LD HEALTH ORGANIZATION

ANISATION MONDIALE DE LA SANTE

EAL DISEASE CONTROL PROGRAMME

DISTR: GENERAL
WHO/CDD/91.37
ORIGINAL: ENGLISH

INTERVENTIONS FOR THE CONTROL OF DIARRHOEAL DISEASES AMONG YOUNG CHILDREN: FLY CONTROL

by

Steven A. Esrey[1]

SUMMARY

The effect of fly control measures on diarrhoea morbidity and mortality is analysed, and interventions to reduce the fly population are reviewed. Although the evidence examined suggests that flies are able to transmit enteric pathogens from faeces to human beings via food or drink, the extent to which this takes place remains unknown. The literature is limited, consisting mostly of studies conducted prior to 1960 which suffered from numerous methodological problems. The median reduction in diarrhoea morbidity rates that might be achieved through fly control measures, derived from seven studies, is 40% (0% - 67%). The potential impact of fly control on diarrhoea mortality is unknown; the data from the only two studies that could be located ranged from reductions of 50%-75% to a 143% increase. Long-term, environmentally safe fly control is difficult to achieve and sustain. Effective methods for short-term control, which involve the use of insecticides, are unsafe for humans and other animals. The available evidence suggests that fly control is not feasible in many settings and that, even if successfully implemented, it is not a cost-effective intervention for national diarrhoeal disease control programmes.

[1]Faculty of Agriculture and Environmental Sciences and Faculty of Medicine, 21,111 Lakeshore Road, McGill University, Ste Anne de Bellevue, H9X 1C0, Canada

INTRODUCTION

Flies have been implicated as disease vectors for thousands of yea[illegible] workers and the general populace believe that flies transmit diarrhoea. [illegible] therefore widely promoted, and the protection of food and beverages from flies is also advocated.

This review is one of a series in which potential interventions for the control of diarrhoeal diseases are being examined (5-8, 19, 20, 23-30). It is one of four reviews that examine the role of interventions to interrupt transmission in the control of diarrhoeal diseases. The other three interventions are improving water supplies and excreta disposal facilities (24), promoting personal and domestic hygiene (26), and promoting food hygiene (23). Some overlap exists between fly control and the other potential interventions to interrupt the transmission of enteric pathogens. To the extent possible, this paper will examine the role of fly control independently of its association with the other interventions to reduce transmission.

Where possible, information has been restricted to the common house fly, Musca domestica Linnaeus, the synanthropic fly that has been studied most frequently in connection with the transfer of enteric pathogens to man. In most cases no distinction of species was made, and thus the term flies will be used in this review. Knowledge about the common housefly may or may not apply to the other species, since behavioural differences exist among synanthropic fly species.

EFFECTIVENESS

For fly control to be an effective diarrhoea control intervention, it must be true that:

either

flies contribute to the transmission of diarrhoea-causing pathogens and thereby increase the incidence of diarrhoea morbidity or mortality among young children	hypothesis 1

and

fly control measures are effective in reducing the fly population in a community	hypothesis 2

or

fly control measures can reduce diarrhoea morbidity or mortality rates among young children	hypothesis 3

The potential effectiveness of fly control would be suggested by a demonstration either of the correctness of hypotheses 1 and 2 or of the correctness of hypothesis 3. The evidence for and against these hypotheses is examined below:

Hypothesis 1: <u>Flies contribute to the transmission of diarrhoea-causing pathogens and thereby increase the incidence of diarrhoea morbidity or mortality among young children</u>

Evidence that flies contribute to the transmission of diarrhoeal disease agents is derived from three sources of data: biological studies that have recovered diarrhoeal disease agents from flies, epidemiological studies that have associated flies with diarrhoea rates, and experimental volunteer studies that have reported that flies act as a vehicle for the transmission of diarrhoeal disease agents. These three sources of data are considered in turn.

<u>Recovery of diarrhoeal agents from flies</u>.

Many pathogens that are known to cause diarrhoea in man have been recovered from flies (Table 1). Bacteria, viruses, and protozoa have been found on the integument of flies, in the crop, midgut, and hindgut, and in the faeces and vomit. Although rotavirus is not included in Table 1, it is possible that this virus, if looked for, could be recovered from flies. Helminth ova and cysts have also been recovered from flies (38, 52, 65).

Table 1. Enteric pathogens recovered from flies

Type of organism	Species	References
Bacteria	<u>Bacillus cereus</u>	57-59
	<u>Campylobacter jejuni</u>	64, 73, 78
	<u>Escherichia coli</u>	13, 22, 41, 44 57-59, 68
	<u>Salmonella</u> spp.	10, 13, 31, 33, 57, 68
	<u>Shigella</u> spp.	9, 10, 22, 31, 45 57-59, 62, 68, 79
	<u>Staphylococcus</u> spp.	34, 50
	<u>Vibrio cholerae</u>	22, 44
	<u>Vibrio parhaemolyticus</u>	14
Viruses	Coxsackie virus	48, 49
	Enteroviruses	13
	Polio virus	48, 49, 54
Parasites	<u>Balantidium coli</u>	21
	<u>Entamoeba histolytica</u>	21, 39, 56, 60
	<u>Giardia lamblia</u>	21, 39, 60, 70
	<u>Strongyloides stercoralis</u>	21, 60

The number of enteric pathogens carried on the integument of flies may be proportional to the concentration of those pathogens in the contaminated material with which the flies have contact (71). This may account for the wide range of numbers of bacteria (10^2-10^6) recovered from the external surfaces of flies by early investigators (79).

Enteric bacteria can survive on the integument of flies for up to 10 days, whereas Giardia has been reported to survive for no more than 1 day (Table 2). Several factors tend to reduce the survival time of enteric pathogens on flies (34). Pathogens may be dislodged when flies preen their wings and brush their heads and legs. Desiccation of bacteria occurs during flight, and solar radiation has been reported to reduce markedly the average number of live bacteria carried on flies (53).

Table 2: Survival times of enteric pathogens on and in flies

Type of organism	Species	Survival time (days)	Reference
	ON FLIES		
Bacteria	Campylobacter spp.	3-7	73
	Escherichia coli	6	40
	Salmonella spp.	6-10 6	37 40
	Shigella spp.	6	40
	Vibrio cholerae	7	44
Protozoa	Giardia lamblia	<1	42
	IN FLIES		
Bacteria	Shigella spp.	6	40
	Staphylococcus spp.	8	50
	Vibrio cholerae	30	44
Viruses	Coxsackie virus Polio virus	12 17	49 49
Protozoa	Giardia lamblia	<1	42, 63

Enteric pathogens may also be carried in the gut of flies and deposited in vomitus or excreta. As might be expected, the reported survival times of enteric bacteria in flies are somewhat longer than the survival times on flies (Table 2). Enteric protozoa, however, appear to survive for a very short period, even in flies.

Multiplication of enteric bacteria in flies has been reported to occur for Vibrio cholerae (44), Salmonella typhimurium (35,40), in Escherichia coli (40, 57-59), and Shigella (40), but the evidence is inconclusive. Multiplication is facilitated in laboratory experiments in which flies are exposed to a single organism. Where flies are ingesting a mixed flora, as in reality they must, multiplication of the relatively fastidious enteric pathogens is less likely (35). The ingestion of at least 10^3 bacteria may be necessary before survival and multiplication of the organisms can occur (40).

However, it may not be necessary for enteric pathogens to multiply in flies for flies to play a role in the transmission of diarrhoeal disease. Flies feed once every 4-5 hours and deposit faeces and vomit several times per hour (41). Some flies breed in and seek out faecal matter and are most likely to pick up and deposit enteric pathogens innumerable times during their adult life-span, which may last from less than 1 week to 2 months in natural conditions. Enteric bacteria deposited in small numbers on food could, if conditions were right, multiply rapidly to the concentration necessary to produce infection in humans. Viruses and protozoa deposited on food would not multiply, but their infectious dose for humans is low and thus disease transmission could still take place.

Epidemiological studies associating flies and diarrhoea

Fourteen studies have been located that have reported associations between fly populations and diarrhoeal disease (2, 3, 12, 16, 22, 36, 45, 51, 62, 66, 69, 77, 79, 81) (Table 3). Seven of these studies (3, 16, 22, 45, 62, 69, 79) reported a positive association between fly densities and health outcomes such as diarrhoea morbidity, *Shigella* infection, or deaths. However, the results are inconsistent, even within individual studies.

Table 3. Reported associations between fly population levels and diarrhoea morbidity and mortality

Country	Health indicator	Reported association with fly population	Comments	Reference
China	Mortality	Yes	Fly densities and death rates rose and fell in parallel. Death rates were also associated with water quality and use of *juan mu tang* (a beverage of water, sugar, dried fruits, and ice).	79
Guatemala	Diarrhoea morbidity	No	Fly populations were highest in the rainy season, following the peak diarrhoea rates at the end of the dry season.	12
India	Diarrhoea morbidity	No	From 1912-1914, a close correlation (0.69) between flies and diarrhoea was noted at the beginning of the monsoon; the relationship ended before the summer diarrhoea epidemic subsided. In 1915, treatment of the water supply was associated with reduced diarrhoea despite high fly counts.	51
India	Diarrhoea morbidity	Yes	A correlation coefficient of 0.26 between monthly fly densities and diarrhoea episodes was calculated. Monthly changes in fly density did not always parallel monthly changes in diarrhoea morbidity.	3
Thailand	Diarrhoea morbidity	Yes	The number of flies increased in kitchens and animal pens during the hot spring, when diarrhoea prevalence was highest.	22
USSR	Dysentery	No	Six towns were observed for dysentery rates and fly populations over several months. Fly populations were increasing as dysentery was decreasing in five of the towns. Only in one town did the rates coincide.	36

USSR	Dysentery	Yes	Fly rates over several years were compared with dysentery rates among children 0-1 years, 2-3 years, 4-6 years, and >6 years. An association was found only for children 4 years and above. The authors concluded that flies transmitted dysentery via food.	69
USSR	Dysentery	No	Dysentery rates declined over a 13-year period (1955-1968). While fly populations also declined, the author concluded that the expanded coverage with water supplies was responsible for most of the decline.	2
USSR	Dysentery Intestinal disorders	Yes No	Fly and dysentery rates rose and fell together. Intestinal disorders rose before fly counts. The authors assumed that food-borne disease was responsible.	81
USA	Shigella	Yes	Fly density and Shigella cases increased and decreased in parallel. Water, ice, and milk samples were shown to be satisfactory, but were examined after the Shigella epidemic; 11% of food handlers and 3% of flies were infected with the same strain of Shigella.	45
USA	Shigella isolations	Yes	Shigella was recovered from flies and humans in a migrant labour camp in Arizona. Shigella was isolated from 8% of the inhabitants, 18% of the fly pools, and 25% of faeces found on the ground.	16
USA	Shigella isolations	Yes	Eleven different Shigella types were isolated from flies and the same 11 types were isolated from humans; of the flies collected outside and inside premises, 0.1% and 0.2%, respectively, were positive for Shigella.	62
USA	Diarrhoea morbidity	No	Months of highest morbidity preceeded months of highest fly counts; fly counts were also considered low.	66
Venezuela	Diarrhoea morbidity	No	An increase or decrease in the fly index was not always followed by an increase or decrease in diarrhoea, whether in an area of high or low diarrhoea morbidity.	77

In two of these positive studies (45, 79) other known risk factors, besides flies, were also found to correlate with the health outcome. For instance, in China (79) death rates rose and fell in parallel not only with fly densities but also with the quality of the drinking water and the consumption of a local beverage. In another study in an army camp (45), fly densities and Shigella cases increased and decreased in parallel, but food handlers (11%) were also found to be infected.

In two other studies (3, 51), high fly counts preceded or paralleled high diarrhoea morbidity rates, but the relationship was sometimes reversed. In India (3) it was reported that fly density and diarrhoea episodes were associated, but closer inspection of the data showed that monthly changes in fly density did not always parallel monthly changes in diarrhoea morbidity. In another Indian study (51), fly densities and diarrhoea cases at a jail rose in parallel, but this relationship ended before the summer diarrhoea epidemics were over, and in the subsequent year diarrhoea rates were lower despite high fly counts.

Several investigators in Guatemala (12), the USA (66), and USSR (36), reported that diarrhoea rates were highest at times when fly counts were low and that the rise in fly counts followed the rise in diarrhoea cases. In other studies, the fly counts were not associated with morbidity rates (2, 77).

Correlation coefficients between fly population and diarrhoea were calculated when possible. In one study in which a positive association was reported (3), the correlation coefficient ($r = 0.26$) was much lower than in three other studies in which no association was reported. The correlation coefficients in these three negative studies, one in India (51) and two in the USA (62, 66), were calculated to be 0.69, 0.87, and 0.75, respectively.

Simple correlations such as those above do not establish that flies are a vehicle for the transmission of pathogens that cause diarrhoea. In such associations it is not always clear whether flies infected humans or humans infected flies. Spurious correlations may be obtained because high fly populations and high rates of bacterial diarrhoeas are correlated independently with the hotter periods of the year (9, 22), or with other factors such as excreta disposal facilities and personal and domestic hygiene.

<u>Experimental volunteer studies</u>

Three experiments attempted to use flies as a vehicle in transmitting bacterial and protozoal organisms to humans. In one of two experiments in the USA (61), an attempt was made to infect 18 volunteer prisoners with food that had been exposed to flies experimentally infected with <u>Entamoeba coli</u> cysts. The flies, infected with 1-24 cysts, were released into a combined kitchen and dining room where the prisoners ate. No prisoner developed an infection due to <u>Entamoeba coli</u>, which is not a diarrhoea pathogen, during the next few months. The prisoners were observed from 43-169 days; only 3 of them were observed for less than 100 days. It was not known whether the volunteers actually ingested cysts or whether the flies deposited cysts on the food or on items that would lead to their ingestion. A limited fly-food contact time may have prevented the contamination of food.

The second experiment by the same authors sought to ensure fly-food contact (61). flies that had been infected with <u>Entamoeba coli</u> and <u>Giardia lamblia</u> cysts fed upon food that was subsequently given to 16 volunteers. At 30- to 60-minute intervals the food dishes were removed and replaced by petri dishes to prevent desiccation and bacterial overgrowth. Later, the infected food samples were mixed with the larger tray of food that was given to the volunteers at their evening meal. One volunteer became infected with <u>Entamoeba coli</u> and none with <u>Giardia lamblia</u>. In this experiment the specks that were observed to have been deposited on the food were not known to contain cysts; however, the authors believed a true fly-borne infection occurred as evidenced by the volunteer who became infected. The failure to produce <u>Giardia</u> infection may have been a result of poor viability or a low available dose of cysts.

In another experiment in Mexico City, 10 hospital patients were selected to be infected with <u>S. typhimurium</u> via flies (33). Participants were chosen according to the following criteria: absence of gastrointestinal symptoms in the previous 6 months, or of any ailment or physical condition that would interfere with the experiment; absence of <u>Salmonella</u>, <u>Shigella</u>, and enteropathogenic <u>E. coli</u> from one stool examination and one rectal swab taken four days apart; and negative sera for <u>Salmonella typhi</u>, <u>Salmonella paratyphi</u> A and B, and <u>S. typhimurium</u>. Nine-day-old sterilized flies were placed three to a cage, one cage for each participant. The flies were exposed for 2 hours to 7 g of dog faeces containing <u>S. typhimurium</u>. Thirteen hours later the flies were exposed to <u>atole</u> (a drink) for a total of 7 hours; the drink was then given to the patients. Each cage was associated with a particular drink given to a particular volunteer.

Flies were found to be positive for <u>S. typhimurium</u> by either agar plating or when tetrathionate broth enrichment was used, but only six of the 10 cages were positive. The number of organisms per contaminated fly ranged from 43 to 635. Eight of the 10 <u>atole</u> drinks were positive and contained from 10^3 to 10^5 organisms per ml. For six cages, both the flies and the drink were contaminated, but in the remaining two cages only the drink was positive, not the flies. For the six cages where both the flies and the corresponding drink were contaminated, only five prisoners were found to be positive for S. typhimurium. For each of the five cases, only one stool was positive for S. typhimurium over a 2-week period. No change in stool pattern occurred, including diarrhoea, in any of the 10 volunteers.

In summary, the results of a number of studies suggest that fly-borne diarrhoea morbidity is possible. First, it is clear that pathogens can be picked up, harboured, and transmitted by flies. Second, associations between fly density levels and diarrhoea rates have been reported in epidemiological studies. However, these studies do not establish flies as a vehicle for the transmission of pathogens that cause diarrhoea. The possiblity remains that other correlated risk factors may have been responsible for the association, or that the flies were infected with human faeces. Third, the experimental studies suggest that fly-borne infection is possible. The controlled conditions may have resulted in fewer pathogens being transmitted than would actually be the case under natural conditions.

Hypothesis 2: Fly control measures are effective in reducing the fly population in a community.

Fly control is defined as the restriction of the density below a level at which flies may be harmful to humans (43). Thus, efforts to keep flies away from humans without controlling their numbers will not be considered. For example, covering food may prevent flies from coming into contact with it and thus interrupt transmission, but the act of covering food does not control the population of flies.

Three basic fly control measures have been used over the years to attack different stages of a fly's life as well as different locations in the fly's milieu (Table 4). Measures can provide initial or residual relief and be safe or toxic, cheap or expensive, invasive or noninvasive. A thorough review of fly control measures has been undertaken by Keiding (43). Table 4 outlines the various measures that can be used.

Table 4. Fly control measures

Sanitary measures	Biological measures	Insecticidal measures
Fly proof privies Composting or covering of manure and garbage Garbage collection and disposal Reduction of sources attractive to flies	Predators Parasitoids Microorganisms that infect flies Trapping	Larvicides Residual treatments Impregnated strips, etc. Toxic baits Space treatment Fumigation

Sanitary measures are a primary type of fly control. The measures are designed to eliminate fly breeding, remove attractants, and prevent flies from gaining access to material that ensures reproduction and survival. To eliminate fly breeding, however, is virtually impossible since flies breed in any decaying, fermenting, or rotting organic matter. There is a better chance of success in urban areas, if garbage disposal is well organized, than in rural areas. It is difficult to prevent flies from gaining access to animal dung, which is an ideal breeding source. Preventing access to human excrement may be easier, but would require the provision of more disposal facilities of greater efficacy (e.g., ventilated improved pit latrines). This measure, which would not only protect against flies but interrupt other routes of transmission, has been reviewed elsewhere (24). Refuse disposal, composting, and garbage treatment may be helpful, but require community participation, constant attention, and resources that are unavailable in the areas that are most in need.

Recent biological measures offer some potential for controlling fly populations because a number of natural predators attack eggs, larvae, pupae, or adult flies. For instance, ants will attack eggs, larvae, pupae, and newly emerged flies, and may destroy up to 90% of the potential fly population in garbage cans (55). Beetles and birds will attack larvae, pupae, and flies. Parasitoids, such as wasps and beetles, attack pupae and larvae. Some microorganisms may act as larvicides; for instance, Bacillus thuringiensis when applied to animal excrement will act as a larvicide. Biological measures attack breeding sites and would be of little use in developing areas, owing to the ubiquitous breeding sites and the need for a high level of technical expertise and well-organized community participation. It is important to preserve naturally occurring enemies of flies such as ants.

Light traps tend to lure blow flies rather than houseflies, and their effectiveness depends on temperature and location (15).

Insecticidal measures were the method of choice 40 years or more ago when DDT and other chlorinated hydrocarbons were effective in controlling flies and mosquitos. Six different types of insecticidal preparation were available and are still used in some areas. Some methods, when effective, pose additional problems.

Larvicides have comprised hydrocarbons, organophosphorus compounds, or, more recently, insect development inhibitors, in the form of an emulsion, a suspension, or a solution. The drawbacks of larvicides are that they need to be applied regularly to affected sites and must penetrate deep into the breeding medium to be effective. In addition, the development of resistance to the toxin may limit their effectiveness after a certain time, and they may kill off natural predators and parasitoids.

Residual sprays can be very effective unless resistance to the toxins has developed. When effective, the compounds can initially achieve a large reduction in the fly population, but their residual effect varies according to temperature, the dosage applied, the surface sprayed, and the level of resistance. Organophosphorus compounds, pyrethroids, and carbamates have been used, but resistance to these products has limited their effectiveness.

Impregnated materials were developed because flies prefer edges, or narrow surfaces, and ceilings for night resting. Suspended strips, cords or wires can be used in a number of places, are noninvasive, and are less conducive to the development of resistance than residual sprays. The control of flies may take time and depends on location, air currents, and the area covered.

Toxic baits use insecticides in a solution of sugar, sometimes with an attractant. If the solution is mixed with dry material such as sand or corncobs, it can be scattered. Baits can also be formulated as paints. They are usually cheap and resistance develops slowly; however, their effect is localized, and they can be toxic to mammals.

Mists, aerial sprays, and fogging provide temporary relief both indoors and outdoors. They are useful only if flies are concentrated around a particular site, and do not have a residual impact. Fumigation by slow release from material impregnated with dichlorvos poses the same problem of resistance and also a risk of contaminating food.

The control of flies is possible. Its effectiveness will depend on the environment, the methods, and the flies. Total elimination and lasting relief are virtually impossible, but some methods will greatly reduce the fly population at least for a short period of time. Repeated application of any solution may not be feasible in most settings; thus, a method with a longer-lasting effect should be sought. The reduction of fly breeding by proper garbage and faecal disposal appears to meet the criteria.

Hypothesis 3: Fly control measures can reduce diarrhoea morbidity or mortality rates among young children.

Twelve studies were located (Table 5) in which the effect of fly control methods on diarrhoeal disease morbidity or mortality was investigated (1, 4, 17, 32, 46, 47, 67, 72, 74-76, 80). Different fly control measures were used in these studies with varying degrees of success, but most studies reported on insecticidal control measures and their effect on diarrhoea morbidity and mortality rates.

The magnitude of the reduction in diarrhoea morbidity was reported in seven studies. It ranged from 0%-67% and the median reduction was 40%. Preschool diarrhoea mortality rates are reported to have dropped by 50% (75), infant diarrhoea mortality by 0%-75% (17), total mortality from 0% (76) to 59% (4), and typhoid deaths by 60% (72). Reductions of this magnitude are considerable, and are higher than those associated with improving water supplies and excreta disposal facilities (24), promoting personal and domestic hygiene (26), and promoting food hygiene (23). However, these studies need to be examined in some detail to determine whether fly control was the key factor in the observed morbidity or mortality changes. A brief review of the studies follows.

Sanitary control measures

Two studies at the beginning of the century examined the effect of sanitary measures (4, 72); both were in the USA and both reported positive results. In New York (4), it was reported that the targeted group had less diarrhoea than the untargeted group. The sanitary measures in the targeted area included: an educational campaign; screening; fly trapping and swatting; cleaning of streets, tenements, yards, and stables; and keeping children indoors most of the time. Infant feeding practices, however, favoured the targeted group, in which more infants were exclusively breast-fed, whereas in the comparison group a higher proportion of infants were bottle-fed or exclusively fed solids.

A study in Florida (72) examined the screening of privies and hospital rooms where typhoid patients were being treated, and the use of sticky paper (or poison) to kill flies. Although reductions in typhoid deaths were associated with these fly control measures, it is not at all clear what effect migration had on these deaths. The year before the measures were taken, a large number of people entered the study area, increasing the typhoid rates. No mention was made of the movement of people during the fly control study, nor of other factors that might have played a role in reducing disease rates.

Sanitary and insecticidal measures

Two studies in Egypt examined the combined role of sanitary and insecticidal control measures. In the first study (1), household and street refuse was transported to dumps, where bulldozers buried it under soil. In addition, dumps, garbage disposal areas, animal housing, hospitals, food factories, and streets were treated with chemicals. Too few data were presented to allow actual reduction rates to be calculated, but the diarrhoea rates appeared to be similar to those in the year prior to treatment. No information was presented on other factors that might have changed over the year of comparison. The second study (76) may have failed to find positive effects because the intervention measures, which included more than fly control, still left the living and sanitary situation in a deplorable condition. Thus, the intervention(s) may have been insufficient to produce any effects. In addition, potential confounding factors were not controlled in the analysis.

Insecticidal measures

The remaining studies examined insecticidal control measures, all of which were undertaken 20 to 40 years ago. In most instances DDT was the insecticide chosen, but chlordan, benzene hexachloride, dieldrin, or toxic baits composed of trichlorfon were also used.

Table 5. Studies on fly control and its effect on diarrhoea morbidity or mortality

Country	Intervention/ type of control	Health indicator	Age in months	Reported results	Flaws[+]	Comments	Reference
Egypt	Sanitary + insecticidal	Dysentery	All	Yes	1,5,6	Typhoid, paratyphoid, and ophthalmia also declined. No information given about confounding factors or other control measures; results unclear.	1
Egypt	Sanitary + insecticidal	Total mortality	0-59	0%	2,4,6	Fly control was one of several interventions; none was effective. Study was flawed in several important ways.	76
Finland	Insecticidal	Diarrhoea	0-11	19%	2,3,5, 6	Breast-feeding probably accounted for the differences in diarrhoea	80
Finland	Insecticidal	Diarrhoea	All	0%	1,3,5, 6	Diarrhoea clustered around shops selling contaminated milk.	32
India	Insecticidal	Diarrhoea	0-59	67%	2,6	61% reduction in flies. Fly and diarrhoea rates moved in opposite directions for 2 years.	46
India	Insecticideal	Diarrhoea	0-59	40%	6	Possible differences attributable to avoidance of dirty area and not baits.	67
Italy	Insecticidal	Diarrhoea mortality	0-11	0-75%	2,5,6	Mortality rates also fell in the control area following spraying; malaria was also prevalent and could explain the results.	17
USA	Sanitary	Typhoid deaths	All	60%	1,5,6	Immigration was associated with an increase in typhoid deaths before control measures began; no mention of migration during the year of reduction.	72
USA	Sanitary	Diarrhoea Total mortality	0-59	64% 59%	2,5,6	Breast-feeding accounted for the largest differences in reductions.	4
USA	Insecticidal	Diarrhoea Diarrhoea mortality Non-diarrhoea mortality	0-59	42% 50% 0%	5,6	The periods of comparison were not always the same; fly counts and diarrhoea rates did not always move in the same direction.	75

USA	Inseciticidal	Shigella Salmonella Diarrhoea incidence	0-59	40% 0% 37%	5,6	At times fly counts and diarrhoea rates moved in opposite directions. The periods of comparison were not always the same.	47
USSR	Insecticidal	Dysentery	All	40%	1,6	The effect was not found for all species of Shigella, and sanitary measures followed the use of DDT.	74

+See Blum D & Feachem RG (1983) for a detailed discussion of the following flaws:

1 - No comparison group
2 - One-to-one comparison
3 - No baseline data
4 - Intervention failed or was not effective
5 - Measurement biases in respect of health indicator
6 - Potential confounding not controlled (e.g., age, season, or other routes of transmission)

Poisonous baits

Two studies in India used poisonous baits. In one study, small earthen dishes with toxic bait were placed in dirty areas in the home (67). Health education was also provided and, as a result, children avoided contact with the baits. Because the baits were placed in dirty areas, it is possible that the change in behaviour resulting from the health education (avoidance of dirty areas) rather than the fly control effect was responsible for the reductions in diarrhoea morbidity. It is also possible that families that used the baits correctly had an interest in health and also took other measures to prevent diarrhoea. Thus these results remain inconclusive. In the other study in India that utilized poisonous baits, diarrhoea rates rose while fly indices remained unchanged, and fell when fly indices rose (46). The baseline figures reflected the same erratic pattern between diarrhoea and flies, suggesting the absence of a relationship.

Spraying (DDT)

Six additional studies, mostly conducted in the late 1940s and early 1950s, examined the effect of DDT. One study was in the USSR (74), two were in the USA (47, 75), two were in Finland (32, 80), and one was in Italy (17). Several of these studies reported that flies developed resistance to the insecticide, which often necessitated switching to another product.

In the USSR, the use of DDT was associated with a sharp reduction in fly counts (80%) as well as in the incidence of dysentery (40%) over a two-year period (74). No control group was used in the study. Only the situations before and after treatment were used for comparison. Secular trends could well have accounted for part of the declines reported, since rates of disease tend to vary from year to year even without any intervention. This was evident in the two studies carried out in the USA.

In Texas, diarrhoea morbidity and mortality rates among children less than 5 years old were observed in two groups of towns that received DDT spraying at different times (75). DDT controlled the fly population and no resistance developed during the study. Five towns (group A) were sprayed with DDT from March 1946 to September 1947, at which time the four untreated towns (group B) began receiving DDT treatment, and the spraying in group A towns was terminated.

The fly control efforts were reported to be effective, as measured by grill counts. When the group A towns were treated, children under 5 experienced 38% less diarrhoea than similar children in the group B towns. When treatment was reversed, children in the group B towns had 46% less diarrhoea than those in the group A towns. The reported diarrhoea death rates among children under 2 years of age revealed that diarrhoea deaths were always lower in the treated towns when deaths due to other causes did not change.

Despite this seemingly convincing evidence, it should be noted that the diarrhoea attack rates did not always change in the same direction as the fly population levels. An epidemic appeared in both treated and untreated groups during the spraying of the group A towns; this resulted in higher diarrhoea rates in both groups during spraying. Thus, the reductions in the diarrhoea rates may have resulted in part from changes of a seasonal or other nature from year to year.

In Georgia, DDT was used to control the fly population while diarrhoea incidence rates and the prevalence of Shigella infections were observed among children less than 10 years of age (47). Three treatment towns surrounding the control towns received DDT spraying until resistance developed, when dieldrin was substituted in two towns and chlordane in the other. The investigators reported that fly control efforts were effective in reducing the prevalence of Shigella infection and diarrhoeal disease morbidity, but not the prevalence of Salmonella infection. For Shigella infection a net reduction of 40% was reported, and for all diarrhoea a reduction of 37%. During treatment, Shigella infection rates fell compared with previous levels, but returned to their pre-treatment levels when resistance to the insecticides developed. In the untreated area, infection rates also dropped at the time the other area was treated, but remained low when treatment stopped. The diarrhoea rates during treatment could not be compared with pre- or post-treatment rates because the data were presented for different seasons.

Two studies in Finland examined the effect of DDT spraying on diarrhoea rates (32, 80). Both reported a lack of effect. In one of the studies fly control was effective, but diarrhoea rates were unchanged (32); diarrhoea cases were also reported to be clustered around shops selling contaminated milk, and the fly control area was located around these shops. In the other study, a 19% reduction in diarrhoea was reported, but the difference was not statistically significant (80). Neither study described how diarrhoea was measured or controlled for possible confounding factors.

The study in Italy also examined the effect of DDT spraying over 5 years, 1946-1950 (17). Because resistance developed, DDT was supplemented with Octo-Klor in the last three years of the study. The author reported that infant mortality due to gastroenteritis declined by up to 75% or increased 143% depending on the year of the study and whether or not flies became resistant to the insecticides. How infant mortality was measured was not stated, and the results may well have been affected by malaria, which was present in the area, and by the sanitary efforts that were promoted by the health authorities.

In the studies that examined insecticidal spraying, the drop in fly counts was usually related to a reduction in diarrhoea morbidity and/or mortality, but not always. However, this method of fly control was only effective for a limited time, and could not be used today for reasons of resistance, environmental contamination, and health hazards. It was not determined whether other changes related to the intervention, but not to fly control, occurred.

The results described above and presented in Table 5 are equivocal. Although the majority of the studies reported positive changes, they should be interpreted with caution. All of the studies suffered from major methodological flaws, which diminish the plausibility of the reported results. The methodological problems include: lack of baseline data, lack of a comparison group, and differences between groups in risk factors for transmission, such as feeding mode, source of water, hygiene practices, age distribution, seasonality, and education. Measurement biases, such as reliance on the disease outcome reported at and by clinics, were not addressed. As behaviour changed in some instances as a result of the intervention, that factor, and not fly control, may have been the effective component of the intervention. At times, reductions in fly counts preceded changes in morbidity and mortality rates, but the reverse also occurred. Although fly counts were often reduced, a search for pathogens on or in flies was not carried out. Such confirmation is not essential, but would have helped to increase the plausibility of the findings. These problems suggest that the reported impacts may well have been a result of factors independent of fly control efforts. Because diarrhoeal diseases are multifactorial, each agent being transmitted by more than one route, it is unlikely that flies would have such a large effect as reported in these studies.

CONCLUSIONS

Flies have been implicated as vectors of disease for thousands of years. Flies caught in the wild have been found to harbour pathogens, and they can spread those pathogens to human food and drink under controlled conditions. The majority of the epidemiological studies reviewed have associated flies with diarrhoeal diseases, and a 40% median reduction of diarrhoea morbidity has been reported from seven intervention studies, six of which used insecticidal control measures. However, most of these studies were done either early in the century or were completed over 25 years ago, and in many cases they are difficult to interpret because of methodological flaws, such as uncontrolled confounding, failure to include an appropriate control group, and measurement biases.

Due to the flaws in the studies, it is difficult to implicate flies as significant vectors of diarrhoeal diseases among young children. Although flies may transmit diarrhoea, it is unlikely that they are a major route for the transmission of enteric pathogens. Other transmission routes operate throughout the year, and flies are not present in significant numbers all the year round. Furthermore, the correlation of flies with the hottest time of the year does not indicate that they are responsible for diarrhoea, since bacteria also survive better in warmer seasons.

Long-term, environmentally safe fly control is difficult to achieve and sustain. Effective methods for short-term control, which involve the use of insecticides, are unsafe for humans and other animals. The available evidence suggests that fly control is not feasible in many settings and that, even if it can be successfully implemented, it is not a cost-effective intervention for national diarrhoeal disease control programmes.

ACKNOWLEDGEMENTS

The author would like to thank P. Echeverria, I. de Zoysa, R. Feachem, B. Greenberg, J. Keiding, J. Martines, and M. Merson for contributing to and reviewing the paper. R. Feachem was particularly helpful in the early stages in organizing the paper and providing references. Secretarial assistance was provided by S. Kraut and S. Au-Yeung, and translation into the Italian was assured by S. Miniachi.

REFERENCES

1. Abdel-Gawaad AAW, El-Gayar, FH. House fly control in Alexandria City and its effect on the prevalence of certain summer diseases. Zeitschrift fuer angewandte Entomologie 71:44-52 (1972).

2. Akmammedov, D. Concerning the epidemiology of dysentery in Ashkhabad. Report I. Dynamics of morbidity and etiology. Zhurnal Mikrobiologii Epidemiologii i Immunobiologii 47:21-25 (1970).

3. Anjaneyulu G, Banerji SC, Indrayan A. A study of fly density and meteorological factors in occurrence of diarrhoea in a rural area. Indian Journal of Public Health 19:115-121 (1975).

4. Armstrong, DB. An investigation into the relationship of the house fly to disease - the special importance of the fly in infant welfare. American Journal of Public Health 4:185-196 (1914).

5. Ashworth A, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: prevention of low birthweight. Bulletin of the World Health Organization 63:165-184 (1985).

6. Ashworth A, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: Improving lactation. Unpublished document CDD/85.2. Geneva, World Health Organization (1985).

7. Ashworth A, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: growth monitoring programmes. Unpublished document CDD/86.1. Geneva, World Health Organization (1986).

8. Ashworth A, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: weaning education. Bulletin of the World Health Organization 64:1115-1127 (1986).

9. Bahr PH. A study of epidemic dysentery in the Fiji islands, with special reference to its epidemiology and treatment. British Medical Journal 1:294-296 (1914).

10. Bidawid SP, Edeson JFB, Ibrahim J, et al. The role of non-biting flies in the transmission of enteric pathogens (Salmonella species and Shigella species) in Beirut, Lebanon. Annals of Tropical Medicine and Parasitology 72:117-121 (1978).

11. Blum D, Feachem RG. Measuring the impact of water supply and sanitation investments on diarrhoeal diseases: problems of methodology. International Journal of Epidemiology 12:357-365 (1983).

12. Bruch HA, Ascoli W, Scrimshaw NS, et al. Studies of diarrheal disease in Central America. V. Environmental factors in the origin and transmission of acute diarrheal disease in four Guatemalan villages. American Journal of Tropical Medicine and Hygiene 12:567-579 (1963).

13. Brygoo, ER, Sureau P, Le Noc P. Virus et germes fécaux des mouches de l'agglomération urbaine de Tananarive. Bulletin de la Societé de Pathologie Exotique 5:866-881 (1962).

14. Chatterjee BD, Hati AK, Tandon N. Fly borne Vibrio parahaemolyticus in Calcutta. Tropical and Geographical Medicine 30:499-503 (1978).

15. Clough G. The comparative efficiencies of some commercially available insect-electrocuting devices. International Pest Control 22:4-6 (1980).

16. Coleman PJ, Maier PP. Investigation of diarrhea in a migrant labor camp. Public Health Reports 71:1242 (1956).

17. Corbo S. La mosca domestica principale responsabile della mortalita infantile per malattie gastroenteriche. Rivista di Parassitologia 12:37-45 (1951).

18. Cox GL, Lewis FC, Glynn EE. The number and varieties of bacteria carried by the common house fly in sanitary and insanitary city areas. Journal of Hygiene 12:290-312 (1912).

19. de Zoysa I, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: rotavirus and cholera immunization. Bulletin of the World Health Organization 63:569-583 (1985).

20. de Zoysa I, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: chemoprophylaxis. Bulletin of the World Health Organization 63:295-315 (1985).

21. Dipeolu OO. Field and laboratory investigations into the role of the Musca species in the transmission of intestinal parasitic cysts and eggs in Nigeria. Journal of Hygiene, Epidemiology, Microbiology, and Immunology 21:209-214 (1977).

22. Echeverria P, Harrison BA, Tirapat C, et al. Flies as a source of enteric pathogens in a rural village in Thailand. Applied and Environmental Microbiology 46:32-36 (1983).

23. Esrey SA, Feachem RG. Interventions for the control of diarrhoeal diseases among young children: promotion of food hygiene. Unpublished document WHO/CDD/89.30. Geneva, World Health Organization (1989).

24. Esrey SA, Feachem RG, Hughes JM. Interventions for the control of diarrhoeal diseases among young children: improving water supply and excreta disposal facilities. Bulletin of the World Health Organization 63:757-772 (1985).

25. Feachem RG. Interventions for the control of diarrhoeal diseases among young children: supplementary feeding programmes. Bulletin of the World Health Organization 61:967-979 (1983).

26. Feachem RG. Interventions for the control of diarrhoeal diseases among young children: promotion of personal and domestic hygiene. Bulletin of the World Health Organization 62:467-476 (1984).

27. Feachem RG. Interventions for the control of diarrhoeal diseases among young children: promotion of breastfeeding. Bulletin of the World Health Organization 62:271-291 (1984).

28. Feachem RG. Vitamin A deficiency and diarrhoea: a review of interrelationships and their implication for the control of xerophthalmia and diarrhoea. Tropical Diseases Bulletin 84:R1-R12 (1987).

29. Feachem RG, Hogan RC, Merson MH. Diarrhoeal disease control: reviews of potential interventions. Bulletin of the World Health Organization 61:637-640 (1983).

30. Feachem RG, Koblinsky MA. Interventions for the control of diarrhoeal diseases among young children: measles immunization. Bulletin of the World Health Organization 61:641-652 (1983).

31. Floyd TM, Cook BH. The housefly as a carrier of pathogenic human enteric bacteria in Cairo. Journal of the Egyptian Public Health Association 28:75-85 (1953).

32. Gorbatow O. The water, milk and fly hygiene and their relations to summer diarrhea in a country district. Nordisk Hygienisk Tidskrift 225-239 (1951).

33. Greenberg B. Experimental transmission of Salmonella typhimurium by houseflies to man. American Journal of Hygiene 80:149-156 (1964).

34. Greenberg, B. Flies and disease. Vol II. Princeton University Press (1973).

35. Greenberg B, Kowalski JA, Klowden MJ. Factors affecting the transmission of Salmonella by flies: natural resistance to colonization and bacterial interference. Infection and Immunity 2:800-809 (1970).

36. Gromov AI, Zvyagina RL, Knyazeva NV, et al. Significance of flies for dysentery in Sakhalin. Zhurnal Mikrobiologii Epidemiologii i Immunobiologii 45:104-105 (1966).

37. Gross H, Preuss U. Infektionsversuche an fliegen mit darmpathogenen Keimen. I. Versuche mit typhus paratyphusbakterien. Zentralblatt fuer Bakteriologie, I. Abteilung Originale 156:371-377 (1951).

38. Gupta SR, Rao CK, Biswas H, et al. Role of the house-fly in the transmission of intestinal parasitic cysts/ova. Indian Journal of Medical Research 60:1120-1125 (1972).

39. Harris AH, Down HA. Studies of the dissemination of cysts and ova of human intestinal parasites by flies in various localities on Guam. American Journal of Tropical Medicine 26:789-800 (1946).

40. Hawley JE, Penner LR, Wedberg SE, et al. The role of the house fly, Musca domestica, in the multiplication of certain enteric bacteria. American Journal of Tropical Medicine 31:572-582 (1951).

41. Ingram RL, Larsen JR, Pippen WF. Biological and bacteriological studies on Escherichia coli in the housefly, Musca domestica. American Journal of Tropical Medicine and Hygiene 5:820-830 (1956).

42. Kasprzak W, Majewska A. Transmissions of Giardia cysts. I. The role of flies and cockroaches. Wiadomosci Parazytologiczne 27:555-563 (1981).

43. Keiding J. The housefly. Training and information guide. Unpublished document WHO/VBC/86.937. Geneva, World Health Organization (1986).

44. Kotenok YF, Chicherin YV. Domestic flies (M. domestica L.) as vectors of cholera causative agent. Zhurnal Mikrobiologii Epidemiologii i Immunobiologii 12:23-26 (1976).

45. Kuhns DM, Anderson TG. A fly-borne bacillary dysentery epidemic in a large military organization. American Journal of Public Health 34:750-755 (1944).

46. Kumar P, Singh R, Sehgal BS. Fly control and diarrhoeal morbidity in a rural community in U.P. Indian Journal of Medical Sciences 24:285-291 (1970).

47. Lindsay DR, Stewart WH, Watt J. Effect of fly control and diarrhoeal disease in an area of moderate morbidity. Public Health Reports 68:361-367 (1953).

48. Melnick JL, Dow RP. Poliomyelitis in Hidalgo County, Texas, 1948. Poliomyelitis and coxsackie viruses from flies. American Journal of Hygiene 58:288-309 (1953).

49. Melnick JL, Penner LR. The survival of poliomyelitis and coxsackie viruses following their ingestion by flies. Journal of Experimental Medicine 96:255-271 (1952).

50. Moorehead S, Weiser HH. The survival of staphylococci food poisoning strain in the gut and excreta of the house fly. Journal of Milk and Food Technology 9:253-259 (1946).

51. Morison J, Keyworth WD. Flies and their relation to epidemic diarrhoea and dysentery in Poona. Indian Journal Medical Research 3:619-627 (1916).

52. Oyerinde JPO. The role of the housefly (Musca domestica) in the dissemination of hookworm. Annals of Tropical Medicine and Parasitology 70:455-462 (1976).

53. Parisot J, Fernier L. The best methods of treating manure-heaps to prevent the hatching of flies. Bulletin of the League of Nations Health Organization 3:1-31 (1934).

54. Paul JR, Trask JD, Bishop MB, et al. The detection of poliomyelitis virus in flies. Science 94:395-396 (1941).

55. Pimentel D, Uhler L. Ants and the control of houseflies in the Philippines. Journal of Economic Entomology, 62:248 (1969).

56. Pipkin AC. Experimental studies on the role of filth flies in the transmission of Endamoeba histolytica. American Journal of Hygiene 49:255-275 (1949).

57. Radvan R. Persistence of bacteria during development in flies. I. Basic possibilities of survival. Folia Microbiologica 5:50-57 (1960).

58. Radvan R. Persistence of bacteria during development in flies. II. The number of surviving bacteria. Folia Microbiologica 5:85-91 (1960).

59. Radvan R. Persistence of bacteria during development in flies. III. Localization of the bacteria and transmission after emergence of the fly. Folia Microbiologica 5:149-155 (1960c).

60. Rao CK, Krishnaswami AK, Gupta SR, et al. Prevalence of amoebiasis and other intestinal parasitic infections in a selected community. Indian Journal of Medical Research 59:1365-1373 (1971).

61. Rendtorff RC, Holt, CJ. The experimental transmission of human intestinal protozoan parasites. III. Attempts to transmit Entamoeba coli and Giardia lamblia cysts by flies. American Journal of Hygiene 60:320-326 (1954).

62. Richards CS, Jackson WB, DeCapito TM, et al. Studies on rates of recovery of Shigella from domestic flies and from humans in southwestern United States. American Journal of Tropical Medicine and Hygiene 10:44-48 (1961).

63. Root FM. Experiments on the carriage of intestinal protozoa of man by flies. American Journal of Hygiene 1:131-153 (1921).

64. Rosef O, Kapperud G. House flies (Musca domestica) as possible vectors of Campylobacter fetus subsp jejuni. Applied and Environmental Microbiology 45:381-383 (1983).

65. Round MC. Observations on the possible role of filth flies in the epizootiology of bovine cysticercosis in Kenya. Journal of Hygiene 59:505-513 (1961).

66. Schliessmann DJ, Atchley FO, Wilcomb Jr. MJ, et al. Relation of environmental factors to the occurrence of enteric disease in areas of Eastern Kentucky. Public Health Monograph No. 54 (1958).

67. Sehgal BS, Kumar P. Seasonal fly control through baiting in rural areas. Indian Journal of Public Health 14:116-120 (1970).

68. Shimizu F, Hashimoto M, Taniguchi H, et al. Epidemiological studies on fly-borne epidemics. Report I. Significant role of flies in relation to intestinal disorders. Japanese Journal of Sanitary Zoology 16:201-211 (1965).

69. Spotarenko SS, Tikhomirova ED, Kikodze SL. Assessment of the role played by flies in the epidemiology of dysentery and epidemic hepatitis. Zhurnal Mikrobiologii Epidemiologii i Immunobiologii 46:43-48 (1969).

70. Stiles CW, Keister WS. Flies as carriers of Lamblia spores. The contamination of food with human excreta. Public Health Reports 28:2530-2534 (1913).

71. Takeuchi T, Mori I, Maeda M. Studies on the persistency of bacteria in flies and the quantity of bacteria transmitted. Japanese Journal of Sanitary Zoology 17:226-231 (1966).

72. Terry CE. Fly-borne typhoid fever and its control in Jacksonville. Public Health Reports 28:68-73 (1913).

73. Ullmann U, Kischkel S. Survival of Campylobacter species. Infection 9:210 (1981).

74. Vasiliev LV. The incidence of dysentery and the change of etiological structure of this disease linked with meteorological conditions and the fly population. Zhurnal Mikrobiologii Epidemiologii i Immunoubiologii 47:28-35 (1970).

75. Watt J, Lindsay DR. Diarrheal disease control studies. I. Effect of fly control in a high morbidity area. Public Health Reports 63:1319-1334 (1948).

76. Weir JM, Wasif IM, Hassan FR, et al. An evaluation of health and sanitation in Egyptian villages. Journal of the Egyptian Public Health Association 27:55-115 (1952).

77. Wolff HL, van Zijl WJ, Roy M. Houseflies, the availability of water, and diarrhoeal diseases. Bulletin of the World Health Organization 41:952-959 (1969).

78. Wright EP. The isolation of Campylobacter jejuni from flies. Journal of Hygiene 91:223-226 (1983).

79. Yao HY, Yuan IC, Huie D. The relation of flies, beverages, and well water to gastro-intestinal diseases in Peking. National Medical Journal of China 15:410-418 (1929).

80. Ylppö A, Hallman N, Donner M, et al. The role of insects in the spreading of infantile diarrhea in Finland. Annales Medicinae Internae Fenniae 39:149-150 (1950).

81. Zincenko VS, Nestervodskaja EM. The fly factor in seasonal increase in incidence of dysentery. Zhurnal Mikrobiologii, Epidemiologii i Immunobiologii 27:33 (1956).

- - -