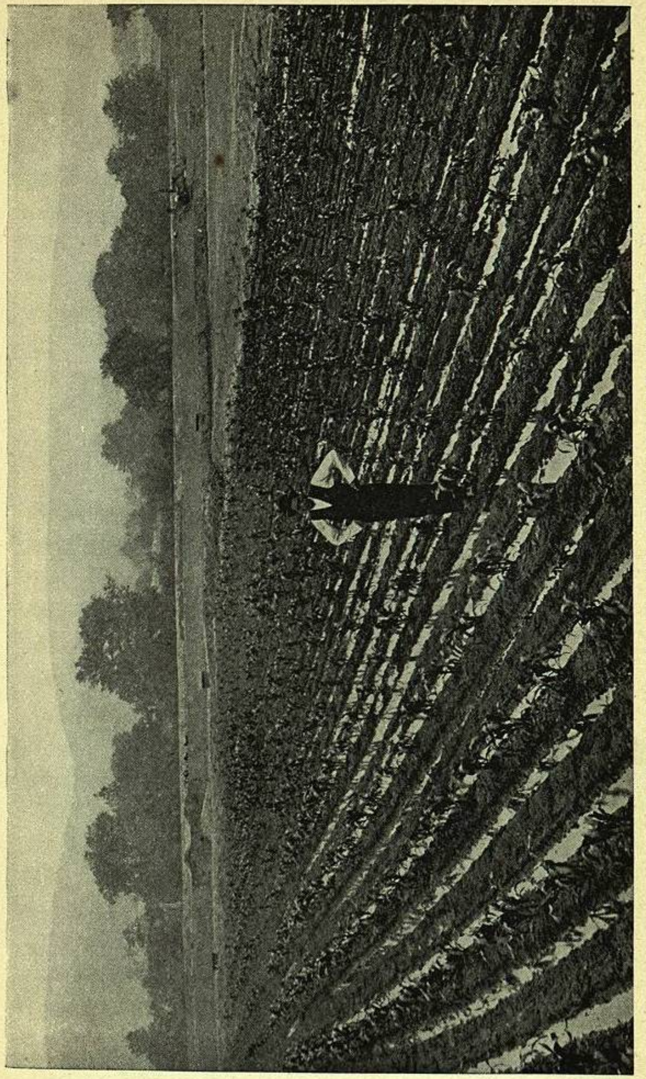
rid of the sewage than with thought of the actual need of the plants.

In the handling of a large quantity of water a very pervious or sandy soil has been found best, since this will take up a large amount of sewage and retain the organic matter where the roots of the plants can reach it, acting to a certain degree as a filter, and delivering clear and harmless water to the drains beneath the surface. The plants, during the season of growth, utilize the organic matter, and by the aid of the nitrifying organisms convert it into food for animals or change it to innoxious substances.

The accompanying illustration (Pl. XLV) gives a view of a field of young corn being irrigated by sewage at Plainfield, New Jersey. The sewage is seen standing in furrows between the rows. The water soaks away rapidly, and after the ground has become partly dry more sewage is let in, this being repeated as rapidly as possible without injury to the growing plants. In this way a rank growth is obtained. On Pl. XLVI, *A*, is shown a view of the sewage-disposal works at Phœnix, Arizona. Here the waste water from the city is carried to a tract of low, sandy ground, portions of which are rented to Chinese gardeners, who produce wonderful crops.

The view on the same plate, *B*, is of a similarly irrigated farm in England, being situated, as shown by the picture, in a densely populated region. If



SEWAGE IRRIGATION AT PLAINFIELD, NEW JERSEY.

properly conducted, there should be no odor from such a farm, and its existence need not be a cause of offence. If neglected, however, or improperly managed, the sewage may become extremely unpleasant.

Sewage irrigation has been found profitable on sandy soils, even in humid climates, where the rain furnishes ordinarily an ample supply of water for plants. The increased yield due to the constant moistening of the soil and the addition of fertilizing material more than repays the additional labor and expense of applying the sewage. In the arid regions, where water has greatest value, it would seem self-evident that sewage irrigation must ultimately be carried on to such an extent that none of this material will be wasted.

This method of disposing of sewage may be considered as a form of slow, intermittent filtration, in which the top of the filter is used for growing crops. After each watering the ground should be cultivated, in order to stir the sewage into the soil and bring the organic matter in contact with particles of earth. The frequent wetting of the ground, followed by thorough cultivation and the sinking away of the water, allowing the air to enter, favors the growth of the nitrifying organisms which convert the waste matter into plant food, this being taken away by the crops as rapidly as it can be utilized. There exists in some localities a strong prejudice against the use of vegetables grown by sewage irrigation. Experience has shown, however, that with proper care in applying the sewage, to keep it away from immediate contact with the plants, and in washing the vegetables when used in cooking, there is no more danger to health than is likely to occur in the use of ordinary fertilizers, such as stable manure. In fact, the precautions

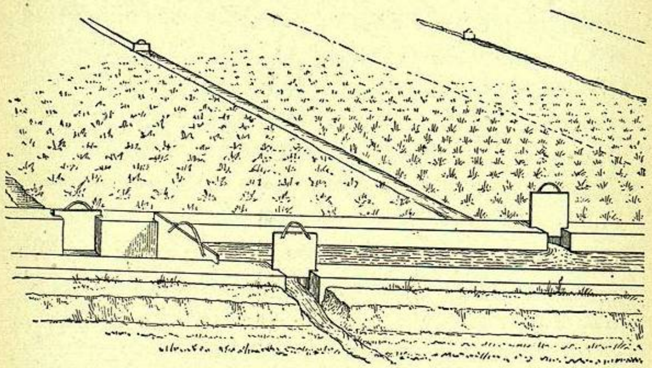


FIG. 88.— Channels and gates for sewage irrigation.

which naturally follow the use of sewage insure a more careful handling of the product than is customary in ordinary market-gardening operations.

The methods of controlling and applying the sewage are similar to those employed in the use of ditch water. The accompanying drawing (Fig. 88) shows a portion of a field through which permanent channels have been constructed. These are made of concrete and provided with iron gates,

making it possible to wash out the conduits and clean them whenever necessary.

ALKALI.

Among the chief disadvantages which are connected with the practice of irrigation is the accumulation of alkali, or earthy salts, which under some conditions may ultimately ruin the cultivated fields. In most cases the injurious accumulation of alkali can be prevented; in others the circumstances are such that destruction seems inevitable. It has been noted on pages 224 and 227 that the excessive use of water upon the fields promotes seepage and movement of waters underground. These ultimately appear upon the surface in the lowest spots, where they may form marshes upon lands which a few years previously were dry and may have been highly cultivated.

The formation of marshy ground can often be prevented by suitable drains, so that in many parts of the country drainage must follow irrigation, and the two become parts of one general system for controlling moisture. The drain from one field often serves as an irrigating ditch for another. In the early days, before drains were built, it was asserted that malarial conditions prevailed around irrigated fields, and some alarm was expressed over the supposed increase of fevers or other diseases attributed to irrigation. There probably is no basis for such fear, and irrigated farms are considered as healthful as any part of the arid region, the climate of which ranks among the most salubrious of all portions of the country.

The waters from seepage reaching the surface may not be sufficient to produce marshy conditions, but, being evaporated, leave on or near the surface any salt which they may be carrying in solution. Only the pure water can escape, and any matter which was dissolved is necessarily left behind. The most easily soluble natural salts are those of sodium, the most familiar of these being sodium chloride, the ordinary table salt, sodium carbonate, commonly known as sal soda, or by the farmer as black alkali, and sodium sulphate or Glauber's salt. All of these, as well as salts of lime, magnesia, potash, and various other compounds, are likely to be present in small quantities in ordinary soils, through the result of the decaying or breaking down of various rocks which compose the crust of the earth. The water seeping through these soils and rocks, dissolves minute quantities of these salts and carries them in suspension until evaporation takes place.

Before irrigation is introduced the soluble material is found to be rather uniformly distributed through the soil. When water is applied to the surface in considerable quantities, this immediately dissolves the salts to the depth to which the water penetrates. When the supply is continuous, a part of the water may escape beneath the surface by

A. SEWAGE IRRIGATION AT PHŒNIX, ARIZONA.

B. SEWAGE IRRIGATION IN ENGLAND.

seepage and carry with it the salts in solution. This seepage water, travelling slowly underground for a distance perhaps of a mile or more, ultimately finds its way to the surface, where it may enter a stream and flow away, or may appear as moist spots on valley lands.

Water evaporating from these moist spots leaves behind the dissolved salts, and in course of months or years these substances may accumulate until they are visible to the eye as either a black stain or a white glistening salt. Thus a fertile field which is being cultivated year after year may become wet by seepage, through the development of irrigation at higher points in the valley, and the yield per acre rapidly increase, due to this supply of moisture and to the enriching material brought by the water. Soon, however, spots appear where the crops do not thrive, and an examination shows that the earthy salts, beneficial in small quantities, have become injurious and destructive by concentration.

Part of the water applied to a field, after saturating the soil returns gradually to the surface, to be evaporated, being drawn up by capillary attraction or by the action of the roots of the plants. If there is an impervious subsoil, nearly all of the water will, in time, thus be drawn up. In its passage downward the water, as previously stated, dissolves the soluble salts, and in its return to the surface brings these with it and leaves them when evaporation takes place. Thus, in the original condition, the alkali may be distributed uniformly through 10 or 20 feet in depth of soil, and not be sufficiently great to be noticeable, so that with ordinary dry farming no difficulties are encountered; but when water is applied, the salts are brought toward the surface by the action just described, and are concentrated within a few inches of the top, where, if not removed, they prevent the development of the plants. There are some soils, as in Southern California, where an excavation, such as a cellar, will show on its walls the bright, glistening alkali. Here orchards have been successfully cultivated, but the artificial application of water would immediately kill these by bringing the alkali to the surface. Such conditions are extreme, but illustrate the necessity of taking certain precautions.

The accumulation of alkali can be frequently prevented by draining, the seepage water carrying away the salts into the streams when an ample amount of water has been applied to the surface. The alkali can thus be washed out by producing a rapid movement of the water away from the field, either on the surface or through the soil into drains. The mere flooding without washing away of the salts is not effective. It has been pointed out that where the chief difficulty arises from small quantities of black alkali or sodium carbonate, this can be neutralized in part by the application of land plaster, or gypsum. This, consisting of sulphate

of lime, changes the sodium carbonate into the less harmful sodium sulphate and makes the lands tillable.

There is always likelihood of a considerable amount of alkali in the soils of arid regions, since these have not been washed through countless centuries by copious rains, such as occur in the humid regions. More difficulty is experienced with clayey soils than with sandy, as the water passes rapidly through the latter, washing out the alkali, and the roots of the crops are more widely spread. Open, sandy soils do not become injured by alkali, except under extreme conditions.