ALTERNATIVES TO CONVENTIONAL INSECTICIDES FOR URBAN VECTOR AND PEST CONTROL

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INTRODUCTION

The Target Species and the Need for Alternatives

The predominant mosquito in tropical urban areas is *Culex quinquefasciatus* which breeds in polluted water in wet pit latrines, imperfectly sealed cess pits, blocked or slowly flowing open drains and polluted marshy ground (Curtis and Feachem, 1981). It is the main vector of Bancroftian filariasis (which leads to elephantiasis) in India, Myanmar (Burma), urbanised areas on the East African coast and north east Brazil. It is also the main nuisance mosquito in most tropical towns – biting rates of one per person per minute throughout the night have been recorded. This mosquito has never responded well to the residual house spraying method, apparently because of natural tolerance to DDT, evolved resistance to organophosphates and a tendency to rest on hanging clothing etc., rather than on walls or ceilings. It has been well controlled in the past by spraying organophosphates in breeding sites, but there is now widespread resistance. This does not completely prevent the killing of larvae, but means that after a week or two of dilution and decay the insecticide residue can no longer kill the larvae (Curtis *et al.*, 1983). In the absence of much longer residual effectiveness, spraying programmes are unaffordable in most tropical countries.

Malaria is predominantly a rural disease because the larvae of its *Anopheles* vectors cannot tolerate polluted water. However, in the suburbs around many African cities *Anopheles gambiae* penetrates (Trape and Zoulani, 1987) especially where there are marshy patches or cultivation with irrigation. In India, *Anopheles stephensi* is able to breed in water tanks and to maintain transmission even in areas where rural malaria has been largely eradicated by residual house spraying (Sharma and Mehrotra, 1986). This method is unpopular with residents of houses with painted walls, or who have believed lurid accounts in the media of the supposed dangers of insecticides, or who are dissatisfied with the inability of house spraying to deal with nuisance *Culex* mosquitoes.

Aedes albopictus and *Ae. aegypti*, the main vectors of dengue, have been allowed to invade or re-invade many parts of the Americas from which they were absent or had been eradicated and have continued to be a problem in South East Asia (Chan *et al.*, 1991). Aerial spraying against adults appears to be inappropriate in the Americas where adult mosquitoes hide in tightly closed houses (Reiter 1991) and larviciding or elimination of breeding sites in domestic water pots, discarded tyres etc. is ineffective (Gratz, 1993) unless rigorously applied as in Cuba (Tonn *et al.*, 1982; Knudsen, 1983).

Mechanical transmission of pathogens without a biological cycle of development inside the vector has tended to be under-emphasised. However, there is compelling evidence that houseflies play a significant role in the transmission of diarrhoea due to *Shigella* (Watt and Lindsay, 1948; Lindsay *et al.*, 1953; Levine and Levine, 1991; Cohen *et al.*, 1991). This evidence comes from monitoring the effects on incidence of *Shigella* diarrhoea of intensive fly suppression in some communities, in comparison with the incidence in untreated communities. In many tropical and sub-tropical countries, diarrhoea is an even more important cause of child mortality than malaria: in many of these areas houseflies may be the most important vector species. Tropical and subtropical food markets are notoriously infested with multi-resistant strains of housefly. It seems possible that *Chrysomya putoria* blowflies which breed in latrines and enter kitchens may also be involved in transmission of gut pathogens (Brygoo *et al.*, 1962).

The possible contribution of insects, especially bedbugs (*Cimex spp.*) and stable flies (*Stomoxys spp.*) in the transmission of Hepatitis B and HIV has been much discussed (e.g. Zuckerman, 1977;

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Miike, 1987; Brandner *et al.*, 1992). The most convincing evidence on such questions comes from carefully monitored intervention trials. A recent trial in The Gambia on intensive bedbug control using pyrethroids showed no impact on rate of sero-conversion of children to Hepatitis B positivity (Lindsay, 1992). Since HIV is a more fragile virus than Hepatitis B, it seems unlikely that insect control has any significant role in stemming the AIDS pandemic.

Non-insecticidal control of *Culex quinquefasciatus* mosquitoes

A five year programme of *Cx quinquefasciatus* control in Pondicherry in South India showed a dramatic reduction in population of the mosquito and some reduction of the prevalence of chronic filariasis infection, especially in children born after vector control began (Rajapopalan *et al*, 1991). Insecticide was used in soakage pits, but non-insecticidal methods were also employed, such as the filling in of an extensive sewage "lagoon", drain cleaning and attempts to enforce bye-laws against allowing water to stagnate on unoccupied building plots etc.

In the town of Makunduchi, Zanzibar, there was a prevalence of almost 50% of microfilariae of *W. bancrofti*, with much elephantiasis. Swollen scrotum due to filariasis was the largest single cause of admission to the male ward of the local hospital. There were found to be 1700 pit latrines and unsealed cess pits in the town, 550 of which contained water for all or part of the year, but there were no drains, and puddles and marshes only existed for a few weeks at the height of the rainy season. The overwhelming majority of the mosquitoes coming into bedrooms were *Cx quinquefasciatus*, and 2.4% were found to be carrying infective stage filarial larvae (Maxwell *et al.*, 1990).

When water is confined within four walls, floating layers of expanded polystyrene beads are a long lasting way of suffocating mosquito larvae and inhibiting egg laying (Reiter 1978). After collecting a year of baseline data on mosquitoes entering bedrooms, all 550 potentially, or actually, mosquito-infested wet pits were treated with a total of about a tonne of polystyrene beads which had been expanded in boiling water in cooking pots. The consequence, over the following year, was a 98% reduction in number of mosquitoes entering bedrooms (Table 1, based on Maxwell *et al.*, 1990). In the first three years after application, 1988-91, the beads persisted in all treated pits. However, during that time about 200 new, or newly wet, pits have required treatment and, in 1992, there was exceptional flooding in part of the town which washed beads away and required re-treatment of about 30 pits. This emphasises the point that open sites, subject to flow or flooding, would be unsuitable for the polystyrene method.

We were unwilling to wait for the dying out of long-lived filarial worms and therefore, shortly before the polystyrene campaign, we organised mass treatment of all 12,000 people in Makunduchi with di-ethyl carbamazine, through the local government system. This immediately lowered the microfilarial infection rate and density in the human population (Table 2, based on Maxwell *et al.*, 1990) and this fed through to the mosquito population whose infective rate dropped to 0.4%. This reduction, coupled with the reduction in mosquito population density shown in Table 1, led to an

Table 1 Number of bites/person in Makunduchi, Zanzibar, before and after treatment of all 550 wet pit latrines with polystyrene beads in April-June 1988. The data are based on light trapping in bedrooms calibrated to give estimated numbers of bites (Lines et al., 1991).

	Estimated no. bites/person	
Months	'87-'88	'88-'89
May–June	8188	—
July–Sept	7659	174
Oct–Dec	4182	9
Jan–Feb	2548	58
Mar–Apr	2415	176
May–June	—	22
Whole year	24,992*	439

*In 1987 2.4% of biting mosquitoes contained infective stage filarial larvae; this declined to 0.4% after mass DEC treatment of the human population.

Table 2 Microfilarial prevalence and density in Makunduchi, Zanzibar before and after intervention with DEC and polystyrene beads in 1988.

	Before	1-6 mo. after	9–11 mo. after	3 yrs after	4 yr 9 mo. after
% +ve for mf	49.5	10.5	9.4	9.1	3.1
Geom. mean mf/100 µl in +ves	30.2	3.8	3.6	2.4	3.3
no. sampled	655	669	646	66	223

overall reduction in transmission of 99.7%. Without any further drug treatment the infection rate in the human population has continued to decline to 3.1% at the most recent survey (Table 2, based on Maxwell *et al.*, in prep.). Our comparative study of what happens with drug treatment without vector control is not yet complete, but we suggest that in Makunduchi one can see the benefit of integrating one round of drug treatment with sustainable vector control to eliminate much of the human infection and then preventing re-infection while the remaining worms die out.

In Egypt, polystyrene beads have been shown to be a more effective and long-lasting method of treating cess pits against *Culex pipiens* larvae, than is the use of oil (Bekheit *et al.*, 1991).

Where there are open breeding sites, in addition to pits, supplementary methods of control are required. In Zanzibar Town and Dar es Salaam, respectively, the larvicidal bacterium *Bacillus sphaericus* (de Barjac and Sutherland, 1990; Ragoonanansingh *et al*, 1992) and the insect growth regulator pyriproxyfen (Suzuki *et al.*, 1984; Chavasse *et al.*, in prep.) are being tested for this purpose to supplement the effect of the treatment of several thousand pits with polystyrene beads in each town.

Control of urban malaria vectors

In the past, drainage of marshy areas in towns and suburbs was extensively used against *Anopheles* breeding. However, more recently the drains have often been neglected and now require re-habilitation. Control of irrigated agriculture and horticulture and accumulations of water on urban building sites may also be necessary. However, bye-laws and municipal campaigns to stop the growing of unirrigated maize and bananas and to cut grass, as supposed anti-*Anopheles* activities, should be abolished or re-directed as they are based on mis-apprehensions about the biology of these mosquitoes.

Polystyrene beads are being used against *An. stephensi* breeding in water tanks in Madras (Chandrahas and Sharma, 1987; Chandrahas, 1990).

The pyrethroid treatment of bednets renders the nets a better method of personal protection than if they are untreated, and also makes them act like traps baited by the carbon dioxide and body odour emitted by the sleeper. This lowers the density and probability of survival to the age at which the mosquitoes can contain mature malarial parasites (Magesa *et al.*, 1991). Numerous projects are now in progress using this method in many parts of the tropical world (Curtis, 1993). The most extensive and successful have been in China and The Gambia where most people already own nets and the cost of treating them with low doses of a pyrethroid is considerably less than spraying the houses with DDT (see data from Sichuan, China in Curtis, 1992). There are two problems with extending this method to the rural areas of Africa: (i) malaria transmission is so intense that even, for example a 95% reduction in numbers of infective bites may leave sufficient to maintain saturating levels of malaria (Lyimo *et al.*, 1991), (ii) subsistence farmers may not be able to afford nets and the present harsh politico-economic climate may forbid subsidies. These problems are not so severe for urban areas because transmission is less intense and people earn money and already spend considerable sums on rather ineffective methods of mosquito control such as aerosol cans of insecticide and mosquito coils (Desfontaine *et al.*, 1990; Zandu *et al.*, 1991). Thus the extension of this method to towns should be effective and feasible.

Pyrethroid impregnated bednets have the welcome side effect of destroying bedbug infestations in the beds on which they are used. Though it now seems unlikely that these insects play a role in Hepatitis B or HIV transmission, it is perhaps too soon to rule this out completely.

Legal and biological control of *Aedes* mosquitoes

The tight social and legal control of *Aedes* breeding sites in stored water and in water-filled tyres and garbage in Cuba and, until recently, Singapore reduced their earlier dengue problems, in contrast to their regional neighbours, where the problem has been increasing.

Temephos ("Abate") has been used in domestic water pots, but some people can taste it and object to it. Partly for this reason a variety of biological agents have been field tested, e.g. (i) the predatory, non-biting mosquito *Toxorhynchites* in New Orleans (Focks *et al.*, 1986), (ii) dragonfly larvae in Yangon (Rangoon) (Sebastian and Corbett in Reuben *et al.*, 1991), (iii) fish in China (Wu Neng and Liao Guohou in Reuben *et al.*, 1991); (iv) tablets of the toxin from the bacterium *Bacillus thuringiensis israelensis* in Indonesia (Becker *et al.*, 1991), (v) the copepod *Mesocyclops* in Brazil (Sleigh *et al.*, 1992).

Fly traps for urban areas

The trial by Cohen *et al.*, (1991) which demonstrated that housefly control reduced the incidence of *Shigella* was conducted using simple traps on the "lobster-pot" principle, baited with a mixture of yeast, ammonium carbonate and water and with a screened panel to admit sunlight (Mer & Paz, 1960; Davidson, 1962).

Chrysomya putoria blowflies breeding in latrines may be trapped with simple "lobster-pot" traps placed over the latrine hole (J. Raybould, pers. comm; Curtis, 1981). Kilograms of flies can be caught in this way. A more sophisticated means of rendering pit latrines fly-free, as well as odourless and therefore more likely to be used, is the Ventilated Improved Pi (Morgan, in Curtis *et al.*, 1991). The essential features are (i) a straight-vertical vent pipe topped by a durable fly screen and (ii) a spiral ground plan so that the latrine building is relatively dark inside. Thus phototropic emerging flies are attracted up the vent pipe but cannot exit because of the screen. Wind shear across the top of the pipe draws air up the pipe so that gravid female flies are attracted there by the odour but cannot enter because of the screen. Placing exit or entry traps on the vent pipe or latrine aperture proved the effectiveness of a well built latrine of this type (Curtis and Hawkins, 1981) and they are popular with users and householders.

CONCLUSION

There are a number of alternatives to conventional insecticides for urban vector control which have given good results as assessed by simple entomological measures. With the exception of the examples mentioned there is as yet insufficient evidence for their effectiveness against disease transmission. Thus there is need to set up extensive intervention trials to evaluate to what extent these attractive methods really have benefits for human communities.

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