SURFACE AND SUBSOIL DRAINAGE.

By F. C. Griffin, *Chief Engineer, Public Health Department, Government of Bengal.*

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The general principles affecting the relation between the control of water and malaria prevention are now well known. They may be re-stated as follows :—

(1) Mosquitoes breed as a rule around the *edge* of water,—out in the middle of a large tank or lake the surface movement is too great.
(2) Most of the malaria-carrying anophelines prefer *clear* water, not necessarily stagnant water.
(3) Mosquitoes cannot breed in water which is heavily laden with silt.
(4) A number of varieties of small fish feed on mosquito larvæ, so that a good-sized tank, well stocked with fish, and with sides kept clear of weeds, can be considered as practically non-malarious.

It is obvious that the simplest way to prevent mosquito breeding in a particular area is to drain away all water from that area. The ease with which this can be done depends however on natural conditions,—and my note is divided into two main parts,—the first part being with regard to areas where drainage is comparatively easy and the second with regard to areas where it is difficult, owing to conditions being against natural drainage.

Easy drainage applies of course to land where there are sufficient differences in level and where the water can run off down the natural slopes, and a very moderate amount of slope can be made sufficient for this purpose. It is surprising how effective natural surface drainage can be made even in a comparatively flat country, when the ground is accurately graded and the water channels are carefully trimmed to exact slopes, as is the case with the Calcutta Maidan.

Practically the whole of the land has its natural surface drainage,—formed by the rain water in its endeavour to pass down to the sea. Stagnation of surface drainage is sometimes due to natural occurrences such as landslides or earthquakes, but is more often due to man's interference with natural conditions. The establishment or restoration of good drainage therefore amounts to an investigation as to what are,—or should be,—the natural drainage channels, and the construction of means for overcoming any obstructions that may be in the way. Among the various ways in which man's

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interference with nature has caused drainage obstruction, the following may be mentioned :—

(1) Encroachments on drainage channels,—either by building over them, or too close to them—thereby confining the channel in too small a width.

(2) Obstruction of drainage channels by throwing into them rubbish, earth, or filth.

(3) By putting fishing weirs across drainage channels and failing to remove them again when the fishing is done.

(4) The construction of embankments for roads, railways, or canals, without making sufficient provision for the natural surface drainage.

(5) Paddy field terracing.

(6) Mining subsidence. The results of mining operations in many places have been to cause the surface of the ground to cave in, with the result that water stagnates in pools and the gradients of surface channels are interfered with.

Other more general points might be mentioned, such as denudation of forest land. When the forests are cut and no re-planting is done, the exposed soil moves more quickly down the slopes to the stream in the valley below, sometimes through landslides. The soil comes down more quickly than the stream can carry it away, and accumulations here and there tend to hold up the drainage in the valley. Also the extra volumes of soil and stones which *are* carried away by the streams block up the rivers lower down in the plains, and accentuate the drainage difficulties there.

Where there are good natural slopes, the improvement of drainage should be simple. Encroachments can be pushed back and the drains kept sacrosanct. Rubbish must be cleared away and arrangements made for keeping the drains clean. By proper grading of channels and continuing them to suitable outfalls, it is generally easy to get good drainage.

One of the experimental antimalarial schemes carried out by the Bengal Public Health Department in 1917 was in connection with colliery land near Raniganj. Here the land had been tumbled about by mining subsidence, and in one place there was a level swamp. The engineering work done consisted of re-grading the natural surface channels, putting in culverts where embankments were obstructing drainage, and in draining the swamp by means of a network of sub-drains. These consisted of earthenware pipes, laid open jointed in a bed of gravel and broken stone. There was a main sub-drain, and branch drains in herringbone fashion. Of course careful levels were taken to shew that there would be a proper outlet for the main sub-drain. The drain at its outlet end was about 4 feet below ground, but there was a lower level channel into which it could discharge.

Subsoil drainage is practised in many parts of the world,—perhaps more for agriculture than for antimalarial purposes. Machines are available which construct a rough sub-drain at great speed. More often the 'agricultural tile' is used,—a rough earthenware pipe, without socket, 3 or 4" in diameter, and laid end to end without any joint. The water finds its way in through the abutting ends of the pipes. Of course it is all important that such a drain should be laid with the proper amount of slope,—a 4" pipe should have a slope of not less than 1 in 60.

An interesting form of sub-drain was constructed in connection with the antimalarial scheme at the Meenglas Tea Estate, in the Duars. This estate is traversed by a number of streams (*jhoras*), and there is a good natural slope from north to south. As the anophelines were breeding along the edge of the running water, it was decided to put the streams underground by means of sub-drains. The long distance for transport would have made earthenware pipes expensive, and as plenty of stone was available at the site, it was decided to make the sub-drains of stone. A stone bed was laid to a continuous gradient, side walls of dressed stone were built on it, and big stone slabs laid across the top,—the whole being then filled in with small stones up to the natural bed of the *jhora*. The side walls and top stones were laid without mortar so that water finds its way into the drain through the crevices of the stonework. One or two lengths of small drains were done with pipes, so as to make a comparison in cost. The cost of a sub-drain 9" wide and one foot high worked out at 7 annas 6 pies per foot run.

The areas where drainage is difficult are of course those areas where there is insufficient natural slope. In the low-lying parts of flat country like the deltaic areas of Bengal water *must* lodge during the rainy season, and often,—as far as malaria is concerned,—it is found better not to attempt drainage, but to bring in river water so as to *raise* the general level and thereby reduce the amount of edge round which the mosquitoes breed. Hence the "flood-flush" drainage schemes. Good results have been obtained by the application of this principle. With the river water, silt and fish are brought into the channels, ditches and tanks, and these are inimical to mosquito breeding. Also the silt helps in the gradual building up of lowland, and the fish, when developed in the tanks, form a useful article of diet. Of course the connection with the river is controlled by a sluice, so that in case of extraordinary high flood in the river, the flow in the flood-flush channel can be restrained so as to avoid damage to property from excessive flooding. An alternative to flood-flushing in low-lying areas is the application of power for pumping off the water. In urban areas, where the surface water must be removed from the vicinity of habitations, underground sewerage systems are constructed. These, with their pumping stations, of course are expensive. As a rule they do not come within the range of practical politics unless they serve a double purpose, i.e. the conservancy system of the town must be dealt with in addition to the drainage of low-lying areas. But the possibilities of removal of surplus water by means of simple surface drains and modern types of pumps must not be overlooked. When cheap electric power is available, as in the Calcutta area, neither the capital nor running cost is high. A low level tank can be constructed or an existing tank or series of tanks can be made use of to act as a storage reservoir to receive the water from the land to be drained, and by means of a pump of moderate size and cost, the water can be pumped away at leisure. An example of this can be seen at the Jodhpur golf course, where a pump driven by a 4 horse-power motor deals satisfactorily with an area of 80 acres. The power required for the pump is so small, because, the height through which the water is lifted is only six feet.

In a deltaic area, the land near the river-bank is above flood level, while further away from the river it is below flood level. It follows that there is a natural line,—roughly parallel with the river, and at a certain distance from it, such that, between the line and the river the policy of land raising and natural surface drainage should be pursued. Within that area excavations should be discouraged. If there were no small tanks and ditches in that area, there would be very little mosquito breeding. On the other side of the line, the digging of tanks, excavations for brickworks, and other works to provide earth for filling purposes, may be allowed,—for, during the flood season, the low ground will become one sheet of water and there will be no mosquito-breeding edge.