gynecology had already made considerable progress. These Pompeian instruments are far superior to any which have been found in Greece or Asia Minor.

But the beginnings of surgery must be sought at a far earlier epoch. The Berlin museum of anthropology possesses surgical instruments which were found in the ruins of Troy, or Ilium, and which consequently date from the period 1500 to 1100 B. C. These instruments (Fig. 6) are strikingly like those of Roman times. An antique vase (500 B. C.) bears a representation of Achilles dressing the wounds of Patroclus (Fig. 7), and the Naples museum possesses a Pompeian wall painting in which the physician Iapyx is

shown in the act of dilating with the forceps a wound in the thigh of Aeneas, in order to extract an arrow-head. (Fig. 8.)

In antiquity Egypt was celebrated as the land of physicians. A few surgical instruments, very similar to the less ancient specimens described above, have come down to us from the middle period of Egyptian history. (Fig. 11.) Among them are probes of various forms, needles, forceps, universal implements in which pincers, knives, and probes are combined, and a dissecting knife of peculiar shape. (Fig. 10.) Another singular instrument is a long probe terminating in a pointed spoon, which was probably used by embalmers

for the purpose of extracting the brain through the nasal orifice. A small medicine chest similar to the Roman one mentioned above has also been found in Egypt. (Fig. 12.)

W. Max Müller reproduces in his "Egyptological Researches" a very interesting relief found in a tomb at Sakkarah and dating from 2500 B. C., in which various surgical operations, including circumcision, are illustrated. Still older, and contemporary with Abraham and Hammurabi, is a Babylonian clay cylinder on which the cupping apparatus of the surgeon Urugaedinn is represented.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Die Umschau.

THE SEWAGE PROBLEM POPULARLY STATED.*

THE BATTLE OF THE MICROBES.

BY CLARK P. COLLINS.

SANITARY engineering is that branch of civil engineering which is concerned with the constructions for promoting the health of the community.

It is wide in scope, but it can be generalized under two important heads, viz., water supply and sewerage.

In this connection it should be said that pure water supply and good sewerage are both essential, and that it is impossible to separate the value of one from that of the other.

A polluted water supply may spread disease, no matter how perfect the sewerage, and an abundant water supply is essential to the proper working of sewers.

On the other hand, without sewers and drains an abundant water supply simply acts as a carrier of filth to impregnate the soil.

No town or city can submit to a continued want of an adequate supply of pure water and a systematic plan for the removal of its wastes without a serious check in its prosperity.

Sanitary improvements are therefore among the first and chief duties of public officers and guardians, and should ever be the object of most earnest thought to those in whose charge and under whose direction these improvements are furthered.

Our rivers should prove a great blessing to our cities, and it is nothing short of a crime that their waters should be contaminated by filth.

Most foul and fearful of all the artificial pollutions which ignorant and careless humanity permits to reach the streams is the drainage of cess-pools, sewers and stable yards.

The authorities who subject their citizens to the dangers of water-courses impregnated with fecal substances, that the bodies of other persons and animals have already excreted, open for them the gates to aches and pains and weakness of mind and body.

There is no community, there are few families and comparatively few animals without disease.

In very large communities there is rarely a time when virulent disease does not exist, and unless the excretions from such sources are properly disposed of much trouble must be expected and many lives must pay the penalty of this sad neglect.

First—after water supply—for the health of any community is a carefully arranged system of sewers whereby these deadly enemies to mankind may be speeded away and properly disposed of.

This subject naturally invites our attention to the methods whereby the most favorable results may be reached, that the people who are called upon to bear the expense of these improvements may feel assured that the best plan has been adopted.

The methods of sewage disposal which are now practised in this country may be spoken of as crude disposal, disposal by chemical precipitation, by irrigation, and by filtration.

CRUDE DISPOSAL.

Crude disposal contemplates discharging the sewage in its crude or unclarified state into some near water-course or body of water. This is usually by far the cheapest method of disposing of the sewage where the flow of the stream is large enough sufficiently to dilute the sewage at all seasons of the year; or should the town or city be located on the coast the sewage may be conducted in pipes into deep water and thereby sufficiently diluted to render it harmless.

CHEMICAL PRECIPITATION.

Chemical precipitation consists in collecting the sewage in tanks, having just previously mixed with it certain chemicals, usually calcium oxide or "lime," the result of which is to precipitate all matter in suspension and a portion of the material in solution.

A semi-fluid mass collects at the bottom of the tanks, called sludge, which may be drawn off or pumped into

beds to drain and dry out, after which it is disposed of as the authorities see fit.

IRRIGATION, OR SEWAGE FARMING.

In irrigation the sewage is used to irrigate the crops, and the process is frequently called sewage farming.

It is very efficient when the land is of sufficiently porous, sandy or gravelly material, such being much better than that which is fine and more compact.

The sewage is discharged upon the ground, the coarser material being left on the surface, while the finer portions pass into the earth to a greater or less depth, depending upon the coarseness of the soil.

The water freed from the matter in suspension descends still further into the ground, coming in contact with the air in the earth. The impurities which it contains are thereby oxidized, that is, purified by the action of bacteria dependent for life upon the oxygen contained in the air.

The purified liquid may descend still lower, or it may be carried off in underground drains laid for that purpose.

The insoluble matter is also oxidized by slow combustion, and is thereby reduced to a fine powder and mingles with the elements of the earth.

In irrigation only such sewage is applied as will be beneficial to vegetation, and the prime object more often is the profit that may be derived from the crops raised.

Irrigation therefore requires a large area, and the difficulty experienced by cities in successfully operating sewage farms restricts the use of this method in the United States almost entirely to the arid regions, where the soils require irrigation anyhow and where water for irrigation is scarce and valuable. This method is used to a considerable extent in Europe, notably in Paris, in Berlin and in Birmingham and several other English cities.

From 5,000 to 25,000 gallons per acre per day may be purified by irrigation, the amount depending upon the porosity of the soil.

A very high degree of purification can be attained by irrigation.

FILTRATION.

With the exception of irrigation under very favorable conditions, intermittent sand filtration furnishes the most efficient means of purifying sewage which is in common use.

In this method the sewage is discharged intermittently upon the surface of sand filters from three to five feet deep. The area of filter needed will usually be one acre to every 100,000 to 150,000 gallons of sewage per day.

Any clean, good, coarse sand will answer for the filter.

The bottom of the bed is generally covered with a layer of graded pebbles or broken stone to make the drainage more nearly perfect.

The filter is usually underdrained by lines of drain tile, placed about twenty feet apart.

The theory of action of sand filters is, that upon the surface of the sand grains, bacteria of purification become established in innumerable quantities and work upon the organic matter in the sewage slowly trickling past them. In sand filters the bacteria are of the general class known as aerobic bacteria, or those which require oxygen to live.

Hence the application of the sewage must be intermittent to allow each dose to penetrate down into the sand out of sight and draw air into the pores after it, before the next dose is applied.

Sewage disposal plants having sand filters remove from 90 to 98 per cent of the organic matter from the sewage and from 98 to 99.9 per cent of the bacteria.

In case the highest efficiency of purification is not essential, sprinkling filters are used to very good

advantage, especially when a very high rate of filtration is required.

The sprinkling filters are made of coarse material, say one-eighth inch to one inch in size.

Sewage flowing upon such coarse material would pass through the large pores too quickly to receive much purification. Hence the sewage must be sprinkled upon the top surface in drops to insure its simply trickling over the surface of the pieces of filter material.

There are many devices for distributing the sewage in this way, including principally perforated arms and spray-nozzles.

In the case of sprinkling filters, owing to the coarseness of the filtering material and the fact that the sewage is applied in drops and runs over the filtering material in films without filling the pores, sufficient air remains constantly in the pores of the filters to keep alive the aerobic bacteria of purification.

Hence the application of sewage need not be intermittent, as in the case of sand filters.

Sprinkling filters will purify from 1,000,000 to 2,000,000 gallons per acre per day, but they are not so efficient as sand filters. Fine black particles of partly purified organic matter often cloud the effluent to such an extent that settling tanks must be provided for clarification.

COMPARISON OF METHODS.

These form the principal methods of finally disposing of the sewage.

The first, viz., that of crude disposal, cannot now be classed as a scientific disposition of the sewage for inland towns and cities.

The country as a rule has been so denuded of timber that the rivers become very low during the periods of little rain, thus rendering this method of disposal at such times very dangerous; the flow of the stream not being adequate to dilute the sewage sufficiently.

In many States legislation prevents the adoption of this method.

Chemical precipitation, on account of the great cost of chemicals and labor required and the difficulty of satisfactorily disposing of the large amount of sludge precipitated, is now being considered a back number, although it was quite popular twenty years ago.

Only 45 to 50 per cent of the organic matter can be removed by this method, which in itself condemns its use in most cases.

The method of filtration is by far the best and is now being adopted all over this country.

As a preliminary treatment of the sewage in connection with the methods described, settling tanks and septic tanks are often used.

SETTLING TANKS.

Settling tanks are used in order to dismiss part of the solid matter from the sewage, which might tend to compact the filters.

Very little bacterial purification is carried on in the settling tanks.

SEPTIC TANKS.

In the septic tanks the sewage is retained for a sufficient length of time for the solid matter to settle and for a certain species of bacteria called anaerobic (for the reason that they do not require the oxygen of the air to live) to germinate.

In the decay of organic matter anywhere these germs are the active agents, and the septic tanks present very favorable conditions for the large development of the anaerobic bacteria.

The sewage is introduced into these tanks and allowed to stand sufficiently long for the bacterial action.

Usually the septic tanks are cleaned out once each year.

So much then for the final disposal of the sewage. We will now state briefly the two methods for the

* Abstracted from a bulletin published by the Merchants' Association of New York.

conveyance of the sewage to the place of treatment.

Two sewerage systems, the combined and the separate, have been successfully operated in this country and Europe.

THE COMBINED SYSTEM.

The combined system is one with which all towns are more or less familiar.

It consists of a single set of sewers calculated to receive and carry away a certain portion of the storm water flowing on the surface and all the house drainage and industrial wastes produced along lines of streets where sewers are laid.

Mechanically considered, it performs all these offices in a satisfactory manner and seems to comply with the requirements of purely engineering considerations.

It prevents sidewalks and streets from being overflowed during ordinary storms and generally disposes of the surplus water, clean or foul, with a considerable degree of completeness.

But let us see if there are not some defects in the method of disposal, even though some of the larger cities in this country have adopted the combined plan and consider it the most economical and practical one.

There are many cases where the combined plan would be preferable, especially where the point of outlet is far removed from the center of the city and where the sewage does not have to be treated, as when it is discharged into the ocean.

In order to provide for the removal of storm water, the sewers are made larger than are required for house drainage only; so that, during an interval between storms, the stream which would be ample to keep the sewer properly flushed, were the diameter small, is spread out over a larger surface and loses its power to keep it clean.

The sewer being large, the air space is large, and ordinary methods of ventilation fail to change its contents with sufficient frequency to prevent the formation of foul gases.

The drainage from the streets carries into the sewer foul rubbish of every sort, which remains deposited there to a greater or less extent.

These deposits form a nucleus for further accumulation of putrefaction from the solid matter of house drainage, leading to greater foulness of an infrequently changed atmosphere, and thereby requiring the house connections to be carefully trapped, lest they deliver foul and infected air into the interior of dwellings.

As combined sewers are made so foul in this way, it is also of great importance that their atmosphere be trapped away from the streets; and also that the amount of foul deposit may be reduced it is necessary to keep street rubbish out of them, and thus their inlets from the gutters are shut off by trapped catch-basins.

These become the receptacles of sand, chips, mud and droppings from the streets, forming together a polluted, rotten mass, a source of local infection, the dangers of which are manifest to all.

The whole tendency of modern investigation is to show that the zymotic diseases are produced by bacteria, where germs are developed under favorable conditions.

It is well known that the most favorable conditions for the growth of these low organisms are heat, moisture, darkness and the presence of ammonia.

The damp walls of sewers present, therefore, all the requirements for the most abundant growth of these bacteria, whose germs may float off on the sewer air and be carried into dwellings by mechanical action, as dust is borne into our windows.

Large sewers necessarily become the hotbeds for the propagation of these deadly organisms, the moist, porous walls forming a good soil for the pestilent growth, the ammonia from the sewage supplying the nutriment essential for their development, and the moist, warm air completing the process.

The storm water falling per hour in violent rains over an area of closely built-up city land is nearly fifty times the amount of waste water and sewage produced per hour in the same area.

The sewage, therefore, is a mere trickling thread in the bottom of a sewer large enough to carry off storm water.

Let us suppose the sewer in question be one built of brick. In time of rain the sewer will be nearly or quite full of diluted sewage which is absorbed by the bricks and leaves a coating on them, as the flow decreases.

The velocity of the stream being great, enough power is gained to carry along with it particles of solid matter which, as the stream subsides, are deposited along the water line of the sewer. These deposits form miniature dams at first, but are greatly enlarged by the constant additions of solid matter from house drains, which during the dry weather have not sufficient depth of flow to carry the matter on. Foul gases are then emitted, which in themselves are a source of great discomfort and danger.

The occasional flushing of these large sewers, while it may clean out silt and accumulated filth and thus decrease the amount of heat and ammonia from decom-

position, can never prevent the growth of bacteria on the sewer walls, nor will ventilation prove efficient.

Every device of engineering has been exhausted to keep large sewers clean and well ventilated, but the air from them is still deadly.

Experience, therefore, has taught and is teaching that there are some radical defects in the system of large or combined sewers.

Perfect plumbing may prevent sewer gas from entering dwellings, but perfect plumbing is a rare exception, especially in rented houses.

In view of this fact, are we not forced to conclude that the combined system is defective as far as sanitary requirements are concerned?

Each and every town has, as a rule, certain requirements to be met, when a system of sewerage is to be devised, which should regulate the choice of the method to pursue.

Naturally, great attention should be paid to economy, and, other things being equal, economy should control.

Where the special requirement is to dispose of a surplus of surface water during storms, this object should be in precedence to all else, yet the sanitary requirements must not be forgotten.

All sanitarians are agreed that the chief aim, as far as removal of foul waste is concerned, whatever may be the system adopted, should be immediate and complete; and this principle of immediate and complete removal should apply to all laterals as well as main sewers.

THE SEPARATE SYSTEM.

Let us now turn our attention to the separate system and see wherein it differs from the combined.

In this method the chief aim is to separate the house drainage from the surface drainage, and storm water, where it is necessary to be carried off in conduit, is disposed of through special storm water sewers.

By this separation, much smaller sewers will suffice for the house drainage, and on this account the flow through them will be more constant and there will be less chance for deposits, and less wall surface will be exposed on which bacteria can germinate, and there will be less space for storing up germ-laden air.

The gases and heat decomposition which so powerfully stimulate the growth of organic matter are prevented by thorough daily flushing, which is practicable only in small sewers. The smooth glazed surface of the pipe-sewer is unfavorable soil for this vegetable growth, compared with the porous bricks, moistened with sewage.

So much smaller sewers will suffice to carry off the sewage only that their cost need be but a fraction of what would be required to build sewers admitting rain; and by adopting this plan many towns can avail themselves of the benefits of sewerage which would otherwise be prevented by this extra expense.

THE MEMPHIS SYSTEM.

It was at Memphis, Tenn., that the separate system of sewerage was first given a practical test. In the year 1878 the city was visited by a dire contagion, the deaths resulting from yellow fever alone amounting to 5,150. This city naturally became an important subject for sanitary discussion. Many engineers were called upon to give their views as to the best way to cleanse the city and make it habitable.

The plan submitted by the late George E. Waring was finally adopted, and in January, 1880, the work was begun.

All those interested in sanitary improvement now turned their attention to Memphis, for Waring's plan was the separate system pure and simple, and this was a vital test of its efficiency.

The house drains were four-inch pipes, and the sewers ran from 6 to 12 inches in diameter, except in special cases where larger pipes were used, but these were rare.

Flush tanks were put in and rendered very good service.

The effect of the flush is not only to wash out the sewer, but also to force air through the house drains, which it has been frequently observed to do with considerable power.

The report of the City Engineer of Memphis for the year 1886 was very favorable and spoke very highly of the result of the finished work.

In places of moderate size the accumulations of storm water can be led by short and inexpensive drains directly to a suitable outflow without being taken in artificial channels over a longer course, and this applies to a greater extent than is generally supposed to large cities. Since the separate system of sewerage underwent its first test at Memphis in 1880—and from that time it has been known as the "Waring system"—it has been adopted in a great number of towns and cities, and the results are most favorable.

Flushing tanks, by the regularity and frequency of their discharge and by the large body of water precipitated into the dead end of the sewer, sweep out with one rush any chance accumulation of filth. The flush caused by the introduction of rain water through sewage is constant and wholly dependent upon its intensity.

The flush from an automatic flush tank is sudden and violent.

Considering 1 inch per hour as the maximum rainfall, from the roof of a house 25 x 50 feet in size, or 1,250 square feet in area, there will flow 780 gallons in one hour. The flush tank discharging 160 gallons in fifty-five seconds, which was the average capacity of those at Memphis, would have great advantage over the former, for while the roof discharges 780 gallons in an hour, in fifty-five seconds it would discharge only 12.37 gallons; so in violent storms the discharge from thirteen buildings of the above dimensions would be necessary to equal that of the ordinary flush tank.

In case the sewage has to be purified, the separate system is more economical, because only the sanitary sewage need be treated.

GENERAL CONCLUSIONS.

The general conclusions of sanitary engineers at present regarding the relative merits of the separate and combined systems are as follows:

(a) Either system can be made satisfactory from a sanitary point of view.

(b) On a basis of cost the separate system is usually best for small cities and for all cases, even in large cities, where the sanitary sewage requires treatment, while the storm water can be safely discharged into nearby water-courses. The separate system is to be used in Baltimore on this last account.

(c) Often a combination of the two systems can be used to advantage, storm water being admitted to the sewers only in certain business districts.

It appears, generally speaking, unwise to dilute sewage with storm water and to befool storm water with sewage in the attempt to remove both by the same underground channel.

While a foul and ill-ventilated sewer is always a source of danger and much worse than none at all, a well planned, well built, well used, well ventilated and well flushed sewer approaches very near to sanitary perfection.

To those who are interested in the treatment of sewage a visit to the city of Worcester, Mass., affords a very excellent opportunity to study the most up-to-date methods now practised in this country.

At Worcester they are using chemical precipitation, intermittent filtration, sprinkling filters and also the septic process as a preliminary treatment.

At Worcester, it is stated, they can handle 150,000 gallons per acre per twenty-four hours by intermittent filtration, and by the sprinkling filter process a daily capacity of 1,000,000 gallons per acre can be realized.

Chemical precipitation appears to be a back number on account of the low degree of purification and the large quantity of sludge which must be disposed of.

LAYING CONCRETE IN COLD WEATHER.

It is always risky work for property owners or builders to lay concrete during cold weather, but in extreme cases this class of work can be done if proper precautions are taken. In the cold and damp winter months concrete sets more slowly than during the warm periods, and for this reason it is argued that the centering under it must be left in position for a proportionately long time. A writer in a recent issue of Municipal Engineering says that below a temperature of 50 deg. F. concrete sets slowly, and below 40 deg. is very inactive. At 32 deg. concrete freezes before setting. Remove any concrete known to have been frozen. A slight frost extending only one-fourth of an inch into concrete is not detrimental to strength. Some builders claim that concrete can be frozen, thawed out, and will then reset. This may be so in many cases, but it is always best to remove any concrete in which the freezing has extended throughout the mass.

Concrete work can be carried on when the temperature is as low as 20 deg. (never lower), if the precaution is taken to incase the building with canvas and place heating grates or salamanders under the floor being concreted. Keep the building at a uniform temperature of about 60 deg. Do not allow intense heat to come in contact with the concrete, as it will dry out the concrete before it has set. Cover the concrete after being laid with some good insulating material, such as sawdust, straw, cement bags, manure, etc. Be sure to cover the concrete work before stopping work at night, even though it is warm during the day time. Salt dissolved in the water used in mixing concrete helps to prevent freezing by lowering the freezing point. A 5 per cent solution (by weight) of common salt is ordinarily used and is not detrimental to strength when so used. Calcium chloride has an advantage over salt in that it reduces the freezing to a lower point. Dissolve in the water needed to properly mix the concrete 2 pounds of calcium chloride for each bag of cement used.

Heating the cement, sand, stone, and water used in the concrete is helpful, but the materials must never be heated to a temperature of over 100 deg., as the strength of the concrete will be weakened. Be sure that the concrete is thoroughly set (not frozen) before any centering is taken down. Leaving all the upright