MALARIA CONTROL IN IRAN—PRESENT AND FUTURE

M. ZAIM

Department of Medical Entomology, School of Public Health, P. O. Box 6446-14155, Teheran, Iran

ABSTRACT. The malaria eradication campaign in Iran, which started in 1958, has not been able to achieve its final goals. The technical, administrative, socio-economic and financial obstacles involved in this unfinished task are mentioned and the present status of malaria in the country is discussed. It is urged that eradication policy, presently used, be substituted by malaria control program, as defined by The World Health Organization. This would serve as a prerequisite for eventual eradication of malaria, from the country, in the future. Within such agreement, the improvement of basic health services and search for better technical means of controlling the transmission of the infection are emphasized as vital to achieve this goal. Intensive training of experienced staff, in Iran, for stimulation and promotion of relevant research and training activities in malaria control is highly recommended.

INTRODUCTION

Malaria is still the most important parasitic disease in Iran. Annual prevalence rates average 30 to 40 thousand cases with 80 to 85% of the cases occurring in the south and southeastern parts of the country, bounded by Jiroft (Kerman Province), Minab (Hormozgan Province) and Baluchistan (Sistan and Baluchistan Province).

Iran entered the world malaria eradication campaign in 1958. The attack phase covered 50% of the population by 1961 and 90% of it had entered the consolidation phase by 1963; however, the south and southeastern parts of the country had to be put under reinforced attack in 1967. Since then one or two rounds of indoor-residual spraying of human and animal dwellings per annum, accompanied by larviciding and active and passive case findings have continued.

Certainly technical factors such as resistance of anopheline vectors to insecticides and exophilic habits of some of the vectors, as well as a number of factors related to human ecology such as outdoor sleeping customs of people, relative inaccessability of some localities, reluctance of some communities to have their houses sprayed and movements of human populations (e.g., refugees, nomads, seasonal labor forces, etc.) have interfered with antimalaria activities. However, inadequacy of planning, administrative shortcomings, financial stringency; especially in the areas of training and research, shortage of trained manpower, a sharp decline in the attention devoted to malaria control by the government (other health problems have seemed more urgent and more interesting and there has been a great setback in training and recruiting young malariologists), and various logistic difficulties, such as transportation, have been equally, if not more, responsible for not achieving better control.

The resurgence of chloroquine resistance in *Plasmodium falciparum* in Baluchistan, Iran (Dr. Gh. Eddrissian, School of Public Health, Teheran; personnal communication) makes it apparent that more technical problems have to be faced in the near future.

PRESENT STATE OF MALARIA AND MALARIA CONTROL IN IRAN

Iran is an arid land of 1.6 million square kilometers, extending north to the USSR and the Caspian Sea, to Afghanistan and Pakistan in the east, to the Persian Gulf and Sea of Oman in the south and bordered by Turkey and Iraq in the west. Mountains spread in a gigantic V-shape over the nation. Between these ranges lies a high plateau where flowing waters from the mountains disappear into desert sand. The mountain ranges divide the country into three separate climatic and biotic regions: the Caspian Sea littoral; the central plateau; and the Persian gulf littoral and the Khuzistan plain.

The Caspian Sea littoral comprises the northern slopes of the Alborz mountains and the Caspian plain, a narrow strip of land, forest covered, with Mediterranean climate. The average temperature ranges between 10° and 35°C and the average relative humidity between 70 and 100%. Water sources are abundant, keeping the region green throughout the year.

The central plateau, situated between the Alborz and Zagors ranges of mountains, is very mountainous in the northwest where the ranges originate and is a somewhat lower desert in the east. The climate is dry, with average temperatures between 0° and 40°C, with hot, dry summers and cold, snow-bound winters. The few rivers originate on the southern slopes of the Alborz mountains, and these, together with "ganats" (underground water sources) and springs, provide potable and irrigation water.

The Persian Gulf littoral and Khuzistan plain, to the south of the foothills of the Zagros mountains, has a tropical climate. The average temperature ranges between 12° and 50°C. The average relative humidities range between 40 and 80%, the highest values being along the coastal plain. The coastal plains become broader as the Zagros Mountains lose height towards Pakistan.

Recently, malaria control in most of the northern parts of the Zagros range of mountains with a population of about 35 million, is in the consolidation phase. From March 1985 through March 1986, out of 1,042,727 slides actively or passively collected and tested for the presence of malaria parasites, in the area under consolidation phase, 5,246 were positive (*Pl. vivax* 95.1%; *Pl. falciparum* 3.4%; *Pl. malariae* 1% and mixed 0.5%). About 87% of these cases have been imported into this area (Malaria Eradication Unit, Ministry of Health and Medical Education, annual report, 1986). The area under consolidation phase remains under entomological and parasitological surveillance since the danger of returning malaria from in and/or outside country's endemic foci are still very great. *Anopheles maculipennis* Meigen is the major vector of malaria in the Caspian Sea littoral and *An. sacharovi* Favre and *An. superpictus* Grassi are considered as the principal vectors in the central plateau.

The southern parts of the Zagros range of mountains are still under the attack phase of malaria control. This area, with a population of about 13 million can be roughly divided into two sections. One with a population of about 9.7 million where transmission of malaria has been substantially reduced; and the other with a population of about 3.3 million (2.2 rural and 1.1 urban) where malaria transmission still occurs with varying degrees. Many of the villages which are located in the latter area are small, well scattered and relatively inaccessible with low populations. From March 1985 through March 1986, out of 1,670,980 blood smears tested for malaria parasites in the area under attack phase, a total of 20,400 were positive (82.2% *Pl. vivax*; 16.9% *Pl. falciparum* and 0.9% mixed) (Malaria Eradication Unit, Ministry of Health and Medical Education; annual report, 1986). *Anopheles stephensi* Liston is the chief vector of malaria in the Khuzistan Plain and Persian Gulf littoral. *Anopheles dthali* Patton, *An. fluviatilis* James, and *An. superpictus* are secondary vectors of malaria in this part of the country. *Anopheles culicifacies* Giles is regarded as the chief vector of malaria in the southeastern corner of Iran.

The status of insecticide resistance in anopheline vectors of malaria in Iran is given in Table 1. *Anopheles stephensi* was first recorded resistant to DDT in 1957 (Mofidi et al. 1958) and to dieldrin in 1960 (Mofidi and Samimi 1960). Due to this double resistance, residual house spraying was discontinued from 1961 until 1967. Malathion house spraying, using 50% water-dispersible powder, 2g/m^2, was implemented one to two rounds per year, starting in 1968. However, in 1976 resistance to malathion was also noticed (Manouchehri et al. 1976). Since 1978, the more expensive carbamate insecticide, propoxur, has been used. It is interesting that resistance to malathion in adult *An. stephensi* did not decrease the susceptibility of the larvae to malathion and temephos (Abate). The latter compound is presently used along with oil for larviciding of anopheline populations in the country.

Table 1. Status of insecticide resistance in anopheline vectors of malaria in Iran.

Species	DDT	Dieldrin*	Malathion
An. culicifacies	+	−	+**
An. dthali	−	+	−
An. fluviatilis	−	−	−
An. maculipennis	+	−	−
An. sacharovi	+	−	−
An. stephensi	+	+	+
An. superpictus	−	−	−

* Use of dieldrin in intradomiciliary sprays was phased out during the 1970s and is no longer recommended.

** Verification is required.

From March 1985 through March 1986, 783 tons of propoxur were applied in one or two rounds of indoor residual spraying per year, mostly in the southern part of the country (covering population of about 3.7 million) to combat anopheline vectors of malaria. Two hundred and eighty-nine tons of DDT were also used, mostly in the central and western states (covering a total population of about 1.3 million), where DDT resistance is not yet a problem (e.g., in *An. superpictus*). Malathion (4 tons) was only used in northwestern Iran (Moghan, East Azerbaijan Province) where *An. sacharovi* is responsible for maintaining a relatively small malaria transmission focus close to the USSR border.

A total of 4,401,910 liters of oil and 12,187 liters of temephos were used in larviciding programs in areas under attack phase as opposed to 4,712,476 liters of oil and 19,459 liters of temephos used in areas under consolidation phase.

FUTURE OF MALARIA CONTROL IN IRAN

The advent of DDT in 1943 made it possible to undertake the control of anopheline mosquitoes on a scale sufficiently large that it led to a malaria eradication campaign on a global basis in 1955. The program was defined as an operation aimed at cessation of transmission of malaria and elimination of the reservoir of infected cases in a campaign limited in time and carried out to such as degree of perfection that, when it comes to an end, there is no resumption of transmission. The program is usually carried out over eight or more years, in four phases; preparatory, attack, consolidation, and maintenance phases. Today, after three decades of this unique international endeavor in the field of public health, the overall results are of great interest; they justify the original concept and yet show that under some conditions it cannot be put into practice. The latter situation was re-examined at the 31st World Health Assembly, meeting in 1978, where a revised strategy of malaria control with four tactical variants of it were recommended. These tactics ranged from reduction of malaria mortality to a comprehensive countrywide antimalaria program.

Although malaria eradication should remain the final aim in Iran due to its overall impact on health and its socio-economic benefits, the existing serious technical problems and administrative limitations justify the replacement of eradication strategy, presently used, with that of "antimalaria control programs". This, of course, would form a transitional stage toward the future launching of an eradication program. Improvements of basic health services, promoting community participation, as well as finding better means of controlling the transmission of the infection are vital in such programs. Integration of specific curvative and preventive measures of malaria control in the framework of primary health care at the community level may be of great value in achieving this goal. This can only be done if appropriate ways of managing control strategies through the involvement of the community is properly studied and intensive training of medical and health personnel are properly done.

Our technical means of controlling anopheline vectors of malaria are still inadequate. Vector control based on chemical insecticides has always been a major technique to combat malaria in many parts of the world as well as in Iran. However, the emergence and spread of insecticide resistance, along with the high cost of new types of chemical insecticides and concern with environmental pollution, makes it apparent that vector control can no longer be solely dependent on the use of chemicals, and alternative methods of control have to be developed. As was mentioned earlier, *An. stephensi* the chief vector of malaria in southern Iran is resistant to DDT, dieldrin and malathion, and the expensive carbamate insecticide, propoxur, has been used against it since 1978. It is expected that this insecticide would also become obsolete in the near future due to mosquito resistance. The continuation of the control program then requires new substitutes, which of course have recently been very slow in coming.

Environmental management measures and reduction of mosquito breeding sites is of course, in the long term, the best way to control vectors of malaria. However, the high capital cost, the length of time required for completion, as well as the complexity of important works which require resources beyond those of mosquito-borne disease control programs make these measures impracticable in the present situation of the country. Small scale operations, however, are feasible and should be incorporated in control strategies and applied in combination with other methods of malaria control.

In the area of biological control of anopheline vectors certain improvements have been made in the past 10 years. However, we are still trailing a long way behind the progress made in biological control of agricultural pests. As Bay et al. (1976) and Service (1983) have already discussed, there are reasons for this. These are mainly:

1. The diversity of mosquito habitats: some mosquito larvae inhabit a variety of breeding sites at a given location, so that an effective predator in one of these breeding sites might not have a noticeable effect on the adult mosquito population as a whole.

2. Larval habitats are very unstable ecosystems. This makes the study of population dynamics of mosquitoes very difficult. Permanent water constitutes only a fraction of the available mosquito breeding sites in many localities, and in those areas where water is relatively permanent many larvae breed in side-pockets of shallow waters.

3. Mosquitoes generally have high fecundity, short generation time and high dispersal potential and not only have most established biocontrol agents little chance to discover and respond to such "instantaneous" mosquito breeding, but man even has less time to mobilize for mass release those parasites or predators that he may be successful in rearing.

4. In general mosquitoes are efficient colonizers.

5. Mosquitoes can experience large natural mortalities. However they are very resilient and can quickly recover from such population reductions. Natural mortalities of immature mosquitoes may commonly be 95% of more, yet the number of emerging adults may still constitute a problem.

These life history strategies are not very important in insecticidal control, but they can create difficulties with biological control.

Biological control tends to have been practiced on a trial and error basis (Service 1985). Failure to understand the complex ecology and population dynamics of pests is an important reason why many projects have failed or have only been partially successful. So we have to go back and start to examine the biology and gather more rigorous information on population dynamics of our vectors before conducting a sound biological control study. These kinds of studies have always been neglected in the past due to the presence of cheap and effective insecticides.

Of course ecological studies like these not only take a long time, but they also have to be tailored to the specific local area of concern. Lack of trained manpower, especially in the area of vector ecology, in Iran (as well as many other developing countries) make such studies very difficult to conduct.

Research in the area of biological control of anopheline vectors of malaria has received a top priority by the Ministry of Health and Medical Education in Iran, in the past few years. While the study on the potential use of the larvivorous fish, *Aphanius dispar* is under planning, a relatively great amount of research has been done with the bacterium, *Bacillus thuringiensis* (H-14), and the parasitic nematode, *Romanomermis culicivorax*—the two better known biological control agents.

The most famous biocontrol agent for mosquitoes, *B. thuringiensis* (H-14), is actually a microbial insecticide acting as a stomach poison. This is one of the better new insecticides though it is not without its limitations. It has been used against certain anopheline vectors in southern Iran with a very high percentage of larval control (Ladoni et al. 1986, Motabar et al. 1987). The effectiveness of *B. thuringiensis* in reducing the adult population, as a whole, and hence, bringing down the number of malaria cases is presently under investigation in Iran, by using a locally produced *B. thuringiensis* (H-14).

Romanomermis culicivorax was also tested against some of the anopheline mosquitoes in southern Iran (Zaim et al., unpublished data). However: 1) the average parasitism was only 60%; 2) the level of parasitism fluctuated greatly between sites and treatments; and 3) it was established in release sites but caused only minor reductions in anopheline larval populations. In many locations where *An. stephensi* breeds in water of high salinity, this parasitic nematode is of no use. We concluded that although *R. culicivorax* has a role in biological control of anopheline mosquitoes in southern Iran, effective long term control levels are not likely to persist from a few artificially created epizootics. On the other hand, the technical procedures of production, storage and transportation of the nematode make it costly to use for periodic innundative releases for immediate control. I believe this nematode will be of limited use in antimalaria campaigns in southern Iran, based on our knowledge at this time.

It is noteworthy that the larvivorous fish, *Gambusia affinis*, native of the Mississippi Valley, was brought to Iran for malaria control in 1928, where it was successfully bred, introduced and established in many anopheline breeding sites. However, with the introduction of fast acting insecticides the use of this biological control agent became of secondary importance and was almost neglected. Although many credits have been given to the efficiency and adaptability of this species in the past, it has its own limitations (Motabar 1978), mainly: 1) they are handicapped by matted vegetation at the water surface; 2) it is often impossible to maintain effective numbers of *Gambusia* in running water; and 3) some vectors breed in such temporary and small bodies of water that breeding of *Gambusia* is impossible.

This species was considered of limited use by The World Health Organization (1985) due to its effects on nontarget organisms, and is no longer recommended.

Integrated Pest Management (IPM) which is based on ecological principles and integrates multidisciplinary methodologies in developing ecosystem management strategies that are practical, effective, economic, and protective of both public health and the environment (Axtell 1979) is believed to be the best approach to vector control in the future. However, it should be realized that IPM is the reduction of pest problems by actions selected after life systems of the vector are understood and the ecologic as well as economic consequences of these actions have been predicted, as accurately as possible. Integrated pest management is not merely the use of several control methodologies, but the judicious meshing of disciplines and control methods to maximize the results. So, in order to accomplish this, mosquito management programs have to be more firmly grounded on more sophisticated mosquito, weather and habitat monitoring and on the prediction of mathematical models of mosquito population dynamics and the effects of implementing various actions. As a result, until more reliable, uniform and standard sampling and monitoring methods are devised, it is doubtful whether much progress can be made in understanding the population dynamics of mosquitoes and hence implementing IPM programs. Once more, the future role and contribution of vector ecologists in such programs has to be emphasized, and training of young vector ecologists has to receive a top priority.

In conclusion, we have to admit that we have not developed the technological means to control malaria in all circumstances. As Bruce-Chwatt (1980) so aptly states, "With the general recognition of the magnitude of our unfinished task, comes the understanding of pressing needs for further research into methods of malaria control and a return to the provision of adequate information on many essential aspects of parasitology, entomology, epidemiology, prevention, treatment and control of malaria".

It is a fact that there is an acute shortage of experienced staff for stimulation and promotion of relevant training and research activities in malaria control in Iran and in view of this, training of different categories of medical and health personnel and community workers is highly recommended.

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REFERENCES CITED

Axtell, R. C. 1979. Principles of integrated pest management (IPM) in relation to mosquito control. Mosq. News 39:709–718.

Bay, E. C., C. O. Berg, H. C. Chapman and E. F. Legner. 1976. Biological control of medical and veterinary pests. pp. 457–479. *In*: C. B. Huffaker and P. S. Messenger (Eds). Theory and practice of biological control. Academic Press, New York.

Bruce-Chwatt, L. J. 1980. Essential malariology. William Heinemann Medical Books Ltd., London, 354 pp.

Ladoni, H., M. Zaim and M. Motabar. 1986. The effect of *Bacillus thuringiensis* on the anopheline mosquitoes in southern Iran. J. Entomol. Soc. Iran 8: 45–52.

Manouchehri, A. V., B. Djanbakhsh and R. Rohani. 1976. Studies on the resistance of *Anopheles stephensi* to malathion in Bandar Abbas, Iran. Mosq. News 36:320–332.

Mofidi, Ch. and B. Samimi. 1960. Resistance of *Anopheles stephensi* to dieldrin in Iran. Inst. Parasitol. Malariol., Teheran, Iran. Publ. 650.

Mofidi, Ch., B. Samimi, N. Eshghi and M. Ghiassedin. 1958. Further studies of anopheline susceptibility to insecticides in Iran, result of Bosvine and Nash method. Inst. Parasitol. Malariol., Teheran, Iran. Publ. 585.

Motabar, M. 1978. Larvivorous fish, *Gambusia affinis*—A review. WHO/VBC/78-703.

Motabar, M., H. Ladoni, and M. Zaim. 1987. Larvicidal activity of Teknar on mosquito larvae in rice fields of southern Iran. Iran. J. Publ. Health (In press).

Service M. W. 1983. Biological control of mosquitoes—Has it a future? Mosq. News 43:113–120.

Service, M. W. 1985. Some ecological considerations basic to the biocontrol of Culicidae and other medically important insects. pp. 9–30. *In*: M. Laird and J. W. Miles (Eds). Integrated mosquito control methodologies. Vol. 2. Academic Press, New York.

World Health Organization. 1985. Tropical Disease Research Seventh Program Report. Biological control of vectors. 16 pp.