rise the extreme variation in the proportion of sandflies showing red blood points to the possibility of waves rather than steady local production or infiltration. Nevertheless, we have no satisfactory explanation for this peak.

20-22 August. Catches on these three dates were 22, 38 and 58. (House V had 146 on 21 August.) The burro rate, however, averaged only 5 on 20 August, and on the following evening there was only 1 bite in 75 minutes at five stations, compared with 37 for the same period at Station 7, 55 yards outside the sprayed area.

22 August. House P sprayed. It was decided to modify this experiment so as to include house-control. As we were nearing the end of our stay in Peru, the results were to be checked by our associates at approximately weekly intervals. (See also Experiment III.) The house was thoroughly sprayed as follows: all inner walls on both floors; the edges of the sheet metal ceiling (roof) of the upper floor; the entire wooden ceiling of the lower floor; the outside of windows and doors and a little of the outer wall surrounding these openings.

On the same evening a burro near the house attracted only 1 sandfly in two separate 15-minute periods, while at Station 7 there were 30 in 22 minutes.

23 August to 5 September 1945. House catches were zero on 23 and 27 August. On 5 September the house could not be entered but a burro attracted a total of 8 sandflies at six stations. This house was vacated a few days later and remained unoccupied for several months. We have no further observations for this period. Meanwhile in the neighboring House V, eight catches between 21 August and 10 November averaged 82 sandflies, with extremes of 40 and 170. In November 1945 the Institute's *Phlebotomus* work was shifted to other places in the Rimac Valley and we had no further reports or observations at Surco until we revisited the place in company with our three Peruvian associates in March and April 1947.

26 March to 10 April 1947. House P had been vacant off and on for about a year but had been continuously occupied since October 1946 by people who had cooperated with us and our associates in previous work. The fields had been cultivated continuously. The occupants informed us that they had had "no bites" and that there had been "no sandflies" during their five months in the house, pointing out in the same breath that their neighbors, indicating Houses V, T and C and several others known to us, had complained constantly about the sandflies. Their story was supported by circumstantial accounts which included

the information that they were not bitten when sitting outdoors in the evening. Thorough search of the upper floor on 26 and 30 March yielded no sandflies at all. None of the occupants showed sandfly bites. The occupants of the lower floor were not at home on these visits. On 10 April four of our group made a thorough search of both floors, which netted one sandfly. An attempt to measure the biting rate with three burros and a horse that same evening was spoiled by high wind and rain. There were no bites at all on any of the animals either in the experimental area or at Station 7, from five-thirty to seven o'clock, when the test was abandoned on account of the weather. No sandflies were seen in the wall at Station 2 at several thorough inspections with smoke, although in a retaining wall at Station 7 sandflies appeared spontaneously or with smoke, but refused to take flight on account of the weather.

On 10 April a hurried, partial catch in House V yielded about 150 sandflies with as many more estimated to be present. In two nearby houses, C and T, 80 and 70 sandflies were caught, with more seen. In one of these houses the children's faces showed many bites, while in the other 72 bites were counted on one woman's forearm. The reports of the people, well known to our associates, indicated that this was the usual situation. On 30 March, a house at Matucana, several miles higher up the valley, known in other years to harbor many sandflies, showed sandflies to be normally abundant. Our associates had found the sandfly level normal in their work elsewhere in the general region.

We thus had indications that sandflies were and had been at their normal level of abundance not only in the general region but in the immediate vicinity, 75 to 200 yards, of House P. We are unable to assign any reason for the virtual absence of sandflies in the latter place except the DDT applied to the walls 21 months, and to the house, 19 months previously.

II. *Area-control; group of houses, including House V* (see map; Figures 1, 2). Ten dwellings in a crowded row along the highway were known to have many sandflies. On account of open fires, house catches were usually very low in all but House V, the first house in the row, located diagonally across an open field 75 yards from House P of the previous experiment. Three narrow orchards and gardens (Gardens 1, 2, and 3) with stone or adobe walls extended from the rear of these houses for about 70 yards. In front of the houses were the highway and railway embankment, with cultivated fields and gardens beyond.

Preliminary observations. Burro rates on 26 June and 3 July 1945, at three stations in Garden 1 nearest both Houses V and P, averaged about 13 per 15-minute period. Tests on the open paved highway were negative.

Over 100 sandflies were caught in House V on 4 July. Four other houses were searched, with very low catches, typical of houses with open fires. Reports of the occupants together with bites which could be seen, indicated that sandflies were plentiful during the night.

4 July 1945. DDT. The garden walls and other stone walls associated with these houses were sprayed for a maximum distance of about 75 yards. The side of the railway embankment facing the houses had irregular stretches of retaining wall and projecting boulders, which were sprayed. The houses were left untreated.

5 July to 10 November. House catches on 5 and 6 July in House V were 117 and 56. A catch of 19 on 14 July was followed by a moderate rise (coincident with the sharp increase in House P) with four catches from 18 July to 1 August, of 32, 17, 45 and 43. Thereafter catches did not fall below 40 during the period of observation up to 10 November. There were two high peaks, one 21-25 August, with 146 and 94 sandflies (which coincided with the rise in House P terminated by spraying), the other represented by a catch of 170 on 25 September, with a drop to 42 within two days.

Throughout this period the other houses were sampled from time to time, but the catches

were so low before the spraying that the low catches afterward were without significance. The highest were 16 and 10 in two houses on 23 August. Usually they did not exceed two or three. The people in other than House V reported a marked reduction of bites immediately after the spraying, with confused information thereafter. We have preferred to take the catches in House V as the most reliable house index in this experiment.

4-5 July. On the evening of the spraying the burro rate in Garden 3 was zero; on the following evening a burro in Garden 1 attracted 5 sandflies in 50 minutes, Garden 2, 7 in 45 minutes, Garden 3, 4 in 95 minutes, an overall average of a little over 1 sandfly per 15-minute period. The maximum in any one period was 4, compared with two high periods of 30 and 47 before spraying.

Beginning 9 July, burro rates were taken in these three gardens weekly up to 20 August. They averaged a little over 2 sandflies per 15-minute period. Garden 3 on 25 September gave a rate of nearly 2 and on 15 October, about 3. There was a slight rise in the period from 17 to 26 July, rates on these two dates averaging nearly 5, while thereafter the average was less than 1. Our last burro rates outside the sprayed area, at Station 7, were on 21 and 22 August, when they averaged 7 and 22 respectively per 15-minute period.

In this experiment the burro rates in the gardens, which were practically enclosed by sprayed walls, dropped promptly and stayed at a low level. On the other hand, it was realized soon after the experiment was under way that the houses were insufficiently protected on one flank. The sprayed portions of the railway embankment did not constitute a raised barrier which might intercept those sandflies coming from walls beyond the railway. The reduction, if any, of the sandflies in this group of houses was transient. Even though the people's reports indicated that there may have been some reduction of sandfly bites in those dwellings beyond House V, the catches in the latter indicated that sandflies were still abundant. This house had a special status in several respects. It was the only good daytime sandfly shelter of the ten houses, which in itself would tend to concentrate the sandfly population. As the first house of the row, it was exposed on three sides and could conceivably intercept a disproportionate share of the sandflies coming from the unsprayed walls beyond the railway. It was decided not to modify this experiment but to leave House V as a control for House P.

26 March to 10 April 1947. There have already been mentioned the extreme abundance of sandflies in House V on 10 April, with high catches in Houses C and T. Reports indicated that the other houses in the row of ten, which were not entered, had sandflies in normal abundance.

III. House and outdoor walls sprayed. House G (see map), an isolated house 370 yards beyond House P, between the highway and the railway track, stands on a narrow terrace with stone retaining walls above and below. Terrace and walls are about 40 yards in length. Below and beyond the highway are irrigated pastures; above the house is the rather bare railway embankment and a steep rocky slope. A small orchard occupies one end of the terrace. The house is a tiny adobe hut, smoothly finished and whitewashed inside, with rough adobe outside. A cane lean-to against the retaining wall provides additional living quarters. There are two chicken coops and one guinea-pig hutch, small dark structures of stone and mud. A dog was the only other domestic animal.

This place in previous work had had a consistently high sandfly population, with frequent catches of 100 or more. This was one of the two places which we sprayed with DDT in January 1944, the small house alone being treated. After a week in which no sandflies were found the hut was temporarily vacated. Observations were continued for another four weeks without finding any sandflies. We have few data for this place in the intervening period up to August 1945. The rainy season of December 1944 to March 1945 had been far below normal in precipitation. Our Peruvian associates had found sandflies abnormally low in some places, including Surco and Matucana. This was true not only of house catches but of caves. At House G there had been a low catch of 16 in December 1944 (influence of previous treatment unknown) with even less on two occasions in May 1945. It may be remarked that those houses which showed high catches at the latter period, and which we selected for our work, were associated with continuously cultivated and irrigated fields or gardens. The terrace on which House G is located is dry except during the rainy season.

Preliminary observations. House G was not visited until August 1945 when sandflies were once more found abundant. Several small caves along the railway, 200 to 280 yards away and about the same distance from House P, also had their normal quota of sandflies, at least 20 or 30. On 21 August a total of 94 sandflies were caught at House G, most of them in the house. On the same evening a burro attracted 46 sandflies in 110 minutes, during which time various sandflies were seen on walls, doors and windows of the house and on the chicken coops. A few were seen emerging from stone walls.

22 August 1945. DDT. There were estimated to be 25 sandflies in the house, and a few were seen in a chicken coop. No catches were made. The whole place was sprayed as follows: the inner walls of the house, together with the outside of doors and windows and a little of the outer wall around them and along the caves; the cane lean-to inside and out; bed frames and some bedding wherever found; the outside of chicken and guinea-pig shelters and all stone walls within about 15 yards of the house. Various boulders along the highway were also sprayed.

The evening of the spraying, a burro stationed at the house for one hour attracted only one sandfly; during the next hour in the orchard just outside the sprayed area there were 3 sandflies. The weather was favorable and at Station 7 there were 30 sandflies in 22 minutes.

23 August. On the day after spraying there were no sandflies in the house, while one was seen in a chicken coop.

27 August. At our last visit before leaving Peru, there were no sandflies either in the house or in the animal shelters. The people reported that they were bitten occasionally while in the orchard but not within the sprayed area.

5 September to 27 November 1945. Sr. Caballero made ten searches of house and animal shelters, with completely negative results. On 19 September, 5 and 8 October, burros attracted only an occasional sandfly, the totals not exceeding 4 in any evening.

26 March to 10 April 1947. We had no further information until 26 March 1947, when four of our group visited the place. We were greeted with the information that "there aren't any more sandflies." According to the occupants' account there had been very few bites since the spraying 19 months before. Four bites were counted on the neck of the woman. She slept in the semi-open lean-to and in other years usually showed numerous bites. A thorough search netted only two unfed sandflies in the guinea-pig hutch. On 30 March a brief search yielded no sandflies. Another thorough search was made on 10 April. Two sandflies were seen in the guinea-pig hutch and two unfed females were caught in a small chicken coop; the house and larger chicken coop were negative. No bites were observed on the woman. The two captured sandflies were alive 24 hours later. On each

of these three visits the nearby caves harbored their normal sandfly quota: 35 were caught on the first visit, with at least as many estimated to be present on the last two occasions. The high catches on 10 April 1947 in Houses, V, T and C have already been mentioned. A burro test at House G on the evening of 10 April failed on account of the weather, as it had elsewhere that same evening.

The treatment of Houses P and G had been similar to the extent that in both cases, houses and animal shelters, *i.e.*, the sources of a blood meal, had been sprayed together with nearby stone wall shelters and potential breeding places. In both cases the results were comparable in that observations and reports, though admittedly very incomplete, pointed consistently to a very low level of sandfly activity after the spraying, a condition which certainly prevailed during our own observations 19 months later. This effect was sharply localized, since sandflies were at a high level in the immediate vicinity and also in the general region.

IV. Outer walls of house sprayed. House M, an isolated adobe house with cane-and-thatch roof, was located on a hillside on the far side of the village from the other experimental houses. The walls inside and out were smoothly finished with adobe, not whitewashed. The boundary walls nearest the house were mostly of smooth adobe, although stone walls and rocky surfaces were liberally distributed over the hillside. Chickens and a dog shared the one room with the family of three.

Preliminary observations. In May 1945 four house catches had averaged 66 sandflies. Other isolated houses on the same hillside were also known to have many sandflies. On 26 June 1945 a burro at the house attracted 5 sandflies in 15 minutes, and 15 at a stone wall within 20 yards. The counts at four other stations on this hillside averaged 11. On the following morning 65 sandflies were caught in the house, and two days later just before spraying, 18.

29 June. DDT. Only the outside of the house itself was sprayed, including the lower side of the projecting thatch. At five-thirty that evening about 10 sandflies were counted in the house. A burro stationed outside attracted 11 sandflies in 65 minutes. Meanwhile at the nearby stone wall another burro attracted 29 in 96 minutes. At the latter point a local resident had 25 bites while our observer, unprotected by repellent, was bitten only once or twice.

30 June to 14 July. On the day after the spraying only one sandfly could be found in the house. Of six catches in the next two weeks, four were zero, while two catches totaled 1 and 3.

18-31 July. On 18 and 19 July the catches were 7 and 8 respectively, but dropped to an average of 3 sandflies on three later catches in this period. The people reported that bites were few or none.

6-8 August. Two catches were 10 and 11 respectively.

8 August. Second spraying. It was thought likely that the effect of the DDT on the raw adobe was lessening. The outer walls of the house were sprayed as before.

9-27 August. One sandfly was caught the day after the spraying. Four other searches in August netted one sandfly on one occasion. The people reported that there were no bites.

5 September to 20 November 1945. Sr. Caballero made eleven searches in this period. During September the catches averaged 1 sandfly, in October, 4, and in November, 5. The highest catch was 9; four were zero. The last three catches in November averaged 7 sandflies.

No further information was available until on our return to Surco, 26 March 1947, we found that the roof had burned in August 1946 and that the place had then been abandoned. No information could be secured about the sandfly abundance prior to that time.

V. *Inside of living quarters sprayed.* We are indebted to Sr. Caballero for the following data: He had a room in Tornamesa, the first village below Surco in the Rimac Valley, 35 miles from Lima, altitude 1500 meters. Sandflies were annoying, with catches of the order of 15. The walls were unwhitewashed adobe. On 17 May 1946 the inner walls of this room were sprayed with 5 per cent DDT in kerosene. The application was made with some difficulty and probably irregularly, with a household hand sprayer. No sandflies were found during the 111 days up to 5 September, when with the reappearance of a few sandflies, spraying with pyrethrum or other material was begun.

SANDFLY CONTROL EXPERIMENTS IN CONSTRUCTION CAMPS

Construction projects represent one of the most important public health problems of the Peruvian sandfly regions. Great numbers of non-immune workmen and their families are required to live in areas from which it is not feasible to remove them at night. The problem is acute during actual construction but persists as an inseparable part of operation and maintenance. We therefore felt that early trials of area-control with DDT in such places were a prime objective. These considerations, together with the willing and effective cooperation of the management of two large projects, made it desirable to carry out such trials of area-control on a practical scale concurrently with those being run with isolated houses at Surco.

VI. *Austisha.* A hydroelectric project had been under construction for several years at Austisha in the Santa Eulalia Valley, a tributary of the Rimac, about 50 miles from Lima at an altitude of 2200 to 2400 meters. The workmen's camp housing 800 persons was spread out over about 14 acres of steep hillside (Figure 4). The buildings were mostly of smoothly plastered and whitewashed adobe or of sheet metal, all with openings between walls and roof. The hillside was partly terraced with retaining walls of loose-laid stone. This area had formerly been cultivated with irrigation but was mostly dry, though an irrigation ditch above the camp was maintained as part of the water supply. There were a few cultivated gardens. Around the periphery of the camp were scattered a number of pigpens, small enclosures of stone. The buildings were of a type which would normally harbor few sandflies and few were found in daytime searches. Maximum catches were six or eight sandflies. The pigpens and stone walls were our principal index of sandfly abundance, which in general was rather low. Searches were made on three evenings between 7 and 11 July 1945. Catches or counts in

PLATE II

WORKMEN'S CAMP AT AUTISHA, PERU

FIGURE 3. Loose stone wall being sprayed with DDT-kerosene solution.

FIGURE 4. General view of camp, 1945. By 1947, when construction work had been finished, the rows of barracks in the middle distance had been demolished. Permanent maintenance personnel occupied buildings in right foreground. The latter had few sandflies a year after the last application of DDT, while they were abundant in a recently constructed, unsprayed hut just outside the photograph, left foreground.

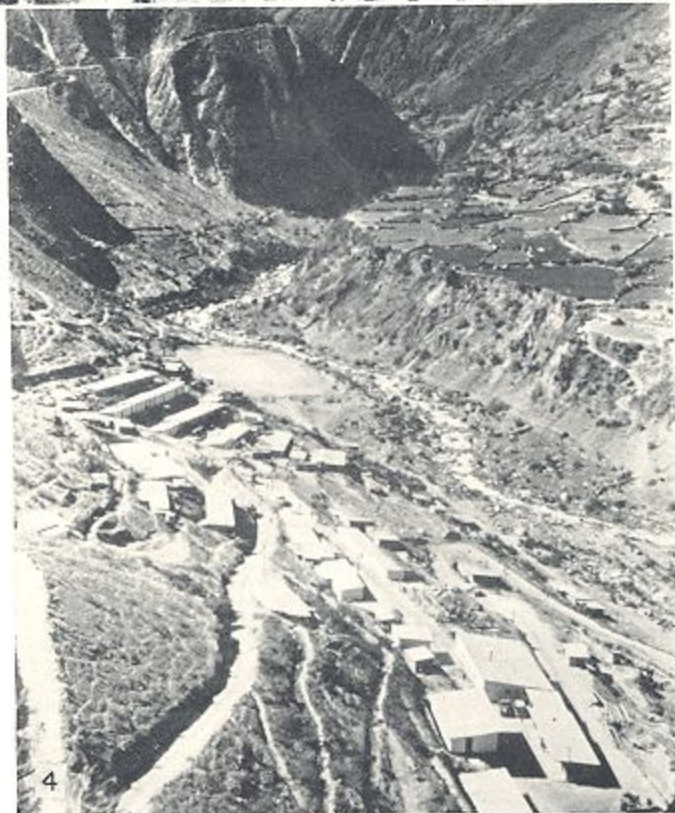


PLATE II

pigpens rarely exceeded 25. Various stretches of wall would yield one or two per yard. The sandflies were practically all *P. verrucarum*. Some of the workmen claimed they were much bitten by sandflies, but we had no satisfactory data on this point. Mosquitoes are rare at that altitude. Evening observations with two horses were made on 7 July. They attracted only one or two sandflies in the two hours of observation, even when stationed near a wall where sandflies were seen. Burros were not available.

In spite of the low sandfly density per dwelling, bartonellosis had been serious in the early years of the project, though most of the workmen were immune by 1945. New cases amounted to only one or two per month. However, cutaneous leishmaniasis, known locally as *uta*, was a current problem, with 15 or 20 new cases per month. Although this camp was far from ideal for a sandfly-control experiment, compared with the heavily infested houses in Surco, the possibility of observing the long-term effects on sandfly-borne diseases made the project worth while. The engineers in charge⁴ and the camp physician, Dr. Luis Vásquez L., undertook to repeat the application of DDT at regular intervals and to follow the results, both as to sandflies and disease.

12-13 July 1945. DDT. The pigpens and retaining walls, which probably included most of the sandfly hiding places, were distributed around and through the camp in such a way as to intercept most of the sandflies entering the area. All these structures of loose stone together with large projecting boulders, were sprayed with 5 per cent DDT in kerosene (Figure 3). The buildings themselves were not sprayed with the exception of bed frames, mattresses or other bedding. The latter was done for bedbug and flea control, partly as a good-will measure and partly to avoid confusion in the insect bites reported. Some DDT unavoidably reached walls near beds. One pigpen with counts averaging 25 sandflies was left unsprayed as a control.

No more sandflies were seen in the sprayed stone walls. The control pigpen dropped to 2 or 3 sandflies, rising to an average of about 5 after a month. The workmen were delighted and reported nearly complete freedom from bites of any sort.

It appeared to us that under the conditions peculiar to this camp, a very high degree of area-control had been achieved by the very economical method of treating only certain selected outdoor structures and objects. The whole treatment had required only about 25 pounds of DDT. It was our recommendation, based on our evaluation of the Surco results at that time, that the same outdoor treatment be repeated every six weeks, with beds to be sprayed when insect bites were once more reported. However, for various reasons, the subsequent sprayings included not only the outdoor walls and pigpens but all the buildings both inside and out. The first such spraying was in October 1945 about three months after our treatment, when reports of insect bites were increasing, along with a slight increase of sandflies in the control pigpen, and was repeated in December 1945 and March 1946. The cases of *uta* under treatment had dropped to about four in October 1945 with no new cases of either *uta* or bartonellosis, which were very scarce thereafter, although unfortunately we do not have exact data. The directors and medical staff of the construction work were unanimous in pronouncing the whole DDT project a thorough success.

On 31 March 1947 the camp was visited with Doctors Herrer and Vásquez. The construction had terminated in March 1946 and the camp had been abandoned except for a few families of maintenance personnel. Most of the workmen's barracks had been demolished. No DDT had been applied for a full year. The residents reported that after the spraying was discontinued there had been some sandflies but not many. Daytime searches in the houses and in covered stone chicken coops, yielded only one sandfly in a vacant house. The chicken coops, which did not exist when we began our work, were built against retaining walls and were of a type which would normally harbor sandflies. During the evening prolonged searches of the same walls and other places where we had found sandflies in 1945 yielded a total of only two under a large rock. The only occupied pigpen, a roofless adobe house, was negative both by day and by night. The "control" pigpen had been obliterated by debris from road construction. A cane hut had been built within six months against a retaining wall just above the camp and perhaps 50 yards from the sprayed area and within 100 yards of the permanent residences. Early in the evening a dozen or so sandflies were seen within a few moments emerging from the wall. The people were being bitten and on the following morning one child showed numerous bites. On the same morning searches of the houses and animal shelters in the sprayed area again netted only one sandfly. No bites were noted or reported. A cave along the highway about a mile from the camp and formerly used for storing explosives, had over 100 sandflies.

In its later phases, this project was comparable to Houses P and G at Surco in that DDT was applied to both houses and outdoor stone walls. A year after the last application no sandflies at all were found in walls known to harbor them before spraying. It is true that for the most part there were no longer any immediately adjacent sources of a blood meal. However, sandflies had not attained even their former modest level within the part of the sprayed area which was still occupied, while at the only available observation point just outside the area, they were abundant.

VII. *The Cañon del Pato* in the Santa River Valley, Department of Ancash, about 250 miles north of Lima and at an altitude of 1100 to 1800 meters, is the site of an extensive hydroelectric project, which has been called the "Peruvian TVA." The canyon itself is a very deep narrow gorge about ten miles long which is normally uninhabited. Above it lies a broad, well populated valley, known as the Callejón de Huaylas. Immediately below the canyon is the small railhead town of Huallanca in a less densely populated part of the Santa Valley. The region lies in a notorious bartonellosis zone. It was surveyed in 1942 (7) at which time *P. verrucarum* was very abundant at certain haciendas and towns above the canyon, while the town of Huallanca had a rather sparse sandfly population. It was anticipated that bartonellosis might be serious in workmen's camps about to be established at the upper end of the canyon, which turned out actually to be the case.

We visited the area in July 1945 in company with Dr. Herrer. Every facility was placed at our disposal by the Corporación Peruana del Santa¹ and by the Chief Medical Officer, Dr. Guillermo Górbitz. There were a total of about 1500 workmen in addition to their families housed in seven or eight camps in the canyon and near Huallanca. The buildings were mostly of adobe, smoothly plastered or whitewashed. Bartonellosis had been and still was a serious problem. One camp at the upper end of the canyon had been abandoned on account

of the high incidence of bartonellosis with several fatal cases. The canyon is below the leishmaniasis zone. Malaria, which is endemic above and below the canyon, had been effectively controlled since 1942 by antilarval measures.

Beginning in October 1944 Dr. Görbitz had carried out a limited sandfly control experiment with a small quantity of DDT obtained commercially. In effect this was a house-control experiment in which living quarters at one of two comparable camps were sprayed. There was good control in the sprayed camp while sandflies and bartonellosis continued at a normal rate in the other. We were able to see Dr. Görbitz' report which was later published (8).

In searching for a community suitable for an area-control project we made a survey of villages in the Callejón de Huaylas, where sandflies had been found abundant in 1942. Even though our search was made at the same time of the year and frequently in the same houses, sandflies were rather scarce, a situation comparable to that previously noted for certain parts of the Rimac Valley. Sandfly density per dwelling was also low in the camps in the canyon, although it was obviously sufficient to cause a continuing bartonellosis problem. We finally selected one camp, Los Cedros, with a population which varied between 150 and 300 persons, which was comparable to the Autisha camp in construction and terrain, except that there were fewer good stone walls. Again the sandfly density did not lend itself for a clear-cut sandfly control experiment, but we had the opportunity to observe the long-term effect on bartonellosis.

On 21 July 1945 spraying was carried out as at Autisha, with 5 per cent DDT in kerosene applied to loose stone walls and boulders within a radius of about 50 yards from the camp. The buildings were untreated except for bedbug control. The chief sanitary inspector, Sr. Martín Arroyo, who had had much experience in *Phlebotomus* field work, carried out semi-weekly searches for sandflies, which were completely negative after spraying. It was arranged that the spraying was to be repeated with DDT which we left for that purpose, and the observations to be continued under the direction of Dr. Görbitz.

The area was visited early in April 1947 in company with Dr. Herrer. We are indebted to Dr. Görbitz for the privilege of reading a report which he has prepared for publication and to him and Sr. Arroyo for the data which follow.

The camp at Los Cedros was sprayed again in October and November 1945, January, March, April and May 1946. The first three of these applications included the outside of windows and doors, after which the inner walls were sprayed. In the period March through July 1945, this camp had had 11 cases of bartonellosis. Only three later cases were known among the residents of this camp, one each in September 1945, March and April 1946. Of these three cases, at least one and perhaps all were contracted elsewhere. Meanwhile, within several months after our visit in July 1945, Dr. Görbitz had been able to arrange a commercial supply of DDT, so that by February 1946 the interiors of all buildings of whatever nature, under his jurisdiction, and in addition the entire town of Huallanca, were being treated with DDT in kerosene. The intervals between spraying varied at first, but had been finally established at four months as the routine. At certain camps stone retaining and other walls im-

mediately associated with buildings have been sprayed, but for the most part the treatment has been confined to buildings. Since April 1946 only one or two cases of bartonellosis have come to Dr. Görbitz' attention and these were contracted in another part of the valley. Frequent searches for sandflies have been maintained but no sandflies have been found in sprayed buildings. One new camp had been in operation for several months at a point near the old camp which had been abandoned on account of bartonellosis. The buildings, which had walls of straw matting, had been routinely sprayed. There had been no cases of bartonellosis. Several small caves about 200 yards from one camp had been visited regularly and had usually yielded a fair number of sandflies. 20 or 30 were seen by us on our only visit. No general survey of the region was attempted by us on our brief visit in 1947, although at the two points where searches were made, we found sandflies abundant. These were the town of Huaylas, situated at an altitude of 2800 meters in a small mountain valley high above Huallanca, and a cave near Chancos at the upper end of the Callejón de Huaylas.

In evaluating the effects on bartonellosis in a project of this sort, it must be borne in mind that there is usually a decline after the peak of the first year or two on account of the increase of immunes. Such a decline had been in progress from the end of 1943 through 1944. Nevertheless, there had been and still continued a considerable turnover of personnel with constant recruiting from a non-endemic area. In any case, the extensive spraying with DDT reduced sandflies to the vanishing point in living quarters and coincided with the virtual cessation of bartonellosis. All concerned felt that after the general spraying of DDT was instituted, they had ceased to have either a sandfly or a bartonellosis problem. It was planned to maintain the current DDT program for the duration of the construction work.

DISCUSSION

These preliminary experiments and control projects have certain obvious shortcomings by reason of their limited number and extent, and the lack of precise, continuous measurement of results throughout. Nevertheless, there emerges a consistent pattern of results, all supporting the practicability of area-control of *Phlebotomus* with DDT. These results considered in relation to sandfly habits and life history, show the following to be vulnerable points which may be exploited in practical control work:

a. Sandflies may be denied their sources of a blood meal in houses and animal shelters. The data here reported, while not primarily concerned with house-spraying, tend to confirm its great effectiveness in the protection of persons while indoors. It has been our invariable experience both in the Mediterranean and in Peru, that only rarely can any sandflies be found in a room or stable which has been adequately treated with DDT. All available evidence indicates that bites are correspondingly rare. How long this effect may last is not known. In the Mediterranean area during observations terminated by the end of the sandfly season, undiminished effectiveness persisted for about two months. In

Peru, an adobe room remained free of sandflies for nearly four months. An adobe house sprayed only outside (a method less effective than treatment of the interior) had very few sandflies for at least three months after a second spraying. At the Cañon del Pato, where the sandfly control program has become principally one of house spraying, the results indicate that on whitewashed or plaster walls DDT may remain effective for at least four months. It may be noted that this period would cover practically the entire sandfly season in temperate regions such as the Mediterranean and North China. The significant point is that with DDT it is possible to establish a protective barrier around the principal hosts which few sandflies are able to pass for long periods of time.

b. Sandflies may be denied their principal outdoor shelters and breeding places. Stone walls known to be sandfly shelters ceased completely to harbor them after spraying. The factors operating here are the same as those in sprayed houses, namely, the flight habits which involve resting for relatively long periods on surfaces at or near the entrances.

In this connection, those inner surfaces of stone walls which DDT may reach, even in reduced amount, may prove to play a very important role. Such surfaces of non-absorbent stone are frequently well protected from light, rain, air currents and dust, with, it may be assumed, a correspondingly low rate of loss of DDT toxicity. It is on just such surfaces that sandflies would spend a large proportion of their adult life. The combination of these factors would operate to prolong the period of effective toxicity of the sprayed surfaces.

Sandflies alight and rest on objects in their line of flight. Above-ground objects such as stone walls treated with DDT would act as barriers and reduce the number of sandflies entering or moving about in an area.

These considerations would apply only when the entrances to sandfly shelters are associated with surfaces capable of retaining a residual coating of DDT, such as stone, masonry or wood, which, however, are characteristic of most sandfly situations. We have no information applicable where entrances are in open soil, as in the case of animal burrows⁷.

c. The results are sharply localized within the sprayed area. This would mean in practice that control measures would need to be undertaken only within a limited radius of the area to be protected, probably a few hundred yards at most.

⁷ Semi-desert regions where rodent burrows are the principal shelters and breeding places constitute special cases. We have in mind the situation described by Russian investigators (9) in Turkmenistan, where rodents are the principal hosts and also apparently the reservoirs of cutaneous leishmaniasis. Superficially the terrain, sandfly and disease relationships of the salt desert near the Dead Sea closely resemble those of Turkmenistan and may prove to be essentially the same. For the protection of settlements in such regions there occur to us the following methods as worthy of trial: In addition to house spraying, the treatment of a belt of the surrounding desert with (a) DDT dust, with special attention to the rodent burrows and the clumps of vegetation under which they are often located; (b) DDT aerosols; (c) wettable DDT sprayed on desert vegetation in the attempt to secure a residual effect. The first two of these methods could be expected to be more effective if the work is done during those hours of the evening or night when the greatest proportion of the sandfly population is abroad.

d. The long life-cycle of Phlebotomus would mean that a sandfly population reduced by DDT could be replaced only slowly. Where breeding places are effectively denied to sandflies, normal production could not begin until the effect of the DDT had worn off. Replacements would not be available until after the additional period of weeks or months required for the development of a new generation. Any shortage of gravid females would tend further to delay sandfly recovery.

In the several cases where combined house and outdoor spraying reduced sandflies to an extremely low level and where recovery had not occurred after a year or a year-and-a-half, it appears to us that the local sandfly populations were delivered a paralyzing blow. Unfortunately we do not know when the effective toxicity of the DDT ended and when the process of sandfly recovery began. The part played by infiltration from outside the sprayed area is also unknown. The factors involved obviously require the most searching study. The ability to deliver such a blow with one application of DDT is of the greatest practical importance. It should be the goal of future study to determine the conditions under which comparable results may be obtained and the most economical methods of achieving them.

The most striking results were obtained when the treatment of houses and animal shelters was combined with outdoor spraying. It is possible that a comparable reduction of the sandfly population could be obtained by either of these methods alone if a sufficiently great area were involved to minimize the effects of incomplete control at the periphery.

It is of particular importance to explore the possibilities of house spraying alone, since there are various advantages in treating houses whatever the nature of the sandfly problem. If malaria is also present, this alone would dictate the treatment of houses in any case. The advantages of controlling flies and other household insects are well known and, far from being mere by-products of house spraying, are important in themselves. From the standpoint of sandfly control alone, house spraying gives immediate and long-lasting protection. In speaking of house spraying in relation to area-control, we have in mind the treatment of every house and animal shelter in the area, that is, every structure housing sources of a blood meal. The method of spraying should be the treatment of the inner walls primarily, together with the outside of doors and windows. The problem would be to determine whether or not a campaign of house spraying alone could reduce the entire sandfly population so as to yield a satisfactory degree of area-control within the time required for the current sandfly generation to exhaust itself. It might be found that a high initial degree of area-control resulting from combined house and outdoor spraying, could be maintained thereafter by house spraying alone.

Our work was done in the tropics with a continuously abundant sandfly population throughout the year. It is reasonable to expect that control would be a somewhat simpler problem in temperate regions where the sandfly season is frequently limited to four or five months. A pre-season application of DDT, able to operate with maximum initial toxicity and lying in wait, so to speak, for the over-wintering generation, could conceivably cripple the summer generations.

SUMMARY

Experiments to test the possibility of area-control of *Phlebotomus* with residual DDT were carried out in Peru, 1945 to 1947.

1. The results furnish additional support for the effectiveness of house spraying in protecting persons indoors.

2. Treatment of stone walls (the principal outdoor shelters and breeding places) produced marked reduction of sandflies.

3. Treatment of stone walls combined with house spraying reduced sandflies to an extremely low level. This effect still persisted after twelve to nineteen months.

4. The results were sharply localized within the sprayed areas, sandflies occurring in normal abundance in houses or caves 75 to 200 yards distant.

5. Practical control programs in camps of two large construction projects gave an extremely high degree of sandfly control, followed by the virtual cessation of new cases of cutaneous leishmaniasis or bartonellosis.

6. Analysis of the results in terms of the habits and life-history of *Phlebotomus* supports the possibility of achieving practical control by methods applicable to many of the *Phlebotomus* regions of the world.

a. Their flight habits make sandflies vulnerable to residual DDT throughout their adult life.

b. The long life-cycle delays the recovery of a depleted sandfly population.

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