Title: Impact of Environmental Changes on Endemic Vector-Borne Diseases

by

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Introduction

The purpose of this presentation is to review briefly the interactions between changing environments and endemic vector borne diseases. More than 100 water-, soil-, food-, and vector-borne diseases caused by viruses, fungi, bacteria, protozoa and helminths may be considered "tropical diseases". This paper considers only four (4) diseases (malaria, schistosomiasis, Japanese encephalitis and dengue fever), because they are better known and, in aggregate, exemplify some of major environmental concerns.

Let me point out immediately that environmental change is not necessarily bad. In fact, we often use environmental modifications to reduce or eliminate vector populations, thereby reducing the intensity of disease. But such changes have to be well-planned and maintained if they are to be effective. Conversely, unplanned environmental changes most frequently exacerbate the problems caused by vector-borne diseases. Similarly, environmental changes planned to improve one economic sector (e.g. agriculture, water management, forestry, etc.) without consideration of the potential risks in the other sectors (e.g. public health and conservation concerns) may prove as damaging as unplanned changes.

Malaria and schistosomiasis were among the first diseases for which large-scale control programs were developed. From the beginning, workers recognized that intensity of transmission was
associated with environmental changes, either natural or man-made. For various reasons, largely economic, control has relied heavily in the past decades on chemotherapy, ignoring to a great extent the underlying ecological dynamics of transmission. In stable communities and with reliable, inexpensive drugs, this approach may be effective. However, rapidly growing human populations, the expansion of agriculture to feed these people, and the exploitation of forestry and mineral resources have produced very unstable populations exposed to a host of new risks. Chemotherapy and vaccines (for schistosomiasis and Japanese encephalitis) are expensive, chloroquine treatment for malaria is threatened by resistance, and no specific treatment or vaccine exists for dengue and dengue hemorrhagic fever.

Therefore, we must find environmentally based approaches to control consistent with the environmental changes that are occurring, and will continue to occur. We also must find better mechanisms to coordinate the public health sector with those responsible for, and those who profit from environmental changes to ensure that the costs of disease control are properly assessed as part of the development process that produces the changes.
Case Studies

1. Malaria is the best known of the vector-borne diseases. It is not a single disease but four (4) diseases caused by protozoan blood parasites of the genus *Plasmodium*. These are vectored by 60 different anopheline species of mosquitoes. Because the biology and behavior of all these species vary greatly, control measures effective against one may be useless against related species.

Malariologists have long used the term "man-made malaria" to indicate the transmission exacerbated by human practices, including damming, irrigation, poor drainage practices and leaving "borrow pits" along roads and construction sites (Bruce-Chwatt, 1985). This is often most severe in areas where malaria transmission is seasonal and climatically related (i.e. "unstable"), and likely to result in epidemics when the environment is modified in favor of increased vector populations that enhance transmission.

The migration of large segments of a population into endemic areas to meet labor demands in agricultural projects and other development schemes is another factor related to increased malaria transmission. In many instances, immunologically naive individuals enter areas where they are certain to become infected with malaria parasites.
Examples of agricultural and urbanization trends that have produced changes in patterns of malaria transmission include:

a) Following studies in the far west of Nepal in the 1950s, it was determined that *An. maculatus*, a forest species, was the main vector and control measures were directed against this species. Following decades of deforestation, *An. maculatus* is now uncommon in the area, apparently surplanted by *An. culicifacies*, a species favoring open agricultural land, and of different habits. New approaches to malaria control in the area are required to adapt to this change in vectors caused by a man-made environmental change.

b) The urbanization of malaria in Pakistan is cited by Wernsdorfer and Wernsdorfer (1988):

"Outside tropical Africa, malaria is still a predominantly rural disease, but is has recently made its way into many cities of the Indo-Pakistan subcontinent where *An. stephensi* has found suitable ecological conditions, largely helped by explosive urban expansion along the perimeters of the cities."

Two classic examples illustrate the intensity of malaria resurgence during the past decade. They are by no means unique,
but are better documented than other examples.

a. **Sri Lanka** - During the malaria eradication period (1956-1969), the number of reported cases was reduced to 17 (1963) from around half a million per year. The recent severe outbreak began in 1982 and had risen to 600 thousand cases by 1987 (Fig. 1). Factors that have contributed to this increase in malaria incidence are the deterioration of the malaria control program, migration of populations into and out of the major irrigation and hydroelectric schemes on the Mahaweli river, and flooding and puddling caused by these schemes, which produce vector breeding sites. Civil disturbances have exacerbated the problems facing the control efforts. Both chloroquine resistance and vector resistance to the insecticide (malathion) used in the control program have been recorded, but there is no recent evidence that this resistance has caused major operational problems. Mijusundera (1988) details the contribution of the Mahaweli Project to the recent epidemic, citing the lack of coordination between health and development sectors, but the overall resurgence of malaria on the island has resulted from all the factors mentioned above.

b. **Brazil** - As recently as 1970, Brazil reported 53,000 cases of malaria, which had risen to over 500 thousand by 1987. The vast majority of cases came from Amazon region (Figure 2). Extensive mining and forest exploitation in Amazonia resulted
Figure 1

Positive Malaria Cases
Sri Lanka

![Graph showing positive malaria cases in Sri Lanka from 1980 to 1987.](image)

Figure 2

<table>
<thead>
<tr>
<th>Malaria cases in Brazil, 1985 and 1986</th>
<th>1985</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasmodium falciparum</td>
<td>254,439</td>
<td>177,774</td>
</tr>
<tr>
<td>Plasmodium vivax</td>
<td>1,400</td>
<td>3</td>
</tr>
<tr>
<td>P. malariae</td>
<td>230,679</td>
<td>198,381</td>
</tr>
<tr>
<td>P. ovale</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing malaria cases per year in Brazil from 1971 to 1986.](image)

Fig. 1. Malaria cases in the Amazon Region of Brazil, 1971-1986. (*data for 1986 are provisional, no survey was in Guiana was interrupted by a man-in-lung strike*)
in rapid immigration of non-immune people from malaria-free areas. For example, the population of Rondonia doubled to more than 1 million people between 1975 and 1985. Subsequently, many of the immigrants returned to their points of origin, reintroducing the infection into areas previously cleared of malaria. When these "extra Amazonian" cases were investigated, only 7 percent were found to be due to local transmission. In all, 26 foci of malaria were reestablished in the country (Cruz Marques, 1987).

The Brazilian experience exemplifies the role that changing human ecology has had on the local resurgence of malaria. It also indicates the difficulty of developing the required health services to keep pace with such rapid human changes. The government of Brazil is presently negotiating a massive loan with the World Bank (in the order of $400 million) to address the malaria problem in Amazonia and its reintroduction into formerly cleared sections of the country.

Not all governments are in a position to command such resources. As we know, health expenditures are low in African countries, where malaria is most severe. Data recently collected in other African countries demonstrate the severity of childhood malaria and the burden this places on already inadequate health services (Table 1).
Table 1  Examples: National Health Expenditures

<table>
<thead>
<tr>
<th>1984 US $s</th>
<th>Cameroon</th>
<th>Kenya</th>
<th>Nigeria</th>
<th>Zimbabwe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Capita Health Expenditure</td>
<td>$6.40</td>
<td>3.80</td>
<td>2.20</td>
<td>10.0</td>
</tr>
<tr>
<td>% of Govt. Allocation for Health</td>
<td>5.1</td>
<td>7.8</td>
<td>2.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Statistics on Childhood Malaria

<table>
<thead>
<tr>
<th>Children &lt; 5 years</th>
<th>Malawi</th>
<th>Ghana</th>
<th>Zaire</th>
<th>Zanzibar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported deaths</td>
<td>19%</td>
<td>10-15%</td>
<td>13%</td>
<td>no data</td>
</tr>
<tr>
<td>Out patient visits to clinics</td>
<td>36%</td>
<td>43%</td>
<td>no data</td>
<td>&gt; 60%</td>
</tr>
<tr>
<td>Hospital Admissions</td>
<td>30%</td>
<td>59%</td>
<td>38%</td>
<td>48%</td>
</tr>
</tbody>
</table>
Some of the most important changing environmental and related factors contributing to localized resurgence of malaria include the following:

a. changes in human ecology - the shift toward extensive and intensive agricultural development, often replacing subsistence agriculture and resulting in the movement and resettlement of inadequately housed and otherwise unprotected people;

b. development of insecticide resistance, often associated with the use of the same or similar insecticides in agriculture;

c. planned or unplanned settlement due to enterprises, such as prospecting or mining or construction of dams and roads, particularly in forested areas, may establish new foci of intense transmission;

d. migration of rural populations to unplanned urban slum areas with makeshift housing produces population densities that favor transmission and intensify endemicity;

e. deterioration of existing malaria control programs and/or premature incorporation of malaria services into rudimentary or ineffective primary health care systems; and
f. increased costs of labor and commodities requiring foreign exchange (e.g. insecticides and vehicles).
2. Schistosomiasis - is caused by a small parasitic flatworm or fluke that lives in the bloodstream and produces eggs that become lodged in the person's tissues. The accumulated effect is one of lost organ function, internal bleeding and chronic illness that may plague the victim for the remainder of his or her life. The intermediate hosts of schistosomiasis are freshwater snails that give off larvae ( cercariae) that can penetrate the unbroken skin. One needs only to step into water that contains infected snails to become infected. The snails become infected when infected people urinate or defecate eggs into the water where they live. The entire cycle could be arrested if these practices were eliminated.

WHO estimates that some 700 million people are at risk of infection in 79 countries. There are an estimated 250 million total cases. Great concern about the association between the spread of schistosomiasis and irrigated agriculture is warranted. Next to its effect on health of children, the effect of schistosomiasis on the productivity of agricultural workers is of prime concern.

Environmental change has always played a major role in both the control and spread of schistosomiasis. The eradication of the disease during the 1970s in Japan, which was once highly endemic for schistosomiasis, was primarily a byproduct of economic and social development.
On the other hand, schistosomiasis has become a major problem in Sudan, where vast irrigation projects for cotton cultivation are a major contributor to the GNP of the country and a major export for foreign currency. In Ghana, schistosomiasis entered Lake Volta shortly after its formation and as many as 95% of the lakeside village children became infected.

The Lake Volta situation is interesting because tropical disease specialists of the London School of Tropical Medicine and Hygiene had prepared an early "white paper" before the construction of the dam that predicted that schistosomiasis would become a major problem when the snails became established in the still waters and infected fishermen from nearby schistosomiasis foci entered the lake to fish. Unfortunately, their observations and other recommendations for preventive measures at an early stage of the development project were never heeded.

A 1985 survey of the two types of schistosomiasis occurring in the Nile Delta was conducted comparing results with those from an earlier (1935) survey in the same area (Cline, et al. 1989). One form, S. mansoni, and its host snail (Biomphalaria) had become the most abundant in 1985, and S. haematobium and its host snail (Bulinus) had been reduced, reversing the 1935 frequencies. The reduction of one in favor of the other seems associated with the hydrologic changes that have occurred along the Nile since the construction of the high dam at Aswan.
Dengue, Dengue Hemorrhagic Fever and Urbanization  The second half of the 20th century has been a period of urban growth on a massive scale -- certainly one of the greatest environmental changes in human history. The vector-borne diseases have shown their adaptability to this phenomenon in the form of dengue and its related manifestations. Uncomplicated dengue fever is caused by one of four closely related strains or serotypes of dengue virus. Dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS) are thought to be caused by infection with different strains in hypersensitized individuals, resulting in the shock and/or hemorrhagic symptoms. Whereas dengue fever is characterized by a mild to severe influenza-like illness, DHF and DSS are very severe, often requiring hospitalization and intensive supportive therapy, including fluid replacement. DHF and DSS are most severe in children, often resulting in death.

Dengue is circumtropical. DHF was first recognized in the Philippines (1946) and from the 1950s through 1970s, occurred in epidemic form in many southeast Asian cities, where it continues in an endemic form at present. The largest number of cases is in Thailand (Figure 3), which reported an average number of 45 thousand cases per year between 1981 and 1985.

DHF first appeared in the Americas in the Caribbean in the mid-1970s. The most severe epidemic occurred in Havana in 1981, when more than 350 thousand dengue cases occurred during a four-
month period: 116 thousand (33%) showed hemorrhagic/shock symptoms and required intensive hospital care (Guzman, et al. 1984). Only a very efficient and very costly national mobilization by the Cuban government prevented the mortality (154 deaths, mostly children) from being much higher.

Dengue is now widespread throughout cities of the Caribbean basin and South America, where epidemics have occurred recently in Brazil (>500,000 cases, 1986-87); Guayaquil, Ecuador (400,000 cases in 1988); Santa Cruz, Bolivia (160,000 cases in 1988) and Asuncion, Paraguay (50,000 cases in 1988-89).

The dengue viruses are transmitted to man by Aedes aegypti, the same mosquito that transmits yellow fever. This species is highly domestic and its preferred breeding sites are in artificial containers (used tires, water storage drums, plastic and tin cans, flower pots). In most parts of the world it is never found away from human habitations. The massive shift of people to urban environments and the concurrent crowding, inadequate housing and lack of water and sanitation services have provided, and will continue to provide, an ideal environment for perpetuation of dengue epidemics or the established endemicity of the diseases produced by the dengue viruses.

There is no vaccine or specific therapy for dengue fever, DHF or DSS. The antagonistic reactions produced by the different
serotypes of the dengue virus have, to date, blocked efforts to produce an effective polyvalent vaccine. The only control measure is prevention – i.e. elimination or reduction of the vector populations to levels that will not support transmission of the virus. Repetitive treatment of whole cities with insecticides is expensive, and, unless maintained with considerable zeal, is not sustainable. The most effective control measure is to eliminate the *Aedes* breeding sites. This has been done successfully in Singapore through concerted municipal effort, enforced legislation, education and improved housing. In other parts of the world this same approach will require considerably more education, changed population behavior and development of community participation (Gubler, 1989).

Dengue fever is perhaps one of the most dramatic products of rapidly changing human environmental conditions.
4. **Japanese Encephalitis** is a mosquito-borne viral disease produced by a flavivirus related to the viruses that cause dengue and yellow fever. Its distribution is Asian, from Southern USSR and Korea to Indonesia, and from India and Nepal east to the Philippines. As the name implies, the disease was first identified in Japan. Its distribution is largely associated with rice-growing areas where the major vectors (mosquitoes of the genus *Culex*) breed in the paddy fields and associated irrigation channels. As with many arboviruses, the transmission cycle involves a number of vertebrates as well as the mosquito vector.

The virus appears to be maintained in nature by birds — especially herons and egrets that utilize the habitat afforded by the paddy fields. The mosquito, breeding in the paddy fields, transmits the virus to man and domestic animals (cattle, horses, pigs and ducks). Man and other mammals can become infected and develop the disease, an encephalitis, often with serious neurological sequelae. Apparently the disease cannot be further transmitted by a man-mosquito-man or horse-mosquito-man/horse route. Pigs, and to a lesser extent ducks, develop high viremias and serve as amplifying hosts, producing an adequate pool of virus for mosquito transmission to man and other animals. Pigs are also affected, with serious losses due to miscarriages. Muslim countries are less affected by Japanese encephalitis, probably because of the lesser number of pigs farmed (Rosen, 1986).
As would be expected from the description above, JE is a rural Asian disease intimately associated with rice culture. The expansion of rice culture into arid areas of Sri Lanka under the Mahaweli irrigation and resettlement project and agricultural expansion programs in the Terai of Nepal and parts of India have increased the number of reported cases in those countries (Figure 4). Routine case reporting is deficient due to a lack of diagnostic and virological facilities, and for every case reported, there may be 20 to 1,000 inapparent infections. A conservative estimate places the number of cases annually in Asia at 40 thousand/year, of which one-third will die and another third will suffer very severe, long-term effects.

Control of the disease requires either vaccination or vector control. Effective vaccines are produced in Japan, Korea and China. Each of these countries has routine vaccination programs, but at costs that are not affordable in other countries. Korea, for example, uses some 11 million doses of vaccine per year and has vaccinated up to 30% of the pigs in peri-urban and densely populated areas. As with most viral infections, specific treatment of the disease is not available.

Control of the mosquitoes (adult or larvae) by use of insecticides is not economically feasible over broad areas. The most logical form of prevention lies in planning rice cultivation to eliminate or minimize production of mosquitoes in the paddy
fields. Because the mosquitoes require 5-7 days to produce emerging adults, the use of intermittent irrigation, periodic flushing of the fields and maintenance of irrigation channels to prevent pooling or puddling would be effective. Better, or in combination with the above, would be the use of rice cultivars that do not require flooding for periods long enough to produce adult mosquitoes in the fields (Goonasekere and Amerasinghe, 1988). If properly planned, such preventive measures would be less costly at the outset of the project than later. Furthermore, such costs could then be absorbed in the cost of the development program and not allocated later to the health services as a remedial action.
Agriculture and Vector Resistance to Insecticides

Another area in which the changing environments of development projects have adversely affected the control of vector-borne diseases is in the development of resistance to insecticides. With only a few exceptions, the insecticides used in vector control are the same as those used against agricultural pests. The reason is purely economic -- the disease control market is not large enough to support the R and D necessary to develop and test new insecticides and to conduct the trials for human and environmental safety required for registration in the developed countries. Agriculture accounts for at least 90%, and often more, of the insecticides used in most developing countries. One result is that in areas of intense monocultural agriculture, the vectors of malaria and other vector-borne diseases rapidly develop resistance to the insecticides available to public health workers. To date, 56 anopheline mosquitoes, the vectors of malaria, have developed resistance to DDT and other organochlorine insecticides; 31 species show resistance to organophosphates such as malathion and fenitrothion. Resistance is not global, but most often occurs in areas where the same or similar insecticides are used in agriculture (Table 2).

Among the best-known examples is the case in Central America, where the principal malaria vector, An. albimanus, is resistant to virtually all commonly used insecticides in one country or another.
This has been well-documented and largely traced to the development of cotton cultivation on the Pacific coast from southern Mexico (Oaxaca and Chiapas) south to Nicaragua. Starting in the early 1950s, applications of multiple insecticides increased from a rate of 5-7 to over 40 per growing season to combat the insect pests of cotton, reaching doses of as much as 30 liters of active ingredient per hectare (= 3 gals./acre) (Georghiou, 1986). The larval and adult mosquitoes living in and around the agricultural fields developed resistance to some insecticides before they were actually used in malaria control! Ironically, cotton-growing in these areas has been greatly decreased, due in part to the cost of insecticides needed to protect the cotton crop. However, it has left a legacy of insecticide resistance mosquitoes that cannot be controlled easily or economically. Similar examples can be seen in cotton-growing areas around Adana, Turkey, and in Sudan and in rice-growing areas in Asia.

The relative cost of different insecticides for malaria control is seen in Table 3. Without counting the labor costs, which vary from country to country, and using DDT as an index or set value of 1, the cost of control programs will escalate rapidly as one shifts to other classes of compounds to overcome resistance.

The difficulty of the situation for donor organizations and national officials alike is that insecticides generally account for between 50-60% of conventional control programs. Donors do not
Table 2

Number of Species of Insects and Miles Resistant to Insecticides—1984

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Diptera</td>
<td></td>
<td>108</td>
<td>107</td>
<td>62</td>
<td>11</td>
<td>10</td>
<td>—</td>
<td>1</td>
<td>23</td>
<td>132</td>
<td>1</td>
<td>156 (35)</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td></td>
<td>41</td>
<td>41</td>
<td>34</td>
<td>14</td>
<td>10</td>
<td>—</td>
<td>2</td>
<td>67</td>
<td>—</td>
<td>2</td>
<td>67 (13)</td>
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<tr>
<td>Coleoptera</td>
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<td>24</td>
<td>26</td>
<td>9</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>64</td>
<td>—</td>
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<td>Acarina</td>
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<td>45</td>
<td>45</td>
<td>13</td>
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<td>—</td>
<td>27</td>
<td>36</td>
<td>16</td>
<td>6</td>
<td>58 (13)</td>
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<td>Homoptera</td>
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<td>3</td>
<td>3</td>
<td>46</td>
<td>—</td>
<td>—</td>
<td>46 (10)</td>
</tr>
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<td>Heteroptera</td>
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<td>8</td>
<td>6</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>16</td>
<td>4</td>
<td>—</td>
<td>20 (4)</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>23</td>
<td>21</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>—</td>
<td>2</td>
<td>12</td>
<td>19</td>
<td>3</td>
<td>34 (8)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>276</td>
<td>233</td>
<td>212</td>
<td>64</td>
<td>32</td>
<td>11</td>
<td>38</td>
<td>264</td>
<td>171</td>
<td>12</td>
<td>447</td>
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<tr>
<td>(%)</td>
<td></td>
<td>(62)</td>
<td>(52)</td>
<td>(47)</td>
<td>(14)</td>
<td>(7)</td>
<td>(2)</td>
<td>(9)</td>
<td>(59)</td>
<td>(38)</td>
<td>(3)</td>
<td>(8)</td>
</tr>
</tbody>
</table>

*Records obtained through October 1984.

*Cyclod. = cyclodiene, OP = organophosphate, Carb. = carbamate, Pyr. = pyrethroid, Fumig. = fumigant.

Agr. = agricultural, Med./Vet. = medical veterinary, Benef. = beneficial.


Table 3

RELATIVE COSTS OF PESTICIDES USED FOR INDOOR HOUSE SPRAYING:
INCREASED LABOR COSTS (2X) FOR OP AND C COMPOUNDS NOT INCLUDED

<table>
<thead>
<tr>
<th>Insecticide (Type)</th>
<th>Dosage 1 a.i. g/m²</th>
<th>Applications 1 per year</th>
<th>Cost US$/kg</th>
<th>Relative Costs of Insecticides (DDT=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT (OC)</td>
<td>2.0</td>
<td>2</td>
<td>1.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Malathion (OP)</td>
<td>1-2.0</td>
<td>4</td>
<td>3.50</td>
<td>4.6</td>
</tr>
<tr>
<td>Fenitrothion (OP)</td>
<td>1-2.0</td>
<td>4</td>
<td>5.50</td>
<td>7.3</td>
</tr>
<tr>
<td>Propoxur (C)</td>
<td>1-2.0</td>
<td>4</td>
<td>16.00</td>
<td>21.0</td>
</tr>
<tr>
<td>Bendiocarb (C)</td>
<td>0.4</td>
<td>4</td>
<td>50.00</td>
<td>26.6</td>
</tr>
</tbody>
</table>

1World Health Organization/Vector Biology & Control/82.841
like to continue purchasing increasing quantities of insecticides for which they are criticized on environmental grounds, and the host countries cannot afford to pick up the costs of the insecticides, which generally have to be purchased with scarce foreign exchange.

This represents another situation where planning between the agricultural and health officials has not been effected. Again, the public health officials, with relatively meager resources, have had to bear the costs of remedial control that possibly could have been avoided through cheaper preventive measures developed in coordination with agriculture.
Expanding environments - Movement of People and Diseases

Most mosquitoes and snails, the vectors or intermediate hosts of some of the diseases discussed, do not move far under their own power. However, some of the disease phenomena we see in the modern world are due to the great movements of people. We have already mentioned changing agricultural practices resulting in resettlement of inadequately housed and immunologically unprotected people, as well as planned and unplanned settlements in relation to mining, forestry and construction.

Diseases can move too. It seems likely that some of the serotypes of dengue virus that have led to outbreaks of DHF in the Caribbean were transported from other endemic areas by people in the latent (i.e. post-infected, pre-symptomatic) phase of the disease. In fact, the main vector of dengue, Aedes aegypti, is native to Africa and was established in the Caribbean and adjacent areas during the period of slave transport from Africa. Yellow fever was also introduced at that time in the same manner. Currently, there are more than 250 thousand Thais living and working for limited periods in Kuwait and the other Gulf states. They represent just one of a large number of enclaves of foreign workers available to transport pathogens over long distances.

The most crucial setback to malaria control in the past 30 years has been the development and rapid spread of chloroquine-
resistant strains of *Plasmodium falciparum*, the most dangerous of the four malaria parasite species. Starting in the Thai-Kampuchea area in 1957, it spread west and north to Pakistan and Nepal by 1984, west to Sri Lanka and as far east as Papua New Guinea and the Solomon Islands. A possibly unrelated development of resistance also was recognized along the Colombia-Venezuela border in 1959, swept through the Amazon in the 1960s, and reached the Pacific coast of Colombia, Panama and Ecuador 10 years later. The first reports of chloroquine-resistant falciparum malaria in Africa came from Kenya and Tanzania in 1979-80, and in the subsequent 10 years we have had reports from 24 countries (Figures 5 and 6).

To appreciate the importance of this resistance, one must recognize that throughout Africa, where malaria is most severe, distribution of chloroquine often has been the only means of control. Chloroquine distribution is also the major control measure in many areas of Asia and the Americas, but these regions have vector control operations. The loss of chloroquine is not complete -- there are broad areas where resistance is partial and increased dosage is still curative. The pattern, however, is clear. Chloroquine cannot last forever. The alternative drugs are more expensive, and unlike chloroquine, may produce side effects that prohibit unsupervised use. Furthermore, in all three continents we have also seen the development of *P. falciparum* resistance to these drugs as well.
Figure 5

Global Spread of Chloroquine-Resistant Malaria

Source: Clyde (1987a; 1987b)
Figure 6

Spread of Chloroquine-Resistant *P. falciparum* by Dates of Reported Occurrence, 1979–1988

Source: VBC Project. Information as reported in Global Disease Surveillance Report, October 1988
Impact of Endemic Diseases on Development

In this paper I have concentrated on presenting examples of changes in human ecology, often associated with economic development projects. I have attempted to demonstrate that such man-made environmental changes strongly affect vector-borne disease patterns in both distribution and severity. Conversely, severe levels of endemic diseases also may impinge upon the success of economic development in the affected areas. Consider the following:

- The government of Egypt estimates that it loses US $500 million in agricultural productivity per year, primarily in lost work, due to schistosomiasis.

- By very conservative estimates, 5-10 days of work are lost during each case of malaria (in severe cases it may be more). In Sri Lanka, where over 600 thousand cases were reported in 1987, the loss would amount to 15,000 man-years to the work force (US $31 million when calculated at the per capita income), mostly in the agricultural sector. Additional costs would include:
- individual expenditure on antimalarial drugs and treatment;
- cost of treatment and hospitalization borne by the community;
- pressure on health services;
- limitation of land use;
- premature mortality; and
- other repercussions, such as school absenteeism, damage to the tourism industry, reduced capital flow and investment, detrimental mental and psychological effects of the disease (after Wernsdorfer and Wernsdorfer, 1988).

In a study in Paraguay (Conly, 1975), families with "much malaria" in a new agricultural settlement had:

- slowed expansion of cleared land;
- reduced cropped area;
- caused some early-season loss of crops;
- increased labor-hour requirements;
- lowered agricultural productivity by 25%; and
- caused some emigration.

A study conducted in Ghana, and likely characteristic of other African countries,
quantitatively marked malaria as the disease most responsible for days of work lost to the population. This study was based on an accounting approach using incidence, case fatality, and duration and extent of disability to calculate the member of health days lost from specific diseases (Barnum, 1987).

On the positive and historic side, it should be mentioned that it was estimated that malaria cost the U.S. over $100 million in 1917, and some $500 million in 1938. Many people do not recall that the Tennessee Valley Authority (TVA) pioneered the development of environmental methods to control malaria in that area. In addition to flood control and generation of hydroelectric power, malaria control was an integral part of TVA's mandate. Kitron (1987) describes the TVA work and other successful environmental control programs in the US, Italy and Israel.

Unfortunately, not many studies on parasitic vector-borne diseases and their control are designed to capture data that allow detailed cost-benefit analysis. The World Bank has released a document by Barlow and Grobar (1986) that summarizes the best information available at this time. Wernsdorfer and Wernsdorfer (1988) also discuss economic impact of disease on productivity, as well as the contribution of malaria control to increased productivity in agriculture, mining and other enterprises.
In preparing this report, I scanned more than 100 documents and books in the A.I.D. Library in Washington D.C. These were documents catalogued in the development field, or obtained through a computer search using key words such as development assistance, environmental change, health and agriculture. Only 25% discussed health, usually with morbidity and mortality statistics. The importance of increasing food supplies and nutrition are mentioned in about one-third of the documents. Only three discussed parasites/microbial diseases. This was not a comprehensive review, and the library is a "development" rather than a "health" library, but it does suggest a lack of coordination between the various sectors in foreign assistance.

Currently, the technical journals in tropical medicine and medical entomology provide a great number of articles that document disease patterns associated with agriculture, water management projects and unplanned environmental changes. Unfortunately, there does not seem to be a good exchange between these development and epidemiological specialists.

What can be learned from the limited data presented above is that the impact of endemic diseases should not be measured only by the number of cases reported or estimated, but also by the economic impact produced. If we continue to bring about environmental changes for economic profit, we should be aware of the ancillary costs incurred.
Ecological Perspectives

Pressure of increasing human populations for space, food and other natural resources is rapidly changing ecosystems and biotic communities that have developed an equilibrium of structure and function over time. Within these systems, vector-borne diseases are a component dependent for their maintenance on an equilibrium between host, vector and pathogen. Although some variations in transmission caused by climatic changes are expected, rapid changes in the environment may influence the behavior or physiology of either the vectors, pathogens or host and produce an increase in transmission beyond the expected limits or reduce the efficacy of available means of control. Malaria may serve as a good example.

- The vectors have often expanded their ranges and population levels due to man-made changes and have developed resistance to insecticides or changed behavior to avoid contact with insecticides;

- The pathogens have developed resistance to available drugs;

- The host (man) has brought about these changes due to excessive or injudicious use of drugs and insecticides, and, through vastly increased population growth and movement, has made
transmission more intensive and geographically diverse. Malaria is not a zoonosis (there is no alternate vertebrate host), so the intensity of transmission is largely driven by human population size and man's influence on the vectors and pathogens.

Considering malaria (above) or the other diseases discussed in this paper, one would expect environmental changes to produce an increase in the diseases -- unless we are wise enough to use the same principles of environmental change to modify the environment in our favor, basically by eliminating vectors or reducing human-vector contact.
Newly Emerging Diseases

Since 1950, we have seen the emergence of a number of "new" diseases, many restricted to the developing countries. Some of these are vector-borne, some spread by rodents and some are of unknown etiology. The identification of some of these diseases may be due to better means of diagnosis and identification, but most also can be related to changing environments and/or expanded human contact with vectors or hosts. These include:

1950 - Korean hemorrhagic fever (Asia)
1954 - Dengue hemorrhagic fever (Asia and Americas)
1956 - Argentinian hemorrhagic fever
1957 - Chloroquine-resistant malaria (Asia)
   - Kyasanur Forest Disease (Asia)
1959 - O'nyong-nyong virus disease (Africa)
1963 - Bolivian hemorrhagic fever
1967 - Marburg Virus Disease (Africa)
1969 - Lassa fever (Africa)
1970 - Monkeypox (Africa)
1975 - First Epidemic of Lyme Disease Described
   (North America and Europe)
1976 - Ebola Virus Disease (Africa)
Conclusions

There can be little doubt that environmental changes, especially man-made changes in the developing world, have increased the spread and intensity of vector-borne diseases in recent years. Many of these changes have been unplanned, but quite a number are due to economic development programs in other sectors (e.g. agriculture). Case studies in the developed world demonstrate that environmental management can be used in a positive manner to reduce the breeding sites of vectors and the man-vector contact rate.

Vector-borne diseases are a major component of the total world health picture and the costs of conventional control mechanisms now exceed the ability of most countries to sustain them. Future control strategies must focus available resources on specific problems in order to decrease their cost and increase their efficiency. Achieving that goal will require the resolution of a number of issues currently facing countries with vector-borne disease control problems. These include:

When applicable, linking the costs of vector-borne disease control to the development rather than the health budget.

Development activities such as irrigated agriculture, rice cultivation and resettlement have predictable and
significant effects on some vector-borne diseases. The mechanisms for disease control, as well as their costs, can be included in the design of development efforts, effectively reducing the financial burden on the often underfunded Ministry of Health. Private sector enterprises also are amenable to this approach and their activities can often realize gains in productivity as a result of disease control initiatives.

Seeking opportunities to integrate vector-borne disease control efforts into other sector initiatives.

Vector-borne diseases do not exist in isolation. In many cases, significant control can be achieved through the improvement of water and sanitation, agricultural planning and community development. In some instances, such as the growing threat of dengue hemorrhagic fever in rapidly urbanizing countries, or in the control of urban filariasis, community action in environmental sanitation may be the only effective intervention.

The need for documentation and verification of cost information associated with the impact of vector-borne diseases as well as the cost effectiveness of control options.
The state-of-the-art with regard to the understanding of socioeconomic factors associated with vector-borne diseases and their control should permit more quantitative documentation than currently exists. Cost analyses and simulations of control options hold promise for helping to make wiser decisions, to say nothing of their ability to promote advocacy for control.

Increasing coordination between the international donors.

Donor coordination is often lacking, and within individual agencies assistance may be uncoordinated—e.g. between agriculture, use of renewable and non-renewable resources, and health. By failing to coordinate our activities along ecologically sound and sanitary principles, the developed countries give poor guidance and assistance of questionable value to the developing world.
References


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