and not to any residual lindane action. Wind velocity during the test was 2–3 miles per hour and the temperature was 40 degrees F.

Results of the dieldrin test, in terms of per cent reduction after the time intervals named are as follows: 2 hrs., 85 per cent; 12 hrs., 75 per cent; 24 hrs., 50 per cent; 36 hrs., 76 per cent; 48 hrs., 67 per cent; 72 hrs., 30 per cent.

3. *Second Lindane Test:* A 15 square mile plot at Umiat was treated with lindane on 12 July, 1952. Very high pretreatment counts were obtained, the highest being an estimated 800, and the average 350. This average count prevailed in the control area throughout the test period of 9–15 July. Reductions given represent averages between inner and outer zones of the test plot. The outer zone of the plot was that area within one-half mile of the plot boundaries. Wind velocity during the spray flight was eight miles per hour and the temperature was 50 degrees F.

Species found at Umiat included *Aedes nearcticus, Aedes communis,* and *Aedes* sp. (probably *A. punctor*). No larvae or pupae were found in the many pools, indicating that the single generation of mosquitoes per year had all emerged. Jachowski and Schultz (1948) studied the biologies of mosquitoes at Umiat in 1947 and state that no pupae were found after 5 July.

Results of the test in terms of per cent reduction after the time intervals named are as follows: 15 min., 50 per cent; 5 hrs., 95.5 per cent; 22 hrs., 95 per cent; 43 hrs., 86 per cent; 50 hrs., 82 per cent.

SUMMARY: Field tests with the insecticides lindane and dieldrin were conducted by personnel of the Alaska Insect Control Project during the summer of 1951. Galena, Alaska, was treated with both lindane and dieldrin, and Umiat, Alaska, was sprayed with lindane. Results indicate that a 10 per cent emulsion concentrate of either lindane or dieldrin applied at the rate of 0.05 lb. of toxicant per acre is quite effective as an adulticide for several northern species of mosquitoes for periods of time up to three days.

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MOSQUITO AND MALARIA CONTROL IN TAIWAN (FORMOSA)

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Malaria is the most important endemic disease in Taiwan. It affects the majority of the rural inhabitants occupying about 75 per cent of the total population (7,500,000) of the island. Generally speaking, the hilly regions are hyperendemic, with spleen rate 40–85 per cent and parasite rate 15–40 per cent. The plains have moderate or low endemicity, with spleen rate 10–40 per cent and parasite rate 2–15 per cent. The coast has low endemicity (i.e., is "healthy"), with spleen rate less than 5 per cent and parasite rate less than 2 per cent.

As early as 1909 the control of malaria was started by the Japanese Government which was then occupying Taiwan. In 1913 the order and regulations for malaria control were issued by the government.

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After China took back Taiwan in 1945, DDT was introduced for mosquito control, newer anti-malarial drugs were tested and over one hundred local anti-malaria stations were re-established.

Mosquito and malaria control work done from 1901 to 1951 in Taiwan can be summarized in the following two periods.

I. FIRST PERIOD: 1901–1944 (Work done by the Japanese Government)

A. *Mosquito studies.* The earliest scientific report on anopheline mosquitoes in Taiwan seems to be the one by Kinoshita (1901) who described the occurrence of *A. hyrcanus sinensis.* Up to the end of this period, 16 species of anophelines were reported (Morishita, 1936; Matumoto and Motoura, 1939; and Omori and Noda, 1943). Seven species were reported to be naturally infected with malaria parasites (Anazawa, 1931). The work done during this period was mainly on mosquito survey, with few studies on bionomics such as the *sinensis* density (Katagai, 1931; Koidzumi and Tsuchimochi, 1926), blood meals (Morishita and Katagai, 1938) and time of feeding (Omori, 1942).

B. *Malaria control.* Since 1910 many local anti-malaria stations, each with one technician and microscope, were established in different parts of the island, the number of stations being increased to 185 by 1934 and over 200 by the end of this period. General blood survey was done monthly by these stations, and nearly half of the population of the island was examined each year. Those positive for malaria parasites were treated with quinine. As a result of the establishment of these stations malaria generally decreased in prevalence.

Some other methods were also tried, such as drainage and filling, clearing bushes and grasses around human dwellings, encouraging the use of mosquito nets and fumigation, introducing *Gambusia* in 1911, and transplanting cinchona trees in 1922. However, these measures were not carried out systematically and thoroughly.

During World War II, malaria in Taiwan suddenly increased because of the scarcity of drugs and the evacuation of people from the large cities into the country.

II. SECOND PERIOD: 1945–1951 (Work done by the Chinese Government with the assistance of the Rockefeller Foundation and of the Sino-American Joint Commission on Rural Rehabilitation)

During this period malaria again decreased in prevalence as a result of the widespread use of atabrin freely distributed by the UNRRA, the mosquito control activities by the Taiwan Malaria Institute with the help of the Rockefeller Foundation and the JCRR, and the re-establishment of 144 local anti-malaria stations.

A. *Establishment of the Taiwan Provincial Malaria Research Institute.* In July 1946 R. B. Watson of the Rockefeller Foundation and the writer were asked by the Government to make malaria reconnaissance and to find a suitable field station for malaria studies on the island. Four months later, Chaochow, a small town in southern Taiwan, was selected as the station and training of personnel was started by Dr. Watson and the writer with the financial support of the Rockefeller Foundation. In the following year two branch stations were set up separately at Keelung, northern Taiwan and at Shui-li-keng, central Taiwan. The latter branch was closed in 1948 but resumed its activities in April 1949 at Taichung, central Taiwan. All these stations were officially established in April 1948 as the Taiwan Provincial Malaria Research Institute by the Taiwan Provincial Government.

Unfortunately the Rockefeller Foundation withdrew its support from whole China in September 1949. Since the beginning of 1950 the JCRR has given financial help to the Malaria Institute.

B. *Mosquito studies. Anopheles fluviatilis* was added to, and *A. kochi* was removed from the list of Taiwan anophelines (Chow, 1949). An extensive collection of culicine mosquitoes was first made in Taiwan by Chow (1950).

A. minimus was proved as the impor-

tant vector of malaria (Chow *et al.*, 1950), but *A. hyrcanus sinensis* still needs further confirmation (Chow *et al.*, 1951). As to the other five species reported by Anazawa (1931), they seem not important in malaria transmission in Taiwan. The seasonal prevalence of anophelines in human dwellings, animal stables and ground pits was reported by Chang *et al.* (1950), while detailed study on their resting places in human dwellings was made by Chow *et al.* (1951). Time of feeding, egg-laying behavior, host preference, relation of anopheline breeding and rice cultivation, and other bionomics studies were also in progress.

C. *Malaria control.* (1) Drug control: In order to study the efficacy, optimum dosage and reaction, if any, of the Oriental people to certain newer anti-malarial drugs, field trials of chloroquine (SN-7618-5) and chlorquanide (paludrine) were carried out since 1947 in central and southern Taiwan (Watson *et al.*, 1950, a and b).

(2) DDT larvicide and residual spraying: The results of these experimental controls will be reported in another paper; but it may be noted here that with the help of J. C. Carter of the Rockefeller Foundation these experiments were carried out in southern Taiwan since 1947.

As the common solvents for DDT, such as xylene and kerosene, were expensive and difficult to obtain in quantity, some local materials were searched for this purpose. Camphor oils (brown and white) were found to be satisfactory (Chow *et al.*, 1951, a) and used for making DDT emulsion with Triton X-100 as emulsifier. Paddy fields, which are the main breeding place of *A. hyrcanus sinensis*, were sprayed with DDT emulsion at the rate of 0.05-0.1 lb. of technical DDT per acre of water surface, at intervals of ten days during the crop seasons. Hudson "Industrial" hand sprayers with nozzle "LN 2" of Spraying Systems Co., at discharge rate of 2 gal. per hr., were used. It is worthwhile to mention here that DDT emulsion at the above dosage showed no damage to rice crops.

For indoor residual spraying, 50 per cent wettable powder of DDT was used, and different dosages of 0.5, 1 and 2 gms. of technical DDT per sq. m. surface, twice a year, were tested. The "Clinton" Power Sprayers, Hudson Wheelbarrow sprayers and hand sprayers (both Hudson and Lofstrand) with flat nozzle "8002" were used. No chemical or biological tests of DDT residual effect were done.

(3) Automatic siphons: Five automatic siphons were built with the help of J. C. Carter in five streams at Keelung, northern Taiwan, in July 1948 for controlling *A. minimus* larvae.

(4) Rehabilitation of local anti-malaria stations: In 1950-51 a total of 144 stations have been re-established in different parts of the island. The technicians, who are in charge of these stations and have had good experience on blood examination, were given a refresher course and later on were under the supervision of the appropriate branches of the Malaria Institute. Each station was equipped with one microscope and other supplies, anti-malarial drugs, bicycle, etc. The activities of these stations are to carry out regular blood survey and distribution of anti-malarial drugs to the patients, either in the dispensary or in the field of their own area. It is interesting to mention that these stations are practically supported by the communities they serve.

By the administration of anti-malarial drugs (paludrine and atabrin) to the positive cases examined in these stations, the parasite rate has been reduced from 18.6 per cent among 244,566 people in July-December 1950 to 11.7 per cent among 236,760 people in January-June 1951.

D. *DDT plant.* A DDT plant was established in 1948 in southern Taiwan, now known as the Taiwan Agricultural Chemical Works. The plant is in good condition and its products are of good quality. However, due to lack of a sufficient amount of benzene, only 20 tons of technical DDT have been produced per month. The plant has been producing 10 per cent DDT dust, 5 per cent DDT solution in refined kerosene and 25 per

cent DDT emulsion concentrate in camphor oil, and is making 50 per cent DDT wettable powder.

III. OUTLOOK OF MALARIA CONTROL IN TAIWAN

Based on our studies and experimental control in Taiwan since 1946, it appears that DDT residual spraying is the control method of choice. As to larvicide, it needs strict and constant supervision of the laborers. For paddy field spraying it is very difficult to reach the water surface when the rice plants grow over 80 cm. in height. It is not suitable as the sole method for malaria control in a place where paddy fields occupy an enormous area and form the main breeding place of the mosquito vector.

The mosquito vectors in Taiwan are domestic in habit, and the possibilities of control through limited selective spraying of human dwellings (bedrooms and part of sitting rooms) seem worthwhile to be tested in the field as suggested by Chow *et al.* (1951).

As Taiwan has an excellent foundation on malaria work, a well-developed malaria institute, over one hundred local anti-malaria stations, a large number of trained personnel, good communication and co-operative people, the prospect seems very encouraging of controlling, if not eradicating, malaria from the whole island within a few years. Francisco J. Dy, Malaria Adviser of the Western Pacific Regional Office of the World Health Organization, visited Taiwan in August 1951 to arrange with the government for the sending of a WHO malaria control demonstration team, probably early in 1952, to assist Taiwan in approaching the above-mentioned goal.

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