The insecticide DDT has been an effective and affordable means of malaria control in many countries, but pressure for its use to be banned is mounting. Here, Chris Curtis and Jo Lines take a critical look at evidence that links house spraying by DDT with harm to the environment and human health, and stress the need for resources for alternatives to DDT to be made available to countries that would be affected by a DDT ban.

The World Wildlife Fund for Nature (WWF) and The United Nations Environment Programme, among others, are pressing to include DDT (dichlorodiphenyltrichloroethane) in the proposed treaty to ban persistent organic pollutants. They consider that there is sufficient evidence that DDT is harmful to the environment and/or human health and that the imminence of a ban would stimulate the development of alternatives to DDT. Many malariologists, however, argue that the evidence that house spraying with DDT is harmful is not very convincing, and that, in many areas, such spraying has been the only affordable means of controlling malaria (and visceral leishmaniasis where it is transmitted by endophilic sandflies). Countries that use or might use DDT have very low health budgets and, without providing the financial and other resources to replace DDT adequately, a DDT ban would endanger human health by causing further contraction in the already small proportion of the world’s malarious areas in which there is any vector control.

DDT and vector control

Ninety percent of worldwide malaria morbidity and mortality occurs in tropical Africa, but there has been little mosquito control there in recent years. The few African countries with house-spraying programmes include Ethiopia, Zimbabwe, Botswana, South Africa and the highlands of Madagascar (see Table 1); elsewhere, many relatively small programmes using insecticide-treated nets (ITNs) have been set up in the past decade. During the 1960s and 1970s, some local field trials and pilot campaigns of house spraying in equatorial Africa using DDT or other organochlorines were very successful, for example, in the islands of Zanzibar and Pemba, where malaria transmission is naturally extremely intense; DDT spraying reduced prevalence of malaria parasitaemia to <5%. This was an extraordinary achievement that has not yet been matched by ITNs. It is argued that African countries should not be denied the option of taking up house spraying with DDT, the most affordable insecticide, if, in the future, they can find the resources for it. Apart from South Africa and Madagascar, it is from Asia, Europe and Latin America that there are reliable data showing the impact on vector-borne disease of energetic use of DDT, and, in several cases, the resurgences that have followed its partial or complete withdrawal (Table 1). Presumably, these resurgences are at least partly because the additional costs of using alternatives to DDT necessitated a reduction in the area covered by spraying. In India, partly because of the bad publicity created by the campaign against DDT, the percentage of households allowing spraying of their houses has declined far below that achieved in the heyday of the Malaria Eradication Programme in the 1960s.

How harmful is DDT?

DDT was used in agriculture in the 1950s in far larger quantities than against malaria mosquitoes. In fresh water, it was lethal to fish and it accumulated in food chains and harmed the eggs of attractive top predators such as peregrine falcons. Consequently, DDT has been banned since the 1970s for agricultural use in most countries. However, the extent of harm caused by the use of DDT indoors for malaria control is not clear; in particular, it seems unlikely to be an appreciable source of DDT in food chains and a link between DDT and ill health in humans has not been convincingly demonstrated (Box 1). Who gets the benefit of the doubt?

Proponents of the ban stress the precautionary principle, ie. a biologically active chemical should not be used until it has been proved to be harmless. However, one cannot prove anything to be totally safe as one can never exclude the possibility of unanticipated, rare adverse effects. Opponents of the ban advocate a response based on weighing the known health costs against the known health benefits. This evidence, however, tends to be biased, because the benefits of DDT to malaria control are limited to some parts of the rural tropics, while the risks (if any) may be difficult to measure because they are scattered worldwide. As WWF contends, DDT spreads from inside sprayed houses to the whole ecosystem. Thus, there appears to be a conflict of interest. In all malaria areas, where DDT-spraying remains the most cost-effective and practicable form of control, although human exposure to DDT is relatively high, it seems unlikely that any risks from this will outweigh the benefits of being protected against malaria. Therefore, a precautionary ban on DDT without adequate replacement would leave people in these areas less healthy than before.

However, a precautionary ban would appeal more to people in areas where there is no malaria or no attempt to control it with DDT. They may be exposed to low doses of DDT as a result of house spraying elsewhere, but they envy no antimalaria health benefits from DDT. If billions of people are exposed in this way, adverse health effects that are undetectably rare might still amount to an impressive number of deaths or...
cases of ill health. The conflict of interest surrounding a precautionary ban is sharpened by the fact that the people who would be likely to be harmed by it are poor and powerless while the people who might benefit from it include the rich and influential.

Who will pay for alternatives?

As long as a switch to alternative methods of malaria control does not entail reduction in effectiveness or contraction of the area where vectors are controlled, it would be generally agreed that the switch is desirable on the precautionary principle. Alternative insecticides of the organophosphate, carbamate or pyrethroid groups available for house spraying are more biodegradable than DDT and are equally or more effective.\(^2^{1}\) Switching from spraying DDT to use of pyrethroids is happening successfully in several malarious countries, eg Vietnam, where both ITNs and pyrethroid spraying are used extensively. It is surprisingly hard to pin down the relevant costs of insecticides, but it seems that pyrethroids cost two to three times\(^3\) as much as DDT per house sprayed, given that, in low-income countries, the insecticide represents a larger share of programme costs than spraymen’s wages.

Bio-environmental control of malaria mosquitoes has been studied for almost a century, but there seems little prospect of success against the vector species in Africa and Southeast Asia, where breeding places are generally numerous and small temporary water collections that are difficult to keep track of. Trials in India look more promising and cheap, but need adequate, replicated controlled trials to distinguish the effects of the interventions from the cyclical changes in malaria incidence that occur in India. Remedies such as mosquito-repellent plants and burning cow dung have their advocates, but these methods need to be proved to be effective, not just in reducing biting nuisance, but in suppressing malaria morbidity and mortality in communities in highly endemic areas.

Comparative trials in six countries have shown that when pyrethroid treatment of nets was provided free to whole communities (so that there was high population coverage), this method was as effective as house spraying with pyrethroids or with DDT\(^2\^2\). In Pakistan, malathion spraying was less expensive than provision of bednets and annual re-treatment with the same pyrethroid would be more expensive than provision of bednets, but in Tanzania\(^2\)\(^3\)–\(^2\)\(^6\) treated nets are generally more acceptable to villagers than house spraying but, where there is an epidemic, as in the Madagascan highlands\(^7\) a ‘fire-brigade’ reaction with house spraying is more rapid and better targeted.

To avoid DDT elimination leading to reduced population coverage (the probable effects of which have been illustrated in Table 1), subsidies to cover any additional costs of replacement methods have been advocated by the United Nations Environmental
Box 1. Adverse Effects of DDT:
Examining the Evidence11–13

DDT in food chains
• The long persistence of DDT residues in soil is often emphasized, this is mainly based on data from temperate zones – in Sudan the half-life in soil was found to be only about three weeks.
• A worldwide survey14 of DDT residues and its deriva-
tives suggests that their distribution reflects past or present local agricultural usage and does not fit the distri-
bution theory whereby residues are vaporized in the tropics and deposited in colder areas (which does fit better with the distribution of more volatile organo-
chlorine insecticides).
• Illegal diversion of DDT intended for anti-malaria use to agriculture (which will occur so long as spraymen are paid low wages) might be the source of detectable residues in agricultural products intended for export, which may make them unacceptable to importers. Whether the very low residues detectable by modern analytical equipment are actually harmful to health is not known.
• Because DDT is sprayed on the inside surfaces of houses (especially mud walls), it has seemed unlikely that much would enter outdoor food chains, particularly as sprayed mud walls tend to be replastered. We think that the WWF's conclusion that 60–82% of DDT sprayed on a wall reaches the outside within six months (based only on K. Fellmate, Bachelor's Thesis, Trent University, Ontario, 1998) requires further investigation.

DDT and human health
• The health of spraymen in Brazil and India was similar to that of other men of their age15.
• Earlier claims of DDT carcinogenicity were based on abnormally high DDE (a metabolite of DDT) residues in serum of patients dying of cancer. However, these were probably a consequence of the cancer causing body-washing and hence mobilization of DDE from body fat deposits. A better design of such studies, to detect causes rather than effects of cancer, has been to store numerous serum samples, to wait until some of the subjects develop cancer and then to compare the DDE levels in their stored sera with those of matched controls. One such study found a just significant excess of DDE levels in their stored sera with those of matched controls. A better design of such studies, to detect causes rather than effects of cancer, has been to store numerous serum samples, to wait until some of the subjects develop cancer and then to compare the DDE levels in their stored sera with those of matched controls. One such study found a just significant excess of DDE levels in their stored sera with those of matched controls.
• Abnormally high DDE was found in breast milk of women living in a South African area with anti-malaria spraying, compared with those in another area without spraying16. Whether this is harmful to the babies con-
suming the milk is not known. A negative correlation of time for which mothers lactate and DDE in their milk was reported in the USA17. However, much longer lac-
tation times were reported from rural Belize, where there had been anti-malaria spraying with DDT for many years, than in urban populations in the USA or Belize where there has been no such use of DDT18.
• DDT is claimed to be an oestrogen mimic19 and possibly responsible for declining sperm counts in European men20. However, this decline has continued even though DDT usage is much less than it used to be, and it is very difficult to disentangle which of numerous pollutants might be responsible for the decline.

Programme and the Intergovernmental Forum on Chemical Safety. The World Bank provided $150 million to India to aid the replacement of DDT. A recent expert committee of the WHO emphasized that such subsidies should not be found by diversion from other health programmes. If affluent taxpayers consider that elimination of DDT is a matter of high priority, they, and not subsistence farmers, should be required to foot the bill.

Acknowledgements
We are grateful to Graham White, Donald Roberts and Wei Klama for helpful comments, and to Shiv Lal, Manel Yaibananda, Anatole Kondrackiene, Natalja Nikoleva and Mayra Sojo-Mlano for unpublished data.

References