ARTICLES

DISEASE VECTOR CONTROL IN THE PEOPLE'S REPUBLIC OF CHINA

R. PAL[1]

1. INTRODUCTION

At the invitation of the Academy of Sciences which was very kindly extended by Dr. Liu Weide, Vice-Director, Institute of Entomology, Shanghai, I visited the People's Republic of China for 2 weeks from 28 June to 13 July 1981. Mr. Li Shubao of the Foreign Bureau of the Academia Sinica made excellent arrangements and Mr. Zhu Binhu acted as my able interpreter throughout the period of my visit. I visited 5 places—Beijing (Peking), Qufu, Jinning (Tsining), Shanghai and Hangchow—and 9 institutions.

I had the good fortune to hold extensive discussions with the technical staff of the above institutes and gave 3 lectures on international vector control in Jinning and on insecticide resistance and vector genetics in Shanghai (to a joint session of the Institute of Entomology and the Shanghai branch of the Entomological Society of China), which was followed by discussions with over 150 participants. During my tenure with the World Health Organization over a period of about 20 years, I have had the privilege of visiting most parts of the world, both developing and developed, except for China, and I therefore looked forward very much to this first visit to China. My hosts in various institutions did their utmost to make my visit both enjoyable and profitable and I owe them a great debt of gratitude. It would also be an omission if I did not mention that during a visit to the Chuasha Hygiene and Anti-epidemic Station, I expressed a desire to meet a production brigade. This visit was expeditiously arranged and not only was I able to meet the brigade but I also visited the home of the production team leader and met his family.

2. DISEASE VECTOR CONTROL

MASS PATRIOTIC HEALTH MOVEMENT. It should be mentioned that most of my impressions are based on visits to institutes of hygiene and anti-epidemic stations, and not on participation in rural field operations. As pointed out by a WHO team, the key to understanding the structure of the vector control services in China is an appreciation that the responsibility for their execution lies at the grass-roots level, i.e., with the barefoot doctors of the production brigades in rural areas or with one of the wardens in a factory or in a street committee. One of the greatest strengths of China lies in the mass patriotic health movement, by which periodic operations for cleaning up an entire village or neighborhood are undertaken. The patriotic health movement was conceived at the highest governmental level and selected the 4 pests for intensive control: namely, mosquitoes, houseflies, bedbugs and rats.

COMMUNITY PARTICIPATION. Personal protection is another commendable feature. Thus, workers are provided with ointment or socks to prevent cercaria from penetrating their skin, and many people use mosquito netting over their beds especially in areas where large mosquito populations emerge from nearby rice fields. Participation by individuals

[1] Formerly Chief, Vector Genetics and Bionomics, World Health Organization, Geneva. (Present address: 38, Ch. du Pont Céard, 1290 Versoix, Geneva, Switzerland).

and the whole community is the hallmark of disease vector control in China. The WHO strategy for "Health for All by the year 2000" rightly places emphasis on this aspect of disease prevention and control.

SETBACKS DURING THE PAST DECADE. I was greatly impressed by the scientific workers and their enthusiasm to learn as much as possible about the latest advances in vector biology and control, in order to fill in the gaps after nearly a decade of isolation. In spite of the commendable activities in disease vector control, the scientists are fully aware of the shortcomings and are eager to catch up both in research and in teaching. It was quite apparent that the institutions and scientists still have a long way to go, but considering the speed and eagerness with which this is being done, the gaps should be filled within a few years. The laboratories are fairly up-to-date by the acquisition of books, journals and reprints.

3. A BRIEF ACCOUNT OF THE INSTITUTIONS VISITED AND THE RESEARCH INVESTIGATIONS BEING CARRIED OUT

INSTITUTE OF ZOOLOGY, BEIJING. I was received by the Director (Prof. Chen Zhixiang), Prof. Xiong Yao (Dept. of Pesticides and Toxicology) and Prof. Chin Chun-teh (Dept. of Insect Physiology). The Institute, which until 1962 was an institute of entomology, now comprises 2 main sections, zoology and entomology, with 5 departments in each.

Approximately 300 scientists are on the staff of this Institute which also awards higher degrees and there is a museum attached. The Institute of Zoology is mostly concerned with insects of agricultural importance and only a small group is working on mosquitoes. The Institute publishes *Acta Entomologica Sinica*. Studies are being carried out on the taxonomy of natural enemies, parasites, wasps and on the effectiveness of *Bacillus thuringiensis* serotype 14. The production of *B.t.i.* H-14 at village level in peoples' communes has not been very successful. Some work is also in progress on insect viruses for the control of the cotton bollworm (*Anthonomus grandis*).

Dr. Xiong Yao's laboratory is engaged in studies on the synthesis of insecticides and insecticide metabolism, with a view to developing organochlorine insecticides of low toxicity.

Dr. Chin Chun-teh and his laboratory of insect physiology is working on insect nutrition. His graduate student (Nee Yi-lin) is studying the physiology of *Anopheles sinensis*, and isozymes of sibling species of *An. hyrcanus*. They have found egg differences in *An. sinensis* and *An. lesteri* from North and South China.

INSTITUTE OF MICROBIOLOGY AND EPIDEMIOLOGY, BEIJING. I was received by Dr. Gao Shou-Yi (deputy director and professor of microbiology), Dr. Zhang Shu-Yuan (assistant researcher of entomology), Dr. Wang Cheng-Xin (associate professor of entomology) and Dr. Zu Shen-hua (deputy chief of the scientific research office).

Prior to 1955 this institute was known as the Peking Institute of Epidemiology and was under the Ministry of Health. In 1958 it was transferred to the Chinese Academy of Medical Sciences. The Institute has 13 research laboratories and is staffed by about 400 personnel, of which 60% are professional staff, including associate and assistant research fellows and technicians; 40% are administrative staff.

The terms of reference of the Institute are to investigate prevention and control measures of diseases such as viral hepatitis, viral hemorrhagic fever (HF), intestinal infections such as dysentery, typhoid, etc., and quality control of biological products. In the past, the Institute also conducted a campaign against the prior mentioned 4 pests. The Institute has an excellent collection of rodents, ticks and mites, mosquitoes, flies and fleas.

Since 1973, a colony of *Culex tritaeniorhynchus* has been maintained and studies are being carried out on its ecology and control. Barefoot doctors and communal hospitals undertake the con-

trol operations. Diesel oil (10–15 ml/m^2) and fish, such as the guppy *Lebistes reticulata,* are also being used to control *Cx. tritaeniorhynchus.* DDT, benzene hexachloride, trichlorfon and fenthion were used as larvicides but now trichlorfon, temephos, fenitrothion, malathion and fenthion are in use. It seems that this species has developed high-to-moderate resistance to both organochlorine and OP compounds. It seems that this species has developed high-to-moderate resistance to both organochlorine and OP compounds. However, temephos, applied at the rate of 2 ppm as a larvicide by ground application, has given good results. Examples of resistance are:

Locality	Insecticide	Fold resistance
Kai feng	DDT	32.5
Tin jin	benzene hexachloride	33.0
Tin jin	malathion	12.9
Beijing	malathion	12.9

Pyrethroids such as Decis® (deltamethrin) are being used for fly control. It has been observed that Decis has residual effectiveness extending to about a month. A sample of Actellic® (pirimiphos-methyl) was obtained from ICI (UK) in 1978. WHO resistance test kits for flies and fleas are available in the Institute.

Experiments have also been carried out with high-voltage light to attract mosquitoes and ULV application of a malathion and fenitrothion mixture has been found very effective. During the earthquake in 1976–77 at Tang Shan, ULV spraying of a mixture of malathion and fenitrothion gave excellent results in the control of mosquitoes and flies.

In addition to research on *Cx. tritaeniorhynchus,* studies are also being carried out on *Cx. pipiens pallens* and *Aedes albopictus.* These include, (a) investigation on the ecology of *Cx. tritaeniorhynchus* in the Beijing area, (b) determination of the physiological age of females by the ovariole dilation after oviposition, (c) observations on laboratory colonies, (d) hibernation of *Cx. tritaeniorhynchus,* (e) effect of insecticides.

A rapid increase in the number of rodents has been observed during the past few years. Instead of warfarin, diphacinone is being used and a new rodenticide, Brodifacoum, is being introduced.

SHANDONG INSTITUTE OF PARASITIC DISEASES, JINNING. I travelled overnight from Beijing to Yanzhou by train and was put up at Qufu. Dr. C. T. Wang (Director of the Institute), Dr. Zheng Yinying, and Mr. Wang Dailian very kindly received me at the railway station. We spent 2 July at Qufu where Dr. Wang briefed me about this provincial institute and its work, using maps and charts which were brought from Jinning.

The Province of Shandong, one of the largest provinces in China, is situated along the coast in the northern part of East China. Part of the province is hilly or mountainous and the rest is extensive plains. It has 116 counties. Before liberation, life was miserable owing to lack of sanitation and because of parasitic diseases such as kala-azar, filariasis and malaria, intestinal worms and liver flukes. The Institute was established in 1950 and has the honor of being the first parasitic diseases institute in China. Some remarks on individual diseases are given below.

KALA-AZAR has been controlled. The vector *Phlebotomus* as well as the reservoir of infection—dogs and wild animals—are under constant surveillance. The bionomics of sand flies, including their breeding and resting habits, are under study. Control was instituted by one application of DDT and benzene hexachloride in late May 1973. This has resulted in complete eradication of sand flies for 8 years after spraying. There is also no evidence of resistance to insecticides. Cases were treated with sodium antimony; a course of 6 injections resulted in complete cure in 93% of cases. Dermal leishmaniasis has also been brought under control.

FILARIASIS occurs in 15 provinces in China; both *Wuchereria bancrofti* and *Brugia*

malayi are present. In Shandong, bancroftian filariasis is most prevalent. Mass surveys were carried out in 1958; 74 counties were infested with *W. bancrofti* while 10 counties in the southern part were highly endemic with 20–30% microfilaria rate and 5–10% of the population showed elephantiasis. The principal vectors are the *Culex pipiens* complex, especially *Cx. p. pallens,* and *An. sinensis* and *An. lesteri.* During 1958–60, more than 100,000 cases were discovered and all were treated with hetrazan. After a break of nearly 10 years, surveys were conducted in 1970 and microfilaria rates were less than 1%. They dropped further to 0.3% a year later as a result of the administration of medicated salt. Strict surveillance is being maintained at present. *Culex p. pallens* is a domestic species; the adults hibernate in winter, mostly in pits. By closing these pits, hibernation of this species can be arrested. To some extent the residual application of DDT/benzene hexachloride inside houses further reduced mosquito density. The filaria rate also dropped and the infection seems to have been controlled. This Institute is now using a membrane filtering technique for mass surveys and evaluation purposes.

In 1978 resistance was observed to DDT, benzene hexachloride, malathion and fenitrothion in larvae of *An. sinensis, Cx. pipiens pallens* and *Cx. tritaeniorhynchus.* A slow-release preparation of temephos is now being used. Tests have also been carried out with *Bacillus thuringiensis* serotype H-14 and it has been found that, while *B.t.i.* H-14 is satisfactory for the control of *Cx. pipiens,* it is not effective against *An. sinensis.*

MALARIA. Since many of the institutions visited are involved in malaria research and control, a brief resumé of work is given in section 4 for the sake of continuity.

INSTITUTE OF ENTOMOLOGY, SHANGHAI. This Institute was established in 1959. These are 5 laboratories concerned with the following:

1. Insect physiology—hormones and pheromones of pink bollworm (*Pectinophora gossypiella*) and mosquitoes.
2. Insect toxicology, through 3 research groups, dealing with: resistance to insecticides, genetic control of mosquitoes and residue analysis of insecticides applied in the environment.
3. Insect virology.
4. Insect taxonomy and ecology—relationship between rice paddy pests and natural enemies. (The objective is the minimal use of pesticides without contamination of the environment; biological control by the use of parasite wasps is also being carried out in paddy fields.)
5. Experimental technology—assisting other laboratories to make and maintain equipment, instruments, etc.

In addition there is an excellent insect museum with 475,000 specimens and a library with 47,000 books. About 100 periodicals and journals are received from abroad.

In the laboratory of insect toxicology, studies are being conducted on cuticular penetration, insecticide metabolism, and susceptibility to insecticides. No significant difference has been found in acid phosphatases in trichlorfon susceptible and resistant strains. But there was nearly 3 times more carboxyesterase in resistant than in susceptible strains. It seems that in trichlorfon resistance, carboxyesterases are an important mechanism. The resistance can be overcome by (a) use of an insecticide with an OP synergist (Kitazui), (b) use of mixtures of insecticides, (c) use of insecticides in rotation. Biochemical mechanisms of resistance to trichlorfon in *Culex* is being investigated.

Experiments are being carried out on *B.t.i.* H-14 with WHO support. It has been found to be effective against *Culex* species but not the anopheline species, as also observed at Jinning. It seems formulation is the greatest problem. As stated earlier, the production of *B.t.i.* H-14 at village level in peoples' communes has not been very successful according to the Institute of Zoology, Beijing.

Genetic studies are in progress on *Cx. pipiens pallens* and *An. sinensis*. Mosquitoes have been exposed to X-rays and chemosterilants to obtain translocations. Sixteen mutants have been studied in *Cx. p. pallens*. This laboratory has been successful in rearing *An. balabacensis*,[2] the principal vector of malaria on Hainan Island (second largest island) which is difficult to control because of its habits (see section 4). It is, of course, a very important vector in South-East Asia. Studies on the sibling species of *An. balabacensis* are contemplated in collaboration with the London School of Hygiene and Tropical Medicine, UK.

The group working on residue analysis is mostly engaged on residues in crops and animals. Very little DDT is now used, and then only for cotton; a mixture of benzene hexachloride and parathion is being used in paddy fields; fenitrothion and malathion are also used to control rice pests. Most of the pesticides are made in the country.

During a discussion with the various research groups, it was stressed that the control of *An. balabacensis* has the highest priority in research because no successful method has yet been found. It was clear that the genetic control of *An. balabacensis* would be very difficult. Dr. Liu Weide was especially interested in determining the frequency of resistant genes in a field population of mosquitoes. Control of mosquitoes in rice fields also poses a special problem to scientists in China.

INSTITUTE OF PARASITIC DISEASES, SHANGHAI. I was received by Prof. T. C. Chow, Vice-Director (malaria) and Prof. Xu Jingjiang (medical entomology). This Institute was established in 1950 at Nanking and was moved to Shanghai in 1956. The terms of reference of the Institute were to study the problem of major parasitic diseases of the country, such as filariasis, schistosomiasis, malaria, kala-azar, hookworm, etc.

The Institute is concentrating on 5 major parasitic diseases as mentioned above; in addition, it is responsible for training, organization of national programs, and exchange of scientific information. There are 300 staff members, 222 of whom are research workers (108 graduates and 114 senior and junior research workers). The rest are administrative staff. The Institute has a very good library and over 100 journals and periodicals are received.

The Institute has carried out a number of projects concerned with, for example, (a) epidemiology of schistosomiasis, the search for new drugs and new ways of diagnosis, biology and biochemistry of snails, etc., (b) epidemiology of malaria, pilot control of malaria, use of integrated methods, treatment, chemoprophylaxis, environmental management, occasional use of pesticides by residual spraying, study of vectors in the north and south malaria zones, ecology, biology and systematics of *An. sinensis, An. lesteri, An. minimus* and *An. balabacensis* on Hainan island, biological studies on malaria parasites *P. vivax*, resistance of *P. falciparum* to chloroquine, (c) epidemiology of filariasis, especially its distribution, biology of vectors, testing of new drugs other than hetrazan, (d) hookworm, how to prevent disease transmission, testing new drugs, etc., (e) kala-azar, which in 1958 was completely under control, but has now reappeared in frontier areas; the relationship between vectors and humans is under investigations.

SCHISTOSOMIASIS has been controlled by using integrated control methods including case finding and treatment, safe disposal of feces, and control of snails by environmental management (filling up old ditches and digging new ones in the mass patriotic health movement). In 1956 there were 16 million cases of schistosomiasis and in 1980 only 2.4 million, despite the set-back during the cultural revolution (work was stopped, anti-schistosomiasis stations were closed). Personal protection is ensured by applying a

[2] This is probably *Anopheles dirus* Peyton and Harrison (Editor).

chemical or paste and by supplying stockings for people working in paddy fields.

FILARIASIS is present as both bancroftian and brugian. In 1960 some 20 million cases were recorded; the figures for 1980 are being compiled. Medicated salt, control of *Cx. p. pallens* and *Cx. quinquefasciatus* and environmental management have given good control of the disease. *Brugia malayi* is transmitted by *An. lesteri, An. sinensis* and *Mansonia* spp.

DEPARTMENT OF VECTOR BIOLOGY AND CONTROL. This department is engaged in the following studies on mosquito vectors, vectors of kala-azar and the intermediate hosts of schistosomiasis:

MOSQUITOES. Studies are being carried out on taxonomy, biology, ecology and control of mosquitoes; 50 species of anophelines are found in the country—the most important being *An. minimus, An. sinensis, An. lesteri, An. balabacensis, An. jeyporiensis* and *An. fluviatilis. Anopheles sinensis* is a complex of a number of sibling species—*An. sinensis, An. lesteri, An. kiangsuensis* and *An. yatsushinoensis;* the differences are based on the eggs and on feeding habits. Furthermore, *An. sinensis* is widely distributed, but *An. lesteri* is only found along rivers. Environmental management, use of biological agents (such as *Romanomermis* on which the Institute would like to have all the literature available, and *B.t.i.* (H-14) and integration of all available methods are being tried for the control of anopheline mosquitoes, especially *An. balabacensis.*

SNAILS. *Schistosoma japonicum* is prevalent in 12 provinces of China. The endemic area is divided into 3 regions—plains, mountainous and hilly regions, and swamps. The principal intermediate host is *Oncomelania hupensis.* The control of schistosomiasis has now been achieved by environmental management, particularly water-level reclamation and special plantings. Molluscicides (such as niclosamide, sodium pentachlorophate, bayluscide and chloroacetamide) are also being used. The mass patriotic health movement has been one of the important factors in the control of schistosomiasis: the existing drains with snails were filled in and new drains were dug in parallel.

CHUNSHA COUNTY HYGIENE AND ANTI-EPIDEMIC STATION. This station covers an area of 200 km² and has a population of 640,000; the population density is thus very high. The basic function of public health stations throughout the country is to promote public health and prevent epidemics.

This station has a staff of 81 (senior doctors 20, middle-level 39, junior doctors 4, administration staff 4, drivers 4, and 10 others such as accountant, cook, etc.). The annual budget is 400,000 yen per year (approx. $200,000) which is paid by the government, exclusive of drugs, vaccines, etc. On average, during a year, 4 mass movements are organized for general cleaning, treating of breeding places, environmental sanitation (disposal of manure, etc.).

The main problems are (1) training of the people in good sanitary habits, (2) management of water supplies (80% of drinking water is from wells), the ultimate aim being to provide a piped-water supply, (3) management of waste and treatment of manure, every household having a manure pit and pigsties and (4) public health education to change the habits of the people (the most difficult).

The most common diseases occurring in this area are liver diseases (viral), diarrhoeal diseases, a few cases of malaria, filariasis and Japanese B encephalitis. Schistosomiasis has been eradicated (only 27 old patients still survive—one is 80 years old). The 4 pests under attack are mosquitoes, flies, bedbugs, and rodents.

VECTOR CONTROL. There are 4 large towns, 27 communes, and 332 brigades in this county. The area under cultivation is about 200,000 hectares—mainly rice, cotton and vegetables; there are 2 rice crops a year. The main insects are mosquitoes *(Cx.p. pallens, Cx. tritaeniorhynchus, An. sinensis, Ae. albopictus),* house flies (*Musca domestica*) (2 subspecies), cockroaches, and rodents.

The following control methods are employed:

Mosquitoes. Management of environment—by mobilizing the patriotic mass movement—filling up breeding sites, turning water containers upside down, providing covers to water jars, sealing the jars, and maintaining the flow of waste water and sewage. Biological control by the use of *Gambusia* in ditches, small streams and pools, big pools, domestic jars and water containers, reservoirs (used for preventing spread of fires), unused wells, and rice fields.

Physical control by the use of attraction to UV lamps, water management in the cultivation of rice, chemical control by the use of OP compounds (trichlorfon, dichlorvos, malathion, fenitrothion) mainly as larvicides and also temephos.

Personal protection by the use of mosquito nets (cost $2–$4 each), mosquito coils (cost 4 cents each) and fumigation. To meet emergencies, ULV application of insecticide is instituted, the sprayer in use being of the type Dong Fanghong 18.

House flies. Breeding places are mostly in pig and cow manure, other excreta and foods, and in restaurants. Control is effected by swatting, traps (using the guts of fish and chicken, etc.), paper coated with plant oils, etc.

Cockroaches. By mobilizing people to catch them, by using traps (boxes with food) or spraying with insecticide (trichlorfon) in houses.

Rodents. Twice a year, the patriotic mass movements are mobilized to dig or flood the burrows, to catch the animals in traps, and occasionally to use rodenticide.

Dogs. There are no rabies and there are very few dogs (about 200), all of them being inoculated.

Lice and Fleas. Are rare.

Mosquitoes, flies and cockroaches are the most important pests. Each brigade or professional team has one person trained in vector control in which public health education forms a major part. Inoculation of children against measles, whooping cough, Japanese B encephalitis and typhoid is highly recommended.

I was told that the life expectancy in 1951 for males was 53.8 and for females 56.3 years; in 1981 it had increased to 70.2 and 75.3 years, respectively. A professional team of 10 staff members is in charge of vector control. Many such stations have been established around the towns, by brigades. The staff meet once a month and report on the assigned work. They are then given new tasks to check in the villages (without missing any breeding places) including management of vector population density, to advise the government of the commune, and to breed and distribute *Gambusia.*

ZHEJIANG INSTITUTE OF EXPERIMENTAL MEDICINE AND HYGIENE, HANGZHOW. I was received by Dr. Xu Zhou, Prof. Sung Chang Tsun (Dept. of Parasitic Diseases) and Dr. Chen Jian Shien (an entomologist in charge of vector control). The Institute was founded in 1950 and was the first of its type; its terms of reference are to: (1) deal with the problems of health in the province, (2) carry out experimental research work both in the laboratory and field, and (3) treat patients in the hospital.

The public health problems are mostly related to parasitic diseases—schistosomiasis, hookworm, filariasis, malaria. The Institute carries out surveys of epidemics and control of vectors of the above-mentioned diseases.

The staff numbers over 380 of whom 240 are professionals. The annual budget is 1 million yen (approximately $500,000).

VECTOR CONTROL. *Anopheles sinensis* is controlled by DDT and HCH house spraying as well as stocking *Gambusia* fish in rice fields. *Culex p. pallens* is found in the cities and prefers to lay eggs in polluted waters. Trichlorfon is used as a larvicide. *Aedes albopictus* density is rather low. Water jars are turned upside down routinely and overwintering eggs are controlled by pouring in hot water.

Resistance in *Culex* species has been found to DDT, benzene hexachloride, malathion, and fenitrothion; DDT and benzene hexachloride have been banned, but public health workers can still obtain

DDT. *Anopheles sinensis* is also resistant to DDT but susceptible to benzene hexachloride, malathion and fenitrothion.

At present, work is being carried out on the following: (a) new insecticides for the control of *An. sinensis;* pyrethroids such as deltamethrin are being tested, (b) resistance of *Culex* to trichlorfon (more than 50-fold resistance has been observed).

SCHISTOSOMIASIS has been controlled. Surveillance is being maintained for the detection of hookworm and filaria cases. The Elisa test is used.

MALARIA (see section 4).

CHINESE ACADEMY OF MEDICAL SCIENCES, BEIJING. I was glad to have an opportunity to spend some time with Prof. C. C. Wu, Vice-Director of the Chinese Academy of Medical Sciences, who is one of a dozen medical entomologists in China. Professor Wu is a well-known authority on sand flies and kala-azar. The Chinese Academy of Medical Sciences is in the process of reviving the National Committee on Malaria Research under the chairmanship of Dr. T. C. Chow, Vice-Director, Institute of Parasitic Diseases, Shanghai. It already has a National Committee on Schistosomiasis.

Malaria is still a problem in China with sporadic epidemics. (See section 4.) The control of tertian malaria is receiving attention both by means of radical treatment and by residual spraying of houses; these were stopped during the cultural revolution and *An. minimus* has again appeared. Prof. Wu is strongly of the view that, besides treatment and control activities, much more research should be carried out on the biology of the malaria parasite, e.g. on what are the main factors needed to complete the life cycle of the malaria parasite.

MINISTRY OF HEALTH. The Minister, Dr. Qiau Xinzhong, was absent and so was Prof. Xue Gongchuo, the Director of the Bureau of Foreign Affairs. I was received by Dr. Wu Ta Shou, Deputy Chief, Division of International Organizations, Bureau of Foreign Affairs. He commented upon the patriotic health campaigns at the county, provincial and national levels and referred to the campaign against the 4 pests. There was a setback in the last few years, but now the situation has improved. Control of vector-borne diseases is being given a very high priority by the Ministry.

4. MALARIA SITUATION IN THE PEOPLE'S REPUBLIC OF CHINA

Malaria is still one of the major parasitic diseases in China. Epidemiological investigations during 1950 indicated that 30 million malaria cases occurred yearly and that 70% of the counties were malaria stricken. The population at risk at that time was about 350 million.

There are 3 malaria zones: 1) Zone south of 25°N latitude with *An. minimus* as the main vector. All 3 species of malaria parasites are present with *P. falciparum* being the predominant one. In addition to *An. minimus, An. jeyporiensis* is the secondary vector; *An. balabacensis* being an important vector in the jungle areas of Hainan island. *Anopheles sinensis,* although found in large numbers, is a relatively inefficient vector. 2) Zone between 25 to 35°N latitude with *An. lesteri* and *An. sinensis* as vectors. Usually *P. vivax* is prevalent although cases of *P. falciparum* are also found. 3) Zone north of 33°N latitude with *An. sinensis* as a vector. Only *P. ovale* infections are prevalent. *Anopheles sinensis* is the main vector and *An. messeae* is found in Yili Valley in the northwest of Xinjiang region. Different control measures were undertaken according to the malaria zone. In the first zone indoor residual spraying and mass drug administration was carried out. On Hainan Island, antilarval measures were also undertaken to control *An. balabacensis.* In the second zone indoor residual spraying was carried out once a year and in the third zone measures for vector abatement suited to local conditions were instituted.

At Shandong Institute of Parasitic Diseases investigations are being carried out on *An. sinensis.* It is a semi-domestic exophilic species, found mainly in cattle

sheds and outdoor shelters. Window trap collections have been made as well as collection after tagging mosquitoes with P_{32}. Breeding places are widespread.

Malaria control has been achieved by chemotherapy, by residual spraying of all cattle sheds with DDT and HCH and by instituting anti-larval measures in and around the villages. ULV application of a malathion/fenitrothion mixture has also been carried out. Strict surveillance is being maintained. Qinghaosu, a new type of squiterpene lactone with low toxicity, is being tested as an antimalarial drug.

At the Department of Epidemiology, Institute of Parasitic Diseases, Shanghai, maps and charts are being maintained with regard to the incidence and control of malaria. Malaria control on Hainan Island is presenting a special problem. Three to six malaria cases per 1000 population are persisting because of *An. balabacensis* which is exophilic and difficult to control. Chloroquine resistance in *P. falciparum* has also been found on the island. Problems concerned with the control of *An. balabacensis* and diagnostic tests for case detection are now being studied on a priority basis. Residual spraying with DDT and mass treatment of chloroquine are being carried out.

The Zhejiang Institute of Experimental Medicine and Hygiene, Hangzhow, is engaged in studies on vector species. The chief vectors of malaria in this area are the *An. sinensis* group and *An. lesteri*. These species rest in houses and prefer animal to human blood. The majority of *An. sinensis* (58%) were found resting in houses and 92% had animal blood. In June–September, the infection rate in *An. lesteri* was 0.79 times higher than in *An. sinensis*. Therefore *An. lesteri* is regarded as the main vector in this province. The density of this species has dropped rapidly as a result of changes in the environment in the field, as well as ecological improvements. The 2 species differ in their behavior. *Anopheles lesteri* overwinters in egg stages whereas *An. sinensis* overwinters in the adult stage; the peak density of *An. lesteri* in this province is during the summer months. *Anopheles sinensis* has 2 biting peaks—in the evening at 2300–0300 hr and at dawn, whereas *An. lesteri* has only one peak—between 2300 hr and 0300 hr.

Malaria control is being carried out by stocking *Gambusia* fish in rice fields. In addition, DDT and benzene hexachloride are used for spraying. Bioassay and resistance tests are carried out using WHO test kits, and resistance to DDT has been found in *An. sinensis* (less than 5% mortality after 1 hr exposure to 4% DDT papers).

PRESENT STATUS OF MALARIA AND SOME TECHNICAL PROBLEMS. According to the statistics collected in 1979, about 2.3 million cases were reported in the whole country. In the southern part of China *P. vivax* is the predominant species (65.9%), *P. falciparum* (35.1%) and *P. malariae* only 0.02%. But in the central and northern parts, *P. vivax* alone was found. *Anopheles sinensis,* which is widely distributed, is difficult to control in view of its exophilic habits. *Anopheles balabacensis* is the most important vector in the persistent foci in forested hill regions on Hainan Island and is difficult to control as in the neighboring counties. Control of mosquitoes in rice fields was also posing a special problem to scientists in China. An efficient method is lacking to prevent the spread of malaria due to chloroquine resistant strains of *P. falciparum* found on Hainan Island and the China-Burma border in Yunnan province. The scientists are confident that these problems will be overcome in the course of time.

5. CONCLUSIONS

In my opinion highest priority should be given to train young medical entomologists in different vector-borne diseases and different aspects of vector control. In addition to regular courses up to M.Sc. level, workshops and seminars should be organized to give practical field orientation. To fill in the void created during the past decade, updating of information and libraries in most Institutes should receive a high priority. The re-

search being carried out also needs to be augmented by introducing modern techniques and concepts. Scientists from advanced laboratories should be encouraged to spend sabbatical leave to work in collaboration with Chinese scientists.

On the other hand medical entomologists and vector control specialists from the developing countries should visit China to gain first hand experience of primary health care and individual and community participation at its best and especially the mass patriotic health movements. This cross fertilization at Technical Cooperation between Developing Countries (TCDC) level should greatly assist WHO in fulfilling its goal for "Health for All by the year 2000" based on Primary Health Care.

EFFECTIVENESS OF *BACILLUS THURINGIENSIS* SEROTYPE H-14 AGAINST *CULEX QUINQUEFASCIATUS* IN SMALL DITCHES

R. E. McLAUGHLIN AND T. FUKUDA

Gulf Coast Mosquito Research, Agricultural Research Service, U.S. Department of Agriculture, Lake Charles, LA 70601

ABSTRACT. *Culex quinquefasciatus* larvae were effectively controlled by applications of *Bacillus thuringiensis* serotype H-14. Two roadside ditches were treated every 1–4 days from August 16 through October 14, 1979 with ca. 0.6 gm/m^3 of a preparation assayed at 491 International Toxic Units per mg. A large, continuously ovipositing adult population maintained a newly hatching larval population throughout the test. A population of 4th instar and pupae developed in the untreated ditch as normally expected, but these stages were not produced in the treated ditches.

Culex quinquefasciatus Say is a serious pest in the southern United States both as an annoyance and as a potential carrier of disease (Chamberlain et al. 1959, Villavaso and Steelman 1968). Populations of *Cx. quinquefasciatus* in urban areas develop in drainage ditches polluted with various types of household and commercial organic waste products. Storm sewer construction also provides breeding habitats in cities. Higher costs of diesel oil as well as commercial larvicides and undesirable side effects have increased the need for alternative control agents. Williams and Palmisano (1981) reported satisfactory results in roadside ditches with methoprene and indicated costs would be lower than for diesel oil. Use of manure disposal lagoons from farm animals provides a breeding habitat that has increased in recent years (Axtell et al. 1975, 1980; Ruiz and Axtell 1978). The high organic content of these lagoons was suggested as a contributing factor for low efficacy of the chemicals at recommended label rates.

Bacillus thuringiensis var. *israelensis* (flagellar antigen serotype 14) (deBarjac 1978, Goldberg and Margalit 1977) was applied to two small ditches containing household effluent and *Culex quinquefasciatus* larvae. The test was conducted from August 16 through October 11, 1979 at Lake Charles, Louisiana. An adult population of mosquitoes provided large numbers of continuously hatching egg rafts throughout the test. The purpose of the test was to observe the effect of *B.t.* H-14 when applied on a regular schedule against a continuously hatching population of mosquitoes.