MOSQUITO REMEDIES AND PREVENTIVES*

MOSQUITOES, as a whole group, utilize breeding places of the most diverse character. While some species, however, have general breeding places and their larvae will live in almost any chance accumulation of water, other species are restricted in the character of their breeding places. Certain forms breed only in holes in trees; others in accumulations of water in epiphytic plants; others, only in crab-holes on sea beaches. Some species breed only in salt marshes and lay their eggs on mud; others lay their eggs on the surface of water. Certain species breed only in pools formed by melting snow, and as such pools occur only at one time of the year there is but one generation, and the eggs are laid in midsummer or later in hollows in the earth that will be filled with water from melting snow in the ensuing spring. Another species, frequently very annoying, breeds only in certain permanent swamps, where the larva lives attached to the roots of certain aquatic plants. Still another breeds in the pitchers of pitcher plants.

Where rain barrels and rain-water tanks are necessary they should be screened. The waste places in the immediate vicinity of a house should be carefully searched for tin cans, bottles, and wooden or tin boxes in which water can accumulate and all such receptacles should be destroyed or carried away. It is good practice to punch several holes in each can as it is emptied so that, wherever it may be finally deposited, water will not be held in it. The roof gutters of every building should be carefully examined to make sure that they are not clogged and allowing water to accumulate. Where the branches of tall trees overhang roofs this is especially likely to occur by the agency of falling leaves or twigs. The chicken pans in the poultry yard, the water in the troughs for domestic animals, the water cup of the grindstone, are all places in which these mosquitoes will breed, and water should not be allowed to stand in them for more than a day or so at a time.

Water accumulating under water tanks should be treated or drained away. Urns in cemeteries have been found to breed mosquitoes abundantly. Holy-water fonts in churches, have been found to breed many mosquitoes. In slightly marshy ground a favourite breeding place is the footprints of cattle and horses. In one country village, which contained many small vegetable gardens in clay soil, during a rainy season mosquitoes were found breeding abundantly in the water accumulating in the furrows in the gardens.

Even in the house these mosquitoes breed in many places where they may be overlooked. Water in vases or in the pitchers in guest rooms should be frequently changed, as otherwise mosquitoes may breed therein. They will breed in the tanks in water-closets, in pipes, and under stationary wash-stands where these are not freqently used. In warehouses and on docks they breed abundantly in the fire buckets and water barrels. Treatment of such places with borax will prevent mosquito breeding. The borax is used in the proportion of 2 ounces per gallon of water to be treated. Water so treated cannot be used for drinking or for watering plants.

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In country houses, where ants are troublesome, and where it is the custom to insulate the legs of the tables with small cups of water, mosquitoes will breed in these cups, unless a small quantity of kerosene is poured in. Where broken bottles are placed upon a stone wall, water accumulates in the bottle fragments after rains, and mosquitoes will breed there.

Old, disused wells in gardens are frequent sources of mosquito supply, even where apparently carefully covered, and here the nuisance is easily abated by the occasional application of kerosene. The same thing may be said of cesspools. Cesspools are frequently covered with stone and cement, but the slightest break in the cement, the slightest crack, will allow the entrance of these minute insects, and unlimited breeding often goes on in these pools without the cause of the abundance of mosquitoes in the neighbourhood been suspected.

Fountains and ornamental ponds are common breeding places, and here the introduction of fish, as indicated in another place, is usually all-sufficient. It frequently happens, however, that the grass is allowed to grow down into the edges of ornamental ponds, and mosquito larvae find refuge among the vegetation and so escape the fish. Broad-leaved water plants are also often grown in such ponds, and where broad leaves lie flat on the surface of the water, as they frequently do, one portion of a leaf may be submerged so that mosquito larvae may live undisturbed in the water above the submerged portion of the leaf, protected by the leaf itself from the fish rising from below. It is necessary, therefore, to keep the edges of such ornamental ponds free from vegetation and to choose aquatic plants whose growth will not permit mosquito-larvae protection.

In these latter localities will be found not only the house mosquitoes, previously mentioned, and the rain-barrel mosquitoes, but also some of the other forms, and particularly the malaria-breeding mosquitoes of the genus Anopheles. Some of these breed in all sorts of water accumulations.

In many small country towns, even where there is a water supply, tanks to supply bath rooms are built under the roofs. Such tanks should be screened since mosquitoes gain entrance to the tank room either through dormer windows or by flying up through the house from below, in search of places to lay their eggs.

About a large old house or a public building there are so many of these chance breeding places that only the most careful and long continued search will find them all. As an example, in a State hospital, after a search which lasted for many days, and after treatment of all possible breeding places found, mosquitoes still continued to annoy the patients. Finally in the darkest part of a disused cellar was found a half-barrel containing water, which was giving out mosquitoes at the rate of hundreds per day. Frequent change of water or the use of kerosene will render all such breeding places harmless.

In community work in cities all of the points mentioned must be borne in mind, and where the residences are for the most part villas, in the absence of swampy suburbs, the householders are in the main responsible for their own mosquitoes. There are, however, breeding places for which the municipality may be said to be responsible, and these entirely aside from public fountains, reservoirs or marshes. Open gutters or ditches on the roadside may breed a generation of any one of several species of mosquitoes, including malarial mosquitoes. On a pasture or common, where sod has been removed, water accumulating in the excavations thus formed may breed a generation of malarial mosquitoes. All such accidental breeding places should be filled in.

It seems unlikely that in any general sewage system mosquitoes may breed in the sewers proper. That they do breed in the catch basins is well known. The purpose of the catch basin is to catch and retain by sedimentation sand and refuse which would otherwise enter the sewer and be deposited in it. It is intended to be water-tight and to hold a considerable body of water, which stands in it up to the level of the outlet pipe. Such catch basins are very commonly located in back yards and at street crossings. The water is removed only by rain or when the street or yard surfaces are washed. In dry seasons the period of stagnation may last several weeks, certainly, long enough for mosquito breeding. As a matter of fact, mosquitoes in midsummer do breed in such traps or catch basins by millions. These basins may be treated with fuel oil, or the municipal authorities may flush them once a week, carrying away such larvae as may be hatched. Oiling such places is best, however.

Since many serious mosquitoe-breeding conditions have been brought about by railroad, highway, and other construction work, such operations should be well supervised and the contractors prevented from creating mosquito nuisances.

Public dumps are great breeding places, because here accumulate old bottles, cans, boxes, bits of tin or iron vessels, and other objects in which water may stand for a time. Even a very small quantity of water will make a breeding place for very many mosquitoes. It is quite possible for half of a bottle to contain enough water to give out literally thousands of mosquitoes. The writers know of one instance in which a veritable plague of mosquitoes was traced to a case of empty bottles allowed to remain in a back yard for some weeks in midsummer. It is of great importance to have unburnable refuse from village and cities dumped in definite places, and the dumps properly cared for. It is usually possible to find a hollow in a convenient location where the dumping may be done systematically and where the unsightliness of the debris as well as the danger of mosquito breeding may be avoided, at reasonable expense, by keeping the freshly dumped material covered with earth.

The suitability of such places for mosquito-breeding should be destroyed by carting away chance receptacles, by turning over vessels, by filling in excavations, or by treating other receptacles with a film of kerosene, or by introducing fish into fountains and artificial pools.

Under certain circumstances mosquito may breed in water accumulating in the troughs of underground-conduit electric railways.

DRAINAGE MEASURES

Drainage measures are one means of treating breeding places. The value of reclaimed swamp lands for agricultural and industrial purposes has been fully demonstrated, and the advantages of eliminating swamp areas in the vicinity of well-populated districts are manifold. The drainage of swamp areas primarily to improve sanitary conditions and to reduce the scourge of mosquitoes, which in itself often prevents the proper development of near-by regions, is being done. Drainage on a small scale to do away with mosquitoes has been practised for a long time, and in many parts of the country large-scale drainage for mosquito abolition is going on here. Methods of draining cannot be discussed here but it should be pointed out that in case of salt-marsh land the operation is comparatively inexpensive, and results of great value have been obtained in California, New Jersey, Florida, and other States.

Mosquito breeding along small streams can often be prevented at small cost by straightening and cleaning the banks and cutting small ditches from pools and seepage areas to the stream. While ditching may not always eliminate all the pools, the ditches allow minnows to gain ready access to them, and these minnows can be relied upon to destroy all accessible mosquito larvae.

Great numbers of mosquitoes breed in irrigation waters on meadows, in sloughs created by waste water, and in rice fields. These create problems that are difficult to handle, but the periodic drainage of rice fields and occasional cutting off of irrigation waters are possible methods of attack under certain conditions. Proper grading and the installation of drainage ditches or the tile drains often aid in reducing mosquito breeding in slough and marshes created by irrigation. The utilization of minnows and other control methods are usually necessary supplemental measures in rice fields and meadows.

Where the abolition of mosquito-breeding places demands extensive drainage, it is most effective and economical to employ a drainage engineer to map out the entire programme before the work is actually begun.

OILS AND LARVICIDES

While it is obviously best to abolish breeding places in the ways mentioned, it often happens that it is not possible to drain them and as a temporary expedient at least it becomes desirable to treat the water so as to kill the mosquito larvae. Many substances have been tried, and, aside from certain proprietary mixtures, nothing has given such good results as oils. Efforts to find oils that can be used to better advantage than petroleum have failed. Because of its general availability and low cost, ordinary low-grade kerosene is very satisfactory. For extensive oiling operations, however, one of the petroleum distillate fuel oils, known also as gas oils, is preferable to kerosene.

In choosing the grade of oil two factors are to be considered: (1) It should spread rapidly; (2) it should not evaporate too quickly. The heavier grades of oil will not spread readily over the surface of the water, but will cling together in spots and the coating will be unnecessarily thick. The rapidity with which the film spreads is also important. If the water is still, an ounce of kerosene to 15 square feet of surface space is about the right proportion, and in the absence of wind such a film will remain persistent for 10 days or slightly longer. Even after the iridescent scum apparently disappears there is still an odour of kerosene about the water. Wind will frequently blow the film of kerosene to one side, but a change of wind will blow it back again, so the larvae are destroyed. Not only are larvae and pupae destroyed by the kerosene film, but many adult mosquitoes alighting on the surface of the water to drink or to lay their eggs are killed by it. In California, H. J. Quayle has used a combination of heavy oil of 18° gravity and a light oil of 34° gravity, in the proportion of 4 to 1, respectively. This mixture made an oil just thin enough to spray well from an ordinary spray nozzle and yet thick enough not to evaporate rapidly. It was applied from a barrel pump where this could be used, and from an ordinary knapsack pump in other regions. A single application was found to be effective sometimes as long as four weeks. The army of occupation in Cuba used oil every two weeks.

In New Jersey much experimental work with various larvicides has been done. The authorities in charge of anti-mosquito work in that State have found very satisfactory distillate fuel oils of a specific gravity ranging between 28° and 38° Baumé with a minimum flash point of 150° F. J. M. Ginsburg, of the New Jersey Experiment Station, has also found that the

addition of one gallon of crude cresylic acid containing 95 per cent of tar acids to 100 gallons of fuel oil increases the spreading of the oil on both salt and fresh waters covered with dead organic matter and vegetation.

There is some objection to the use of the coloured petroleum oils and to kerosene on small ornamental pools on account of the discolouration effected by such oils and their adverse effects on plants. Where it does not seem feasible to utilize fish in such pools, the mosquito larvae can be destroyed by covering the surface with a film of gasoline, but the effect of this treatment is of short duration.

In this connection mention should be made of the pyrethrum mosquito larvicide developed by workers of the New Jersey Experiment Station, which appears to be admirably suited for use in ornamental pools or wherever oil is objectionable. This larvicide is made up to contain 66 per cent kerosene, or a similar light petroleum oil, containing pyrethrum extract (equivalent to 1 pound of pyrethrum flowers to the gallon of oil) and 34 per cent of water containing from 3 to 5 per cent of soft soap. The ingredients are thoroughly mixed by violent agitation, thus forming an emulsion which mixes readily with water. For use in killing mosquito larvae and pupae, dilute this stock solution with from 10 to 15 times its bulk of water and spray it on the mosquito-breeding pools. Extensive tests by the New Jersey authorities have shown it to be efficient in mosquito control and harmless to water-fowl, fish, or ornamental plants.

The use of a spray pump has been mentioned. Small ponds can be sprinkled with an ordinary watering pot with a rose nozzle, or pouring the liquid out of a dipper or cup will be satisfactory. In larger ponds, the pumps with straight nozzles may be used. A straight stream will sink and then rise and spread until the whole surface of the pond is covered without waste. The English workers in Africa advise mopping the kerosene upon the surface of the water by means of cloths tied to long sticks and saturated with kerosene.

In many cities of the eastern States it has been found both economical and efficient to oil open breeding places regularly by means of a tank truck equipped with a good lead of hose and a spray nozzle. Catch basins along the streets can be expeditiously treated by means of an air pressure hand sprayer carried in a motor cycle side car, the stop at each basin consuming something less than a minute.

In Panama a larvicide made as follows is being used: 150 gallons of carbolic acid is heated in a tank to a temperature of 212°F. Then 150 lb. of powdered or finely broken resin is poured in. The mixture is kept at a temperature of 212°. 30 pounds of caustic soda is then added and the solution is kept at the same temperature until a perfectly dark emulsion without sediment is formed. The mixture is thoroughly stirred from the time the resin is added, until the emulsion is made. One part of this emulsion to 10,000 parts of water is said to kill Anopheles larvae in less than half an hour, while 1 part to 5,000 parts of water will kill them in from 5 to 10 minutes. At a larvicide plant at Ancon, 4,600 gallons of this mixture was made at a cost of 0·1416 dollars per gallon. Although this mixture has been used to a large extent in Panama, crude oil was also used on streams having a fair velocity.

It has been found that Paris green of standard quality mixed with fine dust and blown as a powder over the surface of water will kill the top-feeding larvae of Anopheles mosquitoes. This method has come into use in anti-malaria operations in many parts of the world. Paris green is mixed with road dust, fuller's earth, powdered soapstone, or something of the sort.

in the proportion of about 10 per cent by weight of Paris green. This dust may be distributed over breeding waters in many ways. A very convenient and effective distribution over comparatively small bodies of water may be made from a boat by means of a hand or motor-driven dust gun such as is used for dusting cotton for boll-weevil control. On large areas of marsh the airplane has been found an expeditious and economical means. In malaria mosquito control operations at Quantico, Va., in 1927, under the joint auspices of the Public Health Service and the Medical Department of the Navy, the effective quantity of Paris green was found to be about 1 pound per acre of marsh and the cost of material 72 cents per acre.

It has since been shown that Paris green may be used against mosquito larvae that feed below the surface of the water if it is mixed with moist sand which drags it below the surface film.

IMPOUNDING WATER TO CONTROL MOSQUITOES

The breeding of mosquitoes, especially of those species which carry malaria, is greatly favoured by the presence, along the banks of streams, ponds, and bayous, of vegetative growths, shallow water, and irregular bank lines. In certain sections the drainage depends upon extensive systems of sluggish streams and bayous. By raising the water level in such bayous by means of dams, it is possible greatly to reduce the opportunities for mosquito breeding. Such a plan increases the wave action, reduces the quantity of vegetation growing in the water, and enables top minnows and mosquito-feeding insects to carry on their work more effectually. The shelter along the banks of the streams is also reduced, thus giving less protection for the adult mosquitoes and decreasing egg laying.

PRACTICAL USE OF NATURAL ENEMIES OF MOSQUITOES

The common goldfish and silverfish destroy mosquito larvae and should be put in artificial ponds. Top minnows of several species have been introduced successfully in several localities and are great feeders upon mosquito larvae. Certain species introduced from Texas into Hawaii have been successful, and a small top minnow of the genus *Girardinus*, known in the Barbados as "millions," has been carried with success to other British West Indian Islands. In Rio de Janeiro another top minnow has been placed by the public health service in tanks and boxes where it was impossible to use petroleum. Top minnows are present in all parts of this country and are very useful in destroying mosquito larvae. One of the most effective mosquito-destroying top minnows, which occurs abundantly in the fresh or brackish waters of the Southern States, is known as *Gambusia patruelis*. This top minnow has been successfully introduced into most northern localities. The effectiveness of these minnows may be increased by clearing the water of any vegetation or debris which will prevent the minnows from free access to all parts.

Many predatory aquatic insects feed upon mosquito larvae; others catch the adults. Certain birds prey upon the adults, and bats also eat them, but the erection of bat roosts in the hope that this action will bring about an appreciable reduction in the mosquito population is not recommended by this department.

LOCATION OF DWELLINGS IN RELATION TO MOSQUITO-BREEDING PLACES

In the establishment of new town sites and of sites for camps the importance of choosing high, well-drained ground, well removed from mosquito-breeding areas is obvious.

Since most mosquitoes do not travel great distances, (the salt-marsh mosquitoes are notable exceptions to this rule) especially in non-wooded areas, it is possible to avoid a great deal of mosquito annoyance by a proper choice of such sites.

RELATION BETWEEN LIVE-STOCK AND MOSQUITOES AND MALARIA

In many parts of the country, especially along the coast where the salt-marsh mosquitoes breed, live-stock are greatly annoyed by the attack of these insects. In fact, when swamps of mosquitoes become especially large the cattle, which normally feed in the more or less wooded areas along the coast, are so beset that their flesh condition and vitality are reduced, and they are ultimately driven into the open country, where the mosquitoes are less numerous. In irrigated areas in the west, as well as in inland swampy areas, live-stock and poultry are often greatly annoyed by mosquitoes. No satisfactory method of protecting live-stock from mosquitoes has been found. Well-constructed dairy barns may be screened so as to give some protection and kerosene-pyrethrum extract sprays will kill great numbers of the mosquitoes and have a slightly repellent action on others. Smudges have also been found to give a certain degree of protection to live-stock, both in buildings and in pastures. The fact that mosquitoes will feed upon various animals and poultry apparently has some protective effect for man. It has been observed frequently that where domestic animals are in close proximity to human beings the mosquitoes will feed upon the former and neglect the latter. It is possible that this may be a factor in reducing the incidents of malaria under certain conditions. The statement has been made that when malaria-infested mosquitoes feed repeatedly upon domestic animals they soon lose their ability to carry the disease.

DETERRENT TREES AND OTHER PLANTS

A great deal has been published about the properties of certain growing plants which are said to keep away mosquitoes. Among these may be mentioned several species of Eucalyptus, the castor-oil plant, the China-berry tree, and others. Although the evidence in regard to these plants is contradictory, all observations made by scientific men in different parts of the world negative their value as mosquito repellents; claims of such properties are made only by people who have not made thoroughly scientific tests. Evidence is accumulating, however, that certain algae of the genera Chara and Nitella will render water pools distasteful to mosquitoes.