Malaria, Mosquitoes, and DDT
The toxic war against a global disease

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This year, like every other year within the past couple of decades, uncountable trillions of mosquitoes will inject malaria parasites into human blood streams billions of times. Some 300 to 500 million full-blown cases of malaria will result, and between 1 and 3 million people will die, most of them pregnant women and children. That’s the official figure, anyway, but it’s likely to be a substantial underestimate, since most malaria deaths are not formally registered, and many are likely to have escaped the estimators. Very roughly, the malaria death toll rivals that of AIDS, which now kills about 3 million people annually.

But unlike AIDS, malaria is a low-priority killer. Despite the deaths, and the fact that roughly 2.5 billion people (40 percent of the world’s population) are at risk of contracting the disease, malaria is a relatively low public health priority on the international scene. Malaria rarely makes the news. And international funding for malaria research currently comes to a mere $150 million annually. Just by way of comparison, that’s only about 5 percent of the $2.8 billion that the U.S. government alone is considering for AIDS research in fiscal year 2003.

The low priority assigned to malaria would be at least easier to understand, though no less mistaken, if the threat were static. Unfortunately it is not. It is true that the geographic range of the disease has contracted substantially since the mid-20th century, but over the past couple of decades, malaria has been gathering strength. Virtually all areas where the disease is endemic have seen drug-resistant strains of the parasites emerge—a development that is almost certainly boosting death rates. In countries as various as Armenia, Afghanistan, and Sierra Leone, the lack or deterioration of basic infrastructure has created a wealth of new breeding sites for the mosquitoes that spread the disease. The rapidly expanding slums of many tropical cities also lack such infrastructure; poor sanitation and crowding have primed these places as well for outbreaks—even though malaria has up to now been regarded as predominantly a rural disease.

What has current policy to offer in the face of these threats? The medical arsenal is limited; there are only about a dozen antimalarial drugs commonly in use, and there is significant malaria resistance to most of them. In the absence of a reliable way to kill the parasites, policy has tended to focus on killing the mosquitoes that bear them. And that has led to an abundant use of synthetic pesticides, including one of the oldest and most dangerous: dichlorodiphenyl trichloroethane, or DDT.

DDT is no longer used or manufactured in most of the world, but because it does not break down readily, it is still one of the most commonly detected pesticides in the milk of nursing mothers. DDT is also one of the “dirty dozen” chemicals included in the 2001 Stockholm Convention on Persistent Organic Pollutants. The signatories to the “POPs Treaty” essentially agreed to ban all uses of DDT except as a last resort against disease-bearing mosquitoes. Unfortunately, however, DDT is still a routine option in 19 countries, most of them in Africa. (Only 11 of these countries have thus far signed the treaty.) Among the signatory countries, 31—slightly fewer than one-third—have given notice that they are reserving the right to use DDT against malaria. On the face of it, such use may seem unavoidable, but there are good reasons for thinking that progress against the disease is compatible with reductions in DDT use.
Malaria is caused by four protozoan parasite species in the genus Plasmodium. These parasites are spread exclusively by certain mosquitoes in the genus Anopheles. An infection begins when a parasite-laden female mosquito settles onto someone’s skin and pierces a capillary to take her blood meal. The parasite, in a form called the sporozoite, moves with the mosquito’s saliva into the human bloodstream. About 10 percent of the mosquito’s lode of sporozoites is likely to be injected during a meal, leaving plenty for the next bite. Unless the victim has some immunity to malaria—normally as a result of previous exposure—most sporozoites are likely to evade the body’s immune system and make their way to the liver, a process that takes less than an hour. There they invade the liver cells and multiply asexually for about two weeks. By this time, the original several dozen sporozoites have become millions of merozoites—the form the parasite takes when it emerges from the liver and moves back into the blood to invade the body’s red blood cells. Within the red blood cells, the merozoites go through another cycle of asexual reproduction, after which the cells burst and release millions of additional merozoites, which invade yet more red blood cells. The high fever and chills associated with malaria are the result of this stage, which tends to occur in pulses. If enough red blood cells are destroyed in one of these pulses, the result is convulsions, difficulty in breathing, coma, and death.

As the parasite multiplies inside the red blood cells, it produces not just more merozoites, but also gametocytes, which are capable of sexual reproduction. This occurs when the parasite moves back into the mosquitoes; even as they inject sporozoites, biting mosquitoes may ingest gametocytes if they are feeding on a person who is already infected. The gametocytes reproduce in the insect’s gut and the resulting eggs move into the gut cells. Eventually, more sporozoites emerge from the gut and penetrate the mosquito’s salivary glands, where they await a chance to enter another human bloodstream, to begin the cycle again.

Of the roughly 380 mosquito species in the genus Anopheles, about 60 are able to transmit malaria to people. These malaria vectors are widespread throughout the tropics and warm temperate zones, and they are very efficient at spreading the disease.
Malaria is highly contagious, as is apparent from a measurement that epidemiologists call the “basic reproduction number,” or BRN. The BRN indicates, on average, how many new cases a single infected person is likely to cause. For example, among the nonvectored diseases (those in which the pathogen travels directly from person to person without an intermediary like a mosquito), measles is one of the most contagious. The BRN for measles is 12 to 14, meaning that someone with measles is likely to infect 12 to 14 other people. (Luckily, there’s an inherent limit in this process: as a pathogen spreads through any particular area, it will encounter fewer and fewer susceptible people who aren’t already sick, and the outbreak will eventually subside.) HIV/AIDS is on the other end of the scale: its BRN is just above 1, the minimum necessary for the pathogen’s survival. With malaria, the BRN varies considerably, depending on such factors as which mosquito species are present in an area and what the temperatures are. (Warmer is worse, since the parasites mature more quickly.) But malaria can have a BRN in excess of 100: over an adult life that may last about a week, a single, malaria-laden mosquito could conceivably infect more than 100 people.

Seven years, seven months

“Malaria” comes from the Italian “mal’aria.” For centuries, European physicians had attributed the disease to “bad air.” Apart from a tradition of associating bad air with swamps—a useful prejudice, given the amount of mosquito habitat in swamps—early medicine was largely ineffective against the disease. It wasn’t until 1897 that the British physician Ronald Ross proved that mosquitoes carry malaria.

The practical implications of Ross’s discovery did not go unnoticed. For example, the U.S. administration of Theodore Roosevelt recognized malaria and yellow fever (another mosquito-vectored disease) as perhaps the most serious obstacles to the construction of the Panama Canal. This was hardly a surprising conclusion, since the earlier and unsuccessful French attempt to build the canal—an effort that predated Ross’s discovery—is thought to have lost between 10,000 and 20,000 workers to disease. So the American workers draped their water supplies and living quarters with mosquito netting, attempted to fill in or drain swamps, installed sewers, poured oil into standing water, and conducted mosquito-swatting campaigns. And it worked: the incidence of malaria declined. In 1906, 80 percent of the workers had the disease; by 1913, a year before the Canal was completed, only 7 percent did. Malaria could be suppressed, it seemed, with a great deal of mosquito netting, and by eliminating as much mosquito habitat as possible. But the labor involved in that effort could be enormous.

That is why DDT proved so appealing. In 1939, the Swiss chemist Paul Müller discovered that this chemical was a potent pesticide. DDT was first used during World War II, as a delousing agent. Later on, areas in southern Europe, North Africa, and Asia were fogged with DDT, to clear malaria-laden mosquitoes from the paths of invading Allied troops.
DDT was cheap and it seemed to be harmless to anything other than insects. It was also long-lasting: most other insecticides lost their potency in a few days, but in the early years of its use, the effects of a single dose of DDT could last for up to six months. In 1948, Müller won a Nobel Prize for his work and DDT was hailed as a chemical miracle.

A decade later, DDT had inspired another kind of war—a general assault on malaria. The “Global Malaria Eradication Program,” launched in 1955, became one of the first major undertakings of the newly created World Health Organization. Some 65 nations enlisted in the cause. Funding for DDT factories was donated to poor countries and production of the insecticide climbed.

The malaria eradication strategy was not to kill every single mosquito, but to suppress their populations and shorten the lifespans of any survivors, so that the parasites would not have time to develop within them. If the mosquitoes could be kept down long enough, the parasites would eventually disappear from the human population. In any particular area, the process was expected to take three years—time enough for all infected people either to recover or die. After that, a resurgence of mosquitoes would be merely an annoyance, rather than a threat. And initially, the strategy seemed to be working. It proved especially effective on islands—relatively small areas insulated from reinfection. Taiwan, Jamaica, and Sardinia were soon declared malaria-free and have remained so to this day. By 1961, arguably the year at which the program had peak momentum, malaria had been eliminated or dramatically reduced in 37 countries.

One year later, Rachel Carson published Silent Spring, her landmark study of the ecological damage caused by the widespread use of DDT and other pesticides. Like other organochlorine pesticides, DDT bioaccumulates. It’s fat soluble, so when an animal ingests it—by browsing contaminated vegetation, for example—the chemical tends to concentrate in its fat, instead of being excreted. When another animal eats that animal, it is likely to absorb the prey’s burden of DDT. This process leads to an increasing concentration of DDT in the higher links of the food chain. And since DDT has a high chronic toxicity—that is, long-term exposure is likely to cause various physiological abnormalities—this bioaccumulation has profound implications for both ecological and human health.

With the miseries of malaria in full view, the managers of the eradication campaign didn’t worry much about the toxicity of DDT, but they were greatly concerned about another aspect of the pesticide’s effects: resistance. Continual exposure to an insecticide tends to “breed” insect populations that are at least partially immune to the poison. Resistance to DDT had been reported as early as 1946. The campaign managers knew that in mosquitoes, regular exposure to DDT tended to produce widespread resistance in four to seven years. Since it took three years to clear malaria from a human population, that didn’t leave a lot of leeway for the eradication effort. As it turned out, the logistics simply couldn’t be made to work in large, heavily infested areas with high human populations, poor housing and roads, and generally minimal infrastructure. In 1969, the campaign was abandoned. Today, DDT resistance is widespread in Anopheles, as is resistance to many more recent pesticides.

Undoubtedly, the campaign saved millions of lives, and it did clear malaria from some areas. But its broadest legacy has been of much more dubious value. It engendered the idea of DDT as a first resort against mosquitoes and it established the unstable dynamic of DDT resistance in Anopheles populations. In mosquitoes, the genetic mechanism that confers resistance to DDT does not usually come at any great competitive “cost”—that is, when no DDT is being sprayed, the resistant mosquitoes may do just about as well as nonresistant mosquitoes. So once a population acquires resistance, the trait is not likely to disappear even if DDT isn’t used for years. If DDT is reapplied to such a population, widespread resistance will reappear very rapidly. The rule of thumb among entomologists is that you may get seven years of resistance-free use the first time around, but you only get about seven months the second time. Even that limited respite, however, is enough to make the chemical an attractive option as an emergency measure—or to keep it in the arsenals of bureaucracies committed to its use.

**Malaria taxes**

In December 2000, the POPs Treaty negotiators convened in Johannesburg, South Africa, even though, by an unfortunate coincidence, South Africa had suffered a potentially embarrassing setback earlier that year in its own POPs policies. In 1996, South Africa had switched its mosquito control programs from DDT to a less persistent group of pesticides known as pyrethroids. The move seemed solid and supportable at the time, since years of DDT use had greatly reduced Anopheles populations and largely eliminated one of the most troublesome local vectors, the appropriately named *A. funestus* (“funestus” means deadly). South Africa seemed to have beaten the DDT habit: the chemical had been used to achieve a worthwhile objective; it had then been discarded. And the plan worked—until a year before the POPs summit, when malaria infections rose to 61,000 cases, a level not seen in decades. *A. funestus* reappeared as well, in KwaZulu-Natal, and in a form resistant to pyrethroids. In early 2000, DDT was reintroduced, in an indoor spraying program. (This is...
now a standard way of using DDT for mosquito control; the pesticide is usually applied only to walls, where mosquitoes alight to rest.) By the middle of the year, the number of infections had dropped by half.

Initially, the spraying program was criticized, but what reasonable alternative was there? This is said to be the African predicament, and yet the South African situation is hardly representative of sub-Saharan Africa as a whole.

Malaria is considered endemic in 105 countries throughout the tropics and warm temperate zones, but by far the worst region for the disease is sub-Saharan Africa. (See map.) The deadliest of the four parasite species, *Plasmodium falciparum*, is widespread throughout this region, as is one of the world’s most effective malaria vectors, *Anopheles gambiae*. Nearly half the population of sub-Saharan Africa is at risk of infection, and in much of eastern and central Africa, and pockets of west Africa, it would be difficult to find anyone who has not been exposed to the parasites. Some 90 percent of the world’s malaria infections and deaths occur in sub-Saharan Africa, and the disease now accounts for 30 percent of African childhood mortality. It is true that malaria is a grave problem in many parts of the world, but the African experience is misery on a very different order of magnitude. The average Tanzanian suffers more infective bites each night than the average Thai or Vietnamese does in a year.

As a broad social burden, malaria is thought to cost Africa between $3 billion and $12 billion annually. According to one economic analysis, if the disease had been eradicated in 1965, Africa’s GDP would now be 35 percent higher than it currently is. Africa was also the gaping hole in the global eradication program: the WHO planners thought there was little they could do on the continent and limited efforts to Ethiopia, Zimbabwe, and South Africa, where eradication was thought to be feasible.

But even though the campaign largely passed Africa by, DDT has not. Many African countries have used DDT for mosquito control in indoor spraying programs, but the primary use of DDT on the continent has been as an agricultural insecticide. Consequently, in parts of west Africa especially, DDT resistance is now widespread in *A. gambiae*. But even if *A. gambiae* were not resistant, a full-bore campaign to suppress it would probably accomplish little, because this mosquito is so efficient at transmitting malaria. Unlike most *Anopheles* species, *A. gambiae* specializes in human blood, so even a small population would keep the disease in circulation. One way to get a sense for this problem is to consider the "transmission index"—the threshold number of mosquito bites necessary to perpetuate the disease. In Africa, the index overall is 1 bite per person per month. That’s all that’s necessary to keep malaria in circulation. In India, by comparison, the TI is 10 bites per person per month.

And yet Africa is not a lost cause—it’s simply that the key to progress does not lie in the general suppression of mosquito populations. Instead of spraying, the most promising African programs rely primarily on "bednets"—mosquito netting that is treated with an insecticide, usually a pyrethroid, and that is suspended over a person’s bed. Bednets can’t eliminate malaria, but they can "deflect" much of the burden. Because *A. gambiae* species generally feed in the evening and at night, a bednet can radically reduce the number of infective bites a person receives. Such a person would probably still be infected from time to time, but would usually be able to lead a normal life.

In effect, therefore, bednets can substantially reduce the disease. Trials in the use of bednets for children have shown a decline in malaria-induced mortality by 25 to 40 percent. Infection levels and the incidence of severe anemia also declined. In Kenya, a recent study has shown that pregnant women who use bednets tend to give birth to healthier babies. In parts of Chad, Mali, Burkina Faso, and Senegal, bednets are becoming standard household items. In the tiny west African nation of The Gambia, somewhere between 50 and 80 percent of the population has bednets.

Bednets are hardly a panacea. They have to be used properly and retreated with insecticide occasionally. And there is still the problem of insecticide resistance, although the nets themselves are hardly likely to be the main cause of it. (Pyrethroids are used extensively in agriculture as well.) Nevertheless, bednets can help transform malaria from a chronic disaster to a manageable public health problem—something a healthcare system can cope with.

So it’s unfortunate that in much of central and southern Africa, the nets are a rarity. It’s even more unfortunate that, in 28 African countries, they’re taxed or subject to import tariffs. Most of the people in these countries would have trouble paying for a net even without the tax. This problem was addressed in the May 2000 "Abuja Declaration," a summit agreement on infectious diseases signed by 44 African countries. The Declaration included a pledge to do away with "malaria taxes." At last count, 13 countries have actually acted on the pledge, although in some cases only by reducing rather than eliminating the taxes. Since the Declaration was signed, an estimated 2 to 5 million Africans have died from malaria.

This failure to follow through with the Abuja Declaration casts the interest in DDT in a rather poor light. Of the 31 POPs treaty signatories that have reserved the right to use DDT, 21 are in Africa. Of those 21, 10 are apparently still taxing or imposing tariffs on bednets. (Among the African countries that
have not signed the POPs treaty, some are almost cer-
tainly both using DDT and taxing bednets, but the
exact number is difficult to ascertain because the sta-
tus of DDT use is not always clear.) It is true that a
case can be made for the use of DDT in situations like
the one in South Africa in 1999—an infrequent flare-
up in a context that lends itself to control. But the
routine use of DDT against malaria is an exercise in
toxic futility, especially when it’s pursued at the
expense of a superior and far more benign technology.

Learning to live with the mosquitoes

A group of French researchers recently
announced some very encouraging results for a new
anti-malarial drug known as G25. The drug was
given to infected aotus monkeys, and it appears to
have cleared the parasites from their systems.
Although extensive testing will be necessary before it
is known whether the drug can be safely given to
people, these results have raised the hope of a cure
for the disease.

Of course, it would be wonderful if G25, or some
other new drug, lives up to that promise. But even in
the absence of a cure, there are opportunities for
progress that may one day make the current inci-
dence of malaria look like some dark age horror.
Many of these opportunities have been incorporated
into an initiative that began in 1998, called the Roll
Back Malaria (RBM) campaign, a collaborative effort
between WHO, the World Bank, UNICEF, and the
UNDP. In contrast to the earlier WHO eradication
program, RBM grew out of joint efforts between
WHO and various African governments specifically
to address African malaria. RBM focuses on house-
hold- and community-level intervention and it
emphasizes apparently modest changes that could
yield major progress. Below are four “operating prin-
ciples” that are, in one way or another, implicit in
RBM or likely to reinforce its progress.

1. Do away with all taxes and tariffs on bednets,
on pesticides intended for treating bednets, and on
antimalarial drugs. Failure to act on this front cer-
tainly undercuts claims for the necessity of DDT; it
may also undercut claims for antimalaria foreign aid.

2. Emphasize appropriate technologies. Where,
for example, the need for mud to replaster walls is
creating lots of pothole sized cavities near houses—
cavities that fill with water and then with mosquito
larvae—it makes more sense to help people improve
their housing maintenance than it does to set up a
program for squirting pesticide into every pothole.
To be “appropriate,” a technology has to be both affordable and culturally acceptable. Improving home maintenance should pass this test; so should bednets. And of course there are many other possibilities. In Kenya, for example, a research institution called the International Centre for Insect Physiology and Ecology has identified at least a dozen native east African plants that repel *Anopheles gambiae* in lab tests. Some of these plants could be important additions to household gardens.

3. Use existing networks whenever possible, instead of building new ones. In Tanzania, for example, an established healthcare program (UNICEF’s Integrated Management of Childhood Illness Program) now dispenses antimalarial drugs—and instruction on how to use them. The UNICEF program was already operating, so it was simple and cheap to add the malaria component. Reported instances of severe malaria and anemia in infants have declined, apparently as a result. In Zambia, the government is planning to use health and prenatal clinics as the network for a coupon system that subsidizes bednets for the poor. Qualifying patients would pick up coupons at the clinics and redeem them at stores for the nets.

4. Assume that sound policy will involve action on many fronts. Malaria is not just a health problem—it’s a social problem, an economic problem, an environmental problem, an agricultural problem, an urban planning problem. Health officials alone cannot possibly just make it go away. When the disease flares up, there is a strong and understandable temptation to strap on the spray equipment and douse the mosquitoes. But if this approach actually worked, we wouldn’t be in this situation today. Arguably the biggest opportunity for progress against the disease lies, not in our capacity for chemical innovation, but in our capacity for organizational innovation—in our ability to build an awareness of the threat across a broad range of policy activities. For example, when government officials are considering loans to irrigation projects, they should be asking: has the potential for malaria been addressed? When foreign donors are designing antipoverty programs, they should be asking: do people need bednets? Routine inquiries of this sort could go a vast distance to reducing the disease.

Where is the DDT in all of this? There isn’t any, and that’s the point. We now have half a century of evidence that routine use of DDT simply will not prevail against the mosquitoes. Most countries have already absorbed this lesson, and banned the chemical or relegated it to emergency only status. Now the RBM campaign and associated efforts are showing that the frequency and intensity of those emergencies can be reduced through systematic attention to the chronic aspects of the disease. There is less and less justification for DDT, and the futility of using it as a matter of routine is becoming increasingly apparent: in order to control a disease, why should we poison our soils, our waters, and ourselves?

NEW AND NOTEWORTHY

Fateful Harvest: The True Story of a Small Town, a Global Industry, and a Toxic Secret, by Duff Wilson (New York: Harper Collins, 2001). "Who in the world would think to look for toxic waste in plant food?" writes investigative journalist Duff Wilson in the prologue of Fateful Harvest. Based on an exposé series that Wilson wrote for the Seattle Times, the book is an eye-opening account of how citizens in a farming community in Washington state found out that hazardous industrial wastes are being put into fertilizers. In the small town of Quincy, Mayor Patty Martin watched some farmers' fields become unproductive, horses die after eating contaminated hay, and cases of cancer and chronic lung problems increase, galvanizing her to lead a small group of farmers in a fight with local business interests to discover the truth about what farmers were putting on their fields. They found heavy metals including lead, chromium, and cadmium in their fertilizers and, more alarmingly, discovered that this was legal. In the name of "recycling," industries were paying fertilizer companies to take their hazardous wastes, thereby avoiding the high cost of disposing of these wastes in special dangerous-waste landfills. Fertilizer companies then made the wastes into "products" and advertised the fertilizing ingredients such as phosphorus and zinc without listing the toxic ingredients.

Wilson chronicles Quincy Mayor Martin's path to awareness and to activism, as well as her confrontations with the town's moneyed interests and complacent government officials. Martin's efforts, as well as Wilson's journalism, have led to some state-level regulation of fertilizers and have increased consumer awareness of the issue. But on a national level, the U.S. Environmental Protection Agency maintains that increased regulation is not necessary because there is no proof that recycled fertilizers have negative effects on health—despite the fact that studies have shown that plants absorb toxics from the soil, and that traces of cadmium in particular have been found in wheat flour and other foods. And although there is greater regulation of fertilizers in Canada and Europe than in the United States, U.N. regulations on waste-to-fertilizer exports from wealthy countries to developing countries are easily subverted. Evidently, the risk of harm from toxic fertilizer is not just a local problem for Quincy, but is a widespread problem around the world.

— Vanessa Larson

Power Politics, by Arundhati Roy (Cambridge, MA: South End Press, 2001). In her new collection of essays, Booker Prize winning author Arundhati Roy rescues from obscurity a number of difficult issues that have been neglected by the international media corps since September 11. She questions whether it is possible for terrorism to be conquered by brutal force and war; exposes corporate efforts to privatize water, electricity, and other resources by eliminating public oversight; and challenges the global regime of free trade in which, she says, "life is profit."

The title essay, "Power Politics" carefully deconstructs the corporate colonization of public resources that all too frequently leaves citizens footing the bill for a few individuals' big profits. For example, Roy dredges up the Enron scandal, but not the one most readers are familiar with: In the 1990s, the company bribed its way into the Indian energy market and secured a $30 billion deal—the largest in India's history—to produce electricity in Maharashtra at guaranteed prices twice that of its nearest competitor.

Roy's writing is frequently provocative and intensely pertinent, and serves as an important call to action for those concerned with environmental justice issues.

— Curtis Runyan