DDT'S RESURRECTION

One year after WHO recommended the use of DDT in developing countries to prevent the spread of malaria, the debate over its safety continues.

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Powdered DDT, used in South Africa's KwaZulu-Natal province for controlling mosquitoes that carry malaria, may be mixed by pregnant women or others who do not understand its potential toxicity.

When the World Health Organization (WHO) announced last September that it supported the return of DDT in the fight against malaria, many environmentalists were taken aback. The persistent pesticide responsible for the decline of birds and other fauna in the 1950s would resuscitate what many deemed a failed approach against a disease that claims millions of lives each year.

In certain settings, DDT remains a proven tool to hinder the transmission of malaria to humans, but the compound is not the long-term answer, environmentalists and public-health specialists argue.

DDT, past and present

Used as an insecticide to control malaria for the first time during World War II, DDT quickly found widespread use around the world as an agricultural spray during the "green revolution". Production hit 36,000 metric tons per year in the mid-1950s.

But scientists (including Rachel Carson, author of *Silent Spring*, a seminal text that spurred the environmental movement in the late 1960s) began documenting some detrimental side effects: the decline of bird populations, including the bald eagle, due to the thinning of eggshells and other effects not pinned down completely until years after DDT was banned in 1972. And scientists found that some mosquitoes had become DDT-resistant, as occurs with any drug or chemical that is overused.

Even today, mosquito populations develop resistance to DDT, as its use continues in some regions. South Africa used DDT for more than 60 years with no evidence of resistance, but Nigeria experienced DDT-resistant mosquitoes within 1½ years of introducing the insecticide, says Janet Hemingway, director of the Liverpool School of Tropical Medicine (U.K.). Why some populations develop resistance while others don't remains a mystery, she adds.

Malaria control requires far less of the pesticide than agricultural use. In Guyana, which once applied DDT to 215,000 square kilometers (km^2) of farmland, the amount used for an indoor residual spraying program is equivalent to that applied to only 4 km^2, according to WHO data.

DDT's persistence makes it attractive for indoor spraying programs. It sticks for 6 months or more once sprayed onto walls—a key reason WHO has recommended its use, because reapplications are needed less frequently. The chemical's behavior also fits the specific life cycles of the mosquitoes that carry malaria-causing *Plasmodium* parasites, says Don Roberts, a former researcher and professor at the Uniformed Services University of the Health Sciences. Some mosquito species are adapted to living indoors and must land on walls to rest and process their human blood meals.

DDT works—but not alone

From African communities with mud-wall huts to Central and South American ones where open-plan huts are the norm and window screens are not, "DDT works," Roberts says. Early in his career as a researcher in the Amazon basin, Roberts conducted trials with two side-by-side huts—one sprayed, one not—to track mosquitoes' response to DDT. Almost all the mosquitoes left the sprayed hut—repelled, if not killed, by the DDT; in the other hut, "we were eaten alive," he recalls.

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In Tanzania, Jamila Hassan leads a trained team that sprays DDT indoors as part of the Zanzibar Urban District Indoor Residual Sprayers, sponsored in part by USAID.

That efficacy has led to an infrastructure of indoor spraying programs throughout Africa, says Rick Steketee, director of science for the Malaria Control and Evaluation Partnership in Africa, a program funded by the Gates Foundation. But "it is very clear that there is no single approach to controlling malaria that gets you sufficient benefits," Steketee says. "We have chemicals, either as drugs or insecticides. I think there is universal consensus that neither one alone will solve this."

Alongside their mosquito hosts, malaria parasites themselves have grown resistant to the drugs introduced to combat the disease. Yet new pesticides and drugs always seem to be a decade away. Researchers and policy makers alike say that only recently have money and international attention returned to malaria control, and pressure from that renewed interest is part of the reason WHO reversed its position on DDT.

The new landscape of malaria vector control may decrease reliance on DDT, but change will come slowly, says Hemingway. "We had relied on agriculture to develop new pesticides," she says. But in the past 25 years, companies began focusing more on what happens inside a plant by using protein pathways, for example, instead of focusing on the pests.

Hemingway now directs the Innovative Vector Control Consortium (IVCC), established to "try to speed up that process." IVCC takes on some development costs and helps to manage the risks of creating a new product in such an emotionally charged arena.

Two or three new formulations of old pesticides are likely to be introduced within the next year, Hemingway notes; these will last longer and might be competitive with DDT in the marketplace. Making a product that "lasts as long on a wall is relatively easily solvable. Bringing a brand-new product to market will take 7 to 10 years," she says.

Persistent evidence of DDT's harm

Decades after North America and Europe banned DDT, environmental scientists continue to find the legacy of the neurotoxin's historic use. DDT's metabolites continue to accumulate in terns and humans in the Arctic. North Americans still have the metabolites in their bodies, decades after DDT use stopped, according to data from the U.S. Centers for Disease Control and Prevention.

The "grasshopper effect" of transportable persistent organic pollutants, compounds that are addressed by the Stockholm Convention, offers an explanation for the high levels of exposure in northern regions, and even in places where DDT may not have been used. Past and present aerial transport could be responsible, but black-market acquisition and illegal use also remain a source in some regions.

"The issue about DDT is really that most of the world has stopped using it, but it seems that the impact will be with us for quite a long time," says Riana Bornman at the University of Pretoria (South Africa). "We've found it in places that it's not supposed to be."

Data on human effects, such as endocrine disruption, are incredibly hard to get in areas where spraying is ongoing, says Matthew Longnecker, an epidemiologist at the U.S. National Institute of Environmental Health Sciences. Bornman recently coauthored data reports on DDT's endocrine-disrupting effects in rats and its neural effects in chicken embryos. She and her co-workers will soon publish data on DDT's effects in humans, after tracking congenital anomalies, such as hypospadia, in newborns. These data were first presented at the Society of Environmental Toxicology and Chemistry (SETAC) Europe 17th Annual Meeting, held last spring in Porto, Portugal.

Other researchers in South Africa, including Henk Bouwman of North-West University (South Africa), have documented the accumulation of DDT in human breast milk. Bouwman and colleagues have also found pyrethroids accumulating alongside DDT.

Several years ago, South Africa tried pyrethroids, a broadly used new pesticide, for malaria control, with disastrous results: pyrethroid-resistant mosquitoes from bordering countries that used the pesticide in agriculture caused a frightening spike in malaria cases, and South Africa returned to using DDT after complex bargaining under the Stockholm Convention.

"Risk assessments have never been done on breast milk as a route of exposure to infants for insecticides [such as pyrethroids] that are used as alternatives to DDT in malaria control," Bouwman says. And with indoor spraying, he adds, "we don't know what the intake would be." Even if a hut's inhabitants don't have contact with a sprayed wall, DDT could easily linger in the air. As-yet-unknown impacts of newer pesticides mixed with DDT must be considered alongside unknown exposures in agriculture and other unregulated applications of this controversial compound.

New and old solutions

Despite a growing body of evidence on human exposures, the data are not definitive—nor, most agree, are they enough to outweigh the specter of millions of children dying without adequate malaria vector control efforts. "I think the truth is somewhere in the middle," Hemingway says, referring to the arguments for and against banning the pesticide. "DDT is generally effective in killing and repelling mosquitoes and, used sensibly, has saved many lives. That's why it's still there on our books."

MANUEL GUTIÉRREZ ALVARADO

Workers from Costa Rica's Ministry of Health cull mosquito larvae in order to estimate mosquito abundance, as part of a larger control program.

WHO and the U.S. Agency for International Development (USAID) have backed that same consensus within the public-health community with money to promote DDT indoor residual spraying. Last year, the U.S. gave $16 million to Senegalese programs alone through USAID for spraying as well as other control methods.

Nevertheless, some say the fight against malaria will continue until the conditions that allow transmission are improved. "In malarial epidemics in places like Nigeria or Ethiopia, you have a constellation of issues," says Patricia DeMarco, executive director of the Rachel Carson Homestead Association, a nonprofit organization that promotes Carson's environmental ethic. Challenges include "vastly

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Fish from DDT-contaminated bodies of water could be a route of exposure to the pesticide in regions of South Africa, for example, where it is used for malaria control and agriculture. However, data show that eating fish cannot account for total human body burdens of DDT.

inadequate health care available to the bulk of the [rural] population, . . . no good sanitation and water management, plus the climate—[with its] propitious breeding areas for the insect." Issues such as poverty and even physical infrastructure that would allow people to protect themselves with window screens need to be addressed.

In Costa Rica and elsewhere in the Americas, researchers have been working on an integrated pest management approach to controlling malaria. Elba de la Cruz and Marco Vinicio Herrero of Universidad Nacional (Costa Rica) are part of an international team that is collecting human bioaccumulation data, which will be put into context with soil and other environmental data in a geographic information system matrix.

The project encourages "as much community participation as possible to modify some of the habits that may be responsible for disease incidence," says de la Cruz. The team also promotes control efforts, such as introducing fish that eat mosquito larvae. "We use as many methods as are available to reduce the host [and] reduce the interaction between mosquitoes and humans," Vinicio Herrero adds. The researchers expect to have their initial results before the end of the year.

Whether such methods will work elsewhere—with different mosquito species, geographic terrain, and other controlling factors—remains to be seen. Meanwhile, DDT continues to be a stopgap in the fight against malaria and its mosquito vectors.

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