SCHISTOSOMIASIS IN JAPAN, THE ECOLOGY OF ITS VECTOR SNAILS AND ITS CONTROL

YOSHITAKA KOMIYA

Chief, Department of Parasitology
National Institute of Health, Tokio

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1. *Schistosomiasis japonica* in the far east.

Schistosomiasis due to *Schistosoma japonicum* is widely distributed in Asia and particulary in the far east, namely in continental China, in Phillipine, in Formosa, in Thailand and in Japan.

In continental China the endemic area covers the 24 provinces among all of its 48 provinces and the number of the infected is estimated to be about more than twelve millions. In Phillipine it is distributed particurlarly in the island of Leyte, but in certain areas in Mindanao and other islands the rate of the infected population is estimated to be far more than 10 % in average. In some places of the endemic areas this ratio amounts to 50 to 70 % of the population.

In Thailand a limited small endemic area has been found in 1959 in the southern part of this country, but the incidence is small in number. The author has been in this country in the year of 1960 and made the stool examination of peoples of the endemic area and could find only 2 positive cases among about 1 000 examined. But the rectal biopsy among the residents in the endemic area showed eggs in about 7 to 8 % of the population in the mucosa of their rectum.

(1) Entregue para publicação em 26 de Dezembro de 1960.

In Formosa the endemic area is located in the limited area of northeast portion of this island. Here, as alike as that of Thailand, very few positive human incidents are to be found only by rectal biopsy but never by stool examination. Cattles and some wild animals, especially pigs, however, are often found here to be infected.

2. The incidence of *Schistosomiasis japonica* in Japan.

In Japan are five endemic areas of schistosomiasis which are rather restricted to small dimensions. Among these, however, two of them have been proved to have very few infected human beings, and in the other three endemic areas, the basin of Kofu, a part of the valley of Chikugo and the so called Katayama area, the infected people is now still found and among them those manifested clinical symptoms can still be observed, although not so large in number.

Before the II World War in these areas the number of the infected was found more frequent as compared with now. Particularly before the application of molluscicides, i.e. about fifty years ago, more than the half of the population, and in some endemic areas about 60 to 70 % of the population was found infected. At that time a lot of very severe cases of this disease could easily be found there.

But just before the war the incidence of human infection was found to decline gradually, which was due to the successive application of molluscicides since 1917. The compound applied at that time was initially lime and then it was replaced by calcium cyanamide.

During and just after the war, however, difficulties to gain the molluscicides have been confronted and at that time farmers had some shortness to get the fertilizer to the rice field. For this reason some of the farmers utilized the compound, chiefly calcium cyanamide, as a fertilizer, instead of applying it as a molluscicide. Owing to the reason stated above the incidence of human infection appeared to increase to a certain extent directly after the II World War.

Several years ago, however, a new molluscicidal compound has been introduced and its application in Japan has been undertaken since 1951, and from that time the new method of the environmental control of the vector snails, i.e. cementing the irrigation ditches has also been realized with the financial aid of the government, the rate of the human infection showed to have been declined gradually, and

now the rate of the infection among the people in endemic areas is estimated less ten %.

3. The vector snails of *Schistosoma japonicum* and the shedding of its cercaria.

The vector snails of *Schistosoma japonicum* belong exclusively to genus *Oncomelania,* fam. *Bithyniidae*. Though they belong to *Prosobranchiate* they are amphibious in nature. Each country having

TABLE I —*Schistosomiasis in Japan*

Endemic area	Area	Population	Infection rate	No. of patients (Presumption)
Kofu	90.00 km²	217,000	30.0 %	65,000
Basin of River Tome	—	—	3.9	—
Numazu	5.70	—	5.0	—
Katayama (Hiroshina)	9.00	38,000	30.0	11,000
Okayama	1.25	2,500	0	—
Basin of River Chikugo (Fuhuoka)	39.00	51,600	30.00	15,000
Saga	29.00	30,000	30.00	0,000
Total	173.95	339,100	—	100,000

the endemic areas of schistosomiasis has its own species of vector snails as follows:

In Japan, *O. nosophora.*

In continental China, *O. hupensis.*

In Taiwan, *O. formosana* and

In Phillipine, *O. quadrasi* (vide photo).

Very recently it is said that in South America a probably new species of *Oncomelania* was found. Fortunately the author could observe its living specimen in Tropen Institut in Hamburg, where he stayed few days recently. It is alike to *Oncomelania* in the feature of its shell, which measures about the same length in hight and has the so called «eye brow» upon the eye as it is one of the characteristic of this genus. But it appeared to be rather much less amphibious in character. Dr. Berry suspects whether it belongs to the genus *Onco-*

melania. He is a malacologist in the National Institute of Health in U. S. A.

The shedding of schistosoma cercariae from one infected snail can continue very long, at times over three to five months. The shedding is most prevalent during June to September. It is interesting that all the shed cercariae are found to be floating on the surface of water adhering on the water film with its ventral sucker, thus facilitating their contact to the final hosts, particularly to the human being.

In Japan the young rice plant is transplantated into the rice fields from the bed during June, at times at the beginning of July. The young rice plant is cultured in a limited rice cultivation bed prior to their transplantation. During May the seeds of rice were distributed densely in the bed. At the time of their transplantation they grow up to about 20 cm in hight. The water is introduced to the rice field from the irrigation ditches prior to transplantation. The most favourable habitat of the vector snails are on the moist soil of the bank of the irrigation canal. Because of the filling up the ditches with water the cercariae shed from snails and on the surface of the rice field cercariae can be found in mass and the farmers who enter the water in the field to plant the rice can easily be infected with schistosoma cercariae.

4. The control measures.

Theoretically, schistosomiasis can be controlled conceivably by employing one or more of the general methods, namely: 1. Mass treatment of all human cases to reduce or abolish release of eggs. 2. Reduction or prevention of fresh water pollution with the schistosoma eggs by killing them in stools of the infected, which are to be utilized as a good fertilizer in the vegetable and rice field. 3. The reduction or complete prevention of human contact with water containing the infective stages. 4. The reduction or elimination of vector snails which are essential to transmission of schistosomiasis to man.

But the practice of the first and second method would result the least preventive effect in case of *Schistosoma japonicum*, because this worm is maintained in non human final hosts. In Japan several cattles, namely oxes and cows, sheeps and dogs, and several wild animals particulary wild rats, can serve as the reservoir hosts. So the

elimination of egg producing humans as well as killing eggs in human night soil would not always eliminate snail infection and the possibility of the reinfection of man.

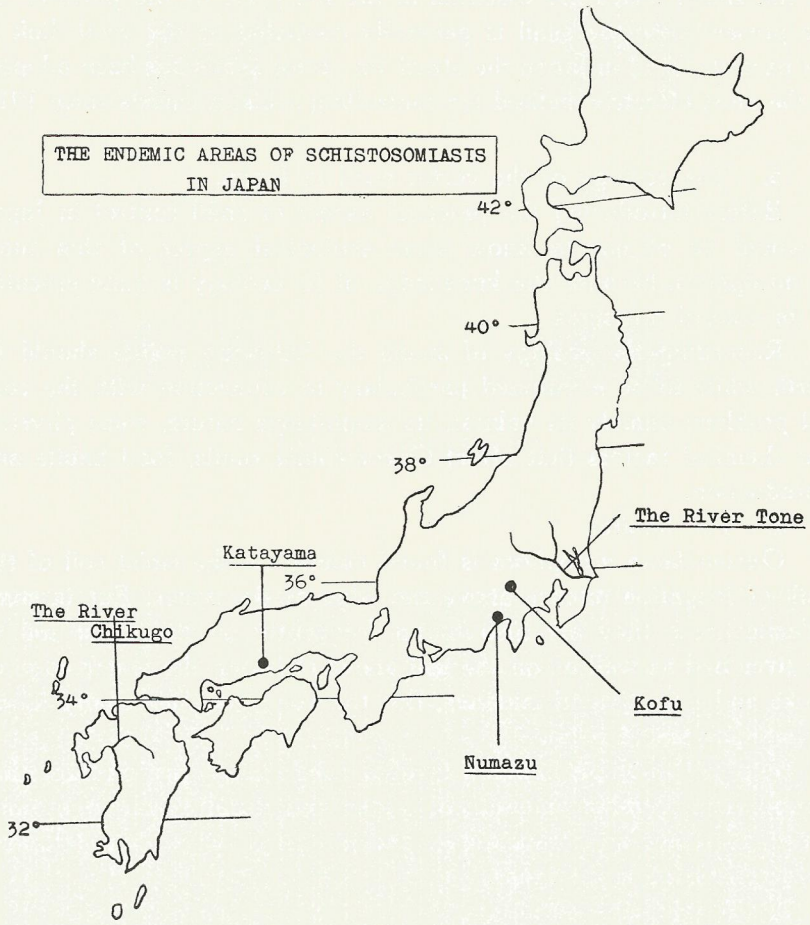

Fig. 1

The reduction or complete prevention of human contact with water containing the infective stages can not be carried out in Japan in the present state of social conditions. Because the contact with water is closely connected with the professional work of the farmers.

The farmers in Japan must get in touch of water during and after the rice transplantation in the rice fields where are to be filled with water from the irrigation ditches.

The fourth general means for schistosoma control is the attack on the snails which are essential in the life cycle of the parasite. At the present time the snail is generally conceded as the weak link of the parasite. And in Japan the attack on vector snails has been adopted as the most effective method for controlling schistosomiasis since 1917.

5. The ecology of the vector snail in Japan.

Before introducing the practical aspect of snail control in Japan it would be of use to know some ecological aspect of this snail, *O. nosophora,* because the knowledge of its ecology is quite essential of its control measures.

Regarding the ecology of snails the following points should be worth while to be mentioned particulary in connection with the control problem; namely its habitat, its amphibious nature, some physical and chemical factors that affect *Oncomelania* snails, food habits and reproduction.

a. The habitat.

Oncomelania nosophora is found chiefly on the moist soil of the bank of irrigation ditches above the edge of the water. But in some endemic areas they are also found frequently on the moist soil in the river bed as well as on the soil above or along the water edge of creeks and uncultivated marshes. But the young one is usually found in water as stated below.

The soil in these habitats is of a sandy and cray mixture that contains considerable amounts of water and usually rich in organic matter, diatomes and other algae, and is overgrown with vegetations characteristic of moist areas.

b. Amphibious nature.

Oncomelania nosophora is amphibious in nature. It is even so in its very early stage of development. It is said, however, that it is aquatic in its youngest stage of development. In practice the youngest form is usually found in water up two to three months after its hatching.

But, according to the author's experience, it is of amphibious in nature even at the youngest stage of development. On the course

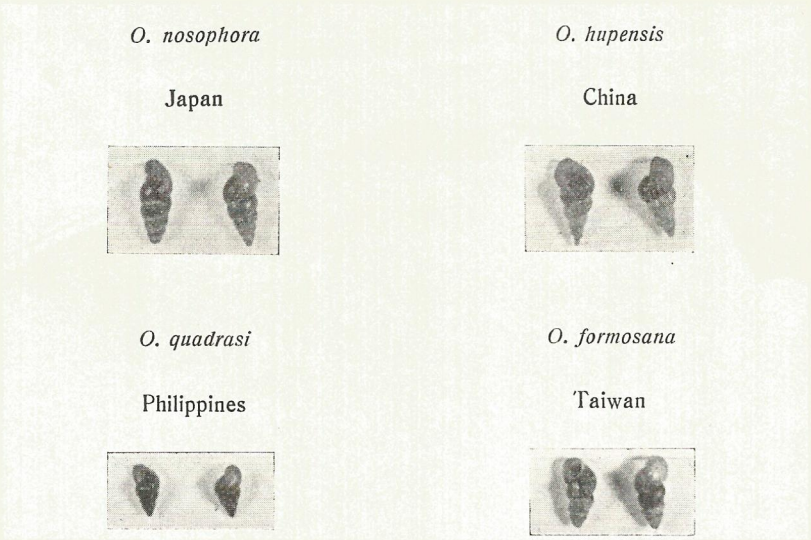

Photo 1 — *Oncomelania* spp.

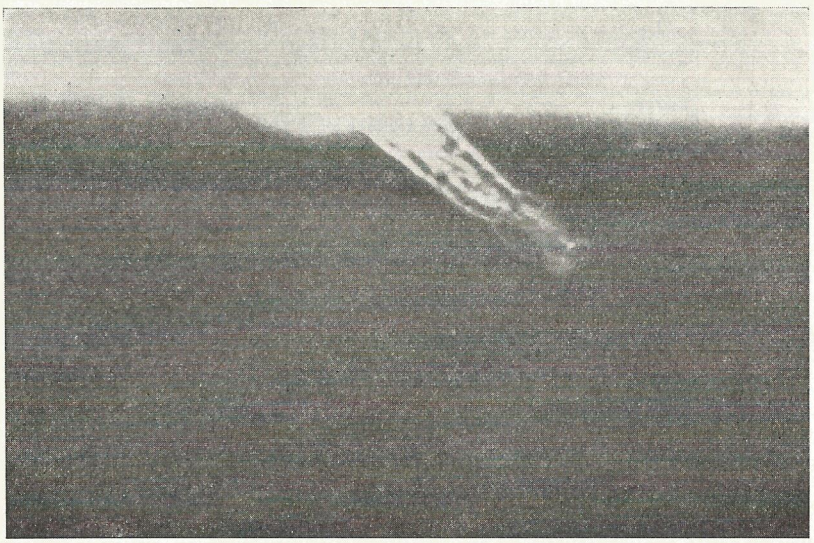

Photo 2 — Cercaria of *Schistosoma japonicum* floating on the surface of water

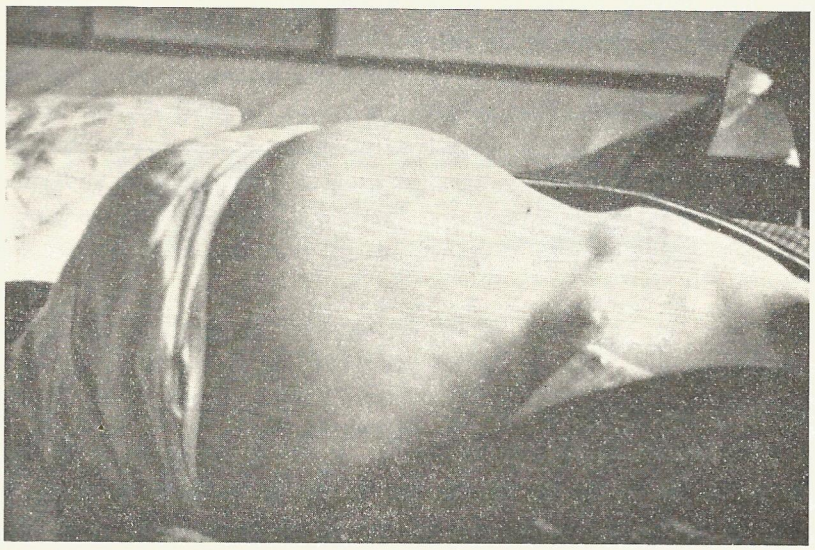

Photo 3 — A patient of *Schistomiasis japonica* with ascites

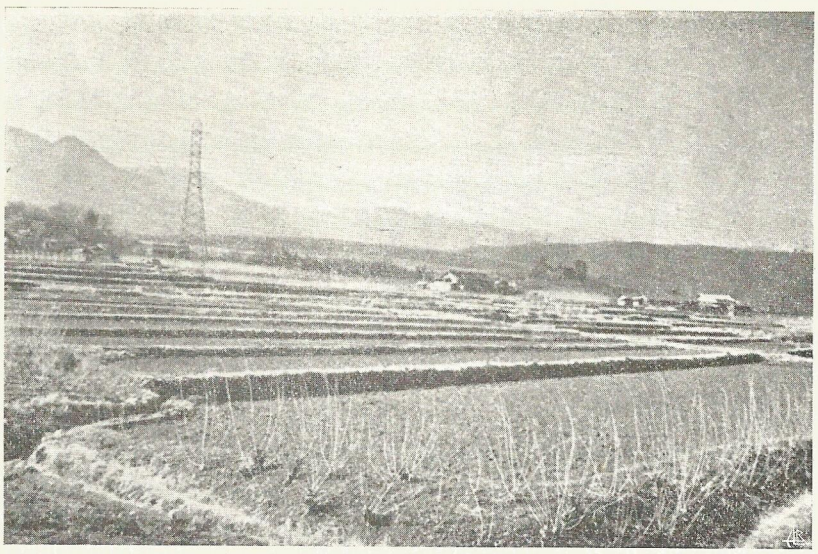

Photo 4 — General view of the endemic area of Yamanashi prefecture

of rearing even the youngest form is very often found on the moist wall of the container. Because of its less resistance for desiccation than the adult it will soon be found dead in such a condition. Thus it is

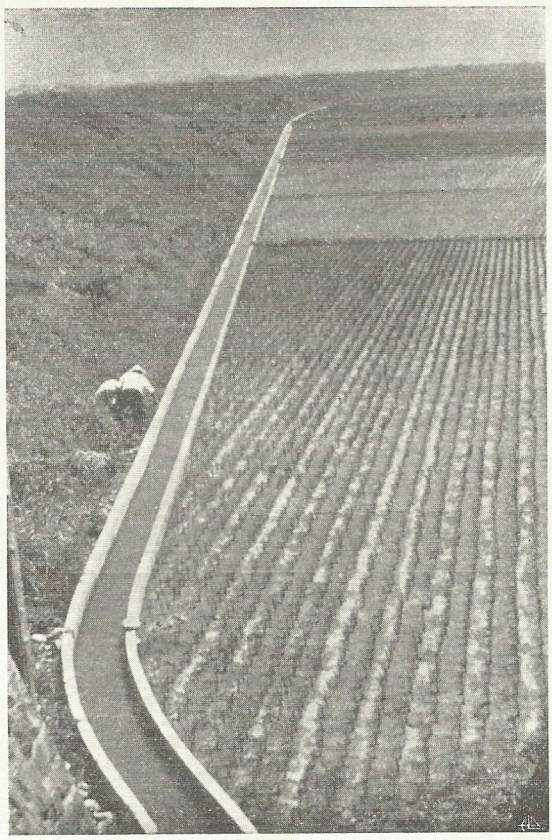

Photo 5 — Cemented irrigation ditch in left hand of rice field filled with water

thought that the younger must remain in water in order to survive. So the living specimen of the youngest can only be found in water.

c. Temperature.

Temperature is one of the most important factors for their activity. *Oncomelania nosophora* hibernates during the winter months, but when the temperature rises to a certain point, the snail opens

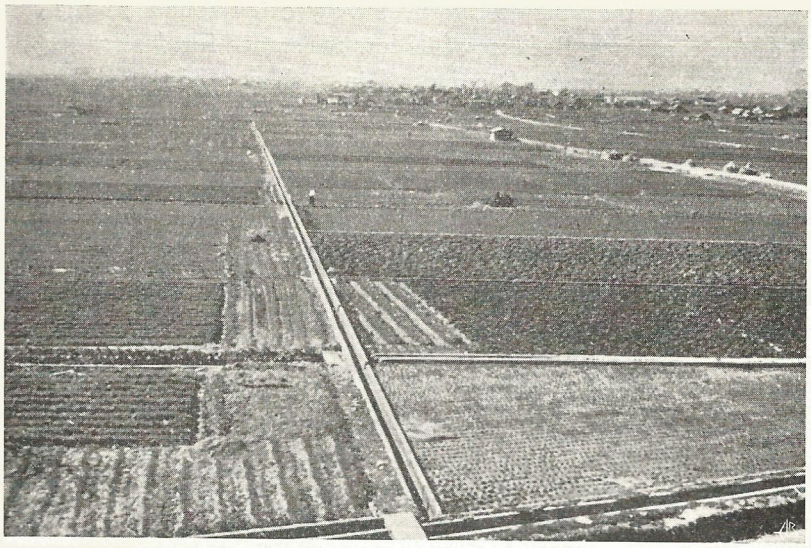

Photo 6 — A certain place of the endemic area. Here the cementing ditches are already completed and no vector snail can be found now

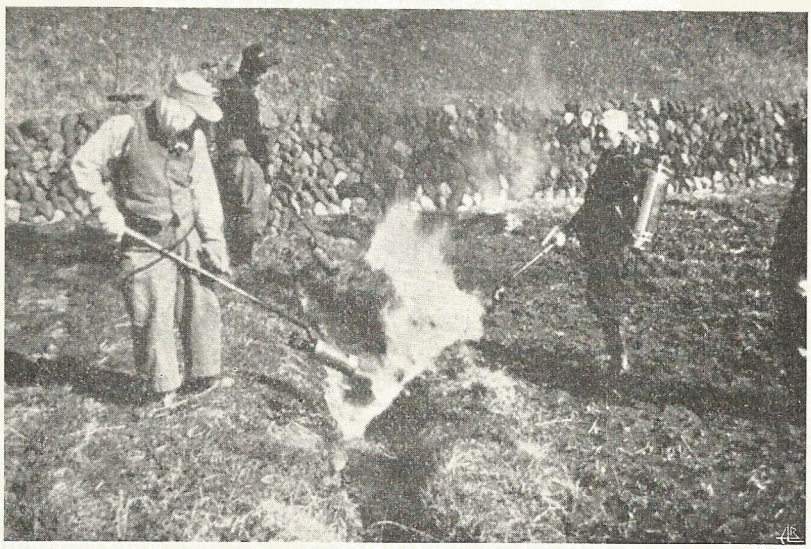

Photo 7 — Application of portable burner for the killing of snails

its operculum and becomes active if there is sufficient water or moisture in its habitat. This critical temperature is believed to be about 13-14°C, which coincides with that in the beginning of April in the endemic area in Japan.

Observations indicate that the optimum temperature is about 22--26°C. The lowest temperature the snails are exposed in the endemic areas is about — 7°C and under such temperature they remain to be alive.

Photo 8 — Spraying of *pcpNa* on the habitat of snails

d. Water and soil.

Water: The process of the exchange of oxygen in these snails depends on the water film on their gills. When feeding it is also necessary to have a film of water over their proboscis.

When the film of water around the body decreases to a certain extent, the snail retracts its body into the shell and the operculum is closed to prevent the loss of water. Under such condition the adult snail can withstand a considerable grade of desiccation. Experimentally

it can withstand for about 40 days without showing large mortality in the room temperature.

Soil: The snail can live on any kind of soil if its particles are small enough to be taken into its mouth provided that it is sufficiently moist, rich in diatomes and algae and its *pH* ranges about 5 to 8.

e. Foodhabits.

This snail always ingests soil along with its foodstuffs contained in it. It was found experimentally that the snail prefers rice and wheat powder, diatomes and algae. Examination of the soil in the habitat showed that it contains many diatomes and algae. Newly hatched snails were fed on pure cultures of diatomes and they grew to maturity. Thus it was concluded that the principal food of the snail in the natural habitat consists of diatomes and algae. This does not prevents the snail at times ingesting old moist leaves and vegetations.

6. Reproduction.

The mating of these snails is seasonal in a temperate climate and in the field they have been observed in copla from April to October.

The oviposition begins in April. Eggs were not laid in August but there is a period of egg laying in the autumn.

The eggs thus laid are to be found separately, here one and there the other. Each egg is found covered by a film of soil, which makes it very difficult to find out. The number of eggs laid per female has been estimated to be about 16-100 or 5-36 per female per day.

7. The control method being applied in Japan.

a. Environmental control.

For the control of snail vectors the two methods have been applied and now are being applied. The one is the environmental method, namely the cementing ditches which are the suitable habitat of *Oncomelania* snails. After cementing ditches snails cannot utilize the mud which is essential media of their food (diatomes and algae) and which is also necessary for their oviposition. Cementing does not allow, naturally, the growth of vegetation.

Usually no snails can be found in the cemented ditches, but at times they can be found in old ones but very small in number. The cemented ditches can also facilitate the application of molluscicides.

Cementing ditches have been carried out since 1953 with the financial aid of the government. One third of the total expenditure is paid by the central and the other one third by the prefectural government. So the inhabitants of the endemic areas are enough only to pay the rest one third of the expenditure.

Within ten years all the irrigation ditches in the endemic areas are to be cemented. Up to now about one third of all ditches has already cemented.

b. Chemical control.

The application of certain compounds as molluscicides was started initially in 1918. Initially lime was used as a molluscicide but afterwards (generally since 1950) it has been replaced by calcium cyanamide. But calcium cyanamide had its shortness. On the first place, prior to its application, all snails on the bank of ditches should be so swept away on the bottom of the ditch that they could get in contact of the solution of the compound more easily. And on the second place the water in the ditch during its application should be kept for several days. This procedure was felt rather inconvenient.

And thirdly, as already stated, directly after the war farmers utilized this compound for fertilizer instead of using it as a molluscicide.

From 1953 this calcium cyanamide was replaced by sodium pentachlorophanate spraying. Dusting of it has not used in Japan, because snails required water to get active and the liquid form is suitable to stimulate snails to activity.

The spraying of the habitats of snails in the endemic areas has been conducted either once or twice a year, namely once at the beginning of April and once in the autumn.

The killing rate of snails was examined every year after the application of molluscicide and about 80 % of them has been proved to have been killed every year. The spraying of this compound was formerly conducted by a portable sprayer but in recent years it was replaced by a sprayer equipped with electric power in the major part of the endemic areas.

c. Application of the buring instrument.

A portable burning instrument was recently introduced for killing snails in a small scale. Its killing effect of snails is proved to be relatively high. About 80 % of snails were found killed after the application of burning.

Owing to the application of these methods, the environmental and the chemical, for every year the density of the snail population in the endemic areas has been considerably reduced and in some areas practically no snails can be found.

RESUMO

A bilharziose japónica inscrevia-se nalgumas áreas do Japão com a taxa de 60 % a 70 % de infectados há cerca de cinquenta anos. Mas a aplicação dos moluscicidas a partir de 1917 fez reduzir notàvelmente a sua incidência, a qual voltou a aumentar, porém, a partir da II Grande Guerra.

As medidas de *contrôle* aplicadas a partir de 1951 fizeram reduzir a taxa de infectados, a qual se fixa actualmente em cerca de 10 %.

A *Oncomelania nosophora,* hospedeiro intermediário do *Sch. japonicum* no Japão, cria-se especialmente nas margens lodosas dos canais de irrigação dos arrozais e elimina cercárias, sobretudo de Junho a Setembro.

No *contrôle* da doença os mais exequíveis métodos têm consistido na luta contra o vector, o que exigiu um conhecimento prévio detalhado da sua ecologia. Para isso estudos sobre o seu *habitat,* alimentação, reprodução, etc. foram realizados.

Como meios de destruição dos moluscos fizeram-se construir em cimento os canais de irrigação, utilizaram-se moluscicidas, de entre os quais o pentaclorofenato de sódio tem sido usado ùltimamente com toda a eficiência, e recorreu-se a aparelhos lança-chamas, com que se actuou nos viveiros.

RÉSUMÉ

Il y a environ cinquent ans, la bilharziose japonaise présentait, dans certaines régions du Japon, le taux de 60 % à 70 % d'infectés. L'application des mollusquicides à partir de 1917 a fait réduire notablement l'incidence de la bilharziose, laquelle, néanmoins, a augmenté après la 2ème Guerre Mondiale.

Les mesures de contrôle mises en pratique depuis 1951 on fait réduire à nouveaux le taux d'infectés, lequel est, actuellement, d'environ 10 %.

L'*Oncomelania nosophora,* hôte intermédiaire du *Sch. japonicum* au Japon, pousse spécialement dans les rives boueuses des canaux d'irrigation das rizières et élimine des cercaires, surtout pendant les mois de juin à septembre.

Les méthodes plus exécutables dans le contrôle de la maladie ont consisté dans la lutte contre le vecteur, ce qui a exigé une connaissance préalable et détaillée de son écologie. Pour cela on a fait des études sur l'habitat du vecteur, son alimentation, sa reproduction, etc.

Comme moyens de destruction des mollusques on a construit les canaux d'irrigation en béton, on a utilisé des mollusquicides, parmi lesquels le pentachlorophénate de sodium a été employé dernièrement avec toute l'efficacité, et on a aussi agi avec des appareils lance-flammes dans les viviers.

SUMMARY

About fifty years ago in certain areas of Japan, there was a percentage of 60 % to 70 % of people infected with *Schistosoma japonicum*. After 1917 the use of molluscacides reduced considerably those percentage, wich increased, however, after World War II.

The control measures applied after 1951 determined a reduction in the percentage of people infected to the extent of being today only 10 %.

The *Oncomelania nosophora*, wich is the intermediate host of *Sch. japonicum* in Japan, lives specially in the muddy banks of the irrigation channels in the rice fields and eliminates cercariae, mostly from June to September.

For the control of the disease the fight against the vector has proved to be the best method; this fight asks for a detailed previous knowledge of the vector's ecology. To this purpose thorough studies had been realized on its habitat, alimentation, reproduction, etc.

In order to obtain the destruction of the molluscs, the following methods may be used: irrigation channels built with hydraulic cement, the use of molluscacides and flame-throwers. The molluscacide wich has given best results is the sodium pentachlorophenate and the flame-throwers have been used against vector's nurseries.

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