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The Area Distribution of an Insecticide (Fenthion) Sprayed inside the Huts of an African Village*

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In the course of a village-scale trial of fenthion, carried out in a village near Lagos, Nigeria, 40 % fenthion water-dispersible powder was used at a 3.75 % concentration. This was applied by Galeazzi "OM" sprayers with constant-pressure assemblies. The target concentration was 1.5 g/m². Filter-papers were placed on walls, ceilings and roof beams to determine the actual average rate of application, and glass plates were placed on the floors to determine the rate of "bounce-off" from the walls or of "drop-out" from the ceilings. The results of chemical tests show that the rate actually applied came closest to the target concentration on the walls, followed, in that order, by ceilings and roof beams. There were heavy deposits on the floors up to 30 cm away from the walls. The authors analyse the causes for the variations encountered.

In August 1961, the village of Araromi, 27 miles (43 km) from Lagos in the Western Region of Nigeria, was sprayed with fenthion [3] to determine the effect of this on the natural mosquito population of the area. The entomological results of this field trial are presented elsewhere [4] but the opportunity was taken in this trial to examine in detail the distribution of the insecticide over various surfaces inside the huts of the village. This problem has been studied in experimental huts,[5, 6] but does not seem to have been given much attention under field conditions.

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[3] Fenthion is the name designated for O,O-dimethyl-O-4-(methyl mercapto)-3-methyl phenylthiophosphate (also known as Baytex or Bayer 29493) by the International Organization for Standardization.

[4] See the article by Gratz & Carmichael on page 197 of this issue.

[5] Yeo, D. (1961) *Miscellaneous report No. 286*, Arusha, Colonial Pesticides Research Unit (unpublished).

[6] Yeo, D. (1961) *Miscellaneous report No. 292*, Arusha, Tropical Pesticides Research Unit (unpublished).

EXPERIMENTAL VILLAGE

The sprayed village, Araromi, consisted of 24 huts and one mosque, all of mud-wall construction, laterite mud being laid over a supporting inner frame of rough wooden poles; both the inner and outer surfaces of the walls were smooth but unplastered. The pH of the mud used in the village was 5.5, which was favourable for the persistence of the organophosphorus insecticide. Fifteen of the huts had roofs of galvanized corrugated-iron sheets and nine of thin thatch. The number of rooms varied considerably from hut to hut, but the usual pattern was a central corridor extending from the front to the rear of the hut with a wooden outer door at each end. Two or three rooms opened off each side of the corridor and either were closed by wooden doors or raffia mats or had no doors at all. The floors of all houses but one were of beaten mud, the exception being of rough concrete. Most rooms had a ceiling either of raffia palm or of raffia palm mid-ribs; some rooms and most central corridors had no ceilings at all. The inner partition walls were constructed in the same manner as the outer walls and rose to a height of 2.75 m. The roofs of both the tin-roofed and thatch-roofed huts were supported by an intricate structure of rough beams made of branches or young saplings cut from the surrounding secondary forest. Furniture within the rooms was sparse, usually consisting of no more than some low stools, boxes used for the storage of clothes, and either a wooden bed or raffia floor mats. Since most of the children and many of the adults sleep on these mats a special effort was made to determine the amount of insecticide that fell upon the floors.

Cooking may be done either inside the hut or in a small, partially walled, thatch-roofed " kitchen " behind the hut. In most thatch huts the open wood fire is made in the central corridor of the hut, whereas with most of the tin-roofed dwellings cooking is done in the kitchen hut. In both cases considerable preparation of the food is carried out on the floors of the huts.

METHODS AND MATERIALS

The spraying was carried out by a crew of six spraymen and a supervisor, all supplied by the Lagos Town Council. The crew was specially trained by a World Health Organization sanitarian in the care and maintenance of the compression sprayers, in spraying techniques, and in precautions to prevent excessive exposure to the insecticide. A training wall was marked off into swaths and the men were taught the correct speed and distance at which to apply the spray. All the crew wore protective clothing while mixing the insecticide and when carrying out the spraying operations.

Fenthion 40% water-dispersible powder [1] was used for preparing the spray mixture. The consignment was received by the WHO Insecticide Testing Unit shortly before spraying began and was not, therefore, subjected to any lengthy period of storage under tropical conditions. The active material content was determined by an oxidation method in which the fenthion is oxidized with an excess of acidified standard bromide-bromate solution and the excess bromate determined by titration, with standard sodium thiosulfate solution, of the iodine liberated on addition of excess potassium iodide. Two samples were examined and three tests made on each sample batch; the average fenthion content for each sample was 40.7% and 40.6%.

The team was trained to spray surfaces at the standard rate of 40 ml/m². The recommended rate of application of fenthion is 1-2 g/m² so that the concentration required in suspension to achieve a rate of application of, say, 2 g/m² would be 5%.

[1] Supplied to WHO by courtesy of Farbenfabriken Bayer A.G., Leverkusen, Germany.

It is known that the concentration of water-dispersible powder in a suspension can affect the suspensibility of that powder and this point was checked at the Tropical Products Institute, London, using two samples of fenthion water-dispersible powder taken from the material used by the WHO Insecticide Testing Unit for the 1961 trials in Nigeria.

Suspensibilities were determined by the method described in *Specifications for Pesticides* (World Health Organization, 1961) for DDT and other water-dispersible powders but without subjecting the powder to tropical storage pretreatment. Tests were made on suspensions containing 0.5% and 5.0% fenthion. Analyses were carried out by the bromate oxidation method and the following results obtained:

Fenthion content	38.6%
Suspensibility:	
0.5% suspension	59.2%
5.0% suspension	69.8%

Sieving tests

The particle size of the powder was examined in accordance with the requirements of the World Health Organization (1961; Annex 10) for water-dispersible powders using a 200-mesh (74 μ) sieve; the percentage of powder passing through the sieve in each of three tests was 96.8%, 98.0% and 97.1%, giving an average of 97.3%. (For all water dispersible powders included in the WHO (1961) specifications, the requirement is that not less than 98% of the material shall pass a 200-mesh sieve.)

Field application

The fenthion water-dispersible powder was weighed out in the laboratory into portions of 750 g, each portion being placed in a plastic bag for transport to the field. Eight litres of water were added to 750 g powder in a galvanized-iron pail to make a suspension containing 3.75% of the active ingredient. When this was then poured into the spray tank through a 422-μ sieve (British Standard mesh No. 36), very little sludge deposit was observed.

Compression sprayers

The compression sprayers used for applying the insecticide were Galeazzi " OM " sprayers with constant-pressure assemblies. Each spray pump was calibrated before use and the average rate of emission for those tested was 950 ml/minute. The pressurerelease valve was adjusted to blow off at 3.8 atmospheres, this pressure being attained after 75-80 pumping strokes.

Spraying operations

An effort was made to ensure that operations were carried out by the spray crews as would be done in a normal antimalaria residual spray application programme. All inner walls, doors, ceilings and roof beams were sprayed, these last by means of extension lances made by screwing two lances together, and spraying from a stepladder 1.8 m high. A swath of spray was also applied to the eave opening from the outside. The inner surface of the corrugated iron roofs was not sprayed, but that of the thatch roofs was. All food, food utensils and bedding were removed from the huts prior to spraying and the inhabitants were requested to remain outside for an hour after the operation had been completed.

Twenty-three dwellings were sprayed, the mosque and one control hut being omitted; 24.75 kg of 40% fenthion water-dispersible powder were used for a target deposit rate of 1.5 g/m².

Method of sampling

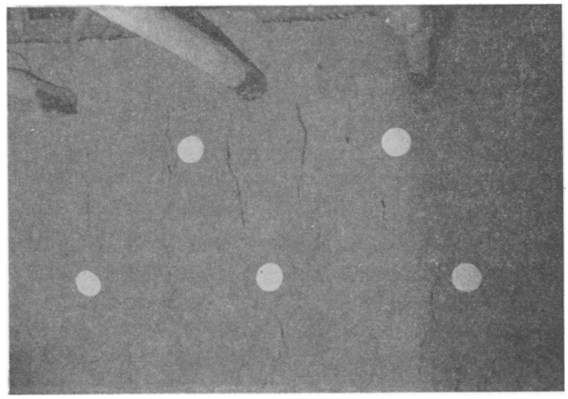
There were two purposes in sampling the insecticide deposits on the various surfaces: first, to check the efficiency of the spraying method; and, second, to correlate the results of bio-assay tests with the amount of deposit on different types of surface.

Six houses were selected for this study and filter-papers and glass floor-plates were distributed as follows:

4 walls per house in six huts = 24 walls sampled.
10 filter-papers per sampled wall = 240 wall filter-papers.
1 ceiling per house in six huts = 6 ceilings.
10 filter-papers per sampled ceiling = 60 ceiling filter-papers.
12 roof beams per house in six huts = 72 roof beams.
2 filter-paper strips per sampled beam = 144 beam filter-papers.
1 room per house with 10 glass floor-plates = 60 glass floor-plates.

Whatman No. 1 filter-papers, 11 cm in diameter, were pinned on the wall or ceiling to be sampled in three rows, two of three and one of four papers, about two feet (60 cm) apart (Fig. 1). They were so placed on pins that there was no contact with the surface. The attention of the spraymen was not drawn to the papers and they had no idea of their purpose.

FIG. 1
TWO OF THREE ROWS OF FILTER-PAPERS ON INNER MUD WALL OF HUT



Langbridge [1] used four large sheets of absorbent paper, 32.5 cm × 20.5 cm, when sampling the spray deposits in huts in the course of the Malaria Control Pilot Project in Western Sokoto, Nigeria. Although this method allows larger areas to be sampled, the use of 10 sampling-points permits the variation of deposit over a single wall to be assessed. In addition, many small papers reduced the possibility of " over-attention " by the spraymen.

Of the filter-papers exposed, 238 from the walls of 18 rooms and six central corridors were analysed for fenthion content. Of those placed on the ceilings, 44 filter-papers were examined together with 122 filter-paper strips from roof beams—a total of 404 determinations.

The amount of spray falling to the floor was assessed using glass sampling-plates, 20 cm × 20 cm, on the floor. Ten plates were used in each of the six rooms sampled and they were distributed over the floor as follows:

Two plates in corners (edges of plate 10 cm from the walls).
Three plates in the middle of the walls (edge of plate 10 cm from wall).
One plate in centre of room.
Four plates placed mid-way between centre of room and walls.

Of the 60 glass plates exposed, 51 were examined for fenthion deposits, nine plates having been broken

[1] Langbridge, D. M. (1955) *The delivery and estimation of deposits of water-dispersible insecticide formulations in malaria control* (unpublished working document WHO/Insecticides/41).

during the spraying operations. Of those examined, 32 plates were from positions on the floor 10 cm from the walls (either in the middle of one of the walls or in one of the corners) and the remainder from the centre of the floor or from the mid-way points.

Chemical determination of fenthion deposits

To determine the fenthion content of the filter-paper samples each paper was removed from the surface 30 minutes after spraying and rolled up and inserted into an individual test-tube with a glass stopper. The tube was marked with the hut and room number.

In the laboratory a square of 10 cm^2 area was cut from the centre of the filter-paper and the amount of insecticide determined. The square of paper was placed in a 250-ml conical flask with 10 ml glacial acetic acid and 5 ml of concentrated hydrochloric acid to dissolve the fenthion residue. Exactly 5.0 ml of 0.02 N bromide-bromate solution were added to the reaction flask, which was then closed with a glass stopper. After three to five minutes, 25 ml of distilled water were added, followed by 5 ml of 10% potassium iodide solution. The mixture was thoroughly shaken and the liberated iodine titrated with 0.02 N sodium thiosulfate solution, 4-6 drops of 1% starch solution being added just before the end-point was reached.

Insecticide which had fallen on to the glass floor-plates during the spraying was allowed to dry; the plates were then placed in specially slotted boxes to reduce the risk of loss of insecticide and transported to the laboratory. In the laboratory the insecticide from each glass plate was washed quantitatively into a conical flask, through a funnel, using cotton-wool pieces wetted with a 1:1 chloroform-alcohol mixture to facilitate the transfer. The insecticide was extracted from the cotton-wool pieces by squeezing them a few times each with the solvent. The solution was then evaporated completely to dryness under reduced pressure at a temperature of 40°C. The residue was dissolved in 10 ml glacial acetic acid and 5 ml concentrated hydrochloric acid and the fenthion determined as described above, but using 0.1 N bromide-bromate and sodium thiosulfate solutions and a slight excess of 10% potassium iodide.

RESULTS AND DISCUSSION

The results of the chemical examination of the filter papers are given in Annex 1; for each hut and for each room within the hut the averages have been calculated from one determination on each filter-paper.

Difficulties encountered in this type of spraying operation make it impossible to obtain a uniform rate of application. In spite of careful training of the spray team the results obtained on the individual samples show considerable variation—from 0 to 2.77 g/m^2. As would be expected, the spraying of the roof beams is much less satisfactory than the spraying of the more readily accessible flat surfaces of the ceilings and especially the walls.

The average deposits for the walls of rooms and corridors (Annex 1, Table 1) show extremes of 0.08 g/m^2 and 2.28 g/m^2. However, with only eight of these 24 walls sampled is the average deposit less than 1.125 g/m^2 or greater than 1.875 g/m^2 (i.e., differing from the target deposit of 1.5 g/m^2 by more than 25%), and in only three cases is the average deposit less than 0.75 g/m^2 or greater than 2.25 g/m^2 (i.e., differing from the target deposit by more than 50%). This group includes Room B of Hut 6 with an average deposit of only 0.08 g/m^2. This value is so low that it seems probable that this particular wall was not, in fact, sprayed, the small deposit found being due to " bounce-off " or " drop-out " of spray directed at the other walls or the ceiling. It is interesting to note that this sort of mistake can be made even in a closely controlled experimental spraying; in a large-scale spray programme the risk of such an error would be much greater.

The average wall deposit for all rooms and corridors was 1.38 g/m^2 (Annex 1, Table 5). It is unlikely that there was more " bounce-off " of spray droplets from the wall surfaces (laterite mud) than from the filter-papers. As the total amount of insecticide actually sprayed over the total wall areas was carefully controlled, the figure of 1.38 g/m^2 suggests that the efficiency of spraying of the walls was slightly higher than 90%. This is rather better than figures previously reported (Burnett & Woodcock, 1956; Robinson [1]). Apart from the question of wastage, spraying efficiency is important as being one of the factors influencing the hazard of the spraying operation to the spray team (Wolfe et al., 1959; de Courcy, 1960).

The 44 filter-paper samples from five ceilings in five different huts show extremes of fenthion deposit

[1] Robinson, J. (1957) *The control of insecticide deposits in house-spraying schemes* (unpublished working document WHO/Insecticides/58).

FIG. 2
FILTER-PAPER STRIP BEING PLACED ON VERTICAL ROOF BEAM

of 0.11 g/m² and 2.61 g/m², while the average deposit for all ceiling samples (Annex 1, Table 5) is 1.12 g/m² (i.e., 25% less than the target deposit). This smaller amount of insecticide on the ceilings appears to be primarily due to drip-off of liquid and to fall-out of the smaller drops from the spray before reaching the 2.1-to-2.4-m-high ceilings. Also it is more difficult for the sprayman to control the speed of movement of the lance when spraying almost overhead.

In order to examine the amount of insecticide deposited on the roof beams, strips of filter-paper 11 cm wide were wound round the beams, the ends overlapped and held in place by a pin (Fig. 2). For determination of the fenthion content two 10-cm² squares were cut from the strip, one representing the top and the other the bottom of the beam.

The individual results for the beam samples (Annex 1, Table 3) are almost invariably low, only eight of the 122 samples showing deposits greater than 1.5 g/m². This is not surprising when the difficulties of spraying in the roof space of a hut are considered. The average deposits for the upper and lower surfaces of the beams show a significant difference only in the case of horizontal beams, where the deposit on the lower surface, easily reached by the sprayman standing on the ground, is approximately twice that on the upper surface.

The average deposit for all beam samples was 0.45 g/m² (Annex 1, Table 5).

The average fenthion deposit on the 19 glass floor-plates, placed either in the centre of the room or half-way between the centre and the walls, was equivalent to 0.39 g/m² (Annex 1, Table 4). These plates would be affected primarily by spray intended for the ceiling and it is interesting to note that the sum of the average deposit on ceiling samples (1.12 g/m²) and the average deposit on these plates is 1.51 g/m²—almost exactly the target deposit.

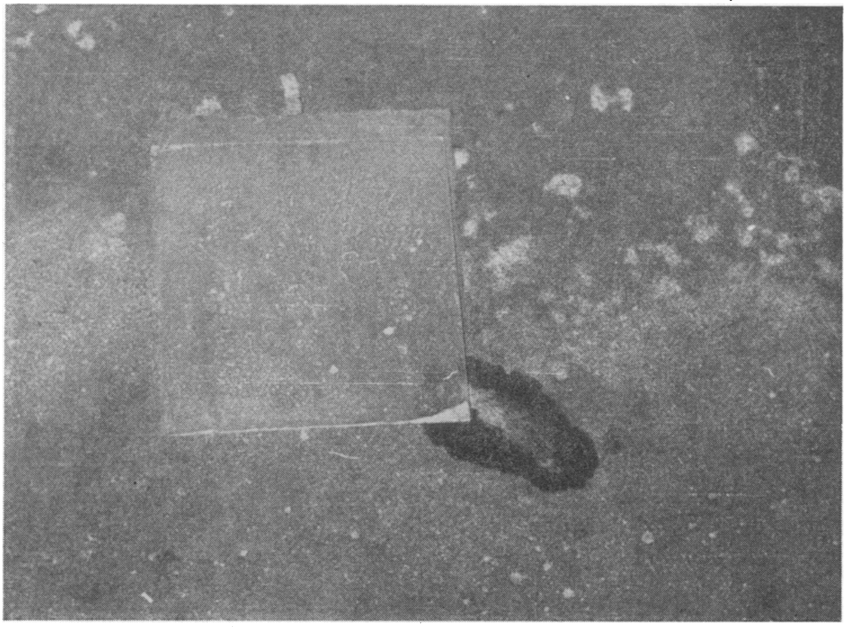
The average fenthion deposit on the 32 plates 10 cm from the juncture of wall and floor was 1.14 g/m², which is 75% of the target concentration for the walls, etc. The reason for this heavy deposit on the plates was the " bounce-off " of liquid from the walls on to the plates. Indeed, the amount on some plates was so great that some of the insecticide ran off on to the floor before drying (Fig. 3). As will be seen in Annex 1, Table 4, the mean of plates in the corners (1.24 g/m²) was rather greater than the mean of those in the middle of the walls (1.06 g/m²), as some " bounce-off " was received from both walls. When the amount of contact with the floors by the inhabitants, particularly the younger children, is considered these heavy residues must be of some concern. However, a positive result of such heavy deposits is frequently a reduction in the numbers of other insects of medical importance which come in contact with the floors. This has been noted in a number of antimalaria campaigns—e.g., the disappearance of *Tunga penetrans* and rat fleas in Doula following the application of DDT and dieldrin to the walls (Voelckel & Mouchet, 1959).

A separate toxicological study,[1] which was conducted in the village at the time of spraying, revealed that the greatest drops in plasma cholinesterase levels occurred among the 0-to-6-years age-group. Should residual insecticides of any greater toxicity than those currently in use be introduced, consideration should be given to methods by which the deposits due to " bounce-off " from the wall surfaces can be reduced. In addition, this " bounce-off " represents considerable wastage of material, but it is difficult to see how this could be avoided.

The variation in amount of active material deposited on walls, ceilings and roof beams also implies considerable uneveness in the amounts of insecticide to which mosquitos are likely to be exposed when resting on these different surfaces.

[1] See the article by A. Taylor on page 213 of this issue.

FIG. 3
INSECTICIDE "BOUNCE-OFF" ON GLASS FLOOR-PLATE 10 CM FROM WALL [a]



[a] Insecticide which has bounced off the walls is shown in this photograph as white "stippling" on the floor-plate and on the floor itself. Note also the small pool of insecticide that has run off the floor-plate.

The over-all results for walls, ceilings and beams are given in Table 5 of Annex 1; the results of a statistical analysis of all figures for walls, ceilings and beams are given in Annex 2. The average deposit on all wall samples was 1.38 g/m², with a standard deviation of 0.668 g/m². If the sample areas examined are truly representative of the whole sprayed area, these figures indicate that, on the total wall area sprayed, approximately 17% received a fenthion deposit of less than 0.75 g/m² (i.e., less than 50% of the target deposit of 1.5 g/m²). The statistical examination, however, shows that 11%-12% is a better estimate of this area. Similar examination of the results for the ceiling samples indicates that 30%-35% of the total ceiling area received a deposit of less than 0.75 g/m²; while for all beam samples approximately 80%-84% of the total beam area received a fenthion deposit of less than 0.75 g/m².

These figures show clearly the extent of variation of spray deposit between different surfaces within a hut. It is obvious that if the roof beams and, to a lesser extent, the ceilings are sites favoured by resting mosquitos, considerable additional care must be taken to ensure that these surfaces receive an insecticide deposit more nearly approaching the desired rate. It would seem likely that many past field studies of the effectiveness of different insecticides would show at least such variations as are revealed in the present one. Clearly these variations should be taken into account when considering the entomological results of such studies.

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RÉSUMÉ

Au mois d'août 1961, des essais de fenthion ont été effectués dans un village du Nigéria. Ces essais étaient, bien entendu, destinés à évaluer l'action proprement insecticide du produit. Cependant, on en a profité pour étudier la distribution exacte du fenthion pulvérisé à l'intérieur des cases. Pour cela l'on a utilisé des solutions étalonnées de fenthion, l'on s'est servi de pulvérisateurs émettant des particules de diamètre égal (74 μ), l'on a surtout entraîné les équipes à pulvériser de façon uniforme et constante afin d'obtenir sur chaque surface une concentration de fenthion de 1,5 g/m².

Avant toute pulvérisation l'on a placé des papiers filtres sur les murs, les plafonds et les poutres ainsi que des plaques de verre destinées à recueillir les « retombées » provenant du rebondissement sur les murs ou du plafond.

L'analyse des résultats obtenus montre que sur les murs la concentration a été bien près de la concentration recherchée, soit 1,38 g/m² (déviation standard: 0,668 g/m²) mais qu'elle a été plus faible au niveau des plafonds (1,12 g/m²) et surtout des poutres (0,45 g/m²). Si l'on se souvient que les plafonds et les poutres sont les lieux de repos favoris des moustiques, l'on doit à l'avenir apporter un soin particulier aux pulvérisations à ces endroits.

Par ailleurs l'importance des « retombées » de fenthion sur le sol doit retenir l'attention si l'on utilise un insecticide plus toxique car ce sont les enfants qui, à longueur de journée, sont en contact plus ou moins étroit avec le sol. Or une enquête toxicologique effectuée chez les habitants au moment de la pulvérisation a montré que l'abaissement du taux de cholinestérase du plasma a été surtout marqué chez les enfants de moins de six ans.

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Annex 1

FENTHION SPRAY DEPOSITS

(Calculated, for walls, ceilings and beams, from results obtained with 10 cm^2 squares cut from exposed filter-papers, and expressed as g/m^2).

TABLE 1
FENTHION DEPOSITS ON WALLS

	Room A	Room B	Room C	Corridor
HUT 3				
	2.54	1.46	2.77	1.06
	2.62	1.28	1.52	1.98
	2.37	1.36	2.70	1.06
	2.01	1.10	1.17	1.81
	1.70	1.82	2.73	1.16
	2.60	1.86	1.06	1.44
	1.59	0.96	2.69	1.18
	2.65	1.04	2.18	1.50
	2.56	0.73	1.81	
	2.42	1.49	1.39	
	2.03			
Mean	2.28	1.31	2.00	1.40
Standard deviation	0.384	0.365	0.694	0.349
HUT 4				
	0.57	1.82	2.07	1.60
	2.03	1.37	0.73	1.18
	1.05	1.67	0.88	1.64
	0.67	2.31	2.73	0.49
	0.84	1.64	0.63	1.04
	1.19	1.18	1.84	1.58
	1.06	1.83	1.37	1.29
	0.87	1.51	1.08	1.46
	0.88	2.00	0.20	1.11
	1.26	0.77	1.19	
Mean	1.04	1.61	1.27	1.27
Standard deviation	0.409	0.433	0.756	0.366
HUT 6				
	1.52	0.04	0.90	1.93
	1.78	0.16	1.42	1.02
	1.05	0.13	2.40	0.64
	0.92	0.13	1.34	1.12
	0.73	0.13	1.04	1.21
	0.51	0	1.60	0.80
	0.81	0.13	1.70	1.54
	2.12	0	1.05	1.11
	1.89	0.05	1.73	1.81
	2.33	0.05	2.10	0.61
Mean	1.37	0.08	1.53	1.18
Standard deviation	0.642	0.060	0.480	0.458

	Room A	Room B	Room C	Corridor
HUT 8				
	1.72	1.73	1.17	1.37
	1.30	2.57	1.13	2.68
	1.02	0.28	0.84	2.74
	1.82	1.25	0.75	1.64
	0.75	1.25	0.21	1.48
	1.24	1.55	0.11	1.08
	0.99	2.71	0	0.74
	1.84	1.26	1.17	1.36
	1.44	1.21	0.42	1.12
	1.44	1.51	0.02	1.27
Mean	1.36	1.53	0.58	1.55
Standard deviation	0.369	0.700	0.486	0.660
HUT 9				
	1.20	2.54	2.44	0.95
	2.22	2.47	2.39	1.44
	1.54	2.68	2.18	1.35
	2.63	1.28	1.30	1.80
	2.62	1.25	1.34	2.34
	0.74	2.26	1.21	2.09
	1.66	1.90	1.38	1.35
	1.36	1.07	0.16	2.11
	1.62	2.12	1.02	2.22
	1.91	1.62	1.36	0.39
Mean	1.75	1.92	1.48	1.60
Standard deviation	0.608	0.586	0.695	0.624
HUT 10				
	1.29	0.97	0.67	0.72
	1.43	0.55	1.02	0.96
	2.21	1.04	1.96	0.31
	0.41	1.49	1.55	1.19
	2.08	1.81	1.59	0.80
	2.09	0.76	1.10	1.82
	0.96	0.69	1.81	1.34
	1.02	1.58	0.96	0.28
	1.02	0.91	1.16	1.97
	1.40	1.06	1.34	1.33
Mean	1.39	1.09	1.32	1.07
Standard deviation	0.584	0.412	0.407	0.571

Annex 1 (continued)

TABLE 2
FENTHION DEPOSITS ON CEILINGS

	Hut 3	Hut 4	Hut 8	Hut 9	Hut 10
	0.83	0.57	0.38	2.11	0.38
	1.00	0.66	1.23	2.40	0.99
	1.48	0.71	2.34	0.65	0.51
	1.08	0.54	1.44	1.48	1.06
	1.26	1.02	1.30	1.36	0.24
	0.90	0.90	2.50	2.55	0.11
	0.68	0.11	2.25	2.61	1.28
	1.12	1.22	0.84	0.97	0.58
	1.66	0.54			
	0.71	0.86			
Mean	1.07	0.71	1.54	1.77	0.64
Standard deviation	0.321	0.308	0.762	0.753	0.420

TABLE 3
FENTHION DEPOSITS ON ROOF BEAMS

	Horizontal beams [a]		Longitudinal beams [a]		Angled beams [a]		Vertical beams [a]
	Upper surface	Lower surface	Upper surface	Lower surface	Upper surface	Lower surface	
	0.12	0.08	0.15	0.24	0.08	0.10	0.17
	0.23	0.93	0.20	0.51	0.12	0.15	0.28
	0.17	1.95	0.09	0.08	0.13	0.17	0.17
	0.20	0.76	0.96	0.20	0.85	0.12	0.25
	0.54	2.09	0.15	0.29	0.26	2.14	0.11
	0.22	0.48	0.20	1.81	0.17	1.05	0.20
	0.22	0.90	0.14	0.48	0.14	0.14	0.17
	0.34	0.59	0.17	0.11	0.14	0.14	0.15
	0.62	0.15	0.17	0.17	0.31	0.70	0.29
	0.23	0.71	0.17	0.09	0.17	0.26	0.08
	0.54	2.73	0.87	0.17	2.26	0.09	0.09
	0.37	0.25	0.22	0.60	0.23	0.54	0.06
	1.55	0.34	0.04	0.19	0.33	0.40	0.76
	1.51	1.44	0	0.14	0.43	0.56	0.66
	0.26	0.54			0.69	0.79	0.69
	0.39	0.59			0.31	0.09	0.48
	0.34	0.68			0.46	0.23	0.78
					0.31	0.41	0.60
							0.14
							0.21
							0.07
							0.09
							0.49
							0.20
Mean	0.46	0.89	0.25	0.36	0.41	0.45	0.30
Standard deviation	0.426	0.739	0.288	0.447	0.504	0.506	0.237

[a] Horizontal beams are those running across the width of the room; longitudinal beams are those running the length of the room; angled beams are those rising at approximately 45° up to the central ridge; and vertical beams are those rising at approximately 90° up to the central ridge of the roof.

Annex 1 (continued)

TABLE 4

FENTHION DEPOSITS ON FLOOR-PLATES

	Corners	Sides	Away from walls
	0.96	1.40	0.92
	1.00	0.83	0.36
	1.01	1.67	0.33
	1.27	0.71	0.65
	1.19	1.21	0.43
	0.35	1.54	0.93
	1.33	0.74	0.21
	1.30	1.22	0.05
	1.06	0.68	0.15
	1.57	0.81	0.21
	0.93	0.91	0.53
	1.22	1.22	0.31
	1.76	0.81	0.38
	2.39	1.01	0.32
		0.89	0.23
		1.08	0.14
		1.55	0.23
		0.80	0.92
			0.14
Mean	1.24	1.06	0.39
Standard deviation	0.466	0.316	0.276

TABLE 5

FENTHION DEPOSITS: OVER-ALL RESULTS

Site sampled	No. of samples	Mean	Standard deviation
Walls	238	1.38	0.668
Ceilings	44	1.12	0.669
Beams	122	0.45	0.497

Annex 2

ANALYSIS OF RESULTS

WALLS

TABLE 6
ANALYSIS OF VARIANCE (ALL RESULTS INCLUDED)

Source of variation	Sums of squares	Degrees of freedom	Variance estimate	Variance ratio
Between huts	16.63	5	3.326	11.88
Between walls within any one hut	29.21	18	1.623	5.80
Residual	59.96	214	0.280	—
Total	105.80	237	—	—

The differences between huts and between different walls in any one hut are both very highly significant ($P < 0.001$).

On inspection it appears that the sampled wall in Room A of Hut 3 was treated greatly in excess of instructions (possibly by double treatment), that the sampled wall of Room B in Hut 6 was missed entirely and that the sampled wall in Room C of Hut 8 was started but not completed.

If it is desired to assess the effects when the correct spraying procedure is followed, the results for Room A in Hut 3, Room B in Hut 6 and Room C in Hut 8 should be omitted.

The revised analysis of variance is shown in Table 7.

TABLE 7
REVISED ANALYSIS OF VARIANCE (3 ROOMS OMITTED)

Source of variation	Sums of squares	Degrees of freedom	Variance estimate	Variance ratio
Between huts	6.04	5	1.208	3.99
Between walls within any one hut	7.12	15	0.475	1.57
Residual	56.32	186	0.303	—
Total	69.48	206	—	—

The differences between huts are still highly significant, but differences between walls in a hut are well within the limits of sampling error. It is difficult to account for the difference between huts; details of the deployment of the spray team might throw some light on the matter but unfortunately this information is not available.

CEILINGS

In view of the small number of observations on the ceilings, no detailed analysis has been carried out; but it is perfectly obvious that variance between ceilings is much greater than variance within ceilings. The skill of the individual spraymen may account for this difference but it is not possible, with the information available, to be definite on this point.

BEAMS

The target deposit is not approached in any instance. Either the spraying procedure was not being followed or the procedure does not give the desired result in this case. In view of the difficulties involved in spraying awkwardly situated and difficult-to-reach roof-beams, it is probable that the standard spraying procedure could not, in fact, be followed.

EFFICIENCY OF THE SPRAYING TECHNIQUE

If all the observations in each group (with the exception of those on walls already discarded) are assumed to be from a normal population, then the proportion falling below 0.75 g/m² (i.e., 50% of the target deposit) will be the area of the normal distribution curve to the left of the ordinate at $\bar{x} - 0.75$ in each case.

Considering the normal curve plotted in units of standard deviation, s, with the mean $(\bar{x})$ as origin, then this ordinate is at $Z = \dfrac{0.75 - \bar{x}}{s}$

For walls, $Z = -1.170$, leaving 0.121 (i.e., about 11%).

For ceilings, $Z = -0.553$, leaving 0.290 (i.e., about 29%).

For beams, $Z = +0.604$, leaving 0.727 (i.e., about 72%).

This method gives satisfactory results only if the approximation of the distribution to the normal curve is reasonably good. In fact, for walls the fit is reasonable but not good, for ceilings slightly worse and for beams very bad. If some function of x can be found which improves the fit of the distribution to the normal curve, then generally the estimate from the transformed variate will be an improvement.

A transformation of the type $\mu = \dfrac{1}{x+a}$ was tried and in each case the fit was improved. For walls and ceilings, $a = 0.80$; for beams, $a = 0.24$.

Owing to the form of the transformation the " area of rejection " now moves to the right of the distribution curve. The revised estimates of the proportion of areas showing less than 0.75 g/m² are:

For walls, $Z = +1.195$, leaving 0.116 (i.e., about 12%).

For ceilings, $Z = +0.314$, leaving 0.377 (i.e., about 38%).

For beams, $Z = -1.137$, leaving 0.872 (i.e., about 87%).

The estimate for walls is hardly altered. The small number of observations on ceilings makes any estimate somewhat doubtful. For beams the data are not particularly homogeneous and the transformation appears to have a tendency to overcorrect. Probably the best estimates which can be made are:

Walls: 11%-12% below 0.75 g/m².
Ceilings: 30%-35% below 0.75 g/m².
Beams: 80%-84% below 0.75 g/m².

If *all* the observations on the walls are included the estimate rises to approximately 17%.