# ANALYSIS OF THE PRINCIPAL PROBLEMS IMPEDING NORMAL DEVELOPMENT OF MALARIA ERADICATION PROGRAMS[1]

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*This article presents a brief overview of the principal problems confronting malaria programs in the Americas. In so doing, it seeks to stimulate discussion and criticism, and, hopefully, to serve as a guide in the shaping of future strategy.*

It is appropriate, by way of introduction, to set forth five basic premises. These are as follows: (1) There is a sufficient basis to assert that because of the complexity of existing malaria problems, no single method will serve to solve all the problems. (2) Many avenues for malaria program advances can be opened up by confronting these problems and by making people aware that current knowledge on the subject is not definitive. (3) When experience, present knowledge, and established procedures fail to solve problems—and what is more important, fail to define them—we must inexorably embark upon a course of study and research. (4) It must be recognized that we have exaggerated the utility of "reasoning by analogy" in thinking and acting as if a vector, a parasite, or even a person will necessarily behave the same way in different places, much less in different ecological situations. (5) There is an urgent need to revise training programs and to concentrate on preparing technicians who can assume responsibility for research in countries confronting problems of persistent transmission.

## Vector Resistance

### Physiological Resistance

Of the ten anopheline species considered important vectors in the Americas, four have shown physiological resistance to insecticides in some part of their range: *A. quadrimaculatus* in the United States; *A. pseudopunctipennis* in Guatemala and Mexico; *A. albimanus* in Costa Rica, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama; and *A. albitarsis* in Colombia and Brazil. With reference to Central America, *A. albimanus* has shown resistance to DDT, BHC, dieldrin, and malathion in various parts of the region, plus resistance to propoxur in much of El Salvador and some parts of Guatemala and Nicaragua, and resistance to fenitrothion in El Salvador and Nicaragua.

In Guatemala, where *A. albimanus* has manifested high generalized levels of DDT resistance, very satisfactory results have been achieved with propoxur, but there is some concern that limited areas of vector resistance

to the latter insecticide may spread. With regard to El Salvador, it is apparent that this country faces more serious and complex problems than other Central American nations. Generalized *A. albimanus* resistance to both DDT and propoxur, along with operational and administrative difficulties, have resulted in deterioration of the program and a considerable rise in the incidence of malaria. In Nicaragua, where propoxur resistance was first detected, the number of malaria cases—as well as the number of *P. falciparum* and mixed infections—has risen again after declining in 1972 and 1973. In Honduras, although DDT resistance exists, current administrative problems occasioned by shortages of DDT and propoxur appear to pose more important obstacles to control. In Costa Rica and Panama, small pockets of DDT-resistant *A. albimanus* have been found, and propoxur has been substituted for DDT with favorable results up to now. In Mexico, although *A. pseudopunctipennis* resistance to DDT is widespread, it does not reach high levels in most places, and tests using malathion, fenitrothion, and propoxur indicate that the vector is susceptible to these insecticides (see Figure).

It is also noteworthy that a number of situations greatly complicate analysis and interpretation of the "resistance" phenomenon. For example, neighboring regions in one country (El Salvador) both contain localities with persistent malaria transmission; *A. albimanus* is susceptible to DDT in some of these places and resistant in others, but this is not accompanied by marked variations in malaria incidence. Likewise, a biological enigma is presented by vector resistance in one area (Oaxaca, Mexico) where the vectors rest only briefly inside dwellings or are entirely exophilic, and where insecticides are not used for agricultural purposes. Then there are instances where transmission has been successfully interrupted despite *A. pseudopunctipennis* resistance (in Morelos, Mexico) and *A. albimanus* resistance (in Chiapas,

Mexico); areas of *A. albitarsis* resistance to DDT in Colombia and Brazil that have responded favorably; and observations showing that while massive agricultural insecticide applications are nearly always accompanied by *A. albimanus* resistance, development of *A. pseudopunctipennis* resistance under similar conditions is less certain.

Moreover, reliable studies have shown that where transmission continues and physiological vector resistance is present, this resistance is not solely responsible for creating the persistence problem—a point that must be kept in mind when deciding whether to change insecticides. That is, before reaching such a decision, it is essential to gain a better understanding of what is happening with respect to other entomologic, anthropologic, and epidemiologic factors.

Another important point is that use of organophosphorus larvicides may produce vector resistance to chlorinated adulticides. The first report on this problem was presented at the Seminar on Insect Susceptibility to Insecticides held in Panama in 1958. Recently, the problem was noted in some districts of the States of California and Florida in the United States, where use of the two types of insecticides against both adults and larvae led to a rapid rise in resistance. It would appear that "selective action of the chlorinated insecticides does not give rise to resistance to the organophosphorus compounds, but the selective action of the latter creates resistance to the former."

Many years have now passed since it was first recommended that chemically analogous insecticides should not be used simultaneously in the same district or area against both adults and larvae of the same species. In this regard, we consider it very important to note that cross-resistance to organophosphates and carbamates has recently been discovered.

Current differences in classification and interpretation of susceptibility test results should be subjected to further analysis and discussion. Also in this vein, it has been

*Geographic distribution of areas of malaria transmission where progress depends on application of new attack measures to resolve technical problems.*
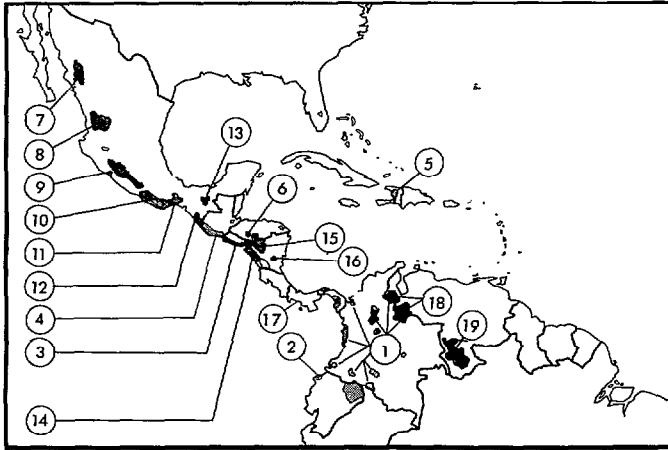


| Countries, code numbers (keyed to map), and names of affected areas | Population of affected regions | Area involved (Km²) | Insecticides used | | Principal vectors | Causes of the problem |
|---|---|---|---|---|---|---|
| | | | Types used | Years of coverage | | |
| COLOMBIA (1) Gulf of Urabá, Catatumbo River, Central Magdalena River Valley, Upper Vásquez Territory, Central Pacific Coast, Ariari River, Lower Cauca, Sarare area, Upper Caquetá | 605,587 | 151,936 | DDT | 8–14 | *A albimanus* *A darlingi* *A nuñeztovari* *A neivae* *A punctimacula* | Vector behavior, poor housing, colonization, social problems, parasite resistance to chloroquine, operational difficulties, refusal to permit spraying, population movements, actions that neutralize sprayed surfaces, temporary housing |
| ECUADOR (2) Provinces of Esmeraldas and Napo | 263,795 | 40,583 | DDT | 6 | *A albimanus* *A punctimacula* | Colonization, poor housing |
| EL SALVADOR (3) | 864,762 | 7,689 | DDT propoxur | 16 3 | *A albimanus* | Vector resistance |
| GUATEMALA (4) Southern Coast, town of Nueva Concepción | 331,891 | 6,439 | propoxur | 3 | *A albimanus* | Vector resistance to DDT and propoxur |
| HAITI (5) Gros-Morne; Coma Valley, Simone O. Duvalier City; towns of Cayes-Jacmel, Jacmel, and Petit Goave | 85,500 | — | DDT | 5–12 | *A albimanus* | Vector resistance to DDT, population movements, inadequate coverage |
| HONDURAS (6) Southern region, Jamastrán Valley, Cedros and Talanga valleys | 204,486 | 5,436 | DDT dieldrin malathion | 6 1 1½ | *A albimanus* *A pseudopunctipennis* | Vector resistance to DDT and dieldrin, internal and external population movements, traditional style of dwellings |
| MEXICO Fuerte, Sinaloa, Humaya and Tamazola river basins (7); "Huicot" area of Jalisco State (8); Balsas River Basin (9), the "Costa Chica" of the states of Guerrero and Oaxaca (10), town of Matías Romero (11); the area of Tapachula-Suchiate (Chiapas State) (12); central Chiapas State (13) | 4,228,551 | 179,086 | DDT dieldrin | 16 | *A albimanus* *A pseudopunctipennis* | Internal population movements, vector resistance, poor housing, actions neutralizing sprayed surfaces, use of temporary shelters |
| NICARAGUA Pacific region (14), Central region (15), Atlantic region (16) | 1,364,650 | 27,581 | DDT malathion propoxur | 4 4–5 3½–3¾ | *A albimanus* | Vector resistance to DDT and malathion |
| PANAMA (17) Gatún Lake, the trans isthmian and Portobelo areas, and areas of eastern Panama | 13,466 | 3,625 | DDT | 11–12 | *A albimanus* | Vector and parasite resistance |
| VENEZUELA Western (18) and southern (19) areas | 487,687 | 139,946 | DDT | 24 | *A darlingi* *A nuñeztovari* | Vector exophily, population movements, colonization, refusal to permit spraying, poor public cooperation. |

observed that larvae may show a higher degree of mortality than adults, with larval resistance levels differing from those of adults. These differences between mortality induced among larvae and among adults by certain insecticides can be used to advantage and can make all the difference in the selection of a complementary or substitute control measure.

Another point about the resistance phenomenon, one which will probably become more important in the future, is the apparent ability of spatial ultra-low-volume insecticide applications to produce higher mortality among mosquitoes, including resistant mosquitoes, than traditional insecticide formulations.[3] This discovery will also influence the need to develop new methods for conducting and interpreting susceptibility tests.

Another problem closely tied to physiological vector resistance is the indiscriminate use of insecticides in agriculture. Here urgent action is needed. The first step should be procurement of information, as detailed as possible, by national malaria eradication services concerning this practice in areas of persistent transmission. These data, together with malaria statistics, will provide a vital basis for exchanging information with agricultural services and establishing the necessary coordination. A second step could be establishment of a working group composed of representatives of agricultural, health, and malaria services. If appropriate, the group could also include an official familiar with public and private insecticide production or importation, nor should specialists in agricultural entomology be forgotten. Ultimately, the desired result would be revision or enactment of more ample legislation directed at putting a more rational use of insecticides into practice and ensuring adequate protec-

tion against the risks inherent in the handling of insecticides.

*Behavioral Resistance*

A knowledge of vector habits is indispensable for undertaking an attack measure or for employing complementary measures. In the Americas, many years of experience have shown vector exophily to be so pronounced in an appreciable number of areas with technical problems that it poses an important obstacle demanding study and adoption of alternative attack measures. Exophily of this sort is exhibited by *A. nuñeztovari* in western Venezuela and in northern and eastern Colombia, and by *A. (Kerteszia) cruzi cruzi*, a vector that transmits malaria outside dwellings as well as inside them, on the southern coast of Brazil. In some areas, *A. darlingi* and *A. aquasalis* have also shown as much inclination to be exophilic and exophagous (feeding and resting outdoors) as endophilic and endophagous. Various studies in areas of persistent transmission (in Mexico, for example) have shown that *A. pseudopunctipennis* has a clear tendency toward exophily and will bite people or animals indiscriminately. These examples merely serve to illustrate what is generally acknowledged—that anopheline vectors (such as *A. punctimacula* in Colombia and *A. cruzi cruzi* in Brazil) are not strictly domiciliary, endophilic, or endophagous, but rather contain within their populations fractions of varying size that will bite and rest outside of human dwellings. There are, in other words, vectors that will rest outside of houses in certain areas of their geographic range, typical examples being *A. nuñeztovari* and *A. punctimacula*—which will rest on deeply shaded soil—and *A. darlingi*—which will rest above ground in moderately dense vegetation.

It is known that populations of the same anopheline species may display different habits in different areas. But identification of these variant populations and possible

[3] For related data on this subject, see G. Echevers, *et al.*, Results of spraying with ultra-low-volume malathion at ground level in Panama City, *Bull Pan Am Health Org* 9:232–237, 1975.

subspecies is really outside the realm of our morphological keys, depending instead on cytogenetic methods and the preparation and interpretation of chromosome "maps."

Failure to make careful study of feeding and resting places invariably leads to problems when we try to determine the possible causes of persistent transmission. For example, to help analyze several instances of persistent transmission in Venezuela, the number of mosquitoes captured while resting indoors engorged with blood was compared to the number that had been observed in the act of biting. This led to the finding that, besides the already known causes of this persistent transmission, vector exophily was a significant factor.

Frequently, *A. pseudopunctipennis* and other vectors will have the habit of biting people inside or near a sprayed house and then selecting resting sites at varying distances away—in vegetation, in caves, close to breeding areas, or in other places where conditions are excellent for development of the parasite's gonotrophic cycle. Knowledge about such resting places could be another decisive factor in the selection of effective complementary measures.

Within houses, three possible types of vector behavior can have adverse effects: failing to rest, resting for only a short period, and resting on unsprayed surfaces.

Ecological conditions in a variety of malarious regions of the Americas strongly favor survival of vectors (*A. darlingi, A. nuñeztovari,* and *A. punctimacula*) in external resting places. These malarious regions are generally less than 100 meters above sea level and frequently coincide with areas of colonization and poor housing or with crops, such as cotton, that involve large seasonal human migrations to places infested with efficient vectors such as *A. albimanus, A. punctimacula,* or *A. pseudopunctipennis.* An apt current example would be the present situation in certain new petroleum development areas.

In Colombia, the three vectors *A. darlingi, A. nuñeztovari,* and *A. punctimacula* are known to have been exophilic long before the advent of DDT. Furthermore, various studies have shown that these three species combine exophily with endophagy in different areas (*A. darlingi* in Brazil and Colombia, *A. punctimacula* in Colombia and Ecuador, and *A. nuñeztovari* in Colombia and Venezuela).

A vital point that must be noted here is that we often ascribe transmission to exophilic behavior, which undeniably exists, while forgetting that human behavior can pose a greater problem than that of the vector.

Studies carried out in refractory areas suggest that the vectors transmit malaria mainly inside houses, but that they do not make sufficiently long contact with the sprayed surfaces. According to Elliott *(19),* the length of surface contact is very short — one to three minutes, on the average, for *A. nuñeztovari* and *A. punctimacula,* and longer for *A. darlingi.*

It is also important to remember that the vectors may be reposing on unsprayed surfaces. One frequently finds clothing and other objects that have not been sprayed hanging in rural homes, on which abundant vector mosquitoes are captured. In studies with *A. darlingi* and *A. nuñeztovari,* Garcia Martín *(26)* observed that more than half of the vectors were resting on such unsprayed surfaces; added to this is the liklihood that some surfaces remain unsprayed because of operational failings, a circumstance by which we ourselves help the vector to avoid contact with the insecticide.

Another way in which the vector can avoid sprayed surfaces is by resting at heights above three meters. Various studies with different vectors in Ecuador and Colombia have shown that the average resting height is less than one meter, about 15 per cent of the vectors resting above one meter and only 1 per cent above 1.8 meters. Obviously, the

availability of resting places above three meters depends on the height of interior structures and roofs. Shed-type (lean-to) habitations erected by transient workers, largely in sugar cane areas, constitute one example of sufficiently high constructions. Another example is houses built with a very sharp pitch to the roof that are typically found in regions of heavy rainfall. Houses of this latter kind, studied by Rachou in Central America, were as much as 4.5 or even 6 meters high, but they revealed few instances of *A. apicimacula, A. punctimacula* or *A. albimanus* resting at heights above three meters.

Other possible components of resistant behavior are irritability and avoidance. DDT has an irritating effect on mosquitoes, but the present methods of measuring this effect have certain limitations, especially with regard to epidemiologic interpretation. The irritability of *A. albimanus* in some areas of Central America and the avoidance behavior of *A. nuñeztovari* in Venezuela exemplify these types of behavior. The combination of irritability or avoidance with anthropophilia can have significant epidemiologic implications.

Finally, persistent transmission problems involving behavioral or physiological vector resistance could stem from events that occur in the course of eradication programs in the Americas; but these problem situations are generally so complex that it is not easy to establish the degree to which such events constitute causal factors. Up to now, mathematical models have not been able to clarify situations of this kind effectively.

*Insecticide Deactivation*

Another facet to consider in the multi-faceted picture of persistent transmission is inactivation of insecticide by adsorption—a process by which the insecticide particles disappear from a sprayed surface for primarily physical rather than chemical reasons. Of substances commonly encountered, red laterite clays have the greatest adsorptive potential. Aside from the material involved, differences in temperature and relative humidity will also affect adsorption— higher temperature promoting greater adsorption and higher relative humidity promoting less. Despite numerous studies conducted in Brazil and Mexico in the 1950's, however, it has still not been possible to incriminate adsorption as a cause of persistent transmission.

## Chloroquine Resistance in *P. falciparum*

Chloroquine-resistant strains of *P. falciparum* have been identified in certain regions of Brazil, Colombia, Guyana, Panama, Surinam, and Venezuela over the past 15 years. Degrees of resistance found by *in vivo* susceptibility testing have ranged from RI to RIII. *In vitro* tests have also been carried out; these showed that tested *P. falciparum* strains from El Salvador, Haiti, and Mexico were susceptible to chloroquine, while confirming resistance in strains from Brazil, Colombia, and Panama. In this vein, it is worth mentioning that Rieckmann's *in vitro* technique is simple and easy to perform under field conditions; it is not necessary to wait the time required for *in vivo* tests, or to follow up cases in order to obtain the results. It should also be remembered that if insecticides are effective in interrupting transmission, the problem of parasite resistance to medication has less epidemiologic importance.

Overall, three aspects of the chloroquine resistance problem should be emphasized:

1) Just because the phenomenon of chloroquine resistance is not yet an established fact in some countries does not mean that its appearance is impossible or highly improbable. In particular, today's rapid means of international transport greatly increase the likelihood that malaria cases may be imported from countries where the problem of *P.*

*falciparum* resistance to the 4-aminoquino-lines exists.

2) The possible development of resistance must always be kept in mind when anti-malarial drugs are used—in mass treatment programs, as family reserve stocks, or in any system of administration involving massive and frequent exposure of the parasite to the drugs.

3) *In vitro* testing completely avoids the doubts about ingestion and adsorption of chloroquine that accompany *in vivo* testing, and also reduces the role of immunity as a factor. Thus, by knowing the degree of maturity of the asexual parasites in the patient's blood, we can find the extent of *P. falciparum* susceptibility or resistance to chloroquine or other drugs under field conditions and within twenty-four hours.

## Simian Malaria

The parasites of human malaria can develop in some monkeys and can be transmitted to man by various anopheline species, including Western Hemisphere species such as *A. cruzi cruzi, A. quadrimaculatus, A. albimanus,* and others. Nevertheless, this type of transmission seems to have such limited implications for malaria programs in the Americas that it does not merit consideration as a significant problem.

## Anthropological Factors

A valuable introduction to the role of anthropological factors in persistent transmission is provided by Gabaldón's assertion that if eradication should prove unattainable or unduly delayed, it would be largely because of human factors, not all of which could be attributed to the inhabitants of malarious areas. That is, human ecology is as important as vector ecology. In fact, it is very likely that problems relating to human ecology and human conduct have contributed to

persistent transmission more often than difficulties of any other kind. Some of the more important problems in this group are as follows:

### Houses and Shelters

Poorly built houses are often found in areas where malaria transmission persists. In particular, a very large number of rural dwellings in the Americas have only one or two walls, either because they are customarily built that way in the local region concerned or because they are merely provisional or temporary shelters; also, many buildings have discontinuous walls with openings of various sizes. Despite the frequency of their occurrence, the role of such "open" houses in promotion of persistent malaria transmission is not always easy to prove.

Houses with high roofs can have epidemiologic significance if they are numerous and if they have attics, lofts, decks, or floored areas in their upper portions that are used as sleeping quarters. Also, houses with outside verandas, passages, and terraces encourage outdoor gatherings during the hours when some vectors are most active.

Dwellings built between spraying cycles, those built in stages (as is often the custom in rural areas), and of course those that are not sprayed at all for one reason or another, may raise problems in the following circumstances: (1) when there is malaria transmission in the locality; (2) when the population is widely dispersed; (3) when the existing shelters are temporary or make-shift; (4) when they are located near vector breeding areas; and (5) when there are malaria cases inside the dwelling or in neighboring dwellings.

Other human behavior patterns that pose obstacles include refusal to permit house-spraying and practices destroying its effect—such as whitewashing, papering, or cleaning of walls or other such modification of sprayed surfaces. Such behavior is often the result of

inadequate information programs, or of cultural patterns not having been taken into account in scheduling malaria program activities.

People can often be observed sleeping outdoors, and while there is little chance of quantifying the practice so as to provide a satisfactory basis for evaluation, it can be listed as a possible cause of transmission, especially where the vectors tend to be exophilic. In addition, there are many malarious areas where the inhabitants often sleep overnight in temporary shelters to watch over crops or harvests, or to attend public or religious meetings. A variety of studies have shown that in most affected countries this latter practice contributes to persistent transmission.

## Human Migrations

The present dynamics of the development process in Latin America involve demographic changes that are closely related to malaria transmission. This point is illustrated by population movements of all kinds—whether they are organized or unorganized, whether they involve individuals, families, small groups or great assemblages, whether they are seasonal (*e.g.*, for harvesting) or non-seasonal, and whether they are temporary (*e.g.*, for highway construction) or permanent (*e.g.*, for colonization). There are numerous examples that demonstrate the presence of cases imported from transmission areas of the same country or a neighboring country when frequent population movements occur. These phenomena, along with the possibilities for malaria control, have been studied in connection with several malaria programs, and in some cases preventive measures have been applied; but in general, studies are made and emergency measures applied only after the problem has emerged.

We must remember that it is not easy to detect asymptomatic carriers, even by means of a complete survey, especially when the migrants are farm workers and when they are bound for areas with poor communications—circumstances that can favor reestablishment of malaria transmission.

## Primitive and Isolated Population Groups

Extreme examples of primitive and isolated groups would include the jungle peoples of the Amazon region—living in nomadic, often hostile, utterly primitive tribal societies—and the likewise isolated people living along river banks and on innumerable islets who engage in production of rubber, wood, nuts, livestock, gold, diamonds, and other raw materials. Such circumstances require an in-depth operational and anthropological approach in order to define the present possibilities with regard to malaria and its control.

## Man-made Malaria

The Americas contain a wide range of situations illustrating so-called "man-made" malaria. Dams, irrigation systems, mining operations, power stations, highway construction projects, and establishment of new settlements can all create extensive breeding sites for vectors of malaria and other diseases when ecological consequences are not given sufficient consideration during the processes of planning, constructing, and operating these facilities.

## Education

As a final comment on anthropological factors, it is essential to remember that the cultural patterns of affected population groups must be taken into account when educational campaigns are planned or executed.

## Operational, Administrative, and Financial Difficulties

These problems merit special consideration. Many of them can be resolved by improving the present operating methods and by procuring adequate financing. Areas where improvement is feasible include the following: The continuous updating of geographic reconnaissance and of working itineraries; the use of supervision to provide operational evaluation of coverage and to determine whether coverage was timely, sufficient, total, and complete; the logistics of supplies and personnel; the personnel policy, which should provide incentives seeking to compensate the hardships of field work and the invariably inadequate salaries—especially those of lower-ranking workers—that create recruitment and retention problems; and the malaria service's coordination with government entities directly or indirectly related to the program, such as municipal authorities and central government ministries in charge of finance, health, education, agriculture, public works, communications, transportation, water resources, and defense.

With regard to financing, we believe that in general the funds presently allocated to malaria eradication programs are not adequate to offset salary increases, inflation, growing needs imposed by technical problems, and above all the tremendously increased prices of DDT and propoxur now purchased by the Governments.

To be more specific, the CIF prices (in US$) paid this year and three years ago in Central America are as shown:

|      | DDT (75%)        | Propoxur (50%)   |
|------|------------------|------------------|
| 1972 | $0.26 per pound  | $3.76 per kilo   |
| 1975 | $0.58 per pound  | $6.07 per kilo   |

These prices will continue to rise. If we also consider that the prices of vehicle fuel and of many other products have risen over 100 per cent in the last three years, it can be seen that there is no alternative but to urge the Governments to provide more administrative and financial support.

When financial difficulties arise which result in reduction or suspension of operations, the experience of other regions of the world should be remembered. This shows that calling an untimely halt to antimalaria operations, either for lack of funds or for other reasons, has led to epidemics, heavy morbidity and mortality, considerable production losses, new problems, and ultimately to much higher program cost.

## Concluding Comments

We have gained sufficient experience to recognize that almost all evaluation studies, whatever their scope or level, reveal many operational and administrative shortcomings. This makes it difficult to single out technical causes contributing to persistent transmission.

Furthermore, in situations where the malariologist is called upon to intervene, it is unusual to find problems that can be considered strictly administrative, operational, or technical; the great majority of these problems must be approached with a multidisciplinary perspective requiring knowledge and experience not only of subjects within the field of malariology but also of subjects outside it, a circumstance that requires us to train ourselves in other fields and to continually promote interdisciplinary coordination in program activities, teaching, and research.

To epidemiologically justify, develop, and apply alternative measures we need more knowledge than we currently possess. Thus it will be necessary to pursue in greater depth our study of epidemiology, entomology, parasitology, statistics, operations methodology, ecology, anthropology, general principles of public health, and the social, cultural, and economic factors that currently define malaria pathology in the rural areas of Latin America.

This will be the best way of complying with the request made to the Governments and the Director of the Pan American Sanitary Bureau by the representatives of all the countries of the Americas at the XIX Pan American Sanitary Conference—a request contained in the resolution on malaria eradication (Resolution XXVI) in the Conference's final report.[4]

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## SUMMARY

The problems currently impeding the advance of anti-malaria programs in the Americas fall into several different categories. These include vector resistance to insecticides, parasite resistance to chloroquine, human behavior patterns which promote human/vector contact or reduce the impact of control efforts, and developments affecting operation, administration, and financing of the control program itself.

Vector resistance, of course, may be either physiological, behavioral, or both. With regard to physiological resistance, four of the ten anopheline species considered important in the Americas have shown physiological resistance to at least one insecticide in some part of their range. One of the most serious and complex problems of this kind currently confronts El Salvador, where generalized *Anopheles albimanus* resistance to both DDT and propoxur (along with operational and administrative difficulties) has sparked a considerable rise in malaria incidence.

In many places, such physiological resistance is closely related to indiscriminate use of insecticides in agriculture. Here coordinated action by each country's malaria, health, and agricultural services is urgently needed.

Besides physiological factors, the article reviews ways in which vector behavior creates problems. With regard to residual spraying on the inside walls of houses, such behavioral resistance may involve failure to come to rest after biting, resting for only a short period, resting on unsprayed surfaces, or resting only outside the house.

Concerning the malaria parasite itself, *Plasmodium falciparum* resistance to chloroquine has been found in parts of Brazil, Colombia, Guyana, Panama, Surinam, and Venezuela over the past 15 years. Furthermore, the rapidity of modern travel has greatly increased the chances for importing malaria cases from areas of *P. falciparum* resistance into areas now free of this problem.

Human behavior patterns that promote transmission or tend to negate control efforts include the following: lack of education, existence of isolated population groups, refusal to permit spraying, modifications of sprayed surfaces that neutralize their effect on the vector, human migrations, the practice of sleeping outdoors, house construction that encourages transmission in various ways, and industrial, public works, or other activities that tend to create vector breeding sites if proper precautions are not taken.

Finally, with regard to control program difficulties there appear to be a number of areas where significant improvements can be made. At present, financial difficulties pose the greatest potential problems, owing to inflation, the tremendously increased prices of propoxur and DDT, and growing needs created by increased technical difficulties of the kinds cited above.

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