MALARIA AND ANTI-DDT CAMPAIGNS

IMPACT OF ANTI-DDT CAMPAIGNS ON MALARIA CONTROL

Donald R. Roberts, Ph.D. Professor Emeritus, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, MD 20814, USA describes the successful history of the use of DDT for the eradication of malaria and how single issue anti-DDT campaigners have compromised the success of this programme. Email: droberts@usuhs.mil Contact information: 118 First St, Clifton Forge, VA 24422 USA

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Introduction

Public health insecticides have greatly improved human welfare. In the past century, insecticides were deployed strategically to control numerous human plagues, but successes in those endeavors brought new and unforeseen challenges. As insecticides rose to prominence in disease control through the mid-20th century, environmentalists and population control advocates increasingly targeted insecticides in general, and DDT in particular, for elimination. The goal of anti-insecticide advocacy was to use propaganda and emotional arguments to convince people insecticides were dangerous and their use must be stopped. Backed by richly funded environmental advocacy and supported by science writers of the popular press, the movement created a backlash against DDT and other beneficial insecticides. Successes of anti-insecticide activism, and anti-DDT activism in particular, led to public health programs being abandoned around the world – and suffering of epic proportions.

Anti-insecticide activism is an even stronger force today. Indeed, it seems that anti-insecticide advocates are even more determined to deny people in developing countries protections from disease and death that only insecticides can provide. Because of their activism, the World Health Assembly (WHA) adopted a resolution (WHA 50.13) in May 1997 that calls on countries to reduce reliance on use of insecticides for disease control (WHA, 1997). Then, in 1998, the United Nations Environment Program (UNEP) began negotiations for a Persistent Organic Pollutants (POPS) treaty targeting DDT and 11 other chemicals for global elimination (Chemical Management, 2002). The startup 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, despite the 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 production facilities are being closed and countries that make appropriate and effective use of DDT for disease control are pressured by anti-DDT advocacy groups and are being enticed by financial mechanisms of the Global Environment Facility (GEF) to stop.

WHA resolution 50.13 and the Stockholm Convention on Persistent Organic Pollutants, described above, are only the most recent signs of anti-insecticide groups successfully eliminating disease control programs over the past half century. This progress was achieved by unrestrained use of fear tactics and misinformation by anti-insecticide advocacy. Indeed, the use of fear was, and still is, the sine qua non of the anti-DDT movement. Anti-DDT propaganda typically claimed that insecticide caused all manner of harm to human health. Readily embraced and trumpeted by the popular press, the claims, in reality, never satisfied even the most minimal cause-effect criteria (Hill, 1971). These criteria are:

- 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 to strongly harmful agents. 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 level of harm. This is true even if the chemical is characterized as persistent. DDT is described as persistent, but levels of DDT...
in the environment decline rapidly after DDT use is stopped. Key cause-effect relationships are illustrated by the example of cigarette smoke.

The link between smoking and human cancer has been validated through experimentation and vital statistics. Epidemiological studies reveal differences in cancer risks for smokers versus non-smokers, and smokers who quit versus those who continue to smoke. Consistent with the principles of causation, once smoking ceases, the risk of cancer declines.

In general, the argument that cigarette smoke caused cancer was convincing not because of laboratory data, but because patterns of low or high cancer rates correlated with patterns of low or high smoking rates and duration of smoking. Furthermore, as people stopped smoking their risk of cancer actually declined. Since smoking provides no health benefits and public health insecticides do, we cannot compare the benefits and harms of one versus the other. Yet, if we focus only on claims of health harm we find that, unlike the campaign against cigarette smoke, health statistics do not confirm claims of harm from public health insecticides. The occasional observational study that suggests use of a public health insecticide causes a human disease is countered by many other studies that suggest otherwise. Nevertheless, and as illustrated below, the appearance of even a single study suggesting a link between DDT and health harm can become a cause célèbre within the anti-DDT advocacy community.

Mary Wolff and co-authors (1993) published a paper, that was widely covered in the popular press, in which they claimed a statistically significant association of DDE (a major DDT metabolite) with breast cancer. Years later, with completion of many other studies, researchers concluded DDE was not a cause of breast cancer. Yet, for many years, anti-DDT activists heralded the 1993 paper as ultimate proof of DDT harm and used it to generate funds and recruit new members to campaigns for DDT elimination (World Wildlife Fund, 1998). 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 and recruit new members to anti-insecticide campaigns.

The breast cancer example reveals a general trend of anti-DDT campaigns railing against DDT while failing to meet minimal evidentiary standards for proof of cause-effect relationships (as defined by the principles of causation (Hill, 1971)). 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:

- Consistent with current biological or theoretical knowledge of the type of harm and its known risk factors,
- 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.

Decades ago developed countries used extraordinary quantities of DDT. The richer countries placed DDT in the human food chain as a consequence of its heavy agricultural use. More explicitly, DDT was used in the environment, around houses, and intensively inside homes. Human exposures during many years of peak usage far exceeded any exposures that occur today because of the high background levels of DDT in the human food chain. 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 those days of intense exposures goes far in explaining why, to this day, there is no evidence human health has been improved in any way by stopping public health uses of DDT.

The dichotomy of huge benefit from use of DDT to prevent diseases and deaths versus no definable benefit from stopping its use reveals the falsehoods of anti-DDT advocacy. Dichotomies in outcomes are well documented in countries around the world. For slightly more than 3 decades (1945–1979) many disease endemic countries maintained house spray programs. That era was followed by decades, from 1979 through to present time, when 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 dramatic stoppage of DDT spraying occurred in agriculture. The dichotomies of outcomes are listed in Table 1.

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 makes 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

### Table 1. Grid of cause-effect relationships for public health outcomes during periods of use and non-use of public health insecticides

<table>
<thead>
<tr>
<th>Benefits versus harms of public health insecticides</th>
<th>1946–79 (period of DDT spraying in houses)</th>
<th>1980–present (period when DDT spraying was reduced or stopped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harm from insecticide exposures</td>
<td>Increases in poisonings and deaths from insecticide exposures in houses.</td>
<td>Reductions in poisonings and deaths as house spraying is eliminated</td>
</tr>
<tr>
<td>Benefits from using insecticides to control malaria and other diseases</td>
<td>Reductions in malaria infections and deaths as a consequence of DDT on house walls</td>
<td>Increases in malaria infections and deaths as house spraying of DDT is eliminated</td>
</tr>
</tbody>
</table>
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have documented no meaningful improvements in health or reduced deaths as a result of having eliminated 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.

The purpose of this paper is to elaborate on only the last part of this equation. I will present selected historical records of how DDT saved lives and improved the wellbeing of hundreds of millions of people. To make it easier for readers to fact-check what is presented here, I will, to the extent possible, use examples from recent reviews or published books.

The exception will be eradication of malaria from the United States for which I rely heavily on the original publications of the Communicable Disease Center in Atlanta, Georgia. Also data will be presented to show grievous and continuing harm to populations as a result of anti-insecticide pressures forcing countries to stop using DDT. In this latter task, I will rely on my own analyses of raw data compiled by the Pan American Health Organization.

DDT: A Valuable Wartime Commodity

The first large public health use of DDT is described in a classic text on DDT. The authors, West and Campbell (1946), describe the use of DDT in Naples, Italy. In December 1943, typhus broke out in overcrowded, poverty-stricken and louse-infested populations of Naples. Allied Forces took control and began dusting (delousing) people to stop the outbreak. Delousing was accomplished by spraying DDT powder directly on the skin and underclothing of louse-ridden people. In January 1944, over a million people were dusted with DDT and the outbreak was suddenly brought under control. The Naples success was a historic event. Never before had a typhus outbreak been stopped in mid-winter (West & Campbell, 1946). Success at Naples was just the beginning of DDT’s meteoric rise to international fame as a public health insecticide. DDT was suddenly in heavy demand for all wartime activities. The role of DDT in WWII is further revealed in descriptions of its use in the liberation of concentration camps. This is exemplified in its use for delousing liberated populations from the Belsen concentration camp in 1945 (Shepherd, 2005). At time of liberation, typhus had been rampant for four months in the camp, with an estimated 20,000 cases (Baumslag, 2005). Those being liberated from the camp had four months in the camp, with an estimated 20,000 cases (Baumslag, 2005). At time of liberation, typhus had been rampant for four months in the camp, with an estimated 20,000 cases (Baumslag, 2005).

As WWII ended, DDT was quickly transitioned from wartime to peacetime uses. As early as 1944 it was already being employed in malaria control programs.

Consistent and Rapid Reductions of Malarial Morbidity and Mortality by Indoor Residual Spraying (IRS) of DDT on House Walls

The Swiss brought DDT to the attention of Allied Forces in December 1942. The United States and other countries started testing DDT on walls as a means of malaria control as early as 1943. This use of DDT came to be known as indoor residual spraying (IRS). Illustrated in this section are examples of country programs that almost overnight achieved remarkable reductions of malarial morbidity and mortality by using DDT in IRS programs. IRS with DDT was so effective that it eventually led to creation of a program for the global eradication of malaria.

Italy: Malaria Eradication – DDT was employed to eradicate malaria from Italy. The history of that program is recounted in the book by Frank Snowden (2006) “The Conquest of Malaria: Italy, 1900–1962.” Initially, the Italian program to control malaria focused on mass use of quinine and draining marshes. Those methods did not lead to eradication and the impact of wars and political turmoil repeatedly led to the resurgence of malaria on the peninsula. Not until the end of WWII did political and peaceful conditions plus availability of DDT lead to a successful campaign for eradicating malaria. After the war, a five-year malaria eradication plan was adopted. The plan called for spraying DDT in houses. As a consequence of that program, the Sicilian province of Agrigento experienced its last known malaria epidemic in 1955. The last autochthonous cases of malaria were reported in 1962. By 1969, through effective use of DDT and case treatments, Italy became entirely malaria-free.

Sardinia: Malaria Eradication – The following observations on malaria eradication in Sardinia were extracted from a recent review of that program (Tognotti, 2009).

At the end of WWII Sardinia was the most malarious political region of Italy. Historically characterized with high incidence of falciparum malaria and associated high mortality, Sardinia was characterized as an unhealthy island. Malaria persisted as an endemic disease in spite of prolonged efforts by the Italian government to eliminate malaria from the mainland and from Sardinia. The government provided free quinine for malaria early in the 20th Century and malaria mortality declined. Later the government invested heavily in drainage schemes and maintained emphasis on free malaria treatments in rural areas. All told, those measures led to considerable reductions in malaria deaths, a result that was interrupted only by events of WWI and WWII. As a result of civil disruptions in WWII, 74,000 malaria cases were reported for Sardinia in 1946. The impact of malaria was severe and it was obvious that the cycle of poverty and disease would end only by eradicating malaria from the island. Highly malarious conditions on Sardinia were the backdrop to what can be described as
the first and only major test for using DDT to eliminate a malaria vector mosquito from its native habitat.

The Sardinia project got underway in 1946 and, as stipulated in an October 1946 agreement, the plan included IRS, trial larviciding, and all-out larviciding of the entire island. By June 1947, roughly 85% of villages and towns had been sprayed with DDT. In 1949, the breeding places of the primary malaria vector had been reduced by an estimated 99.93%. In 1950, and for the first time in history, no new cases of malaria were reported on the island. In the end, the Sardinia project sprayed 267 metric tons of DDT over the island, malaria was eradicated, but the malaria vector was still present.

In summation, the Sardinia project revealed two fundamental facts. First, IRS with DDT was effective in quickly eradicating malaria from the island. Second, DDT, used as a larvicide, was not effective in eliminating the native malaria vector mosquito from Sardinia.

**United States: Malaria Eradication** – At the turn of the 20th Century, the continental United States was intensely malarious. Malaria was a cause of death, illness, and economic loss. In 1916, malaria was estimated to reduce economic productivity in the US by $100,000,000 (Hoffman, 1917). The economic loss from malaria in the state of California alone was estimated to be $3,000,000, and California was not even considered a highly malarious state. A conservative estimate of malaria cases for the country as a whole was 1,000,000 or more cases per year (Hoffman, 1917).

Malaria rates declined gradually in the United States through the first half of the 20th Century, with occasional increases as a result of war and other events. Regardless, by the 1940s, infectious diseases were still major public health problems throughout the country. Malaria remained a major public health problem in southeastern states. By the early 1940s, the ability of the United States to exert effective control over malaria was still limited in spite of growing wealth and improving standards of living. In fact, control was possible only in urban settings where draining and eliminating aquatic habitats for mosquitoes and using larvicides to kill mosquito larvae was cost-effective. In contrast, the only real progress in poor rural areas was to screen houses to prevent mosquitoes from entering and transmitting disease (US Public Health Service, 1944–45).

The office of Malaria Control in War Areas (MCWA) was created immediately after the bombing of Pearl Harbor in 1942 “to prevent or reduce malaria transmission around Army, Navy, and essential war industry areas [in the United States] by extending the control operations carried on by military authorities within these reservations.” (CDC, July–Sept 1946).

Spraying houses with DDT quickly became established within the program as the most effective method of stopping malaria transmission in and around military installations in the US. Then, beginning in 1945, the MCWA launched its Extended Program of Malaria Control. The extended program was not limited to military posts, camps, and stations, but instead was extended to more malarious civilian areas (CDC Bulletin, Jan, Feb, Mar, 1947). It consisted of spraying DDT on interior walls of homes and privies. The spraying program covered large areas of the southern US. From January 1945 to September 1947, 3.2 million houses were sprayed (CDC Bulletin, Oct, Nov, Dec, 1948). This sum apparently did not include numbers of houses sprayed through use of local funds. As described in a 1946 report, “a number of larger cities have contributed sufficient funds to spray the cities in the 2,500–10,000 population group. The entire cost of this type of residual house spraying is paid from local funds.” (CDC Bulletin, Oct, Nov, Dec, 1946).

The MCWA was a wartime organization and changes were needed when the war ended in 1945. With demobilization of military forces in 1945 and 1946, the MCWA went into a phase of rapid liquidation (CDC, July–Sept 1946). Liquidation of the MCWA led to creation of the Communicable Disease Center (CDC) of the United States Public Health Service on July 1, 1946 (CDC Bulletin, Oct, Nov, Dec, 1946). The CDC was created to capture resources and expertise of MCWA. The CDC was tasked to continue and expand MCWA programs in all areas of public health in the United States (CDC Bulletin, Oct, Nov, Dec, 1946).

The MCWA’s Extended Program of Malaria Control already had been successful in reducing numbers of malaria cases in areas where houses were sprayed (Figure 1).

To build on early success, the CDC started a National Malaria Eradication Program, commencing operations on July 1, 1947. It was referred to as the Residual Spray Program. Spraying DDT on inner walls of rural homes in malarial-endemic counties was the key component of that program. From July 1947 to the end of 1949, the program sprayed over 4,650,000 houses. Based on surveys conducted in thirteen southeastern states, the CDC concluded that “over-all control (reduction in houses infested) was approximately 90% for the 5-year period [1945–1949].” (CDC Bulletin, Jan 1950).

Beginning in 1945 (US Public Health Service, 1944–1945), millions of houses were sprayed for malaria control throughout the southeastern US. Other programs contributed to the goal of malaria elimination, such as those of the Tennessee Valley Authority in the Tennessee Valley. However, unlike the TVA, the residual spray program was not limited in geographic focus and it had flexibility to target operational areas by actual risk of disease. Many highly malarious areas were on the coast and far outside the TVA sphere of influence. Malaria rapidly disappeared when houses were sprayed and the result was the same whether or not the area was within the Tennessee Valley. The residual spray program with DDT broke the cycle of malaria transmission and, in 1949, the United States was declared free of malaria as a significant public health problem (CDC, 2004).

**Guyana: Malaria Eradication** – The history and successes of early efforts to control malaria in Guyana are extensively reviewed in a recent book “Demerara Doctor: An early success against malaria” (Curtis, 2006).

As documented by data collected by Dr. George Giglioli, who was a medical officer for a bauxite mine in Guyana, malaria was highly prevalent in many areas of Guyana. In one collection of data in 1945, 40.3% of people were positive for malaria parasites. Word about potential for using DDT
to control malaria was brought to Guyana in 1944. Three important visiting British scientists described possibilities for using DDT against malaria during a meeting in Guyana on the morning of August 14, 1944. Dr. Giglioli attended the meeting. As a result of that meeting, Dr. Giglioli began field-testing DDT for control of malaria at the bauxite mine by spraying rooms on February 16, 1945. DDT sprayed on walls exerted extraordinary power over the primary malaria vector in Guyana, *Anopheles darlingi*. During seven weeks of observations, 8,554 *An. darlingi* mosquitoes were captured in eight unsprayed rooms; but only seven *An. darlingi* mosquitoes were captured in eight rooms that had been sprayed with DDT.

Based on the results of the pilot study, DDT spraying was expanded into a program of large-scale control in 1946, and into a Colony-wide campaign in January 1947. Consistent with its extraordinary performance in pilot tests against malaria vector mosquitoes, wide-scale use of DDT brought spectacular reductions in all public health parameters of malaria. In comparisons of average infection rates before DDT spraying (1943 to 1945) and after countrywide spraying (1949–1950) malaria infections declined in rural areas by 99% and declined by 96% in urban areas. A comparison of infant mortality for the same time intervals showed that infant mortality declined by 39% and maternal mortality declined by 56%. By March 31, 1948, malaria was controlled in the whole coastal area of Guyana. By 1954, Guyana was recognized as having eradicated malaria from large geographical areas, especially in the large and densely populated coastal region.

*South Africa: Malaria Control* – The vector-control programs in southern Africa quickly adopted DDT after the end of WWII, and as a direct consequence, malaria cases declined rapidly. According to Mabaso et al. (2004), in the Transvaal Province of South Africa, hospital admissions “fell from 1,177 cases during the 1945–46 transmission season to 601 in 1946–47 coinciding with the availability of DDT in 1946, and falling to 454 in 1948 and to a low of 61 cases in 1951.” For decades, use of DDT to control malaria in South Africa was maintained and malaria persisted as a low-level public health problem only. Then in 1996 the malaria program decided to phase DDT out of the malaria control program. Unfortunately, mosquitoes quickly developed resistance to the pyrethroid insecticides that had been used as a replacement for DDT. Years of DDT use had effectively rid South Africa of an important malaria vector, *Anopheles funestus*. However, once the government stopped using DDT, the mosquito reappeared and once again started transmitting malaria.

As early as 1997, malaria cases and deaths started to rise. By 2000, in KwaZulu-Natal Province, traditionally the most malarial province, malaria cases had increased almost five-fold, from just over 8,500 cases to almost 42,000 cases (South African Department of Health, 2000). Malaria deaths increased from 22 in 1996 to 320 in 2000. In 2000, the Department of Health decided to reintroduce DDT to the IRS program (Barnes, 2005). As a result of that and other changes, within one year the number of malaria cases fell by around 80% in KwaZulu-Natal Province (Barnes, 2005). Malaria deaths also plummeted as the change in the IRS program and change in malaria treatments took hold. The other malarial provinces, Mpumalanga and Limpopo, have been able to keep malaria at bay by adopting the same strategies since 2001. Public-health experts widely acknowledge that South Africa’s malaria-control strategy is one of the most successful in the world. In 2004, WHO even gave the South African Department of Health an award for the best malaria-control program in southern Africa.

*Taiwan: Malaria Eradication* – The national malaria eradication program was started in Taiwan in 1952 (Taiwan Department of Health, 1991). The program was based on use of IRS with DDT. A conservative estimate of 1.2 million cases
occurred in 1952. As illustrated in numbers of malaria cases for years after 1952 (Table 2) malaria declined precipitously after the government started spraying houses with DDT. On December 4, 1965 the World Health Organization officially registered Taiwan as having eradicated malaria.

**Increased Numbers of Malaria Cases with Reductions in Numbers of DDT-Sprayed Houses**

Many countries, to include many highly developed countries, used DDT in IRS programs to control malaria. In contrast to the experiences of more temperate and developed countries, the gains against malaria were sustained in poorer and more endemic countries only by continuing the IRS programs. However, growth of the anti-insecticide movement, and anti-DDT campaigns in particular, resulted in many countries reducing or eliminating their house spray programs. Just as the IRS programs brought about great reductions in malarial morbidity and mortality, elimination of IRS programs allowed numbers of malaria cases to increase.

Re-emerging Malaria in Brazil, Colombia, and Peru – In 1979, the WHO changed the global strategy for malaria control to emphasize case detection and treatment and de-emphasize spraying houses for malaria control. Over the next few years, countries complied with WHO guidance and gradually reduced the numbers of houses being sprayed with DDT. Trends presented in Figures 2 and 3 reflect those changes and also show the increasing numbers of malaria cases that resulted from reduced numbers of DDT sprayed houses.

In considering the data presented in Figures 2 and 3, it is important to understand that the pattern of decreasing numbers of sprayed houses and increasing numbers of malaria cases is not unique to the three countries listed. In fact, the analysis could be repeated, with essentially the same result, with data from many malaria endemic countries and from many geographical areas.

**Discussion**

Described in this paper are several spectacular examples of countries using DDT to control or eradicate malaria. Under pressure from anti-DDT advocacy groups, DDT was eventually withdrawn from many ongoing national malaria control programs. As DDT was withdrawn, numbers of houses sprayed with DDT declined and numbers of malaria cases increased. This relationship is illustrated with data analyses presented in Figures 2 and 3. The examples and data analysis attest to a powerful cause-effect relationship between the use of DDT and the control of malaria. The association of DDT with effective control of malaria fulfills the epidemiological criteria for a true cause-effect relationship. For the first of these criteria, and as illustrated by the examples described in this paper, there is no temporal ambiguity in the control of malaria once walls are sprayed. When houses are sprayed in poor, malaria endemic regions, malaria rates fall; and when houses are not sprayed, malaria rates increase. For the second criterion, the relationship of DDT efficacy in the control of malaria is consistent over time and across multiple countries. As demonstrated by country examples described herein, spraying houses with DDT consistently produced high, but variable, levels of control. For the third criterion, actions of DDT in preventing mosquitoes from entering houses and transmitting malaria or of entering and absorbing an irritant or toxic dose of insecticide that deters malaria transmission have been demonstrated in laboratory and field studies and is
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theoretically sound (Roberts, et al., 2000). As a consequence, the relationship is biologically plausible, both in theory and in practice. For the fourth criterion, the findings described herein do not conflict with broadly accepted facts about methods of malaria control. For the fifth and last criterion, control of malaria by DDT residues is a product of specific chemical actions of DDT residues, e.g., repellent, irritant, and toxic actions (Roberts, et al., 2000). The overall duration of effective control is defined by the residual life of DDT on wall surfaces.

Those who advocate against public health use of insecticides, and DDT in particular, seldom demonstrate any understanding at all of the huge service DDT has provided to public health. Even as the critics ignore its public health record, they vigorously claim it has caused severe harm to human health. Claims of harm run the gamut; from cancers, reduced duration of lactation, pre-term births, deficits in child development, and birth defects. However, none of the claims against DDT fulfills epidemiological criteria for a cause-effect relationship.

The malaria eradication project of Sardinia presented researchers with an optimal setting to test for human health harm as a consequence of exposures to DDT in a malaria control program. Sardinia presented optimal test conditions because DDT was used only for a short span of years; but exposures during those years were intense and within a defined geographical space. The first of the studies showed that widespread and intense use of DDT did not affect stillbirth rates, infant mortality rates, or the male:female ratio of newborns. The second study was on potential carcinogenicity of DDT as a result of occupational exposures. This follow-up study of deaths among 4,552 male workers occupationally exposed to DDT showed little or no evidence of linkage between DDT exposures and any of the cancers previously claimed to result from DDT exposure (Tognotti, 2009). The studies in Sardinia do not, however, signal an end to claims of DDT harm or of advocacy to stop the use of DDT for control of malaria. Regardless, one can hope that future studies will take note of widely accepted epidemiological criteria for establishing a cause-effect relationship.

In spite of the failings of evidence for claims of DDT as a cause of public health harm, some DDT opponents have gone so far as to claim that the harm from DDT exposures might equal or exceed the health benefits from control of malaria (Rogan & Chen, 2005). Such claims are published without due consideration of the seriousness of a malaria infection or any consideration that the direct affects of malaria are only one part of harm from malaria. Chronic effects of malaria infections are the other element of harm.

As described by Giglioli, the chronic effects of malaria can become deeply rooted, “setting up a multiplicity of indefinable but vital interactions and vicious circles with other diseases.” (Curtis, 2006). He supported those observations by a study of “changes in the general pattern of mortality which took place on the Guyana sugar estates...from pre-eradication to post-eradication conditions.” Selections of Giglioli’s data are presented in Table 3.

As he described these results, “When malaria was still highly endemic (1937-1946), each year, consistently, there were more deaths in males than in females, but among women of child-bearing age (15 to 40) the mortality was 34% higher than in males. On average on the sugar estates each year, there were 112 deaths in females belonging to this age group and 61% of all such deaths were due to malaria, chronic nephritis, anaemia, anaemia of pregnancy, toxamaemia and accidents of labour (haemorrhage, syncope, exhaustion etc.); only 0.9% were due to infection.” He added that “In recent years [with control of malaria infections through use of DDT] the excess of females over male deaths has been reversed so that, even in the 15 to 40 year age group, male deaths exceed females by 24%.”

Giglioli explained that, “This great change in maternal health has affected foetal development, with the result that the number of deaths from prematurity and congenital deformity has been much reduced and the weight of children at birth has substantially increased. Compared with pre-eradication figures (1937–1946), infant mortality in the first 10 days of life, per 1,000 live births registered, has been reduced by 75% (1959–1966).”

As revealed in Giglioli’s statistics, control of malaria had impact on many public health parameters, from both the acute and chronic effects of malaria. It is against this background of severe and grievous harm, both from acute and chronic effects of malaria infections, that claims against the use of DDT and other public health insecticides should be weighed.

Observations presented in this paper document how disease control programs declined as activism against public health insecticides grew. It is no surprise that diseases once controlled by spraying houses with insecticides reemerged once a spray program was eliminated. The impact of reducing or eliminating use of DDT and IRS programs is illustrated in Figure 3. Only in countries that underwent economic transformations during the decades of disease control were spraying programs stopped without major reemergence of diseases (e.g., the United States and Taiwan).

There is now a new emphasis and new funding for controlling malaria in developing countries. Yet, ideology and

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**Table 3.** Average annual vital statistics on Guyana sugar estates (Curtis, 2006)

<table>
<thead>
<tr>
<th>Population parameter</th>
<th>Pre-eradication years 1937–1946</th>
<th>DDT campaign to control malaria 1947–1950</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population</td>
<td>69,000</td>
<td>72,000</td>
</tr>
<tr>
<td>Relative increase in live births (relative to 1937–1946)</td>
<td>– 32%</td>
<td></td>
</tr>
<tr>
<td>Deaths from malaria (all ages)</td>
<td>140</td>
<td>30</td>
</tr>
<tr>
<td>Relative decrease in mortality</td>
<td>– 25%</td>
<td></td>
</tr>
<tr>
<td>Deaths from anaemia (adults only)</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Deaths in females aged from 15 to 40 years</td>
<td>115</td>
<td>55</td>
</tr>
<tr>
<td>Deaths from chronic nephritis (all ages)</td>
<td>115</td>
<td>83</td>
</tr>
</tbody>
</table>
politics, not science, continue to play the dominant roles in determining how malaria and other diseases can be controlled. There is an urgent need to put science back in place as the foundation of those disease control programs. All effective tools should be made available to disease endemic countries, not just those that are currently being pushed by commercial interests or anti-insecticide advocacy groups.

**Acknowledgements**

I want to dedicate this paper to the memory of Professor Chris Curtis, LSTMH. Professor Curtis asked me to write on the theme of this paper in 2007. Professor Curtis generously offered many helpful suggestions for its preparation. Unfortunately, he did not live to see the final version, so any failings or errors in this paper are mine alone.

**Literature Cited**


CDC Bulletin. Jan. 1950. U.S. Public Health Service, Communicable Disease Center, Atlanta, Georgia. Page 11. Surveys were conducted in thirteen southeastern states and approximately sixty-five thousand houses were inspected. Evaluations of effectiveness were based on inspections of randomly selected sprayed and unsprayed houses for presence or absence of the malaria mosquito.


Chemical management, last updated 01/18/2002: http://www.isd.ca/chemical/chemicalintro.html


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