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Flies, Cockroaches, and Excreta

MANY INSECTS are associated with excreta. Those of importance to health, however, are mainly from two groups of insects: the two-winged flies (Diptera) and the cockroaches (Dictyoptera). There are many species of Diptera, including the mosquitoes (dealt with in the preceding chapter), so that this chapter concentrates on other flies and the cockroaches.

Patches of animal feces are worlds unto themselves, with parasites, predators and dung feeders living as a community together (Laurence 1977). Manmade environments with innovations such as sanitation and waste disposal units are invaded and colonized from more natural breeding places. Waste disposal provides two attractive materials for the development of insects—rich organic material and water. The kinds of insect found breeding in human waste disposal systems are, in consequence, those that breed in various forms of decaying organic material, including feces, or those that breed in freshwater and yet tolerate organic pollution. Relatively few species are able to take advantage of the new opportunities for breeding provided by waste disposal, but these often appear in very large numbers. The balance of a more varied fauna found in the natural breeding places may be lacking in the new manmade habitats. Consequently, the numbers of insects may build up to a level sufficient to cause a definite nuisance or endanger health. The presence of animal life in waste treatment systems, where there is a mixed culture of organisms (including the insects), is also part of the process of purification and breakdown of the organic material (Lloyd 1945; Usinger and Kellen 1955).

Flies Associated with Waste Disposal

The most common flies associated with waste disposal are found in eleven families (Laurence 1977). The most important families are the flies that transmit disease organisms from man to man: the mosquitoes, or family Culicidae; and the flies that breed in fecal material and also come into contact with man as adults by feeding on his food (the housefly and the blowfly, families Muscidae and Calliphoridae). Other flies cause a nuisance by invading human habitation (families Psychodidae, Chironomidae, and Anisopodidae), may land in food, and are known to cause contact and inhalation allergy in sensitized persons. In addition, other families of fly (Stratiomyidae, Syrphidae, Sepsidae, Ephydridae, Phoridae, and Sphaeroceridae) are very common on sewage installations or in cess pits, but normally have little contact with man and are less of a problem except that they can cause confusion in the identification of the more important sewage-breeding nuisances.

Among the flies that breed in or feed on excreta, two families are implicated in particular in the carriage of fecal material: the Muscidae and the Calliphoridae. The most important species are the housefly (*Musca domestica*) and species of the tropical green blowfly (*Chrysomya*). The adults of these flies will enter houses and shops readily and are attracted to human food as well as to feces and garbage around the home. They are medium to large flies, 7–10 millimeters long, and have greyish (*Musca*) (figure 37-1) or green (*Chrysomya*) body color. The larvae are maggot-like and 10–12 millimeters long when fully grown. The three larval stages are found in excreta or mixtures of excreta and decaying vegetable matter. For the breeding of the housefly, *Musca domestica*, solid, moist, and fermenting matter are required; other species of *Musca* breed in wetter materials. Human feces are attractive to houseflies mainly in their solid state. The presence of another fly. *Hermetia*, in latrines renders the contents soupy and less attractive to houseflies. Reduction of the water content, by drainage or by killing the *Hermetia* with insecticides, causes an increase in housefly breeding (Kilpatrick and Schoof 1959). In contrast, the larvae of the blowfly, *Chrysomya*, are found in more liquid feces and may liquify masses of fecal material.

Figure 37-1. *The common housefly,* Musca domestica. (Photo: Wellcome Museum of Medical Science)

The housefly will develop from egg to adult in 10 to 20 days over the temperature range 20–30°C (the higher the temperature, the shorter the period of development), with a minimum developmental period of about 1 week. No development takes place below 12°C, and eggs, larvae, and pupae are killed at 47°C (Keiding 1976). *Chrysomya* (blowfly) larvae develop from egg to adult in Sri Lanka at room temperature in 8.5 days.

A survey of the insect fauna in some latrines in east Africa and Taiwan was conducted in 1978 by B. R. Laurence. The results are summarized in table 37-1, which shows that *Chrysomya* was ubiquitous. In east Africa *Chrysomya putoria* was the species involved, whereas in Taiwan it was *Chrysomya megacephala.* Similarly, Lien and Chen (1974) reported that the majority of flies breeding in vaults in Taipei (Taiwan) were *Chrysomya megacephala.* Pit latrines are notorious as breeding places for blowflies. Raybould (1966) reported that, at Amani in Tanzania, ninety pit latrines produced 3.5 kilograms of *Chrysomya putoria* in a single month (one adult *Chrysomya* weighs about 50 milligrams).

Cockroaches

Cockroaches are attracted by the moisture of waste disposal systems of various kinds. They are also potential carriers of fecal pathogens, and they live in and around human dwellings. They often visit human food when they emerge at night from their noisome daytime hiding places. Cockroaches, in contrast to the very rapid turnover of the fly population, take several months to more than a year to develop to the adult stage, but large populations of adult and young cockroaches may be found together in the same habitat. Also, young cockroaches resemble the adult insect, whereas fly larvae have a very different appearance from the adult fly. Flies are able to breed in much more transient habitats than cockroaches.

Flies, Cockroaches, and Health

Disregarding *Culex* mosquitoes, which are discussed in chapter 36, there are two ways in which insects related to excreta may affect man. First, large

Table 37-1. *Insect fauna of "dry" latrines*

Location	*Type of toilet*	*Insect fauna*
Tanzania, Kenya	Pit latrines including Reed Odorless Earth Closets (ROECs)	*Chrysomya*, cockroaches *Culex quinquefasciatus*, if flooded
Tanzania	Continuous 'multrum' type composting toilets	*Chrysomya* in feces and vegetable fiber *Musca* in dry compost *Telmatoscopus*, *Hermetia* and *Eristalis* in wet compost Phorid flies, cockroaches
Tanzania	Batch double-vault composting toilets	*Chrysomya* in feces Phorid flies, cockroaches
Taiwan	Latrine vaults	*Chrysomya* Phorid flies *Telmatoscopus*, *Hermetia*, *Eristalis*

Note: *Chrysomya* = blow fly; *Eristalis* = rat tailed maggot; *Hermetia* = soldier fly; *Musca* = housefly; *Telmatoscopus* = moth fly.
Source: B. R. Laurence, unpublished data.

numbers of flies will breed in the various environments associated with waste disposal systems. Some of these may have a close association with man (the so-called synanthropic species) and can cause a nuisance. More seriously, they can cause allergy, with sensitization reactions (skin rash and asthma) as a response to the presence of the bodies of the flies (see, for instance, Ordman 1946; Phanichyakarn, Dockhorn and Kirkpatrick 1969). Second, and of greater importance, is the potential role of flies and cockroaches, which either breed in excreta or eat excreta, in disseminating fecal pathogens. It is on this aspect that we concentrate here.

Any insect that breeds in excreta or visits excreta to feed may carry particles of feces from place to place. This may be done either on the legs or other parts of the external body surface or by the insect vomiting or depositing pathogenic organisms, previously ingested, in the feces. Either of these mechanisms can assist the dissemination of human fecal pathogens in the environment.

Transmission of Excreted Pathogens

Many studies have shown that insects that breed in excreta, or feed on it, may carry human pathogens on their bodies or in their gut. The massive literature on this subject shows that practically every excreted pathogen has been isolated at some time in a viable state from a fly or cockroach. This includes the excreted viruses (see, for instance, Melnick and Dow 1953), the excreted bacteria (see, for instance, Bidawid and others 1978; Burgess and Chetwyn 1978; Cox, Lewis and Glynn 1912; Steinhaus and Brinley 1957), the excreted protozoal cysts (see, for instance, Frye and Meleney 1936, Gupta and others 1972; Pipkin 1949; Rendtorff and Holt 1954; Root 1921), and the excreted helminth eggs and larvae (see, for instance, Gupta and others 1972; Oyerinde 1976; Round 1961). The literature on insectborne pathogens is very extensive and has been reviewed by Greenberg (1971, 1973) for flies and by Cornwell (1968, 1976) and Roth and Willis (1960) for cockroaches.

The medical significance of the carriage of excreted pathogens by insects depends in part upon the behavior of the insect and in part upon the other modes of transmission of these pathogens. Insects that enter human dwellings and visit human food are especially likely to promote disease transmission, and it is for this reason that the flies *Musca* and *Chrysomya* and cockroaches are so often implicated. Given that these insects are moving fecal pathogens into houses and onto food, however, it remains unclear what their contribution is to the spread of particular infections. A feces-fingers-food cycle is more direct and more probable than a feces-insect-food cycle.

The main epidemiological evidence of the importance of flies and cockroaches in the transmission of enteric infections comes from the results of surveys of infection in the human population before and during insecticidal control programs. Decrease of human enteric infection (especially *Shigella* infections) has sometimes been recorded in the sprayed areas (see, for instance, Abdel-Gawaad and El-Gayar 1972; Mackie and others 1956; Watt and Lindsay 1948; Wolff, van

Zijl and Roy 1969). In some experiments a rise in human infection accompanied the development of insecticide resistance in the flies (see, for instance, Lindsay, Stewart and Watt 1953).

Methods of Fly and Cockroach Control

Whatever their exact role in disease transmission, it is always desirable to control any fly or other insect nuisance associated with excreta disposal. Control of human excreta alone, however, will not be sufficient because the insects will with some certainty be breeding elsewhere (in the excreta of other animals and in other materials), and the flies will disperse quickly into the controlled areas. For instance, surveys in three cities in the USA (Charleston, Phoenix, and Topeka) showed that the primary site for housefly and blowfly breeding was garbage (Schoof, Mail and Savage 1954). A survey of garbage disposal pits in an army camp in the USA also showed them to be a major breeding site (Mathis, Schoof and Mullenix 1969). In Dar es Salaam (Tanzania), the majority of flies emerging from pit latrines were *Chrysomya putoria*, whereas 9 percent of flies caught in kitchens were *Musca domestica*, thus clearly indicating that major breeding activity was taking place in other sites (Bang, Sabuni and Tonn 1975).

The control of fly and cockroach breeding in association with human excreta may not, therefore, have any measurable effect on the total fly and cockroach population. However, such control will reduce the population of flies and cockroaches that have been in contact with human excreta, and—because many excreted pathogens are found exclusively, or almost exclusively, in human excreta (for instance, poliovirus, hepatitis A virus, *Shigella*, *Vibrio cholerae*, *Entamoeba histolytica*, and the eggs of human roundworms and hookworms)—this reduction could be epidemiologically important (McCabe and Haines 1957).

Modifying the physical environment

An ideal sanitary unit should exclude flies and other insects and prevent access to the feces but should not inhibit people from using it. The success of fly-proofing methods (self-closing lids, screening, darkness, proper coverage of the fecal material) depends upon the acceptance and maintenance of these methods by the local population. An enclosed, dark and fly-proof box that overheats would clearly not be acceptable as a toilet to the residents of tropical countries, and would probably also attract cockroaches. Hence, there is no easy, universal solution.

The feces of different animals attract different associations of insect species, and this reflects the differing consistencies of the feces. Sanitary measures designed to prevent housefly breeding, such as bored hole latrines, may not be successful against the blowfly. Wherever possible, improvement in sanitation design should aim to protect the feces from the visiting insects and provide conditions of disposal unsuitable for the development of the larval stages in the fecal material.

Housefly eggs are killed at 42°C, larvae at 47°C, and pupae at 45°C (Keiding 1976). Hence, composting should aim at maintaining the lethal temperature throughout the consolidated mass of excreta. Low temperatures at the edges will still permit larval development to adult fly.

A variety of design suggestions for controlling fly breeding in latrines, animal manure, and garbage are given by Busvine (1982). Fly control in garbage disposal plants using composting and sanitary landfill is described by Alvarez, Blanton and Putnam (1972) and Black and Barnes (1956), respectively. Data on fly control in composting plants for excreta plus garbage in China are given by Scott (1952).

The most important advances in thinking on the control of fly breeding in pit latrines concern the role of pit ventilation and the use of exit traps. Modern concepts of pit latrine design include a pit vent pipe or chimney, one major role of which is to exhaust foul gases and thus make the latrine odor-free and pleasant (see, for instance, Feachem and Cairncross 1978). Experiments conducted in Botswana, Tanzania, and Zimbabwe have shown that vent pipes also play an important role in reducing fly production by pit latrines. In Zimbabwe (Morgan 1977), four pit latrines were built in a row, two with vent pipes and two without, and were used for 6 months prior to the start of the experiment. During 2.5 months, 13,953 flies were trapped from the unvented pits, but only 146 were trapped from the vented pits. Most flies were *Chrysomya*. The studies in Botswana and Tanzania (Curtis and Hawkins 1982) found that, in vented pit latrines with their doors kept closed, about 90 percent of the emerging flies (mainly *Chrysomya putoria*) went up the vent pipe and were caught by the gauze at the top. When the doors were left open, only about 50 percent of flies attempted to exit via the vent pipe; the rest left through the drop hole. This suggests that keeping the latrine dark by closing the door encourages the newly emerged flies to go toward the main light source, which comes down the vent pipe. The studies in Botswana and Tanzania also showed that female flies attempting to enter latrines to lay eggs were strongly attracted by the fecal odors from the vent pipes and therefore tried to enter the pits by flying down the vent pipes. They were prevented from doing this by the gauze at the top end of the vent pipe. Thus, screened vent pipes reduce the numbers of gravid female flies gaining access to the pits and prevent a considerable proportion of young flies from leaving the pits. [See note on page 81.]

The second important new approach to fly control in pit latrines is the use of an exit trap on the squatting hole instead of a lid. This is described in chapter 36 and by Curtis (1980) and Curtis and Hawkins (1982) and requires large-scale field testing.

Insecticides and other chemicals

The ideal cheap and nonbulky compound that reduces the attractiveness of feces to flies has yet to be found. Addition to feces of diesel oil, chloride of lime, borax, paradichlorbenzene, and thiourea, as well as other larvicides—some toxic to man—has been used. Such chemicals should be used with caution whenever the excreta will subsequently undergo some biological treatment process, such as digestion or composting, that could be adversely affected by the added chemicals. Caution is also required if the excreta may be reused in agriculture or aquaculture.

Fly control programs with the use of chlorinated hydrocarbon insecticides, such as DDT and BHC, have produced widespread resistance in the housefly, and resistance to other insecticides has also developed. Resistance to insecticides has also been recorded in *Chrysomya*. In some control programs resistance of flies to insecticides has developed extremely rapidly—for instance, in about 3 months (Lindsay, Stewart and Watt 1953). In Georgia (USA) the use of dieldrin, BHC, or chlordane in pit latrines greatly increased the breeding of insecticide-resistant *Musca domestica* because it reduced the population of *Hermetia illucens* larvae, which were making the pit contents too liquid for housefly breeding (Kilpatrick and Schoof 1959).

Flypapers, insecticide-impregnated cords and plastic blocks, baited fly traps, and poison baits have all been used against the adult fly. Distribution of this type of equipment is a possibility given the organization, understanding, and cooperation of the local population.

The control of insects other than houseflies and blowflies presents similar problems. As with the flies, widespread insecticide resistance is known in cockroaches. Fumigation of sewers, the use of residual insecticides as sprays or lacquer paints, and poison baits have been found to be effective, but the control of cockroach infestation in excreta disposal units is part of a wider problem of cockroach control in the human community. A combination of water, food, and darkness is ideal for renewed cockroach infestation in the tropics. A comprehensive review of cockroach control strategies is given by Cornwell (1968, 1976), and a recent survey of approaches to cockroach control in Hungary is presented by Bajomi and Elek (1979).

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