

Malaria kills over one million people, mainly children, in the tropics each year, and DDT remains one of the few affordable, effective tools against the mosquitoes that transmit the disease. Attaran *et al.* explain that the scientific literature on the need to withdraw DDT is unpersuasive, and the benefits of DDT in saving lives from malaria are well worth the risks.

## Balancing risks on the backs of the poor

Few chemicals stir the feelings of the 'man on the street' quite like DDT (dichlorodiphenyltrichloroethane). Since Rachel Carson's *Silent Spring*, conservationists in rich, developed countries have waged a decades-long campaign, no less persistent than DDT itself, to convince governments and citizens that DDT is an irredeemable pollutant. They have been very successful: Every industrial country, without exception, has ceased using DDT.

However, DDT remains one of the few affordable, effective tools against the mosquitoes that transmit malaria, a plague that sickens at least 300 million and kills over one million, mainly children, in economically underdeveloped areas of the tropics each year. Such a toll is scarcely comprehensible. To visualize it, imagine filling seven Boeing 747s with children, and then crashing them, every day.

Until now, developed countries have grudgingly tolerated the use of DDT against malaria in poor tropical countries; at least 23 countries do so<sup>1</sup>. However, this may now be ending. Led by the United Nations Environment Programme, more than 110 countries are negotiating a treaty to "reduce and/or eliminate...the emissions and discharges" of 12 persistent organic pollutants, citing their "unreasonable and otherwise unmanageable risks to human health and the environment."<sup>2</sup> If it becomes law, the treaty will likely end DDT manufacture, or at least make the supply scarce and unaffordable to tropical countries.

This, in our view and that of nearly 400 colleagues who have signed an open letter to the diplomats negotiating the treaty, is simply dangerous<sup>3</sup>. The scientific literature is unpersuasive of the need to withdraw DDT; on the contrary, it is clear that doing so risks making malaria control ineffective, unaffordable, or both.

### Ecological effects

DDT became emblematic of the toxics movement because of its effects on the non-human environment. Ecological studies have demonstrated that bioaccumulated DDT could cause thinning of eggshells and reproductive failure in birds of prey. The fault for this lies in the massive agricultural use of DDT. Dusting a single 100-hectare cotton field, for example, can require more than 1,100 kg of DDT over 4 weeks<sup>4</sup>.

In contrast, DDT spraying for malaria control is less intensive, less frequent and far more contained. The current practice is to spray the interior surfaces only of houses at risk, leaving a residue of DDT at a concentration of 2 g/m<sup>2</sup> on the walls, ceiling and eaves, once or twice a year. Half a kilogram can treat a large house and protect all its inhabitants. Doubtless some fraction of this escapes to the outdoors, but even assuming it all did, the environmental effect is just 0.04% of the effect of spraying the cotton field. Guyana's entire high-risk population for malaria can be protected with the

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DDT that might otherwise be sprayed on 0.4 km<sup>2</sup> of cotton in a season<sup>5</sup>. Compared with its agriculture uses, public health uses of DDT are too trivial to merit banning with any urgency.

### Tonic...or toxin?

Environment aside, health considerations arise, and with them the dilemma that one man's benefit is another man's risk. Environmentalists in rich, developed countries gain nothing from DDT, and thus small risks felt at home loom larger than health benefits for the poor tropics. More than 200 environmental groups, including Greenpeace, Physicians for Social Responsibility and the World Wildlife Fund, actively condemn DDT for being "a current source of significant injury to...humans."<sup>6</sup> But five decades of experience with DDT shows that it is highly effective and safe when deployed in house spraying<sup>7</sup>.

Reliance on DDT reached its zenith, and malaria, its nadir, with a campaign to eradicate malaria from large parts of the world in the 1950s and 1960s. The early results were impressive: in less than two decades, spraying of houses with DDT reduced Sri Lanka's malaria burden from 2.8 million cases and 7,300 deaths to 17 cases and no deaths. India and South America achieved similarly impressive reductions, and several countries fully eradicated malaria<sup>1</sup>. Even in sub-Saharan Africa, where mosquitoes are most difficult to control, DDT spraying resulted in great reductions in malaria<sup>8</sup>.

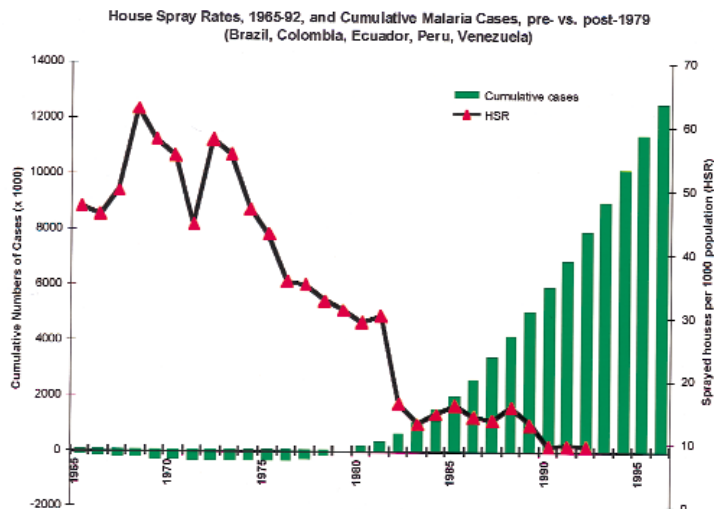
Unfortunately, many of these successes were short-lived. American funds, which underwrote the eradication campaign, soon lapsed, and overuse of DDT in agriculture bred DDT-resistant mosquitoes. Back in malaria's grip, Sri Lanka returned to a half a million cases by 1969.

But despite 'resistance' in itself, DDT still works to alleviate mortality and morbidity. Resistance tests work by measuring whether mosquitoes survive a normally toxic dose of DDT. The tests wholly overlook two non-toxic actions of DDT: contact-mediated irritancy<sup>9</sup>, which drives mosquitoes off sprayed walls and out of doors before they bite, and volatile repellency<sup>10,11</sup>, which deters their entry in the first place. Both actions disrupt human-mosquito contact and disease transmission.

Data from the Pan-American Health Organization show a strong inverse correlation between malaria cases and rates of spraying houses (1959–1992) in South America, even after DDT resistance became widespread in the 1960s (Fig. 1). Here, 'cumulative cases' represent the population-adjusted, 'running' total of cases that exceed or fall short of the average annual number of cases from 1959 to 1979 (years in which World Health Organization strategy emphasized house spraying<sup>12</sup>). Cumulative cases increase considerably in later years, coincident with a sharp decrease in rates of spraying houses.

This inverse correlation is readily understandable because it is so biologically plausible. For mosquitoes, DDT is a toxin, irritant and repellent all rolled into one chemical. All three

**Fig. 1** Cumulative malaria cases derived from Pan-American Health Organization data for Brazil, Colombia, Peru, Ecuador and Venezuela. The components of the calculations include the number of blood slides examined annually (*a*), number of positive slides annually (*b*), annual proportion of positive slides ( $b/a = c$ ), annual population for five countries (*d*), baseline annual blood examination rate (*e*), standardized number of slides examined (*f*) and standardized number of malaria cases annually (*g*). Two time periods, of high (1965–1979) and low (1980 on) house spraying are used for comparison, as the World Health Organization deemphasized house spraying in 1979.  $e = a/100$  population (sampling effort). Using the average values of *a* and *d* over the high spraying period ( $a/d \times 100$ ), yields an *e* value of 2.525, which was used to standardize *f* for each later year:  $f = 100 \times e \times d$ . The value *f* was used to estimate *g* as  $g = f \times c$ . Data represent the cumulative (running total) values of *g* for all years. Red triangles, houses sprayed per 1,000 population, calculated from *d* and the number of houses sprayed annually in all five countries; green bars, cumulative cases. The Pan-American Health Organization stopped publishing rates of house spraying after 1992, although DDT use since then has been minimal (data not shown).



properties decrease the odds of being bitten by mosquitoes, and toxicity particularly reduces the odds that parasite-bearing mosquitoes will survive to infect others. Lowering these odds slows disease propagation by second- or higher-order relationships and therefore is very important<sup>13,14</sup>. Indeed, renewing the spraying of houses with DDT, as Ecuador did in the early 1990s, rapidly decreases case rates<sup>5</sup>.

This body of evidence is so indisputable that even environmental groups such as Physicians for Social Responsibility concede that DDT is “highly effective” in malaria control<sup>15</sup>. Campaigning for a DDT ban given this benefit would seem politically difficult unless one alleged even greater health risks associated with its use, which is precisely what environmentalists do. Recent bulletins from Physicians for Social Responsibility and the World Wildlife Fund cite animal studies indicating involvement of DDT in neurological and immune deficits, and epidemiological studies linking DDT to human cancers and endocrine-disrupting effects, such as reduced lactation<sup>15,16</sup>.

In this kind of ‘balance of risks’ paradigm, the evidence must be scrupulously weighed. Although the International Agency for Research on Cancer rates DDT as a possible human carcinogen (along with, notably, several pharmaceutical drugs), not one case-control study of DDT’s human carcinogenicity has been affirmatively replicated. Breast cancer furnishes the clearest example: the first study to correlate DDT exposure with statistically elevated risk<sup>17</sup> has now failed to be replicated at least 8 times<sup>18–25</sup>, and of these later studies, some found exposure to significantly reduce risk<sup>24,25</sup>. Much the same can be said of studies indicating involvement of DDT in multiple myeloma, hepatic cancer and non-Hodgkin lymphoma<sup>26,27</sup>.

That DDT interferes with maternal lactation is also questionable. The leading study to correlate DDT metabolites in breast milk with unexplained, premature weaning<sup>28</sup> does not reach statistical significance unless the data are first ‘adjusted’ for potential confounders, but the authors did not disclose how their adjustment was done, and other labs have yet to confirm the result<sup>28</sup>. Lactation’s many social, nutritional and cultural influences make inferences difficult, but even if DDT

really abridges lactation, the authors found a “lack of any detectable effect on children’s health.”<sup>28</sup>

With such weak evidence of harm to human health, one must decide whether to set policy as a precaution and ban DDT based on animal studies. Ordinarily, this makes sense (given the alternative of experimenting on humans with toxins), but not for the spraying of houses with DDT. Acting with precaution because there are risks in animals, and thus denying people the known health benefits of malaria control, is very unethical: house spraying exposes millions of people to DDT, any of whose health can be studied, making extrapolations from animal studies unnecessary. Proper case-control studies should be done before policy is cast in treaty law.

Indeed, if precaution is relevant, it favors spraying houses with DDT, because it is affordable or effective where other interventions may not be. Cost data from India show that, even using DDT alone, the entire national malaria-control budget is sufficient to protect only 65% of high-risk persons. Switching to malathion, the next-cheapest alternative, reduces that coverage to 21%, which leaves 71 million more persons unprotected<sup>29</sup>. House spraying also has the advantage that it protects whole families, which is sometimes overlooked in comparing it with insecticide-treated bed-nets, which protect only one or two people at a time<sup>30</sup>. Simply put, there are too few economic studies to determine with certainty whether bed-nets are more or less cost-effective than DDT house spraying<sup>31</sup>. However, the fact that spraying houses with DDT can lower the prevalence of malaria parasitemia in highly endemic African communities to levels below that achieved by bed-nets (less than 5%) indicates that it is careless to treat them interchangeably<sup>8</sup>.

#### Patience in all things

How then to reconcile DDT’s ‘Janus-faced’ character? Its benefit in alleviating the suffering of malaria, at a reasonable cost, outweighs any reasonable speculation of its health risks. Living with this may not be easy; changing it is harder still.

Above all, rich countries must allow, and even facilitate, poor tropical countries to make choices about DDT freely,

and with informed consent. African countries in particular lack the resources to dispatch health experts to the treaty negotiations, and although it provides financial assistance, the United Nations Environment Programme has declined to assist with this, or even to provide a translator when French- and English-speaking diplomats meet to discuss DDT. The resulting lack of knowledge suffocates debate. At worst, threats are used, as Belize learned when the US Agency for International Development demanded that it stop using DDT.

Such arm-twisting is as lamentable as it is effective. Highly indebted poor countries must of necessity rank poverty reduction over environmental orthodoxy, and stimulating growth and foreign investment will require nearly eliminating malaria from economically productive zones. This is essential for development in sub-Saharan Africa, where malaria subtracts more than one percentage point off the gross domestic product growth rate, for a compounded loss (since 1965) now reaching up to \$100 billion a year in foregone income<sup>32</sup>.

Seen in this way, the insistence to do without DDT is 'eco-colonialism' that can impoverish no less than the imperial colonialism of the past did. Sub-Saharan Africa, which never experienced much spraying of houses with DDT, should consider starting this. South Africa, Swaziland and Madagascar, among others, run successful DDT-spraying programs and prove it can be done<sup>1,33</sup>.

At present, the United Nations Environment Programme mandate to "reduce and/or eliminate" DDT probably cannot be accomplished safely, without causing extra disease. As 'preachers of precaution', environmental groups and rich country governments should start by committing at least \$1 billion annually to roll back malaria in Africa. That is the sum requested by African leaders at their first-ever Malaria Summit earlier this year<sup>34</sup>. Meeting this request is a small price to pay for respecting the lives of the poor, and will bring us much closer to no longer needing DDT. Denying it, on the other hand, is to again embrace indifference, and the pursuit of environmental goals, on the backs of world's sick-est and poorest.

*The views expressed are those of the authors and do not reflect the official policy or position of the Uniformed Services University of the Health Sciences, the Department of Defense or the United States Government.*

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