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Malaria Research and Eradication in the USSR

A Review of Soviet Achievements in the Field of Malariology

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Relatively little is known outside the USSR about the past history of malaria in that country, the contribution of its scientists to malaria research, the recent progress of Soviet malariology, or the achievements of the Soviet Union in the eradication of malaria. These achievements are of particular interest because the general strategy of malaria eradication in the USSR has many technical, administrative, and economic and social features not seen elsewhere.

This paper attempts to summarize as concisely as possible a considerable amount of information gathered from important recent books and manuals (Sergiev & Zhdanov, 1955; Sergiev & Yakusheva, 1956; Beklemishev & Shipitzyna, 1957; Nabokov, 1958), from published papers and available unpublished reports. Some appreciation of the present trends and future aims of Soviet malariology was gained during conversations with P. G. Sergiev, A. Y. Lysenko, N. A. Diomina, S. N. Pokrovsky, and G. M. Maruashvili at the Sixth International Congresses on Tropical Medicine and Malaria (Lisbon, September 1958). A number of corrections and comments were received from Professor P. G. Sergiev, whose kindness is gratefully acknowledged. This review does not pretend to be complete: many problems mentioned in it could receive greater attention were it not for limitations of space. References to authors quoted from standard books are undated. Names followed by a date indicate recent papers, included in the list of references.

It might be usefully pointed out here that the USSR is composed of 15 Union republics (including the Russian Soviet Federated Socialist Republic); within the full Union republics there are 17 secondary or Autonomous Soviet Socialist Republics (see map). According to the United Nations Demographic Yearbook for 1957, the mid-1956 population of the Soviet Union, including Byelorussia and Ukraine, numbered 200 200 000. The combined population of the two last-named Soviet Socialist Republics was 48 600 000.[2]

History of malaria in Russia[3]

During the nineteenth and the first quarter of the twentieth century, malaria was one of the most important endemic diseases in Russia. The disease was known to exist over the whole country, but was particularly prevalent in the Caucasus, in Transcaucasia (Georgia, Armenia, Azerbaidzhan), in Middle Asia, and along the lower Volga.

Reports of Russian Army medical services, especially those of Toropov, reveal that in the garrisons stationed during the late nineteenth century on the northern shore of the Black Sea and near the Persian frontier the annual mortality from malaria amounted to 25 % of the actual strength.

The Russian malariologist Favre estimated that during the period 1890-1900 the average annual malaria morbidity in Russia was 5 million; this figure was much higher during epidemic years.

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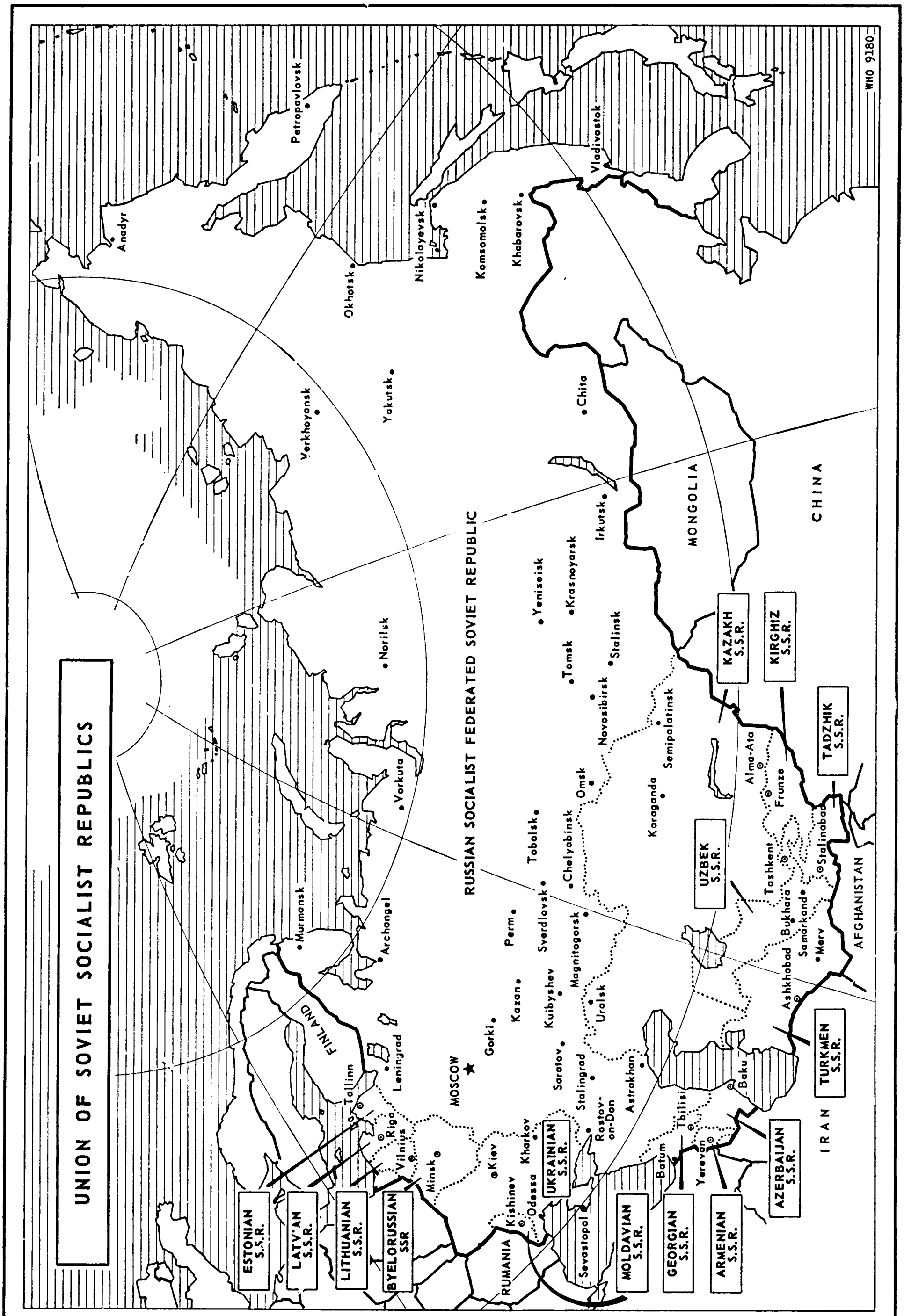
[2] The latest census of the Soviet Union was taken on 15 January 1959 and showed the total population to be 208 800 000. Since the preliminary estimate in 1956 the population of the USSR has increased by about 3 000 000 every year (*New York Times*, 12 May 1959).

[3] The history of general and Soviet medicine and public health is treated in a book by Rossiysky (1956). Fuller details on the development of malariology in Russia and the USSR will be found in books or papers by Roubakine (1933), Moshkovsky (1949), Zasukhin (1951, 1953) and Sergiev & Yakusheva (1956). The most recent account of the history of administrative measures and antimalaria legislation is that of Prokopenko (1959).


UNION OF SOVIET SOCIALIST REPUBLICS
RUSSIAN SOCIALIST FEDERATED SOVIET REPUBLIC
ESTONIAN S.S.R.
LATVIAN S.S.R.
LITHUANIAN S.S.R.
BYELORUSSIAN SSR
UKRAINIAN S.S.R.
MOLDAVIAN S.S.R.
GEORGIAN S.S.R.
ARMENIAN S.S.R.
AZERBAIJAN S.S.R.
TURKMEN S.S.R.
UZBEK S.S.R.
KAZAKH S.S.R.
KIRGHIZ S.S.R.
TADZHIK S.S.R.
FINLAND
RUMANIA
IRAN
AFGHANISTAN
CHINA
MONGOLIA
MOSCOW
Leningrad
Tallinn
Riga
Vilnius
Minsk
Kiev
Kishinev
Odessa
Sevastopol
Kharkov
Rostov-on-Don
Stalingrad
Saratov
Astrakhan
Gorki
Kazan
Kuibyshev
Perm
Sverdlovsk
Chelyabinsk
Magnitogorsk
Uralsk
Tobolsk
Omsk
Karaganda
Semipalatinsk
Novosibirsk
Tomsk
Stalinsk
Yeniseisk
Krasnoyarsk
Irkutsk
Chita
Yakutsk
Verkhoyansk
Norilsk
Vorkuta
Murmansk
Archangel
Okhotsk
Nikolayevsk
Komsomolsk
Khabarovsk
Vladivostok
Anadyr
Petropavlovsk
Tbilisi
Batum
Yerevan
Baku
Ashkhabad
Merv
Samarkand
Bukhara
Tashkent
Stalinabad
Frunze
Alma-Ata
WHO 9180

A malaria commission of the Pirogov Medical Society organized in 1911-1912 by Gabrichevsky, Berestnev, and Martzinovsky carried out a series of surveys in the coastal areas of the Black Sea and along the Volga River. It reported on the dramatic effects of malaria in the Caucasus, where whole areas were depopulated. Shortly before the First World War a malaria station was founded at Batumi, but its activity was shortlived.

During the First World War at least 3.5 million people suffered every year from malaria in Russia. As a result of the huge movements of population and the general lowering of economic and social standards in the wake of the war, the early years following the Russian Revolution saw, in 1922-1923, the greatest malaria epidemic of modern times in Europe. " In the middle Volga basin there had been an almost complete lack of rain for two successive years. The crops suffered the first year and in the second year they were destroyed. All the domestic animals died, either from lack of food or because they were sacrificed to the hunger of the population. Great masses of people emigrated to more fortunate regions, where they became infected with new kinds of malaria, and in the meanwhile the immunity of those who stayed at home fell to a low level. The following year a great flood of the Volga inundated kilometres of plain along its left bank, and the receding waters in the summer turned all the depressions in the steppes into marshes which persisted through the breeding season. On this physically reduced population, destitute of any biological defence either of domestic animals or of acquired immunity, descended the hordes of anophelines, and to add to the tragedy returning emigrants, who had heard that the land was again productive, brought their new parasites." (Hackett, 1937).

More than 2 million cases were registered in 1922 and more than 5 million in 1923. It has been estimated, however, that the actual number was at least four times as high. The disease, which had previously been localized in the sub-tropical regions, spread to the north and even into the Arctic. At the time when the epidemic was at its height the country had not more than 8-10 000 kg of quinine available. Thus it was practically impossible to treat the patients (Sigerist, 1947).

There were 60 000 fatal cases of malaria every year during that period, and in many areas of Central Asia, the Caucasus, and the Volga basin, 75-100 % of the population were infected. According to Dobreitzer's report (quoted by Gill, 1938), the malaria pandemic in Russia in 1922-1923 involved not less than 12 million cases.

The following figures of malaria morbidity were quoted for 1913 and the period 1922-1929 by Roubakine (1933):

Year	*No. of cases*	*Incidence per 10 000 population*
1913	3 521 213	216
1922	2 490 982	186
1923	5 556 856	415
1924	5 983 477	417
1925	5 124 719	353
1926	4 523 696	312
1927	3 684 041	254
1928	3 296 752	227
1929	2 993 072	183

The setting up in Moscow in the early twenties of the first Institute of Protozoology and Chemotherapy (today the Institute of Malaria, Medical Parasitology, and Helminthology) was one of the landmarks in the development of Soviet malariology. This Institute was created by E. I. Martzinovsky, an outstanding epidemiologist and public health administrator, who introduced the idea of rural antimalaria stations and was responsible for their widespread distribution.[1] Eight such stations were manifestly insufficient in 1921, but their number began to grow steadily. In 1922 there were 33, and their number increased in 1924 to 139.

In 1925-1927 antimalaria decrees and ordinances were promulgated, and a fund was created for malaria control from a special tax on the sale of peat.

By 1930 the situation had improved greatly because of the better execution and wider spread of public health measures generally and malaria control measures in particular. The following years were devoted to the country-wide planning of programmes directed against all communicable diseases. This was made possible by the setting up of institutes of tropical medicine in several Soviet republics such as Abkhazia (1926), Armenia (1923), Azerbaidzhan (1931), Dagestan (1927), Georgia (1924), Tadjikistan (1931), Turkmenia (1932), Ukraine (1923), Uzbekistan (1924). An additional tropical institute was opened in 1934 in Rostov on the Don for the benefit of the southern parts of the RSFSR. The date of 1934 is regarded as

[1] A historical note on Martzinovsky's work in the organization of campaigns against infectious diseases in Russia was written recently by Sokolov (1959).

a milestone in the history of malaria in the Soviet Union. In that year the Government approved the plan of antimalaria measures covering the whole territory of the USSR (Prokopenko, 1959).

Apart from a brief period (1932-1936) when malaria morbidity temporarily increased, especially in Middle Asia and in the Caucasus, the prevalence of this disease showed a gradual fall every year, and in 1939 the malaria morbidity in the USSR was the lowest ever recorded. The number of antimalaria stations was then 1236, without counting additional antimalaria dispensaries. In 1942-1945 the devastation and hardships brought by the Second World War were responsible for the greatly increased number of cases of malaria, particularly in the Ukraine, Byelorussia, and all the north-western areas occupied by the enemy.

The post-war years were devoted to the reorganization of the general public health services and the tightening up of malaria control. Malaria morbidity decreased from 222 per 10 000 in 1940 to 39 per 10 000 in 1950.

In 1951 the country-wide antimalaria programme proposed by Sergiev and his collaborators was approved, and included in the 1951-1956 five-year plan. The results of this programme can be appreciated by the following figures, quoted from Grashchenkov,[1] Sergiev (1958), Zhdanov (1959) and Sergiev, Rashina & Lysenko (1959). The total number of cases of malaria in 1950 was 781 239; in 1951, 351 178; in 1952, 183 603; in 1953, 115 869; in 1954, 72 860; in 1955, 35 704; in 1956, 13 015; in 1957, 5 097; and in 1958, 2 504.

The concept of elimination of malaria as a mass disease was adopted in the USSR in 1952; three years later it became obvious that total malaria eradication from the country might be possible by 1960.

The progress of malaria eradication in the Soviet Union will be outlined in a separate section of this review.

Health services in the USSR

There is little doubt that the Soviet achievements in the field of malaria eradication could not have been accomplished without the advantages offered by the structure of the existing health services of the Soviet Union and the existence of a large number of medical, scientific, and auxiliary technical personnel. Some understanding of the general organization and salient features of the health services of the USSR is therefore necessary.

Much information in this respect will be found in the study by Sigerist (1947), in the US Department of Health Report on the USA/USSR Medical Exchange Missions (1957), but more recent data are provided in the *First Report on the World Health Situation* (World Health Organization, 1959*a*) and in a special report of a WHO Group which visited the Soviet Union in 1958 (World Health Organization, 1959*b*). The following information is taken from these two sources.[2]

At the Soviet Union level there is a Ministry of Health, which is an integral part of the Council of Ministers. The Union Ministry of Health is responsible for the planning and co-ordination of health programmes and services for the entire Union, for setting up standards for various health establishments, and for the approval of health budgets and plans submitted by the Republics. In each of the 15 Republics there is a Ministry of Health dealing with the administration of health services within its jurisdiction.

The organizational structure of the health services of the USSR may be divided into six functional groups: (1) the directing, planning, and supervising group composed of the Union Ministry of Health and the respective Ministries of the Republics; (2) the academic and scientific group represented by the Academy of Medical Sciences and a number of scientific institutes; (3) the advisory group represented by scientific councils attached to the ministries of health and major health departments; (4) the educational group composed of medical schools and similar institutes; (5) the executive group responsible for health departments at city, *oblast*, and *krai* levels; (6) the operational group formed by a series of regional or district health units based on the regional or district *(rayon)* hospitals.[3]

[1] Grashchenkov, N. I. (1958) *Measures for eradication of malaria in the USSR*, WHO Regional Committee for Europe, seventh session (unpublished document)

[2] The most complete and up-to-date manual on the organization of medical and health services in the USSR is that by N. A. Vinogradov, "*Organizatsya zdravookhranenya v SSSR*", published in two volumes in 1958 by Medgiz in Moscow.

[3] The Soviet Republics are divided into *oblasts*, each with an autonomous health department. An *oblast* is subdivided into *rayons*, which correspond either to large urban areas or to specific areas in rural parts of the country. A *rayon* is further subdivided into sectors and smaller units. Translations of some Russian administrative terms employed by Sigerist (1947) are as follows: *krai* - territory; *oblast* - region;

The operational group is of the greatest interest from the point of view of malaria eradication, since it forms the backbone of the peripheral organization described in the report of the WHO Fellowship Group as: "a unified system embracing all health disciplines and reaching into every locality of the 15 constituent republics, to the smallest and most remote villages and farming areas. The basic principle of this structure is highly centralized planning and supervision, coupled with almost complete executive and operational decentralization..."

For general medical care there is a network of hospitals and out-patient establishments—such as polyclinics, both independent and attached to hospitals, maternal and child health consultation centres, medical posts, medico-sanitary units, and feldscher-midwife posts in the rural areas.

Thus the *rayon* health organization of the USSR offers comprehensive and integrated treatment; it is responsible for the regular "health screening" of the population, and undertakes the follow-up and surveillance of specific conditions, such as malaria, brucellosis, trachoma. This screening and follow-up system is known as "dispensarization". The district health authority is also responsible for environmental sanitation and control of communicable diseases through a network of "sanitary and epidemiological stations". These health centres are supplemented by a number of peripheral units headed by a doctor, and by the smallest units, called "feldscher-midwife points".[1]

The key unit of preventive medicine is the sanitary-epidemiological station. The stations are organized in compliance with the particular requirements of the region in which they are located. Each station has four departments: sanitation, anti-epidemic, disinfection, and laboratory. In addition some districts may have special services depending upon local needs. The size of the unit depends on the area and the local problems, and may vary from a dozen to several hundred workers. The stations are distributed geographically, and their number rose from 1958 in the year 1940 to 5230 in 1956 (Ministry of Health, USSR, 1957).

The chief physicians of sanitary and epidemiological stations have the functions of Medical Officers of Health (State Sanitary Inspectors); their personnel are the health officers in charge of districts; feldscher-sanitarians carry out the duties at the level of district hospitals; general duty feldschers perform similar work at the lower level. Finally, the police and voluntary organizations (such as the Red Cross and Red Crescent, which have a total membership of 27 million) can be relied upon for any additional duties and for the health education of the people.

The chief physicians of sanitary and epidemiological stations have mandatory powers, and a degree of independence which guarantees great freedom of action and power to execute appropriate measures with no interference.

It is interesting that posts of specialized sanitary engineers or inspectors are unknown in the Soviet Union. Environmental sanitation work is carried out by doctors or (in the peripheral units) by feldschers, graduates of the schools of hygiene.

The following numerical data obtained from the recent sources are of interest: In 1956 there was a total of 25 178 hospitals (with 1 360 800 beds) and 33 854 establishments providing out-patient services; all these establishments also provide domiciliary medical care and first-aid.

In addition to that, there were in 1956 16 400 dispensaries, 5230 sanitary and epidemiological stations, 19 974 health points (*zdrawpunkt*), 46 966 maternity and child welfare units, and 68 300 auxiliary health units (feldscher-midwife points) (Ministry of Health, USSR, 1957).

The number of medical personnel in the USSR (excluding the Armed Forces) was 140 769 in 1940 and increased to 329 442 in 1956. Of these 24 058 (about 7%) employed by the Ministry of Health are specialized in public health work. The ratio of the population to one doctor decreased from 715 in 1950 to 625 in 1955. A comparison between the ratio in some European countries and the USA is given in Table 1 below.

The number of qualified paramedical personnel such as dentists, pharmacists, feldschers, sanita-

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okrug - area; *rayon* - district. These terms are also used by the USA/USSR Medical Exchange Missions (1957).

Oblasts are usually designed to include well co-ordinated economic regions, while *krais* are administrative units in frontier areas or thinly populated parts of the USSR. As the economy of the USSR changes, so the boundaries of *oblasts* and *krais* constantly alter. (Oxford Regional Economic Atlas, 1956).

[1] *Feldschers* are auxiliary medical officials with limited rights and responsibilities. Their training in special schools takes approximately half the time needed for training a medical graduate. The feldscher has played an important part in the health services of Russia ever since the middle of the last century. Although recent plans are for the provision of fully-graduated medical personnel everywhere, the feldschers will continue to be the backbone of rural health units for many years to come.

TABLE 1

NUMBER OF POPULATION PER DOCTOR IN SELECTED EUROPEAN COUNTRIES AND THE USA

Source	Austria	Federal Germany	France	Italy	Switzerland	United Kingdom	USSR	USA
World Directory of Medical Schools (WHO, 1957)	628	745	1093	828	976	1149	784	740
Statistical Yearbook (United Nations, 1957)	610 (1956)	740 (1955)	980 (1955)	820 (1951)	700 (1956)	—	610 (1956)	790 (1955)

rians, midwives, nurses, laboratory technicians, etc. was 386 748 in 1940 and 858 497 in 1957. Of the latter figure 22% were feldschers and 2% sanitarians and epidemiological assistants (Ministry of Health, USSR, 1957).

It appears that in 1958 the total number of medical graduates rose to about 360 000 (one to 590 inhabitants). It is planned that in 1965 there will be 490 000 doctors in the country, a ratio of one doctor to every 460 inhabitants (World Health Organization, 1959 b).

It might be pointed out that in 1956 not less than 2 780 000 persons, or about 1.3% of the entire population of the Soviet Union, worked in one way or another in the field of public health (Ministry of Health, USSR, 1957; Gunther, 1958; World Health Organization, 1959 b).

The health budget of the USSR for 1958 makes provision for an expenditure of over 40 billion roubles (equivalent to US$ 10 billion); this means that approximately 200 roubles (US$ 50) will be spent for every inhabitant in one year. Apart from this official budget, other bodies and institutions are also required to contribute for additional expenditure on health services (WHO Fellowship Group, 1959).

Research organizations and publications dealing with malaria

A description of some important Soviet scientific organizations might be of interest. Much of this information is quoted after Ashby (1947).

The Academy of Sciences (*Akademia Nauk*) of the USSR, one of the most powerful and distinguished scientific bodies known, was founded in 1725 by Peter the Great on the model of the Royal Society of London. The Academy of Sciences is a very select institution with 151 academicians and 325 corresponding members (1956). It combines the functions of an independent, high-level scientific society, of an advisory body to the Government and of a managerial department of scientific and industrial research. It has 8 divisions (physics and mathematics, chemistry, geology and geography, biology, technology, philosophy, economics and law, literature and languages). It finances and controls about 200 institutes, laboratories, museums, libraries, research stations, etc. Some of the branches of the Academy of Sciences, and particularly those in Siberia (Novo-Sibirsk), in the Far East (Vladivostok) and in the Urals (Sverdlovsk) have been prominent in carrying out pioneer research work in newly developed areas.

The Ministry of Health, USSR, deals with technical and scientific problems through two main bodies: the Scientifiic Medical Council and the Academy of Medical Sciences (*Akademia Medicinskikh Nauk*).

The Scientific Medical Council is a consultative body which reviews advances in medicine and public health, advises the Ministry on their practical applications and co-ordinates applied research in the institutes of the Ministry of Health of the USSR and in those which depend on ministries of the constituent republics.

The Academy of Medical Sciences, founded in 1944, concentrates on fundamental medical research and on high-level applied research. It supervises the work of 27 central research institutes, but not of the hospitals or the pharmaceutical industry, leaving this to the Ministry of Health. The Academy of Medical Sciences has three divisions: (1) medico-biological sciences; (2) hygiene, microbiology and epidemiology; and (3) clinical medicine. The Academy of Medical Sciences had in 1958 about 250 academicians and corresponding members. It follows the same pattern of organization as the Academy of Sciences, by bringing together the most distinguished medical scientists, who enjoy a substantial financial security attached to the title of academician. In addition to providing scientific and managerial guidance to medical research, the Academy also has its own library and publishing house.

The main research institution devoted to problems of malaria is the Institute of Malaria, Medical Parasitology and Helminthology (named after E. I. Martzinovsky) of the Ministry of Health, USSR, in Moscow. (Director, Professor P. G. Sergiev, Member of the USSR Academy of Medical Sciences). Nine other institutes are actively engaged in work on malaria. These are situated in Ashkhabad (Turkmenia); Baku (Azerbaidzhan); Samarkand (Uzbekistan); Kiev (Ukraine); Rostov on the Don (RSFSR); Stalinabad (Tadzhikistan); Alma-Ata (Kazakhstan); Tbilissi (Georgia) and Yerevan (Armenia).

Other institutions situated in Moscow where work on subjects connected with malaria is being carried out are:

(1) Institute of Pharmacological Chemistry of the Academy of Medical Sciences.

(2) Central Disinfection Institute of the Ministry of Health (insecticides and spraying equipment).

(3) Central Institute of Health Education of the Ministry of Health.

(4) Institute of General and Communal Hygiene.

(5) Institute of Epidemiology and Microbiology (named after N. F. Gamaleya).

(6) Institute of Health Administration and of the History of Medicine (named after N. A. Semashko) of the Ministry of Health.

Research on medical entomology is carried out at the Institute of Zoology of the USSR Academy of Sciences, at the Zoological Institutes of the Union republics, at the faculties of several universities, and at the Military Medical Academy (Pavlovsky & Gutsevitch, 1957).

Most of the papers related to malaria are found in the journal *Medical Parasitology and Parasitic Diseases* (*Meditzinskaya Parasitologia i Parasitarnye Bolezni*) published in Moscow every two months (editor, Professor P. G. Sergiev). The interest taken in malaria in the USSR can be judged from the comprehensive bibliographical index of relevant Soviet publications quoted in each issue of the journal.[1] Thus in 1956 papers on all aspects of malaria published in the USSR numbered 132; the figure for 1957 was 244, and for 1958, 79. In 1957 this journal alone published a total of 96 papers on malaria (some of them consisted of reviews of Soviet achievement during the past forty years, and were prepared for the commemorative anniversary of the October Revolution). The journal often publishes comprehensive reviews of recent work done outside the Soviet Union on some specific problems.

Papers on medical entomology dealing with the systematics, genetics and physiology of malaria vectors are usually published in two other periodicals: the *Entomological Review* (*Entomologicheskoye obozrenye*) and the *Zoological Journal* (*Zoologicheskiy zhurnal*).

Papers referring to insecticides are published mainly (but not exclusively) in *Hygiene and Sanitary Engineering* (*Gigiena i sanitarija*) but also in *Pharmacology and Toxicology* (*Farmakologia i toksikologia*), in the *Journal of Military Medicine* (*Voyenno-medicinskiy zhurnal*) and the *Journal of Microbiology, Epidemiology and Immunology* (*Zhurnal mikrobiologii, epidiemiologii i immunologii*).

In 1955 the number of scientific workers in the USSR was 223 893, of whom 9 460 were doctors of science and 77 961 were candidates of science (Central Statistical Board, USSR, 1957). A recent assessment of scientific and technological manpower in the USSR prepared by Schur (1959) gives the following figures more relevant to medical and biological research. In 1956 the USSR had a total of 1784 research institutes (including branches and scientific stations) employing 83 531 persons, of whom 11 009 were devoted to biological research. Two hundred and sixty-eight institutions were devoted to public health problems and the total number of medical and pharmaceutical scientists was 28 663. (World Health Organization, 1959 b).

Russian contribution to malaria research

All the Soviet writings on malaria emphasize the part played by Russian scientists in early

[1] A series of reviews, in English, of papers printed in this journal in the years 1940-1942 were published by Hoare (1943).

research on malaria (Moshkovsky, 1949). Zasukhin (1951, 1953)[1] made an interesting historical study of the problem of priority of several Russian workers in the discovery of the malaria parasite and in the mechanism of its transmission. A brief, popular history of malariology seen from a Soviet angle was published by Plotnikov & Zasukhin (1953).

It appears that Afanasiev noticed in 1879 the presence of pigmented bodies in the brain capillaries of a fatal case of malaria and suspected that this pigment might be produced by some lower micro-organisms.

The work of Danilevsky[2] in 1884-1885 on avian malaria is universally known and recognized; he was undisputedly the first to have seen pigmented parasites in the blood corpuscles of birds, and he gave a detailed description of the disease produced by the avian parasite. The correct interpretation of exflagellation is one of the interesting parts of Danilevsky's work (Hewitt, 1940). In his outstanding monograph, *La parasitologie comparée du sang,* published in 1889, the following prophetic sentence can be found: "I believe that these researches will throw some light on the complicated questions concerning the nature of the malaria parasites of man and in so doing will enlarge and facilitate the experimental study of malaria in general."

Some Soviet authors emphasize Danilevsky's early hypothesis of the development of plasmodia in tissue cells. It is true that Danilevsky described in 1890 intracellular, non-pigmented parasites in the cells of avian bone marrow. These parasites might have been exo-erythrocytic forms of *P. elongatum* but as Danilevsky used the word "malaria" with regard to all Haemosporidia, the bodies described might have been Leucocytozoon or even Atoxoplasma (Bray, 1957). It is interesting that the available Soviet sources do not quote Shingarev, who in 1906 described non-pigmented schizonts of *P. murinum* of bats in leucocytes and in Kupffer cells of the liver (Bray, 1957). It is probable that Shingarev was the first author who ever recorded the tissue forms of mammalian malaria (without, however, realizing their importance).

In 1887 Metchnikov commenced work on the systematics of malaria parasites and emphasized the part played by phagocytosis in the defence system of the organism. During the period 1888-1890 Sakharov had apparently identified the parasite of "malignant tertian malaria" and understood the part played by the gametocytes. In 1890 Romanovsky discovered the new differential staining which later became the method upon which all subsequent modifications such as Giemsa's, Leishman's and others were based.

A long series of other Russian workers, little known outside their own country, contributed to the early development of malariology. Among these pioneers the names of Toropov (1828-1884) and Favre (1874-1920) deserve special mention. Toropov's survey of malaria in the Caucasus (1864) is outstanding even today, while Favre's (1903) comprehensive review of malaria in Russia is a minor classic.[3]

In 1868 Fedchenko described two species of anopheles in Russia, and a few years later Favre produced a valuable report on the distribution of anopheles and on their breeding habits.

At the beginning of this century (1904) Portchinsky's pioneer work on the systematics of anopheles in Russia provided the basis for all the later studies on the biology of vectors of malaria in the USSR. In 1924 Pavlovsky established, under the aegis of the Academy of Sciences, a permanent commission for the study of malaria vectors. The commission produced a series of entomological keys, handbooks and monographs, and organized the training of entomologists. Many of its publications were of particular importance, such as two manuals by Pavlovsky (1946, 1948), a series of keys to the mosquitos of the USSR by Shtakelberg (1956), and two monographs on mosquito larvae by Monchadsky (1951). The physiology and ecology of mosquitos and the relationship of these studies to the epidemiology of malaria was investigated by Beklemishev (1949), whose followers (Almazova, Detinova, Shlonova, Shipitzyna, Polovodova) developed the present approach to applied entomology as a guide to malaria eradication.

[1] In these interesting books a series of factual statements are interspersed with many remarks of a political character. The same could be said about the monograph by Plotnikov & Zasukhin (1953), who claim national priorities for many discoveries in the field of malaria; some of these claims are at variance with claims generally accepted elsewhere.

[2] A biographical sketch of Basil Yakovlevitch Danilevsky written by Hoare (1939) is of interest.

[3] In order to verify Ross's theory of the part played by mosquitos in the transmission of malaria, Favre while working n Kharkov infected himself with falciparum malaria, through he bite of an anopheles which was previously fed on an acute case of this disease (Plotnikov & Zasukhin, 1953).

Martzinovsky's (1874-1934) pioneer work in organizing antimalaria measures in Russia and in the Soviet Union has been mentioned. This task was taken over and the organization carried out on a much wider scale by Sergiev, the present Director of the Institute of Malaria, Medical Parasitology and Helminthology in Moscow.

Butlerov's early work on quinine alkaloids in 1878 was followed in the nineteen-thirties by the researches of a large group of chemists and clinicians on synthetic antimalarials. Among the clinicians the names of Tareev, Nesterov, Kassirsky, Zavadsky and Gontaeva are particularly well known. Moshkovsky, Magidson, Knuniantz, Tchelintzev, Grigorovsky, Bekhli, Ufimtzev, Topchiev, Braude and Stavrovskaya represent Soviet chemotherapy.

Nearly all Soviet work on the development of insecticide-dispersing equipment is linked with the name of Nabokov (1940).

It was previously mentioned that a country-wide programme of malaria eradication was adopted by the Soviet Government in 1951. In 1952 a group of distinguished Soviet malariologists (P. G. Sergiev, W. N. Beklemishev, M. A. Buslaev, P. S. Djaparidze, L. M. Isayev, V. A. Nabokov, M. G. Rashina, N. K. Shipitzyna, A. I. Yakusheva, S. N. Pokrovsky and G. A. Pravikov) were awarded the Stalin prize for their services to the country.

An outstanding and colourful personality in the field of parasitology is Professor E. N. Pavlovsky, the "grand old man" of Soviet biological science, a link between pre-revolutionary days and the present régime. During the 55 years of his scientific activity Pavlovsky has written over 1200 papers covering an extraordinarily wide field of biology generally and protozoology in particular. His books on human parasitology have become standard reference volumes in his own country and outside it. Pavlovsky was in charge of the permanent committee on the entomology of malaria organized by the Academy of Sciences in 1924, and he carried out a series of surveys in Transcaucasia and in South Central Asia. In 1935 Pavlovsky turned his attention to the field study of Diptera feeding on man and animals (this group of insect pests is known in the Soviet Union under a general Siberian term *gnus*). He has devoted much work to the study of the general ecology of communicable arthropod-borne infections and expanded the theory of "natural foci of transmissible diseases" (*prirodnaya ochagovost'*), which explains the ecological links between the host, agent and environment.[1] This theory, as also the concept of the higher organism as environment of its parasites, has influenced much of contemporary biological work in the USSR. Professor Pavlovsky, who is 75 this year, holds probably a world record in the number of zoological genera and species linked with his name: 75 animals, from diatoms to fishes and reptiles, have been named after Pavlovsky by his colleagues and pupils.

A more detailed account of Soviet research work in various fields of malariology and of their achievements in malaria eradication will be found in the subsequent sections of this paper.

Parasitology

P. falciparum was recorded mainly in parts of the USSR in Middle Asia, Trauscaucasia, southern Ukraine and along the lower Volga River. Small foci were found in central Russia in the regions of Riazan, Gorky and Kuibyshev, but sporadic cases of falciparum malaria were recorded occasionally (in 1936) in northern Russia, as far as Arkhangelsk. Quartan malaria was found in some regions of the Azerbaidzhan Republic, on the shores of the Black Sea and in the Volga delta. Vivax malaria was known in all the remaining malarious areas of the USSR. Nicolaiev distinguished two sub-species of *P. vivax*.[2] The southern *P. vivax vivax* has a short incubation period of 14-20 days, while the northern *P. vivax "hibernans"* has a long incubation period of several months. Sergiev and Tiburskaya confirmed the dissimilar incubation period of several strains of *P. vivax* from Russia. Two cases of malaria due to *P. ovale* were recorded in Armenia and in Bashkiria but it is now believed that both were misidentified (Sergiev, 1958).

The preference of *P. vivax* for reticulocytes, and the absence of such preference in *P. falciparum*, was confirmed by Voino-Yasenetzky and by Istamanian, though some exceptions were found in a proportion of patients.

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[1] A summary of the theory of natural foci of transmissible diseases in relation to arthropod-borne infections of mau will be found in a paper by Petrishcheva (1957).

[2] The long incubation period of some European strain of *P. vivax* was observed by James and independently by Korteweg in 1920, by Martini in 1921, by Swellengrebel, Schuffner and Korteweg in 1929 (Swellengrebel & de Buck, 1958; Gill, 1938).

Tareev agrees that recrudescences and some " early relapses " of malaria are due to a revival of erythrocytic schizogony kept at a low level in the blood, while late relapses have their origin in exo-erythrocytic schizogony.

Blood examination for malaria parasites is carried out in the Soviet Union with the thick-drop technique and the Romanovsky-Giemsa stain. Rukhadze advises that the thick film be tilted before drying, so that the sickle-shaped thicker part should reveal the presence of parasites if they are scanty. The Soviet authors doubt if acute symptoms of malaria can coincide with a negative blood film but emphasize the need for repeated blood examinations. (In a series of over 20 000 blood films taken in Armavir it was shown that only one-third of these slides were positive, but in the repeated series of blood slides taken from all initially negative cases 20 % were found to be positive; the same proportion of positives was found on the third examination of blood slides found to be negative in the second examination.)

Examination of the bone marrow for the presence of malaria parasites showed that this method does not increase the number of positive findings and has no advantages over the examination of the peripheral blood.

An interesting method of diagnosis of malaria was proposed by Nesterov but is not widely used. Nesterov's (1953) method of cross-erythrocyte sedimentation (measuring the sedimentation rate of erythrocytes of a malarious subject suspended in the plasma of normal subjects and *vice versa*) is based on the finding that in malaria and pernicious anaemia the higher sedimentation rate of red blood cells depends on changes in those cells and not in the composition of the plasma (Sergiev & Yakusheva, 1956).

A few words should be said about some differences in terminology relating to malaria parasites. Soviet sources occasionally use the term " gamont " for gametocyte and " agamont " for asexual forms of the erythrocytic cycle. Trophozoites (" rings ") are frequently referred to as " young schizonts ", while mature schizonts divided into merozoites go by the name of " morula ". Tissue merozoites are called "crypto-merozoites" (of the pre-erythrocytic generation) and "phanero-merozoites" (of exo-erythrocytic generation *sensu stricto*).[1] The heavy stippling of erythrocytes infected with *P. ovale* is known as " James' granules " (Sergiev & Yakusheva, 1956).

In reporting on malaria surveys Soviet workers use the classical indices: spleen rate and parasite rate. They also use the " endemic index ", combining the two previously-mentioned indices and the " anamnestic index ", which refers to the past history of the disease. Ross's old index of the average enlarged spleen is also employed, and the " weighting " of the proportion of the three classes of the enlarged spleen is obtained by multiplying the frequency by the factors 3, 6 and 9.

Entomology

Some methods of collection of adult mosquitos employed in the Soviet Union are of interest. The assessment of the density of the vector is carried out in capture stations (*kontrolnaya dniovka*) which usually number 10-15 per village. Mosquitos are collected by pyrethrum spray catch or by hand catching. For the latter method the Soviet entomologists use either test-tubes or various suction devices. One method of hand-collecting employs a small Barraud-type cage with a sleeve fitted with a wide glass tube. For collecting with a suction tube many workers use the apparatus (*komarolovka NZ*) developed in 1940 by Nabokov and Zeifert, in which suction is obtained by the pressure of a rubber bulb; the air current thus produced bypasses a constriction within a wider tube and produces the suction effect. A simpler mouth-suction apparatus known as an " exhauster " is similar to Majid's tube, used elsewhere.

For the outdoor collection of biting Diptera and the quantitative assessment of their density and biting rate, the Soviet workers use net traps (*uchotnyi sadok*) of various designs and sizes. One of these traps consists of a bell made of netting 1 x 1.5 x 2 m (*uchotnyi kolokol*) in which the observer acts as a bait; the bell unfolds when drawn down periodically and encloses the observer, who collects the captured insects (Nabokov, 1958).

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[1] The report on malaria terminology prepared by the Drafting Committee appointed by WHO suggests the term " cryptozoite " for tissue schizonts arising directly from sporozoites. The second and succeeding generations of tissue schizonts appearing concomitantly with or later than the infection of erythrocytes are called phanerozoites. No specific names for merozoites arising from these two tissue stages have been suggested, although in avian malaria the term " cryptozoic merozoites " was advocated for the products of the first tissue schizogony (Covell, Russell & Swellengrebel, 1953).

Some of these traps are made of dark cloth and provided with a sleeve that leads into a killing tube. Captured insects are attracted by light, fly into the sleeve and are automatically collected.

The anopheline fauna of the USSR and the adjacent regions of Asia has been excellently described by Beklemishev (1949). The following summary is based on Beklemishev's review.

1. *A. maculipennis* Martini (= *typicus* Hackett & Missiroli) is present throughout European Russia, abundant in the Caucasus, common in the Altai mountains and in southern Turkmenia. It is absent to the east of the Ob River and in Trans-Volga and the Trans-Ural steppes.

2. *A. maculipennis messeae* Falleroni has the widest distribution of all. Its area includes the whole of European Russia, Siberia, the major part of Kazakhstan and the reaches of the Amur Basin. In the south it is not found beyond the Caucasus range.

3. *A. maculipennis subalpinus* Hackett & Lewis occurs in the lowlands of Transcaucasia and especially on the southern shore of the Caspian Sea. (*A. maculipennis melanoon* is considered by Beklemishev a mere melanic variety of *A. maculipennis subalpinus*.)

4. *A. maculipennis atroparvus* van Thiel has been recorded from Byelorussia west of the Dnieper, South and West Ukraine and the North Caucasus. It is especially abundant on the northern shore of the Black Sea and the northern and eastern shore of the Azov Sea.

5. *A. maculipennis sacharovi* Favre (= *A. elutus* Edwards) is the most heat-enduring of the eastern subspecies of the maculipennis complex. It inhabits the lowlands of eastern Transcaucasia, the coastal plains of the Caspian Sea and Dagestan. It is common in some valleys of the rivers Syr and Amur. In some parts of Tadzhikistan it reaches the exceptional altitude of 2000 metres.

6. *A. bifurcatus* Meigen is widely distributed in European Russia, but relatively scarce in other parts of the USSR, though fairly common in the hilly regions of Middle Asia.

7. *A algeriensis* Theobald occurs in the lowlands of the Caucasus and Middle Asia.

8. *A. marteri* Senevet & Prunelle occurs as its subspecies *sogdianus* Keshishian in Tazhikistan.

9. *A. plumbeus* Stephens is associated with the presence of deciduous forests. Its north-eastern limit of distribution in European USSR runs approximately along the 50°N parallel. (The North Indian *A. barianensis* James is probably a subspecies of *A. plumbeus* and was found in Tadzhikistan).

10. *A. lindesayi Giles*, an essentially montane species, was found in southern Tadzhikistan.

11. *A. hyrcanus* Pallas is found in the southern Ukraine towards Bessarabia and Romania ; the northern limit of the distribution crosses the lower parts of the Don, the Volga and the Ural Rivers, then runs through Mongolia and the valley of the Amur. It is a common species in Middle Asia and the Caucasus.

12. *A. superpictus* Grassi occurs in Transcaucasia and Middle Asia ; in Tadzhikistan it is found up to 2600 m above sea-level.

13. *A. pulcherrimus* Theobald is an oasis dweller of the Middle Asian desert, particularly common in the flat valleys of Turkmenistan, Uzbekistan and Kazakhstan.

14. *A. pattoni* Christophers, common in the hilly regions of North China, might be expected occasionally to extend its distribution to the frontier areas of Manchuria.

Of the 14 species mentioned above the principal malaria vectors are: (*a*): in European Russia, Siberia, North-West Manchuria, Mongolia, central and northern Kazakhstan and northern Kirghizia: *A. m. messeae* throughout the whole territory, *A. m. maculipennis* and *A. m. atroparvus* only locally; (*b*) in the Caucasus and near the Iranian frontier: chiefly *A. m. maculipennis* and *A. superpictus* ; (*c*) in middle Asia: *A. m. sacharovi, A. superpictus* and *A. pucherrimus* ; (*d*) in some areas of the basin of the Amur River: *A. hyrcanus*. *A. pattoni,* the chief vector of the hilly regions of North China, is geographically outside the territory of the Soviet Union.

Under certain conditions *A. messeae* may act as an important vector of malaria ; on the other hand " anophelism without malaria " is not uncommon in some parts of the USSR, though less likely in the south of the country. *A. hyrcanus, A. bifurcatus* and *A. plumbeus* are of secondary importance, while *A. algeriensis, A. lindesayi* and *A. marteri* have not been incriminated as vectors of malaria.

A useful taxonomic character — the spiracular structure of larvae — was introduced by Monchadsky (1936), who also suggested that the size of the larval collar can be used for the determination of the mean instar of larvae as a guide for control measures in the field. Methods of estimating the number of larvae have been introduced, and the relationship between the type of aquatic vegetation and the breeding potential of malaria vectors was established in several areas. Special monographs on malaria vectors of the Transcaucasian and Central Asian Republics have been produced by Monchadsky & Shtakelberg (1943), by Petrishcheva (1936), Akhundov (1940) and others.

Investigation of the physiology and behaviour of malaria vectors has been actively pursued, particularly by Beklemishev and his colleagues ; only a brief reference to their important work can be given in the present paper.

Beklemishev found that the mean mortality of anopheles during their aquatic cycle of development amounts to 90-92.5 %. Nevertheless, the total output of adults from a large breeding place can be very large. In areas where the transmission season does not exceed two to three months, one hectare (2.47 acres = 11 960 square yards) of water surface produces one to two million adult anophelines per season ; naturally in areas where the transmission season is longer the figure can be several times higher.

The mean range of flight of anopheline vectors was found to be 3 km but some specimens have a flight range of 6-7 km.

Investigations on the hibernation of anopheline vectors showed that females of *A. maculipennis atroparvus, A. m. sacharovi* and *A. superpictus* overwintering in cattle sheds continue feeding on animals during the diapause and survive until the next spring; females of other species which have fed and oviposited during the autumn cannot survive the winter.

The duration of the sporogonic cycle in malaria vectors was investigated by Nikolaiev, who found that in *A. maculipennis* the period from the infective blood meal to the presence of sporozoites of *P. vivax* was 45-60 days at 16°C, 10 days at 25°C and 6½ days at 30°C. The respective time at 25°C was 12 days for *P. falciparum* and 16 days for *P. malariae*.

The duration of the gonotrophic cycle in various temperatures and relative humidities was investigated by Shlonova & Beklemishev who found that the relationship of sporogony to the gonotrophic cycle changes in different temperatures; it is 5:1 at 20°C and 4:1 at 25°C.

Investigations on the longevity of malaria vectors and its relationship to their infectivity have been carried out by Soviet entomologists and epidemiologists for several years, and their results are of great interest.

The study of the physiological age of insect vectors of disease is often the best criterion of the efficacy of control measures. Rational planning of antimalaria measures requires not only knowledge of the general biology of the vector but also of its longevity, or at least the number of blood feeds it takes. The malaria vector can have a " calendar age " or a " physiological age ". For years entomologists have attempted to assess the " physiological age ", and Kozhevnikov pointed out in 1903 that through the study of ovaries of female anopheles it may be possible to distinguish between nulliparous and parous females (Detinova, 1957).

The method based on measurement of ampullae of the oviduct introduced in Israel by Mer in 1932 was promising and widely used in the USSR until 1941, when Polovodova showed that it distinguishes only between nulliparous and multiparous females, and has its limitations. During the forties a number of Soviet entomologists (Polovodova, Almazova, Detinova, Dolmatova, Kuzina, Lineva) devoted much attention to the " physiological age " of blood-feeding insects. In 1942 Detinova described the morphological changes seen in the ovaries of *Aëdes* and, in 1945, in anopheles. In nulliparous females the ovarian tracheoles are tightly coiled up, while in females which had laid at least one batch of eggs the uncoiled tracheoles have a net-like appearance. In 1947-1948 Polovodova found that after each oviposition by the female anopheles there remains in the follicular tube of the ovariole a round dilatation; the number of dilatations correspond to the number of gonotrophic cycles and give a direct indication of the physiological age of the female. It was subsequently shown by Polovodova that each dilatation is formed by the contraction of the follicular sac left by the mature egg after its passage from the site of its growth and differentiation into the oviduct prior to final expulsion. The technique of age-grouping based on the number of follicular dilatations in *A. maculipennis* is much used in the Soviet Union.[1]

These data permit the assessment of the physiological age at which the female anopheles vector becomes potentially dangerous. The mosquito can be infected during any of the gonotrophic cycles and the epidemiological importance of each individual female increases with her age, as the chances of contact beween the vector, the source of the infection and the potential victim are correspondingly greater. (It was found that *A. maculipennis* can undergo in nature up to 13 gonotrophic cycles.)

For the assessment of the physiological age distribution (*vozrastnyi sostav*) of the vector population, the methods of Polovodova and Detinova are commonly used by the Soviet entomologists. Comparative investigations of the age composition of the local vector population in two areas, one treated with residual insecticide (which increases the mortality of the vector) and the other untreated, give an estimate of the value of the residual insecticide treatment. With a good coverage of the area and an active residual deposit, anopheline females showing more than one or two gonotrophic cycles should be virtually absent, and any increase in the age composition found in a reasonably good sample of the vector population indicates that the imagocidal measures applied are insufficient for the interruption of transmission. These methods of entomological assessment were used during the period 1946-1956 during the malaria eradication programme in the Moscow region, in Moldavia, Azerbaidzhan, Tadzhikistan and other areas with much success, and more recently have been applied to other insects such as houseflies, sandflies and blackflies (Detinova, 1957).

Much work on the bionomics of malaria vectors has been carried out by Beklemishev and his school. Great importance is attached to deviation of the main malaria vectors by cattle: some epidemics of malaria seen in the past (during the droughts in 1921-1922 on the lower Volga) are explained by the loss of cattle and subsequent increase of the proportion of people on whom the anopheline vectors fed.

The Soviet basic and applied research on phenology[2] in relation to the epidemiology of malaria is of exceptional interest. Much information on this subject was gleaned from a review by Shipitzyna (1957). Co-ordination of ecological observations commenced in the nineteen-twenties with the creation by Martzinovski of a network af antimalaria stations, but methodical investigations of seasonal changes in the behaviour of malaria vectors were organized later by Beklemishev. Beginning in 1935, the Institute of Malaria set up a network of over 200 stations with 650 observers distributed over many ecological areas of the country.

Some of the problems investigated in the course of this large-scale programme are of special significance. The study of the timing, duration and degree of the diapause showed that several subspecies of *A. maculipennis* have distinct patterns in their physiological changes. The seasonal trends in the density of malaria vectors were studied in relation to many ecological factors (climatic, hydrological, topographical and others). Using this method it was possible to relate the seasonal density of *A. maculipennis* in Omsk to the variation in the water table in western Siberia; similar work showed the influence of the floods of the Volga on the trend of anopheline density in distant areas of the river basin.

In 1950 phenology was consecrated as a branch of science applied to the timing of malaria eradication programmes. Thus for instance the knowledge of the hibernation period, the first spring flight and feeding, the beginning of oviposition, etc. permit a dynamic planning of imagocidal spraying and chemotherapy in each ecological zone. This adaptation of antimalaria programmes to local conditions has resulted in a considerable saving of human effort and material resources.

Anopheline ecology of the European part of the USSR and of much of Transcaucasia has been thoroughly investigated by the Soviet entomologists, but Siberia, the Far East, Azerbaidzhan and Dagestan are relatively less known. The mass of

[1] A review of Soviet methods of age-grouping by the use of techniques introduced by Detinova & Polovodova was recently published by Gillies (1958), who also translated some of the relevant papers. These translations have been mimeographed by WHO and are available to any research workers interested. A set of lectures on age-grouping techniques given by Detinova in April 1959 at a special course in London has now been issued as a WHO mimeographed document. A paper on the determination of physiological age in anopheles has recently been prepared by Beklemishev, Detinova & Polovodova (1959).

[2] Phenology: recording and study of periodic biotic events (such as flowering, breeding, migration, etc.) in relation to climatic and other factors.

recorded observations on the seasonal bionomics of malaria vectors in the USSR has only recently been consolidated and published in a comprehensive monograph edited by Beklemishev & Shipitzyna (1957).[1]

The future programme of Soviet research on the phenology of malaria vectors has now been somewhat curtailed, but it is proposed to carry on with observations in lesser-known areas where *A. superpictus* is the main vector. More attention will be given to the study of other disease-carrying insects.

Epidemiology of malaria

In the northern and central parts of the Soviet Union, anopheles infected before their hibernating period die out before they become infective in the spring. The important part in the annual transmission belongs to the first generation of mosquitos arising from eggs laid after hibernation. This generation has its first flight in May or June and is usually the only one responsible for transmission of malaria, although during some exceptionally long and warm summers (1938 and 1948) the second generation might also be of importance. In the south of the Soviet Union the transmission of malaria is spread out over several months (with a peak in July and August) and several generations of the local vectors. In Middle Asia the main vector in the spring is *A. m. sacharovi,* while *A. superpictus* and occasionally *A. pulcherrimus* take over in the summer.

The greater prevalence of malaria in the south of the Soviet Union as compared with the north is explained by the concept of the " turnover of the causative agent " (*skorost' oborota vozbuditela*), which depends on the basic epidemiological factors linking the infected and infective host, the agent and the environment. For vivax malaria with a short incubation period the " turnover of the causative agent " takes one month in the south and about two months in the north. Vivax malaria with a long incubation period has a " turnover " of 8-10 months or longer. New cases of vivax malaria with a short incubation period appear mainly during the third quarter of the year (in the south as late as November); new cases of vivax malaria with a long incubation period and delayed relapses of vivax malaria with a short incubation period appear mainly during the second (occasionally at the commencement of the third) quarter of the calendar year following that of the year of infection. On the other hand, relapses of vivax malaria with a long incubation period are seen usually within three months after the primary attack or during the third quarter.

The curve of the monthly malaria morbidity in the USSR can be classified into three types: northern, southern and bimodal. The northern type of curve usually shows a single high peak in May or June and represents primary attacks of vivax malaria with a long incubation period. The southern type shows a peak in August or September which can also be preceded by a short wave in the spring. This curve is composed of cases of vivax malaria with a short incubation period and of cases of falciparum malaria; the spring wave consists of relapses of vivax malaria from the previous year and of a small number of cases of vivax malaria with a long incubation period. The bimodal curve seen in the Moldavian Republic, in the provinces of Kuibyshev, Saratov, Penza, Stalingrad, etc. shows two peaks—one in May-June due to cases of vivax malaria with a long incubation period and relapses of vivax malaria with a short incubation period; the other, generally seen in August, due to new cases of vivax and falciparum malaria and to some belated cases of vivax malaria with a long incubation period. The Soviet workers use the concept of the epidemiological year, which covers the period from the appearance of the first cases of vivax malaria with a short incubation period to the appearance of new cases due to the infection of vectors from relapses during the next calendar year. Thus in 1948-1949 the epidemiological year in the Moscow region ran from 1 July 1948 to 15 July 1949.

Soviet malariologists emphasize the uneven focal distribution of malaria in their country and the importance of local climatic and hydrographical conditions on the prevalence of the disease.

The transmission season covers the whole period during which the vectors are infective from a feed obtained during the calendar year. This definition discounts the possibility of the vector carrying over

[1] Beklemishev, W. N. & Shipitzyna, N. K. (1957) *Seasonal phenomena in the life of malaria mosquitos in the USSR,* Institute of Malaria, Medical Parasitology and Helminthology, Ministry of Health, USSR. This book of 527 pages contains papers by 36 authors and is composed of four parts dealing with the following subjects: (1) timing of seasonal phenomena in anopheles of the USSR; (2) duration of the imaginal diapause in anopheles of the USSR; (3) phenological observations in relation to timing and duration of control methods; and (4) seasonal periodicity in *A. maculipennis* and its importance in malaria eradication.

the infection through hibernation. In northern areas of the USSR the duration of the transmission season is limited to one to one-and-a-half months (June-July), in the central part it amounts to two to two-and-a-half months (June-August), while in the south it extends to five to six months (April-September). According to Sergiev, in the north of the country two thirds of infections are contracted in July and one third in August, but because of the presence of *P. vivax* with a long incubation period the number of cases does not increase until the next May. Thus in 1948 one sixth of all cases in the north-central part of the Soviet Union were infected in June, one half of them in July and one third in August (Sergiev & Yakusheva, 1956).

Antimalaria measures may change quite considerably the local curve of malaria incidence. Schizontocidal chemotherapy usually delays the appearance of primary cases, while anti-relapse treatment decreases greatly the number of late relapses and thus the morbidity during the spring of the next year. Good imagocidal measures will eliminate the new infections during the late summer, and in consequence the southern localities of the USSR might show the northern type of epidemiological curve with peak morbidity during the late spring.

The strain of vivax malaria with a long incubation period as seen in the northern and central areas of the USSR shows early relapses, usually in June and July. It was noted that the cases with the early primary attack have more frequent relapses. Only about 1.4-4.0 % of cases of vivax malaria with a long incubation period show any relapses during the following year. Vivax malaria with a short incubation period, seen mainly in the south and south-east of the USSR, relapses more often and is characterized by the delayed timing (7-11 months after the primary attack).

It was noticed that in areas with intense transmission of vivax infections with a long incubation period these relapses were frequent even during the spring or early summer. An investigation of the pattern of malaria morbidity in those areas where imagocidal measures were carried out thoroughly showed that the number of these early summer " relapses " greatly decreased. Thus it was confirmed that these cases are not late relapses of vivax malaria with a delayed incubation period but new infections in individuals with a low degree of immunity acquired after the first infection.

In falciparum malaria recrudescences are not infrequent, but a small proportion of relapses were seen during the 5-6 months following the primary attack. Subclinical relapses of falciparum malaria with circulating and infective gametocytes might be seen for several months in cases left without treatment.

The importance of asymptomatic parasite carriers in the epidemiology of human malaria was recognized by Berestniow in 1903 and underlined by many other authors. It is estimated by Rashina that these carriers may occasionally form as much as 30-40 % of the total infective reservoir available to the vector. Two groups of asymptomatic gametocyte carriers are distinguished:

(1) primary carriers who deny ever having had an acute attack of malaria, and

(2) secondary carriers who after an overt primary attack have subclinical relapses, with a low gametocytaemia which is yet sufficient to infect the vector. It was found by Yakusheva & Dukhanina that 14-19 % of patients with falciparum malaria contracted in the autumn showed asymptomatic gametocytaemia in the spring and summer of the following year (Sergiev & Yakusheva, 1956).

These carriers are the most important link in the year-to-year maintenance of falciparum malaria in localities where the transmission period is short. Similar findings of even higher (30-50 %) proportions of asymptomatic parasite carriers were recorded in vivax malaria by Sarikian & Remennikova.

Much work has been done in the USSR on the duration of the malaria infection. The results of a collective investigation co-ordinated by the Institute of Malaria indicate that the duration of infection with *P. falciparum* does not as a rule exceed one year, with *P. vivax* two years, and with *P. malariae* three-and-a-half years. In the case of mixed infection, each species disappeared within its own limit of time (Sergiev & Yakusheva, 1956; Tareev, 1958).

The quantitative bases of the epidemiology of malaria were reviewed and developed by Moshkovsky (1950). His book deals with the mathematical approach to the problem of the transmission of the disease, and defines particularly the various elements of two main parameters proposed, namely, " transmissibility " and " recovery rate ". The importance of socio-economic factors in the epidemiology of malaria is stressed.

Clinical aspects, pathology and immunology of malaria

The clinical aspects of malaria in the USSR were investigated by Tareev (1943), Kassirsky (1946), Zavadsky (1948), Nesterov (1953) and others. Only a few particularly interesting aspects of their findings can be mentioned here.

Soviet authors (Sergiev, Shingareva, Davidowsky) believe that during the incubation period of malaria in pregnant women, sporozoites of vivax malaria cross the placenta into the foetal liver and may subsequently cause overt malaria in the newborn. Schizonts, on the other hand, do not cross the normal placenta. During delivery there is a likelihood of direct transplacental contact between the maternal blood and that of the newborn, and intra-partum infections are possible.

It was shown by Voino-Yasenetsky in Stalinabad in the early thirties that babies born from mothers with malaria weigh about 600 g less than normal babies delivered by healthy women; one third of new-born babies from malarious mothers were premature and had a high neonatal mortality.

The clinical periodicity of infections with *P. vivax* was thoroughly investigated. In vivax malaria with a short incubation period the primary attack occurs within 14-21 days, usually in late summer; this is followed by a first series of relapses in the spring or summer of the next year and by the second series of relapses in the spring of the following year.

In vivax malaria with the long incubation period the primary attack occurs in the spring or summer 8-11 months after the infective bite; this is followed in the spring of the subsequent year by a series of relapses. This series is rather longer in individuals whose primary attack was in the spring.

One of the most interesting clinical pictures, described in 1945 by several Russian authors (Bystrov, Gontaeva), is of "fulminant tertian malaria", which was previously not uncommon in the areas of Kuibyshev, Tambov and Voronezh and was occasionally seen in other parts of Russia. "Fulminant tertian malaria" was observed usually in the spring and mainly in children of 4-15 years of age, though in a few cases the victims were adults; the majority of the children had previously suffered from malaria. Generally the fulminant attack was preceded by a rigor and accompanied by intense headache and vomiting, followed by coma, convulsions and death. Schizonts of *P. vivax* were found in the blood and in smears from internal organs. At autopsy there was cerebral oedema, enlargement of the spleen and liver, and pulmonary oedema.

The Soviet authors regard the cerebral oedema as an allergic reaction of the central nervous system to decomposition products of the malaria parasites. The clinical picture described above has now become exceedingly rare.

Cerebral forms of falciparum malaria were previously very common in Transcaucasia and in Turkmenistan, Tadzhikistan and Uzbekistan, where *P. falciparum* was prevalent. Gontaeva and Shirokogorov believe that in addition to the mechanical blocking of cerebral capillaries by parasitic thrombi, the characteristic picture of cerebral malaria is also due to an allergic (hyperergic) response of the brain tissue to the altered proteins of the affected cells.

Blackwater fever was occasionally seen during the quinine period in those areas of the Soviet Union where *P. falciparum* infections were prevalent. The introduction of synthetic antimalarials was followed by the disappearance of this syndrome.

The relationship between parasite density and the clinical symptoms of malaria was investigated independently by Pavlovsky, Kassirsky, Tareev, Sergiev & Tiburskaya, Ozeretskovskaya and others. It was confirmed that acute symptoms of malaria can be present with only 10-20 parasites per mm^3 of blood; on the other hand, in the infection induced with very high numbers of parasites, fever does not necessarily follow the first schizogony. The Soviet workers maintain that the classical symptoms of malaria do not depend on any "pyrogenic level" of the parasitaemia but are due to some more of less specific proteins, which gradually sensitize the reticulo-endothelial system and produce conditioned reflexes of the thermo-regulating mechanism of the central nervous system.[1]

Tareev, Kassirsky, and other Soviet authors agree that an acute attack of malaria is accompanied by a sharp fall of neutrophils and eosinophils without any change in the number of lymphocytes or monocytes. Moshkovsky proposed the use of a curve of the differential count of white blood cells ("leucocyte profile") as an auxiliary method for the diagnosis of malaria.

[1] Abrami and Senevet (1919) had previously concluded that the symptoms of an acute attack of malaria are due to a *crise hémoclasique* similar to an anaphylactic shock.

Pathological changes in the liver were investigated by a number of Soviet workers. The frequency of hepatomegaly in malaria was described by Tareev, Miasnikov, Kassirsky, while Prokopenko recorded an exceptionally high incidence of liver enlargement in the malarious area of Pakhta Aral in Central Asia. The well-known early degenerative lesions of the liver in malaria might occasionally lead to either acute parenchymatous hepatitis or later to cirrhotic changes.

The liver changes are due not only to the direct action of the parasites and their pigment present in the organs, but even more to local anoxia (linked with the response of the autonomic system) and to the toxic action of products released from the degenerating cells of the affected organ. Nephritis of malarious origin has been described by several authors (Tareev, Zavadsky, Kassirsky, Shakhmatov) and is accepted as a relatively common complication of the disease. Sergiev & Yakusheva (1956) do not emphasize any association of renal complications with quartan malaria.

Soviet authors believe that there is no genetically acquired immunity to malaria. (This attitude is interesting as it is not fully in accord with certain trends in Soviet genetics towards accepting the inheritance of acquired characters). They maintain that acquired immunity to malaria is short-lived and depends on the phenomenon of " premunition ", or as Moshkovsky calls it, " concomitant infective immunity ". Long-lasting post-infective immunity can be seen in highly endemic areas and is partly " anti-parasitic ", partly " antitoxic ". Discussions by Soviet authors of problems of immunity in holo-endemic areas of the world (particularly in Africa) often reveal some lack of information on this subject.

Chemotherapy

Chemotherapy plays a most important part, not only in the individual treatment of malaria, but also in the collective attack on and the prevention of this disease in the USSR. In all the early control schemes in the Soviet, and in the more recent malaria eradication programmes, the value of chemotherapy has been fully recognized from the beginning. Antimalarial drugs have never been regarded as merely auxiliary methods. Indeed, it seems that chemotherapy has often been given more emphasis than the residual insecticides, since the system of treatment and follow-up of individual cases offers unique possibilities of attacking the infected and infective human reservoir.

Quinine, used widely until the early thirties, is now employed only exceptionally, and has been completely eclipsed by synthetic antimalarials. It was given in a daily dose of 1.0-1.2 g for 3-4 days followed by an interval of 4 days, after which the same treatment was repeated. Usually four treatment cycles were given. Intramuscular injections of 0.5-1.0 g are given (when necessary) twice daily.

The first synthetic antimalarial produced in the USSR, by Magidson, Strukov, Chelintzev & Knuniantz in 1931, was *plasmocide*. Until 1958, it was much used in combination with other drugs.

Plasmocide is an 8-amino-quinoline [8-μ- (diethylamino-1-methylpropylamino) 6-methoxyquinoline] of the same general group as plasmoquine or pamaquine and similar to rhodoquine (= Fourneau 710) (Findlay, 1951).

Plasmocide is produced in tablets containing 0.02 g of base. The maximal daily adult dose is 0.06 g (Sergiev & Zhdanov, 1955). The toxic effects of unduly large doses of plasmocide are well known, however, and atrophy of the optic disc, ataxia, anuria and polyneuritis have been recorded.

Acriquine [1] (= mepacrine) was synthesized in the USSR in 1933 by Knuniantz, Tchelintsev & Benevolenskaya, and is still very widely used. It is probable that the Soviet acriquine is slightly different from the similar drugs of the mepacrine type, such as atebrin, quinacrine and others (Field, 1939).

Acriquine is produced in tablets containing 0.05 g or 0.1 g (for children). Children are also given an acriquine mixture containing 0.5 % of the drug. The loading dose advocated for adults is 0.6 g, the daily dose being 0.3 g. For parenteral administration, dry powder (0.4 g per ampoule) is used after being dissolved in distilled water. Intravenous injections of acriquine are not proscribed, but caution is advocated.

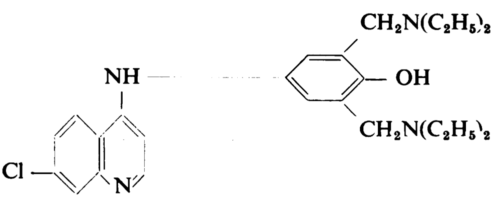
Bigumal (= proguanil) synthesized in the USSR in 1947 (by Bekhli, Ufimtzev & Topchiev) is produced in tablets containing 0.05 g and 0.1 g (for children). There are also combined tablets containing bigumal and plasmocide. Bigumal as a 1 % solution is used for intravenous treatment of cerebral malaria. The therapeutic value of bigumal in falciparum malaria is much emphasized by the

[1] The Russian spelling of the root " quine " is *khin*. Thus the correct names of drugs quoted in this section are: akrikbin, ciklokhin, khinocid. The English spelling is used here.

Soviet workers, while the prophylactic and sporontocidal effect is fully appreciated in malaria eradication programmes.

Chloroquine was also synthesized in the Soviet Union and tried out with good results. Nevertheless chloroquine does not seem to be widely used in the USSR. There are only brief references to this drug in the handbook by Sergiev & Yakusheva (1956), and none whatever in that of Sergiev & Zhdanov (1955) or in reviews by Moshkovsky (1957) or Tareev (1958). Chloroquine is produced in tablets containing 0.25 g of the salt. The adult loading dose advocated is 0.6 g of base, followed 6-8 hours later by 0.3 g and by the same single daily dose for the next two days. The suppressive dosage is two tablets once a week.

Cycloquine is another 4-amino-quinoline recently synthesized in the USSR and used on a small scale, chiefly in field trials. It is a 7-chloro-4-[3′,5′-bis (diethylaminomethyl)-4′-oxyphenyl]-aminoquinoline.

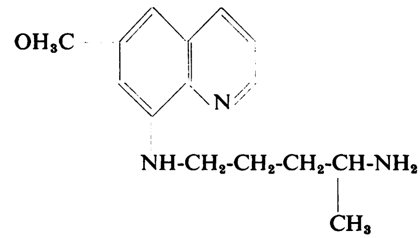


Its structural formula shows that this drug is closely related to amodiaquine, the main difference in the new drug being a double diethylaminomethyl chain in the aniline group attached to the quinoline nucleus. It appears (Gladkikh et al., 1959) that cycloquine is better tolerated than other 4-amino-quinolines. Kellina and Korogodina (1959) found that cycloquine and chloridine given together produce no toxic effects.

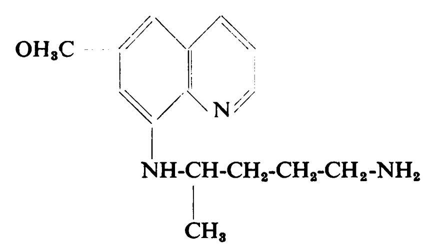
Chloridine (= pyrimethamine) was synthesized in 1953 by Magidson & Voloskoya, and is used as a base or as a hydrochloride in tablets at 0.025 g of base. Sergiev & Yakusheva (1956) emphasize the value of chloridine in the treatment and individual prophylaxis of malaria, and its sporontocidal (= " gamostatic ") effect. This drug was used in Tadzhikistan for collective prophylaxis in a dosage of 10 mg once weekly with very good effects, although relapses of vivax malaria were not prevented after cessation of administration. For treatment of malaria the dosage advocated by Abdullaev (1957) was 0.025 g daily for 3-4 days.

Quinocide, a Soviet 8-amino-quinoline compound, was synthesized in 1952 by Braude & Stavrovskaya (1956) and approved by the Ministry of Health in 1956 (Sergiev & Yakusheva, 1956).

It is a structural isomer of primaquine, the only difference between the two drugs being in the position of the methyl group in the side chain. In the quinocide the methyl group is in position 4′ while in primaquine it is in position 1′.



Quinocide or 6-methoxy-8-(4′-amino-4′methyl butyl-amino)-quinoline dihydrochloride: $C_{15}H_{21}ON_3$, 2HCl (78% of base)



Primaquine or 6-methoxy-8-(4′-amino-1′methylbutyl amino)-quinoline diphosphate: $C_{15}H_{21}ON_3$, $2H_3PO_4$ (56% of base)

Quinocide is used as a hydrochloride in tablets containing 0.01 g or 0.005 g of the salt. Much emphasis is put on the anti-relapse value of this drug in vivax malaria with short and long incubation periods, and on the probable sporontocidal effect. Side-effects of this drug (nausea, cyanosis, pollakisuria, microhaematuria) are seen in about 5 % of patients, especially when any other antimalarials are administered at the same time. Toxic effects of this drug on the eyes are, according to Tiburskaya et al. (1959), virtually absent. A course of treatment with quinocide consists of either (*a*) a daily adult dose of 0.03 g for ten days, or (*b*) a daily adult dose of 0.02 g for 14 days. Treatment is administered after the completion of the standard five-day treatment of acute malaria using bigumal or acriquine. Quinocide is not given to infants.

This drug gave very good results when tried out in Azerbaidzhan (Zhukova et al., 1958), in Tadzhikistan (Lysenko & Gozodova, 1958), and in Georgia (Maruashvili et al., 1958), and the mean number of relapses of vivax malaria was never more than 1%.

Combinations of various antimalarials have always been very popular in the Soviet Union. The following combined drugs are listed in the official handbook (Sergiev & Zhdanov, 1955):

(1) Acriquine 0.1 g and plasmocide 0.02 g
Acriquine 0.05 g and plasmocide 0.01 g (for children)

(2) Acriquine 0.1 g and bigumal 0.1 g, plasmocide 0.02 g
Acriquine 0.05 g and bigumal 0.05 g, plasmocide 0.01 g (for children)
This combination is called ABP or triple drug (*troichatka*)

(3) Bigumal 0.1 g and plasmocide 0.02 g

The following treatment schedules with each of these three combinations are officially advocated:

(1) Acriquine with plasmocide in three cycles (five days, three days, three days) with one week's interval between each cycle. The daily adult dose is 0.3 g of acriquine and 0.06 of plasmocide;

(2) Acriquine, bigumal and plasmocide in combination for seven days, at the adult daily dosage of 0.3 g, 0.3 g and 0.06 g of each drug respectively;

(3) Bigumal (first dose 0.6 g, followed by a daily dose of 0.3 g) alone or with plasmocide (0.06 g daily adult dose) for five days.

The dosage for children is approximately one quarter the adult dose for the age-group 2-4 and one half the adult dose for the age-group 6-8; infants are not given any plasmocide.

The most important aspect of the chemotherapy of malaria in the USSR is the attention paid to the curtailment of clinical relapses and to the prevention of secondary cases. Drug administration is carried out by the medical and paramedical personnel of a very wide network of hospitals, polyclinics, health centres, dispensaries, antimalaria stations, factory medical units, etc., and is based on early diagnosis, reliable notification, good record-keeping, and regular surveillance through the medium of house, school or factory visits or by periodical summoning former patients to dispensaries or health centres. All former patients are repeatedly and emphatically reminded of the importance of reporting whenever they have any clinical symptoms even remotely resembling malaria.

Three types of chemoprophylaxis are known to exist:

1. Individual chemoprophylaxis is based on the seasonal administration to the whole population exposed to malaria of two tablets of bigumal or two of acriquine twice a week. It was confirmed by Tiburskaya, Lysenko & Bobkova that in the form of vivax malaria with the long incubation period bigumal does not delay the primary attack; in the form with the short incubation period the primary attack was prevented, but not relapses (" bigumal effect ").

Since 1952 chloridine has been given in some areas at a dosage of 0.05 g (50 mg) once a week with very good results. More recently cycloquine has been given at 0.5 g once a week. Individual prophylaxis of malaria is now less frequent, because of the general decrease of malaria in the USSR.

2. Collective prophylaxis concentrates on the prevention of relapses and of subsequent infection of vectors by gametocyte carriers. Ten days after the completion of schizontocidal treatment (*kupirovanye*) of the acute attack each case of malaria undergoes anti-relapse treatment. Subsequently, during the transmission season of malaria, which is assessed on the basis of local climatological conditions and phenological observations, each previous case of malaria is given gametocidal and sporontocidal drugs. Generally two tablets of acriquine with plasmocide, or of bigumal with plasmocide, are given for two days every week during the summer. Today the introduction of quinocide has changed this regimen, and those who, after schizontocidal treatment of acute malaria, have had a full course of anti-relapse treatment by quinocide, do not undergo any further " collective prophylaxis " and are considered as cured.

3. Finally, there is the pre-epidemic chemoprophylaxis employed in the northern areas of the USSR where vivax malaria with a long incubation period is common. In these areas, attacks of malaria may be expected in the spring and can be prevented. Bigumal or acriquine alone or with plasmocide are administered at the dosage given

for collective prophylaxis. Recently quinocide has also been given 2-3 weeks before the probable epidemic, at the rate of 0.03 g daily for ten days.

The duration of the follow-up of cases of malaria depends on the type of infection: one year for falciparum malaria, two years for vivax malaria and three years for quartan malaria. The schedule of this follow-up is taken from Sergiev & Yakusheva (1956). During the first calendar year the patient has a course of treatment followed by anti-relapse collective prophylaxis, which commences ten days later and lasts throughout the transmission period. During that period (June to August or September) he is examined by the medical unit once a month and during the remaining 8-9 months once every quarter. In a case of clinical relapse or of asymptomatic parasitaemia, focal insecticide spraying of the patient's and his neighbours' houses will be carried out. During the second year the same schedule is applied, with special attention to antirelapse treatment of vivax malaria with a short incubation period.

General anti-mosquito measures

Mechanical protection of the population from mosquito bites is given by the screening of houses (*zasetchivanye*) and the use of individual mosquito nets (*polog*) in several areas of the country; in these localities the shelters for domestic animals are sited so as to take advantage of the possible zoophilic habits of mosquitos. Among the repellents dimethyl phthalate is the most popular, although it seems that some other unspecified repellents (SK-9) have also been used, with varying success. The use of wide-mesh netting impregnated with naphthalene and phenol compounds was introduced in 1939 by Pavlovsky and Pervomaisky. The value of this method for individual protection was greatly increased when dimethyl phthalate and dibutyl phthalate jellies (made up in acetyl cellulose solution) became available. These impregnated nets are known in the Soviet Union as Pavlovsky's nets.

Several new repellents, derivatives of tetrahydroquinolines (first described in the United States of America), have been produced by the Soviet chemists. Two of these repellents, known as " Cusol A " and " Cusol F " (previously FP99 and RP 122) are acetyl and formyl tetra-hydroquinolines, which were tested in the field by Zolotarev & Tarabukhin (1959) and proved to be two to three times more effective than dimethyl phthalate, though very irritant to the eyes. Another repellent called " Nivif " is a diethylamide of metatoluylic acid, and is particularly effective against ticks (Safianova et al., 1959).

During the past few years the interest in repellents for protection against mosquitos, blackflies, sandflies and ticks has increased considerably. About 200 new compounds have been synthesized, and 150 tested in the laboratory and in the field; three of them (among them " P5 "—a 2-4 dichlorobenzoic acid; " Birio "—a mixture of butylacetanilid and of iso-amylacetanilid) were found to be superior to any others (Maslov & Shamrai, 1959). The physiological action of repellents, the specific, seasonal and geographical variation of the response of insects, as also the methodology of field trials, are being thoroughly investigated (Ivanova et al., 1959). An assessment of the present status of research on mosquito repellents was made recently by Nabokov & Bataev (1959).

An interesting characteristic of mosquito control measures in the Soviet Union is their comprehensiveness and widespread use. Classical methods, such as drainage, filling (" bonification "), intermittent drying, naturalistic control, afforestation, are carried out with vigour.

In the planning and execution of all large-scale hydrotechnical projects allowance is made for the prevention of mosquito breeding in impounded waters. Various methods of water management, such as dyking, sluicing, shore-line preparation, surcharge, fluctuation of level, etc., are widely used, under the guidance of entomologists who have worked out specific vegetation indices for the assessment of the potential danger (*anofelogennost*) of water reservoirs. Most of these problems have been fully dealt with in a volume edited by Beklemishev (1954).

The results of preventive measures incorporated into irrigation programmes were particularly good in the ancient Kolkhis (Kolkhida), Georgia, as also in Dagestan and Uzbekistan. Antimalaria measures were carried out on a large scale in the reconstruction of the water transport system of the Moscow-Volga and other rivers. The larvivorous fish, *Gambusia affinis* and *Gambusia holbrooki* were brought from Italy in 1925 by Rukhadze and used in Transcaucasia, South-Central Asia and Ukraine with conspicuous success (Sokolov, 1958). In Abkhazia 80 % of all potentially dangerous waters have been seeded with larvivorous fish; in some areas the seeding is being done by aeroplanes in low-level flights (Moshkovsky, 1949).

Larvicidal methods have nowadays decreased in importance, but are still widely used in urban areas close to large mosquito breeding-places. Methods of larvicidal control do not greatly differ from those used in other parts of the world. Two types of larvicidal oils are employed: petroleum oil and " green oil "; the second is more active as it contains 5 % of naphthalene compounds. These oils are applied by means of various drip cans, oil pillows (Indian *guddas*) or knapsack sprayers. The application rate is approximately 20-40 ml per m^2 of water (roughly, 18-36 gallons to an acre) and the dosage of the " green oil " is half of that of petroleum oil. There is no information on the use of larvicidal oils with addition of chlorinated hydrocarbons. There are various larvicidal dusts such as Paris green, calcium arsenite, " Arsmal " (an orthoarsenite of copper), thiodiphenylamine, hexachlorane (=BHC); the mean application rate to one hectare of water surface is between 0.8 and 3 kg of the toxicant (approximately 0.8-1.8 lb. per acre) mixed with an inert diluent in the proportion 1:24 to 1:9. Some larvicidal dusts are also used as suspensions in a mixture of kerosene, water and soap.

The larvicidal dusting equipment ranges from sifter cans, hand-operated, portable rotary dusters carried in front (OR) or behind (RV-1, ORM, " Tip-top ") or the latest " Serna-4 ", to power-driven dusting apparatus, such as " Serna-2 " and its later more powerful model, " Serna-3 ", which can be carried in a trailer, truck or motor boat (Nabokov, 1957).[1]

Much " space-dusting " using " Serna-3 " is now being done in Siberia near Krasnoyarsk, where the biggest Soviet hydro-electric plant is being built on the Enisey River and where winged insect pests and ticks abound. " Cloud-dusting " is being tried out using high explosives (Detinova, 1958).

Before the Second World War pyrethrum concentrates in solutions, emulsions (" Flicid ") or fumigants were widely employed in the Soviet Union.

Most Soviet pyrethrum comes from the Crimea, southern Ukraine and Azerbaidzhan. A survey of species of chrysanthemums (*romashka*) growing in the USSR was carried out in 1934 (Nabokov, 1958) and some high-yield new species were found. Pyrethrum dusts and concentrates (5 % and 20 %) have been used for the control of many arthropods since the value of pyrethrum in malaria control was reported on by Nabokov in the early thirties. At the present time pyrethrum is used mainly for space-spraying, as solutions (such as " Flicid ", containing 0.06-0.07 % of pyrethrins I in white spirit), as emulsions, or as fulmigant candles. Recently a pilot plant started the production of allethrin—a synthetic analogue of cinerin.

Space-spraying is carried out in areas where there are many winged pests. In houses pyrethrum solutions (0.03-0.045 % of pyrethrin extract) are used at a dosage varying between 6 and 12 ml per 1 m^3. Fumigant candles made of pyrethrum dust, sawdust, saltpetre, starch and water are also employed. For large-scale treatment aerial spraying is carried out, or DDT and pyrethrum aerosols are dispersed at ground level from liquid concentrates, or released by fumigation. High-pressure Freon 12-propelled insecticide aerosols are produced from cylinders (type VMA contains up to 500 g of DDT or BHC), mechanically-created aerosols—from power-driven aerosol generators (type DASH-16 or AG-L61). Portable pulsating thermal generators (RAG-1 and RAG-2) made in Czechoslovakia (similar to the " Swingfog " generator) are now being introduced.

DDT and BHC fumigant canisters (*shashki*) and candles are now increasingly used for the control of mosquitos and other pests. Candles of the " D20 " type are used mainly for indoor fumigation; they contain 20 g of DDT and are sufficient for one medium-size room; larger canisters (" D-17 " or " G-17 ") contain 1 kg of DDT or BHC and burn for 20 minutes. They are much used for the treatment of warehouses and such, as also for outdoor fumigation; the open-air dosage is 4 canisters to a hectare every 10 days.

An interesting method is the indoor use of fumigant paper, prepared by impregnating blotting paper with a solution of saltpetre and then with a 25 % solution of DDT or BHC. The dry paper is hung on wires and produces, on burning, insecticidal fumes sufficient for the indoor control of winged pests. About 1 g of fumigant paper is sufficient for 1 m^3 of space. Recently fumigant papers impregnated with " chlorofos " (= Dipterex) were tried out for fly control with much success by Tzintzadze, Shnaider & Vashkov (1959).

[1] More detailed references to the Soviet insecticide spraying equipment will be found in the entomological dictionary and vademecum by Shchegolev (1955).

Much use has been made of aerial dusting and spraying of insecticides (*aviaopylenye, aviaopryskivanye*) since 1929 when the first trials of aerial spraying commenced near Moscow.[1] The early PO-2A planes with a speed of 100-110 km/hour were used for many years and later changed to heavier LI-2 and AN-2 planes with a bigger payload, capable of a speed of 155-160 km/hour. According to Sergiev & Yakusheva (1956) the area treated annually from the air averaged during the past years 3-4 million hectares (7.5-10 million acres). Entomologists together with their auxiliary staff (" bonificators ") prepare the plans for aerial insecticide dispersion and check the results. A new trend favours the helicopters (*vertolet*) for aerial spraying; the helicopter MI-4 first tested in 1955 is being used with success (Nabokov, 1957).

The aerial insecticide-dispersing equipment developed in the Soviet Union is unconventional, reliable and rugged. The equipment developed by Popov (1955) can be easily converted for dusting and spraying. For spraying, a 20-30 % solution of DDT is used, while DDT dusts have a 5 % concentration. The amount applied varies between 0.1 and 0.4 kg of BHC and 0.5-1.0 kg of DDT per hectare, depending on the topography of the area. In the northern areas of the USSR pre-flood ground or aerial dusting of DDT and BHC is also increasingly used against the culicine mosquitos (*Aëdes communis, Ae. intrudens, Ae. vexans, Ae. excrucians,* etc.) and against *Ixodes persulcatus,* the vector of virus encephalitis.

Residual insecticides

DDT and BHC[2] have been used on a large scale since 1949 and considerable quantities of both insecticides are now produced by factories working for the State Chemical and Pharmaceutical Industry (*Glavchimfarmprom*).

The Soviet technical DDT complies with the following specifications (Nabokov, 1958):[3]

Total organic chlorine content (% w/w)	51.0
Hydrolysable chlorine content (% w/w)	9.5-11.0
p,p'-Isomer content (% w/w)	not less than 68.0 (usually 70.5-72.9)
Setting-point	not less than 78°C
Chloral hydrate content (% w/w)	0.025
Acidity calculated as H_2SO_4 (% w/w)	0.3
Solid material insoluble in water (%w/w)	0.5
Solid material soluble in water (% w/w)	0.25
Solid material insoluble in acetone (% w/w)	1.0
Alkalinity calculated as Na_2CO_3 (%w/w)	0.5
Water content (% w/w)	not more than 0.5

A number of chlorinated insecticides such as " chlorten " (= a chlorinated alpha pinene), " chlorindan " (= chlordane), " hexaten " (a mixture of chlorinated terpenes and isomers of BHC) and others are being tested, as also heterocyclic carbamates (" pyrolan ", " pyramat ") and many organo-phosphorus insecticides, among which " mercaptofos " (= diazinon), " karbofos " (= malathion), " chlorfen " (= toxaphene), " chlorofos " (= Dipterex), " pyrophos " (tetraethyl monothiopyrophosphate) and " ditio " (tetraethyl dithiopyrophosphate) should be noted (Nabokov, 1958; Korovin, 1958). The production of diazinon, malathion and Dipterex has greatly increased during the past two years (Vashkov, 1959).

DDT and BHC formulations used in the USSR are wettable powders, dusts, emulsions and pastes. Dusts generally contain 5 %, 10 % and 12 % of the active principle; water miscible emulsions (" Detoil ") contain 20-25 % of DDT or 15 % of BHC; wettable powders contain 15 or 25 % of the toxicant; pastes contain 30 % of DDT or BHC. Highly-concentrated pastes containing 66 % of DDT and BHC were recently used in Tadzhikistan by Lariukhin (1957) and showed a longer residual action. A new type of formulation is a highly stable " colloidal suspension ", of a semi-solid consistency and yet easily miscible with water. It is obtained by mechanical homogenization of the mixture in mineral oil and water. It is composed of 40 % DDT, 10 % mineral oil, 15 % emulsifier and stabilizer (ether polyethylene glycol) and 35 % water (Nabokov, 1958). (When no other formulations are available, a suspension of technical DDT in water with soap as an emulsifier is used.) The usual dosage for complete coverage and barrier spraying (see below) is 1 g

[1] The early (1931-1939) reports by Nabokov on aerial spraying and dusting in the Soviet Union are quoted by Covell (1941).

[2] BHC is known in the USSR as hexachlorocyclohexane or hexachlorane and abbreviated as HChCH. The gamma isomer content of the technical produce is 13 %; the proportion of other isomers is: alpha - 70 %, beta - 6 %, delta - 6 %. New formulations are produced with much higher gamma isomer content (Nabokov), 1958.

[3] These requirements fully correspond to the specifications approved by WHO (World Health Organization, 1956).

of the technical DDT per m^2 and 2 g of technical BHC per m^2. This dosage is doubled in the case of focal spraying (see below). The necessary dilution rate of the formulations used is calculated on the basis of a mean delivery rate of 3-10 litres per 100 m^2.

Home-made whitewash containing 5 % BHC or 10 % DDT is also used in some areas, for instance the Ukraine, as it was shown that there is little decomposition of DDT in ordinary whitewash.

DDT is used for residual spraying of human dwellings, while BHC is generally preferred for cattle sheds, stores and other unoccupied premises.

Chemical assessment of insecticide deposits is carried out in some special projects. The samples are collected by scraping or swabbing. Several chemical tests are used. The simplest employs the method of Merkulova & Kambur (1951), based on the decomposition of DDT by hot potassium hydroxide with formation of white precipitate of chlorides on addition of silver nitrate solution. A more precise nephelometric test proposed by Fomicheva (1952) is based on the partial dehydrochlorination of DDT by alcoholic potassium hydroxide. The colorimetric method introduced by Kulberg & Shima (1949) is based on the nitration of DDT by potassium nitrate in the presence of sulphuric acid; to the resulting tetranitro compound lead chloride is added which converts the diamine into a red diazo compound soluble in sulphuric acid and quantitatively assessed in a colorimeter against a set of standards. This method has a sensitivity range of 5-50 micrograms. For the chemical estimation of BHC Koliakova (1956) proposed a method based on the dehydrochlorination by alkali and fast potentiometric titration.

The duration of residual effect of BHC being much shorter than that of DDT, the official manual (Sergiev & Zhdanov, 1955) advises that repeated spraying with BHC be carried out every 1-1 ½ months, if necessary.

The duration of the residual effect of DDT depends naturally on the climatic conditions of the area, but it is stated (Sergiev & Yakusheva, 1956) that in the south the residual effect lasts for several weeks, and in the central and northern areas for several months. In some parts of the Soviet Union (Orekhovo-Zuew) it was found that DDT deposits remain active for 12-14 months. Only one DDT spraying cycle a year is used in the USSR as a rule, though sometimes two cycles might be needed in the south. Normally about 15-25 % of houses in southern parts of the USSR are treated twice a year. The timing of spraying cycles depends on the transmission season and on the local conditions of the area. In the north and in central parts of the USSR the spraying cycle begins in March or early April, in the south in May or June.

Table 2, which is taken from Nabokov (1958), illustrates the dosage and spraying schedules used in the USSR.

There are three methods of residual spraying: complete coverage (*sploshnaya obrabotka*), barrier spraying, and focal spraying (*ochagovaya obrabotka*). The latter, introduced by Sergiev, was used whenever the malaria morbidity was less than

TABLE 2
DOSAGE AND SPRAYING SCHEDULES OF DDT AND BHC IN THE USSR

Area	DDT technical			BHC technical		
	Dosage	Cycles	Remarks	Dosage	Cycles	Remarks
North and central part of the USSR	1 g/m^2	One	First cycle when the first generation of vectors is on the wing.	2 g/m^2	One	First cycle to be completed before the first generation of vectors is on the wing.
Northern Caucasus, southern Ukraine, Moldavia	1.5 g/m^2	One	In March-April. Additional spraying cycles if necessary according to entomological findings	2 g/m^2	Two	First in spring, second by the end of June or beginning of July
Middle Asia, Transcaucasia	2 g/m^2	One	As above.	2 g/m^2	Two	As above.

3 %. Today this method is employed throughout the northern and middle zone of the USSR.

The method of complete coverage is used in all highly malarious rural areas, or in localities where the anopheline density is high and the risk of introduction of malaria from immigrants is considerable. Complete coverage includes not only human dwellings but also all outhouses, cellars, hay lofts, etc. Barrier spraying is carried out in some urban areas close to large mosquito breeding grounds, the width of the sprayed zone depending on local conditions. With the decrease of malaria morbidity during recent years the method of local spraying has become much more common, and is used for the treatment of a group of houses whenever a case of malaria is discovered in the course of surveillance.

In conditions when exophilic vectors, such as *A. pulcherrimus,* might be involved in the transmission of malaria, residual spraying might be carried out also outside inhabited houses, under the eaves, in caves, around trees and bushes, etc.

Spraying of cattle and domestic animals, as a complementary method of malaria eradication in areas where the vector shows zoophilic tendencies, was tried out on a small scale in 1948, and has been widely used since 1952 by Bandin (1957). In the Stalingrad and Altai area it gave very good results, which were confirmed in Tadzhikistan by Lysenko et al. (1957) against *A. superpictus*. The method is particularly valuable in areas with a silkworm industry, its main drawback being the short duration (about 10 days) of the residual effect. The formulation consists of 10% DDT dust mixed with colophonium for better adherence. Water suspensions or water emulsions are also used at an approximate dosage of 1 g of the active compound to 1 m^2 of the surface of the animal.

Two main groups of spraying equipment are used for residual spraying: (1) hand-operated medium capacity sprayers, and (2) power-driven high capacity, wheeled or vehicle-mounted, spraying machines. In the first group there are three types: the hydraulic stirrup pump bucket sprayer (" O.R.D. ", *hydropult-Vulcan*), the pneumatic compression sprayer (*Kraskopult O-11, Tremas*) or the knapsack pneumatic sprayer (*Automax,* " ORP ").

Recently the hand-operated compression sprayers were provided with Schrader valves and the task of compression was mechanized by portable petrol-driven compressors of the NLS-1 type (Nabokov, 1957). These sprayers are known under the mark " OZB ".

In the second group there are several types of heavy sprayers, such as the " OMP-A " (" Pioneer "), the electrically-operated DASH-23, and many others (Shchegolev, 1955 ; Nabokov, 1958).

An interesting type of spraying equipment is the " DUK " high capacity sprayer mounted on a Soviet type of cross-country motor vehicle (GAZ-51) and driven by the vehicle's engine.

Spraying is carried out by squads (" brigades ") composed of 4-6 spraymen and a supervisor (*rukovoditel*). The recommended standard distance between the sprayer nozzle and the wall is 1 m; this is twice the standard distance used elsewhere. Protective clothing used by the spraymen is composed of an overall (*kombinezon*) and a respirator (*protivogaz*) when necessary.

Large-scale residual spraying is normally carried out by the regional, provincial, district and urban health centres. These centres are provided with their permanent spraying personnel and necessary transport, although other non-medical organizations, such as industrial estates and agricultural " collectives ", are usually requested to assist with transportation. The total area of walls and ceilings sprayed in the USSR was a follows:

1950	140.9 million m^2
1951	195.3 » »
1952	207.7 » »
1953	356.6 » »
1954	326.1 » »
1955	345.0 » »
1956	344.0 » »
1957	267.5 » »
1958	239.0 » »

These figures, quoted by Sergiev, Rashina & Lysenko (1959), indicate the gradual decrease of spraying activities, but also show that this decrease was not as great as would be expected from the great reduction in the prevalence of malaria, especially during the past five years.

Resistance

References to insecticide resistance (*ustoichivost*) by arthropod vectors are surprisingly few in the available Soviet writings. Resistance of houseflies to DDT and BHC was recorded several years ago by Derbenieva-Ukhova & Morozova (Nabokov, 1958) and reported more recently from

Moscow, from the Crimea and from some southern Soviet Republics (Derbenieva-Ukhova, 1957; Olenev, 1958).

A special technical meeting devoted to the problem of arthropod resistance to chlorinated hydrocarbons was convened in February 1957 at the Moscow Institute of Malaria and Medical Parasitology. Most of the original papers read at this meeting dealt with the resistance in the housefly, but experimental DDT resistance in lice was also mentioned. The meeting agreed that the problems of arthropod resistance to insecticides should receive more attention, recommended the setting up of a coordinating centre for studies on resistance, and drew up a detailed programme for basic and applied research work.

No resistance of mosquitos generally and anopheles in particular has been reported from the Soviet Union (Sergiev, 1958; Nabokov, 1958). Data on susceptibility levels are not quoted in the available Soviet sources, even though a series of tests of anopheline susceptibility was recently carried out in Gruzia (Georgia). The response of some arthropod vectors to contact with insecticide deposits has been investigated, however, and a few types of bio-assay chambers have been described. One of the early bio-assay kits is that of Korovin & Mironova (1949) for sand-flies. A recent device designed mainly for bio-assays but usable also for susceptibility testing is the "Exposimetre NLZ-3", developed by Nabokov, Lariukhin & Zhukova (Nabokov, 1958). It can be used for mosquitos or for flies, and its design is based on the principle of forced contact of the insect with the toxic surface, by the action of a plunger in a wide glass tube applied to the toxic surface through an intermediate plastic plate provided with a circular hole and a metal slide. A smaller bio-assay chamber similar to a slide-rule and used for single insects was recently described by Turich (1958).

In his recent book Nabokov (1958) discusses briefly the problem of resistance of arthropod vectors to chlorinated hydrocarbons. He mentions that the results obtained by Soviet workers (Derbenieva-Ukhova & Morozova, 1950; Derbenieva-Ukhova & Lineva, 1953) disagree with recent foreign work on the inheritance of the resistant gene according to Mendelian genetics. Some Soviet authors claim that acquired characters are inheritable, as taught by Michurin, and that the inheritance of specific resistance follows this pattern.

Nabokov (1958) discusses the biochemical action of DDT and doubts whether the resistance of flies can be explained solely by the faster conversion of the toxicant into DDE through the action of the specific enzyme.

The Soviet authors do not believe that DDT has a true irritant effect on mosquitos; they admit, however, that contact with DDT increases temporarily the phototropism of poisoned insects (Nabokov, 1958).

The susceptibility of mosquitos to insecticides depends on the stage of their gonotrophic cycle, freshly fed females being less susceptible than the unfed. The most susceptible are those on the wing after hibernation, while the period of relatively high tolerance coincides with the diapause, as shown by Vinogradskaya, Nabokov & Shmeliova (1949).

It is gratifying to learn that Soviet scientists have recently acknowledged the leadership of the World Health Organization in the field of the methodology of susceptibility testing, and have proposed to decentralize and expand this operational research activity in the USSR (Derbenieva-Ukhova & Yaguzhinskaya, 1959).

Malaria eradication [1]

A comprehensive programme for the country-wide elimination of malaria as a mass disease was prepared by Sergiev in 1949 when the use of residual insecticides (mainly DDT) began to gather momentum. This programme was adopted in 1951 and carried out with impressive drive and determination.

It should be pointed out that much malaria in the northern and central zone of the Soviet Union is of the "unstable type", according to Macdonald's (1957) definition. It is often related to the level of environmental sanitation and to general socio-economic conditions. The profound changes in a country which within a quarter of the century has transformed a primarily agricultural society into one of the foremost industrial nations must have contributed to the recession of malaria in the same way as happened (much more slowly) in England, Holland, Germany and France during the eighteenth and nineteenth centuries.

[1] There are two equivalent Russian terms for malaria eradication: *liquidatsia* or *iskorenenye* (taking out by the roots). The first term is more commonly used; the second is occasionally encountered.

Recognition of this does not in any way diminish the outstanding achievements of Soviet malariologists.

There is little doubt that the extensive programme of public health activities generally and of antimalaria work in particular could not have been accomplished by the Soviet Union without adequate medical, scientific and auxiliary personnel. Moreover, from the very beginning, the execution of the programme was based on the existing wide network of dispensaries, health centres, polyclinics, epidemiological stations and antimalaria stations.

The thorough planning of antimalaria measures in relation to general socio-economic development and to some specific aspects of it (hydro-electric or irrigation schemes, opening up of new areas) is perhaps the most obvious characteristic of malaria eradication in the USSR. Public health education (*sanitarno prosvetitelnaya rabota*) receives much emphasis, and is actively carried out by all the available and well-tried methods of political indoctrination: meetings, lectures, discussion groups, pamphlets, posters and films. An important part in these activities is played by voluntary organizations, youth clubs, etc.

It might be of interest at this point to outline briefly the administrative organization of malaria eradication in the USSR. The whole of the malaria eradication programme in the Soviet Union is directed now by the Division of Communicable Diseases (*Protivoepidemicheskiy Otdel*) of the Department of Public Health and Communicable Diseases (*Glavnoe Sanitarno-Protivoepidemicheskoye Upravlenye*) of the Ministry of Health. (Until recently the Ministry of Health, USSR, and the respective ministries of the Soviet Republics each had a special malaria division.)

The Division of Communicable Diseases, advised by the Institute of Malaria of the Ministry of Health, USSR, is responsible for the administrative and technical planning of all antimalaria measures, and for the training of personnel. The epidemiological follow up of cases of malaria is organized jointly with the Division of Medicine of the Ministry of Health, USSR.; the organization of research is vested in the Institute of Malaria of the Ministry of Health and the regional institutes of the respective Republics ; public health education in malaria is organized by the Institute of Health Education of the Ministry of Health.

On the basis of general directives sent out by the Ministry of Health, the planning of antimalaria measures within each district is prepared by the District Medical and Health Unit, with the advice of the corresponding Health Centre. A preliminary survey is carried out by the village Medical and Health Unit and by the District Unit. This plan is submitted to the higher authority, viz. the Regional Health Centre, which adopts it after consulting such local collective farming units or industrial organizations as are relevant. The plan, after approval by the Regional Health Department (*Raizdravotdel*) is submitted to the Executive Board of the region (*Rayonnyi Ispolkom*) and then to the Provincial Health Department (*Oblzdravotdel*), which consolidates the programme for the whole province.

Antimalaria measures are carried out by (*a*) general and medical health organizations, (*b*) special antimalaria stations, and (*c*) temporary paramedical detachments. The organization of special antimalaria stations commenced forty years ago, and had developed by 1952 into a network of 2150 stations, the size and density of which were in relation to the amount of malaria in the area. These regional, district, urban and rural stations linked with the general health service are responsible for the supervision of preventive measures and hydro-technical projects, for larvicidal and imagocidal measures, for treatment of patients, for chemoprophylaxis and for the training of auxiliary personnel. The number of these stations is now decreasing.

The temporary medical detachments were active in districts with high malaria endemicity. In the rural areas on the collective and state farms much of the work was carried ou by " bonificators " and " acriquinizators ". These were auxiliaries who, after having received a short training course in antimalaria work, were paid by the respective farms, plants or other public bodies.

Insecticidal measures on a small scale are carried out by antimalaria stations or the local health units with the co-operation of other collective organizations if necessary. Large-scale spraying is always carried out by the District Health Centre.[1]

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[1] Regulations dealing with the methodology of malaria surveys, chemotherapy, anti-mosquito measures, entomological investigations, etc. approved by the Ministry of Health, USSR, have been collected in the manual edited by Sergiev & Zhdanov (1955). A recent set of regulations (*Instrukcya*) dealing with this subject was issued by the Ministry of Health, USSR, on 15 May 1958.

The medical follow up and drug administration are carried out by the network of provincial, regional, district and other hospitals, polyclinics, dispensaries, school medical services, crèches, nurseries and other health units.

Surveillance is of both types, passive and active, although the wide coverage of the country by medical and health units naturally puts more emphasis on the former type. Passive surveillance (*epidemiologicheskiy nadzor*) is carried out by the hospitals, polyclinics, dispensaries and health centres, whose medical and paramedical personnel are often reminded of the possibility of malaria in cases of obscure fevers. The population is encouraged to avail themselves of medical aid centres for diagnosis and treatment of even minor ailments.

Active surveillance (*podvornyi obchod*) is limited to special areas, usually only during the transmission season. It is organized by the staff of the secondary health centres and carried out either by the visiting staff or by the members of the Red Cross, Red Crescent and other voluntary organizations. Its frequency varies between 5 and 10 days, depending on the size of the district.

Mass surveys of the population (*pogolovnoe obsledovanye*) are carried out occasionally in localities where the malaria morbidity was significant or where the possibility of imported cases is considerable.

Responsibility for surveillance is vested in the integrated medical and preventive organizations, health centres, sanitary and epidemiological sections of rayon hospitals, etc.

A special part of surveillance *sensu largo* is the follow-up action (*epidobsledovanye*) instituted after the discovery of a case or a focus of malaria. This follow-up aims at the discovery of the origin of the case of malaria, elimination of the infection and prevention of secondary cases. All persons with overt clinical malaria are hospitalized, but this does not necessarily extend to asymptomatic carriers, provided that they are under treatment. Should the case of malaria be discovered during the transmission period, the peripheral health unit carries out the necessary DDT spraying of the house and neighbourhood concerned. The regional health centre extends the investigation and carries out anti-anopheline measures, according to circumstances. Every confirmed case of malaria infection is treated with quinocide and followed up for two full years. Should the subject leave the area before the two-year limit, the health authority of the new area receives a notification. Records of cases of malaria and of parasite carriers are forwarded to the regional and oblast health centres.

The extent of surveillance activities carried out in the Soviet Union can be judged from the figures available from the Ministry of Health, USSR (1958). During the year 1957 the number of mass survey blood examinations for the presence of malaria parasites amounted to 5 769 463, of which 1318 were found to be positive. The highest percentage of positive blood slides was recorded in Armenia (0.13%) and in Azerbaidzhan (0.13%) ; then followed Tadzhikistan (0.045%) and Gruzia (Georgia) (0.026%). It should be pointed out that in the RSFSR, out of 2 203 325 slides, 130 were positive (0.006%) while in the Ukraine the figures were 1 259 137 and 5 (0.004%). In 1958, about 6.5 million slides were taken during mass surveys and 2378 were found to be positive. Most of these were *P. vivax*, with only 68 *P. falciparum* and six *P. malariae*.

The results of this intensive programme were spectacular. Figures quoted by Pokrovsky & Leiserman (1957) for the largest single administrative unit, the RSFSR, are particularly interesting. The trend of malaria morbidity in that part of the Soviet Union can be assessed by taking the 1940 figures as 100%. After the peak figure of 103% in 1945, the year 1948 gave the comparative malaria morbidity of 55%, 1949, 42%, 1950, 19%, 1951, 8%, 1953, 3%, 1954, 1.5%, 1955, 0.7%, and 1956, 0.25%. The changing geographical pattern of malaria morbidity in different regions of the RSFSR is well brought out in Table 3.

Tables 4 and 5 show the trend of malaria morbidity during the period 1940-1956 in the RSFSR and in 14 Soviet Republics (Sergiev & Yakusheva (1956) and Sergiev & Rashina (1957)).

An interesting account of the results of the malaria eradication programme in Byelorussia, home of the famous Prypet marshes and Polesie—a notorious malarious area of eastern Europe—was given by Beliatsky & Rubinstein (1959).

The amount of malaria in Byelorussia was imperfectly known during the first quarter of this century, but can be estimated at approximately 150 per 10 000 of the population. The subsequent

TABLE 3

REGIONAL MALARIA MORBIDITY AS PERCENTAGE OF TOTAL MALARIA MORBIDITY IN THE RSFSR DURING THE PERIOD 1940-1955

Regions of the RSFSR	Regional malaria morbidity as percentage of total malaria morbidity in the RSFSR				
	1940	1946	1953	1954	1955
Northern	1.5	0.7	0.5	0.2	0.2
Western	1.0	—	0.3	0.2	0.2
North- western	1.0	2.1	1.8	5.6	0.7
Central	40.0	41.0	6.7	4.0	5.0
Volga-Kama	30.0	22.0	11.5	12.5	18.4
Northern Caucasus	8.0	16.0	9.5	7.9	6.6
Ural	10.0	7.0	13.6	16.5	19.3
Western Siberia	6.0	7.7	41.6	40.6	30.2
Eastern Siberia	2.5	3.5	14.5	12.5	18.8
Far East	—	—	—	—	0.6

After Pokrovsky & Leiserman, 1957

TABLE 4

ANNUAL MALARIA MORBIDITY IN SOME SOVIET REPUBLICS DURING THE PEAK YEAR OF THE PERIOD 1943-1948 AND DURING THE YEAR 1954

Republic	Peak year	Number of cases	Number of cases in 1954
Georgia (Gruzia)	1943	131 841	2 874
Moldavia	1948	155 924	447
Kirghizia	1945	67 552	468
Armenia	1943	86 206	160
Turkmenistan	1943	62 248	365
Karelo-Finlandia	1948	7 057	41
Ukraine	1945	471 479	568
Byelorussia	1946	234 357	295

After Sergiev & Yakusheva, 1956

TABLE 5

MALARIA MORBIDITY IN THE RSFSR AND 14 UNION SOVIET REPUBLICS IN 1940, 1946 AND 1956

Republic	1940		1946	1956	
	Cases	Prevalence per 10 000	Cases	Cases	Prevalence per 10 000
RSFSR	1 924 899	175.3	1 604 925	5 616	0.5
Armenia	57 887	420.5	60 179	68	0.4
Azerbaidzhan	238 145 *	743.0	244 830	3 071	9.04 *
Byelorussia	21 258	21.7	234 357	46	0.06
Estonia	—	—	527	1	—
Gruzia (Georgia)	102 818	290.3	78 604	808	2.0
Kazakhstan	128 368	208.9	227 366	1 103	1.2
Kirghizia	18 927	129.7	52 412	69	0.34
Latvia	—	—	1 590	6	—
Lithuania	—	—	1 632	10	—
Moldavia	59 368 *	—	64 528	51 *	0.19 *
Tadzhikistan	72 224	486.7	80 020	1 305	7.3
Turkmenistan	27 237	217.2	29 361	58	0.34
Ukraine	230 648	54.9	335 930	184	0.04
Uzbekistan	203 552	324.0	348 282	645	0.74
Total USSR	3 164 522	222.1 *	3 517 199	13 015	0.65

After Sergiev & Rashina, 1957

* Figure corrected by Professor Sergiev at the Sixth International Congresses on Tropical Medicine and Malaria, Lisbon, 1958.

trend of malaria morbidity in Byelorussia during the period 1924-1957 (excluding the years 1941-1944) is shown in Table 6.

According to the recent information supplied to WHO by the Ministry of Health, USSR (1958, 1959) the total number of cases of malaria over the whole territory in the Soviet Union was 5097 in 1957 (3652 primary infections and 1445 relapses) and 2504 in 1958 (1859 primary infections and 645 relapses).

The figure of 10 cases of malaria per 10 000 population was accepted as the threshold above which malaria was regarded as a mass disease. Table 7 shows the annual trend of malaria morbidity in the USSR for the period 1950-1956.

According to the criterion mentioned above, malaria was eliminated as a mass disease from wide areas of the USSR about five years ago. The greatest decline was noted during recent years in the Uzbek, Moldavian, Tadzhik and Kirghiz republics.

In 1955 the USSR Ministry of Health prepared a plan, the aim of which is to achieve the complete eradication of malaria by 1960. As a result of this plan a number of specialists were sent on

TABLE 6

ANNUAL MALARIA MORBIDITY PER 10 000 OF THE POPULATION IN THE BYELORUSSIAN S.S. REPUBLIC DURING THE PERIOD 1924-1957

Year	Cases per 10 000	Year	Cases per 10 000
1924	19.6	1939	55.7
1925	29.1	1940	23.8
1926	10.4	1945	324.0
1927	18.0	1946	344.6
1928	28.4	1947	266.3
1929	11.3	1948	147.5
1930	6.7	1949	98.3
1931	4.7	1950	25.8
1932	6.8	1951	4.4
1933	13.6	1952	1.4
1934	17.6	1953	0.5
1935	55.6	1954	0.4
1936	42.2	1955	0.25
1937	63.4	1956	0.05
1938	53.6	1957	0.02

After Beliatzky & Rubinstein, 1959

TABLE 7

MALARIA MORBIDITY PER 10 000 POPULATION IN THE RSFSR AND 11 UNION REPUBLICS OF THE USSR DURING THE PERIOD 1950-1956

Republics	1950	1951	1952	1953	1954	1955	1956	Remarks
RSFSR	31.5	12.8	6.2	4.1	2.4	1.3	0.5	
Armenia	91.0	35.1	10.7	3.0	1.1	0.5	0.4	
Azerbaidzhan	181.0	118.5	87.1	57.4	52.6	24.4	9.0	In 1935 - 1948.8 In 1940 - 743.0 In 1945 - 813.0
Byelorussia	25.2	4.3	1.4	0.56	0.36	0.25	0.06	
Gruzia (Georgia)	43.5	32.8	23.8	14.5	7.5	4.5	2.0	
Kazakhstan	84.0	45.0	20.0	10.9	6.6	3.2	1.2	
Kirghizia	60.7	26.0	10.7	6.6	2.9	1.2	0.34	
Moldavia	115.7	34.8	10.5	3.3	1.6	0.5	0.18	
Tadzhikistan	164.1	118.5	81.5	62.5	50.3	25.9	7.3	In 1940 - 486.7 In 1945 - 530.0
Turkmenistan	55.8	18.7	7.7	2.9	2.7	2.1	0.34	
Ukraine	10.9	2.4	0.6	0.2	0.15	0.08	0.04	
Uzbekistan	172.0	90.0	47.1	27.7	12.1	4.1	0.74	
Total USSR	39.0	17.5	9.2	5.8	3.6	1.7	0.7	In 1940 - 222.1

After Sergiev & Rashina, 1957

The figure for the whole territory of the Soviet Union was 0.25 per 10 000 in 1957 and 0.12 per 10 000 in 1958.

detachment to some difficult areas in Azerbaidzhan, Georgia, Kazakhstan, Tadzhikistan, Uzbekistan and Yakutsk. Moreover, the Ministry of Health convened in 1956-1957 two regional technical meetings on malaria eradication: one in Baku for Transcaucasia and the other in Stalinabad for Middle Asia.

The present geographical status of malaria eradication in the Soviet Union can be assessed from the following information supplied by the Ministry of Health, USSR, to the WHO Fellowship Group. By the end of 1958 not a single case of malaria had been recorded for the previous three years over an area of 7 723 000 km^2 of the Soviet Union with a population of 158 050 000. This amounts to about 60 % of the total potentially malarious area of the USSR, and to 83 % of the population inhabiting this area. A total area of 3 496 000 km^2, with a population of 25 170 000, is in the consolidation phase (*faza ukreplenya*) and under surveillance, even though only a few and sporadic cases of malaria have been recorded within this area during the past three years by mass surveys. An area covering 1 504 000 km^2, with a population of 6 780 000, is still in the attack phase (*faza nastuplenya*) under regular residual spraying combined with the system of follow up described previously.

An evaluation of the progress of malaria eradication in the USSR was made recently by Zhdanov (1959). The Republics of the Soviet Union could be divided into four groups. In the first group are the Republics of Lithuania, Latvia (where no cases of malaria have occurred) and Estonia (where there was one imported case). To the second group belong six Republics (Byelorussia, Ukraine, Moldavia, Armenia, Kirghizia and Turkmenistan) as also the major part of the RSFSR, with the exception of North Caucasus and the Far East; in this vast group covering 52 administrative areas only solitary cases of malaria have been recorded. The third group is composed of four Republics (Gruzia, Uzbekistan, Tadzhikistan and Kazakhstan) and the remaining part of the RSFSR including the North Caucasus, Ural, Western and Eastern Siberia; in this group, covering 21 administrative areas, there were a number of small foci of malaria. In the fourth group there is only the Republic of Azerbaidzhan where, although the general prevalence of malaria has greatly decreased during the past few years, a localized outbreak was recorded in 1958.

Some interesting data on the progress of malaria eradication in the USSR in 1958 are shown in Table 8 (Sergiev, Rashim and Lysenko, 1959).

The problems of asymptomatic parasite carriers and their importance in the last phase of malaria eradication are receiving much attention. Although in several areas the so-called " parasite carriers " were actually cases of malaria which had escaped attention during active and passive surveillance, the practical importance of even temporarily asymptomatic parasitaemia is fully recognized.[1]

In the Soviet Union all cases of primary or relapsing malaria with clinical symptoms are reported by the treatment centres and duly registered for the current year.

According to the previous system all asymptomatic carriers of malaria parasites revealed in the course of mass surveys were treated, but were registered separately and not recorded as " cases of malaria ". Their number was previously very low compared with the number of cases with clinical symptoms.

With the progress of malaria eradication in the USSR the epidemiological importance of asymptomatic cases increased, and in a number of Soviet republics the asymptomatic carriers began to be included in the annual register along with cases of clinical malaria. As from 1959 the over-all figure of cases of malaria in the USSR as a whole will include asymptomatic parasite carriers.

Mass surveys carried out in the USSR in 1957 revealed 1318 asymptomatic parasite carriers. The figure for 1958 was 2496 (the preliminary figure was 2378). A proportion of the cases found in the mass surveys had shown clinical symptoms previously and were included in the clinical cases reported by a treatment centre. Thus the total number of malaria cases for 1957 is actually less than the sum of the cases of clinical malaria and the cases of asymptomatic infection.

Table 9, prepared by Professor Sergiev, gives the figures for 1958 for all the 15 republics of the Soviet Union, and illustrates the value of case detection by ordinary methods of surveillance as compared with the results of mass surveys.

According to Zhdanov (1959), in 1958 there were 1195 inhabited areas where cases of clinical malaria or asymptomatic parasitaemia were re-

[1] According to a WHO Expert Committee on Malaria (1957), the term " malaria case " refers to a person with malaria parasites in the blood, whether or not accompanied by fever or other symptoms.

TABLE 8

STATUS OF MALARIA ERADICATION IN THE USSR IN 1958

Union Republic	Total area and population *		Malarious area and its population		Population (in thousands) within areas where local cases of malaria were absent during the:		Population (in thousands) within areas where cases of malaria were recorded in 1958
	Area in km²	Population in thousands	Area in km²	Population in thousands	Past 3 years	Past 1-2 years	
Azerbaidzhan	87 000	3 400	80 000	3 000	1 300	700	1 000
Armenia	30 000	1 600	25 000	1 500	3 200	270	30
Byelorussia	208 000	8 000	207 600	8 000	8 000	0	0
Gruzia (Georgia)	72 000	4 000	52 000	3 700	1 450	1 550	700
Kazakhstan	2 766 000	8 500	2 200 000	8 000	5 200	2 400	400
Kirghizia	198 000	1 900	35 000	1 500	1 200	300	0
Latvia	64 000	2 000	19 000	500	500	0	0
Lithuania	65 000	2 700	13 000	500	500	0	0
Moldavia	34 000	2 700	33 700	2 700	2 700	0	0
RSFSR	16 901 000	112 600	9 000 000	110 000	90 000	16 000	4 000
Tadzhikistan	142 000	1 800	90 000	1 700	200	1 350	150
Turkmenistan	488 000	1 400	176 000	1 300	650	600	50
Uzbekistan	399 000	7 300	240 000	7 000	4 550	2 000	450
Ukraine	601 000	40 600	601 000	40 600	40 600	0	0
Estonia	45 000	1 100	0	0	0	0	0

After Sergiev, Rashina & Lysenko, 1959

* Figures shown in the first two columns are quoted from the *National economy of the USSR*, published by the Central Statistical Board, USSR Council of Ministers (1957). In the present table the Karelo-Finnish SSR (area, 173 000 km²; population, 600 000) has been omitted.

corded (in 692 only one case was found). Of these 381 were found in Azerbaidzhan and 434 in the RSFSR (mainly in the Yakutsk, Bashkir, Kabardino-Balkar Autonomous Republics, but also in a few oblasts of the Uzbek, Kazakh and Georgian Union Republics). The next was Kazakhstan, where 99 foci were discovered (mainly in the Talda-Kurgan oblast of this Republic). It is interesting to learn that a large proportion of the 195 infections (0.004 % in 31 000 blood examinations) were found in asymptomatic carriers, many of them immigrants from China (Sarynov, 1959).

Buslaev (1959), discussing the general situation in the RSFSR, points out that some of these cases appeared in some areas of the Yakutsk SSR where malaria had been absent for the past 2-3 years and attributes them to imported infections brought by asymptomatic parasite carriers. The same was probably true in the case of a few foci of malaria in 1956-1957 after 2-4 years of absence of any cases, in the Surhan-Daryin area of Uzbekistan (Dukhanina, 1959).

The problem of malaria imported or introduced from outside the territory of the USSR has received much attention. It was found that in 1958 not less than 107 cases of malaria recorded in the Soviet Union originated in other countries, mainly in China (Dukhanina, 1959; Sergiev, Rashina & Lysenko, 1959).

One would be justified in saying that malaria eradication has already been attained or is about to be attained over 88 % of the total potentially malarious area of the Soviet Union, comprising 96.5 % of the total population inhabiting this area. Judging by this achievement there can be little doubt that the few remaining foci of malaria, mainly in Transcaucasia and in Middle Asia, will be eradicated within the next few years.

According to Sergiev & Rashina (1957) the undeniable success of malaria eradication in the

TABLE 9

NUMBER OF CASES OF CLINICAL AND ASYMPTOMATIC MALARIA IN 15 REPUBLICS OF THE USSR IN 1959

Republic	Number of cases of malaria	Number of asymptomatic carriers revealed in the course of mass surveys	Number of asymptomatic carriers previously: included in primary cases	Number of asymptomatic carriers previously: not included in primary cases	Total number of cases and asymptomatic carriers
RSFSR	1036	57	48	9	1045
Ukraine	32	3	3	0	32
Byelorussia	4	0	0	0	4
Moldavia	5	0	0	0	5
Gruzia (Georgia)	191	18	0	18	209
Armenia	10	1	1	0	10
Azerbaidzhan	759	2070	0	2070	2829
Kazakhstan	159	228	0	228	387
Uzbekistan	166	10	10	0	176
Tadzhikistan	128	0	0	0	128
Turkmenistan	6	0	0	0	6
Kirghizia	5	1	1	0	5
Lithuania	0	0	0	0	0
Latvia	1	0	0	0	1
Estonia	2	0	0	0	2
USSR	2504	2388	63	2325	4839

After Sergiev, Rashina and Lysenko (1959)

USSR is due to three simultaneously executed measures (note the order of priority):

(1) early discovery of individual cases of the disease, intensive treatment and careful follow up of each case for not less than two years;

(2) use of residual insecticides (such as DDT and BHC) for the total coverage of an area or for barrier, village or focal spraying, depending on local conditions;

(3) widespread prevention of mosquito breeding by the use of all available methods.

Plans prepared for the post-eradication period of 1959-1965 were outlined by the Ministry of Health (1958). These plans refer to public health activities and to the research programme. First, attention will be concentrated on the prevention of the introduction of malaria from the outside, on the prevention of mosquito breeding, and on the improvement of mosquito control measures. Second, it is proposed to develop new methods for the early recognition of symptomless parasite carriers, to improve anti-relapse treatment, to discover the best measures for the prevention of epidemics from imported cases, to develop the use of old and new insecticides, to adopt insecticidal methods that may be extended to areas with a silkworm industry, and, finally, to study the epidemiology and eradication of malaria in other countries.

There is in the USSR an increased interest in giving other countries any assistance requested, particularly by lending experienced personnel. In 1955 a team of Soviet malariologists went to North Viet Nam, in 1956 another team to the People's Republic of China.

During the next few years the main aims of the health services of the USSR in areas where malaria is still present will be: continuation of insecticidal spraying with complete or focal coverage, treatment of cases, including administration of anti-relapse drugs (quinocide), and follow up of each case for at least two years.

Wherever there is any possibility of the introduction of malaria from outside the USSR, chemoprophylaxis of the population near the frontier will be instituted. One of the most important tasks is tightening up the reporting of suspected cases, their correct diagnosis, treatment and subsequent follow up.

Active surveillance is satisfactory only if every inhabited area can be visited not less than three times a month, which might be difficult in some circumstances. There is a good case for providing special squads to improve the frequency and completeness of local surveillance activities and to develop new methods for the discovery not only of all clinical cases of malaria but even more so of asymptomatic carriers.

Measures to be taken in conditions when malaria is nearly eradicated were described by Sergiev at the Sixth International Congresses of Tropical Medicine and Malaria. The object of the compulsory epidemiological investigation is: (1) to determine the origin of the notified case of malaria; (2) to decide if there is a likelihood of secondary cases; and (3) to determine the necessary countermeasures. The type and extent of these measures depend on many factors (origin of the case, number of persons affected, species of the parasite, coincidence with the transmission season, bionomics of the prevalent vector). As a rule the greater the number of cases the more extensive are the protective measures.

In the present conditions of near eradication of malaria in the USSR, the following epidemiological points are of interest: (1) sharp decrease in the over-all incidence of malaria ; (2) absence of any sizable foci of malaria (though small foci are still to be found and present a potential danger); (3) great rarity of falciparum malaria, most cases being only of vivax malaria; (4) prevalence in all areas, including the south, of the northern seasonal type of tertian malaria, so that most of the attacks are in spring and summer; and (5) annual appearance in some areas of the USSR of a very small number of foci. Over the whole potentially malarious areas of the Soviet Union there are now three groups of communities: (1) those (by far the most common) where eradication has been achieved and where cases of malaria are totally absent or exceptionally imported; (2) those where malaria persists as a small focus of infection; and (3) those where after an absence of malaria cases for one to three years a few local cases have appeared (Dukhanina, 1957).

From the point of view of an epidemiologist the latter cases are particularly important and have been carefully investigated. The results of this investigation have showed that population movements were occasionally responsible for the reinfestation of a small area but the main cause was linked with a premature cessation of antimalaria measures or with gaps in the system of surveillance. The leading Soviet authorities (Zhdanov, 1959) have given a warning, urging that the present success of malaria eradication in their country should not lead to a casual attitude to the problem, to a slackening of the final effort, and to a premature weakening of the whole organization, which is geared to the complete and permanent elimination of malaria from the Soviet Union.

RÉSUMÉ

L'histoire du paludisme en URSS, les travaux des paludologues, les progrès récents des recherches relatives à la lutte antipaludique, et les résultats de la vaste campagne d'éradication entreprise, sont peu connus hors des frontières de pays. L'auteur, dans une mise au point détaillée, en expose les aspects principaux, qui, dans plusieurs domaines (technique, administratif, socio-économique) sont propres à l'URSS.

Il décrit l'organisation des services sanitaires, le travail des instituts de recherches et les acquisitions dues aux chercheurs soviétiques, les formes cliniques de la maladie, la chimiothérapie, les mesures antianophéliennes, et enfin le grand programme d'éradication du paludisme.

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