Chapter 20

Perspectives on Barriers to Control of *Anopheles* Mosquitoes and Malaria

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Additional information is available at the end of the chapter

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1. Introduction

Though mankind has struggled against malaria for countless generations, it remains a major global health problem. The malaria parasite and the *Anopheles* mosquito have evolved and developed with mankind since earliest recorded history, but there is nothing inevitable about the disease. Although thousands of children die from malaria every year, the disease is preventable and entirely curable, and the history of malaria control in the 20th century demonstrates that with the right tools and funding, malaria can be controlled, or even eradicated. The key, of course, is the cost-effective use of the right tools.

2. Statement of the problem

This chapter will examine arguably the most important tool for malaria control – public health insecticides (PHIs). Insecticide opponents often mischaracterize the public health use of insecticides, to include how they are used and consequences of their use in public health programs. Common inferences are that public health use of insecticides results in broad-scale environmental contamination and harm to wildlife. It is important for the reader to understand that there are internationally accepted guidelines for public health use of insecticides and that public health use is very different from how insecticides are used for agriculture. Optimum public health use of PHIs is to spray small quantities on inside walls of houses. In the case of DDT, it is approved only for use in public health programs. Applying it to inside walls leverages DDT's powerful repellent actions, giving continual protection from malaria-infected mosquitoes, for months on end, to those living inside the sprayed house. It should be obvious that a small amount of an insecticide on house walls is a far cry from spraying insecticides on

vast acreages of cropland, as one might envisage for insecticides used in agriculture. Thus we emphasize that the subject of this chapter is public health use of insecticides, with no connotations whatsoever for the use of insecticides in agriculture.

We will summarize, with specific examples, the way that modern PHIs, and DDT in particular, have saved millions of lives since the 1940s. Despite this remarkable achievement, popular campaigns by activists, some scientists and even United Nations (UN) agencies, have stigmatized and often demonized PHIs. Instead of regarding insecticides in the same light as medicines and diagnostics, essential elements of a malaria control program, insecticide opponents have mounted vocal campaigns to halt their use. Frequently these campaigns avoid or ignore the scientific process and rely on the flimsiest of evidence to make great claims about human health or ecological effects of PHIs. We will characterize examples of studies and claims against PHIs used by the activist communities and we will describe the major failings of each as they relate to the use of PHIs.

The claims by those who oppose PHIs, as we will explain and demonstrate with specific examples, do not comply with even the most basic epidemiologic criteria to prove a cause and effect relationship – yet those claims drive public opinion and policy. We will also document how UN bureaucrats have made outrageous claims that malaria can be controlled without PHIs. At the same time, the UN has set grand goals of achieving near-zero deaths from malaria by 2015. There is a valid debate to be had about whether or not this goal can be met, or even properly defined and measured; however, what is clear, is that progress against malaria cannot be achieved and sustained without access to PHIs. For access to be secured, the malaria community, including program managers, researchers, advocates and others, must defend PHIs rigorously and emphatically. The overarching goal of this chapter is to help with that defense. Without it, the lives of men, women and children living at risk of malaria will be greatly imperiled. However, for proper defense of PHIs, there must be a clear understanding about how insecticide opponents have succeeded in past anti-insecticide campaigns, and that influential groups and UN organizations actively oppose the use of PHIs. As anti-insecticide campaigners employ distinct strategies and tactics, it is important to know what they are and how they are used.

3. Malaria control today versus the early years of PHI use

Today there is great enthusiasm and substantial funding to advance global efforts to control and, in some regions, eradicate malaria. Indeed, and as suggested by recent outcomes of control programs, we are beginning to see promising results [1,2]. The necessary change for refocusing efforts to control malaria started in 1998, when, faced with mounting evidence that the global burden of malaria was increasing, and had been for some time, the World Health Organization (WHO) formed a new malaria control partnership, Roll Back Malaria (RBM). The RBM Partnership is made up of WHO and several UN agencies, such as UNICEF and UNDP, and development agencies, such as the World Bank and the US Agency for International Development (USAID), along with the private sector and NGOs. RBM's stated goal in 1998 was to halve the burden of malaria by 2010 [3].

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RBM began with limited funding and an apparent disdain for scientific evidence. The early efforts were disappointing. Far from achieving any reduction in malaria cases, by 2004 there was evidence that malaria cases were in fact increasing. RBM was described in a stinging editorial in the *British Medical Journal* as a 'failing public health campaign [4].' One of the main reasons for this was the Partnership's dogged support for the use of insecticide treated bednets (ITNs) over other vector control interventions, e.g., indoor residual spraying (IRS) with insecticides such as DDT. The limited and controlled spraying of insecticides inside houses has long been known to rapidly reduce malaria cases and deaths, yet in the early years of the RBM Partnership was roundly ignored. In addition RBM's Partners failed to support any change in treatment policy away from failing drug therapies to the new artemisinin-based combination therapies (ACTs).

It was not until 2006 that progress against malaria finally started to be made. To its credit RBM acknowledged some of the problems it faced and set about restructuring and reforming. Much of impetus for these reforms came from a newly appointed head of the WHO's Global Malaria Program, Dr. Arata Kochi. Dr. Kochi had little history in malaria control and perhaps because of this had no need to defend any misguided previous policy decisions. One of Kochi's first acts was to re-issue WHO's treatment guidelines, recommending ACTs.

Shortly thereafter Kochi re-addressed WHO's policy on both DDT and IRS, and in a public and, for WHO, aggressive gesture issued a statement strongly endorsing the use of DDT. At the same time the US global malaria control program run by USAID underwent a major reform, creating the President's Malaria Initiative (PMI). A distinguishing feature of the PMI, which sets it apart from other major bi-lateral donor funded malaria control programs, is its support for IRS and its willingness to pay for use of DDT [5].

Together these reforms marked a change in global malaria control and as a result, malaria cases began to decline. As described below, malaria funding increased by more than 20 fold in a decade and malaria deaths, according to WHO modeling data, have fallen.

Malaria funding for the PMI and the Global Fund to Fight AIDS, TB and Malaria (Global Fund) through 2011 is estimated at $1,858,370,500 for the PMI [6], and $6,156,000,000 in malaria grants through 2011 for the Global Fund (based on $22.8b value of grant portfolio as of December 31, 2011, of which 27% is for malaria) [7].

International funding for malaria control has gone from less than $100 million in 2000 to $2 billion in 2011 [8]. Likewise, the estimated changes in global malaria burden since 2000 are compliant with improved funding of control efforts after 2005. For example, estimated numbers of malaria cases and malaria deaths in 2000 were 223 million and 755,000 respectively. In 2005 the values were 237 million cases and 801,000 deaths, whereas in 2011, the values were 216 million cases and 655,000 deaths [8].

Clearly progress is being made in the renewed focus on malaria. The positive changes with regard to funding IRS and DDT's place in malaria control are obviously welcomed. However these advances can be reversed at any time and as we explain in this chapter, the forces opposing the careful and effective use of PHIs are well-funded, organized, and aggressive. The malaria control community should remember, and learn from history, that we have been at

this stage before. We can get a sense of this by looking back to what was happening in 1959. At this time DDT was used widely in agriculture and for pest management around the world. Aerial spraying of DDT was common as farmers sought to protect their crops, but in malaria control DDT use was entirely different. Most malaria vectors enter houses in search of blood meals, and so protecting people while they are at home, often asleep, is crucial. Soon after the Allied forces first used DDT during World War II, scientists discovered that DDT acts primarily as a spatial repellent. In other words, if the interior of a house is sprayed with DDT, mosquitoes are driven away and are unlikely to enter. DDT will also act as a contact irritant, so if a mosquito lands on a sprayed surface, it is likely to exit the house rapidly, often before feeding. Of course DDT will also act as a toxicant, killing the mosquito. However it is a relatively weak toxicant and its spatial repellency is the insecticide's most important mode of action by far. Widespread area spraying of DDT would have been pointless for malaria control.

In 1959 malaria was in rapid retreat in many endemic countries as a consequence of effective DDT use. The global malaria eradication program was just barely underway. By that time, the malaria control community had already used DDT to free 300 million people from the burdens of endemic disease. By the program's end in 1969, the lives of almost one billion people would be equally improved. In 1959 there was a wealth of malaria control expertise, substantial funding, and programmatic emphasis on malaria prevention; there were powerful and successful national programs, goal-oriented malaria control policies, and great enthusiasm for the goals of the global program. We suggest that few, if any workers of that time could, in their wildest imaginings, have predicted what was to come. In just 20 years from that auspicious beginning most highly effective national control programs would begin grinding to a halt. Their malaria control expertise would be frittered away, their funding would be gone, the price of DDT would be up and its availability down, and the international policies for malaria control would be changed from disease prevention to case detection and treatment. The declining population of malaria control workers would begin seeing the disease they had worked so hard to control expanding back into malaria-free areas. Malaria would once again be inflicting ever-greater harm on the people they had tried to help. We should pause and consider how that happened, how our community failed to recognize the threat, and why it failed to respond.

The answers to these questions are perhaps more simple than one might think. During the 1960s, and into the 1970s, our community was committed, and had its nose to the grindstone, so to speak. From the initial use of DDT in the mid-1940s, our community had been in a position to observe any adverse effects from insecticides, if they were to occur. The community had close and continuous contact with the populations living in sprayed houses, and they saw no meaningful adverse effects. In brief, it had no evidence of any problems that appeared suddenly or gradually with the public health use of insecticides. Simultaneously the community saw great improvements in health when DDT was used to prevent the diseases it sought to eliminate. It was, perhaps, beyond the community's ability to think that anyone would work against a worthy and effective public health program; but the community was wrong. Additionally, the community had not focused on diverging malaria control interests of developed and developing countries. Divergences occurred because the developed countries had used DDT to eliminate malaria and no longer needed it. Meanwhile the developing

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countries still needed DDT to help with their disease control problems. Last but not least, the community had no prior experience with the ruthless and scientifically indefensible fear tactics that were being unleashed against its disease control programs.

Threats to the old malaria eradication effort evolved from two ideologies within the environmental movement. One was that there are too many people on planet earth and malaria elimination allowed excessive population growth of poor people in developing countries. The second theme was that man-made chemicals endangered wildlife and human health. In 1970, George Woodwell, a prominent and entrenched anti-insecticide campaigner, captured the two ideologies in a paper he published in *Science* magazine. He concluded that the answer to the problem of environmental pollution was "Fewer people, unpopular but increasing restrictions on technology (making it more and more expensive) [9]." His concluding comment captured the thinking of major stakeholders within the environmental movement at that time. Through the careful use of fear tactics, global campaigns grew up around each ideology. Eventually the ideologies became established at the highest levels of the UN and national governments of developed countries. Those campaigns eventually destroyed effective disease control programs. The campaigns against PHIs achieved success through misrepresentations of science, by dragging companies and public organizations into courts in order to grab headlines for their fear-invoking claims, by using smear tactics against those who spoke in defense of insecticides, and, lastly, through extremely well-funded anti-insecticide advocacy. Through it all, anti-insecticide campaigners were supported by a popular press that fed off the fear invoked by the movement's predictions of insecticides causing catastrophic harm to wildlife and human health.

Naysayers will claim this is an exaggeration and that the old disease eradication programs were eliminated for a slew of reasons not mentioned here. Indeed there were other factors; but the overwhelming factors, as documented in annual proceedings of the WHO's Executive Board, discussions of the World Health Assembly (WHA), internal documents of UNICEF, and other published and unpublished reports, were those delineated above. Those who choose to believe current programs are not at risk of a similar fate may venture the opinion that regardless of past events, circumstances are entirely different now. They might even conclude movements that brought down the old programs are no longer active. For certain, the people, the claims, and the organizations have changed; but the themes and the scare tactics are the same. Nevertheless we will concede one point. The circumstances facing disease control programs today are entirely different from those that confronted the old disease eradication programs. Chief among the differences are that the old programs were not confronted by:

- Global networks of well-funded anti-insecticide advocacy,
- A WHO that, aside from its support for DDT under Dr. Kochi's brief leadership of the Global Malaria Program, frequently prioritizes the agenda of environmentalist groups over public health interests,
- Educational systems seeded with anti-insecticide propaganda,
- A Conference of the Parties to the Stockholm Convention on persistent organic pollutants that has independent authority to select insecticides for global elimination,

- Large national and international bureaucracies for regulatory control of insecticides,
- A vast, and largely anti-insecticide, research establishment functioning in universities and research institutes around the world,
- Billions of dollars for regulatory control and research against insecticides,
- A declining arsenal of insecticides for malaria control, and
- Regulatory controls that are major impediments to the research and development of new PHIs.

4. Environmentalism over public health policies

With an annual caseload estimated at 216 million and 655,000 deaths, malaria continues as one of the most important insect-borne diseases [10]. Yet, it is just one of many insect-borne diseases that collectively claim millions of lives and stifle economic growth and development in disease endemic countries. PHIs and other public health chemicals are vital to the global struggle to control these diseases. Where PHIs are removed or their use restricted, disease rates increase. For example, two large eradication programs that were based almost entirely on public health use of DDT, freed Bolivia of malaria, dengue fever, and risk of urban yellow fever from the 1950s to the mid-1970s. The WHO acknowledges the importance of one program as follows: "Historically, mosquito control campaigns [that employed DDT] successfully eliminated *Aedes aegypti*, the urban yellow fever vector, from most mainland countries of central and South America. However, this mosquito species has re-colonized urban areas [with cessation of the *Aedes aegypti* eradication program] in the region and poses a renewed risk of urban yellow fever [11]." In spite of marvelous improvements in human health that were achieved by use of PHIs, international anti-insecticide pressures were brought to bear on those programs.

Bolivia abandoned *Aedes aegypti* eradication in the 1970s. This occurred because Bolivia, as with many countries of the Americas, ramped down eradication efforts once the US buckled to anti-DDT pressures in 1969 and ended use of DDT for *Aedes aegypti* eradication. Almost all countries of the Americas followed the US example in the 1970s. Years later Bolivia abandoned use of DDT for malaria control. As a consequence, malaria and threats of urban yellow fever are once again commonplace in Bolivia [12], and in 2009 Bolivia was savaged by a major dengue epidemic.

India is another case study. In the early 1950s, India had an estimated 75 million malaria infections, with roughly 800,000 deaths each year. Spraying DDT brought numbers of cases down to 49,151 by 1961. Today, the number of malaria cases each year is in doubt. What seems certain however is that the number of cases is huge and the number of deaths is on an order of hundreds of thousands. Estimates for cases vary from a few million to tens of millions of cases per year [13].

Despite the considerable human and economic toll caused by past increases in diseases like malaria and dengue, the current arsenal of PHIs for spraying on house walls is limited to just

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12 compounds from four chemical classes, namely pyrethroids, organophosphates, carbamates and organochlorines. Most PHIs are pyrethroids. DDT, the only organochlorine permitted for use, is one of the 12 approved compounds.

Even though production and use of DDT has declined continuously during the last four decades, DDT has grown as a convenient target of environmental science research. A recent PubMed search (in early 2011) for research papers on insecticides uncovered almost 60,000 papers, and about one sixth (9,459) were on DDT. These are remarkable statistics considering that DDT is hardly in use anymore. The decline in usage was sudden and corresponds to precipitous drops in human body burdens of DDT residues. Today, for example, the amount of DDT in human breast milk, based on serial surveys in many countries, is an infinitesimal fraction of what it was in the 1960s—and even those exceedingly low levels are declining [14]. Along with precipitous reductions in DDT use, one could reasonably expect that research on DDT would decline. However, as revealed in Figure 1, the numbers of published papers on DDT have actually increased, and more so in recent years than in the past. Furthermore, papers on DDT and malaria account for only a minor proportion (2.6 to 14.8% per year) of those published papers. So, why is the research effort on DDT increasing even as the use of DDT fades to inconsequential levels? To answer this question we will delve more into the modern themes of environmental research and anti-insecticide advocacy.

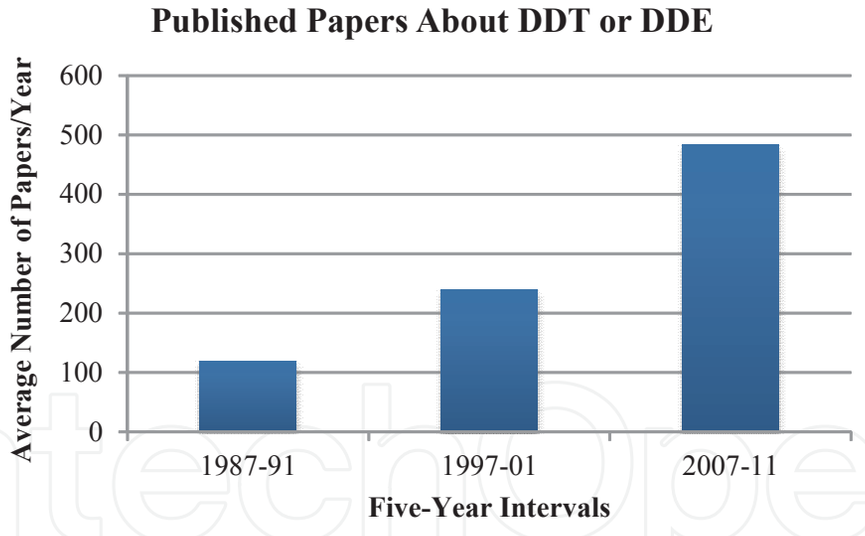

Figure 1. Average number of papers published per year on DDT or DDE. Data based on PubMed searches on key words--DDT and/or DDE. Counts summed for five-year intervals of 1987-1991, 1997-2001, and 2007-2011.

5. Why increased research on insecticides?

A 2005 paper by Dr. Stephen Safe, a Distinguished Professor and recipient of the Distinguished Lifetime Toxicology Scholar Award from the Society of Toxicology, explains much about the modern trend of increased funding and research on DDT [15]. Professor Safe is a professor at

Texas A&M and is a specialist in toxicology and molecular biology of estrogenic and anti-estrogenic compounds. To summarize introductory comments in his 2005 paper, modern emphasis on DDT is linked to a series of 1990 papers and the concept of the precautionary principle. The papers proposed that endocrine disrupting chemicals (EDCs), which include both man-made (synthetic) and naturally occurring chemicals, were contributing to diverse health problems worldwide. The diverse harms include decreased male sperm counts, increased birth defects, decreased fertility, increased incidence of breast and testicular cancers, etc. As Dr. Safe states, the role of synthetic EDCs as a cause of diverse health problems has been subjected to multiple challenges, to include a lack of biological plausibility for some responses and failure to consider that people are more heavily exposed to natural or dietary EDCs compared to relatively low exposures to the synthetic EDCs. Additionally, the natural compounds are often far more potent endocrine disruptors than synthetic EDCs.

The 1990s papers and the concept of the precautionary principle resulted in new funding and renewed interests in insecticides. As described by Dr. Safe, "Regulatory and research funding agencies have taken the endocrine disruptor hypothesis seriously [15]." Funds for research grew and, as a result, "... numerous laboratory animal and clinical studies have been initiated to test the validity of the hypothesis and to determine the association between health problems and exposure to EDCs [15]." This, in large part, seems to explain the huge growth in research and numbers of publications about potential harms from DDT and other insecticides. It is worth noting that extremely sensitive assays are available for DDT and other synthetic EDCs; but assays are often not available for more abundant and more diverse populations of natural EDCs. Thus it seems that the selection of DDT as a research topic is more closely related to availability and familiarity with quantitative assays opposed to some understanding of what the real threats are from synthetic versus natural EDCs.

In his 2005 paper Dr. Safe reviews many recent studies, and we refer the reader to his paper for more in-depth analyses. He comments on the synthetic EDCs as casual agents in breast cancer and male reproductive track anomalies. For the former, he reviews several studies, to include a meta-analysis, and concludes that the evidence does not support the hypothesis that DDE causes breast cancer. He concludes further that "If organochlorines do not significantly impact on this disease [breast cancer], it is now time to generate new hypotheses and focus on identifying other etiological factors that are linked to the high incidence of sporadic breast cancer in women [15]."

Dr. Safe reviewed numerous studies on DDT and other synthetic organochlorines (OCs) reportedly causing diseases of the male reproductive tract. The claim that sperm counts are declining is central to the thesis of many alarmists who propose that synthetic OCs are causing declining male sexual function. Dr. Safe reviews past reports and concludes, "results from various clinics are not sufficient to support a global decrease or increase [15]" in sperm counts. He also concludes "the hypothesized role of *in utero* exposure to estrogens as a factor in regulating sperm count in adult males is also questionable [15]." Dr. Safe goes on to review studies on possible associations between levels of synthetic EDCs with urogenital birth defects and increasing trends of testicular cancer. For the former, he found that both the evidence of increasing rate of birth defects and the hypothetical associations between those rates and

exposures to synthetic EDCs were not persuasive. Additionally, evidence of multiple studies did not support the hypothesis that synthetic EDCs were a cause of testicular cancer.

In this brief section we have described the major themes of research that will be the source of future claims against PHIs. Dr. Safe sounded a warning in his comments about EDCs and breast cancer. He pointed out that our abilities to detect EDCs and a wealth of other variables (for example, biomarkers, genotypes, and a wealth of other biological, biochemical, environmental, and sociological variables) "increases the probability of 'chance' correlations, and there are several examples of these associations that are not consistent across all studies [15]." So, it seems clear that we should expect a greater frequency of claims against PHIs in the future. That said, anti-insecticide advocacy more so than research poses the greatest threat to the future of effective disease control programs. As we observed in the negotiations for the Stockholm Convention on Persistent Organic Pollutants (POPs) described below, well-funded anti-insecticide advocacy is the operational arm of the environmental movement. But unlike the careful deliberations of most environmental scientists, anti-insecticide groups are not constrained by subtle considerations of consistent and meaningful evidence and other criteria for cause-effect relationships, or by considerations of harm versus benefits of insecticide use.

6. Renewed malaria control programs beset by opposition to PHIs

As stated in an earlier section, today there is great enthusiasm and considerable funding to advance the goals of global control of malaria. We arrive at this period of enthusiasm only because we lived through many years of almost no hope at all.

The steady increase in malaria cases that led to RBM's formation had several underlying causes. Among them was the spread of drug resistance around the world. Since the 1940s chloroquine had been a mainstay of malaria treatment programs, but resistance by the *Plasmodium falciparum* parasite to the drug first appeared in the 1950s and slowly spread worldwide. Chloroquine was duly replaced by sulphadoxine-pyrimethamine (SP) in the 1980s, but resistance soon emerged to this drug as well.

Another cause of the growing burden of malaria was the lack of interest in malaria control by major donor agencies and malarial country governments. Enthusiasm for malaria dissipated when the great push against malaria - the global malaria eradication campaign of the 1950s and 60s – was called off. Malaria control is expensive, requiring the employment of trained personnel, logistics specialists, scientists and large quantities of drugs and vector control products. Continuing to pay for malaria control year in and year out when it was clear that global eradication was not feasible was a tough sell. Concurrently the focus for many development agencies was away from disease control and towards population control, as we touch on in this chapter and explain in more detail in *The Excellent Powder, DDT's Political and Scientific History* [16]. Few newly independent and highly malarial African countries sustained malaria control programs that had been run by colonial rulers. In Zambia, for instance, malaria control programs that had been set up when the country was ruled by Great Britain as Northern Rhodesia collapsed along with the Zambian economy in the 1980s.

However, as illustrated in the examples of disease control history in Bolivia and India, arguably one of the greatest obstacles to sustained malaria control was the growing campaign against PHIs, and DDT in particular. DDT had been used in malaria control since World War II. The effectiveness of this insecticide in controlling malaria was unprecedented. As we explain above, DDT, when sprayed on the inside walls of houses, acts to repel mosquitoes, but it will also irritate mosquitoes so they exit houses sooner than they otherwise would and will kill mosquitoes that rest on a sprayed surface long enough.

Through these multiple modes of action, and thanks to the dedicated work of thousands of hard working malaria control program officers, DDT saved around one billion people from malaria during the eradication era. But what some people heralded as a great savior, others decried as a harbinger of doom. Chief among the anti-DDT crusaders was Rachel Carson whose 1962 book, *Silent Spring*, is a florid and grossly exaggerated attack on the chemical for its supposed impact on wildlife and human health [17]. There were, and are, no shortages of Carson acolytes who have joined in with their own attacks on DDT, as we explain later in this chapter.

Following the banning of DDT for most uses in the US and Western Europe in the 1970s, production fell dramatically. Although DDT was still permitted for use in disease control, supplies dwindled and predictably the cost began to rise. It mattered little that the WHO's malaria control advisers still supported the use of DDT, when the reality was that fewer countries could obtain it. In 1969, Scandinavian countries, Canada and the US started to place 'severe' restrictions on the use of DDT [18]. Thus, it was no coincidence that global malaria eradication and the United State's *Aedes aegypti* eradication programs were both stopped in 1969—just as it was no coincidence that both relied on use of DDT [16]. Unsurprisingly, within just a few years, malarial countries were complaining to the WHO of their inability to obtain the chemical and use it to save lives [19]. Along with the growing campaigns against DDT, donor agencies like USAID, under pressure of legal actions, began to withdraw funding for DDT and malaria control in the 1970s.

In the following section we will detail, with a specific example, how the bio-politics of environmental activism against DDT and other PHIs translated into real world harm to human health. For this example we have chosen a country that has a strong tradition in science and a long and proud history of combating malaria.

7. Public health insecticides and malaria

The value of PHIs in controlling malaria is best evidenced by historical data on DDT sprayed houses. Brazil, as with other countries with territory within the Amazon Basin, struggles with difficult malaria control issues. The Amazon Basin is the most enduring environment in the Americas for the persistence of endemic malaria. Populated with many rural, poorly housed and mobile inhabitants, the Amazon Basin covers a vast geographical area of warm, humid environments. More importantly, it is populated with the Hemisphere's most dangerous vector of human malaria, *Anopheles darlingi*. In the absence of this species or in regions of the

Americas where it is less common, the chain of malaria transmission is weaker and more easily interrupted. For this reason, malaria often declines to low levels in the face of organized control programs in regions outside the Amazon Basin. In contrast, within the Amazon Basin, malaria exhibited some refractoriness to control measures even during years of the global malaria eradication program. As a consequence, eradication was not achieved. Nevertheless the spraying of DDT on house walls greatly reduced malaria infections and lifted a large part of the burden of malaria from the backs of people in the Amazon Basin.

Successful malaria control by spraying DDT was maintained for many years. Yet, the succession of bio-political events described in the previous section and elsewhere eventually destroyed Brazil's well-orchestrated malaria control program. Malaria cases began to increase when the numbers of houses being sprayed were progressively reduced in the 1980s. The many years of successful control followed by years when the spray program withered away are detailed in Figure 2.

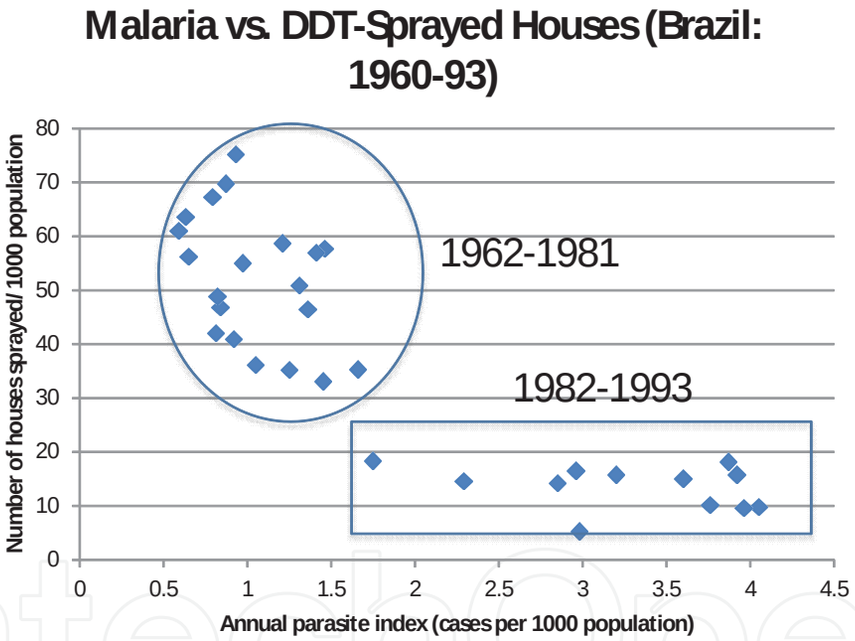

Figure 2. Number of houses sprayed per 1000 population versus the annual parasite index (cases per 1000 population) in Brazil during the years 1962 to 1993. Data for these years were collected under uniform data collection methods (see Roberts et al. 1997. for data sources [34]).

The graph presents annual parasite indices (APIs) and house spray rates (HSRs) from 1962 to 1993. Two clusters of data points are identified. One group represents the years from 1962 to 1981 when house spray rates were high and malaria indices were low. The API is a standard malaria control index, calculated as the annual number of diagnosed malaria cases X 1000/ population size. The HSR represents the number of houses sprayed per 1000 population. As shown in this graph, APIs in years after 1981 increased in response to reductions in numbers of houses being sprayed.

To bring Brazil's story up to date, Figure 3 presents statistics on malaria cases through 2010. As described in the previous section, there has been a global renewal in efforts to control malaria. Thus, in recent years, Brazil expanded its malaria control efforts. But even with increased financial support and availability of new malaria control technologies (e.g., case treatment with the new and effective ACTs, insecticide treated nets and so-called long-lasting nets), the accomplishments of recent years are less than what is needed and certainly far less than what was achieved and sustained during 20 years of spraying houses with DDT. As demonstrated in Figure 3, there was an average of 100,000 cases per year during those 20 years of major reliance on DDT. As DDT use declined in the 1980s, the average number of cases/year increased to 450,000. In the next decade, DDT use was abandoned completely and cases increased to over 500,000 per year. Today, even with an expanded program of control, the average number of cases per year is well over 400,000. The differences in results of the last 30 years over what was achieved with DDT roughly sums to 10.5 million cases that might have been prevented if DDT had not been abandoned. While population growth as an independent variable might account for some growth in numbers of cases, the increased number of cases corresponds, over time, to changes in slide positivity rates. The slide positivity rate is neutral in terms of population size. As a reminder, the estimate of 10.5 million excess malaria cases is for Brazil alone.

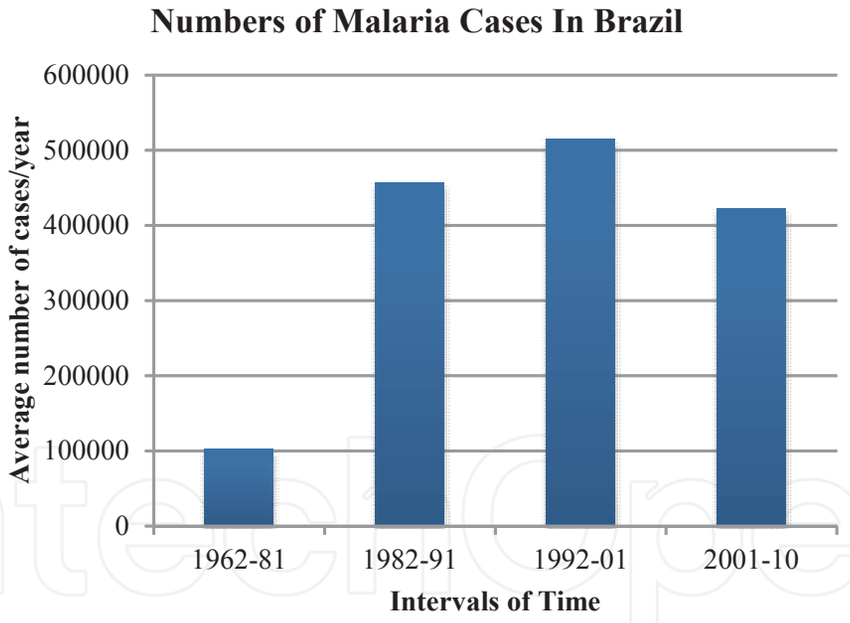

Figure 3. Average number of cases per year in Brazil across defined blocks of years (x-axis). Data for these years were collected under uniform data collection methods (see Roberts et al. 1997 for data sources [34] and PAHO malaria data [57]).

Clearly the great reductions of malaria from 1962 to 1981 compared to later blocks of years reveals the enormous benefit of DDT and other insecticides.

One of the most compelling examples of the usefulness of DDT in malaria control comes from recent experience in South Africa. This country had successfully used DDT in malaria control

since the late 1940s and in so doing had dramatically reduced the malarial areas to the regions bordering Mozambique to the east and Zimbabwe to the north. In 1996 South Africa's Malaria Advisory Group (MAG) advised the national malaria control program to begin phasing out DDT. This advice was based on two main factors. First, DDT is best applied to the mud and dung walls of traditional African houses rather than on the plastered and painted walls of western style houses where the DDT can stain the walls. Given the staining, homeowners were often reluctant to allow the spray teams to enter their houses. As the rural areas of South Africa have developed and become wealthier, more and more people have built western style houses, requiring alternative insecticides. Second, the MAG had taken note of the political pressure against the use of DDT and anticipating greater restrictions on the use of DDT, decided to transition over to other chemicals. In the late 1990s therefore the provincial malaria programs began replacing DDT with pyrethroids. The first province to do so was KwaZulu Natal, which borders Mozambique and at the time was the most malarial of the countries three malarial provinces [16].

Almost as soon as the KwaZulu Natal malaria control program changed over to pyrethroids, malaria cases started to rise. By 2000, malaria cases had increased five fold from just over 8,500 cases to almost 42,000 cases. Malaria deaths increased from just 22 in 1996 to 320 in 2000 as malaria patients overwhelmed clinics and hospitals [20].

Research showed that a major driver of the epidemic was resistance to pyrethroid insecticides. In addition, evidence was rising that malaria parasite resistance had grown to SP, or Fansidar. The Department of Health took the decision to reintroduce DDT and change treatment regimen from Fansidar to the newly-available ACT, artemether-lumefantrine, or Coartem. Within a year malaria cases plummeted by around 80 percent [21]. The combination of a proven and effective PHI along with effective treatment reduced malaria transmission so dramatically that within just a few years, malaria elimination was within sight.

Given the benefit and usefulness of DDT and other PHIs in the control of malaria, as described above, how is it possible that PHIs have been so effectively demonized? In the next section we will describe strategies and tactics that have been employed to paralyze malaria control programs in countries around the world. As an aside, it is worth noting that those who ruthlessly campaign against DDT and other PHIs shamelessly deny any responsibility whatsoever for the increasing burdens of disease that inevitably occur when their campaigns succeed.

8. Goals, strategies, and tactics of anti-insecticide campaigns

The goal for environmental campaigns is to reduce or eliminate use of PHIs for the presumed but ambiguous purpose of better environmental health. Another goal, at least for some, appears to be stopping the use of chemicals that protect health and save lives in order to slow growth of human populations.

In the 1960s, the goal of halting or reducing the use of man-made insecticides was laid out in Rachel Carson's unscientific writings in *Silent Spring*. In 1968, the Malthusian rantings of Paul

Ehrlich in *The Population Bomb* focused attention on the contributions of DDT to growth of human populations in malaria-endemic countries. The goal of reducing human populations was never silenced; and it is once again a topic of heated debate, with some claiming billions of people must be eliminated [22].

The goal of today's anti-insecticide activists is still to reduce or eliminate synthetic insecticides. Achieving such a goal requires strategies and tactics. There are three visible strategies for achieving the goal of reducing or eliminating PHIs. The first is to convince people that PHIs are harmful. The second is to claim the chemicals are not needed in order to control diseases. The third strategy is to predict that grave harm will occur if the PHIs continue to be used. In this section we will give background information and three examples of the first strategy. In most cases we will focus on issues of DDT, but the same strategies and tactics are employed against other PHIs.

In a historical context, anti-insecticide advocates used propaganda and emotional arguments to convince people insecticides were dangerous and their use should be stopped. They were helped by science writers of the popular press and their efforts led to public health programs being abandoned around the world – and a resurgence of malaria infections. We have already presented one example of such an outcome (see Figures 2 and 3).

Anti-insecticide activism is an even stronger force today, and anti-insecticide advocates are even more determined to deny developing countries the protections from disease and death that only insecticides can provide. Because of environmental and anti-insecticide advocacy, the WHA adopted a resolution (WHA 50.13) in May 1997 that calls on countries to reduce reliance on use of insecticides for disease control [23]. Then, in 1998, the United Nations Environment Programme (UNEP) began negotiations for a POPs treaty targeting DDT and 11 other chemicals for global elimination [24]. The beginning of those negotiations stimulated malaria scientists and other public health professionals to mount a global campaign to defend the use of DDT in disease control programs. The public health campaign was successful and DDT was listed on Annex B of the Stockholm Convention on Persistent Organic Pollutants, which allowed its continued use. Yet, and despite the public health campaign's success, anti-DDT and anti-insecticide advocacy is unabated in UNEP, the US Environmental Protection Agency, the European Union, and, to lesser extent, in public agencies financing disease control programs. As a result, DDT factories closed their doors. Today, only one in India is still in operation. Also, environmental campaigners have erected formidable international barriers to the purchase and supply of DDT. Countries are under continual pressure from anti-DDT advocacy groups, and they are being enticed by financial mechanisms of Global Environment Facility (GEF) to stop using DDT.

WHA resolution 50.13 and the Stockholm Convention on Persistent Organic Pollutants, described above, are only the most recent in 50 years of efforts to eliminate DDT and other PHIs. Success in anti-PHI campaigns has been achieved by scaring people with false claims. Anti-DDT propaganda typically claims DDT causes all manner of harm to human health. Readily embraced and trumpeted by the popular press, the claims, in reality, never satisfy even the most minimal cause-effect criteria [25]. These internationally accepted criteria are:

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- Strength of the association. The stronger an observed association appears over a series of different studies, the less likely this association is spurious because of bias.
- Dose-response effect. The value of the response variable changes in a meaningful way with the dose (or level) of the suspected causal agent.
- Lack of temporal ambiguity. The hypothesized cause precedes the occurrence of the effect.
- Consistency of the findings. Most, or all, studies concerned with a given causal hypothesis produce similar findings.
- Biological or theoretical plausibility. The hypothesized causal relationship is consistent with current biological or theoretical knowledge.
- Coherence of the evidence. The findings do not seriously conflict with accepted facts about the outcome variable being studied.
- Specificity of the association. The observed effect is associated with only the suspected cause (or few other causes that can be ruled out).

In the case of a true cause-effect relationship we can reasonably expect measurable levels of harm as a result of human exposures. Levels of harm will be proportional to harmfulness of the agent and to durations and characteristics of exposures. The more harmful an agent, the more likely it is to produce obvious levels of harm. Harm from weaker agents, on the other hand, will probably not be obvious and be definable only through population-based statistics. Regardless, ending use of a weak, but truly harmful, agent will reduce exposure to the chemical, reduce chemical concentration in the environment, and reduce the levels of harm. This is true even if the chemical is characterized as persistent, as is DDT. Persistence does not mean the chemical does not degrade. It just means that in certain compartments of the environment or living organisms it will degrade or be eliminated more slowly. Levels of DDT in the environment generally decline rapidly after its use is stopped. It is precisely because DDT does degrade that house walls are re-sprayed once or twice a year in order to achieve effective levels of malaria control.

Here, with the example of cigarette smoke and cancer, we illustrate application of cause-effect criteria. The link between smoking and human cancer has been validated through experimentation and vital statistics. In general, the argument that cigarette smoke caused cancer was convincing because patterns of low or high cancer rates consistently correlated with patterns of low or high smoking rates and duration of smoking. Furthermore, as people stopped smoking their risk of cancer actually declined. Consistent and persuasive evidence of cause-effect relationships between cigarette smoking and cancers formed the basis of public health campaigns to reduce or stop cigarette smoking. Unlike those public health campaigns, however, the environmental campaigns against PHIs are not based on persuasive and, certainly not, consistent, scientific evidence. The occasional observational study that suggests use of a public health insecticide harms health is countered by many other studies that suggest otherwise. Nevertheless, and as illustrated below, environmental campaigners readily ignore essential criteria for establishing a cause-effect relationship and greedily grab any new study that suggests some association between PHIs and human disease. The activist community has

shown itself to be highly adept at getting such studies widespread national and international media coverage, often with headlines and messages designed to strike fear into people's hearts. These headlines are also very useful in advancing careers and ensuring ongoing research funding. We will describe three examples of how environmental advocates, and in some cases the environmental scientists themselves, ignore the criteria for establishing cause-effect relationships and use preliminary studies to push their anti-PHI agenda, or, more selfishly, their personal research agenda. The three examples are illustrations of the first strategy to convince people that DDT is a public health threat.

Example 1:

Mary Wolff and co-authors (1993) published a paper in which they claimed a statistical association of DDE (a major DDT metabolite) with breast cancer [26]. DDT opponents then used this paper to gain public attention and convince people that DDT caused breast cancer. To be specific, we are talking about anti-insecticide activists, not Dr. Wolff. Years later, with completion of many other studies, and without fanfare or wide publicity, researchers concluded DDE was not a cause of breast cancer. The WHO reassessment of DDT exposures from indoor spray programs states, "Overall, the association between DDT and breast cancer is inconclusive [27]." Regardless, for many years, anti-DDT activists heralded the 1993 paper as final proof of DDT harm and used it to generate funds and recruit new members to campaigns for DDT elimination [28].

Example 2:

Following a different thread of research, Rogan and coauthors reported that DDE was associated with reduced duration of lactation [29,30]. As with the reported association of DDT and breast cancer, this claim was grabbed by the WWF in 1998 and used in the propaganda campaign leading up to the Stockholm Convention on Persistent Organic Pollutants. The stated goal of the WWF campaign was a phase out of DDT by 2007 [28]. In their coverage of this topic, the WWF stated that studies "showed that the duration of lactation was inversely related to the concentration of DDE in milk." Separate from the WWF's use of these claims, the claims were, in part, also the basis for two high-profile publications by Rogan and coauthors in the journals, *Emerging Infectious Diseases* [31] and *The Lancet* [32]. They proposed that the benefits of spraying DDT on house walls to control malaria in Africa would be cancelled out by lowered child survival due to reduced durations of lactation and potential increases in premature births. The claims were used in campaigns against DDT and used to justify more research support.

Once published, the claims became tools for anti-DDT advocacy. For example, the claim is part of a 2005 Physicians for Social Responsibility (PSR) document about DDT and its use in Kenya. The PSR author states, "DDT may have a substantial impact on infant mortality, by increasing the risk of pre-term birth and by decreasing the duration of breast-feeding after birth. In this paper, Chen and Rogan conclude that DDT may cause comparable increase in infant mortality through these mechanisms compared to the decrease in infant mortality it causes by killing mosquitoes and thus reducing malaria cases [33]."

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Without doubt the papers had great value for the anti-DDT advocacy community, yet the background studies for those claims did not fulfill the criteria for establishing DDT as the cause of reduced lactation or of pre-term births. In fact, even Chen and Rogan [31] stated the reported associations did not prove DDT caused any of the illnesses they discussed. Regardless, the claims were used as if they proved, beyond any doubt, that DDT was the cause of harm. This was illustrated in an exchange of letters to the Editor of the journal, *Emerging Infectious Diseases*. The exchange was between Roberts [34,35] and the WWF (written by Matteson) [36]. Matteson stated in her letter, "DDT also is associated with reduced lactation, premature births…" Naturally, Matteson used those reported associations to demonize DDT as part of WWF's push for global elimination of DDT by 2007. Misuse of those claims is further illustrated by an article defending Rachel Carson by the Rachel Carson Council. As with the PSR author, this writer used both claims plus the assertions included in the two papers by Rogan and coauthors about the benefits of DDT being canceled out by increased deaths of newborns in Africa. As stated in this very recent online article: "…significant shortening of the lactation cycle-time that human mothers can produce milk for their babies linked to DDT exposure. Based on reports for both premature births and reduced lactation cycles, scientists have predicted that regular DDT exposure could increase the possibility of higher levels of infant mortality for women in Africa who live in treated environments [37]."

There are many other examples of how these claims have been used and continue to be used in anti-insecticide propaganda. As stated in a 2006 article advocating against the use of DDT by the Pesticide Action Network in the UK, "Other studies have linked DDT to reduced breastmilk production, premature delivery and reduced infant birthweights [sic] [38]." Last but not least, Wikipedia includes the following statement:

Human epidemiological studies suggest that exposure is a risk factor for premature birth and low birth weight, and may harm a mother's ability to breast feed. Some 21st-century researchers argue that these effects may increase infant deaths, offsetting any anti-malarial benefits. A 2008 study, however, failed to confirm the association between exposure and difficulty breastfeeding [39].

Mention of the 2008 study is perhaps helpful; but it is not sufficient. Given that DDT produces great benefit in control of malaria, Wikipedia contributors should be careful in comments about DDT lest their written assessments inflict grave harm on poor people in malaria endemic countries. Point of fact, the Wikipedia assessment leaves the reader thinking that DDT causes premature births and reduced duration of lactation, when the weight of scientific evidence shows it does not.

Example 3:

Unfortunately, the false claims against DDT are unabated. One of the more recent and truly tragic examples of a false public image for PHIs occurred in 2009 when researchers in South Africa reported DDT was associated with urogenital birth defects in boys in a region where houses are sprayed with DDT to control malaria [40]. Although the authors, led by Prof. Riana Bornman of the University of Pretoria, suggest that DDT may not have caused the birth defects, the authors still state people should be informed about risks of birth defects if DDT is used.

Their interpretations and claims were aired broadly in the print and electronic media in South Africa. The public's concern over the researcher's claims created difficulties for the malaria control program. DDT, through decades of use in South Africa, had already proven its disease preventing capabilities. Given its proven record of performance, it is hardly reasonable to alarm people unless DDT is proven to be seriously harmful. In this case, the weaknesses of the researcher's claims had been addressed in the journal where the paper was published. Richard Grady addressed this issue in the editorial comment that accompanied the Bornman *et al*. paper [40]. Grady stated that issues of association and causality could not be distinguished in the paper. Grady was right; Bornman and coauthor's claims that DDT caused birth defects did not fulfill criteria for establishing a cause-effect relationship. As point of published fact, there were no statistically significant differences in the proportions of malformed genitalia among boys in sprayed and unsprayed villages. Given this fundamental failing, their pronouncements should not have been published and certainly should not have been used to scare the public away from having their houses sprayed. However, attempts in South Africa to scare people about DDT continue even now.

One of the researchers behind the urogenital birth defects claims recently reported on the levels of DDT in breast milk in sprayed villages in South Africa compared to results of an unsprayed village [41]. During the 70+ years of DDT use, many studies of DDT in breast milk have been performed. Based on those reports, it is expected that residents of DDT sprayed houses will have higher quantities of DDT in breast milk than residents of unsprayed villages. It is expected that intake by some infants will exceed the Provisional Tolerable Daily Intake (PTDI) and, in some cases, the residue levels will exceed the Maximum Residue Limit (MRL). In order to exaggerate the importance of their study, the authors emphasized the outlier measurements beyond confidence limits of mean values, e.g., in the abstract they report their statistics include "the highest ΣDDT level ever reported for breast milk from South Africa." Their control village was not sprayed and had no history of ever being sprayed. Yet the authors fail to mention that mean values of residues were at or above the MRL in the unsprayed village. They fail to mention that outlier data points in the control village, as with sprayed villages, exceeded the PTDI. They fail to mention that confidence limits for measurements from the control village overlap those of some sprayed villages. Authors emphasize gender differences in infants and associated levels of DDT in breast milk even though the differences were not statistically significant. They suggest the results require further research. Additionally, authors [41] report that mean levels of DDT had no impact on duration of lactation.

In press coverage of this paper the headlines read, "Researchers measure highest DDT levels in breast milk from South African nursing mothers [42]." In fact, outlier data points can result from erroneous dilutions, tests, conversions, or other parts of the experimental process, or just uncommon natural variation. For these reasons most researchers give outlier data points little weight. Yet the authors of this study used an outlier data point as a hook for grabbing headlines in the popular media. Media coverage went on to state, "In the region where the measurements were carried out, malformed genitalia among boys was significantly more common in areas treated with DDT compared with untreated areas." The assertion that DDT affects male urogenital development is mentioned in the paper, e.g., referring to the 2009 study they state,

"Research…identified DDT-associated effects on male urogenital parameters…[41]." However, the statement is misleading because, as described above, there were no statistically significant differences in the proportions of malformed genitalia among boys in sprayed and unsprayed villages.

Presented in three examples above is clear and unambiguous demonstration of orchestrated and non-scientific campaigns against PHIs, and DDT in particular. Claims that DDT causes one sort of harm or another are repeated in anti-insecticide propaganda even after published studies show the claims are false, or published rebuttals draw attention to errors in data analyses or research interpretations. A common part of these campaigns is how activists use the term "association" or "associated" as meaning there is a cause-effect relationship between an exposure and disease. In fact, these terms relate only to a statistical association that is often an artifact of study design or a product of systematic bias. Such issues as bias are of particular concern, and are discussed at length in David Savitz's book *Interpreting epidemiologic evidence* [43].

In the history of efforts to preserve use of DDT for public health programs, this chain of events has been repeated over and over, with claims of causation eventually being disproven, but not before they were used to generate funds, recruit new members to anti-insecticide campaigns, and change public health policies. Last but not least, each change in disease control policy has weakened global capacities to control malaria and other diseases. Almost every change is a result of anti-insecticide propaganda that misrepresents the scientific process, as revealed for the three examples described above:

- The breast cancer example reveals a general trend of anti-DDT campaigners railing against DDT while failing to meet minimal evidentiary standards for proof of cause-effect relationships (as defined by the principles of causation [25]). In brief, those who campaign against DDT have failed to show, through replicated and confirmatory studies, that a specific type of public health harm from DDT was a consistent finding across studies, and that it was consistent with current biological or theoretical knowledge of the type of harm and its known risk factors; for example:
  - More common with higher DDT exposure and less common with lower exposure,
  - Less common prior to DDT exposure and appeared or increased in frequency with onset of DDT exposure, and
  - More common with DDT exposure and less common once DDT use was stopped.
- The example of DDT as a reputed cause of reduced duration of lactation illustrates how an unproven claim can be used in scientific literature to assert that an unintended consequence of DDT might cause as much harm as benefit. Also it shows how the claim can continue to appear in anti-insecticide propaganda long after it is disproven.
- The example of malformed male genitalia illustrates how false associations can be used in attempts to scare people away from allowing their houses to be sprayed. Also the example illustrates how tangential studies (a survey of DDT in breast milk) can be used to exaggerate

dangers of DDT and to cast further attention on the results of weak studies. Sadly, the two studies are being used to scare people who live in malarious regions.

9. Dichotomies in patterns/trends of human disease with/without DDT

Decades ago, developed countries used extraordinary quantities of DDT. The richer countries placed DDT in the human food chain through its heavy agricultural use at that time. More explicitly, DDT was used in the environment, around houses, and intensively inside homes. It is now 40 years since being banned for most uses in the US and other developed countries. Yet, recent claims of DDT causing disease or birth defects are not reflected in the historical medical reports and vital statistics for regions and years of broad and heavy DDT usage. The lack of proof that DDT caused harm to human health back in the days of intense exposures goes far in explaining why, to this day, there is no evidence that human health has been improved in any way by stopping public health uses of DDT.

There is a dichotomy in the huge benefit from use of DDT to prevent diseases and deaths versus no definable benefit from stopping its use. For slightly more than three decades (1945-1979) many malaria endemic countries maintained house spray programs. That era was followed by decades, from 1979 through to present time, when most of the same countries phased house spraying out of national programs. The result is a historical record of years when DDT and other insecticides were sprayed in houses followed by almost as many years when spraying was greatly decreased or stopped entirely. An even more drastic stoppage of DDT spraying occurred in agriculture. The dichotomies of outcomes are listed in Table 1.

Benefits versus harms of public health insecticides	1946-79 (period of DDT spraying in houses)	1980-present (period when DDT spraying was reduced or stopped)
Harm from insecticide exposures	Increases in poisonings and deaths from insecticide exposures in houses	Reductions in poisonings and deaths as house spraying is eliminated
Benefits from using insecticides to control malaria and other diseases	Reductions in malaria infections and deaths as a consequence of DDT on house walls	Increases in malaria infections and deaths as house spraying of DDT is eliminated

Table 1. Grid of cause-effect relationships for public health outcomes during periods of use and non-use of DDT in public health programs.

As explained for smoking and human cancers, the relationship of declining risk with reduced exposure attests to a true and meaningful causal relationship. An inverse finding of increasing risk with increasing exposure to a causative agent also attests to a true and meaningful causal relationship. These indicators of causation make it all the more amazing that through decades of anti-insecticide advocacy, insecticide opponents have documented no obvious public health harm as a result of DDT residues on house walls. Likewise, they have documented no meaningful improvements in health or reduced deaths as a direct result of having eliminated

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DDT exposure by ending house spray programs. These failings suggest DDT opponents have not been challenged to balance an equation of measurable benefits from preventing the use of DDT and other public health insecticides versus the measurable increases in human deaths and diseases, like malaria, as consequence of stopping use of public health insecticides.

10. Models for modern advocacy against PHIs

Now, on the fiftieth anniversary of *Silent Spring*, the goal of reducing or eliminating DDT and other PHIs is, and has been for decades, entrenched in environmental advocacy literature and in bureaucracies of the UN. In the case of DDT, this goal was clearly enunciated by UNEP in 2000:

WHO and UNEP have joined forces to protect both human health and the environment by promoting strategies to reduce malaria with reduced reliance on DDT. An important first step was taken in March 2000 through a WHO-convened Regional Consultation to Prepare African Countries Towards Reduction of Reliance on DDT for Malaria Control, with UNEP support. [44]

For UNEP bureaucrats, the statement codifies the environmentalist's belief that small quantities of DDT sprayed on house walls harms the environment. Also it codifies the belief that DDT is not needed in malaria control programs. In both cases, the bureaucrats are wrong.

Information presented in Figures 2 and 3 illustrate the enormous danger of forcing countries to abandon DDT and other PHIs. Since the early 1980s over 10.5 million preventable malaria cases were recorded above and beyond what might have occurred if Brazil had not abandoned DDT. There were no DDT resistance issues that caused malaria program managers to abandon DDT, there were no important studies showing DDT repellent properties did not work, there were no malaria trend analyses showing a lack of efficacious control with DDT sprayed walls, and there were no cost-effective insecticides that could be used instead. DDT was abandoned in Brazil and in other countries of South America as a consequence of global environmental policies and anti-insecticide campaigns. DDT was not eliminated from Peru's malaria program until the late 1980s. Peru's malaria problems grew exponentially worse immediately after the country dispensed with DDT spraying. These disastrous outcomes were repeated in many countries.

With the beginning of the 21st Century and infused with renewed support and improved targeting in application of control efforts, malaria control programs are beginning to make some progress. But further progress is needed and malaria continues as a huge public health problem. Meanwhile, as in the 1960s, insecticide opponents are poised to counter the recent progress against malaria. We will now focus on specific tactics that are and will continue to be used in the anti-insecticide campaigns.

As we have described, the first strategy of insecticide opposition is to convince people that DDT or other PHIs are harmful. An important tactic for achieving success is to develop and broadcast widely and repeatedly a list of diverse claims of chemical harm. We have already described examples of how this tactic is implemented. A list of diverse sources of harm is not easy to counter. When an authoritative rebuttal of one claim occurs, the other claims are still in play. Additionally, a broad list of claims allows campaigners to tailor platforms for constituencies, advancing one set of claims with one constituency and a different combination for another. Another tactic is to focus on the most recent study hinting at some health impact of the chemical. It is easier to get the popular media interested in a study that can be presented as a new and sensational finding--a favorite theme of science writers. Regardless, a list of multiple claims of harm is hardly sufficient to achieve a ban of a truly useful PHI. Thus, the second strategy of convincing people the chemical is not needed becomes extraordinarily important. The tactic behind this goal is to argue that alternative chemicals or methods can be used as replacements. We will present two examples of tactics employed in support of this strategy. The third strategy is to predict that grave harm will occur if the chemical continues to be used.

The success of Rachel Carson's *Silent Spring* serves as a model for the three strategies. In *Silent Spring*, Rachel Carson used the strategies on her primary target, DDT. She described a very large list of potential adverse effects of insecticides, including human health and ecological effects. She argued that insecticides were not really needed because their use selected for super bugs that were resistant to the insecticides and that the chemicals only made problems worse. Last but not least, she described scary scenarios of severe harm with continued use of DDT and other insecticides.

Carson focused attention on examples of overuse or misuse of DDT and other insecticides and described the effects of their misuse. Nevertheless, the misuse of chemicals is not a valid reason for banning an insecticide. In the case of DDT, a successful campaign to eliminate it requires that even its proper use will cause a large and systematic adverse effect. However, the proper public health uses of DDT yield no large and systematic adverse effects. Absent such adverse actions, the activists must then rely on claims about insidious effects, particularly insidious effects that scientists will find difficult to prove one way or the other, and that activists can use to predict a future catastrophe.

Rachel Carson relied heavily on possible insidious chemical actions as a means of alarming and scaring the public. Many of those who joined the resulting campaign to ban DDT and other insecticides made extensive use of claims of insidious effects. In particular Carson alluded to insidious effects on reproduction. Her assertions were amplified by the popular press and became part of the public perception about insecticides. Although those perceptions are wrong, they are firmly entrenched in anti-insecticide propaganda.

The three strategies, while largely bogus in terms of their scientific underpinnings, were very effective in anti-insecticide campaigns. The strategies are still used today. Rogan and Chen used these strategies in their two papers against DDT [31,32]. The authors presented strategy number two in the form of a superficial review of the role of DDT in malaria control. They strove to cast doubt on DDT's value in modern malaria control programs. They admitted that

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DDT had been very effective in the past, but then argued that malaria control programs no longer needed it and alternative methods of control should be used. Rogan and Chen also employed the first strategy of environmentalism [32]. Their list of potential harms from DDT exposures included toxic effects, neurobehavioral effects, cancers, decrements in various facets of reproductive health, decrements in infant and child development, and immunology and DNA damage. To get the paper past reviewers they presented balanced coverage of their diverse claims of harm, and, as consequence, had to conclude they could not prove that DDT caused any harm at all. Amazingly, they promptly negated this honest conclusion by asserting that if DDT is used for malaria control then great harm might occur. So, while not proving DDT causes harm, the authors still predict severe harm if it is used.

Rogan and Chen end their paper with a call for more research. One could conclude that the intent of the whole paper is merely to lobby for research dollars to better define DDT harm, and what's the harm in that? Surely increasing knowledge is a fine goal. However, having engaged issues of malaria control and what should or should not be done to control the disease, specifying more research funds for research on potential harms of insecticide exposures is unjustified. Large numbers of children and pregnant women die from malaria every year, and the disease sickens hundreds of millions more. Yet, not one death or illness can be attributed to an exposure to the public health use of DDT. Figure 1 illustrates growth in DDT research, with numbers of published papers doubling from one decade to the next. Almost all papers are in environmental literature and many are on potential adverse effects of DDT. Only a small proportion of papers deal with malaria and DDT. It bears repeating that DDT is a spatial repellent, and hardly an insecticide at all, but a search on DDT and repellents will produce even fewer papers. This disparity represents an egregiously disproportionate emphasis on non-sources of harm compared to the enormous harm of malaria.

The US used DDT to eradicate malaria. After malaria disappeared as an endemic disease people in the US became richer. They built better and more enclosed houses. They screened their windows and doors. They air-conditioned their homes. Also, during those early years, the US developed an immense arsenal of mosquito control tools and chemicals. Today, when there is a risk of mosquito borne disease, urban and rural areas can bring this arsenal to bear and quickly eliminate risks. And, as illustrated by aerial spray missions in the aftermath of hurricane Katrina, they can afford to do so. Yet, those modern and very expensive chemicals are not what protect the US from introductions of the old diseases. Use of those chemicals can only respond to a threat; it cannot prevent the old diseases from being reintroduced. What protects US populations is their enclosed, screened, air-conditioned housing, the physical representation of their wealth. Their wealth and living standards stop dengue at the border with Mexico, not the use of insecticides. Stopping mosquitoes from entering and biting people inside their homes is critical in the prevention of malaria and many other insect-borne diseases. This is what DDT does for poor people in poor countries. It stops large proportions of mosquitoes from entering houses. It is, in fact, a form of chemical screening, and until people in disease endemic countries can afford properly enclosed houses and physical screening, or it is provided for them, chemical screening is the only kind they have.

DDT is a protective tool that has been taken away from countries around the world, mostly due to governments acceding to the whims of the anti-pesticide wing of environmentalism, but it is not only the anti-pesticide wing that lobbies against DDT. The activists have a sympathetic lobbying ally in the pesticide industry. DDT opposition was made clear in writings of those within the insecticide industry; a Bayer official stated:

[I speak] Not only as the responsible manager for the vector control business in Bayer, being the market leader in vector control and pointing out by that we know what we are talking about and have decades of experiences in the evolution of this very particular market. [but] Also as one of the private sector representatives in the RBM Partnership Board and being confronted with that discussion about DDT in the various WHO, RBM et al circles. So you can take it as a view from the field, from the operational commercial level - but our companies [sic] point of view. I know that all of my colleagues from other primary manufacturers and internationally operating companies are sharing my view. [45]

The official goes on to say that,

DDT use is for us a commercial threat (which is clear, but it is not that dramatical [sic] because of limited use), it is mainly a public image threat.

However the most damming part of this message was the statement that,

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...we fully support EU to ban imports of agricultural products coming from countries using DDT...

This email message from Bayer, one of the largest global manufacturers of alternatives to DDT, provides clear evidence of industry applying international and developed country pressures to stop poor countries from using DDT to control malaria. This message also shows the complicity of the insecticide industry in those internationally orchestrated efforts.

The environmental movement lobbied for a WHA resolution that required countries to move away from using insecticides in disease control altogether [23]. The WHA is the premier policy-setting forum for all health issues and is the governing body of the WHO. At that time, 1997, there was no evidence that vector-borne diseases could be controlled without man-made insecticides. The same is true today. The resolution was adopted by the WHA in 1997. Essentially, the lobbying of environmental groups elevated politics and anti-insecticide sentiment above scientific evidence and left hundreds of millions at high risk of death and illness from entirely preventable diseases. As we will show in the next section, UNEP has a particularly odious history of elevating environmental politics over science.

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11. UNEP's war against PHIs

The UN Stockholm Convention on POPs, which came into force in 2004, governs the use of DDT. DDT is the only chemical under the POPs Convention that is granted an exemption for use in public health. It is against this background that the Stockholm Convention Secretariat (the Secretariat) and the financial mechanism of the Convention, the GEF, the UNEP, and groups within the Pan American Health Organization (PAHO) and WHO, have engaged in scientific malfeasance to achieve political goals. UNEP's target goal in 2007, now removed from the UNEP website, was DDT elimination by 2020.[1]

The GEF was established in 1991 and is a partnership of 10 agencies, including the World Bank, which houses the GEF. The GEF has allocated over $9bn in funds for projects with the aim of improving the environment and has raised over $40bn from other partners for its projects. At stake is not only increased power over the use of chemicals for the control of diseases but also the reputational benefits of achieving a goal deemed desirable by environmental groups. In addition, one cannot discount the fact that many millions of dollars are programmed by numerous governments via the UN system to rid the world of POPs and find alternatives to DDT. Control over the use of insecticides for public health also gives agencies control over, and benefit from, these funds.

UNEP's and GEF's misrepresentations of scientific records against the use of DDT and other PHIs were exposed in a peer-reviewed paper in *Research and Reports in Tropical Medicine* [46]. The paper exposed the false claims about an insecticide-free malaria control project managed by UNEP and financed by GEF in Mexico and Central America (Mexico/CA). The project was designed to demonstrate successful control of malaria through use of "environmentally sound" methods without DDT and other insecticides. Almost inevitably, the projects' backers claimed it achieved this objective. A proper analysis of epidemiologic data, however, revealed no such success; reductions in malaria cases and deaths in the region were achieved primarily through pharmacosuppression (therapeutic and prophylactic use of anti-malarial drugs). Claims that UNEP's environmental interventions were effective were invalid.

The project, Regional Program of Action and Demonstration of Sustainable Alternatives to DDT for Malaria Vector Control in Mexico and Central America (Mexico/CA Project), was conducted in eight countries (Belize, Costa Rica, Guatemala, Honduras, Mexico, Nicaragua, Panama and El Salvador). It was executed by PAHO's Sustainable Development and Environmental Health Program and implemented by UNEP. It was co-financed by the GEF with additional support from the Commission for Environmental Cooperation of North America (CEC), PAHO, and participating country governments. The project's aim was to improve coordination and national capacity so that new, integrated disease vector (mosquito) control techniques could be implemented, thereby eliminating the need for DDT reintroduction [47]. The objectives of the project (as stated by UNEP) were to: "Demonstrate feasibility of integrated

1 The Stockholm Convention is a UN Convention that arose from UN Environment Program efforts to control and/or ban the production and use of certain persistent organic pollutants. PAHO is an international public health agency and is the Regional Office for the Americas of the WHO and part of the UN.

and environment-friendly methods for malaria vector control without the use of DDT," and "assess the effects of these methods on malaria occurrence [48]."

According to UNEP, the key interventions in the project were as follows: 1) Reduction of contact between mosquitoes and people via treated bed nets; meshes on doors and windows; the planting of repellent trees like neem and oak; and the liming of households. 2) Control of breeding sites by clearing vegetation; draining stagnant water, ditches and channels; and the use of biological controls such as fish and bacteria in some countries. 3) Elimination of places near houses that attract and shelter mosquitoes through, for example, the cleaning and tidying up of areas in and around homes, alongside the promotion of personal hygiene [49].

The project's final evaluation, published in November 2009, mentions various pharmaceutical methods of prophylaxis and treatment within human populations [50]. However, those methods were ongoing components of malaria control in each country prior to the Mexico/CA Project, operating nationally in each country before and during the project. The available evidence suggests national malaria control programs (NMCPs) functioned regardless of the presence or absence of UNEP's project personnel. Thus, anti-malarial treatment (the major component of the NMCPs) in demonstration areas was not part of the epidemiological evaluation of the Mexico/CA Project [51]. Likewise, use of ITNs had no obvious definable role in the Mexico/CA Project. Project successes are therefore advertised as having been achieved without mention of the accompanying use of insecticides.

The project included demonstration areas, where the GEF environmental interventions would be implemented, as well as control areas within epidemiologically similar areas, where the interventions would be excluded, for proper comparisons [51]. As stated by Cesar Chelala, medical consultant affiliated with the Mexico/CA Project, demonstration areas were selected "based on the high incidence of transmission and the persistence of malaria in those places [52]."

An epidemiological evaluation identified 202 demonstration areas and 51 control areas [51]. The former included a total population of 159,018 and the latter 50,834.

The public statements regarding the Mexico/CA Project proclaimed dramatic and very impressive reductions in malaria cases for its environmentally benign interventions. The final report of the Mexico/CA Project, published by the environmental sector of PAHO in December 2008, claims "a 63% reduction in the number of people with the disease without using DDT or any other type of pesticide [53]."

These statistics and claims of success were repeated in an official press release issued by UNEP, WHO and GEF in May 2009 [54]. UNEP Executive Director, Achim Steiner, also repeated these claims and characterized the project as "calculated and tested science [49]." Similar claims have been made in the popular media [52] and used by anti-insecticide activist groups as evidence that malaria control is possible without insecticides [55].

Regrettably, the claims of malaria control through application of GEF interventions were incorrect and fundamentally misleading.

Countries in Latin America were forced away from using DDT in compliance with the North American Free Trade Agreement (NAFTA), wherein the CEC pressured Mexico in the mid-1990s to stop production and use of DDT [56]. Without DDT, countries used more expensive insecticides, which had to be sprayed more frequently, creating problems for malaria control [57]. Over time, the countries in Central America moved to greater use of pharmacosuppression. Malaria cases have fallen as a result of this widespread use of malaria treatments, but not through the environmental controls touted by the UN. Officials of GEF, UNEP and the Secretariat, however, ignored the use of pharmacosuppression in their discussion of successful malaria control in Mexico/CA. Furthermore, these officials falsely attribute changes in malaria burdens to GEF's environmental interventions. A separate epidemiological evaluation which was designed to measure any changes in disease rates, found no statistical differences in malaria rates in demonstration areas versus rates in control areas, and this was consistent across all eight countries [51]. Malaria rates in most countries were falling, but with no difference between the demonstration areas and controls, the decline cannot be attributed to the environmental interventions. But UNEP, GEF, the Secretariat and other officials ignored those findings. Furthermore, despite the fact that the control areas were a crucially important part of the project, they were not even mentioned in the 2008 final report [53]. Ultimately, the successful reduction of malaria was most likely entirely due to pharmacosuppression.

One might wonder why a control program would require insecticides and vector control if pharmacosuppression is such a powerful method of malaria control. This is a complex issue, but it is important to note that even though reductions in malaria cases have been achieved in Mexico and Central America, their model of widespread distribution of the anti-malarial drugs chloroquine and primaquine is not transferable elsewhere and may not be sustainable over the long-term. As a model for malaria control, it is not transferable for several reasons. First, widespread drug resistance to chloroquine in Africa and Southeast Asia would mean the intervention would be largely useless. Second, primaquine is a radical treatment for vivax malaria, whereas in Africa over 90 percent of malaria cases are caused by falciparum malaria, the more deadly form of the disease.[2] Third, pharmacosuppression is expensive and requires more sophisticated health systems than exist in most of Africa, where the greatest burden of malaria lies. So even if UNEP, GEF and their partners were straightforward about the real reasons for the declines in malaria in the project areas, there would be no reasonable argument to claim that pharmacosuppression has any application in most other endemic areas.

Global malaria control policy gives scant notice to pharmacosuppression. In fact, it appears that global leaders are intent on ignoring how countries of the Americas are making use of pharmacosuppression. Yet, and as commonly observed in reports from South America, the only cost-effective insecticides (pyrethroids) they have must be sprayed so frequently as to be of limited value. Thus, countries of the Americas really have no viable cost-effective options for use of PHIs. In absence of an insecticidal solution then, pharmacosuppression becomes the best option for effectively reducing malaria caseloads.

2 In addition, there are concerns about the side effects of using primaquine among people with G6PD deficiency. See Baird K. Eliminating malaria – all of them.Lancet 2010;376(9756): 1883-5. http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2810%2961494-8/fulltext (accessed 19 September 2012).

If we assume there is a decision to keep quiet on how malaria is being controlled in absence of insecticides, then it is easier to understand why there is less transparency in malaria data for the Americas. Historically PAHO openly reported statistics on the numbers and types of curative treatments dispensed per year in each country. However, transparency of malaria control statistics is down from just two or three years ago. A visit to PAHO's website on interactive malaria control data for the Americas will reveal no data on numbers of treatments with chloroquine or primaquine. Indeed, the only data that is readily available is on use of ACTs for treating cases of falciparum malaria.

12. Conclusion

We have described the systematic and often coordinated campaigns by activists, scientists and UN agencies against essential tools for disease control. We will conclude here with statements that bring our analyses full circle. Rachel Carson started broad scale unscientific attacks on DDT in 1962, with publication of her book, *Silent Spring*. The claims of harm by exposures to DDT, as we describe in this chapter, were not and are not true. In other words, the attributed harms are not caused by DDT exposures. Yet, presented in a 2012 article titled "Critisism [sic] of Carson over DDT unfounded" is a denial of any responsibility whatsoever for the reductions and eliminations of DDT in disease control programs as legacy of her book. In their article the Rachel Carson Council makes the following claims: "DDT has been associated with serious adverse effects in humans, including reduced sperm production in men, shorter lactation times and increasing numbers of pre-term births in women,… breast cancer...[58]."

We ask the reader to compare their claims with those we describe as not meeting even minimal criteria for cause-effect relationships. So the Rachel Carson Council denies responsibility for harm inflicted by Carson's anti-DDT rhetoric, while, at the same time, it continues to implement her strategies for DDT elimination and employs her tactics of falsifying the scientific record to scare the public. Amazingly, when the false statements and fear tactics employed by anti-DDT campaigners succeed in stopping use of DDT to protect health and save lives, the anti-PHI advocacy community, as revealed in the Rachel Carson Council's denial of responsibilities, expects the public to think they had no role in such inhumanely disastrous changes in public health policies. As we have shown, they are, in fact, the very cause of those changes in policy.

We have shown that vast sums of money, mostly from taxpayers, have been spent over many decades undermining and often directly attacking the use of DDT in life-saving disease control programs. These vast expenditures have not delivered alternative strategies or tools to replace DDT. The few alternatives that disease control programs do have for some malaria-endemic regions pale in comparison to the powerful life-saving properties of DDT. It almost goes without saying that if the disease control tool in question were not DDT but were a vaccine or a medicine, there would be a sense of outrage in the general public along with well-funded advocacy to preserve and protect a tool that has the power to save lives. Yet such is the power of the environmental movement, that aside from a few outspoken scientists and individuals,

there has been almost no response from the malaria community or the wider public health community. The strategies employed by anti-DDT activists are anti-science and rely on distortions, half-truths and sometimes outright lies. Ordinarily such behavior would be roundly criticized, yet because DDT is being attacked, such actions are given a free pass.

We are greatly concerned that the majority of private insecticide companies far from opposing the unscientific agenda of the anti-DDT campaigns, support them. These companies may be merely motivated to sell more of their own product, but this is surely one of the most short-sighted strategies imaginable. We already see a growing number of studies finding associations between alternatives to DDT and possible human health harm. As with DDT, the anti-insecticide activists are starting to hype and spread fear about these associations. As the Stockholm Convention adds more and more chemicals to its list of banned or controlled substances, and as the UNEP flexes its regulatory muscles, we fully expect it will become more and more difficult to produce, trade, transport and use all PHIs. It is precisely because of such restrictions that countries of the Americas have had to adopt programs of mass drug distributions (pharmacosuppression) to control vivax malaria. Basically those countries have no cost-effective options for use of PHIs. Continuation of these anti-PHI practices, as we have learned from history, will inflict great harm on disease control efforts and eventually exact a heavy cost in lives from some of the poorest and most vulnerable communities on earth.

We hope this chapter has shed some light on the strategies and tactics of environmental groups, activists, scientists and UN agencies. Well-established patterns of behavior have been set with these groups and individuals and we hope that the malaria community and the wider public health community begin to recognize these patterns and begin to more effectively investigate and respond to claims against PHIs long before the claims become the basis for further restrictions on the efficacy of disease control programs.

List of the acronyms used in the text

ACT-- artemisinin-based combination therapies

API—annual parasite index

CEC—Commission for Environmental Cooperation (The full title is North Americas Commission for Environmental Cooperation. Created as a side agreement of the North American Free Trade Agreement.)

DDT/DDE—Diethyl dichloro trichloroethelene. DDE is a metabolic product of DDT.

EDC-- endocrine disrupting chemicals

GEF—Global Environment Facility

HSR—house spray rate

IRS—indoor residual spray

ITN—insecticide treated net

MRL—maximum residue limit

NAFTA—North American Free Trade Agreement

NGO—Nongovernmental organization

NMCP—National Malaria Control Program

OC—organochlorine compound

PAHO—Pan American Health Organization

PHI—public health insecticide

PMI—President's Malaria Initiative

POP—persistent organic pollutant

PTDI—provisional tolerable daily intake

RBM—Roll Back Malaria

SP-- sulphadoxine-pyrimethamine

UN—United Nations

UNDP—United Nations Development Programme

UNEP—United Nations Environment Programme

UNICEF—United Nations Children's Fund

USAID—United States Agency for International Development

WHA—World Health Assembly

WHO—World Health Organization

WWF—World Wildlife Fund

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