VECTOR CONTROL SERIES

THE HOUSEFLY

Training and Information Guide

WORLD HEALTH ORGANIZATION
Vector Biology and Control Division

1986
FOREWORD

Since 1970 the Vector Biology and Control Division of WHO has prepared, with the assistance of collaborators outside the Organization, a number of papers on vector control. The Expert Committee on Insecticides held in October 1974 (Technical Report Series No. 561) recommended that these documents - general reviews of the ecology and control of individual vector groups - should be continued and reviewed from time to time to provide workers with up-to-date practical information on the particular subject.

In 1985, with the greater demand for this material for use as training and information guides by different categories of personnel, particularly in the developing countries, it was decided to develop two separate series of these documents; an advanced series for M.Sc. students in medical entomology and professional staff, and a middle-level series for less specialized workers in the community.

The advanced series will cover the relevant subject in more detail and at a higher technical level. It is believed that this type of information will assist vector control specialists to acquire the knowledge required for their daily work.

In order to improve the value and usefulness of this guide, evaluation forms are attached, and users are requested to send the completed forms to the WHO Division of Vector Biology and Control in Geneva so that their comments may be taken into consideration when the guide is revised.
VII. THE HOUSE-FLY - BIOLOGY AND CONTROL

by

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The issue of this document does not constitute formal publication. It should not be reviewed, abstracted, quoted or translated without the agreement of the World Health Organization. Authors alone are responsible for views expressed in signed articles.
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I. INTRODUCTION

The common house-fly, Musca domestica L., has followed man and been a nuisance to people all over the world wherever livestock are kept or garbage* accumulates (Fig. 1). Musca domestica deserves its name as it is by far the most common fly in and around houses, in villages and in urban areas with insufficient sanitation. The house-fly is of public health importance, because it may transmit infections to food and people, and because it is a plague adding to the daily burden of people living under poor sanitary conditions, and unacceptable where living conditions and hygiene are at a higher level.

* The terms marked with an asterisk are defined in Section VII - Glossary.
II. TAXONOMY*, NOMENCLATURE* AND GEOGRAPHICAL DISTRIBUTION

Classification of the Diptera* of public health importance:

<table>
<thead>
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<th>Order</th>
<th>Diptera Flies</th>
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<tr>
<td>Suborders</td>
<td>Neatocera1</td>
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<tr>
<td>Families</td>
<td>Culicidae</td>
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<tr>
<td>Mosquitos</td>
<td>includes</td>
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1) Antennae* with many segments (>6)
2) Mainly large flies, antennae with three segments, the last being the largest
3) Antennae with three segments. The last bears a bristle called the aristae*.

M. domestica belongs to the Class Insecta. In the Order Diptera* along with the majority of two-winged insects, they are members of the suborder Cyclorrhapha, as shown on the above chart illustrating the classification of Diptera of public health importance.

The genus Musca belongs to the family Muscidae which also contains other synanthropic flies, e.g. Stomoxys, Muscina and Fannia (West, 1951). The genus Musca consists of about 26 species most of which are “wild” and of no public health importance. The Musca species are generally medium-sized flies, with non-metallic black-and-grey striped thorax and a sharp angle in the fourth longitudinal vein of the wing.

The taxonomies of the domestic (and endophilic*) forms of Musca are still unclarified. It is generally agreed that they all belong to one species, M. domestica, but for many years four different subspecies were distinguished: M. d. domestica Linnaeus found in temperate zones all over the world, extending into subarctic and subtropical areas, M. d. vicina Macqvart, found in subtropical and tropical zones in many regions, e.g. in the Mediterranean, Asia, Africa, South and Central America, Pacific and Australia, M. d. nebulo Fabricius, found only in tropical Asia, and M. d. curviforceps Saccà & Rivosecchi restricted to Africa, where it is the common house-fly south of the Sahara (Saccà, 1964) (Fig. 2b).

However, recent investigations suggest that all Musca domestica outside Africa should be regarded as one subspecies M. domestica domestica, including the three previous subspecies, domestica, vicina and nebulo. These were mainly distinguished by the size of the compound eyes (measured as the frons ratio, see Figs. 2, 3) in the males and the pigmentation of the abdomen. However, these characters show overlapping and vary, not only from north to south, but also according to climatic conditions within an area, e.g. due to altitude. In future investigations it will still be of interest to characterize house-fly populations morphologically in various geographical and climatic localities by recording frons ratio in samples of males, but the former subspecific names should not be used.

The ecology and habits of house-fly populations (M. d. domestica) may vary in different parts of the world, adapted to local climate and other conditions (see section IV), but it is uncertain which, if any, of these biological differences are connected with morphological characters.
Fig. 2a. The range and determination of frons ratio F/H (width of frons divided by width of head) in male houseflies (From Saccà, 1967).

Fig. 2b. Some differential characters between male M. d. domestica, M. d. curviforceps and M. calleva. Below: heads, middle, dorso-central bristles; above: shape of paralobus of the terminalia (From Saccà, 1967).

<table>
<thead>
<tr>
<th>Strain</th>
<th>Temp</th>
<th>Pigmentation</th>
<th>Average of Frons/Head Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDIA F1a</td>
<td>12°C</td>
<td>25°C</td>
<td>30°C</td>
</tr>
<tr>
<td>EGYPT F10</td>
<td>12°C</td>
<td>25°C</td>
<td>30°C</td>
</tr>
<tr>
<td>ALGERIA</td>
<td>12°C</td>
<td>25°C</td>
<td>30°C</td>
</tr>
<tr>
<td>MOROCCO</td>
<td>12°C</td>
<td>25°C</td>
<td>30°C</td>
</tr>
<tr>
<td>DENMARK</td>
<td>12°C</td>
<td>25°C</td>
<td>30°C</td>
</tr>
<tr>
<td>FINLAND</td>
<td>12°C</td>
<td>25°C</td>
<td>30°C</td>
</tr>
</tbody>
</table>

Fig. 3. Pigmentation of the dorsal abdomen and average frons ratio in six strains of M. d. domestica bred at various temperatures (From Saccà, 1967).
In Africa two identifiable subspecies of *M. domestica* occur: the domestic endophilic *M. d. curviforceps*, mentioned above, and the exophilic* M. d. calleva* Walker (*= M. cuthbertsoni* Patton). These two common African subspecies regularly occur in the same locality, breeding in garbage in heaps of manure, but *M. d. calleva* does not actively enter houses and is probably of little public health importance. The two subspecies are interfertile*, but interbreeding is restricted due to the difference in habitat selection.

*Musca sorbens* Wiedemann is a distinct species with exophilic habits in most areas, yet it is of considerable public health interest, because it breeds in excrement of man and domestic animals and is strongly attracted to moist human skin, eyes, wounds, etc. It is common in Africa, subtropical and tropical Asia and in the Pacific. Further, it occurs in the extreme south of Europe and in Hawaii. *M. vetustissima* Walker, the Australian "bush-fly", is closely related to *M. sorbens* and has similar habits. *M. sorbens* and *M. vetustissima* are easily distinguished from the *M. domestica* forms by having only two broad dark stripes on the dorsal thorax*, whereas the *M. domestica* forms have four stripes (Fig. 4).

Fig. 4  *Musca sorbens* (Wied.) female 5.5 mm (From colour plate in Greenberg, 1971).

### III. LIFE HISTORY, BIOLOGY AND ECOLOGY

#### III.1. Life history (Fig. 5)

#### III.1.1 The eggs

The banana-shaped eggs are 1-1.2 mm long, opal-white to cream coloured. Clusters of eggs are deposited by the female fly in decaying, fermenting or putrefying organic matter provided it is moist, but not liquid. The eggs require a high humidity, below 90% relative humidity* (RH) the mortality is high. The time for development from oviposition to hatching depends on the temperature (Table 1), from a minimum of six to eight hours at 35°C. No development takes place below 13°C. The percentage of eggs hatching is high between 15°C and 40°C, but below 8°C and above 42°C all eggs die before hatching.
Fig. 5. The life cycle of the housefly (7 x magnification)

a. Female  b. Egg batch from one oviposition of one female. c. Fully grown third instar larva, dorsal view above, side view below. Head to the left. Note mouth hooks in fore end and spiracles in hind end. d. Pupae. Left the puparium, the barrel-shaped hardened skin of third larval instar, right the pupa taken out from the puparium.

<table>
<thead>
<tr>
<th>Minimum duration of different stages (days) in favourable medium (e.g. pig and horse dung*) (after West, 1951)</th>
<th>No development below</th>
<th>Lethal temperature above</th>
</tr>
</thead>
<tbody>
<tr>
<td>at 35°C 30°C 25°C 20°C 16°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E: Egg 0.33 0.42 0.66 1.1 1.7</td>
<td>13°C 12°C 12°C 42°C 45°C 47°C</td>
<td></td>
</tr>
<tr>
<td>L: Larva 3-4 4-5 5-6 7-9 17-19</td>
<td>12°C 12°C 45°C 45°C 47°C</td>
<td></td>
</tr>
<tr>
<td>P: Puparium 3-4 4-5 6-7 10-11 17-19</td>
<td>12°C 45°C 45°C</td>
<td></td>
</tr>
<tr>
<td>Total days E+L+P 6-8 8-10 11-13 18-21 36-42</td>
<td>13°C 12°C 12°C 12°C 42°C 47°C 47°C</td>
<td></td>
</tr>
<tr>
<td>M: Maturation of eggs in female (preoviposition period) 1.8 2.3 3 6 9</td>
<td>13°C 12°C 12°C 12°C 42°C 47°C 47°C</td>
<td></td>
</tr>
<tr>
<td>Total life cycle E+L+P+M (days) 8-10 10-12 14-16 24-27 45-51</td>
<td>13°C 12°C 12°C 12°C 42°C 47°C 47°C</td>
<td></td>
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III.1.2 The larvae

As in most other flies there are three larval instars (I, II, and III) separated by moults. Instar I grows from 1 to 3 mm, instar II from 3 to 5 mm and instar III from 5 to 12-13 mm. The larva has a slender cylindrical body with a conical tapering anterior ("head") and a rounder posterior, with no appendages (Fig. 5). Instars I, II and the first part of III are translucent, but towards pupation the larvae become white or yellowish. It is mainly these late third-instar maggots, the so-called prepupae, that are seen when a fly breeding site is investigated. The larvae have one strong and one small interior mouth hook used for feeding and locomotion; the two sclerotized* plates in the posterior end, looking like a pair of black eyes when viewed with a hand-lens (Fig. 5c), are spiracles* with slits for the fine air-tubes, the trachea, providing the body with oxygen.

The larvae in instars I, II and the first part of III are in the feeding stages, and in natural media most of the feeding is on bacteria or yeasts and their decomposition products, which provide the necessary protein (amino acids), vitamins (of the B group) and sterols. The feeding stages are attracted to odours connected with breeding media; they prefer a temperature of 35°C, require a high humidity (instar I above 97% RH) and strongly avoid light. They usually occur in aggregations.

When the third-instar larvae stop feeding and become prepupae, their reactions change, except that they still avoid light; they become indifferent to odours, and they prefer a lower temperature, less than 15-20°C, and a lower humidity. As they are very active the result is that they migrate to cooler and drier places, e.g. surface or sides of heaps of dung or garbage, or into the surrounding soil, where the pupation takes place, often in aggregations of hundreds or thousands.

The time required for the development of the larvae from hatching of the egg to pupation depends on nutrition, moisture and temperature (Table 1), with a minimum of 3-3.5 days under the most favourable conditions, i.e. 35°C (Fig. 6). Larvae and pupae do not tolerate temperatures above 45°C for long periods, which means that in accumulations of dung, garbage or other fermenting or rotting breeding media, it is often only a narrow outer zone, e.g. 10-15 cm, where the maggots and pupae can develop.

![Diagram showing duration of development of eggs + larvae and eggs + larvae + puparia in relation to temperature.](image-url)
III.1.3 The pupae

When the larva is ready for pupation, its skin contracts and it forms a barrel-shape puparium.* This is soft and white or yellow for the first one to two hours, and then gradually changes through light brown to dark brown or almost black while the cuticle hardens. This process usually takes place within the first 24 hours. Inside the puparium there is a highly condensed fourth larval instar, before the true pupa is formed.

The duration of the puparium stage until the fly emerges depends on humidity particularly on temperature (Table 1). It is roughly of the same length as the larval development, with a minimum of three to four days at 35–40°C and 90% RH. The pupae tolerate lower humidities than the larvae, but below 75% RH some die and below 40% few survive. The lethal temperature is about 45°C as in the larval stage, and below 12°C the development stops. The ability of pupae and larvae to tolerate lower temperatures is discussed under overwintering (section III.3).

III.1.4 The adult fly

(a) The emergence from the puparium. When the adult fly has been formed inside the puparium, it breaks the fore end of the puparium by inflating the frontal sac*, pushing two flaps, and emerges quickly. The newly emerged fly is soft, pale grey and wingless. Using the frontal sac, it is able to "pump" its way up through thick layers of loose soil or other material that is not too solid.

When in the open air it has an active wingless phase lasting 15 min or more depending on temperature and other conditions, until it finds a suitable place to rest, while the wings stretch and the cuticle hardens and becomes dark. This immobile phase lasts 0.5 to 1.5 h more, and it takes one to several hours before the fly can start to use its wings. Location of the resting place is important for the control of flies. The active newly emerged wingless flies have well-defined reactions to gravity and light, which lead them upwards mainly towards dark places, where they prefer to rest upside down, if possible. The wingless flies start feeding when they have become active after the wing-stretching from two to 4 h after emergence at 27°C.

(b) Mating. Males are able to copulate the day after emergence (minimum 18 h) females at an age of 30 h at favourable temperatures. Visual attraction seems most important for the mating, but olfactory stimuli, including a sex pheromone*, are also involved (Colin & Shorey, 1977). A pheromone, muscalure, is produced by the female (Carlson & Leibold, 1967). It attracts males and, to a lesser degree, also females. Recently a pheromone produced by males has been discovered (Schlein & Galun, 1984). It induces aggregation and receptivity in virgin females, but has no effect on males or mated females.

Most normally mated house-fly females are monogamous and none will mate more than a couple of times. The loss of sexual receptivity is caused by components of the seminal fluid at first effective mating, and this substance also stimulates oviposition. The sperm is stored in the female spermathecae* and can fertilize eggs for a period of up to three weeks or more.

(c) Oviposition. The age at which the female is able to lay the first batch of eggs depends on temperature (Table 1) and this preoviposition* period varies from 1.8 days at 15°C to about nine days at 60°C. As a rule oviposition does not take place at air temperatures below 15°C. Gravid females are primarily attracted to the breeding medium by its smell, which carbon dioxide, ammonia, and various other odours of dung and rotting or fermentative materials are involved. (Details about breeding sources and sites are given in Sections II and V.I.1). The eggs are laid beneath the surface, in crevices, etc., where they are protected against desiccation.

The number of eggs per oviposition is normally about 120. If undisturbed, the female usually lays them in one cluster and often several females lay eggs in the same spot. Laboratory colonies of a female house-fly may produce 10 batches or more, but under natural favourable conditions it may be only one or two, as the longevity of the flies is usually less than in the laboratory.
(d) Length of life. Experiments on Danish farms have shown that 50% of the flies die during the first 3-6 days and very few reach an age of 8-10 days, even if no chemical control is applied, whereas in the laboratory the mean life span of adult flies was found to be 17 days for males and 29 days for females (at 25°C and 45% RH). Most people concerned with house-fly control have assumed that the longevity found in the laboratory (mean life span of 3-4 weeks or more) also applied to the field. The finding of a much shorter life-expectancy in the field, which has been confirmed in later investigations in Denmark and in England, is of importance for considerations of the effect and strategy of house-fly control. It means that a high proportion of female flies die before they have had a chance to lay eggs and very few flies will lay three or three batches of eggs under the conditions on the Danish farms. The causes of the shorter life are not known, but in Denmark infection with the fly fungus Entomophthora muscae seems to play an important role, dependent on the type of animal houses (temperature, humidity) and the season. A recent study of house-flies on a Japanese garbage dump showed a daily survival rate of 0.60 to 0.87 (Imai, 1984).

(e) Reproductive potential*. The number of generations per year may vary from about 30 under tropical conditions to about 10 or less in temperate climates. Even with a conservative assumption of 100-200 offspring per female, the theoretical capacity of increase is enormous, and when new favourable breeding opportunities are created sudden outbursts of fly infestation may occur. Obviously, a limit for the increase is the amount of breeding medium available, though 5000-10 000 healthy flies may be produced per kilogram or litre of favourable medium. However, even if there is plenty of unused food for larvae and adults, e.g. after chemical or climatic suppression of the flies, or at the start of the fly season, the rate of increase in a field population is strongly reduced by natural mortality factors. Thus on four subtropical farms in Florida, United States of America, the maximum increase per two weeks at the start of the fly season was found to be 6-8 times, whereas on 25 temperate farms in Denmark it was 10-22 times on half of the farms and 3-9 times on the rest. If the conditions for breeding are fairly constant, a stable population may be established, high or low according to the mortality factors present - climatic, biological and chemical. This was demonstrated during a two-year field study in Grand Turks Island in the Caribbean, where the potential rates of increase of house-flies were low despite their high biotic potential (Weidhaas & LaBrecque, 1970).

III.2. Breeding sources

House-flies can breed in a variety of decaying, fermenting or rotting organic matter, of both animal and vegetable origin (Schoof, et al., 1954). They rarely infest meat or carrion, which is the province of blow-flies and flesh-flies.

III.2.1 Dung

Accumulations of dung constitute a most important and probably the original source of house-fly breeding (Haines, 1953, 1955). Whereas isolated droppings are of little importance for Musca domestica, they are the primary source of M. sorbens (Mau, 1978) and M. vetustissima. House-flies may breed in accumulations of dung of most domestic animals and birds, provided it has the right moisture (not too wet) and texture (not too solid), but the utilization and suitability of dung for fly breeding vary considerably according to which animal produced it, the feed of the animals, the deposition, stacking and mixing of the dung with bedding material, the climate, etc. Besides, house-flies seem to have different preferences for adaptations to dung in various geographical areas. The most important example is cow dung, which is a very important source of fly breeding in many parts of the world, but in north and west Europe dung of adult cattle usually does not breed house-flies, and cow dung has been recommended as a cover on top of pig manure to prevent fly breeding. However, dung of calves, as long as they are fed milk, is an excellent breeding source everywhere, and in north Europe calf pens may be the most important breeding sites for house-flies on farms.

In many regions human excrement is attractive to house-flies and open latrines are important breeding sources, but in some areas (e.g. northern Europe) human excrement does not attract house-flies.
Where available, pig dung seems to be the preferred and most fly-productive type of dung (Ascher, 1958); horse dung is also an excellent fly breeding source, but only for a short time due to its rapid composting process. Fly breeding in accumulations of poultry excrement becomes a great problem in modern egg and chicken industry, involving both M. domestica and lesser house-flies (Fannia species). Other kinds of dung that may play a role for breeding locally include donkey, rabbit, goat, sheep, buffalo, and camel. Dung is suitable for fly breeding in the first few days to a week after deposited. As a rule house flies do not breed much in composted dung.

III.2.2 Garbage and wastes from food processing

Garbage includes wastes from the preparation, cooking and serving of food, and manures from the handling, storage and sale of food. It is a very important source of breeding, and in urban areas it is the predominant source for both house-flies and other synanthropic flies, particularly blow-flies, ranging from individual household garbage through refuse at food shops and markets to garbage dumps (Schoof, et al., 1954). This is further discussed in section V.1. Fly breeding is not confined to accumulations of garbage, but also take place in soil mixed with garbage or impregnated with seepage.

Various wastes from food processing and industry may also be a source of serious house-breeding, e.g. in connexion with canning of vegetables and fruit, breweries and distilleries, sugar plants, etc. (Imai, 1984).

Processing of fish and meat, as well as treatment of vegetables, often give rise to serious fly problems. Although blow-flies are usually dominant where animal protein is the source, houseflies sometimes breed in great numbers; for instance in soil heavily contaminaed with blood, fish or slaughter offal.

In agriculture, waste from growing fruit or vegetables, e.g. discarded tomatoes or melons may be a breeding source of many house-flies.

III.2.3 Organic manure other than dung

In some areas, where fields are heavily manured with organic matter, house-flies may breed in great numbers in the fields, particularly if the manure is applied in lumps. Besides dung, such manure may include excrement, garbage, fish-meal, blood- and bone-meal, oil-seed cake, prawn dust, etc.

III.2.4 Sewage

Under suitable conditions house-flies may breed in sewage sludge and solid organic wastes in open sewage drains, cesspools, seepage pits, etc., or in sewage beds. Moreover, flies may breed in soil wetted by household dish water, where a sewage system is lacking.

III.2.5 Accumulations of plant material

Piles of decaying grass clippings or garden compost heaps have been found as important sources of house-flies in some urban and suburban areas (Silverly & Schoof, 1955), and in rural areas flies may breed in silage (Meyer & Petersen, 1983) and in heaps of other rotten vegetable matter. Heaps of seaweed or seaweed on beaches may breed Stomoxys, the bit stable fly and certain other flies, but rarely house-flies.

III.3. Seasonal fluctuations and overwintering

If no control measures are used, the fly density in a given locality will generally fluctuate with the conditions for breeding and reproduction; in particular the air temperature influences the rate of mating, the preoviposition period, oviposition and feeding of adults. The temperature of the breeding medium is also a factor, but in fermenting heaps of dung, garbage, etc., an optimal temperature will often be reached, even if the air temperature is low. In such sites lethal high temperatures in hot periods may limit breeding. In tropical...
and subtropical areas desiccation of breeding media in hot and dry periods may also restrict fly breeding. In subtropical areas (e.g. Egypt) with a very hot and dry summer and cool winter, there will often be a spring and autumn maximum at mean temperatures of 20-25°C, a summer depression and low density in the winter (Madwar & Zahar, 1953).

Even in some areas with a temperate climate involving hot summers, the summer depression may occur. However, in most temperate and subtropical regions the usual pattern is that of a winter period with few to very few flies, a gradual or sudden increase in spring, a summer fly season of three to eight months and a decline in the autumn. In areas with a coastal temperate climate (e.g. northwest Europe) the fly incidence is correlated with the hours of sunshine and is depressed in wet periods.

Overwintering. The question of how house-fly populations overwinter, especially in places with a cold winter, is still being discussed. M. domestica has no true diapause, and most investigators agree that, whenever possible, the house-fly will overwinter by slow breeding in buildings, particularly cow sheds and other stables, where the temperature, at least at times, is above 16°C. Such winter breeding places become the important foci for fly infestations the following spring. Even on some Swedish farms north of the polar circle prolific fly breeding and incidence occur all through the severe winter in well insulated stables.

Overwintering of adult flies is not likely to be of importance. At the most favourable conditions for longevity, temperatures fluctuating between 5°C and 15°C, females rarely live longer than three to four months. However, Soviet investigators have found that M. domestica can hibernate in an inactive state as adults, and as prepupae and pupae in frozen or cold dung and soil. This is probably a special adaptation of the house-flies in these areas. In temperate China it was also believed that overwintering as pupae played a role for the house-fly infestations and fly pupae were collected in the autumn. Recent investigations in China have shown that most (if not all) of the overwintering pupae are of other fly species, e.g. blow-flies and flesh-flies, which are known to have a diapause. This is also found in the lesser house-fly, Fannia canicularis, in Europe.

III.4. Biology and behaviour of adult flies

The reactions and behaviour of the newly emerged flies and at mating and oviposition have been discussed under Section III.1.4.

III.4.1 Feeding

House-fly males and females can survive well on water plus sugar or other assimilable carbohydrates; in addition, females require protein or protein components (amino acids) for the development of eggs, but not fat and other lipoids (Spiller, 1964). House-flies feed on all kinds of human food and garbage, on excreta including sweat, and on animal dung. They are poorly equipped with smell receptors on the antennae (e.g. compared to blow-flies) and attraction by odour to food at a distance plays a minor role. The food is mainly found by extensive random exploratory movements of the flies combined with visual attraction (e.g. to dark spots) and reaction to humidity and smell at short range, at which many odours show effect (Kelding, 1965). The house-fly reacts to smells of fermenting and putrefying materials, to alcohols, lower aliphatic acids (e.g. acetic acid), aldehydes and esters (which may or may not be included in "sweet smell", (Yamamoto & Jensen, 1967), but also to toxic substances such as chloroform, formaldehyde, and some organophosphorus insecticides (Molla, et al., 1977).

When in contact with potential food the house-fly tastes it with the chemotactic receptors on the feet and the proboscis. These receptors are especially sensitive to solutions of sugar. If the taste is good the fly stops, extends the proboscis and may start feeding. Liquid food is sucked up, but soluble food in solid form (e.g. sugar) must first be wetted and dissolved by liquid from the fly's crop and saliva. Other solid materials may be scraped with tiny teeth on the proboscis. Some compounds, e.g. amino acids and guanosine monophosphate, act as feeding stimulants, i.e. increase the feeding, in female house-flies.
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It is a common experience that food containing sugar or starch becomes more attractive to flies when other flies have fed on it. The explanation is that the saliva of the first flies has moistened and partly decomposed the food to products that are more tasty (e.g. malt-glucose and fructose) and no specific "fly factor" seems to be involved. In addition sight of a group of flies attracts other flies (the "herd instinct"). Hungry flies see move at random, but when they have tasted a small amount of food (e.g. a drop of molasses) they intensify their search by moving in circles or spirals. Recent experts have shown that house-flies can learn to associate different odours or light stimuli with food.

III.4.2 Distribution by day and by night

The distribution of adult flies in their habitat is decisive for their unhygienic role for their control. Adult flies are only active in light, in daylight or in artificial light, in darkness they rest or crawl slowly.

(a) Daytime distribution. Flies are mainly gathered on or around feeding and breeding sources where mating also takes place. Active periods of random and directed movements, feeding, mating and oviposition are interspersed with resting periods.

The distribution of flies both when active and resting are much influenced by reaction to such factors as temperature, humidity, wind and light and to colour and texture of the surface. As a rule the daytime resting places will be close to the feeding (and breeding) sources, the attraction to which was discussed above. In dry weather, water and moisture, strong attractents, and among food sources milk is especially attractive in most places.

Experiments have shown the preferred temperature for resting flies to be 35-40°C (a 27°C for newly emerged flies). Lethal effect (heat paralysis) occurs at 45-47°C. Below 25°C the movements and other activities gradually decrease. Oviposition, mating, feeding, flying cease at 15-20°C and crawling movements at 7-4°C. The reaction to temperature may geographically (populations in warm climates tend to react at higher temperatures and in temperate areas to temperature, and climatic factors, e.g. nutrition, sex, age, maturity, as well as certain physiological factors, e.g. humidity and wind, may influence it. Although thirsty flies attracted to moisture, house-flies generally prefer a low air humidity, at which they are most active. It is well known that house-flies avoid exposure to wind and air drafts, little is known about the critical air velocities.

The reactions of house-flies to light are complex, much depending on other factors: physical, climatic, physiological, etc. As mentioned above, the newly emerged flies upwards (negative geotaxis), but generally to the darkest place (negative phototaxis). Flies show no general avoidance or attraction to light. In some situations they are attracted to dark areas or the borderline between light and dark, in others to light areas. Disturbed or crowded flies always move towards light. At temperatures below 27°C flies move towards dark areas because of the higher temperature.

The reactions of flies to different colours have been subjected to numerous investigations, which have given diverse results (Hecht, 1970). Experiments with col. surfaces have shown that flies generally avoid glossy, light-reflecting surfaces. In (where ultra-violet light is largely excluded) they usually prefer dark surfaces, black or red, and as a rule blue is least attractive, whereas outdoors house-flies may prefer yellow and white and avoid black. These preferences are not strongly influenced by temperature. Both indoors and outdoors the contrast between the background and the color is important for its attractiveness. The reaction of flies to coloured light is another matter: in general house-flies are not strongly attracted to lamps (apart from the heat attractant) light-traps, whether with visible or ultra-violet light; contrary to blow-flies and many other flies, and the attractiveness of the colour is influenced by the air temperature. Thus green and red light (suggesting source of heat) may be more attractive at relatively low temperatures (19°C) and blue or ultra-violet light more attractive at higher temperatures (e.g. 28°C).
The texture of the surface is of importance for the choice of resting place. House-flies prefer to settle on rough surfaces and avoid smooth ones, and they have a special preference for edges.

The general daytime distribution of house-flies differs according to climate and habitat (Keiding, 1965), concentrating around breeding and feeding sites.

In warm climates or seasons much of the house-fly population spends the daytime outdoors or in covered areas near the open air, such as market places, bazaars, sheds and verandas, and shops, restaurants and rooms with an open facade. When not on food or breeding sites most flies are found on the ground in low vegetation, on floors, tables and other horizontal surfaces. However, attractive indoor places, particularly kitchens, privies and animal sheds may also have a high day incidence of flies in warm climates. Moreover, on hot, sunny days flies may move into the cooler houses, e.g. when shade temperature rises above 30°C in the middle of the day.

At the other end of the scale in temperate summers or cool seasons most of the house-flies may remain indoors, especially on wet and windy days, and only leave buildings for short periods, the amount and location of sunshine being of great importance. In rural areas flies concentrate in sheds and stables of domestic animals, particularly cattle and pig, and they spend most of the day on the warm skin of the animals or on partitions, etc. nearby (Fig. 7), but not usually on the floor and not in the upper half of the room.

Fig. 7. Distribution of houseflies in a Danish piggery by day (top) and by night. Each dot represents 1% of the flies and the diagram shows the average counts over several summer days. Such counts have been the basis of strategic fly control.
(b) Night-resting habits. Towards dusk house-flies leave their daytime places of activity or rest and move to special night-resting sites close by. In warm climates or in seasons, e.g., with night temperatures above 20°C, a considerable proportion of house-flies rest outdoors on twigs and leaves of trees, shrubs and herbs, on wires, fences and other narrow objects and edges, often two or more metres above the ground and protected from wind (Maier, et al., 1952). However, even on warm nights many house-flies rest under cover: in doorways, verandas, awnings, open sheds, etc., and in rooms of building (Kelling, 1963). As a rule these covered or indoor night-resting places are near the ceiling or at least well above the floor, and the flies show strong preferences for wires, cords or other narrow objects, especially vertical ones, and for edges, prominences and irregularities. The favoured night-resting places are recognized by their thick cover of fly excrement. During cooler nights with minimum temperatures between 15-20°C part of the population may still rest outdoors, but more flies move indoors. There is no sharp temperature limit for indoor or outdoor resting, and the reaction to temperature may vary from one climatic zone to another. In the temperate summer all flies rest indoors at night, e.g., in cow sheds or pigsties, parl in the ceiling area, but also at lower positions on partitions, etc. (Fig. 7).

A detailed knowledge of local night-resting places is important for rational fly control.

III.4.3 Dispersion*

House-flies are good flyers and can move forward at a rate of 6-8 km per hour, but the are not migratory by nature and do not normally embark upon long flights. They move around their environment, but as long as they find suitable and sufficient food and shelter they tend to remain within a radius of 100-500 m from the breeding site. However, in favourable weather some of the house-flies from a focus may disperse further, especially in case of overpopulation on the breeding site and be found on sites of attraction 1-5 km or more away in a village or town, or in neighbourhing villages or farms.

Much of the information on fly dispersion is based on trapping of marked house-flies at various distances from their point of release, and in such experiments some flies were found up to 10-20 km away (Schoof, 1959). These records show that some house-flies may travel great distances, but they are exceptions, and it is not clear to what extent they fly by themselves or travelled by car, horse, camel or other vehicle. Passive transport of house-flies o vehicles, from the garbage truck to buses and private cars, etc., does play an important rol in their dispersion (Wharton, et al., 1962). However, house-flies are certainly able to fly considerable distances, particularly if left in open country without sites of attraction (and distraction) providing food and shelter. Some investigations have shown a tendency of house flies to fly against a moderate wind, 2-12 km/h, carrying attractive odours, e.g., from a dirt farm, but in other cases flies moved with or across the direction of the wind (Pickens, et al., 1967).

IV. PUBLIC HEALTH IMPORTANCE OF HOUSE-FLIES

IV.1. Potential of flies for transmission of disease

Since the beginning of this century M. domestica has been regarded as a potential an often important agent for transmission of several enteric* infections such as dysenteries infantile diarrhoea, typhoid, food poisoning, cholera and helmiths* and the flies have bee accused of transmitting leprosy, pellomyelitis and certain skin diseases such as yaws* while M. surinamensis has been regarded as important for the spread of eye infections. Recently synanthropic flies other than Musca species, e.g., many species of blow-flies, have receive attention as potential transmitters of enteric infections (Greenberg, 1971). These change against flies of spreading diseases rest on the following observations:

(1) House-flies and other synanthropic flies come into contact both with substrata (such a faeces and other excreta, carcasses, garbage and other filthy matter) that may contam pathogens* and then with human beings, their food and utensils*, etc. (Fig. 8).
(2) Flies have been shown to pick up and carry many pathogens (viruses, bacteria, protozoa, eggs and cysts of helminths, etc.) both externally, on their mouthparts, the body and leg hairs, and sticky pads (pulvilli) of the feet, and internally in their crop and intestinal tract.

As a rule pathogens picked up by the larvae are not transferred to the adult, and most pathogens picked up by adult flies do not multiply in them. The germs on the surface of the fly often survive only for a few hours, especially if exposed to sun, whereas pathogens can live for several days in the crop and gut of the fly and be transmitted when the fly vomits or defecates (deposits fly specks).

(3) Experiments have shown that pathogens carried by flies under certain conditions can infect food, animals and man.

(4) In many cases the incidence of enteric and eye infections is associated with the local or seasonal abundance of flies.

**Fig. 8.** House-flies and other synanthropic flies come into contact with substrata that may contain pathogens, and then with human beings through food, utensils etc.
(5) In some cases effective fly control has caused a clear reduction in the incidence of disease.

This last observation (5) is the best evidence of the role of flies, especially chemical fly control alone reduces the rate of new infections compared to a control area. The most obvious examples concern diarrhoeal diseases (Greenberg, 1973).

There are many possibilities for flies to transport and mechanically transmit pathogens usually connected with low standards of hygiene. However, in each situation the question is how important a factor are flies for spreading infections as compared to other ways of transmission, e.g. directly by food, water, air or dirty fingers and other direct contact from person to person. This leads to another question: what factors influence the transmission of disease by flies? For enteric diseases the following factors may be mentioned:

(a) The number of flies that come into contact both with reservoirs of pathogens (e.g. open latrines or sewage) and with food, utensils, etc.

(b) The average number of pathogens carried by each fly.

(c) The opportunity of pathogens to multiply in food infected by flies.

(d) The number of pathogens required to develop infection in man.

Factor (a) is dependent on a combination of several factors, e.g.:

(e) The abundance of flies, dependent on possibilities for fly breeding, attraction from other areas, the climate, season, etc.

(f) The habits of the flies in a particular situation are decisive for their ability to transmit infections. Populations that are attracted both to excrement and other filth (especially if they feed on it) and to food are most dangerous.

The attraction of house-flies to human faeces may be strong in tropical or subtropical regions, but is much less in many temperate areas. The changes in climate also play an important role for the potential of flies to spread disease, not only as it affects the seasonal prevalence of the flies, but also as it may affect their habits. House-flies may frequent houses in cold weather, but to a great extent remain outside the houses in warm periods or climates.

(g) The amount of infested material (excrement, sewage, offal, etc.) exposed available to the fly. This is obviously a very important factor.

(h) The exposure of food, kitchen utensils, etc., to the flies.

(i) The distance between the infested material (g) and kitchens, restaurants, shops, food-markets, etc.

(j) The radius of activity and dispersal of the flies (both by active flight and passive transport by cars, etc. (see section II.4.3 above).

Most of the conditions favouring fly abundance and transmission of disease by flies are the result of low standards of hygiene and environmental sanitation, which, however, also favours other means of transmitting enteric diseases. Thus in studies of a WHO diarrhoea diseases advisory team working in Venezuelan villages (Wolff, et al., 1969), the main conclusions were:

(i) Overall sanitary measures are of the greatest importance in the reduction of diarrhoea.
(ii) Of the sanitary measures that can be taken, the provision of unlimited amounts of good water seems to be correlated with the most important reduction of diarrhoea incidence.

(iii) Pathogens such as Shigella* and Salmonella* circulate in the community partly because of their transmission by flies.

(iv) Foodborne diarrhoea caused by Shigella or Salmonella may be a result of the transmission of pathogen to food by flies, and the subsequent multiplication of the pathogens in the food before it is consumed.

**IV.2. Important diseases that may be transmitted by non-biting flies under certain conditions**

For none of these diseases are flies necessary and they are rarely the most important agent for transmission.

**Diseases of the intestine**

**Bacterial infections**

*Shigellosis* - bacillary dysentery and other diarrhoeal diseases. Under unsanitary conditions flies may be important (see above). As few as 100 Shigella-bacteria may cause infection in man (Bidadwi, et al., 1978).

*Salmonellosis* - typhoid, paratyphoid, enteritis, food poisoning, etc. Flies may play a role in inoculating food, but in general they are less important than in Shigellosis. The infective dose of Salmonella-bacteria is usually much higher than in Shigella.

*Cholera* - transmission by flies is possible, but usually of little practical significance (Echeverria, et al., 1983).

*Campylobacteriosis* - it has been shown in Norway that *Musca domestica* may play a linking role in the epidemiology of *Campylobacter fetus jejuni* (Rose & Kapperud, 1983).

**Protozoan infections**

*Amoebic dysentery* - flies may transmit cysts, but seem usually to be of relatively little importance.

**Helminthic infections**

Flies do carry eggs and cysts of many intestinal worms: pinworms (*Enterobius*), roundworms (*Ascaris*), whipworms (*Trichiura*), hookworms (*Ancylostoma* and *Necator*), strongylolides, tapeworms (*Taenia*, *Diphyllium*, etc.) and may in some cases contribute to the spread of helminths to man and animals (D'peolu, 1977).

**Virus infections**

Polioencephalitis and related virus (e.g. Cocksackie and ECHO viruses) diseases -flies are able to transmit virus to human foods in quantities high enough to cause infection in some susceptible persons, but generally flies are not considered important for the spread of polioencephalitis.

Likewise, it is uncertain whether house-flies at high densities and in unsanitary conditions may contribute to the spread of infectious hepatitis.

**Rickettsial infections**

Experiments have shown that *Coxiella burnettii*, the rickettsia causing Q-fever, can remain infective for the lifetime of house-flies that have been in contact with the pathogen once (Hučko, 1984).
Eye diseases

Trachoma (viral) and epidemic conjunctivitis (bacillary) - Musca sorbens is strongly attracted to infected eyes and feeds on the secretions. It is considered important in the transmission of these eye infections, but the role of flies relative to transmission by personal contact may differ greatly from one situation to another, and may be difficult to evaluate. Musca domestica is also found on infected eyes, but seems to be less important than M. sorbens, where both species occur (Jones, et al., 1976). "Gnats", small black shiny flies of the family Chloropidae, are also considered transmitters of eye and skin infections in America (Hippelates) and tropical America (Siphunculina).

Infections of skin and wounds

Flies attracted to skin infections and wounds are able to transmit infections such as cutaneous diphtheria, mycoses, yaws and leprosy (Geater, 1975), but, again, the importance of flies is uncertain.

IV.3. Fly nuisance

The importance of the nuisance created by the presence of flies in great or moderate numbers should not be underestimated. Fly nuisance becomes more intolerable as economic conditions improve, but in communities with a low standard of living, the crowds of flies add to the burden of daily life. They disturb and trouble people both during work, at leisure time and when they want to rest. Flies soil the inside and outside of houses. They have a psychological effect not only as a nuisance but also as their presence is a sign of unhygienic conditions. This discourages people from keeping a good standard of personal hygiene, cleanliness in and around homes, and thus a fly problem may both directly and indirectly hamper improvement of general hygiene. Finally, fly nuisance may be an economic problem, as strongly affects the tourist trade. In dairy barns, house-flies by annoying the cows reduce the milk yield.

V. FLY CONTROL

V.1. Environmental sanitation and hygiene

To obtain long-term control of flies in urban areas, villages, and other settlements including individual farms, improved environmental sanitation is absolutely fundamental. Chemical fly control can only be a supplement to sanitary measures (Busvine, 1980; Keldi, 1974). This basic principle applies particularly to regions with a warm climate.

The objectives of fly control by sanitation are:

- To eliminate or reduce fly breeding (1) by eliminating sources suitable for fly breeding (2) by excluding flies (prevent egg-laying) from potential breeding sources (waste excreta) and (3) by killing larvae in infested materials;
- To eliminate sources of attraction, to reduce immigration of flies from other areas;
- To exclude flies from contact with matter that contains pathogenic germs; and
- To protect food, utensils and man from contact with flies.

V.1.1 Elimination or reduction of fly breeding

The breeding habits of house-flies and other synanthropic (living with man) flies were discussed in Sect III.2. The following is a list of important breeding sources, with possible measures eliminating or reducing fly breeding.
(i) Accumulation of animal excrement (and feed) cattle, pig, horse, donkey, sheep, goat, rabbit, poultry, etc.

Farm and domestic animals do not only occur in rural areas, but also may be found in towns and suburbs, particularly in connexion with slaughterhouses and livestock markets.

(a) In animal sheds, stables, pens or feed-lots. Dung and urine together with straw and other bedding on the floor or mixed into the soil. It requires frequent, preferably daily, removal (Pickens, et al., 1967), or a solid impervious floor with drainage.

(b) In poultry houses. Accumulation of droppings under cages or net-bottoms should be frequently removed and flushed clean or mixed with lime and dried.

(c) Dung heaps. Composting (Gotaas, 1956) to kill fly larvae by fermentation heat. Composted manure is generally not suitable for fly breeding (Eastwood, et al., 1967). The dung in tanks should be covered by plastic sheets (Eastwood, et al., 1966), straw, soil, etc. to exclude flies from dung and to raise fermentation temperatures to levels lethal for fly larvae, etc., i.e. above 50°C, (Figs. 9-11). Manure may be stocked on a concrete floor surrounded by gutters with water for trapping migrating larvae or spread and dried.

(d) Manure slurry containers. Fly breeding occurs in "islands" and residues of dung. The solid parts of dung should be eliminated.

(ii) Human excrement (see Wagner & Lanoix, 1958).

(a) Latrine pits, buckets, etc., open to fly infestation. Non-fly breeding privies should be installed (Fig. 12) (e.g. aqua-privies with a slab with a water seal preventing access of flies to the excrement; fly-proofed latrine houses) with a vent-pipe and fly net. The covers or lids of pits, buckets, etc., should be fly-proofed, or water closets installed, but these require septic tanks or a proper sewage system.

(b) Latrine dumps (mainly in rural areas). The excreta may be treated as dung (see (i) above).

(c) Indiscriminate defecation (outside latrines, toilets, etc). This is a source of Musca sorbens. It may be eliminated by the provision of proper latrines, education and change of habits, or the systematic removal of exposed faeces in problem areas.

(iii) Garbage, disposal and storage at source

The following different situations should be considered:

- Disposal and storage inside and outside houses. Garbage containers (bins, boxes, baskets, cans, bags, etc.);
- Hotels, restaurants, coffee shops, etc;
- Institutions: schools, hospitals, etc;
- Food shops, especially where meat, fish, fruit and vegetables are sold;
- Food markets, both wholesale and retail; meat, fish, vegetables, fruit;
- Slaughterhouses;
- Food industries: food packing, products of fruit, vegetables, etc.;
- Rendering plants where dead animals and slaughter offal are processed;
- Streets and roads, roadsides, etc., e.g. resting and gathering places;
Fig. 9. Dung heap covered with heavy plastic sheet (Photograph by J. Keiding.)

Fig. 10. Temperatures in a dung heap before (top) and after covering with tarp
11. Cross-section of haycock-shaped manure compost pile showing area inhabited by housefly larvae on the 6th day (after Gotaas, 1956).

Fig. 12. Supported pit latrine with ventilation with vent pipe provided with fly screen to prevent fly breeding (Chrysomya species or Musca domestica) (from Feachem & Cairncross, 1978).
- Camping sites; and
- Sea shores, particularly where garbage is dumped in the sea.

Measures to improve garbage disposal and storage at source to prevent fly breeding are in principle common to these different situations: (i) provision, cleaning and maintenance of fly-proof garbage containers of sufficient capacity (bins, boxes, cans, bags or bulk storage containers, etc.); (ii) handling garbage to avoid spillage, exposure to flies, etc., e.g., by wrapping; cleanliness and order on the premises; (iii) adequate collection service (see below); (iv) local garbage pits with tight covers or small incinerators for certain premises.

(iv) Garbage collection and transport

Problems in relation to fly infestation:

(a) Frequency of collection: in a warm climate collection twice a week is not enough to prevent fly production from garbage containers, as pupating larvae may emigrate (Flinthoff, 1984). The residue of wet garbage sludge in containers may support continuous breeding.

(b) Points of collection: on-site, at the curb, central collection points, transfer stations, etc.

(c) Spillage of garbage from collecting trucks.

(d) Transport of flies by collecting trucks.

(e) Flies may breed in residues of sludge and grease in the trucks.

(v) Garbage, treatment and final disposal (see WHO, 1971).

(a) Dumping. Refuse dumps give serious fly problems, due to fly breeding and attraction. The distance from settlements is important. Dumping at sea litters the shoreline.

(b) Sanitary landfills. A compact cover of at least 15 cm of soil is needed to prevent fly emergence (Fig. 13).

(c) Composting. Heavy fly breeding may occur in the depot of garbage before composting and during fermentation, but usually not in the finished compost. Frequent turning during composting will kill fly stages.

(d) Incineration. Fly breeding may occur in the depot of garbage.

(vi) Sewage and waste water

Fly breeding, fly attraction, a dangerous source of disease germs.

(a) Accumulation of sludge and solid organic waste in open sewage drains, cesspools, seepage pits, etc. Sewage drains, etc. should be covered.

(b) Sewage beds and sewage farms. Dumps of sewage sludge should be covered with dry soil, sewage beds flushed, soil wetted with waste water. Direct waste water outlets and concentrated throwing of waste water on the soil surface should be avoided.
vii) Soil mixed or impregnated with organic matter

(a) The littering of soil around houses, stables, cattle feedlots, shops, markets, slaughterhouses, places where fish are landed, etc., with garbage or manure, or impregnated with blood or leakage from garbage, manure, etc., should be avoided. In dry areas contaminated areas should not be watered.

(b) In manuring fields, gardens, etc., with excrement, dung, garbage and other organic materials under suitable moisture conditions, heavy applications in lumps should be avoided and composted manure used.

.1.2 Elimination of sources that attract flies from other areas

The important sources of odours attracting flies and strongly increasing local fly density are to a great extent the same as the potential breeding sources in waste mentioned above under .1.1). Such sources may well be very attractive to flies due to the smell, even if fly reeding cannot take place:

- animal manure (both fresh and decaying) in stables, pens, dung heaps, compost heaps, etc;
- human excrement: latrines, latrine dumps, etc.;
- garbage, especially if containing protein (slaughter and fish offal), and allowed to decay for a few days; decaying fruit is also very attractive;
- composting plants for garbage; and
- sewage and waste water.

Cleanliness and frequent garbage collection are most important.

Other sources of attraction are:
- fresh or dried fruit that give off sweet, aromatic odours;
- fish-meal, blood-and-bone meal, some oil cakes, and other odorous industrial organic products;
- molasses and malt from breweries, and other sweet and sour smelling materials in food industries (milk and cheese, etc.);
- odours from preparation of food in restaurants, kitchens, food stalls, etc. and;
- odours from the food industry, e.g. processing mangoes and other fruit.

V.1.3 Exclusion of flies from contact with materials containing pathogenic germs (see also V.1 above).

(i) Animal excrement, especially as regards eggs and cysts of parasitic worms.
(ii) Human excrement and other excreta from infected people.
(iii) Garbage. Special precautions are required in the storage and disposal of refuse from hospitals and clinics.
(iv) Dirty food utensils* after serving of meals, fly attraction may be avoided by screening* of restaurants, kitchens, etc.
(v) Sewage.

(vi) Infected eyes, sores, wounds and skin of humans, fly attraction may be avoided by screening of hospitals, clinics, etc.

V.1.4 Protection of food, utensils and man from contact with flies (non-chemical methods)

Protection of food and food utensils

(i) At the preparation and serving of meals, and storage before and after meals in homes and restaurants, etc., and institutions, kitchens, dining rooms, etc., food stores, larders, pantries.
(ii) In shops and markets (meat, fish, fruit, vegetables, sweets, milk and other beverages, etc.).
(iii) At slaughterhouses.
(iv) In other food industries: dairies, meat, fish, fruit, vegetable-packing, sweets, etc.
(v) In fruit orchards and vegetable gardens.
Protection of materials, instruments, etc., used for medical treatments or personal hygiene

(i) Institutions: hospitals, clinics, maternity wards, sanatoria, infant homes, schools, etc.

(ii) Private dwellings (bathrooms, bedrooms). Special needs for infants, sick and handicapped people must be recognized.

Protection of man

In institutions and homes, buildings and rooms for work, recreation and rest and in the streets and other outdoor areas where people gather.

Apart from insecticide fly control (see below), the following measures against fly contact may be mentioned:

- the prevention of fly access by placing food and utensils, etc., in fly-proof containers, cupboards, wrapping material, etc., the screening of windows, ventilation openings and doors, the use of fly nets to protect babies, people in beds, etc.; the use of antfly curtains (strips of beads, plastic strips, etc.) in doorways (Morgan, et al., 1972); by electric fans to create an "air curtain" (Mathis, et al., 1970), across doorways (air velocity 8 m/sec or more), the deviation of flies to other food sources, and the use of repellents.

Non-chemical control (see Section V.4))

(i) Catching of flies in traps (with baits or light as attractant) or on sticky fly paper (not very effective).

(ii) Killing flies with electric grids (electrocutors*) combined with attractants.

(iii) Killing flies with fly swatters.

Screening of buildings is the most important method of protection against fly invasion, but reduced ventilation and light can cause inconvenience. To keep house-flies out, a 10 mesh screen is sufficient, whereas an 18 mesh is required for mosquitos. Metal screens may corrode and plastic-nylon screens may be torn, so protection by strong, coarse hardware cloth may be necessary in exposed places. Screen doors must be self-closing. Even so, flies may be brought in with people passing. Antfly curtains may be reasonably effective, but more information is needed. "Air curtains" are effective and convenient where they can be installed.

V.1.5 Education and public cooperation in environmental sanitation programmes

Fly control by environmental sanitation must be done by active cooperation between the inhabitants of the community and those organizing rational waste collection and disposal. It is absolutely fundamental that the inhabitants understand the problems and do their part by keeping homes, shops, stables, etc., and their surroundings clean, by correct disposal and storage of wastes and excrement on site to prevent fly breeding and contact, by protecting food, utensils, etc., against contact with flies, and by assisting in any sanitary measures organized by the community.

Sanitary education and information of the public is fundamental:
- education of children in schools (prepared by courses for teachers);
- education and information of the general public through meetings with demonstrations as audiovisual material (movies, pictures), by seasonal posters, distribution of printed illustrated pamphlets, radio and television programmes, the local newspapers, etc.; and
- information of politicians, administrators and other leading persons concerning the importance of environmental sanitation.

The community must have sanitary regulations and ordinances, and means for enforcing them (sanitary inspectors, penalty for breaking the rules, etc.).

V.2. Insecticidal control

There are six main types of application for chemical fly control, one against preadult stages (1) treating breeding places with larvicides, and five against adults: (2) residual treatments, mainly sprays, to resting-sites and other surfaces frequented by flies; (3) introducing toxic resting-sites, mainly impregnated strips, cords, etc., (4) toxic baits,(5) space sprays and direct spraying of fly aggregations indoors and outdoors, and (6) fumigation (WHO, 1984).

V.2.1 Larvicides*

In theory, treatment of breeding places with larvicides would appear to be the logical method for controlling fly populations, but in practice there are several drawbacks. The most important is that the breeding media are accumulating and changing continuously and therefore frequent treatments, e.g. once or twice a week, are required. Further, the penetration and distribution of the larvicide in the medium is often a problem; most larvicides also kill natural enemies of fly stages and may disrupt the biological regulation; and finally use of larvicides may favour development of resistance*.

Most commonly, larvicides are applied as emulsions, suspensions or solutions with sprayer giving a coarse spray (or a watering can) at a rate sufficient to wet the upper 10-15 cm of the medium thoroughly, i.e. 0.5-5 litres/m². Applications of dust or granulate formulations may also be used.

Originally several chlorinated hydrocarbons, e.g. HCH and dieldrin, were used, but are no ruled out due to resistance. Many organophosphorus (OP) compounds are effective larvicides provided resistance to the particular OP is not a problem (Miller, 1970). The dosages recommended below apply to non-resistant fly populations. Diazinon (0.3-1.0 g/m²) is one of the best, when both an initial and a residual effect are considered. Dichlorvos is slightly more effective for an immediate kill and has a fumigant effect, but practically no residual effect except in slow-release plastic formulations. Other OPs recommended as larvicides, but usually requiring higher dosages (e.g. 1-2 g/m²) are trichlorfon, dimethoate, fenchlorphos, coumaphos, tetrachlorvinphos, bromophos, fenitrothion and fenthion. If OP compounds are used as larvicides resistance will often be a problem. Several of the new photostable pyrethroids (see Table 2) are effective larvicides at dosages lower than those recommended for OPs. However, due to the resistance risk, pyrethroids should be reserved for control of adult flies, as there are other effective larvicides available.

Two insect development inhibitors*, diflubenzuron and cyromazine have shown an excellent effect in field experiments and practical use in recent years. Diflubenzuron (=Dimilin® 6040 or TH 6040) is effective at a concentration of 1-2 ppm (lg/m3) in manure and is recommended for spraying or watering the surface of manure accumulations at a rate of 1 active ingredient (a.i.) per m², at 2-3 weeks' interval. Diflubenzuron inhibits the normal formation of chitin and thus has a mode of action that is very different from the conventional insecticides (e.g. organophosphorus, carbamates and pyrethroids) used for fly control.

Cyromazine (= Neporex for treatment of manure, or Larvadex for mixing into the feed of poultry or pigs) is a triazine compound, quite different chemically from diflubenzuron and th
conventional insecticides. It is very effective as a larvicide for fly control in manure, preventing the larvae from developing into pupae and adults. Its mode of action is not well understood. It is effective at a concentration of 0.5-1.0 ppm (g/m²) in manure and recommended at a rate of 0.5-1.0 g of a.i. per m², applied as a 2% granulate or sprayed or watered on the surface of the manure at a concentration of 0.5-1.0% in water (Mulla & Axelrod, 1983).

Diflubenzuron and cyromazine do not adversely affect many of the non-target fauna in the manure, including many predators* and parasites which may be useful as biological control agents of the fly population. These two insect development inhibitors are of low toxicity to vertebrates and are suitable and effective when mixed into the feed of poultry or pigs to kill the larvae in the excrements. Diflubenzuron is effective at concentrations of 6-25 ppm (g/m³) in poultry and pig feed and cyromazine at 1.5-5 ppm.

As far as fly control is concerned this feed-through method has the advantage that it is easy to treat all the manure with the correct dosage, but it has the disadvantage that a strong selection pressure is applied to the fly population and thus greatly increasing the risk of development of resistance to the larvicide. In addition, in most countries there is a growing objection to using insecticides as feed additives, as there may be problems of residues in eggs and meat. The OP-compound tetrachlorvinphos is also suitable for feed-through application where resistance is not a problem.

A great number of other compounds that are not conventional insecticides are (or have been) used for control of house-fly larvae locally, e.g. calcium arsenate, phenothiazine, borax, chloride of lime, calcium cyanamide mixed with superphosphate, hellebore or other plant alkaloids, various crude oils, creolin, etc. (Ascher & Levinson, 1953; Sampson, 1956). However, most of these old larvicides require high dosages and may make manure unfit for use as a fertilizer.

V.2.2 Residual treatment* of resting-sites

Since the appearance of DDT during the Second World War, spraying house-fly resting-sites with a residual insecticide has been the main method of chemical fly control in many areas. DDT was a "miracle" insecticide, one correctly applied treatment controlling fly populations for months, but the development of resistance soon ruled out the use of DDT and other chlorinated hydrocarbons in most places. Various OP compounds and pyrethroids are now used and the residual effect is usually a matter of two to six weeks and rarely as long as two to four months.

The period of effect after a spray treatment for a given compound (and dosage) depends on several factors, e.g. formulation (water dispersible powders may be better than emulsions), type of sprayed surface (reduced effect on absorbant or alkaline surfaces), temperature (decreased residual effect at high temperatures), humidity and moisture, exposure to sunlight, and last but not least the level of resistance in the fly population or their potential for developing it.

The period of fly control, i.e. a satisfactory reduction of fly incidence in the locality, depends on the rate of influx of new flies (local breeding plus immigration*) in relation to the rate of kill, which again depends on the proportion of the flies resting on the treated surfaces and the length of time they stay.

It is therefore essential to investigate and identify the areas where the flies spend most of their time, particularly the night resting-sites, previously described, and to treat these. This may permit selective treatments, where only parts of the sprayable surfaces are sprayed. Thus, in animal sheds it may be sufficient to treat stanchions, parts of partitions, windows, posts, girders, and the ceiling area above the animals, e.g. 30% of the sprayable area (Fig. 7).

It is generally agreed that insecticidal fly control should start early in the fly season, when fly production is still low, but some recommend starting with treatments other than
residual sprays and to save these for the proper fly season. As a rule the risk of developing resistance is greater when residual sprays are used than with other treatments against adult flies.

Residual sprays may be applied by hand-operated or power-operated sprayers at low pressure (to avoid drift) and at the rate of 4-8 litres per 100 m² sprayed surface. The insecticides used as residual sprays for fly control are shown in Table 2.

The choice of insecticide depends on cost, toxic hazards, local conditions (climate, sprayed surfaces, etc.) and fly resistance. Therefore, it is difficult to rank the insecticides. For example, among the OP compounds dimethoate is outstanding in some areas, giving excellent control for two or more months, in others it is not so good. Malathion has a lower toxicity to normal house-flies than most of the others and malathion resistance is very widespread. In some countries the addition of sugar to the spray, e.g. at the rate of 1-2.5 g/m², is recommended to increase the effect and stability of the insecticide on the surface, but this may be unacceptable in rooms with a high humidity. For trichlorfon, which has an important stomach-poison effect, sugar is regularly used in the formulations. Trichlorfon has played a dominant role in insecticidal fly control of the USSR and other countries in eastern Europe. Naled is recommended as a residual spray in the USA, but its residual effect is rather short. For most of the OPs there are restrictions in some countries for their use in milk-rooms, food-processing plants or other places where food is exposed, and several are also restricted as regards exposure to chickens, dairy cows and other animals present during the spraying.

Several photostable pyrethroids are very effective as residual sprays, where pyrethroid-resistance is not a problem (Faraone, et al., 1978). However, in some areas, e.g. parts of Europe and Canada, high resistance to pyrethroids may develop very quickly and make all pyrethroids (including pyrethrum) ineffective for fly control both as residual sprays and as space sprays, aerosols or mists (see section V.3). In areas with a high potential for developing pyrethroid-resistance, photostable pyrethroids are not recommended for use in animal houses.

Some carbamates have shown promise in certain areas, where carbamate resistance is not a problem, e.g. propoxur and bendiocarb mixed with sugar. The dosage rate is similar to that of the OPs mentioned, but candidate carbamates are more toxic to mammals and have so far not been important as residual sprays for fly control.

V.2.3 Impregnated strips, cords, etc.

The observations that house-flies strongly prefer edges, strings, wires, etc., under the ceiling, etc., for night-resting suggested the use of impregnated tapes, strips, cords, paper, etc., for fly control. The idea goes back to the 1940s when DDT and dieldrin were still effective (Chow & Thevasagayam, 1953), but the main development took place in the 1950s, when OP compounds had to be used. Originally the cheap but very toxic parathion was used for commercially impregnated gauze bands or cotton cords. Their use in dairies and military premises were described by Kilpatrick and Schoof (1956). Later less toxic insecticides have been used with good effect, e.g. the OPs diazinon, rotenon, malathion, fenthion, dimethoate and trichlorfon, and the carbamates propoxur and dimethoan, so that there is no longer any point in using the dangerous parathion preparation.

For impregnation with the moderately toxic OPs, solutions or emulsions at concentrations of 10-25%, and even as little as 1%, are used, often mixed with some sugar and attractant plus glue or oil for making a durable film. Besides gauze and cords, felted cellulose and viscose or foam plastic bands are available commercially, and for home-made strips various kinds of strong paper may be used, as well as any available cord or cloth.

When preparing impregnated strips, etc., it should be taken into account that high concentrations of insecticides may be repellent or irritant to flies. Thus a lower concentration may sometimes be more effective: the attractance or repellency should be tested under field conditions before preparing or buying impregnated materials.
<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Common trade name</th>
<th>Dosage g/m² active ingredient</th>
<th>Toxicity to susceptible flies. Topical LD₅₀ µg/fly</th>
<th>Toxicity to rats dermal LD₅₀ mg/kg</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OP compounds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>azamethiphos</td>
<td>Alfacron</td>
<td>1.0-2.0</td>
<td>0.04</td>
<td>&gt;2000</td>
<td>Mainly sold as a sugar bait formulation.</td>
</tr>
<tr>
<td>bromophos</td>
<td>Nexion</td>
<td>1.0 - 2.0</td>
<td>0.05</td>
<td>&gt;5000</td>
<td>Low level of resistance in most places.</td>
</tr>
<tr>
<td>diazinon</td>
<td>Basudin</td>
<td>0.4 - 1.0</td>
<td>0.03</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>dimethoate</td>
<td>Rogor</td>
<td>0.25-1.0</td>
<td>0.01</td>
<td>610</td>
<td></td>
</tr>
<tr>
<td>fenchlorvos</td>
<td>Nankor</td>
<td>1.0 - 2.0</td>
<td>0.05</td>
<td>&gt;5000</td>
<td>Resistance problems in most areas.</td>
</tr>
<tr>
<td>fenitrothion</td>
<td>Sumithion</td>
<td>1.0 - 2.0</td>
<td>0.04</td>
<td>350</td>
<td>Rather short residual effect.</td>
</tr>
<tr>
<td>jodfenphos</td>
<td>Muvanol</td>
<td>1.0 - 2.0</td>
<td>0.04</td>
<td>&gt;2000</td>
<td></td>
</tr>
<tr>
<td>malathion</td>
<td>Naled</td>
<td>1.0 - 2.0</td>
<td>0.25</td>
<td>&gt;4000</td>
<td></td>
</tr>
<tr>
<td>naled</td>
<td>Dibrom</td>
<td>0.4 - 0.8</td>
<td>0.025</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>propetamphos</td>
<td>Actellic</td>
<td>1.0 - 2.0</td>
<td>0.10</td>
<td>&gt;2000</td>
<td>Low level of resistance in most places.</td>
</tr>
<tr>
<td>trichlorfon</td>
<td>Safrotin</td>
<td>0.25-1.0</td>
<td>0.06</td>
<td>2300</td>
<td>Mainly used as a sugar bait formulation.</td>
</tr>
<tr>
<td></td>
<td>Dipterex</td>
<td>1.0 - 2.0</td>
<td>0.3</td>
<td>&gt;2000</td>
<td></td>
</tr>
<tr>
<td><strong>Carbamates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bendiocarb</td>
<td>Ficam</td>
<td>0.1 - 0.2</td>
<td>0.3</td>
<td>570</td>
<td>Animals must be removed.</td>
</tr>
<tr>
<td>propoxur</td>
<td>Baygon</td>
<td>?</td>
<td>0.4</td>
<td>&gt;2400</td>
<td>Cross resistance from use of OPs.</td>
</tr>
<tr>
<td><strong>Pyrethroids</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cypermethrin</td>
<td>Barricide</td>
<td>0.025-0.1</td>
<td>0.015</td>
<td>High</td>
<td>In Canada and some parts of Europe resistance develops very quickly.</td>
</tr>
<tr>
<td>deltamethrin</td>
<td>Decis,K-othrin</td>
<td>0.01 - 0.15</td>
<td>0.001</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>permethrin</td>
<td>(several)</td>
<td>0.025-0.1</td>
<td>0.02</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>fenvalerate</td>
<td>Sumicidin</td>
<td>1.0</td>
<td>0.03</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>
The impregnated strips, bands, cords, etc., are suspended under the ceiling, vertical parts or loops being more attractive than horizontal ones, dark or red better than light. Another method is to stretch the cords or bands on frames that are strategically placed and can be moved according to need. Impregnated strips, cords, etc., may be used in animal sheds, poultry farms, markets and shops, restaurants and any other fly-infested room. The method is still a very useful way of fly control, having the advantage of cheapness, long residual effect and less chance of development of resistance than residual sprays. The reduction of fly density may be rather slow initially; but with the optimum location the effect can be very satisfactory, both in temperate and tropical areas at the rate of 1 m or less of band, etc., per square metre of floor area. However, it does not work in rooms with air draughts under the ceiling as in many modern ventilated rooms and stables. The technique lends itself well to preventive applications before the start of the fly season.

The old method of treating bunches of twigs with fly poisons and hanging them in fly-infested stables or other locales or placing them at breeding sites (dung heaps) may be usefully revived using modern insecticides.

V.2.4 Toxic baits

Use of toxic baits for fly control is very old. Thus, before the modern insecticides appeared, sugar and water or other fly-attracting liquids containing more or less strong poisons such as sodium arsenite were recommended. Milk or sweet liquids with 1-2% formaldehyde can still be recommended as a fairly effective fly killer.

The development of OP compounds and carbamates with a moderate to low toxicity to mammals opened the way to a variety of toxic fly baits which may be grouped as follows:

(i) Dry scatter baits containing 0.1-2% of insecticide in a carrier which may be plain granular sugar or sugar plus sand (Rosen & Gratz, 1959), ground corncobs or oyster shells, etc., often with some other attractant added, e.g. the house-fly pheromone muscalure (Mathur, et al., 1980).

The bait is broadcast in thin layers of 60-250 g per 100 m² onto available dry surfaces at fly aggregations, e.g. floors, pavements, etc., or placed in special bait stations, e.g. trays or containers of metal, wood, cardboard, plastic, etc.

(ii) Liquid sprinkle baits containing insecticide (e.g. 0.1-0.2%) and sugar or other sweetening agent (e.g. 10%) in water. The liquid is applied by a sprayer or a sprinkling can to floors, etc., or to other suitable horizontal or vertical surfaces, which are or can be placed out of reach of animals and children.

(iii) Liquid bait dispensers contain similar formulations to the sprinkle baits and consist of a container, inverted jar or bottle feeding a trough (as in chicken-watering devices), a sponge or a wick with the liquid (Kilpatrick, et al., 1962).

Varieties of the liquid bait dispensers are mats, balls, etc., of absorbant materials impregnated with the insecticide and moistened when used.

(iv) Viscous paint-on baits composed of an insecticide (e.g. 2-6%), a binder and sugar (or just insecticide in syrup or molasses) to form a "paint" that can be applied with a brush in stripes, etc., to partitions, walls, posts, window areas, ceilings, etc., or to strips, plates, etc., that are suspended or otherwise fastened in strategic places. When dry the paint may be active for weeks or months.

Insecticides for toxic baits: many OPs with low to moderate toxicity and some carbamates may be used, the more important are shown in Table 3, with ++ indicating those that appear more suitable or have been most widely used for the particular type of application (WS = water soluble).
For many years dichlorvos and trichlorphon have been the most widely used insecticides for toxic baits. Dichlorvos has a very rapid effect due to its fumigant action, but little residual effect, whereas trichlorphon may be active for months in the paint formulations. Certain impure technical trichlorphon has an attractive effect at low concentrations, e.g. 0.25%. Dichlorvos for quick effect may be combined with a stable insecticide, e.g. fenchlorphos.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Dry scatter</th>
<th>Liquid sprinkle</th>
<th>Liquid dispenser</th>
<th>Viscous paint-on</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OP compounds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dichlorvos ws</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>dimethoate ws</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>trichlorfon ws</td>
<td></td>
<td></td>
<td></td>
<td>++</td>
</tr>
<tr>
<td>azamethiphos</td>
<td>+</td>
<td></td>
<td></td>
<td>++</td>
</tr>
<tr>
<td>diazinon</td>
<td>++</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>fenchlorphos</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>bromophos</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>malathion</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>naled</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>propetamphos</td>
<td></td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Carbamates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>propoxur</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>bendiocarb</td>
<td>++</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>dimetilan ws</td>
<td></td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>methomyl</td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Formaldehyde ws</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

1 granules stuck on strips or boards.

Scattering or sprinkling of toxic baits can give a spectacular reduction of fly densities in a few hours, but has the drawback that frequent applications (one to six times a week) are needed for good control. Liquid bait dispensers and stations (trays) for dry bait may continue working for a week or two, but must be placed out of reach of animals and children. The paint-on bait is the most versatile and convenient application. It can be placed wherever flies congregate, on vertical as well as horizontal surfaces, or on suspended material, and it can have a long residual effect.

The various bait applications may give a satisfactory fly control in places where fly production is limited, provided there is an adequate distribution of the bait in relation to the fly aggregations. As a rule the baits do not attract house-flies at a distance, even when special attractants are added to the formulations, such as hydrolysed or fermented yeast or animal protein (e.g. whole egg), ammonium carbonate, syrups or malt, or even the pheromone.
muscalure. However, such attractants may greatly enhance the effect of baits under suitable conditions and, within a radius of a few metres, compete with the natural attractant odour present. Water is a good attractant in dry surroundings.

The effect of muscalure does not last as long as that of the insecticides used. After 3 weeks the attractiveness is lost. Mulla and his colleagues (1977) have developed a Synthetic Fly Attractant (SFA), which was much more effective as bait ingredient than muscalure on poultry farms in California. The SFA consists of 88% commercial fishmeal, 5% ammonium sulfate, 5% trimethylamine hydrochloride, 1% linoleic acid and 1% indole. The attractants are slowly released when the bait is moistened. The SFA may not be so spectacular in all areas but it is worth trying. The effect of a bait attractant is dependent on the natural attractants that the flies are adapted to and the competition with other attractants present in the area.

Apart from cheapness and ease of application, the toxic bait techniques have the advantage that development of resistances to the insecticide generally is less than when residual sprays are used, and that an insecticide in a concentrated bait formulation may still kill flies even if their resistance to the insecticide is quite high compared to normal flies.

V.2.5 Space treatments and direct spraying of fly aggregations

(i) Indoor space treatments. Flies are quickly knocked down and killed by mists of aerosols of Insecticide solutions (usually in kerosene) or emulsions. The treatment may be carried out with the convenient aerosol pressure cans, hand sprayers or small portable power sprayers. The most suitable insecticides are pyrethrins (e.g. 0.1-0.4%) plus a synergist (e.g. 0.5-2.5%) or synthetic pyrethroids which knock down the flies in a few minutes and do not present toxic hazards (Schmidtmann, 1981). However, pyrethrins, pyrethroids and synergists are expensive and may be combined with, or replaced by various OPs such as dichlorvos (0.1-0.5%), fenclophos (0.5-2%), malathion (2-4%), naled (1%), pirimiphos-methyl (2%), propetamphos (0.1-0.5%) and azamethiphos; but in many countries the use of OPs for indoor space treatments is restricted and in some OPs are not permitted at all for this purpose. Moreover, the OPs give a less rapid knock-down than the pyrethroids.

Indoor space treatments are useful for quick relief of a fly nuisance in dwellings, kitchens, restaurants, shops and any other room where flies may be a problem, and in animal sheds, stables, poultry houses, etc. For fly control in animal houses space sprays are mainly used as a supplement to residual treatments or toxic baits, but on farms where these treatment fail (e.g. due to resistance) frequent space treatments may be used as the primary chemical control of flies. The treatments should be done when the maximum proportion of the fly population is indoors, e.g. in the evenings. However, even on farms in temperate areas where apparently the great majority of the flies can be hit by treating the stables, it may be difficult to achieve more than temporary control by frequent treatments, e.g. twice a week (shorter than the preoviposition period) with space sprays which have no residual effect, i.e. fly breeding is heavy.

For continuous control of fly infestations automatic aerosol devices are available. By means of a time switch or clock they deliver a small puff of pyrethroid aerosol at regular intervals, e.g. every 15 minutes. These devices may be quite effective, but rather expensive. Moreover, the continuous use of automatic aerosol treatments involves an increase risk of development of resistance compared to the use of aerosols or space sprays when the fly density is too high.

(ii) Outdoor space treatments are used for quick temporary or routine elimination of fly concentrations, e.g. at refuse dumps, recreational areas, places where people gather, markets, food industries or for area control in cities and towns, especially in emergencies.

The types of application may be mist spraying, fogging or ultra-low-volume (ULV) spraying applied by power units from the ground or from aeroplanes (Mount, 1985). Mist blowers are more generally useful than thermal fog generators or mechanical aerosol generators because they are less dependent on air currents to distribute the insecticide. Moreover, fogging ma
interfere with traffic. In recent years ULV spraying from the ground or the air has shown great promise (Mount, et al., 1974).

### TABLE 4 DOSAGES FOUND EFFECTIVE FOR OUTDOOR SPACE TREATMENTS FOR FLY CONTROL

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Dosage a.i.g/ha</th>
<th>Insecticide</th>
<th>Dosage a.i.g/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP compounds</td>
<td></td>
<td>Pyrethroids</td>
<td></td>
</tr>
<tr>
<td>azamethiphos</td>
<td>50-200</td>
<td>bioresmethrin$^2$</td>
<td>5-10</td>
</tr>
<tr>
<td>diazinon</td>
<td>340</td>
<td>deltamethrin</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>dichlorvos</td>
<td>340</td>
<td>d-phenothrin$^2$</td>
<td>5-10</td>
</tr>
<tr>
<td>dimethoate</td>
<td>220</td>
<td>permethrin$^2$</td>
<td>5-10</td>
</tr>
<tr>
<td>fenchlorvos</td>
<td>450</td>
<td>pyrethrins</td>
<td>20</td>
</tr>
<tr>
<td>jodphenphos</td>
<td>350</td>
<td>+ synergist (pb)</td>
<td>+160</td>
</tr>
<tr>
<td>malathion</td>
<td>670</td>
<td>resmethrin</td>
<td>20</td>
</tr>
<tr>
<td>naled</td>
<td>220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pirimiphos=methyl</td>
<td>250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$Provided the flies are not too resistant to the insecticide.

$^2$May be combined with other pyrethroids giving quick knock-down or synergists (e.g. pb = piperonyl butoxide).

As a rule outdoor space treatments have only a temporary effect, merely killing flies that are exposed during treatment, but not controlling those which are indoors; also, flies in sheltered locations, on the lee-side of buildings, etc., may survive. The lack of residual effect also means that flies emerging from the breeding sites or invading the area soon after treatment are not controlled. These factors have to be considered when using space sprays in antifly campaigns, and especially if the objective is to reduce the fly population for a longer period. OP compounds and pyrethroids used, and dosages found effective for outdoor space treatments for fly control, are shown in Table 4.

Outdoor aerial space treatments should be applied at a time when observations show that the maximum proportion of the fly population is exposed, usually in the morning. Daily treatments over a period, e.g. two weeks, may reduce the breeding population to a point where further fly control can be obtained by treatments at longer intervals, e.g. one to two weeks. However, generally it is difficult to get permanent fly control by space treatments, if conditions for fly breeding are favourable, as in the case of the farms in temperate areas mentioned above. In places where a great part of the fly population rests outdoors at night, treatment of the night-resting sites, e.g. trees and shrubs, may be important.

(iii) **Direct spraying of fly aggregations.** It is a common practice in urban antifly programmes to spray fly aggregations on fresh garbage both in garbage containers and at temporary refuse collections, and as it is deposited at the refuse dump.

Also, garbage trucks are regularly sprayed before they return from the dump. These spray treatments may reduce the fly density, breeding and dispersal in connexion with the garbage disposal and collection. They may be done with a hand or power sprayer, applying a relatively wet spray, which not only kills the flies hit directly, but also wets the surface, giving a short after-effect for killing flies arriving for oviposition or emerging later in the day. These direct treatments may also have some larvicidal effect.

A variety of OP compounds may be used for direct spraying, in kerosene solution or water emulsion, at concentrations of 1-2%, e.g. malathion, diazinon, fenthion, fenitrothion or the carbamate dichlorvos.
V.2.6 Fumigation

At one time, vapourizing HCN or lindane by gentle electric heating was an effective and convenient method of fly control, e.g. in animal houses; but resistance and the risk residues in food have now ruled it out.

In the 1960s, formulations and dispensers for slow release of dichlorvos were developed and found effective against house-flies in rooms, stables and other spaces with limited ventilation (air exchange). Most common are resin or plastic strips impregnated with dichlorvos. The release of dichlorvos should be fairly stable over a long period. Dichlorvos strips are commonly made to cover 30 m³ of space and may be effective for two to three months' residual fumigant effect, provided the ventilation is suitably limited.

In some countries the use of dichlorvos dispensers is prohibited in rooms where food is stored, processed or eaten, and some also forbid its use in dwellings and in any other places where people spend their time. Dichlorvos strips are, however, useful for garbage cans and other refuse containers.

V.3 House-fly resistance to insecticides

Before planning to use insecticides in fly campaigns it is necessary to have a knowledge of the resistance of the local flies to the insecticides in question, particularly the house-fly is the insect species that has shown the greatest ability to develop resistance to insecticides (Brown & Pal, 1971; Kelding, 1977).

V.3.1 Development of resistance

Resistance develops through exposure of several generations of flies to insecticides, and it is the result of a selection and breeding of a genetically resistant type of fly. To begin with, these resistant flies constitute only a small fraction of the population. Often the fecundity and vigour is low and the few survivors are not noticed. But as the use of an insecticide continues and selection of the resistant types is repeated generation after generation, the resistant flies become noticeable and of practical significance, first as decreasing effect of the insecticide, later perhaps as a m ore or less complete failure control.

Failing control with treatments that used to be effective may be due to factors other than resistance, e.g. (1) an unusually high production or invasion of flies, so the rate of kill cannot keep pace with the influx of flies; (2) deficient insecticide formulations; (3) deficient application; (4) high temperatures or absorption of insecticide in the spray surfaces reducing the residual effect of the treatments; (5) selective mortality of parasites and predators; (6) repellency to flies of the insecticide formulation used; (7) change in fly behaviour due to season or other environmental factors; and (8) change of fly behavior due to selective pressure with the insecticide treatments (behavioral resistance).

Resistance has to be proven by proper tests in which the flies are exposed to known dosages of the insecticide under standard conditions, as described in the WHO method.1

Factors promoting the development of resistance to an insecticide:

- High selection pressure, i.e. a high proportion of the fly population exposed to insecticide dosages at which the resistant flies can survive and breed;
- Use of the same (or related) insecticide over large areas;
- Use of the same (or related) insecticide over long periods;
- A short life cycle (many generations per year);
- Exposure of both larvae and adults to the same or related insecticides;
- The isolation of the treated population from contact with untreated populations; and

Previous use of related or unrelated insecticides and development of resistance to them (see cross-resistance, below).

Widespread use of residual sprays and larvicides generally has a greater chance of inducing resistance than other treatments. Use of insecticides against other insects, e.g. in malaria and other antimosquito programmes, or against agricultural pests may induce resistance in house-flies.

V.3.2 Occurrence of resistance in various insecticides

The global situation in 1985 is shown in Table 5. Information on resistance is incomplete in many areas (see also WHO, 1986).

Apart from the factors mentioned above the resistance of house-flies in a locality depends on the history of insecticide use in the area. Therefore information on the previous use of insecticides to which flies have been exposed is important.

Recent investigations have shown the following important trends and findings:

Resistance to organochlorine compounds including DDT, HCH, and cyclodienes is still present practically everywhere. In many parts of the world DDT-resistance is due to dehydrochlorination of DDT by the dihydrochlorinase enzyme (WHO, 1980). This means that certain DDT-analogues, such as trichlophenidin may be effective against DDT-resistant flies. However, DDT-resistance may also be due to a factor called kdr or super-kdr*, which makes the nervous system rather insensitive to DDT and all available DDT-analogues. Moreover, kdr also gives protection against pyrethroids (e.g. 20-fold resistance) and super-kdr gives quite a high resistance to pyrethroids. The kdr-factor (gene) is common in parts of north and central Europe and probably occurs in other areas at a low frequency (Keiding, 1977).

Organophosphorus compounds (OPs). On a global scale OP-resistance has increased greatly in recent years as to distribution, levels and compounds involved. Malathion resistance is almost universal, and moderate to high resistance occurs locally to other OPs depending on the local selection pressure, which may be due to use of OPs for other purposes than fly control. High multi-OP resistance to most or all OPs available is found in Japan, USA, northern Europe and parts of central Europe. Resistance to many OPs occurs also locally in China, the Mediterranean region, the Middle East, and the Caribbean. The resistance-mechanisms and cross-resistance may differ from area to area. Widespread, high resistance to trichlorfon has developed in countries where residual sprays with trichlorfon have been commonly used for fly control, e.g. Eastern Europe (Rupeš, et al., 1983).

Carbamates. Carbamates have been used widely in sugar baits, but otherwise have not played an important role in house-fly control, and information on the present occurrence of carbamate resistance in house-fly populations is more limited than for OPs.

Cross-resistance to carbamates is often found in fly populations that have developed OP-resistance due to the use of various OPs, but high carbamate resistance has also been found in strains pressured with chlorinated hydrocarbons only. Often the cross-resistance to carbamates is heterogeneous with a sector highly resistant to carbamates and a rather susceptible one separated by a plateau. Therefore LD_{50} may be misleading. Flies highly resistant to OPs and various carbamates have shown little or no cross-resistance to methomyl, a carbamate used in a widely sold toxic fly bait.

Pyrethroids (including natural pyrethrum). Until recently high resistance was only found locally in Denmark and Sweden in populations exposed to frequent treatments with aerosols. However, since residual sprays with permethrin and other stable pyrethroids were used from 1977-78 in the Federal Republic of Germany, Switzerland, and the United Kingdom, high pyrethroid resistance developed rapidly and this is likely to take place in other areas. In most places kdr forms an important component of pyrethroid resistance, and it is strongly recommended to monitor for kdr before considering using residual pyrethroids for fly control.

Such use is not allowed in Denmark where the kdr is common. However, kdr seems to be rare in most parts of the world outside northern and central Europe, and residual pyrethroids may be very effective in such areas.
### TABLE 5 OCCURRENCE OF HOUSE-FLY RESISTANCE TO INSECTICIDES¹, 1985

#### ORGANOCHLORINE COMPOUNDS

<table>
<thead>
<tr>
<th>Compound</th>
<th>Resistance Level</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT</td>
<td>High R very common, everywhere.</td>
<td>Often H.</td>
</tr>
<tr>
<td>HCH (lindane)</td>
<td>High - inter R very common.</td>
<td></td>
</tr>
<tr>
<td>dieldrin</td>
<td>High R very common.</td>
<td></td>
</tr>
</tbody>
</table>

#### ORGANOPHOSPHORUS COMPOUNDS (OPs)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Resistance Level</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>malathion</td>
<td>Mod - high R very common.</td>
<td>Often H.</td>
</tr>
<tr>
<td>diazinon</td>
<td>Mod - inter R common.</td>
<td>High R local in Japan, USA, Europe.</td>
</tr>
<tr>
<td>trichlorfon</td>
<td>Mod - high R in many areas.</td>
<td></td>
</tr>
<tr>
<td>dichlorvos</td>
<td>Mod - inter R in many areas.</td>
<td>High R local in China, Japan, USA, Europe, etc.</td>
</tr>
<tr>
<td>fenitrothion</td>
<td>Mod - inter R in many areas.</td>
<td>High R local in several areas, e.g. Japan, USA, Europe. Very high in Japan.</td>
</tr>
<tr>
<td>fenchlorphos, bromophos, jodfenphos</td>
<td>Mod - inter R in many areas.</td>
<td>High R local in several areas in USA, Europe, East Asia.</td>
</tr>
<tr>
<td>tetrachlorvinphos</td>
<td>Low - mod R common.</td>
<td>High R, often H in USA, northern Europe, etc.</td>
</tr>
<tr>
<td>dimethoate</td>
<td>Low - mod R in most areas.</td>
<td>Inter - high locally in USA and E develops slowly.</td>
</tr>
<tr>
<td>azamethiphos, pirimiphos-methyl</td>
<td>Low - mod R in most areas.</td>
<td>High R locally in Europe.</td>
</tr>
<tr>
<td>propetamphos</td>
<td>Low - mod R.</td>
<td>High R rare.</td>
</tr>
</tbody>
</table>

#### CARBAMATES

<table>
<thead>
<tr>
<th>Compound</th>
<th>Resistance Level</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>bendiocarb</td>
<td>Low R in some areas, high R, often H, local in Europe, etc.</td>
<td>Cross-resistance from use of OPs.</td>
</tr>
<tr>
<td>propoxur</td>
<td>Low R in most areas.</td>
<td>A few cases of high R in Europe.</td>
</tr>
<tr>
<td>methomyl</td>
<td>Low R in several areas.</td>
<td></td>
</tr>
</tbody>
</table>
### PYRETHROIDS

<table>
<thead>
<tr>
<th></th>
<th>Low - low R in most areas. Inter - high R after use of residual pyrethroids or frequent use of space sprays in Canada and parts of Europe. Few cases in other areas.</th>
</tr>
</thead>
<tbody>
<tr>
<td>pyrethrins + synergests</td>
<td>As above. High R may develop very quickly in areas with the kdr-factor</td>
</tr>
<tr>
<td>pyrethroids alone (residual)</td>
<td></td>
</tr>
</tbody>
</table>

### LARVICIDES, IDIs

<table>
<thead>
<tr>
<th></th>
<th>Low - inter R found in USA and Europe, cross-R from OPs. High R laboratory selection.</th>
</tr>
</thead>
<tbody>
<tr>
<td>methoprene</td>
<td></td>
</tr>
<tr>
<td>diflubenzuron</td>
<td>No - low R in most multi-R field populations. Cross-R from OPs found in the laboratory.</td>
</tr>
<tr>
<td>cyromazine</td>
<td>No cross-R from OPs. Only a few cases of mod R known, but little experience from field use of cyromazine.</td>
</tr>
</tbody>
</table>

Kdr alone gives only a moderate resistance, e.g. R/S\(^1\) 3-20, depending on the particular pyrethroid, but an intensive selection pressure with pyrethroids, e.g. residual sprays or frequent aerosol applications may increase the resistance to serious levels. In these cases high pyrethroid resistance may be due to the interaction of kdr with other factors or to an unknown factor. Pyrethroid resistance involving kdr extends to all pyrethroids tested (Narahashi, 1980). It may be reduced partly by piperonyl butoxide (pb) or related synergists, and it is usual to see natural pyrethrum + pb. Pyrethroid resistance is often found to be heterogeneous a fly population with a moderate LD 50 (e.g. R/S 3-10) and a sector of resistant flies. Therefore it may not be noticed, if only the LD 50 is recorded. The resistant sector will increase by further selection. In places where aerosols are only used infrequently or occasionally, serious pyrethroid resistance may not develop for many years even if kdr is present, as has been seen on most Danish farms. However, the presence of kdr shows that there is a great potential for pyrethroid resistance to develop when intensive selection pressure is applied, if only for one fly season.

For these reasons residual sprays with pyrethroids (e.g. permethrin) are not allowed to be used for fly control in Scandinavia. However, pyrethroid resistance can also develop with kdr. This has recently been found on some farms in Japan, the United Kingdom and the United States of America. On the Japanese farms permethrin was used for six years for fly control before resistance appeared (Kudamatsu, et al., 1983).

With the widespread use of permethrin and other residual pyrethroids it is likely that pyrethroid resistance is already developing in other areas even if it has not been reported yet.

There is no general correlation between OPs and pyrethroid resistance. House-fly populations with extremely high multi-resistance to OPs, e.g. in Japan and California, USA, have shown normal susceptibility to pyrethroids or only a low level of tolerance.

Insect development inhibitors (IDI), used as larvicides. Recent studies in Denmark showed no resistance to cyromazine and low or no resistance to diflubenzuron when larvae of a variety of fly strains with high resistance to other insecticides were exposed to larval media treated with these IDIs.

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1 R/S = resistance ratio, LD of resistant strain divided by LD of the susceptible reference strain.
V.3.3 Nature of resistance

Resistance is due to genetic factors (resistant genes), usually one or a few major genes for each type of resistance (WHO, 1976). The genes determine certain physiological resistance-mechanisms. Most of them are specific enzymes that detoxify the insecticide but resistance may also be due to insensitive target, e.g. acetylcholinesterase in case of OPs and carbamates, the nerve sheath in case of organochlorine insecticides. Finally reduced penetration of the insecticide may be a resistance factor.

Some resistance mechanisms are specific to one or a few closely-related insecticides, others are common to several insecticides (unspecific). High resistance may be due to a single resistant gene or to the combination of two or more (interaction). The resistance of an individual fly is determined by the resistant genes and their combination in the cells (its genotype) and modified by several non-genetic factors (age, sex, nutrition, temperature, etc.).

The resistance of a fly population is determined by the frequency (proportions) of resistant flies of various genetic types in the population (Plapp & Wang, 1983). For the development (and stability) of resistance it is important whether hybrid flies (RS) from crossings between resistant (RR) and susceptible (SS) flies are resistant (R dominant), intermediate or susceptible (R recessive).

V.3.4 Cross-resistance and multiple resistance

(i) Cross-resistance

When fly populations are exposed to selective pressure with one insecticide (the selector) they may develop resistance also to other insecticides. This phenomenon is called cross-resistance (WHO, 1976). Examples:

Selector: 

Chlorinated hydrocarbons

<table>
<thead>
<tr>
<th></th>
<th>Cross-resistance to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) DDT</td>
<td>methoxychlor, pyrethroids in some cases</td>
</tr>
<tr>
<td>(b) HCH (lin dane)</td>
<td>dieldrin and chlordane</td>
</tr>
</tbody>
</table>

Organophosphorus compounds

<table>
<thead>
<tr>
<th></th>
<th>Cross-resistance to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c) diazinon</td>
<td>parathion</td>
</tr>
<tr>
<td>(d) fenchlorphos</td>
<td>bromophos, jodfenphos</td>
</tr>
<tr>
<td>(e) dichlorvos</td>
<td>trichlorfon</td>
</tr>
<tr>
<td>(f) fenitrothion</td>
<td>diazinon</td>
</tr>
<tr>
<td>(g) dimethoate</td>
<td>fenthion, trichlorfon</td>
</tr>
<tr>
<td>(h) Pyrethroids</td>
<td>DDT</td>
</tr>
</tbody>
</table>

In some of these cases cross-resistance is found between insecticides with a closely-related chemical structure, in others (e.g. cases (b) and (g)) the chemical relationship is less, and in case (h) there is no chemical relationship between pyrethroids and DDT.

As a rule cross-resistance is explained by a common resistance (defence) mechanism, but there are other possibilities. The problem is complicated by the presence of more than one resistance mechanism to a single insecticide, unspecific and specific resistance factors. There are often cross-resistances on various levels. For example, selection with one OP compound commonly gives a moderate increase of tolerance (unspecific) to many other OPs, but not as much as to the selector (specific resistance).

On the other hand development of resistance to the selector may be rather slow and moderate by the use of some insecticides, e.g. dimethoate and naled, whereas the selection pressure raises the resistance to high levels in several other insecticides. Such "cross-selectors" may be detrimental for a long-term control programme.
As mentioned above, a development of resistance to one insecticide often facilitates development of resistance to another.

(ii) **Multiple resistance**

By exposure to two or more insecticides, either at the same time or one after the other, a fly population may develop resistance to several insecticides, namely the selectors. This is called multiple resistance (Kelsing, 1975).

**V.3.5 Stability of resistance**

When the use of an insecticide X is abandoned in an area, the resistance to X in the fly population will usually decrease somewhat as the selection pressure is removed. However, reversion to normal susceptibility is a very slow process, resistant-genes remain at a significant frequency, and high resistance to X develops very quickly if X is used again. Experience in many parts of the world has shown that even 20 years after DDT or HCH were abandoned for fly control, it has not been possible to resume the use of these insecticides due to the residual resistance in the fly populations. Resistance to some organophosphorus compounds (e.g. malathion and diazinon) have shown a similar stability when they were abandoned after several years. Resistance is often less stable if it is newly developed and not been sustained for some years ("old" resistance is more stable than "young").

**V.3.6 Preventing or reducing the development of resistance (WHO, 1980)**

(1) The key is reduction of selection pressure with insecticides

(a) **Restrict frequency of treatment.** Treat only when necessary. Use source reduction, sanitation, and other non-chemical methods as far as possible.

(b) **Restrict extent of treatment.** Treat only where necessary. Avoid widespread blanket treatments. Use spot treatments (including baits, strips, etc.) where applicable.

(c) **Restrict use of residual sprays.**

(d) **Avoid larval (and adult + larval) pressure with insecticides useful for adult fly control.**

(ii) The sequence of insecticides used in a long-term programme is of importance for the rate and extent of development of resistance. Use first insecticides with a specific resistance-factor and little cross-resistance (e.g. malathion) and last insecticides with broad cross-resistance (e.g. dimethoate and naled). Alternation between unrelated insecticides and between chemical and non-chemical control methods may postpone resistance development (but the use of mixtures of insecticides is not recommended).

**V.3.7 Significance of resistance for fly control**

A low level of resistance (e.g. two to tenfold) may reduce the residual effect and may be apparent in use of space sprays or fumigants. Moderate resistance, e.g. ten to twentyfold, may already give rise to control failures, especially where fly production or invasion is high. However, the initial effect of residual sprays or direct sprays may still be good, and toxic baits may be effective. Higher resistance may cause complete failure at all practical dosages.

**V.4 Biological and other means of control**

**V.4.1 Biological control and regulation of house-fly populations**

A rich variety of predators feed on eggs, larvae, pupae or adults of synanthropic flies and several species of small parasitoid wasps are specialists on fly pupae (a parasitoid is a parasite that kills its host) (Fig. 14).
Fig. 14 Diagram showing the housefly stages and examples of its enemies at the dung heap. The lines show the stages that are attacked by each predator or parasitoid. The scales are arbitrary, the actual lengths in mm are given below.

Housefly stages: Egg: 1 mm, larva I: 3 mm, larva II: 5 mm, larva III: 13 mm
Puparium: 6 mm, adult: 6 mm.

1. Macrocheilid mite 1 mm
2. Staphilinid beetle: Oxytelus 4 mm
3. Staphilinid beetle: Philontus 12 mm
4. Staphilinid beetle: Creophilus 20 mm
5. Hen
6. Yellow dung fly: Scatophaga stercoraria 10-15 mm
7. Earwig: Labia minor 6 mm
8. Hydrophilid beetle: Cercyon with larva 2-3 mm
9. Histerid beetle: Hister with larva 3-4 mm
10. Chalcid wasps: Spalangia 3 mm
11. Chalcid wasps: Muscifurax 2 mm
12. Spider: Trochosa 20 mm
A list of important natural enemies of flies are given below:

(i) Predators feeding on one or more fly stages:

<table>
<thead>
<tr>
<th>Predators</th>
<th>Fly stage attacked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mites: Macrocheilids (Macrocheles) (Fuscoropoda)</td>
<td>Eggs and small larvae</td>
</tr>
<tr>
<td>Spiders (both free-living and net-spinning)</td>
<td>Flies</td>
</tr>
<tr>
<td>Earwigs</td>
<td>Eggs and small larvae</td>
</tr>
<tr>
<td>Mantids</td>
<td>Flies</td>
</tr>
<tr>
<td>Beetles and their larvae, e.g. Staphylinids (rove beetles) Histerids (living in dung) Hydrophilids (living in dung) Fly larvae: Muscoids (e.g. Ophyra, Muscina)</td>
<td>Larvae, pupae and flies</td>
</tr>
<tr>
<td>Fly adults: Robber flies Dung flies</td>
<td>Flies</td>
</tr>
<tr>
<td>Ants</td>
<td>Flies</td>
</tr>
<tr>
<td>Predatory wasps</td>
<td>Flies</td>
</tr>
<tr>
<td>Reptiles (e.g. geckoes and lizards)</td>
<td>Flies</td>
</tr>
<tr>
<td>Amphibia (e.g. toads)</td>
<td>Flies</td>
</tr>
<tr>
<td>Birds (including chickens)</td>
<td>Larvae, pupae and flies</td>
</tr>
</tbody>
</table>

(ii) Parasitoids

| Small pteromalid wasps, e.g. Spalangia spp. Muscidifurax spp. Nasonia Tachinaephagus Small parasitoid beetles, e.g. the staphilinid Aleochara | Pupae |

(iii) Microorganisms

| Bacteria, e.g. Bacillus thuringiensis, exotoxin | Larvae |
| Fungi: esp. Entomophthora (= Empusa) | Flies |

Under relatively stable conditions of fly-breeding habitats and in a suitable climate these predators and parasitoids may effectively regulate the population and possibly limit it to an acceptable level. This is particularly the case in tropical areas, where ants seem to play an important role, and may destroy 70-90% of the potential fly population in garbage cans (Pimentel & Uhler, 1969). Predatory mites and certain beetles, e.g. Alphitobius and Carcinops may be effective in poultry manure under certain conditions, such as the manure not being too wet, but emigrating beetles may become a problem. The effect of other predators is less
known, but the parasitoid wasps may at times kill a high percentage of pupae of the house-fly
and other species.

Where such natural regulating fly enemies exist, it is important to preserve them, make
the conditions favourable for them and to avoid killing them with larvicides or treatment of
their resting-sites or nests. When manure is cleaned out a little may be left to keep the fly
regulating fauna going (Peck & Anderson, 1970). Predators and parasitoids should be an
important part of integrated fly control.

Active biological control by release of wasps (or predators) has not been very effective
in fly control except in some oceanic islands, where house-flies have been introduced
relatively recently, or in the experimental introduction with very large numbers of wasps at a
breeding site to parasitize fly pupae. However, attempts are still being made, especially in
the USA, to find effective parasitoid wasps for control of house-flies breeding in manure and
to develop practical and economic methods for mass production and for organization of the
releases (Morgan, et al., 1978). Many experiments have been done in recent years on the
release of great numbers of small parasitic wasps, especially Spalangia and Muscidifurax
species, and in the USA such wasps are sold to farmers for fly control. The experiments have
shown, however, that a vast number of wasps has to be released, e.g. 40 000-100 000 per week,
in order to control the flies on a farm, and the wasps can only be produced by rearing on fly
pupae, one wasp per pupa. So, this method of inundating fly populations with parasitic wasps
still does not seem very practical or economic.

In a review in 1986, Axtell concluded:

"The use of biocontrol agents for fly control in poultry houses illustrates that a multi­
agent approach is needed. One should not seek a single agent as the ideal one. Rather a
combination of parasites and predators should be used. The problem, of course, is how to
choose these and mesh them together in a biocontrol programme."

"Based on our knowledge to date, it appears that we should use macrochelid mites,
Carcinops beetles and pteromalid parasites (perhaps 2 species) in poultry houses. These
biocontrol agents are not a panacea. They will be successfully used in integrated control
approach which also includes minimizing fly breeding and maximizes the heterogeneity of the
manure fauna by means of proper manure management. (Manure management and biocontrol are
complementary approaches which are the basis for muscid filth fly control in all types of
confined animal production facilities). The use of insecticides must be in a manner
complementary to those approaches". A number of studies have been undertaken on the use of
macrochelid mites as biological control agents of house-flies (Filipponi, 1964; Axtell, 1969;

In Europe tropical starlings (Lamprotornis) have recently been introduced from Africa and
used for fly control in piggeries. The reports on their effect are contradictory.

Microbial control of houseflies has also been investigated in recent years. In Finland a
strain of Bacillus thuringiensis serotype 1 for fly control in manure has been developed. It
produces an exotoxin that kills fly larvae and it is claimed that the strain can live and
produce exotoxin in manure (including latrines) and thus prevent fly-larval development over a
long period. However, the efficacy of this Bacillus strain and the preparations containing it
in manure under various conditions on farms has still to be investigated and demonstrated.
Certain nematode species kill fly larvae. Their possible use for practical fly control is
under investigation.

The fly fungus, Entomophthora muscae, may be an important mortality factor for flies in
animal houses, especially in the latter part of the fly season as mentioned under longevity in
Section III.1.4(d). However, until now it has not been possible to mass-culture the fungus
and make preparations for practical fly control. Moreover, it seems only to be effective
under certain climatic conditions. Recent experiments in Denmark have shown that infected
flies can be cured by staying at temperatures between 34°C and 40°C. The higher the
temperature the shorter exposure time was needed.
V.4.2 Sterility methods and genetic control

In recent years there has been a great interest in using sterility methods for fly control. Many chemosterilants are effective at low dosages in baits or by contact, but safe compounds are not yet available (LaBrecque & Meifert, 1966). Small-scale field tests have been promising and if the risk to man and animals can be sufficiently eliminated (but the experts are pessimistic), chemosterilants may become an important weapon in the battle against house-flies, especially if better attractants were to be developed (Meifert, et al., 1967).

Theoretically, release of mass-reared sterilized male flies may be used effectively in control schemes (LaBrecque & Weidhaas, 1970). However, this sophisticated method is not realistic for ordinary fly control programmes. It requires a thorough study of the ecology and dynamics of the fly population, a high level of organization and expertise for the production and release of sterile flies and for monitoring the effect (Weidhaas, 1968). Moreover, the method is primarily suited to isolated fly populations (e.g. on islands) that can be reduced by other means and where total eradication is feasible (Pausch, 1972). This also applies to genetic control of house-flies, etc., in which extensive research has been carried out in the United States of America. The theoretical possibilities are highly interesting, but they do not offer practical solutions to the fly problems of cities, towns and farms for the near future (Wagoner, et al., 1974).

V.4.3 Trapping

Lack of success with insecticides for fly control has revived the interest in using traps (Davidson, 1962; Thimijan, et al., 1970). Traps and "electrocutors" with black light or other light as attractants are frequently tried and may be quite effective against blow-flies in shops, dark entrances and other indoor situations. However, their ability to lure house-flies and reduce populations is rather limited and very dependent on location, temperature and the physiological conditions of the flies (sex, age, maturity, nutrition, etc.). Experiments with marked flies in animal houses showed that electrotraps with "black light" or other fluorescent light tubes used at the recommended rate killed a small fraction of the houseflies and were not able to control the fly population (Clough, 1980). To do this a high number of electrotraps have to be used or the electrotraps may be combined with a chemical attractant, e.g. muscalure or the Synthetic Fly Attractant. The development of more effective baits has also improved the possibility of using baited traps (or toxins baits).

VI. FLY SURVEY METHODS

In order to plan and evaluate fly control programmes it is necessary to obtain a reliable assessment of fly population densities* and their changes in relation to the control methods used. This involves pre-control surveys to determine where, when and how fly control should be carried out, and post-control surveys to evaluate the effect and success of the fly control measures.

Pre-control surveys include determination of the important species that cause problems, their breeding sources and places, seasonal fluctuations, distribution and habits of adults (including night-resting), the adult density in different areas and premises, and the insecticide susceptibility. Post-control surveys mainly involve assessment of adult densities and insecticide susceptibility.

There are several methods for evaluating changes in adult densities and the most important are mentioned below. None of the methods will measure the absolute number of the fly population†, but will give an index. For choice of method it is important that it fits the biology and behaviour of the local fly populations, that it assesses fly density at the places where this is of interest, that the size of the sample is adequate to represent the area, that the method is easy and quick to use and that it is as objective and standardized as possible. Sometimes a combination of methods is necessary to get a comprehensive picture of the fly

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* This requires more elaborate methods involving catching, marking, releasing and recapturing the flies.
densities in important sites. However, it is essential that the same method be used throughout for surveys to assess the changes of fly density in time, especially before and after control operations.

The methods depend either on counting or estimating the number of flies on selected areas, or attractants, trapping flies, catching flies, or counting fly specks. A comparison of the advantages and disadvantages of the methods discussed is shown in Table 6.

VI.1. Counting flies on selected areas or attractants

VI.1.1 The fly grill count

Flies are counted on a grill that is placed over natural fly concentrations. The method is one of the most widely used, since it was described by Scudder in 1947. The grill, often referred to as a Scudder grill (Fig. 15 (a)) may consist of 16-24 wooden slats, fastened at equal intervals to cover areas of from 0.8 m² (big grill) down to 0.2m² (small grill). The big grill is for outdoor use, but unpractical for indoor use. For general use a small or medium sized grill is suitable. For making a count the grill is lowered over a fly concentration. The flies are thus disturbed but return to the attractant and settle temporarily on the grill. The number that lands during 30 seconds is counted. In each locality counts are made on three to five or more of the highest fly concentrations found at the result averaged. In each area there may be fixed stations and random (moving) stations. Counts on fixed stations should be done at the same time of the day for comparability.

Fig. 15 Devices for fly survey. a. Fly grill; b. Bait trap (1 inch = 2.54 cm).
**TABLE 6. COMPARISON OF FLY SURVEY METHODS**

<table>
<thead>
<tr>
<th>Survey method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly grill count</td>
<td>Simple, rapid, versatile for assessing fly concentrations. Many sites can be sampled. Well established and tested method.</td>
<td>Identification of flies difficult. Much dependent on the chance aggregation of flies, and only measures the momentary density. Grills cannot be used everywhere, e.g. where flies concentrate on animals. Unreliable results at very low and very high densities.</td>
</tr>
<tr>
<td>Counts on baits</td>
<td>Simple, useful at low densities.</td>
<td>More complicated than the grill. Dependent on bait attraction.</td>
</tr>
<tr>
<td>Counts on available surfaces</td>
<td>Simple, rapid, versatile, etc. (see VI.1.3).</td>
<td>Subjective, depends on training and experience.</td>
</tr>
<tr>
<td>Baited traps</td>
<td>Sample over a period. Flies obtained for identification, susceptibility tests, etc.</td>
<td>Dependent on location and bait. May attract flies from other premises. Requires construction and maintenance of traps.</td>
</tr>
<tr>
<td>Sticky traps</td>
<td>Sample over a period. Flies obtained for identification. Sensitive to population changes. Effective at low densities.</td>
<td>Catch much dependent on location. Time consuming and messy. Requires purchase or preparation of sticky strips, etc. Overloading by flies.</td>
</tr>
<tr>
<td>Light traps</td>
<td>Sensitive to population changes.</td>
<td>Expensive, can only be used indoors. Attractiveness varies from place to place and with temperature.</td>
</tr>
<tr>
<td>Catching flies</td>
<td>Flies obtained for identification, susceptibility tests etc.</td>
<td>Unreliable for quantitative sampling.</td>
</tr>
</tbody>
</table>

The procedure outlined on page 46 is the one most recommended and used in various parts of the world, but the interpretation of grill counts may vary from place to place. In some premises, e.g. restaurants, a count above three may be unacceptable, whereas in a dairy barn counts below 20 may be acceptable.

Local modifications of the grill count method are used, e.g. leaving the grill for a longer time in each place or even using it as a permanent counting station. However, these modifications are against the idea of the grill method: to give quick counts of fly concentrations wherever they occur.
VI,1.2 Counts of flies landing on baits

Dishes, trays, plates, strips, etc. with a fly attractant are exposed for a suitable time, e.g. 2-30 minutes, and the flies landing on the bait are counted. Baits may be syrup, molasses, milk or hydrolysate of protein.

The method has been used a great deal for estimating the effect of fly control in animal houses, especially in the USA, but is not so versatile and quick as the fly grill method, and not suitable for community fly surveys.

VI,1.3 Counts or estimates on available surfaces

The number of flies may be estimated at available (illuminating) fly concentrations to give rapid visual estimates corresponding to grill counts. To do this reliably a good deal of training is required.

Another method is to count or estimate the number of flies on a number of fixed areas, where flies are known to concentrate, e.g. on animals, stanchions, partitions or feeding troughs in stables. This may be done where the distribution of flies is reasonably constant, but the time of day, the weather and the work in the stable (feeding, cleaning, etc.) are important factors. The method does not lend itself well to fly surveys in towns and cities.

In pigsties and cow sheds in temperate countries (e.g. Denmark) where most of the flies are on the animals or close by in the daytime, an estimate of the number of flies per animal may be used for the fly index.

VI,2. Trapping flies

VI,2.1 Baited traps

The common type of fly trap, a cylindrical screen-wire cage with an inverted-cone entrance (Fig. 15b) is useful for fly surveys, especially for qualitative sampling of the fly fauna for identification. Recently a simple trap made of a 3.9 litre plastic jug with four 5-cm-diameter access holes has been introduced by Burg and Axtell (1984) for monitoring fly densities in poultry houses. The trap was baited with a granulate containing 0.025% muscamin and 1% methomyl. The reliability for quantitative estimates of fly populations by baited traps is dependent on the numbers and location of the traps and the local efficacy of the bait. Moreover, baited traps may attract flies that would not normally be in the premises.

VI,2.2 Sticky traps

Sticky tapes or strips are widely used for assessing fly densities, particularly indoors in animal houses and in rooms where flies may occur, but also outdoors to some extent (Raybould, 1966, 6° b). The sticky tapes may be exposed to flies for two hours to one or more days. The number of flies caught in a room depends largely on the location of the sticky trap, e.g. whether it is suspended above an animal or 1-2 m away from it. Therefore, reliable estimates of changes in density depend on the experience of the operator and preferably several traps should be used per premises sampled. However, catches on sticky tapes can be quite sensitive to changes in fly populations (Picken, 1951, 1972), and they count a much larger number of flies than the grill, which is important in low densities (Anderson & Forbaugh, 1963).

VI,2.3 Light traps

In areas and situations where light traps (e.g. provided with fluorescent "black light" lamps) do attract house-flies, the 24-hour catch may be used to estimate fly densities. Experiments in dairy barns showed that the trap catch was sensitive to fairly small changes (2 x) of the number of flies released in the barn.
VI.3. Catching flies

VI.3.1 Sweeps of net

Netting flies is useful for collecting specimens for identification, susceptibility tests, etc., but standard sweeping for quantitative estimates of fly population is difficult and unreliable.

VI.3.2 Movable suction device

A suction device like a big vacuum-cleaner may be used for collecting and monitoring fly densities in animal houses in connection with experiments. However, for routine surveys the device is not practical.

VI.3.3 The fly cone

A cone made of wire netting with a diameter of 75 cm can be used for sampling flies on natural attractants (garbage, manure, etc.). The fly cone is good for collecting specimens in such places, but not suitable for general surveys, as there are many places where it cannot be used to collect flies.

VI.4 Counting fly specks

Suspension of paper, cardboard, plastic, glass, etc., in fly infested premises and counting the number of fly specks deposited per day has been considered in some places for estimation of fly densities, but the experience is not encouraging.
VII. GLOSSARY

ANTENNAE

ARISTA
A slender bristle, usually found dorsally on the terminal joint of the antennae of certain Diptera.

BIOLOGICAL CONTROL
Control measures by means of living organisms.

BIONOMICS
The (quantitative) relation of the development, reproduction and survival of an organism or population of organisms to factors in the environment.

CAMPYLOBACTERIOSIS
Infection with a Gram-negative bacteria Campylobacter fetus causing dysentery.

CONTROL
Of insects (or other undesirable animals); the restriction of the population density of such insects to a level below that at which they can be harmful to the interests of man.

DENSITY (of flies)
Number of flies per given area or other unit.

DIPTERA
An order of insects containing the two-winged flies which have only the anterior pair of wings well developed.

DISPERSION
The movements of flies in and around a locality or area in which they emerged or are found at a given time.

DUNG
Animal excrements.

ELECTROCUTOR
A device to kill flies by a grid of wires with an electric charge. Electrocutors are usually provided with tube light which may attract some flies.

EMIGRATION
The movement out from a given locality or area.

ENDOPHILIC INSECTS
Insects that regularly enter houses and spend at least part of their life indoors.

ENTERIC INFECTIONS
Intestinal infections.

EXOPHILIC INSECTS
Insects that normally do not enter buildings.

FECUNDITY
Reproductive potential.

FRONTAL SAC
Also called pilium. An eversible sac at the front of head of the fly. This sac can be expanded and withdrawn in the newly emerged fly and assist in the escape from the puparium.

GARbage
Waste from preparation, cooking and serving of food, and market wastes from the handling, storage and sale of food.

HELMINTHS
The general term for worms of the phyla Platyhelminthes, Nematoda and Acanthocephala, especially parasites.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity or Relative Humidity</td>
<td>The content of water vapour in the air measured as a percentage of the content of saturated air (100% RH).</td>
</tr>
<tr>
<td>Immigration</td>
<td>The movement into a given locality or area.</td>
</tr>
<tr>
<td>Interfertile (Subspecies)</td>
<td>Subspecies which are able to produce fertile offspring when a member of one subspecies mates with a member of the other subspecies (see also species).</td>
</tr>
<tr>
<td>Insect Development Inhibitors (IDI)</td>
<td>Chemicals which inhibit the development of larvae or pupae into adults or of eggs into larval. The IDIs are often included in the term insect growth regulators (IGR).</td>
</tr>
<tr>
<td>KDR-factor</td>
<td>A gene that is involved in the mechanism of insecticide resistance, reducing the sensitivity of the nervous system to that insecticide and its analogues.</td>
</tr>
<tr>
<td>Larvicides</td>
<td>Chemicals which kill larvae directly or by preventing them from developing into adults (see V, 2, 1).</td>
</tr>
<tr>
<td>Nomenclature</td>
<td>The scientific (Latin) names given to species, genera, families, etc. of animals and plants.</td>
</tr>
<tr>
<td>Olfactory</td>
<td>Associated with the sense of smell.</td>
</tr>
<tr>
<td>Pathogens</td>
<td>Microorganisms (germs) such as viruses, bacteria, protozoa and eggs and cysts of worms, which can cause disease if man is infected.</td>
</tr>
<tr>
<td>Pheromone</td>
<td>Chemical substance that is produced by an animal and functions as a communication which affects the behaviour of other individuals of the same species.</td>
</tr>
<tr>
<td>Predator</td>
<td>An animal which preys upon insects or other animals.</td>
</tr>
<tr>
<td>Preoviposition Period</td>
<td>The time from the emergence of the female fly from the puparium and until it is able to start laying eggs.</td>
</tr>
<tr>
<td>Puparium</td>
<td>A barrel-shaped case formed by the contracted and hardened skin of the third larval instar and inside which the pupa develops.</td>
</tr>
<tr>
<td>Reproductive Potential</td>
<td>The theoretical capacity of increase in numbers of a pair of flies in a given time, e.g. a year.</td>
</tr>
<tr>
<td>Residual Treatments</td>
<td>Treatments with insecticide formulations having a long-term effect (weeks or months).</td>
</tr>
<tr>
<td>Resistance to Insecticides</td>
<td>Resistance is a genetic ability in an insect population to tolerate higher dosages of an insecticide than normal, developed as a consequence of insecticidal treatments.</td>
</tr>
<tr>
<td>Salmonella</td>
<td>A genus of the family Enterobacteriaceae, pathogenic to man causing typhoid and paratyphoid fever and food poisoning.</td>
</tr>
<tr>
<td>Sclerotized</td>
<td>Hardened cuticle.</td>
</tr>
<tr>
<td>Screening</td>
<td>The use of fly screens or nets for excluding flies.</td>
</tr>
<tr>
<td>Shigella</td>
<td>A genus of the family Enterobacteriaceae, members of which cause bacillary dysentery in man.</td>
</tr>
</tbody>
</table>
SPECIES

The smallest unit of classification commonly used, i.e., the group whose members have the greatest mutual resemblance, are able to interbreed (if not separated in space or time), but not to breed with organisms of other groups (species). Species may be divided into subspecies which differ in certain genetic characters but are able to interbreed. (See INTERFERTILE).

SPECIMEN THECA

An organ of the female reproductive system in which mature sperms are stored after copulation.

SPERENCES

External openings of the tracheae, the air tubes providing oxygen for the tissues of insects.

SYNANTHROPIC FLIES

Flies that occur in and around human settlements, e.g., houses, villages, towns, farms, camps, refuse dumps, etc., and are dependent on these.

TAXONOMY

Classification of animals and plants divided into species, genera, families, etc.

THORAX

Flies and other insects are divided into three regions: head, thorax and abdomen. The thorax carries the legs and wings.

UTENSILS

FOR FOOD

Pots, pans, vessels, bowls, dishes, jugs, cups, glasses, forks, knives and other kitchen and table ware.

YAWS

A tropical disease caused by the spirochaeta causing skin lesions and bone manifestations.
VIII. SELECTED REFERENCES

Abstracts of most references up to 1972 may be found in West and Peters (1973).


Acknowledgements

The author wishes to express his sincere thanks to colleagues in Denmark and elsewhere from whom he has received personal communications on the subject of the document, e. K. Arevad, J.B. Jespersen, U.S. Olesen, O. Skovmand and P. Ystrøm, Denmark; Gao Jin-Ya a Gong Kun-Yuan, China; V. Rupeš, Czechoslovakia; D.B. Pinniger, England; T. Shono a N. Motoyama, Japan; G.P. Georghiou and M.S. Mulla, United States of America.
IX. EVALUATION

A. Questionnaire for self-evaluation

(All questions relate to the common house-fly, Musca domestica, unless otherwise stated. Sections where the answers can be found are indicated in brackets).

1. State the geographical distribution of the house-fly by climatic zones (tropical, subtropical, temperate, subarctic) and continents (page 5) ..............................................................

2. What is the difference in breeding habits between Musca sorbens and Musca domestica? (page 11) ..........................................................................................................................

3. Number of larval instars? (page 9) ..........................................................................................................................

4. The difference in behaviour between the larvae that are ready to pupate and the previous larval stages? (page 9) ..........................................................................................................................

5. The temperature at which the development from egg to adult is most rapid (optimum temperature): 25° - 30° - 35° - 40° - 45°? (page 8) ..............................................................

6. Shortest length of development of egg + larvae + pupae? 2-4-6-8-10-12 days? (page 8). ..............................................................

7. State 3 main breeding sources in rural areas (a) ......................................................... (b) .......................................................... (c) ..........................................................

8. State the difference in night resting habits of house-flies in tropical and temperate climates (page 16) ..........................................................................................................................

9. State the main diseases which flies may transmit (pages 19/20) ..............................................................

10. State at least four factors that influence the transmission of enteric diseases by flies (pages 17-19) ..........................................................................................................................

11. State the most important methods of environmental sanitation for fly control (pages 20-28)

(a) in rural areas..........................................................................................................................

(b) in urban areas ..........................................................................................................................
12. State two insect development inhibitors which are effective as housefly larvicides (pages 28-29) .................................................................

13. Which application is most likely to select for resistance? (pages 29-35)
   (a) Space sprays
   (b) Residual sprays of potential resting places
   (c) Toxic baits
   (d) Impregnated cords or strips

14. State areas where DDT is an effective insecticide for control of house-flies (pages 37/38) ..............................................................................

15. Mention four common predators of fly larvae (pages 41-44) .........................

16. Mention four methods for estimating relative fly density, and state their main advantages and disadvantages (page 47)
   (a) ...................................................................................................................
   (b) ...................................................................................................................
   (c) ...................................................................................................................
   (d) ...................................................................................................................
B. Questionnaire for return to VBC

To be filled in by readers and trainers.

You can help us to improve VBC's documents by answering the following questions:

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How was the presentation of this document?

very good  good  fair  bad

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very important  important  not very important  not at all important

What do you think about the terminology?

easy  clear enough  difficult  very difficult

Comments: ..............................................................................
Which information did you find irrelevant for your work?

What do you think about the illustrations?

| poor | fair | good | very good |

What do you think about the style of writing?

| too simple | very easy | just easy | not easy |

Was the document the right length?

| too short | about right | too long |

How valuable were the different sections of this document?

<table>
<thead>
<tr>
<th>Extremely valuable</th>
<th>Valuable</th>
<th>Of little value</th>
<th>No value</th>
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<tbody>
<tr>
<td>Life history and biology</td>
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<td>Public health importance</td>
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<td>Survey and surveillance</td>
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<td>Control</td>
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Comments:........................................................................................................................................
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Please send your comments either through the WHO channels in your country or by post to:

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