

WHEN POLITICS KILLS

MALARIA AND THE DDT STORY

Richard Tren and Roger Bate

EXECUTIVE SUMMARY

Malaria, which kills more than one million people every year, including one child every 30 seconds, is rising steeply worldwide. For example, cases of malaria in South Africa have skyrocketed by over 1000 percent in the last five years alone.

Current attempts to control this mosquito-borne plague, which debilitates an estimated 300 million people yearly, include anti-malarial drugs, especially for visitors to the infamous “Malaria Belt” of sub-Saharan Africa, and pesticide-impregnated bed netting for residents of malaria-ridden countries.

In addition to trying to prevent infection with prophylactics like this, public-health officials spray various pesticides indoors to repel, irritate, and kill the mosquito vectors of the disease. Unfortunately, DDT (dichlorodiphenyltrichloroethane), one of the most effective pesticides ever to control malaria, is in very limited use these days and its production is falling.

Hailed for its near-miraculous success in eradicating malaria from North America and southern Europe in the years immediately following World War II, and in sharply reducing malaria incidence in India and other developing countries by the 1960s, DDT was *the* primary public-health tool to fight malaria. Gradually, however, with the growth of the modern environmental movement, governments in industrialized nations were persuaded to restrict DDT because of fears of damage to birds of prey. Today, because they can afford it, the rich nations control insect-borne diseases with alternative, more expensive, but less effective methods.

This retreat from DDT causes havoc in the developing world, however, where public-health programs to fight malaria are partly or wholly dependent on aid from donor countries, which are extremely reluctant to support the use of DDT because of its potential impact on wildlife. This precautionary protection of wildlife takes precedence over human health and well being, and comes at great cost in malaria-endemic countries.

While there is evidence that the widespread, virtually unregulated agricultural use of DDT in the 1950s and 1960s did harm the environment, no study in the scientific literature has shown DDT to be the cause of any human health problem. Low-dose use of DDT *indoors* to protect human health is therefore extremely unlikely to cause any harm to the environment.

Malaria is an obvious human tragedy, but it is an economic disaster as well. According to Jeffrey Sachs, of the Center for International Development, Harvard University, malaria costs Africa about 1 percent of its economic wealth every year. He estimates that it slashes potential economic growth in many countries by 50 percent.

In 1995, the United Nations Environment Program (UNEP) proposed to restrict and possibly ban 12 chemicals, including DDT, considered to be damaging to human health and the environment. Since rich countries neither produce nor use any of the 12, they would not feel the effects of such a ban. But the consequences of losing DDT in the world's poorest countries, where malaria reigns, could be counted in thousands of deaths and economic stagnation. Already, for example, in fear of losing rich-nation support of their public-health programs, Belize, Mozambique, and Bolivia have stopped using DDT; and suffered accordingly in lost life and treasure.

This monograph details malaria's infamous history, describing in particular how political wrangling in the rich world threatens the health and economic well being of the poorest countries. And it offers a working model of a successful, private, and cost-effective solution to the age-old scourge of malaria.

FOREWORD

This is an excellent review of malaria's devastating human toll and the economic disaster looming for Mozambique because of a proposed worldwide ban on the pesticide DDT, the most effective tool available to control malaria. It is also a cogent warning about the consequences to be suffered when narrow political agendas are permitted to drive global health and development policies. Such is the case with the attempt to ban DDT.

In the years immediately following World War II, the United States, Western Europe, and the rest of the developed nations rid their populations of malaria, principally through the application of DDT, the draining of mosquito-breeding swamps, and the use of window screens and mosquito netting to keep mosquitoes away from people. By the 1960s, the incidence of malaria in such developing nations as India, used to losing millions to the disease each year, had dropped to a few thousand cases annually.

However, after decades of widespread use, especially in agriculture, it became evident that DDT also was responsible for environmental problems, especially its impact on birds of prey. In 1972, DDT was banned in the US and, since then, the bald eagle and other endangered birds have begun to recover dramatically.

Scientists and public-health officials around the world now know that DDT cannot and should not be used ubiquitously. But they agree that, when used in limited amounts and as part of a comprehensive program of prophylaxis and treatment, DDT remains probably the most effective, affordable tool with which to fight malaria in the developing world.

Despite this, the developed nations, including the US, are proposing that the developing nations, including Mozambique and the rest of malaria-ridden sub-Saharan Africa, join in a worldwide DDT ban—at enormous health and economic cost.

Sick people can't work, can't afford food, and can't care for their children. These nations need all the tools available to get rid of malaria so they can be well and begin to prosper. Limiting their ability to do so because of DDT's past environmental record could be one of the most unwise public-health decisions ever.

DDT should remain available for focused, limited use to help nations free themselves of malaria's shackles. To ban DDT would be to move backward to a form of rich-world/poor-world imperialism that could significantly hobble the health, well being, and economic development of the world's poorest nations.

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Introduction

Malaria has probably accounted for more deaths and influenced the course of history more than any other disease. It has had a disastrous effect on economic development throughout the world and continues to do so in some of the world's poorest developing countries. While malaria today is associated with tropical countries, it is only within the last 50 years that malaria has been driven out of the temperate and developed countries of the north.¹

Even before Ronald Ross proved in 1898 that the *Plasmodium* parasite that causes malaria was passed to man by the female *Anopheles* mosquito, efforts to control malaria have been swayed and influenced by political and economic agendas. The main methods of control have been prevention—stopping the disease-carrying mosquito (vector) from contacting humans—and cure—treating the parasitical infection.

As late as the end of the Second World War, malaria affected numerous countries, including the United States, Europe as far north as Holland, and the less developed, tropical south. Post-war malaria-control strategies were to a very large extent determined by the northern countries, and proved remarkably successful. Despite the fact that malaria-control strategies failed in some southern countries and that the disease is spreading and increasing in these countries at alarming rates, the malaria-control agenda is still dictated by northern countries.

For example, at the beginning of the 21st century, Mozambique, one of the world's poorest countries, is battling to control malaria and to build a viable economy after 17 years of destructive civil war. Its anti-malaria efforts are being hampered by northern countries intent upon implementing inappropriate policies based on their political agendas.

This monograph will examine historical malaria-control policies and will draw parallels between the political and economic forces behind those policies and the situation today. The monograph will then analyze the effects the disease and efforts to control it have on economic development in southern African nations. A special focus will be the

¹ The literature often refers to a “war” or other military metaphors against malaria. This is partly because the increase in post-World War II malaria resulted from destruction of irrigation and water-control systems by retreating armies (see Harrison, 1978).

role of the pesticide DDT and the current political campaign to ban its use. The paper will use as a case study the Mozal Aluminium Smelter in Mozambique and its malaria-control activities. Mozal displays all the current problems and solutions to malaria control: the poverty of less developed countries which find it hard to address malaria adequately; the desire of wealthy western industrial investors to rid their workforce of malaria; the lack of new technologies to combat third-world diseases such as malaria; and the dominance of political correctness in international aid agencies, which do more harm than good by denying less developed countries the right to use DDT.

Finally, the paper briefly discusses possible future malaria-control strategies, based on the lessons learned from the Mozal case study and from other sources.

Historical Malaria-Control Policies

Malaria-control policies have been in place in many countries for hundreds of years. Most policies were based on land drainage and the removal of standing water. Although the link between the *Plasmodium* parasite, the *Anopheles* mosquito, and man was only made in 1898, malaria has long been associated with swamps, marshes, and wetlands. Without the knowledge that these were breeding grounds for mosquitoes, people thought that foul-smelling air,² or miasma,³ was the cause of infection. Others believed that poisons seeped from the soil into drinking water, thereby infecting people (Harrison, 1978: 26).

The ancient method of planting swamps with water-loving and aromatic eucalyptus trees rapidly dried out wetlands and so reduced malaria rates. The miasma theory gave rise to the view held by monks in the Roman Campagna that the aromatic property of the trees acted as a shield against the malaria poisons and also as an antidote (Harrison, 1978: 26). This practice continued to modern Italy, where malaria was endemic until the mid-20th century (Croumbie Brown, 1890). Confusion was also widespread among the early European settlers in southern Africa. As the settlers frequently camped near water, rates of malaria were high and this frustrated their efforts to settle and develop the land. It was widely believed that malaria was caused not by disease-carrying mosquitoes, but was somehow caused by the *Acacia xanthophloea* tree—commonly known as the fever tree⁴ (van Wyk, 1984).

In 1889, France's efforts to construct the Panama Canal were abandoned due to financial scandals, which brought disgrace on national political figures. The ten-year project caused the loss of millions of dollars and thousands of lives to malaria and yellow fever (Baird, 1999). Working on the miasma theory—that infection seeps up from the ground—the beds of malaria patients were raised off the ground and the feet stood in cups

² The word malaria comes from Italian, mal—bad, aria—air.

³ Miasmas are defined as infectious or noxious exhalations from putrescent organic matter (Shorter Oxford English Dictionary).

⁴ The *Acacia xanthophloea* has a yellow trunk—a color often linked with disease, which helped to entrench the belief that the tree was somehow associated with malaria.

of water. US efforts to complete the canal ten years later benefited from an understanding of vector control once Ross's crucial discovery had begun to gain influence.

Environmental vector control

The understanding that the malaria parasite was transferred to man by the *Anopheles* mosquito helped to focus habitat-removal efforts and allowed them to be more effective.

The fight against malaria in Italy was championed by, among others, social reformers such as Angelo Celli. Celli argued that malaria control should be achieved by ensuring that the poor agricultural workers (who were most at risk) were better fed, better housed, and earned increased wages. Part of Celli's strategy was to reclaim swamps and resettle people on this land (Bruce-Chwatt and Zulueta, 1980: 94). Apart from the specific malaria-control programs, other things such as increasing populations, technological advancement, and a rise in demand for agricultural land led to the drainage of many swamps in Europe and a subsequent reduction in malaria rates.

After Ronald Ross, a military doctor working in India, had discovered the cause of malaria, he was charged with controlling mosquitoes in the British Empire. Sierra Leone was Britain's first west African colony. Endemic malaria and yellow fever made the whole area unhealthy, hampering efforts to develop commerce and trade. Freetown, Sierra Leone's capital, had a particularly bad sewage and rainwater drainage system. Puddles suitable for mosquito breeding were to be found everywhere. Ross first mapped and then applied petroleum to all the breeding sites to kill larvae. However, the task was bigger than Ross and his relatively small team had anticipated. It eventually became impossible to continually clear all breeding sites, and in 1902 a decision was made to move all European settlers to a segregated settlement above Freetown with fewer mosquitoes and a reduced risk of disease (Harrison, 1978: 121-129).

Malaria-control efforts were also made in Lagos, Nigeria, at the turn of the century. The Nigerian governor, Sir William MacGregor, had a medical background and was determined to make the city safe for both Europeans and the indigenous population. His approach was far broader than Ross's. Sir William arranged for public lectures to educate the population on the disease. He also arranged for the malarial cure, quinine, to be made widely available and free of charge, and set about draining the swamps in the midst of which Lagos was built. Despite his efforts, the war on malaria in Lagos was lost. Sir William's efforts were simply not enough. Even his broad range of anti-malaria "tools" was not sufficient to keep the mosquito at bay. Clearly, he didn't have the technology or pesticides to ensure that all breeding sites were eradicated and that the population was sufficiently educated about malaria transmission, even though he spent as much as £10,000 per year, worth more than £4 million (US\$5.73 million) in today's money (Harrison, 1978: 131).

Sir William wrote in 1901 in the *British Medical Journal* that it was "painfully apparent that what is being done at Lagos against malaria is far short of what is required" (Harrison, 1978: 131). His approach was not to segregate the Europeans and the indigenous population; he felt that the success of the empire rested on a healthy native population. These ideas were quite progressive at the time. A member of the Royal

Society's Malaria Commission described MacGregor's efforts to protect the native population as "dangerous sentimentality." After Sir William died in 1903 (of malaria), the program was abandoned (Harrison, 1978: 130-131).

A British military base known as Mian Mir in the Punjab province of India had extremely high incidences of malaria after irrigation canals were constructed in 1851.⁵ The irrigation canals provided ideal breeding habitats for mosquitoes. Due to the severity of malaria at the beginning of the 20th century, it was decided to clear and oil the irrigation ditches, remove infected people, and administer quinine in order to both prevent and cure the disease.

The malaria-control efforts at Mian Mir proved extremely expensive but had remarkably little effect on the incidence of malaria and the numbers of mosquitoes. The control efforts at Mian Mir were "...so exceptionally expensive, not just in money, but in the use of involuntary labor that even if it had succeeded, it could rarely, if ever, have been emulated" (Harrison, 1978: 134).

One problem in Mian Mir was that authorities hadn't figured that mosquitoes could travel. The common belief was that mosquitoes couldn't go very far. What they found, however, was that the adults simply flew in from other areas and the larvae also migrated in by water. As fast as the irrigation ditches were oiled and the pools cleaned out, the mosquito population replenished itself from outside.⁶

Vector-control programs were more successful in other areas, such as Klang in Malaysia, where the removal of jungles and marshes from in and around the town led to a dramatic reduction in malaria cases. In 1903, after the jungle and marshes had been cleared, hospital admissions for "fever" were one-tenth of the normal level (Harrison, 1978: 137). The success at Klang was most likely due to the fact that the *Anopheles umbrosus*, the chief vector, would not lay eggs in full sunlight and therefore retreated when the jungle was cleared.

Chemical vector control

The development of Paris Green, an effective, cheap, and relatively easy-to-apply larvicide, made a significant contribution to vector control. Other larvicide efforts included introducing larvivorous fish (*Gambusia affinis*) and, as mentioned previously, the application of petroleum to breeding sites. In South Africa, Paris Green was used relatively effectively during the 1930s. Some larvicide programs were remarkably successful in South Africa. Between 1932 and 1938, for example, the South African Railways managed to reduce the number of malaria cases among its staff from 1,021 to

⁵ The annual incidence of malaria was often 100 percent, meaning the entire population was infected with the parasite. During epidemics this would rise to over 300 percent, meaning individuals would suffer from at least three bouts of malaria in a year (Harrison, 1978: 131).

⁶ Similarly, *Anopheles funestus* has reappeared in South Africa by just flying in from Mozambique—the same problem 100 years later (Coetzee, 2000b).

57, chiefly through sustained larvicide programs (South African Department of Health, 1997: 5).

Pyrethrum⁷ was introduced to the Panama Canal malaria-control program in 1901, where it was burned like incense inside sealed houses (Harrison, 1978: 161). On its own, pyrethrum used in this way did not reduce malaria incidence, since it was only used in houses where a fever was reported. While the burning of the pyrethrum may have been effective in killing mosquitoes, there were plenty of asymptomatic carriers who were not targeted. A far wider program was required.

A spray version of the insecticide was invented in 1913 and was used primarily for agriculture. It was not used for malaria control until South Africa adopted pyrethrum spraying in 1930. It became the main method of vector control and was used to great success (Harrison, 1978: 210; Sharp *et al.*, 1998). Not only were the pyrethrum sprays more effective in killing the malaria vector, they cost around one-third of the larval-control program (Sharp and le Seuer, 1988). A problem with the pyrethrum spraying was that it had to be repeated weekly during the main transmission season and its use was therefore labor intensive.

The next major advance in vector control came in the form of DDT (dichloro-diphenyltrichloroethane). Like pyrethrum sprays, DDT had been synthesized and used in agriculture before it was introduced as an anti-malaria tool. DDT was developed in the 1930s to control insect pests in farming (and was used to this effect in Switzerland), but was first used in substantial quantities by the military in the Second World War to control typhus-carrying body lice. Its subsequent introduction to the fight against malaria had dramatic effects the world over, though, as will be described below, not every country was to witness long-term victory against the disease.

Drug Therapy against Malaria

Historical drug policies

The bark of the cinchona tree has been used to make quinine for many hundreds of years. Jesuit missionaries in South America discovered the anti-malarial properties of quinine, and the drug was first exported to Europe in the 1630s and to India in 1657. The Jesuits promoted the use of the “Cardinal’s Bark” throughout the world, though its acceptance in Europe was not universal. Orthodox physicians were skeptical of the drug and refused to prescribe it, a reluctance based partly on the fact that the drug was frequently of poor quality and “adulterated with inert bitter substances” (Bruce-Chwatt and Zulueta, 1980: 92). Others’ reluctance was based on faith rather than reason: Some Protestants refused to take the drug, preferring to die rather than be saved by Jesuits’ powder (Bruce-Chwatt and Zulueta, 1980: 133).

Quinine emerged as one of the main weapons for fighting malaria, both as treatment and as prophylactic. Quinine became popular in Italy towards the end of the 19th century,

⁷ Pyrethrum is a natural insecticide derived from a species of chrysanthemum (Harrison, 1978: 161).

when the anti-malaria campaign was headed by social reformers like Celli. Robert Koch, the German pioneer of bacteriology, was so impressed with quinine that he declared in 1899 that “quinine systematically administered to both new and relapsed cases would wipe out malaria in nine months” (Harrison, 1978: 172). What Koch failed to understand was that people could carry the *Plasmodium* parasite and not necessarily feel ill. Screening every person’s blood to determine whether or not he carried the parasite was not feasible. Tests were time-consuming and not entirely accurate. Koch’s approach was never likely to eliminate the disease.

Italy passed a number of acts aimed at controlling malaria. In many cases they were couched in laws aimed at social change. Legislation extended the availability of quinine, for example, and increased the responsibility of landowners to protect workers, control mosquitoes, and report malaria cases. The laws achieved little in the way of social change, but quinine sales rose dramatically after a law was passed on December 23, 1900, which set up a state quinine service.

A social reformer, Celli had lobbied strongly for quinine-based malaria-control legislation, despite being a critic of Koch’s approach. The 1900 Act ensured that all quinine was sold by the state with profits being used for research, quinine distribution to the poor, and special prizes (Harrison, 1978: 174). Celli was a founding member of the *Societa per gli Studi della Malaria* that aimed to promote research and lobby for health legislation. It is likely therefore that Celli and his organization would have profited from the research grants accruing from the sale of quinine.

Italian state sales of quinine rose from 2,242 kilograms in 1902-03 to 24,000 kilograms in 1914. During this time, malaria incidence fell significantly and mortality decreased from 15,000 to just over 2,000 (Bruce-Chwatt and Zulueta, 1980: 94). While the distribution of quinine played an important part in ensuring malaria rates were so successfully reduced, quinine’s role has been exaggerated. Malaria had in fact been declining in Italy for many decades with changes in climate, expansions of agricultural land, and general economic development (Harrison, 1978: 174).

Quinine was widely used in other parts of Europe without the kind of legislation that was passed in Italy. In the United Kingdom, where the effects of malaria had been known for many centuries, the Protestants overcame their initial objection to the Jesuits’ discovery and accepted quinine. The use of quinine along with the reclamation of swamps and marshes and a general improvement in medical care saw malaria rates decline in England from the 1850s onwards (Bruce-Chwatt and Zulueta, 1980: 137).

Current drug policies

Quinine still plays an important part in the treatment of malaria, and in many countries is the drug of choice for complicated or severe cases. Quinine has strong unpleasant side effects, so it is often administered intravenously to hospitalized patients. Up to 70 percent of patients who take quinine, for example, can experience tinnitus, vertigo, and nausea lasting throughout the dosage period (South African Department of Health, 1996b). It is not surprising that there is low compliance when patients are required to take quinine tablets without supervision. After the Second World War,

chloroquine was the preferred prophylactic and treatment for malaria, though resistance began to emerge in the early 1960s in southeast Asia and South America. This resistance has subsequently spread to most other malarial countries, with the exception of those in Central America, the Caribbean, and the Middle East (Baird, 1999).

Chloroquine resistance has dealt a very severe blow to the fight against malaria. Some researchers point to drug resistance as the single most important factor contributing to the rise in the worldwide incidence of malaria. Chloroquine is not only a cheap drug, it is relatively easy to administer and does not have the serious side effects of quinine.

In countries where there is chloroquine resistance, administration of the drug can even promote the transmission of the disease. This is because the use of chloroquine culls any chloroquine-sensitive parasites and leaves resistant trophozoites to differentiate to gametocytes. What this means is that the most robust parasites will be left to thrive in a less competitive environment (Baird, 1999: 23). In these cases, chloroquine-treated patients will feel better quickly, but they will maintain asymptomatic levels of the parasite and remain infectious to the anopheline mosquitoes. This ensures that a mobile pool of asymptomatic carriers of the drug-resistant strain remains and can infect new mosquitoes.⁸

In southern Africa, the main drug used in the treatment of uncomplicated malaria is sulfadoxine-pyrimethamine (SP), which is taken orally and has proved effective. In the Kwa-Zulu Natal province of South Africa, resistance to SP has developed in recent years and treatment is supplemented with chloroquine. (The World Health Organization recommends that a drug should no longer be used when resistance exceeds 20 percent (Maharaj, 2000)). The Kwa-Zulu Natal province has the highest malaria rates in South Africa and is also the main transit route for people migrating from Mozambique to South Africa. It is thought that asymptomatic carriers of the malaria parasite from Mozambique introduced SP-resistant strains of the parasite to the province (Maharaj, 2000). The resistance rates to SP in Kwa-Zulu Natal are approximately 56 percent, while in the other two malarial provinces of South Africa, Mpumalanga and Northern Province, the resistance rates are less than 10 percent and zero, respectively. There is far less migration from Mozambique through these other provinces, which adds weight to the theory that resistance has been imported from Mozambique.

Using combination drug therapies is widely accepted as a reliable strategy to counter the problem of drug resistance, especially as there is little prospect of development of new effective drugs. Using combination therapies ensures that the life span of both drugs is extended and thereby reduces the likelihood that asymptomatic carriers of the malaria parasite will spread the disease. South Africa is currently attempting to introduce co-artemeter, another combination therapy, to Kwa-Zulu Natal (Maharaj, 2000).

Malaria occurs predominantly in less developed countries with low purchasing power, so the potential market for new anti-malaria drugs is relatively small. Without a viable

⁸ The mobility of asymptomatic carriers is important, as carriers will introduce new strains of the parasite to new areas. The relaxation of border controls in South Africa since 1994 and the subsequent movement of people within southern Africa is very likely to have contributed to the rise in malaria rates in the region.

market, pharmaceutical companies have been reluctant to invest in the development of new drugs. With little prospect of a return on their investment, it has been difficult to justify considerable expenditure in research and development and administrative approval.

According to Desowitz (1993), “The best anti-malarial hope on today’s horizon is a ‘new’ two thousand-year-old drug called Qinghaosu.” Decoated from the leaves of sweet wormwood, the recipe was included in a book written in the year 340 AD, which was rediscovered during a search through the ancient Chinese herbal pharmacopoeia begun in 1967. The drug has been shown to be effective against cerebral malaria and against strains solidly resistant to chloroquine. It has been chemically analyzed and could be mass-produced, but, so far, the opportunity has not been seized.⁹

In a recent development, scientists at Cambridge University (see the *Proceedings of the National Academy of Sciences USA* vol. 97, no.1: 331–336) have found that a drug called clotrimazole, which has long been used to treat fungal infections in humans, also has a strong anti-malarial effect. Test-tube trials showed that the drug kills a strain of the parasite *Plasmodium falciparum* that causes a particularly severe form of malaria in humans. The concentrations of the drug used to kill the parasite were similar to those known to be attained in human blood after taking the drug orally.

Because clotrimazole is already known to be clinically safe, and free of resistance reactions by fungi, it holds some promise as an effective way to combat the disease. Researchers are currently seeking funding to initiate a pilot clinical trial of clotrimazole in Iquitos, Peru, where malaria caused by drug-resistant parasites has become a major public-health concern.

Vaccine

The history of the search for a malaria vaccine is replete with unrealistic optimism, data manipulation, and even fraud (Desowitz, 1992). The development of a malaria vaccine has been widely reported as “just around the corner” for decades, though an effective vaccine is not likely to be made available for at least another seven years (De Gregori, 1999). Even when a malaria vaccine is produced, it is unlikely that the poorest nations will be able to buy enough to protect all those at risk. This situation has led to calls by the Harvard Center for International Development for a Vaccine Purchase Fund that would provide a guaranteed market for vaccines once they were developed.¹⁰

While drug therapy has to be part of any malaria-control program, the sole reliance or overemphasis on this form of control is extremely dangerous for the reasons described above. Despite these dangers, drug therapy and the use of “smart” technology forms a major part of the World Health Organization’s Roll Back Malaria program.

⁹ Mefloquine, also known as Larium, is still efficacious, but being a synthetic analogue of quinine, users suffer similar side-effects.

¹⁰ For more on the Vaccine Purchase Fund see www.cid.harvard.edu/cidmalaria/malaria.htm.

In the past, malaria-control strategies were more often than not politically determined, with scant regard for the practical requirements of malarial regions or indeed the best prevailing method of control at the time. As will be expanded upon below, this trend continues. However, politics today appear to be driven by environmentalist groups in developed countries. The casualties in this political war continue to be the victims of malaria in the world's poorest nations.

DDT and the Global Eradication Campaign

We have discovered many preventatives against tropical diseases and often against insects of all kinds, from lice to mosquitoes...The excellent DDT powder, which has been fully experimented with and found to yield astonishing results, will henceforth be used on a great scale by the British forces in Burma, and the American and Australian forces in the Pacific and India and in all theatres.

Winston Churchill, 28 September 1944 (quoted in Mellanby, 1992: 23).

The concept that the world could be completely cleared of malaria was born with the successful eradication of *Aedes aegypti* and later *Anopheles gambiae*¹¹ from Brazil. This eradication was primarily due to the work of the Rockefeller Foundation¹² under the guidance of Fred Soper, who initiated a wide-ranging larvicide and vector-control program using oil, Paris Green, and pyrethrum sprays. After Soper's enormous and costly effort, he was rewarded with victory: *Aedes aegypti* was eradicated from Brazil in 1934, and by the mid-1940s *Anopheles gambiae* was similarly wiped out.

DDT and chloroquine were introduced for malaria control by the US military by 1944, and after the end of the Second World War were in wide use around the world. The use of pesticides led to enormous optimism and the belief that malaria could be eradicated from the entire globe. The reasons for this optimism are not hard to see. DDT was, and is, highly effective in killing the malaria vector and interrupting the transfer of the malaria parasite. It is also cheap, safe, and easy to use, putting it within reach of even the poorest countries' health budgets. Shortly after the end of the Second World War there was also a conviction that vector control, and in particular pesticide spraying, was the only way to tackle the disease.

The early successes of DDT were nothing short of spectacular. Scientists "thought that the whole literature of agricultural and medical entomology would have to be re-written...because of the use of DDT" (Mellanby, 1992: 37). In Europe and North America, DDT was widely used, and within a few years malaria had been eradicated from both continents. It is thought that in one year alone, the transmission of malaria in Greece came to a halt (Harrison, 1978: 231). Mack-Smith (1959: 494) even suggested that

¹¹ *Anopheles gambiae*, a highly efficient vector, is suspected of having travelled aboard ship from Africa to Brazil.

¹² The Rockefeller Foundation was founded by American oil tycoon John D. Rockefeller in 1901 with the aim of promoting the well being of mankind.

malaria eradication “was the most important single fact in the whole of modern Italian history.”

In South Africa, the malaria-control program adopted DDT in 1946. Shortly afterwards, the number of cases in the Transvaal declined to about one-tenth of the number reported in 1942-43. In some areas of South Africa, DDT spraying was so successful that it was stopped altogether and only reintroduced after periods of heavy rains, when malaria cases tend to rise.

Perhaps the most remarkable success story was to be found in Sri Lanka (then Ceylon). DDT spraying began in 1946 and, as with South Africa, was instantly successful. The island’s death rate from malaria fell from 20.3 to 14.3 per thousand. Within ten years, DDT use had cut the incidence of malaria from around three million cases to 7,300, and had eliminated all malaria deaths (Harrison, 1978: 230). By 1964, the number of malaria cases had been reduced to just 29, and at the time it was assumed that the war against malaria in Sri Lanka had been won.

After World War II, India also had a particularly bad malaria problem, where every year around 75 million people contracted the disease and about 800,000 died. Almost the entire country was malarial; then, as now, there were six anopheline mosquito vectors. By using DDT, India managed to bring the number of cases down from the estimated 75 million in 1951 to around 50,000 in 1961 (Harrison, 1978: 247). The achievement of reducing the number of infections to this degree cannot be overstated. Still, this success in India, as in many other countries, was to be short lived.

Complete eradication of malaria was achieved in only ten countries, four of which were in Europe, the other six in the Americas and the Caribbean. The WHO strategy of eliminating malaria from the globe did not stretch to much of Africa, where the vast majority of cases occurred and indeed still occur. It had been hoped that the swift and decisive use of DDT through well-planned and well-funded malaria-control programs throughout the world would achieve success. For poorer countries without sufficient health-care resources or transport infrastructure, the plans were not appropriate and goals were gradually scaled back from eradication to control to containment.

Box 1: Administering a Spraying Program

Successful spraying programs need to be well organized with detailed maps of the malarial areas and a systematic plan to the spraying program. Sprayers need to target the areas most at risk and it is vital that all structures within an area are sprayed, as omitting some will undermine the program. In addition, spraying needs to be followed up with an epidemiological study to measure the efficacy of the pesticides and also to administer blood tests for parasite levels within the communities. All this requires a significant amount of funding, organization, and commitment from the sprayers, medical staff, and higher bureaucratic structures. Malaria-control programs must take account of the capacity “on the ground” to implement them, and where capacity is lacking the program should provide resources and expertise. This “capacity gap” is an important factor in the ultimate failure of many mosquito-eradication plans.

The Global Malaria Eradication Campaign, adopted by the World Health Assembly in May 1955, relied on vector control as the main method of interruption of transmission of the disease, and was to be followed later by case detection and treatment. Mathematical models developed by Professor George MacDonald showed that eradication was possible if the proposed vector-control program was followed. The United States Agency for International Development (USAID) played a major role in supporting and financing the initiative, contributing \$1.2 billion to the program between 1950 and 1972. The WHO contributed far less, \$20.3 million between 1956 and 1963, of which \$17.5 million was contributed by the United States. All other countries combined contributed only \$2.8 million (Baird, 1999: 14).

One of the reasons the WHO pushed for rapid implementation of DDT spraying for an intensive and limited time period was fears of resistance to the pesticide. The problems of resistance¹³ to DDT first emerged in Greece in the early 1950s, where it was observed that the main Greek vector, *Anopheles sacharovi*, showed physiological resistance to the pesticide. Resistance to DDT was later observed in the Middle East, parts of Indonesia, and also in northern Nigeria in 1956.

Fears about the increase in resistance to DDT (and dieldrin, another organochlorine pesticide) led the WHO expert committee in 1956 to call for swift and overwhelming vector-control programs that would eliminate the pool of parasites before resistance could develop. However, many countries did not have the infrastructure or organizational capacity to implement the WHO plans. India's initial successes, for example, were reversed largely because it could not sustain the vector-control program. The staffs of malaria-control programs were not properly trained and were frequently careless in their approach to spraying and detecting malaria cases (Harrison, 1978: 250).

Before long, malaria rates began to rise in many of the countries that had all but eradicated the disease. The resurgence was partly caused by complacency in the early successes. Some countries decided to cut back on their programs in order to save money and others simply became careless. Many developing countries could not have anticipated that the vector-control "blitzkrieg" would have to be sustained over a longer period than originally planned by the WHO.

The unilateral vector-eradication approach to malaria control that constituted the Global Eradication Campaign could have led to its ultimate failure. Whether eradicating the disease is technically feasible or not, the approach followed by USAID under the guise of the WHO imposed unrealistic control strategies that could not be sustained in most poor countries. DDT was remarkably successful in almost all the countries in which it was used, but it was never likely to work as a magic bullet. Malaria is a disease that is influenced by a number of factors, such as climate and migration, as well as control strategies. Developing a malaria-control strategy that is solely reliant on vector control—especially on only one pesticide—was optimistic at best and foolish at worst. The greater

¹³ See Box 2 on page 29 for a fuller discussion of resistance to pesticides.

folly was in the unilateral way in which the policy was developed, failing to take into account the conditions under which the policy would be implemented.

As will be described below, however, far from learning from these errors, the WHO and donor agencies, such as USAID, continue to promote policies unilaterally. The basis for recommending malaria-control weapons has changed, though the political reality in which the agenda for malaria-control strategies is determined by developed countries and imposed on developing countries remains.

There were critics of the eradication campaign from the beginning. The most cogent arguments centered on the over-reliance on DDT, but there were other complaints. It was alleged that vector control was promoted to encourage capitalist development and to fight communism, furthering American political aims rather than always doing what was best for local people (see next section for alternative methods of malaria control). For example, “The real (or imagined) fear that the [Italian] government¹⁴ would be won over by the communists at the next election was used to justify continued external funding for malaria control, even though this was no longer technically required” (Litsios, 1997: 270).

Furthermore, Litsios (1977: 272) claims that the WHO was in a difficult position from inception, “caught in the middle of the problem created by the emergency needs following World War II and the political intricacies of the Cold War.” The USSR left the WHO in 1949 and didn’t return until 1957, and hence no malaria specialist from the southern regions of the USSR was included in malaria-control efforts.

Certain commentators espoused the neo-Malthusian line that it may be unkind to keep people from “dying from malaria so that they could die more slowly of starvation.” One even saw malaria as “a blessing in disguise, since a large proportion of the malaria belt is not suited to agriculture, and the disease has helped to keep man from destroying it—and from wasting his substance upon it” (Vogt, 1949: 13, 28). The modern-day green version of this is stated by Gell-Man (1994: 353): “Some day anti-malarial vaccines will probably be developed, which may even wipe out the various forms of the disease entirely, but then another difficulty will arise: important wild areas that had been protected by the dangers of malaria will be exposed to unwise development.”

Plus ça Change—Past and Present Malaria-Control Policies

Ross’s discovery that the *Anopheles* mosquito transmits the malaria parasite was a crucial step in attempts to control the disease. But the discovery was not universally embraced and its potential value was rejected by some involved in malaria control—namely by supporters of the “Italian way.” In choosing political doctrine over sound scientific and medical research, the so-called social reformers ignored a vital malaria-control weapon. On the other hand, those who were single-minded in their pursuit of

¹⁴ Speaking at the Third Session of a joint WHO/FAO meeting on malaria in 1948, Missiroli of Italy noted that the prosperity of Europe depended on the possibility of exploiting Africa. “Africa cannot be fully exploited because of the danger of flies and mosquitoes; if we can control them, the prosperity of Europe will be enhanced” (cited in Litsios, 1997: 281).

vector control as the only way in which to combat the disease, such as the Rockefeller Foundation, missed out on the potential of drug therapies.

Prior to the introduction of DDT into malaria-control programs, these two divergent approaches dominated efforts to control the disease. On the one hand, Celli and Koch (and more recently by Litsios (1997) and Packard (1997))¹⁵ saw malaria as much a social problem as a medical and entomological one. This so-called Italian way of tackling the disease saw social reform, poverty reduction, and the advancement of vulnerable communities as the main tools. The Italian way strongly favored the use of quinine as the main practical way of eliminating the malaria parasite and, as described above, did this by passing legislation. The supporters of the Italian way were not confined to Italy. The influential Dutch Professor Swellengrebel was also of the opinion that the fight against malaria should have two prongs, namely reduction in mortality and improvement of social and economic conditions.¹⁶ The Italian way favored a centralized approach, promoting state control of the supply of quinine.

The League of Nations Malaria Commission was set up in 1924 as an investigative unit and was active until 1937. Interestingly, according to Harrison (1978: 183), “its mandate was cautiously restricted to stay well clear of any implications of international interference in national affairs.” The Commission argued strongly in favor of quinine use, stating that over 30 years of vector control since Ross’s discovery had produced “a record of exaggerated expectations followed sooner or later by disappointment and abandonment of the work” (cited in Packard and Gadelha, 1997: 217).

On the other hand, the method of control favored by the Rockefeller Foundation—the “American way”—was founded generally on vector control, and with the use of spray pesticides in particular. Ronald Ross could be seen as one of the early founders of this approach, not only with his discovery of the role that the *Anopheles* mosquito plays in the transmission of malaria, but also through his efforts to control malaria in Sierra Leone. The vector-control successes of the Panama Canal and Brazil gave support to the American way. Dr. Lewis Hackett, who was sent by the Rockefeller Foundation to Italy to investigate malaria control, felt strongly that malaria could be defeated by attacking the mosquito. Importantly, he opposed the centralized control of the Italian way and was of the opinion one had to understand local conditions that allowed the disease to spread.

But the Commission only visited Europe, seemingly ignoring the rest of the malarial world. It ignored much of the work by Ross and Hackett and maintained that the only effective way to fight malaria was through quinine. The League’s proposals were widely criticized by those who saw merit in attacking the malaria vector.

¹⁵ Recent critics seem perturbed by the lack of consultation with local “knowledge” and lack of general redistribution of wealth, rather than promoting a particular vision.

¹⁶ Swellengrebel was not wedded to the idea of social and economic reform. During an investigation of malaria in the Union of South Africa in 1930, he recommended “species sanitation” as a main principle of control. He also recommended that no malaria control be conducted in certain parts of Kwa-Zulu Natal for fear of diminishing the natural immunity of the population.

Although the League's Commission later softened its criticism of the Rockefeller Foundation and the American way, the two approaches never found common ground. While the Commission continued to support drug therapy as the main method of control, in its last report it noted that the elimination of malaria by drug therapy and prophylaxis "has not hitherto been found possible in practice" (cited in Harrison, 1978: 186).

The Rockefeller Foundation continued with its vector-control approach, which in time came to dominate all malaria-control work. Vector control was further entrenched as the main method of malaria control once DDT was introduced and had such spectacular successes in so many countries.

Ironically, the Soper/Rockefeller Foundation approach of centralized spray-management based on DDT, ignoring both medical treatment and local social issues, was to establish a model that, although effectual, could not continue to live up to its billing of mosquito eradication. Neither was it more sensitive than the Malaria Commission to local culture and requirements. Once it was partially discredited it, too, was soon abandoned (see Brown, 1997). The goal was gradually scaled back from mosquito eradication to malaria eradication and then malaria control in east Asia and southern Africa, and merely containment in sub-Saharan Africa.

Environmentalism and Malaria Control

While DDT was being used in malaria-control campaigns and also in agriculture, concerns were raised about the environmental impacts of the pesticide.¹⁷ Perhaps the most well known attack on DDT was Rachel Carson's *Silent Spring*, published in 1962.¹⁸ The book popularized the scare associated with DDT and claimed that it would have devastating impacts on birdlife, particularly those higher up the food chain. The fears were based on the fact that DDT and its metabolites DDE and DDD accumulate in the body fat of animals. Even though many of the fears surrounding DDT were unfounded, and the studies upon which they were based unscientific, DDT was banned by the US Environmental Protection Agency (EPA) in 1972.

Numerous scientific reports and evidence given by expert witnesses argued against a ban of DDT and in favor of its continued use. Despite this convincing evidence to the contrary, EPA Administrator William Ruckelshaus argued that the pesticide was "a warning that man may be exposing himself to a substance that may ultimately have a

¹⁷ Before WWII it was generally argued that malaria control could only be afforded if it contributed to agricultural development. For two decades, beginning in 1945, this link was dissolved (Litsios, 1997). But in recent decades a new parallel has emerged with the pre-war phase, in that although much medical control of malaria is done for humanitarian reasons, the only insecticides used in vector control are those that were developed for agriculture.

¹⁸ Entomologists and other scientists in Britain were aware of the potential environmental dangers of DDT in 1945. But, at the time, the acute toxicity problems from other pesticides, including organophosphate pesticides, dominated concerns of various governmental scientific committees (Mellanby, 1992: 83). There is also ample evidence to suggest that the potential impacts of DDT are reversible given sufficient time (Goklany, 2000d).

serious effect on his health” (cited in Malkin and Fumento, 1999: 144). The pesticide was banned outright in the US and in most other countries shortly thereafter, though it remained available for its crucial role as a medical pesticide. Ruckelshaus’s preoccupations with potentially negative environmental and health impacts (despite all the evidence to the contrary), and his refusal to accept the scientific advice offered, most certainly contributed to death in malarial countries by denying them access to this life-saving pesticide.

The possibility that population control was an intentional aim of EPA policy has been raised by some former EPA staff members (Padden, 2000), but there is no explicit documentary evidence to support such a hypothesis.

Most developed countries followed the US lead and imposed outright bans on the chemical for all uses. Some developing countries also imposed a complete ban of the pesticide—some for agricultural use and some for all uses. For example, South Africa banned it for agricultural use in 1974. Sri Lankan officials had stopped using DDT in 1964, believing the malaria problem was solved, but by 1969 the number of cases had risen from the low of 17 (achieved when DDT was used) to over a half million (Silva, 1997). It is alleged that DDT was not widely re-introduced because of mosquito resistance to it, and DDT use was finally abandoned in favor of Malathion¹⁹ in 1977 (Spielman, 1980).

As Packard (1997: 287) points out, “It is likely that the reduction in support of spraying activities leading to inconsistent application of pesticides also played a role in the development of vector resistance.” Furthermore, pressure not to use DDT may have been applied by western donors using resistance as a convenient argument. Recent evidence shows that even where resistance to DDT has emerged, the “excito-repellancy” of DDT causes mosquitoes not to enter buildings which have been sprayed (Roberts *et al.*, 2000). Under test conditions (see Grieco *et al.*, 2000), for at least one type of malarial mosquito in Belize (the only country in which these tests have so far been conducted), DDT is far more successful than the most favored vector-control pesticide—deltamethrin.²⁰ Hence it is unlikely that malaria rates would have increased (significantly) even if resistance was found. Recognizing its continuing efficacy, many countries, such as those in southern Africa, continue to allow DDT to be used for malaria control.

The concern about DDT came at a time when the environmentalist movement was beginning to gain both power and influence, and the issue certainly added momentum to the movement. One of the key concepts of the movement is sustainable development, which achieved prominence largely through the efforts of Norwegian Prime Minister Gro

¹⁹ The introduction of alternative pesticides had disastrous results for those doing the spraying, with many deaths caused by poisoning from replacements. DDT is not harmful to humans; the DDT expert Kenneth Mellanby used to eat a pinch of DDT at every lecture he gave on DDT over a period of 40 years (Mellanby, 1992: 75).

²⁰ It is also worth noting that some malarial mosquitoes in southern Africa are resistant to deltamethrin, so the effectiveness of it will be even lower than in Belize.

Harlem Brundtland and the World Commission on Environment and Development's 1987 report, *Our Common Future*. The Commission stated:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

It contains within it two key concepts:

the concept of "needs," in particular the essential needs of the world's poor, to which overriding priority should be given; and

the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

(Commonwealth Secretariat, 2000)

One interpretation of sustainable development, known as strong sustainability, assumes that natural capital, such as forests, wildlife, and other natural resources, cannot be substituted for other forms of capital, such as man-made capital. The use of pesticides would not be consistent within a strong-sustainable-development framework because of the negative effects they might have on the natural capital.

Within malaria control, policies that try to fulfill the requirements of strong sustainability would not use pesticides or other chemicals but would rather promote the use of bed nets or drug therapies. The WHO and other leading world agencies have all committed themselves to policies that are purported to be more in line with this view of sustainable development and avoid the use of potentially environmentally harmful chemicals. The WHO's Global Malaria Control Strategy focuses on the improved clinical management of malaria diagnosis and treatment rather than on parasite-control programs.

The Roll Back Malaria program, jointly sponsored by the WHO and the World Bank, also focuses on the control of malaria through diagnosis and treatment of malaria patients and does not promote vector control. That the change of focus has taken a markedly more "environmental" stance should not be surprising, given that the head of the WHO since 1997 has been Gro Harlem Brundtland (for details see www.who.int).

Donor agencies, malaria control, and environmentalism

A major setback to malaria-control efforts is the threat to ban DDT by international agreement under the United Nations Environment Program (UNEP). The UNEP Governing Council (Decision 18/32, 25 May) in 1995 decided to proceed with an instrument to control certain chemicals considered to "pose major and increasing threats to human health and the environment" (<http://irtpc.unep.ch/pops/indxhtmls/gc1832en.html>). UNEP set in motion the negotiation of a legally binding instrument for implementing international action on persistent organic pollutants (POPs), which is due to be signed in Stockholm in May 2001. The POPs instrument seeks to restrict or eliminate all uses of DDT and 11 other substances, such as dieldrin, aldrin, and polychlorinated biphenyls (PCBs). Of these dozen chemicals on the POPs list, DDT is easily the most beneficial due to its role in malaria control. The other substances may not have the health benefits of DDT, however some, especially PCBs in electronic goods, are used in many developing countries. Although all the chemicals were invented in developed countries

and were used extensively in the past, none of the 12 substances is still used in the countries now promoting the POPs process. This makes ratifying a DDT ban politically and economically easy for advanced developed nations, though it would deprive developing countries of one of their best weapons against malaria. Some governments appear to be pursuing political goals through agencies such as the UNEP, and a few are attempting to achieve their goals at the expense of those at risk from malaria in developing countries (Dyson, 2000).

The country delegates to the UNEP meetings are either career bureaucrats or environmental specialists. The original representative from the WHO was an environmental specialist who, at the third negotiating session in Geneva in 1999, did not support the use of DDT (see Bate, 2000). While this is understandable, since the POPs instrument is essentially about restrictions of environmental pollutants, it is unnecessarily blinkered and life-threatening to miss the bigger picture of malaria control and development needs of poor countries. Of course, the only way politicians from developing countries would sign on to policies that would harm their citizens would be if there was financial compensation in so doing. Indeed, the POPs Club was established to take donations from western governments for this very purpose, and has so far raised \$3.8 million (see http://irtpc.unep.ch/POPs_Club). The POPs instrument includes articles about transfer of resources (Article J is technical assistance and K is financial assistance) from developed to developing countries. In effect, it is little more than bribery by western diplomats (using taxpayer money) of less developed countries to extract a promise to do without certain chemicals such as DDT.

Even if DDT is not banned, the restrictions that the POPs instrument will place on its use are substantial. In the latest draft of the instrument (see page 31 of <http://irtpc.unep.ch/pops/inc.5/5>) there will be regulatory mechanisms (and probably funding via the POPs Club) to promote alternatives to DDT and push towards “eliminating the use of DDT”; notification to the treaty secretariat (or some other body) of stockpiles, uses, and transfers of DDT; and other anti-trade measures that will make it harder for countries to purchase and use DDT. In short, the POPs instrument will make the alternatives more cost-effective by making DDT more expensive.

Many non-governmental organizations (such as Greenpeace and the World Wildlife Fund), transnational organizations (such as the WHO), and donor agencies (such as USAID) are also against pesticide-based vector control. As all the donor agencies that operate in malarial countries and sponsor malaria programs are from developed northern countries, they are frequently required to follow protocols developed for their countries. For example, USAID cannot support overseas activities that are illegal in the US (Dyson, 2000). This can lead to inappropriate programs being implemented.²¹

²¹ The only paper submitted by Belize to the POPs web site is about the problems of disposing of DDT from Belize (see Alegria, 1999). It explains how nearly three tons of DDT almost fell into a river (implying that Belize cannot be trusted with any synthetic chemicals of any sort), but not why that DDT had not been used for malaria control (which is why it was purchased three years earlier), and was sitting unused in a poorly maintained warehouse. A possible explanation (see Dyson, 2000) is that USAID pressured Belize into not

More sinister is the pressure that donor agencies can and do place on the governments they are purportedly assisting to comply with their (the donor agencies) environmental and health guidelines. There are several examples of pressure placed on impoverished malarial countries by aid agencies. One example is Mozambique, where officials at the Department of Health have been strongly advised by its donors not to introduce DDT into the vector-control program (Mabunda, 2000; Baretto, 2000). Mozambique is one of the world's poorest countries and has been struggling to rebuild its national infrastructure and economy after a civil war that lasted nearly 20 years. Due to these circumstances, the country is heavily reliant on donor funds for the provision of even the most basic services to its population.

The use of DDT in its malaria-control program would be an attractive option because it is cheap, easy to use, and highly effective. The need to use DDT is becoming increasingly urgent because of the resistance of the *Anopheles funestus*²² mosquito to the synthetic pyrethroid pesticides.

In Mozambique, malaria-control initiatives are supported by, among others, the Norwegian Development Agency (NORAD), the Swedish International Development Agency (SIDA), the Swedish Aid Agency, USAID, and UNICEF. With the exception of UNICEF, which said that it would follow the recommendations of the WHO,²³ none of these agencies supports the use of DDT in vector control (Renshaw, 2000).

NORAD discovered several years ago that funds they had donated were being used for vector-control programs using DDT. NORAD reacted by issuing a statement that it could not support policies that used pesticides or other chemicals that could not be legally used in Norway (Azedo, 2000). Similarly, SIDA has stated that it cannot support the use of DDT in any country, as it was banned in Sweden in 1975.

UNICEF has implemented two malaria-control initiatives in Mozambique. The first is an ongoing program that provides pesticide-impregnated bed nets²⁴ to communities in the Zambezia province. This program also uses chloroquine as a "first line of defense" drug. UNICEF also responded to the recent flooding in Mozambique and has begun to supply 150,000 bed nets in the Gaza province (Renshaw, 2000). While bed-net programs can be a useful element in a comprehensive malaria-control program, doubts are emerging about their effectiveness when used on their own. Recent research shows that unless the entire community in a chosen area has insecticide-treated bed nets and they are used consistently, they prove ineffectual in malaria control (see Curtis, 1999).

While insecticide-treated bed nets offer a degree of personal protection, they are only effective in reducing overall malaria rates and in protecting whole communities when

using DDT, and hence the previous importation of the powder became an embarrassment. Another explanation is that the DDT had become "caked" and unusable, and therefore was awaiting disposal.

²² *Anopheles funestus* is a major and highly effective malaria vector in southern Africa.

²³ The WHO has lately recommended the use of DDT. See fightingmalaria.org for a letter, dated May 1, 2000, from Dr. Ibrahim Samba, Head of WHO Africa.

²⁴ The pesticides used are synthetic pyrethroids.

they are distributed systematically and their use is monitored—much in the same way as a spraying program. The efficacy of bed nets varies from location to location and depends largely on cultural norms and their social acceptability (Coetzee, 2000b; Hunt, 2000). Bed nets may also reduce immunity to the infection so that a child of say, ten years old, could contract the disease and die, whereas without bed nets he or she would have built up a certain immunity and would not suffer as greatly from the disease in later years (Curtis, 1999). It is possible the child would have died before reaching ten years had he not had the protection of a bed net, so it is not clear whether this argument is strong.

USAID is currently formulating its malaria-control strategies in Mozambique and has stated that the policy will be “very different” from other strategies and will include a “systematic approach” to the problem, with many different interventions (Ferrara, 2000). To date, USAID has not sponsored or undertaken any vector-control efforts.

Mozambique is not alone in coming under pressure from donor agencies. USAID successfully pressed the government of Belize not to use DDT in its malaria-control program (Bate, 2000). In Madagascar, the United Nations Development Program attempted to stop DDT use for malaria control and wanted the country to use Propoxur, a carbamate, instead. To its credit, Madagascar resisted the pressure and did not change its spraying program, continuing to use DDT for malaria control. It is likely that this episode has soured the relationship between this severely impoverished country and an important donor agency. At face value, the argument that an aid agency cannot do or advocate something in one country that is illegal in the home country (such as condoning the use of DDT) seems reasonable. But aid agencies must often encounter conditions in recipient countries that are far removed from those of the donor country. If they really want to help they surely must be flexible enough to adapt to those conditions. For instance, would SIDA really refuse to fund hospital nurses in Africa if they work in conditions which do not fulfill Swedish health and safety requirements?

Environmental folly

The argument that using pesticides such as DDT is inconsistent with the goals of sustainable development and can damage the natural environment is flawed in many respects. The way in which the pesticide is used in malaria control is highly specific and well managed. Modern malaria-control programs use global positioning satellites to pinpoint the exact locations that require spraying. The pesticide is sprayed on the inside of houses and the chance of it escaping into the wider environment is very low. In South Africa, the use of DDT has received the approval of a leading and authoritative environmental and conservation group, the Endangered Wildlife Trust (EWT). The EWT has trained pesticide sprayers so DDT can be used with the minimum possible impact on the environment. The EWT also continuously monitors DDT use and considers the environmental risks associated with its use to be extremely low (Verdoorn, 2000).

The precautionary principle and DDT

Environmentalists often claim we should apply precaution to decisions involving chemicals. If one were to apply the precautionary principle to DDT, the conclusion

would unequivocally *favor* its continued use and promotion.²⁵ Goklany argues in favor of DDT because of its great value in saving human lives and because human health and human lives must take precedence over other species. Considering that the benefits of DDT's use are far greater than any supposed negative human-health impacts and that the benefits are felt immediately, while any potential negative impacts will take place in the future, DDT passes the precautionary-principle test. Should environmentalists argue that the environmental impacts of DDT are irreversible,²⁶ one is obliged to counter that "the death of a human being is irreversible, and more heinous than the death of a bird, for instance" (Goklany, 2000c: 4).

When one considers the malaria-control strategies of the past, which included pouring petroleum on breeding sites and removing wetlands, the responsible, indoor use of DDT is likely to have a far lower impact on the environment. The loss of habitat for the numerous species that depend on wetlands and marshes for survival is likely to be more environmentally damaging than any of the exaggerated claims of environmental damage that have been levelled against DDT.

Sustainability for whom?

The World Wildlife Fund (WWF), Physicians for Social Responsibility (PSR), and the Pesticide Action Network (PAN) are some of the most vociferous campaigners for a ban of DDT (see, for example, wwf-uk.org/news/news100.htm). The WWF has recently acknowledged the positive role that DDT has played and continues to play in malaria control, but proposes that other malaria-control methods be used instead and that DDT be phased out. Its proposals include a general move away from reliance on pesticides and towards bed nets, drug therapies, and vaccines. The WWF suggests using other pesticides that it claims are as effective as DDT and are without the alleged dangers to human health and the natural environment, although these claims do not stand up to scrutiny (Grieco *et al.*, 2000; Attaran *et al.*, 2000; Bate, 2000).

Numerous criticisms can be made of the WWF proposals and those of PSR and PAN, which resonate with the elitism and arrogance that is so often a feature of such organizations. The logo of the WWF Toxic Chemicals Initiative reads: "Let's leave our children a living planet." Clearly, this emotive message suggests a responsible organization dedicated to protecting the most vulnerable. But if its plans were to be carried out, millions of children would not be alive to see the planet. The consequences of the WWF's one-sided preoccupation are not hard to predict, but do not seem to have been considered.

The proposals proffered by these environmentalists conflict directly with over 350 malaria scientists and physicians from around the globe, including several Nobel laureates, who have signed a letter arguing that DDT use should be actively encouraged

²⁵ See Morris and Bate, 2000, for wide-ranging discussion of the precautionary principle.

²⁶ There is strong evidence to suggest that the potential impacts of DDT are reversible in any case (Goklany, 2000c: 4).

rather than banned (see www.malaria.org). Ignoring or dismissing these calls will take a certain blinkered arrogance.

The WWF proposals, by virtue of their “high-tech” nature, would place significant burdens on malarial countries, forcing them to be ever more reliant on donor funds. Indeed, part of the WWF proposals is for increased funding for malaria control by developed nations. Increased funding for malaria research and control is vital, but so too is the ability of sovereign nations to be able to provide lasting malaria control. A major problem with reliance on donor funds for specific programs is that funds can be withdrawn unilaterally. Examples of this have occurred in the Gambia²⁷ (Coetzee, 2000b) and in Tanzania²⁸ (De Gregori, 2000). Financial sustainability is frequently overshadowed by environmental sustainability in the zeal to achieve “sustainable development.”

In addition to the danger of donors removing funding, there is the additional problem that donors do not always act in the best interest of the recipient country. Recently, agencies such as UNICEF and the World Bank rejected outright proposals made by the Harvard Center for International Development (CID) that would have ensured all donor projects would be evaluated by a multi-disciplinary, transparent expert review panel. The panel would assess the scientific and operational value of proposals, which, according to the CID, would improve the likelihood that donor agencies would fund successful programs (De Gregori, 2000; Yamey, 2000; Attaran, 2000).

The WWF lists as one of its concerns the fact that DDT destined for malaria control or some other health use could be somehow appropriated by other users, such as farmers for use in agriculture (WWF, 2000). These concerns are seriously exaggerated, since the quantities of DDT used in health programs are a fraction of what would be required if farmers used the insecticide in any effective way. Even in countries that have not banned DDT for agriculture, such as Swaziland, the only user is the local Department of Health in its malaria-control program (Kunene, 2000). In addition, the WWF’s concern ignores the fact that DDT, and most particularly good-quality DDT, is difficult to obtain—even by national Departments of Health (Maharaj, 2000).

The WWF is also concerned with “development and irrigation projects” as a possible source of disease outbreaks (WWF, 1998). The logic of this argument is not clear, but it seems to suggest that programs aimed at increasing wealth and prosperity in impoverished communities are a direct contributor to ill health. That the WWF considers development and efforts to increase prosperity somehow responsible for ill health is disturbing.

²⁷ In the Gambia, the British Medical Research Council (MRC) funded a bed-net program which collapsed after the MRC removed funding, and malaria rates returned to previous levels (Coetzee, 2000b).

²⁸ In Tanzania, USAID removed funding from a bed-net program, leaving the community particularly vulnerable to malaria, as the bed nets had reduced immunity to the disease (De Gregori, 2000).

DDT—Environmental Savior?

As will be established below in the discussion of pesticide resistance DDT is cost effective and efficient in malaria control. This means that large numbers of people can be protected at a very low cost. This contrasts with the significantly more expensive options of drug therapy as a malaria-control strategy, the use of bed nets, and more expensive pesticides such as synthetic pyrethroids or carbamates.

Opponents of DDT often fail to appreciate that ensuring people are healthy and able to lead economically productive lives can be highly beneficial to the environment. Those suffering from malaria are anemic, listless, and often unable to work or perform economically productive activities to the best of their ability. If an individual is unable to afford fuel, such as paraffin, because he has been ill with malaria, he will be forced to rely on firewood as a source of fuel. Chopping down forests and the consequent removal of natural habitats is one of the most widely recognized causes of the decline and extinction of animal and plant species. It is expensive in time and money to care for the environment. The use of cost-effective and efficient pesticides can protect the maximum number of people and allow them to lead healthy, safe, and productive lives. Only once people are healthy and their families well fed can they afford the luxury of environmentalism (Morris and Bate, 1999).

Considering the history of malaria-control policies, it is likely that DDT is one of the most environmentally friendly of malaria-control strategies precisely because it allowed, and still allows, governments to provide protection and safety to enormous numbers of people at very low costs.

Pesticide resistance and the case for DDT

There is a more compelling and urgent case against the banning of DDT under the POPs Convention. In 1996, South Africa took a decision to phase out the use of DDT in its malaria-control program. There were several reasons for this move. First, there was a general international move away from the pesticide, initiated by pressure from environmental lobby groups and research-funding agencies (Sharp and Le Sueur, 1996). Second, the pesticide was not always appropriate in all control situations. For example, while DDT successfully controlled the *A. arabiensis* vector, it stimulated bedbugs and other insects which were a nuisance to households. Third, the pesticide leaves a white stain on the walls. While this makes it easy for sprayers to check that the house is protected, many households re-plaster over the pesticide in order to hide the unsightly white marks, rendering it useless. Many houses in rural areas are no longer constructed with mud and dung and are made from brick, with internal walls plastered and painted. In these cases, DDT is less effective as it does not impregnate the wall (Tren, 1999). Finally, there was a concern that DDT levels in men and women in endemic areas were significantly higher than the acceptable daily intake (Sharp and Le Sueur, 1996). DDT toxicity in mammals is likely to be very low or negligible. Even though DDT can be passed to infants through mothers' milk, no associated toxicity has been proven. There is also no convincing evidence that DDT or its metabolites are carcinogenic to humans (Smith, 2000).

Box 2: The Development of Resistance

The exact causes of resistance to pesticides among insects are not entirely clear. One theory is that large concentrations of an insecticide trigger a response, probably an “ancestral response” in insects that originally evolved as a biological response mechanism to naturally occurring toxins. One of the fundamental properties of living matter is genetic variability. Those insects in which the ancestral response is triggered are likely to survive while the others do not. The development of resistant insects following exposure to insecticides derives from this basic property of selection of the fittest individuals as ancestors to the current population.

Another theory is that in some instances, the presence of the insecticide causes a point mutation that could arise at any time. However, there is no substantial evidence that insecticides cause any genetic changes themselves.

Resistance could arise due to behavioral changes. For instance, insects could learn to avoid resting on surfaces that contain the insecticide, as it causes irritation. While such behavioral changes may not result in any genetic changes over time, the efficacy of the insecticide in killing the insect will be reduced.

While there is no unequivocal reason for the development of resistance in mosquitoes, it is likely to be caused by a combination of factors. Obviously, the mosquito population must have the recessive genes in its population that can be selected out to confer resistance. However, the degree and method of insecticide pressure will affect the rate at which resistance appears. If insecticides are applied in sub-lethal doses, survivors will remain. If they breed, then the next generation is tougher, and so on.

Sub-lethal doses are likely where the DDT is not properly applied, or where the DDT spray is not properly mixed. DDT is not soluble in water and has to be suspended with chalk or talc. Manufacturers usually guarantee the mixture for a year or so, but often it may be mixed by sprayers from the powdered DDT. It is probable that there is variation in the quality of the powder produced and even more variation in application.

Also, the spread of resistance comes from multiple uses of pesticides. Where anti-mosquito pesticides are also widely used in agriculture, resistance is more likely to spread rapidly. For example, the same pesticides were used in protecting cotton crops in India, Mexico, El Salvador, and Guatemala as were used for spraying indoors for mosquito control, and there was some increase in insecticide resistance in anopheline mosquitoes as a result (Chapin and Wasserstrom, 1983). Other examples of this phenomenon were found in growing: coffee in Peru (Collins, 1988); bananas in Costa Rica (Packard and Brown, 1997); and rice in parts of Asia (Mellanby, 1992). As is explained in detail later, resistance to synthetic pyrethroids in *A. funestus* may have been encouraged by widespread agricultural use of pyrethroids in South Africa.

So overall, the largest contributor to resistance to any pesticide is intensive use over a considerable area. It selects the carriers of resistant genes and reduces the “competition they would have suffered from the majority of normal mosquitoes” (Mellanby, 1992: 58).

Source: Hunt, 2000; Invest, 2000; Rotrosen, 2000

In South Africa, DDT was phased out of Kwa-Zulu Natal and Mpumalanga in 1996 and out of the Northern Province in 1999. Synthetic pyrethroids, such as deltamethrin and cyfluthrin, were used in its place. Initially, these pesticides proved to be effective and had some advantages over DDT. For example, they do not increase bedbug activity and do not stain walls, making them more socially acceptable. These pesticides are also more acceptable to the environmental pressure groups, and donor agencies are more likely to fund their use. At the time of the phase-out, the South African Department of Health was

highly confident that the use of DDT in malaria control would never be necessary again (Lombard, 1999).

There are, however, several disadvantages to the synthetic pyrethroids. These new pesticides were developed for agricultural use, and immediately went into widespread use. This inevitably led to vector resistance, as it is impossible to guarantee the correct dosage over large areas or to prevent weak solutions escaping in run-off from fields. Therefore, some mosquitoes will come into contact with a sub-lethal dose, triggering the resistance process described above in Box 2. These pesticides are also significantly more expensive than DDT and more complicated to administer. The increased cost to the already limited budgets of the provincial health departments means that fewer structures can be sprayed and fewer individuals protected.

Table 1: Amounts and Costs of Insecticides for Indoor Spraying during 1997-98 Season²⁹

Insecticide (Kg)	Northern Province	Mpumalanga	Kwa-Zulu Natal
DDT	82,791	0	0
<i>Cost (Rands*)</i>	<i>1,661,615</i>	<i>0</i>	<i>0</i>
Deltamethrin	68	1,861	6,641
<i>Cost (Rands)</i>	<i>12,291</i>	<i>336,375</i>	<i>1,200,360</i>
Cyfluthrin	1,350	356	0
<i>Cost (Rands)</i>	<i>1,389,501</i>	<i>366,416</i>	<i>0</i>
Total number of structures sprayed	900,024	131,870	244,271
<i>Total cost</i>	<i>3,063,407</i>	<i>702,791</i>	<i>1,200,360</i>
Cost per structure (Rands/structure)	3.4	5.3	4.9

Source: South African Department of Health, 1996a

*The Rand is the South African unit of currency.

Data for the 1997-98 spraying season show that the Northern Province in South Africa, which still used DDT, managed to spray almost seven times the number of structures as Mpumalanga and at a lower cost per structure.

A comparison of spraying costs of the various pesticides in the various locations is given below in Table 1b. The differences in the cost per structure are affected by

²⁹ Costs calculated as follows: 1Kg DDT=R20.07, 1Kg deltamethrin=R180.75, 1Kg Cyfluthrin=R1,029.26 (South African Department of Health, 1996a).

differences in the types of structures and also in the efficiency with which the sprayers use the insecticides.

Table 1b: Comparative Costs per Structure and per m² of Different Insecticides, 1997-98 Spraying Season for Mpumalanga, Northern Province, and Kwa-Zulu Natal, South Africa

Insecticide	Cost per Structure Sprayed (Rands)	Cost per m ² (cents/m ²)
DDT	2.26	5.35
Deltamethrin	3.81	7.23
Cyfluthrin	9.28	20.58

Source: South African Department of Health, 1996a

Perhaps a more important problem than cost is one of resistance by the major malaria vectors to synthetic pyrethroids. Pyrethroid resistance by the *A. gambiae* vector has been reported in both west and east Africa, where that vector is the major malaria transmitter (Hargreaves *et al.*, 2000). In southern Africa, resistance has been discovered in *A. funestus*, which is a highly efficient vector of the disease, feeding almost exclusively on man and living in and around human structures.

A. funestus had almost completely disappeared from South Africa by the early 1950s, when DDT was widely used in malaria control. There was an isolated sighting of *A. funestus* in a small village near Tzaneen in the Northern Province in 1975; until recently, however, the vector had not been seen in South Africa, although *A. funestus* still remains abundant in neighboring Mozambique.

Table 2: Malaria Cases—Kwa-Zulu Natal

Year	Cases	Deaths	% change cases	% change deaths
1996	8,693	32	-	-
1997	9,928	38	14	19
1998	11,939	112	20	194
1999	27,238	214	128	91
To July 2000	35,798	327	31	26

Source: South African Department of Health, 2000

A. funestus returned to South Africa, particularly to the Kwa-Zulu Natal province, in the late 1990s, and malaria rates have been increasing for the past few years. The return coincided with the withdrawal of DDT from malaria-control programs and the introduction of synthetic pyrethroids (SP). As mentioned earlier, where SPs are used very extensively in agriculture, the chance that resistance will develop among mosquitoes and

other insects is increased. In addition to this change, there has been higher than average rainfall in the past few years and an increase in migration of people between Mozambique and South Africa. While these and other factors have influenced the rise in malaria cases, the withdrawal of DDT and reliance upon an insecticide that *A. funestus* can tolerate is likely to be a major contributor (Coetzee, 2000b).

A. funestus is tolerant of synthetic pyrethroids, but it remains completely susceptible to DDT (Hargreaves *et al.*, 2000). While there are certainly other pesticides that would be as effective as DDT in killing the vector, none can be used as cost effectively as DDT. Carbamates have been introduced to the malaria-control program in southern Mozambique as part of the Lubombo Spatial Development Initiative and the Mozal project (to be described below). Carbamates, such as Bendiocarb, are however 22 times more expensive than DDT in an undissolved state and 4 times more expensive once applied (see Table 2b below). This cost increase limits the scope of other malaria-control activities, such as the provision of drugs, bed nets, and education programs.

DDT spraying was reintroduced into Kwa-Zulu Natal in March 2000. Although it is too early for scientific studies to have recorded any noticeable change in either malaria rates or the number of vectors, anecdotal evidence from malaria-control staff members in the province suggests that the pesticide has proved remarkably successful thus far in removing all anopheline mosquitoes (Mthembu, 2000). It is perhaps most remarkable that DDT is still the cheapest pesticide, given that it is produced by only one or two monopoly/government companies in socialist countries, such as India and China. Its cost would probably be far lower if it were produced by more competitive chemical companies in the west (Bate, forthcoming).

Table 2b: The Cost of Various Insecticides Used for Adult Mosquito Control

Insecticide (Wettable powders)	Concentration (g/active ingredient [a.i]/Kg)	Application Rate (a.i./m ²)	Cost/Kg (Rands)	Cost/m ² (cents)
DDT	750	2	28.00	7.47
Bendiocarb	800	0.4	626.12	31.31
Cyfluthrin	100	0.02	1,623.50	32.47
Deltamethrin	50	0.02	312.00	12.48
Lambda-cyhalothrin	100	0.031	661.92	20.52
Fenitrothion	400	1	65.36	16.34

Source: South African Department of Health, 2000

Economic Costs of Malaria

Malaria is a human tragedy.³⁰ But more than that, the disease imposes enormous economic costs on some of the world's poorest countries. These costs are significant enough for a well-established axiom—"Malaria Blocks Development"—to have been developed by cultural anthropologists (Brown, 1997). Although there is an underlying anthropological concern (see Packard and Brown, 1997) about who predominantly benefits from the development³¹ (historically colonial powers and more recently multinational companies have been the most obvious beneficiaries), there is no doubt that malaria slows growth.

This study examines the economic costs that malaria has imposed on one particular development project in Mozambique, a country that is endemic with malaria. Other studies that have attempted to measure the cost that malaria imposes on economies will then be examined.

Government Regeneration and the Control of Malaria

The Lubombo Spatial Development Initiative (SDI) is a joint initiative between the South African, Swazi, and Mozambican governments. The SDI concentrates mainly on tourism and agriculture, with one of the main focus points being the Greater St. Lucia Wetland Park. There are four additional projects that straddle the three countries involved.³² It is expected that over R1 billion (US\$142 million) will be invested in the SDI and several thousand jobs will be created (Lubombo SDI).

The SDI program has been advanced by the South African government in an attempt to "unlock inherent economic potential in specific southern African locations by enhancing their attractiveness for investment. The SDI aims to facilitate potential investment opportunities, identified through the process, to be taken up by the private sector" (Lubombo SDI).

Malaria and Mozal—Doing Good while Doing Well

The new and highly sophisticated Mozal Aluminium Smelter is located at Matola, close to Maputo in southern Mozambique. Mozal is not within the SDI, but its proximity makes it a good case study of the problems malaria has caused for efforts to generate economic growth in the area. The Mozal project is a joint venture between the London-based minerals group Billiton PLC, Mitsubishi of Japan, the South African Industrial

³⁰ According to Pampana (1963), malaria infection often tragically leads to spontaneous abortions in pregnant women.

³¹ Early malaria control opened up land for development, but it is alleged that often the poor did not benefit from agriculture, rather the "owners of large tea plantations" did (Packard and Brown, 1997:188), with little or no trickle-down effect. However, it is an inescapable fact that those countries with substantial inward investment are wealthier and healthier (Goklany, 2000c).

³² These are: Hlane-Mlawula (Swaziland), Jozini-Luvamisa (South Africa and Swaziland), Ngumu-Thembe-Futhi (Mozambique), and Ponto do Ouro/Kozi Bay (Mozambique and South Africa).

Development Corporation,³³ and the Mozambican government. The first phase of the project involved an investment of \$1.2 billion (projections were initially for \$1.34bn) in order to produce 250,000 tons of primary aluminum each year. The smelter has been designed to allow for a doubling of plant capacity to 500,000 tons a year, which would involve an additional investment of \$800 million.

Billiton PLC already owns and operates two aluminum smelters in the northern Kwa-Zulu Natal province of South Africa and has significant investments in two aluminum smelters in Brazil. The choice of Mozambique as an investment destination for a large multinational firm is not an obvious one. Mozambique is ranked as one of the world's poorest countries and emerged from a 17-year-long civil war in 1992. The war was one of the most brutal and destructive in Africa and left the country with its infrastructure and economy in a state of ruination.

Part of the motivation for the Mozal project came from Eskom, the South African electricity utility, which wanted to expand some of its production outside South Africa, and from the Mozambican government, which wanted to rebuild some of the country's damaged electricity infrastructure. Billiton PLC saw an opportunity to utilize some of the surplus hydroelectric power generated by the Cahora Bassa dam, which was built in the early 1970s under the Portuguese administration of Mozambique (Harvard Business School, 2000). As Mozambique's internal electricity infrastructure has been damaged, electricity from Cahora Bassa dam is directed through the South African grid and then Eskom supplies electricity back to Mozambique.

The Mozambican government provided a number of investment incentives to the Mozal project, the most ambitious inward investment project in Mozambique's history. These included locating the Mozal Aluminium Smelter in an industrial free zone, which ensures that the plant is taxed at only 1 percent of turnover and is exempt from all customs duties, sales taxes, and circulation taxes. The government has also ensured that the plant will be able to repatriate dividends and loan repayments and is able to hold foreign exchange offshore. The Mozambican government also placed an official of the department of trade and industry at the permanent disposal of the Mozal team in order to allow for goods to be imported efficiently and to smooth the entire production process.

The significance of the initial investment in Mozambique is hard to overstate. According to the World Bank Development Indicators (2000) the GDP for Mozambique in 1998 was \$3.9 billion, with little foreign direct investment. The Mozal investment swamped all other foreign direct investment and was a major factor in economic growth.

Aluminum smelters are very power intensive and the Mozal plant is expected to use 450 megawatts of power, double the present total power consumption of Mozambique. Eskom has constructed two lines from South Africa to Mozambique in order to provide power, and has agreed to link the price of electricity to the London Metals Exchange price

³³ The Industrial Development Corporation is a South African-government-owned development bank with assets of \$3.6 billion.

of aluminum. This means that when the aluminum price is low, the cost of one of the major production inputs will be low, and vice-versa.

While labor costs and the cost of raw materials are less important factors to the operation of the aluminum smelter, these costs are lower than they would be in South Africa and significantly lower than they would be in developed countries. Labor costs, for example, are set to be around one-fifth the level that they would be in a western-world smelter (Harvard Business School, 2000). Billiton has undertaken, in an agreement with the Mozambican government, to ensure that 90 percent of the smelter employees during construction and operation phases are Mozambicans.

Data-collection initiative

One factor that the Mozal team could not plan for sufficiently was the problem of malaria. While malaria has always been endemic to Mozambique, there are very few reliable statistics on the incidence of the disease. The civil war brought all malaria-control initiatives to a halt. The government has been unable to initiate a comprehensive and effective malaria-control program since the war ended, though in southern Mozambique a malaria-control program has been started as part of the Lubombo SDI.

Recognition of the impediment that malaria places on development and economic advancement has spurred the SDI to start its own malaria-control program covering South Africa, Swaziland, and Mozambique. Initial studies into malaria infection rates have produced some startling results. In northern Kwa-Zulu Natal, the return of *A. funestus* has contributed to a sharp rise in malaria incidence, from 9.5 percent to 40 percent. In this region, it should be stressed, DDT spraying was halted in 1996 and synthetic pyrethroids were used instead. Swaziland, however, has consistently used DDT in its malaria-control program and the infection rates in this country reflect the efficacy of this strategy. In Shewula, in northern Swaziland on the border of Mozambique, an infection rate of 2 percent was measured. At Namachanga, which is on the Mozambican side of the border and very close to Shewula, an infection rate of 40 percent was recorded. Infection rates in other parts of Mozambique are far higher, reaching 86 percent at Catuane, on the border with South Africa (Coetzee, 2000a).

Mozal malaria costs

Indirect costs

Malaria has imposed significant costs on the developers of Mozal. Preliminary estimates show that direct and indirect costs of malaria to the Mozal construction team are in the order of R19 million (US\$2.73 million). Economic costs comprise the direct health-care costs, which include medication, testing, physician time in treating the disease, and vector control and education. Indirect costs are made up of the cost of lost productivity while workers are incapacitated due to the disease. The cost calculations include all the malaria cases from the inception of the project until June 10, 2000. All the cost data has been collected from the Mozal on-site clinic, which is the first consultation point for all on-site malaria cases. There are some malaria cases that will not be captured by the clinic as certain employees will develop the disease while off-site and will report to

a different clinic and receive treatment elsewhere. These economic costs should therefore be viewed as a conservative estimate.

All workers are entitled to five days of sick leave, even if they are no longer incapacitated after three days. In general, expatriate employees will normally be incapacitated for between five and seven days, while local employees will be incapacitated for between three and five days. For the purposes of calculating the economic costs, it is assumed that expatriates are unable to work for six days and local employees are unable to work for five days. This would not take into account the fact that malaria sufferers will most likely feel enervated and listless for some time after they return to work and that productivity would therefore be lower than normal

The cost of lost productivity accounts for the majority of the economic cost of malaria, at over R5 million (US\$726,000) or 27 percent of the total cost.³⁴ This assumes that the hourly wages of local workers is around R5.00 and that of expatriate workers is R28.13 (Maire, 2000). The disparity in the wage rates is because Mozambican wage rates are in general lower than those in South Africa, as well as because expatriate workers generally are more skilled.

Direct costs

All employees at the Mozal site are treated with the same drug regimens. Fansidar is used for mild cases, while quinine is administered for more complicated cases. In some cases, quinine has to be administered intravenously if the patient is unable to take the medication orally. It is estimated that approximately 60 percent of cases are treated with Fansidar, 30 percent require oral quinine treatment, and the remaining 10 percent require IV quinine (du Plessis, 2000). Drug costs are estimated to be in the order of R640,000 (US\$91,000) or about 3 percent of the total economic cost.

Testing for malaria accounts for approximately 3 percent of the total economic cost of the disease. A malaria slide test is performed between two and three times per malaria episode and costs R22.41 per test. A rapid malaria test is sometimes performed on those cases arriving at the Mozal clinic after normal hours. No records are available on the number of rapid tests that are performed and they have therefore been excluded from the calculations. All cases also receive glucose rapid tests and hemoglobin rapid tests in addition to the malaria slide tests. Each case receives two such tests and they cost R7.91 and R4.25 per test, respectively. The total cost of malaria tests is about R600,000 (US\$85,000).

The most serious, complicated cases of malaria are evacuated to medical centers in South Africa, which imposes a significant cost. A total of 90 cases were evacuated by air and 248 cases were evacuated by road between July 1998 and June 2000. There is no record of where these cases were taken within South Africa, however it is likely that the majority were taken to Nelspruit, the city in South Africa nearest Maputo. Some cases

³⁴ This figure ignores the cost of those who are sick for longer than six days. Even after one has “recovered” one’s work performance is probably below normal for some time.

will have been evacuated to Johannesburg or Durban, which would involve significantly higher costs of transport.

Even though air evacuations are normally reserved for the most serious of malaria cases, they are sometimes undertaken for less serious cases since road evacuations frequently are hampered by poor road conditions and uncooperative customs officials on the Mozambican side (Castle, 2000).

On average, air evacuations from Maputo to Nelspruit cost R9,000, while road evacuations for serious cases cost marginally less at R8,000 (Castle, 2000). It is assumed that all air evacuations use fixed-wing aircraft and that the road evacuations require life-support equipment in the ambulances. On the basis of these costs, the evacuation of malaria cases has cost the project developers in excess of R2.7 million (US\$385,000), or 25 percent of the total economic cost.

In addition to the evacuation costs, there are costs of hospitalizing patients, along with the nursing and physician costs. It is expected that nurses on average will spend half an hour with each malaria patient, while physicians will spend up to three-quarters of an hour (du Plessis, 2000). The hourly rate of nurses and physicians varies from hospital to hospital, but the South African Medical Association standard rate for physicians is R300.00 (\$43) per hour.³⁵ Nursing rates vary widely depending on the number of years of experience and qualifications, however an hourly rate has been estimated at R200.00 (\$28; Millpark Hospital, 2000).

The majority of the malaria patients do not require hospitalization and are treated at home. Those cases that are evacuated require hospitalization and are treated in private clinics in South Africa. The non-medical hospitalization costs, which cover food, laundry, and other general costs are R590.60 per patient per day in a medical ward (Slabbert, 2000). Some malaria cases will require treatment in an intensive-care ward, however this data was not available and it is therefore assumed that all patients are admitted to a general medical ward. The additional hospitalization costs therefore are of the order of R1.2 million (US\$171,000).

Table 3: Summary of Economic Costs

Item		Cost (Rands)	% of total
Indirect Costs	Productivity costs	5,082,550	41
Direct Costs	Malaria tests	595,167	5
	Evacuation costs	2,794,000	22
	Drug costs	640,349	5
	Physician/Nurse time	2,122,577	17
	Hospital costs	1,197,737	10
	TOTAL		12,432,378

³⁵ This is based on the medical-insurance rate for reimbursement.

Mozal vector control

Mozal has implemented a comprehensive vector-control program in and around the smelter site. The vector-control program includes the spraying of structures with synthetic pyrethroid insecticides, supplying of bed nets to staff, applying larvicide to any potential breeding pools, and an education and awareness campaign.

Insecticide spraying has occurred at the smelter site itself and within a 1.6 kilometer buffer zone. The spraying is coupled with a monitoring program that assesses the number of anopheline mosquitoes within the area. An ultra-low-volume spray is used as the spray is required to reach some inaccessible areas such as ceilings that are at a height of approximately 30 meters. The spraying program has proved remarkably successful within the buffer zone. During February and March 2000, when mosquitoes are most active, the monitoring program found approximately 60 anopheline mosquitoes per structure outside the buffer zone. Within the 1.6 kilometer buffer zone, the number of malaria vectors fell to only five, and no malaria vectors were found within the smelter site itself (Kloke, 2000).

The emergence of *A. funestus* resistant to synthetic pyrethroids is hampering the malaria-control efforts and it has therefore been necessary to introduce carbamates as an alternative insecticide. Initial reports suggest that resistance is also developing to the carbamate insecticides, which could further destabilize the malaria-control program (Coetzee, 2000b; Kloke, 2000). Carbamates have an additional problem in that they are highly effective in exterminating cockroaches, crickets, and other insects living in and around dwellings, and the carcasses of these insects are eaten by ducks and other poultry. The high dose of carbamates that are then ingested by ducks frequently proves fatal, which makes the spraying program unpopular with householders. While these social and environmental problems can be addressed by ensuring that all insects are cleared away and poultry locked up during spraying, the issue of resistance cannot be dealt with as simply (Maharaj, 2000).³⁶

Table 4: Vector Control and Education Costs

Item	Cost (Rands)	Total (Rands)
Contribution to SDI spraying initiative	3,360,000	
Mozal vector spraying	840,000	
Education, training, and bed nets	1,050,000	5,250,000

Source: van den Bergh, 2000

³⁶ Resistance management has been more successful at the Hillside plant in South Africa, where there is a choice of several pesticides. As South Africa can afford its own health budget, it has made the decision to allow DDT use for vector control. There is also the more prosaic advantage that the low cost of DDT means a larger area can be protected.

In addition to the spraying program at the smelter site and within the buffer zone, Mozal has contributed US\$580,000 to the Lubombo SDI malaria-control program. This contribution has enabled the SDI to extend the spraying area up to the smelter site, rather than just within the SDI area. It is expected that Mozal will have to make an additional contribution to the SDI malaria program in order to cover the additional costs incurred in purchasing carbamate pesticides. While the additional contribution has not been finalized, it is likely to be in the order of US\$200,000 (van den Bergh, 2000). This may be deleterious to the overall health and safety budget of Mozal and could detract from funds earmarked for other health projects.

Opportunity Costs of Malaria

The direct and indirect costs of malaria that are described above are considerable and at least partially avoidable if a comprehensive and effective malaria-control strategy was in place in Mozambique. In addition to these costs are the opportunity costs imposed by the disease. The Mozal developers have already expressed reservations about expanding capacity of the plant due to the malaria problem (Barbour, 2000). Of great concern to Mozal is that they will not be able to attract the required professional expatriate staff to the smelter. Given that at least ten expatriate employees have died from malaria since construction of the plant began³⁷ and almost 3,300 expatriate cases have been recorded, these concerns should not be underestimated. The expansion is expected to involve an investment of approximately US\$800 million and would provide desperately needed income and employment opportunities to Mozambique.

A major focus of the Lubombo SDI is tourism, and the current malaria epidemic could seriously hamper tourism development in South Africa and Mozambique. The Lubombo SDI is well placed to develop the tourism industry given the wide range and extent of the local natural resources—numerous national parks, private game reserves, coastal reserves, and a wide range of other tourist activities. But tourists are fickle, and should they feel unsafe they are unlikely to be attracted to the area. Given the myriad alternative tourist destinations in southern Africa, the malaria threat to the Lubombo SDI is very significant. It is noteworthy that many resorts in southern Africa specifically and prominently promote the fact that they are in non-malarial areas, giving a partial indication of the seriousness with which tourists view this disease.

Wider Economic Costs

Tren (1999) estimates that malaria costs six southern African countries³⁸ approximately US\$1 billion in direct health costs and productivity costs. It should be noted that these estimates are conservative and do not consider the wider opportunity costs nor the impact that malaria has on cognitive development in children and the ability of countries and regions to develop.

³⁷ As of June 10, 2000.

³⁸ South Africa, Swaziland, Tanzania, Namibia, Zimbabwe, Zambia.

While the majority of malarial countries are poor, the causal relationship between poverty and malaria is not an obvious one. Not immediately clear is whether the disease causes countries to be poor, or whether it is poverty that results in high malaria rates. Gallup and Sachs found that annual growth rates in countries that suffer from severe malaria were between 1 percent and 1.3 percent lower between 1965 and 1990 (see Table 5). This takes into account factors such as the initial poverty of the countries, the tropical location of the countries, and overall life expectancy. Those countries that reduced their malaria index by 10 percent showed a 0.3 percent rise in annual economic growth. Gallup and Sachs conclude that malaria is an important determinant in the cause of poverty and the continued presence of malaria ensures that malarial countries will remain poor (Gallup and Sachs, 2000).

There are many factors that this economic analysis cannot take adequately into account, such as the cognitive impairment of children that suffer from malaria and the full extent of lost productivity of those that care for malaria victims. The cost of a reduction in economic growth rates of 1 percent per annum is estimated at \$100 billion for Africa. In other words, had malaria been eradicated in 1965, Africa's GDP would have been about one-third higher (Gallup and Sachs, 2000).

Table 5: Loss from the Economic Growth Penalty of Malaria Endemicity in 31 African Countries, 1980-1995

Country	Aggregate loss (millions of PPP- adjusted 1987 \$*)	Per person loss (PPP-adjusted 1987 \$)	As a fraction of actual 1995 income
Benin	1,172	214	18%
Botswana	503	347	5%
Burkina Faso	1,684	162	18%
Burundi	730	117	18%
Cameroon	4,227	318	18%
Central African Republic	884	270	18%
Chad	995	154	17%
Congo	759	288	18%
Congo, Dem. Rep.	7,125	162	18%
Cote d'Ivoire	4,107	294	18%
Gabon	1,389	1,290	17%
Gambia	251	226	18%
Ghana	5,355	314	18%
Guinea Bissau	152	142	14%
Kenya	5,272	198	18%

Lesotho	0	0	0%
Madagascar	2,280	167	18%
Malawi	1,072	110	18%
Mali	1,222	125	17%
Mauritania	611	269	15%
Mauritius	0	0	0%
Namibia	832	539	10%
Niger	1,457	161	17%
Nigeria	17,315	156	18%
Rwanda	656	102	18%
Senegal	2,426	286	18%
Sierra Leone	366	87	17%
South Africa	4,056	98	1%
Togo	1,166	285	18%
Zambia	1,359	151	18%
Zimbabwe	4,214	383	18%
Total	73,638	185	10%

Source: Based on results in John Luke Gallup and Jeffrey D. Sachs, "The Economic Burden of Malaria," in *Economics of Malaria* (forthcoming).

*Please note that these figures are reported in purchasing power parity (PPP) adjusted dollars held constant at 1987 prices. This corrects for the effects of price inflation, as well as the fact that in Africa, non-traded goods and services (for example, health services or land) are cheaper relative to internationally traded goods than they are in the United States. In order to convert these units into current US dollar terms, it would be necessary to divide by a factor of about 3, then multiply by the rate of price inflation between 1987 and 1995.

Restricting economic development is problematic environmentally as well as in terms of human well being. This is particularly the case in developing countries because ultimately richer means cleaner, healthier, longer lived, and less susceptible to adversity (Goklany, 1995a; 1995b; 1999; 2000a; 2000b). As Goklany has noted, economic development is not an end in itself, but it provides the means for numerous ends. Virtually every indicator of human well being improves with the level of economic development (Goklany, 1999; 2000a; 2000c). Economic development, which creates wealth, helps increase food supplies per capita, reducing malnutrition. Because economic development reduces malnutrition and hunger as well as makes basic public-health services more available, it reduces mortality rates and increases life expectancies (see Figure 1, page 44; Goklany, 2000b). Also, total fertility rates (a critical determinant of birth rates) drop with increasing levels of economic growth (Goklany, 2000c). For each

of these indicators of human well being, improvements are most rapid at the lowest levels of economic development (Figure 1, page 44; Goklany, 2000b; 2000c).

Conclusion

Malaria has plagued mankind for countless generations. It inhibits development, causes untold suffering and illness, and claims millions of lives every year. The one-weapon war against malaria, ostensibly controlled by the WHO and funded and led primarily by USAID, unravelled in the 1960s. Failure to achieve eradication; environmental concern encouraged by Rachel Carson's ideological adherents; and increasing acceptance of the neo-Malthusian message of overpopulation all contributed to the demise of the use of DDT. The US stopped funding the WHO's special eradication account between 1961 and 1963. USAID switched funding from anti-malaria programs to family-planning programs, and shifted responsibility for malaria to the US Public Health Service, as though it were disowning its previous efforts (Packard, 1997).

USAID deserves credit for saving tens of millions of lives by funding DDT use. Its failure to achieve eradication (although perhaps inevitable) led it to turn its back on DDT and, eventually, on all forms of insecticide spraying. While this is perhaps understandable, its recent action of denying funding to those who want to use DDT again is objectionable. Critics of USAID activities in the post-war years have been joined by modern critics bemoaning the "one-size-fits-all" cultural model of health (see Packard and Brown, 1997). A centralized, narrowly focused attack is still being made on malaria while local conditions and concerns are ignored. Today, it is bed nets and medicines, where previously it was DDT.³⁹ It appears that political control by these agencies will only countenance a single approach at a time. According to Baird (1999), alternatives to vector control are essential in Africa, where the disease is endemic and malaria-carrying mosquitoes proliferate in so many parts. However, in parts of Asia and South America, vector control is still the most effective weapon because malarial areas are smaller and often eradication or significant control of mosquito populations is possible. So not only is the focus on bed nets and drugs misguided for Africa, it is even less applicable outside Africa (Baird, 1999).

Many of the WHO's critics complain that modern-day efforts to control malaria make the same mistakes as before, and fail to address the issue of poverty. They often deplore (albeit tacitly) efforts by companies like Billiton to protect its staff, because such efforts create a stark disparity between the "excluded" surrounding communities and the protected area. They compare this with the governmental authorities of the past in places like Rhodesia (now Zimbabwe) (Packard, 1997). Of course, the objection does not stand up for long if properly aired: Is it not better to protect as many people as possible, even if some are not helped?

³⁹ Similarly, from the 1940s through the 1970s, most research money was spent on new insecticidal discovery, whereas today, most is spent on drugs and vaccines.

Health agencies in developing countries, like working companies such as Billiton, are at least trying to stem the resurgent malarial tide. They require a large arsenal of weapons to fight malaria, and with the spreading *A. funestus* resistance to synthetic pyrethroids the requirement for DDT is stronger than it has been for 30 years. Yet in December 2000 the UNEP POPs process may set a phase-out date for DDT.

Those countries and organizations that are most intent on seeing a DDT ban are not only the ones that will be almost completely unaffected by a ban, they can also afford to send the most delegates to the UNEP POPs negotiations (and thereby have a greater influence on the outcome). We hope that these delegates will think again and consider the wider consequences of their proposal. They must surely be aware by now of the pitfalls of their “green” ideology.

Malaria kills a few million every year; each life lost is a potential Mandela, Shakespeare, or Edison, and nothing is less reversible than death, nor more tragic than the death of a child. Hundreds of millions suffer chronic illness, which creates a painful economic burden and perpetuates poverty. This may not be the intention of those who are debating a DDT ban, but it surely will be the outcome.

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