HOME SEWAGE DISPOSAL

BY

W. A. HARDENBERGH

MAJOR, SANITARY CORPS, O.R.C.; SANITARY ENGINEER AND DIRECTOR OF RURAL SANITATION, JEFFERSON COUNTY BOARD OF HEALTH, ALABAMA

82 ILLUSTRATIONS

PHILADELPHIA, LONDON, CHICAGO
J. B. LIPPINCOTT COMPANY
The object in writing this book has been three-fold: To prepare a handbook suitable for use by health officers and health workers in the field; to furnish reliable data to engineers and others engaged or interested in sewage disposal for single homes, small communities, and institutions; and to give the student an insight into the principles and problems underlying sewage disposal in its relation to health work.

No book has appeared, so far as the writer knows, during the past ten or fifteen years, which covers this field. A few recent books acknowledge the importance of the subject by referring briefly to it. The great number of pamphlets put out by state and governmental agencies interested in health work testifies to the interest in and the importance of the subject. Many of these are very valuable, but nearly all are written to describe or arouse interest in some one particular privy or type of sewage treatment plant, with the result that the advantages are stressed and the disadvantages glossed over. This book attempts to state clearly and fairly the best present-day opinion on the various types of privies and methods of sewage disposal.

To the end that the book may be of greatest value to the health worker in the field, many plans of tanks and forms, and minute details of construction are given.

Acknowledgment is made throughout the text for data
PREFACE

and illustrations. Special mention should be made of Mr. A. Prescott Folwell, Mr. George A. Denison, Mr. W. E. Hardenbergh, and Mr. Wesley Hardenbergh for aid and advice in preparing the manuscript.

W. A. HARDENBERGH.

Birmingham, Alabama,
January 1, 1924.
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HOME SEWAGE DISPOSAL

PART I. INTRODUCTORY

The need for sanitation is almost universal. It is not necessary to search for unsanitary conditions. A few minutes’ walk, unless it be in the midst of our larger cities, will disclose almost unbelievable conditions, differing only in degree in country and city. Evidently the first requisite of sanitation is to impress the dangers of such conditions upon the community, and to show the punishment that is being inflicted, the penalties that are being imposed, because of such conditions.

Simple as are the principles of sanitation, the average mind seems incapable of grasping them at times. The dangers of disease transmission by flies and animals are scarcely realized. People simply refuse to believe that the mere construction of privies, according to simple requirements, will prevent typhoid fever and a host of other diseases, though the fact has been proved a score of times.

For the most part, pathogenic bacteria are spread by rather simple methods. The fly is probably largely responsible for summer typhoid, but in some sections of the country a heavy rain is nearly always followed by a few cases of typhoid. Surface water, of course, carries excreta from poorly-built privies, and washes it into wells or springs.

To apply to the best advantage the principles of sewage treatment, it is necessary to know something about the facts underlying sewage treatment; the various
processes that take place, and the conditions most favorable for them. Such knowledge is important to the health worker, who is always being heckled by some local genius with a septic tank that will turn sewage into clear water, or that never needs to be cleaned out. Moreover, regulations governing the construction, use and maintenance of the various types of sewage disposal apparatus are necessary. A pretty thorough knowledge of this field is an important part of a health worker's equipment.

Part I stresses the need for sanitation, and presents the results that have been accomplished in a few typical instances. The broad principles underlying the campaign against the filth-borne diseases are enumerated and described, and an outline given on the various types of sewage treatment devices, with a discussion of their advantages and their applicability to special problems.
CHAPTER I

NEED FOR AND RESULTS OF SANITATION

Sanitarians have long realized the need for proper sewage disposal in the rural sections and in the unsewered sections of cities. The filth-borne diseases, recognized as among the important health problems of the day, thrive with insanitary conditions and practically disappear with the proper disposal of the bodily wastes. Sewage disposal may be reckoned as much a health necessity as a convenience, and the term should be broadened to include the disposal of human wastes in the rural sections as well as in the cities.

The importance of the filth-borne diseases lies in the fact that they vitally concern a large part of the fifty million people who live in rural sections and in small communities where there are no organized methods of sewage disposal. The difficulty of fighting them is found in the conditions of country life. The sparseness of population, the absence in most rural localities of any authority to watch over the health of the community, the scarcity of money for health work, the age-old lack of interest in sanitation, and the difficulty of convincing the average individual of the value of health work, all combine to make solution of the problem difficult.

The problem of the filth-borne diseases, however, is broader than the rural field, for nearly one-fourth of the urban population lack the protection of sewers, suffer from the same insanitary conditions, and are similarly subject to attack by these diseases.

In this group are found typhoid fever, dysentery,
"summer complaint" of infants, hookworm, and cholera. All these diseases are caused solely by careless and improper disposal of human excreta. All are preventable, and would be practically eliminated by the sanitary disposal of the bodily wastes.

Typhoid fever is probably the best known of these diseases. About 14,000 people die from it every year in the United States, and ten times that number suffer from it but recover. It is caused by tiny germs which are contained only in human filth, or material contaminated with it, and a case of typhoid is a certain indication that such filth or contaminated material has been swallowed.

Dysentery, cholera, and colitis, commonly called "summer complaint" of infants, result, just as does typhoid, from swallowing filth containing germs of these diseases. Tuberculosis germs are often found in excreta, and it is therefore possible that this disease may be transmitted in the same manner that typhoid is, though it is not usually considered that this method of spread is a very important one.

Hookworm is the name given to a disabling disease or condition caused by the presence of certain worms in the intestines. These worms fasten themselves to the bowel walls, and maintain themselves there. They lay eggs in large numbers, which are passed with the excreta, later to hatch out into small worms about one-fortieth of an inch in length. Where the body wastes are scattered carelessly about, these small worms hatch out in the soil. They may be swallowed with green vegetables, or picked up by the feet of persons with no shoes, or with poor shoes. The worms burrow into the skin causing "ground itch" or "dew itch," pass into the blood, and finally make their
way into the intestines, fasten to the bowel walls, grow into full-sized worms, and thus complete the cycle. About two million people in the United States, and nearly all

![Graph showing typhoid fever deaths in Birmingham, Ala., 1910 to 1922, with reduction accomplished by installation of 6000 sanitary privies in homes not reached by sewers. Other filth-borne diseases were similarly reduced.]

the inhabitants of tropical countries, suffer from hookworm.

The solution of the problem of these diseases is the sanitary disposal of our bodily wastes. Sewers, with a proper form of treatment for the sewage, is the ideal
method of disposal, but not everyone can have sewers. At present, probably less than 40 per cent. of the population of this country are provided with sewers, and practically all of these people live in cities. The other sixty-five million people living in the country, in small towns, and in unsewered sections of the cities, are denied the health protection and convenience of sewers.

It is doubtful if the percentage of population served by sewers will ever grow materially larger, but there is no reason why those denied the convenience of sewers should suffer more from the filth-borne diseases than their more fortunately located neighbors. Proper waste disposal can be accomplished without sewers, and with a proper and sanitary method of waste disposal there will be a practical elimination of these diseases.

The privy is the sewer substitute. Under proper conditions of construction and operation, it may be a perfectly safe and satisfactory substitute; but not all homes are provided with privies, and the most of the privies in use are so poorly constructed that they do not fill the requirements of sanitation.

A survey made a few years ago covered more than 250,000 rural homes in the section east of the Mississippi and south of the Ohio rivers. More than one-half of these homes had no privy or other means for excreta disposal. In some of the counties surveyed, more than three-quarters of the homes fell short of this fundamental requirement. Another survey covering 13,000 rural homes in the Middle West and North disclosed conditions that, though much better, seemed especially designed to aid in the spread of the filth-borne diseases. The average of both surveys showed that not more than 2 per cent. of the homes visited had privies that were really sanitary,
and that complied with the elementary requirements of health protection. The rule, rather than the exception, was privies open in the back, the contents exposed to spread by flies and animals, and the well almost unprotected against surface wash. Such open privies are of very little value from the standpoint of health protection, and the result of their use is a dangerous scattering of pollution over the surface of the ground, the carriage of filth by flies and animals, and the contamination of ground water, streams, wells, and springs.

Education is needed. It must be brought home to
everyone that the cost of preventing disease is less than the cost of sickness, and that such prevention can be accomplished, in regard to the filth-borne diseases, only by the proper means of waste disposal. The use of the various types of privies and sewer substitutes, their adaptation to local conditions, their proper construction, and their maintenance must be explained.

What can be done in the reduction of disease by the construction of adequate sewer substitutes, and by educating and interesting the people in sanitation, has been demonstrated many times. As far back as 1909, Richmond, Virginia, installed a sanitary type of privy at every home not reached by sewers. In 1908, there had been fifty-seven deaths from typhoid fever; the following year there were but twenty-eight deaths, and practically every year since then has seen a reduction. Birmingham, Ala., suffered from a heavy typhoid rate for years. In 1917-1918, a sanitary privy system was installed, with the result that the typhoid rate fell from 65.5 per hundred thousand in 1917, to 17.8 per hundred thousand in 1919. This, however, was only one of the returns from the work. In the same period, tuberculosis deaths decreased 20 per cent., and deaths from diarrhea and enteritis among children under two years of age dropped 50 per cent. Other diseases also decreased. The profits of the work did not end with the reduction in typhoid.

Just as the installation of sanitary toilets in the two cities mentioned above yielded tremendous profits, so have scores of similar installations paid big dividends. The same is true of rural communities. The United States Public Health Service in 1910, by a campaign of sanitary education and the construction of sanitary privies, cut typhoid in Yakima County, Washington, from
Fig. 3.—Typhoid in Tuscaloosa County, Ala., before and after sanitary survey by U. S. Public Health Service.
twenty-five in 1910, to eleven in 1911, three in 1912, and none in 1913. In Berkeley County, West Virginia, where a similar campaign was carried on, typhoid deaths decreased from forty-four in the three years preceding the campaign to seven in the four years following it.

Similar results have been obtained in dozens of other places scattered throughout the country. Descriptions of much of this work are contained in Public Health Bulletin No. 94, which furnishes illuminating and interesting data on rural health work, its problems, and results.

Unquestionably the returns listed above, striking though they are, have been but a small part of the actual returns from the health work done. It is hard to secure
actual figures on the returns from sanitation. The descending curve of typhoid deaths is indeed proof that better health conditions have been attained, but is inadequate data upon which to lay claims for the money spent. Nevertheless, such figures are usually all that are available. Many of the places where excellent showings have been made in health work, had never previously carried on organized health work. Naturally, no records are available to show the disease loss of previous years. In these cases the results accomplished by sanitation stand alone, and without the dark background of previous death and disease.

The industrial and agricultural development of a state, county, or city may be, and frequently is, delayed by adverse health conditions. This is the case in a great many sections of the South today, but it is not necessary. Any community is the master of its own health conditions, though few seem to realize the fact. Public health is, to a high degree, purchasable, but our industrial corporations, governing bodies, and citizens fail to appreciate this, or to understand that money spent on health work is an investment which confidently may be expected to yield a far greater return than can be secured in any other way.
CHAPTER II

THE PRINCIPLES OF SANITATION

Any method of sewage treatment or excreta disposal, if it is to be effective in the reduction or elimination of disease, must prevent:

(a) The access of flies to the excreta.
(b) The access of animals to the excreta.
(c) The scattering of the excreta or sewage over the surface of the ground, causing soil pollution.
(d) Ground water pollution, or the contamination of wells, springs, and other sources of drinking water.

There are, of course, other points which must be considered before the workability or practical application of any type of privy or method of excreta disposal can be determined, but the sanitary and health-protective values will depend almost entirely upon compliance with the above conditions.

The importance of the fly as a carrier of disease is great. Examinations of flies have shown them to carry many kinds of pathogenic bacteria, most of which are transported on the hairs which cover the feet, legs, and body of the fly. Disease is spread largely by flies feeding or walking, when smeared with filth, on food or on dishes that later are used for holding food. It is probable that the fly, along with the open-back privy it frequents, is responsible for much of the typhoid and dysentery in our towns and cities. The curves of the prevalence of these diseases and of fly incidence, coincide to a remarkable degree. Probably the persons taken ill are but a fraction of those who partake of contamination through the medi-
um of the fly, but who escape through natural resistance or for other reasons.

Ventilation is usually considered necessary in privies, but thorough screening of the vent openings will prevent the flies from reaching the privy contents. Cracks large enough to admit flies to the excreta should not be permitted, and all material built into a privy should be of such quality that it will not warp or twist. If the privy is not flytight, it lacks one of the most important and one of the most easily obtained essentials of sanitation.

Animals are frequently carriers of filth which may contain germs of disease. The hen is probably the most important factor in the mechanical carriage of filth. Scratching in and around the open-back privy, the contents of which are usually entirely unprotected, chickens carry pollution on bill, feet, and feathers to the well, and possibly to other places. Inasmuch as chickens cannot be educated in sanitation, they must be restrained in their actions.

Rats and mice are frequently important in the mechanical spread of contamination, as they travel from the privy to the food in the cellar or pantry. Hogs are scavengers and occasionally spread filth. The same is true of dogs. The only safeguard is to protect the contents of the privy from animals.

Soil pollution is usually defined as a contamination of the surface or top layers of the soil, so that rain may wash pollution into springs, wells, or streams; or so that persons with poor foot protection may contract hookworm.

The privy should be of such type that, not only will it prevent direct pollution, but in the process of cleaning, even though the work be carelessly done, there will be no
chance for the spread of filth. Direct pollution is usually prevented by having the privy tight, so as to prevent leakage or overflow, raised above storm waters, and so constructed as to require no cleaning, or that cleaning may be simple and easy.

Except in those places where water is obtained from a city system, from deep wells, or from other sources of unquestioned purity, the quality of watertightness is important. Water is such a rapid carrier of contamination and will distribute it over such wide limits, both above and below ground, that especial care must be taken to prevent filth from reaching it. In regions where the water supply is largely derived from shallow wells and springs, contamination of the ground water may be, and frequently is, a cause of disease.

The pit privy is not watertight, but the use of the pit privy should be confined to those sections where ground water contamination will cause no danger, or where, owing to remedial conditions—as considerable depth of ground water, or certain types of soil—no contamination will result. The limits over which ground water is endangered by a source of pollution are unknown. Many elements, such as type of soil, depth of ground water, slope of land, and distance to water supplies, enter into the problem. A more complete discussion of the spread of pollution with the ground water will be found in Chapter XVI.

The four points mentioned above are the ones that must be considered in the design of any home-sewage treatment plant, from the humblest to the largest. If these qualities are not present in a reasonable degree, the expenditure of money is an extravagance. They should be considered first, and afterward the qualities,
very important from administrative and economic points of view, of ultimate economy, life, and fitness for the task.

While there are times when expediency and temporary cheapness are strong factors, the health officer or the man in the field will find that there are few places where privies lacking the essentials already enumerated and described may safely and economically be installed. Serious disease is a matter of life and death. No one can afford to take chances with such stakes at hazard.

Just as in any work, there should be a fair return—in this case a fair degree of sanitation—for the money expended. In this return there should be included only the actual sanitary value. There have been cases where a poorly designed and installed privy system has been excused on the ground that there have been large returns

Courtesy Dr. W. K. Sharpe, Jr.

Fig. 5.—The open back privy invites spread of pollution.
in sanitary education. Such returns exist far more in imagination than in reality. It is much more probable that a faulty, poorly constructed, and temporary system will so disgust the community that the very purpose of the installation will be defeated.

Durability of sanitation is important. An installation of sanitary privies should last for a reasonable time without losing any important part of its sanitary qualities. Generally it is better to install a system that, with occasional care, will last for an indefinite period, than to have one that requires complete replacement every few years, even though the total annual cost of the former is the greatest.

It is useless, experience has shown, to expect any large percentage of the population to interest themselves in, or operate properly, any privy or sewage treatment apparatus that requires care and intelligence. It is essential, therefore, to design an installation so that the care required will be a minimum, and the intelligence in operation and the cost of upkeep infinitesimal.

Abuse must be expected, and the privy or treatment plant built with a view to withstanding rough usage. Proper cleaning or scavenging is most important. The privy, no matter how costly, is worthless if this cannot be accomplished easily and in a sanitary fashion.

Applicability is really but another phase of economy. The type of privy offered must meet the requirements of the situation to a reasonable degree, or it is not applicable or economical. For instance, a costly and permanent installation of privies is scarcely warranted in a section that will be reached by sewers within two or three years. In the case of a rapidly-growing town, a type should be selected that will adequately meet the needs of the future, so far as that may be foreseen.
CHAPTER III
CHEMICAL AND BACTERIOLOGICAL PROCESSES
DURING SEWAGE TREATMENT

In the privy, the principal object is to get rid of the dangerous waste products of the human body. Little attention is paid to anything but economy, convenience and safety. In the treatment of sewage there are two main objects to be accomplished: The elimination of disease-bearing bacteria as far as may be demanded by local health authorities, and the stabilization of the sewage quickly, economically, and without the production of nuisance. The organic matter in the sewage must be separated out, and rendered harmless and stable by decomposition and oxidation. The water, which makes up such a large part of sewage, must be restored to a degree of purity determined by local requirements.

Sewage contains the waste elements of the human body, and in addition, some of the usual household wastes. There is also a large volume of water. Under average conditions there are not more than one or two parts of solid material to 1000 parts of water, but even this small amount renders the entire mixture objectionable and subject to putrefaction. Sewage also contains a vast bacterial life. These bacteria live or die, thrive and multiply, or dwindle and disappear, depending upon the conditions and environments under which they live. The primary processes of sewage treatment, generally speaking, are favorable to them, but the final processes of oxidation are usually accompanied by a high percentage of reduction in their number. Bacteria are very impor-
tant in sewage treatment for they aid in and hasten the actions of reduction, disintegration, and oxidation, by means of which the stabilization of the putrescible elements is obtained.

Domestic sewage ordinarily contains from 200 to 2000 parts or more of solid matter per million, approximately one-half of which is organic and subject to putrefaction. Only about 60 per cent. of the organic matter is in solution, the remaining 40 per cent. being in a state of suspension. Not all sewages, of course, have the same composition, but excluding manufacturing and industrial wastes, and allowing for differences in strength due to differences in water consumption, they do not differ vitally. Those sewages containing large amounts of trades wastes offer individual problems and are outside the scope of this book. It should be noted that house sewage, due to a lesser use of water in isolated homes, is generally much more concentrated than the average city sewage.

The mineral matter contained in sewage consists chiefly of clay, sand, iron, aluminum and chlorides, carbonates, sulphates and phosphates of the alkalies, and alkaline earths. The organic constituents, which are both animal and vegetable in character, consist almost entirely of urea, proteins, carbohydrates, fats, and soap. It is with the organic material that we are chiefly concerned, since by its decomposition nuisance arises.

Before we can appreciate readily the changes that take place in sewage treatment, we must have a definite conception of the composition and chemical behavior of organic matter in sewage.

Proteins are very complex organic compounds, containing carbon, hydrogen, oxygen, nitrogen, and often
iron, sulphur, and phosphorus. They are both aliphatic and aromatic in structure. Our present knowledge of the composition of proteins has been obtained by hydrolyzing or breaking up the complex molecules into simpler ones whose composition may be confirmed more easily. This same hydrolysis also occurs in sewage treatment. In the laboratory, proteins are hydrolyzed by acids and alkalis; in the septic tank protein sewage is hydrolyzed by the action of the anaerobic bacteria and by enzymes, which may be the by-product of living bacteria, or may occur in an unorganized state in the sewage. These produce hydrolysis by catalytic action. Hydrolyzed proteins yield simpler proteins called albuminoids and peptones. These simple proteins on further hydrolysis yield amino acids.

The sanitary engineer knows hydrolysis as clarification or liquefaction because the products formed are soluble. Thus, by hydrolysis much of the suspended organic matter is dissolved and disappears from the sewage.

Carbohydrates are compounds of carbon, hydrogen and oxygen. Those commonly found in sewage include cellulose, woody fibres, starches and sugars. They have the general formulæ:

\[(C_{6}H_{10}O_{5})_x \text{ cellulose;} \quad (C_{6}H_{10}O_{5})_y \text{ starch;} \quad (C_{12}H_{22}O_{11}) \text{ cane sugar.}\]

Cellulose undergoes very little change in sewage treatment, but the remaining carbohydrates are hydrolyzed or reduced to simpler compounds, and some are fermented, possibly by bacterial action, and converted to alcohols. Cotton waste is a form of cellulose common around manufacturing plants. Sewage treatment processes affect it very little, so that clogging of the treatment tanks often
occurs from excessive amounts of this material thrown into sewers.

Fats are the glyceryl salts of fatty acids; soaps are the mineral salts of fatty acids. When sewage becomes acid by the production of amino acids and nitrous and nitric acids, the fatty acids are set free from the fats and soaps and are later oxidized still further to gases. While fats are resistant to many putrefying bacteria, some types readily attack them, forming volatile gases. Some of the more common fatty acid compounds found in sewage are:

\[
\begin{align*}
C_3H_4(C_{12}H_{25}O_2)_2, \text{ stearin; } \\
C_2H_4(C_{18}H_{31}O_2)_2, \text{ palmitin; } \\
(C_{17}H_{33}COO)\text{Na, or (C}_{18}H_{33}\text{COO})\text{K, soaps; } C_{17}H_{33}\text{COOH, or} \\
C_{18}H_{33}\text{COOH, fatty acids.}
\end{align*}
\]

The biolysis of sewage is usually divided into two main steps: (a) putrefaction, generally accomplished by anaerobic action; and (b) oxidation and nitrification, which is accomplished by aerobic action. It may be better for our use, however, to consider the process as taking place in four steps, namely:

1. Preliminary aerobic oxidation of sewage while in the sewers in transit to the plant.
2. Anaerobic clarification and putrefaction by hydrolysis, which takes place in the sewage and in the liquid passing through the tank, generally termed "primary" treatment.
3. Semi-anaerobic breaking down of intermediate dissolved substances, taking place in the scum which forms on the surface of the tank contents.
4. Nitrification and complete aerobic oxidation to gases, nitrates and carbonaceous residues, or "secondary" treatment.

Anaerobic action goes on in the absence of oxygen, as in the interior of a septic tank. This process is destruc-
tive and reduces and disintegrates the complex compounds to simpler forms. This is succeeded by the next step, aërobic reduction, accomplished by the aërobes or bacteria working in the presence of oxygen. This is the stabilizing process. It should be remembered that in these processes of reduction and oxidation nothing is lost, though it may be changed physically or chemically, gasified or liquefied. Matter is indestructible.

The work of bacteria in the reduction of sewage is extremely important. Sewage teems with bacteria. The number contained is enormous, running, possibly, up to twenty or thirty million per cubic centimeter.

It is not necessary for the engineer to know all about all the bacteria found in sewage. Most of them have no special significance insofar as their family and history are concerned. It is necessary, mainly, that the sanitary engineer realize the important part bacteria play in the treatment of sewage, and understand the conditions most favorable for bacterial purification. B. coli should, however, be excepted from this statement. It is not so important in sewage, where it is universally found in vast numbers, as in water where its presence is generally taken to indicate sewage pollution. Most sewage bacteria are classed as aërobic or anaërobic, according to the part they play in sewage treatment, rather than according to family. The effect of these bacteria on the health and comfort of the people, whether in the elimination of pathogenic bacteria or in the reduction and stabilization of sewage, is the main concern of the sanitary engineer.

The first step in the processes of treatment mentioned depends largely upon the length of time elapsing before the sewage reaches the treatment plant. In large cities,
where the sewage must travel through miles of sewers, consuming hours in its passage, this is an important matter, for the sewage reaches the plant "stale." All the oxygen dissolved in the water has been utilized and uncontrolled putrefaction is about to take place. Generally, however, only the most easily oxidized substances have been affected, among them urea, CO \((\text{NH}_2)_2\), which is converted into ammonium carbonate, \((\text{NH}_4)_2\text{CO}_3\). In the average small plant, this preliminary aërobic oxidation does not take place, for the passage of the sewage from the house to the treatment plant is a matter of minutes rather than hours. It may, therefore, be neglected as an important factor in home sewage treatment.

The anaërobic putrefaction and clarification is the first really important step. The facultative anaërobic bacteria, that is, bacteria which normally exists as aërobes, but have the faculty of living under anaërobic conditions, for example, B. enteritidis sporogenes, by hydrolytic action break up the complex protein molecules into albuminoids, peptones, and amino-acids, which are soluble nitrogenous compounds. Starches and sugars are broken up, while cellulose is changed but little. The anaërobic liquefaction of sewage cannot be called a distinctly hydrolytic process, for a large amount of oxidation also occurs, in which methane, carbon dioxide, hydrogen, nitrogen, hydrogen sulphide, and mercaptins are given off. Methane is by far the chief product.

The semi-anaërobic breaking down of the intermediate dissolved substances, which takes place in the scum of the septic tank, is the last stage of anaërobic liquefaction and the real beginning of oxidation of the reduced or hydrolyzed products. Albuminoids and peptones are
CHEMICAL AND BACTERIOLOGICAL PROCESSES

Further changed to amino-acids. These are in turn broken up into ammonia, nitrogen, and fatty acids of the hydrocarbon series. Amino and amido compounds, nitrous and nitric acids are formed. Fatty acids are set free from the fats and soaps.

In the fourth and last step, the facultative aerobic bacteria complete the oxidation and nitrification by breaking up the amino-acids into carbon dioxide, methane, ammonia, water, nitrogen, nitrous and nitric acids, and carbonaceous residues. Soaps and fats are converted into fatty acids in the acid solution and decompose with the remaining carbohydrates to carbon dioxide, water, hydrogen, and methane, while cellulose, undergoing only a small amount of hydrolysis, passes through with little change.

Upon the completeness of the changes taking place depends the resulting degree of purification of the sewage. In few treatment plants is the fourth step carried very far, the end sought generally being only sufficient stabilization to prevent nuisance after discharge from the plant. Nature, of course, carries on the final processes of oxidation and nitrification, returning the dead animal and vegetable matter to a state where it may again be utilized by living plants. Practically the object of sewage treatment is not to produce a safe and potable water from the sewage, but to attain a degree of purity in the effluent sufficient to prevent nuisance and odor, danger to health, and destruction of fish and animal life. Upon local conditions will depend very largely the degree of purification demanded.

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CHAPTER IV
SELECTING THE METHOD OF DISPOSAL

One of the most important problems facing the sanitarian is that of selecting the proper method of waste disposal. Almost every town or village presents some special feature bearing upon the choice of method. It is only in rare cases that a uniform policy can be maintained, even within the narrow limits of a county. Local conditions of soil and water, local prides and prejudices, and local finances combine to exert appreciable influences.

The methods of disposal which experience has shown to be the most suitable include, where running water is not available, the pit, box and can, concrete vault, chemical and septic privies, and, where flush toilets are used, the small septic tank. In general, there are three conditions to meet: Rural, small community, and the unsewered sections of cities. Different types of privies are needed to meet these different conditions.

The pit is the cheapest and simplest form of privy available (Fig. 6). It consists of a hole in the ground, flytight, curbed to prevent the entrance of storm water. Over the hole is placed the seat, and over all the privy house. No cleaning is needed. When the pit becomes
nearly filled, another is dug nearby, and the cover, seat and house moved over the new hole, the old hole being filled in. The pit is especially suited to rural conditions, but occasionally may be installed with profit and satisfaction in more thickly settled communities.

The box and can consists of a flytight box, within which is a watertight can, all contained within a privy house. The tight can prevents soil and water pollution, and the box prevents the access of flies and animals to the can contents. The can must be emptied or scavenged at least once a week. This attention is absolutely necessary, and where it is not available, the box and can system should not be installed. This type is generally of greatest value in the unsewered fringes of cities, where it is used to a very large extent. Its sanitary value depends almost entirely upon proper and systematic scavenging, and where this is available, with a proper means of disposal of the can contents, the box and can privy is a most valuable installation.

Concrete vault privies consist of a concrete vault or box built in the ground, a centre wall dividing the space into two compartments. Seats are mounted on the structure and a house built over it. Each compartment is of sufficient size to receive the wastes of the average family for about three months. One side is used at a time, the other compartment meanwhile undergoing bacterial
action. Scavenging is, however, very disagreeable and difficult, and accordingly, this type can be used under few conditions.

The septic closet is perhaps better known as the LRS toilet from the initials of its originators, Drs. Lumsden, Roberts, and Stiles, of the Public Health Service (Fig. 7). It operates upon the same principles as does the septic tank. Storage space is provided for the retention of the
excreta, and water is added, resulting in fermentation and septic action, with a breaking up of the wastes of the human body. Considerable attention is necessary to secure best results. This type of privy has been of considerable importance in sanitation in the South.

The chemical toilet disinfects, deodorizes, and liquefies the excreta by the action of certain chemicals. A steel or iron tank, protected from corrosion, usually by an asphaltic coating, and charged with a chemical solution, catches the excreta. When the tank becomes filled, the time required for which depends upon the number of persons contributing and the size of the tank, it must be emptied and recharged with chemical. As a rule, all odors are eliminated and all bacteria killed by the action of the chemical. The sanitary quality is high. The chemical toilet is the only privy type of construction that is available for indoor use. The greatest handicap is the high first cost (Fig. 8).

Where homes are equipped with flush toilets and running water an entirely different problem exists. The amount of wastes is multiplied many fold. The small septic tank is the best solution of the problem of caring for these wastes where sewers are not available. The first cost is not high, considering that these tanks
take the place of sewers and they give a maximum of sanitation and convenience for small cost and with little trouble in operation (Fig. 9).

Other means of sewage treatment, available for the home or institution equipped with running water, may include dilution, activated sludge, sedimentation, chemical precipitation, sand filters, etc., but these have, with the possible exception of dilution and sand filters, a very small part in domestic or small community sewage disposal. Occasionally one or another of these methods may be used in a small town, industrial, or institutional sewage treatment plant, but in general, their importance in this field is very small.

The choice between the various methods of disposal is often difficult. Usually the first thing to determine is whether or not running water may be installed and the wastes handled by the water-carriage system. If this is possible, the small septic tank is the best solution of the problem, lacking sewers. If running water is not available, the choice will lie with one of the privy types. To aid in making a selection of the best method, the privies in most common use will be listed and their advantages for particular purposes enumerated.

The pit toilet is especially suited for rural sections, but may also be used advantageously in more thickly-settled communities, and occasionally even in the unsewered areas of cities, especially where piped water is available and wells are not used. The pit is particularly valuable, when well-built, for use in rural schools. The main conditions limiting the use of pits are physical ones. Pits should not be installed in regions where the ground water is less than ten or fifteen feet beneath the ground surface, nor in sections where limestone forma-
tions are near the surface. In general, pits ought to be located as much as fifty feet away, and downhill, from the well.

The box and can has one field in which it is supreme—the unsewered areas of cities—but it should not be used elsewhere unless conditions are exceptional. Occasionally it may be used successfully in smaller towns, but in none that cannot afford an adequate scavenger service. Cheap, and with a high sanitary value while new, it rapidly deteriorates unless given considerable care. Because of the disagreeable nature and difficulty of cleaning, which is required at weekly intervals, the box and can should not be used in small communities, or in isolated homes; it is especially unsuited for schools and public buildings.

The concrete vault type of toilet has a very limited applicability. About the only place where it is superior to cheaper types of privies is where high-ground water prevents the use of the pit or septic closet. Careful and regular scavenging is necessary. The concrete vault should never be recommended for schools or for any other place where it may be abused, as it will not operate without considerable care.

Chemical toilets are well fitted for installation at schools where an indoor toilet is desired, but running water is not available. Little attention is needed, and the outfit will usually function an entire school year without recharging. The chemical toilet is also very satisfactory for home use, though somewhat costly. It is valuable in the sanitation of camps and summer cottages. In fact, the chemical toilet can be used almost anywhere. The initial cost will usually prevent their installation on a large scale or throughout any community.

Septic closets, when installed in numbers large enough
so that a man may be detailed to spend his entire time in caring for them, will work very well. They make a good installation for home service, especially in rural sections or in small communities. Abuse is the invariable portion of toilets installed in schools and in public buildings, so the septic closet, which will not operate under such conditions, is not suited to such use.

Small septic tanks are available for use under almost any conditions except where the ground water is very near the surface. These tanks may be used with equal satisfaction for homes, schools, groups of homes, institutions, and public buildings to care for the sewage produced by the installation of running water and flush toilets; in other words, the small septic tank replaces sewers. Careful construction is necessary, but little care or attention is needed after installation.

In most sections it will be best to specialize on pits and septic tanks, as these are the two types that give least trouble and greatest satisfaction. The box and can privy may be necessary in the large city; elsewhere this type should be used and recommended sparingly, as too much care and attention are necessary after installation to keep the box flytight and the can properly and regularly cleaned. It is better to concentrate on those types that operate after installation with the minimum of care and oversight.

In the following chapters the various types of privies will be discussed, their construction and operation explained, and their advantages and disadvantages pointed out.
PART TWO

SEWAGE DISPOSAL FOR UNSEWERED SECTIONS

In health work, as in many other ways, rural conditions are unlike urban conditions. In the country, sanitation and waste disposal are largely individual problems; in the city they are solely community problems. The individual in the city, for the most part, is unable to care for his own waste products; the city must construct a public sewerage system and operate a public garbage and waste collection service. A rural community cannot do this without excessive cost.

Sanitary requirements are the same, however, for the city and the country. The essential principles enumerated and discussed in Chapter II are just as important for the one as for the other. The relatively greater distance between homes in the country retards the spread of disease, but does not prevent it.

There are some sections of the city where rural sanitary conditions obtain, as, for instance, the areas not reached by sewers. The lack of sewers may be due to any of several reasons, as scarcity of money for sewer extensions, inability to extend sewers due to adverse conditions of nature, or legal limitations, as where a community is contiguous to, but just outside of the city limits. In these sections there is a complication of problems, but the essential requirement remains the same. It is necessary to dispose of the dangerous wastes in a sanitary manner.

Few of these homes are reached by water mains, or have their own water supplies under pressure. Fewer
still are financially able to install plumbing fixtures and build a plant to care for the sewage resulting from the installation. For the great majority the privy will be the method of sewage disposal.

Various types of privies meet the demands of sanitation. Local conditions will largely determine the particular type to be selected. The pit, the box and can, the concrete vault, and the septic and chemical toilets are all available for use, and more or less suitable, according to local conditions. In the following chapters the construction, maintenance and use of these various privies will be taken up in detail and studied with a view of pointing out the advantages and disadvantages of each, their value and applicability.
CHAPTER V

THE PIT PRIVY

The earliest known form of a sanitary privy is the pit. Moses, in the Book of Deuteronomy, instructed the Hebrews in regard to sanitary methods of excreta disposal, thus preventing epidemics of the filth-borne diseases. The present-day pit is larger, is flytight and animal-tight, and is so constructed as to prevent the flow of surface water into it, but the principals are the same.

For the average privy for one family, with one or two seat holes, the pit should be thirty-six to fifty-four inches in length, thirty to thirty-six inches wide, and forty-eight to sixty inches deep. For each additional privy seat, twenty-four inches should be added to the length, but no changes made in width or depth. An increased depth allows greater capacity, but may bring the bottom of the pit near or into the ground water, the effect of which is three-fold. Pollution of the ground water may result; standing water in the bottom of the pit interferes with the drying-out action of the excreta which usually takes place in this type of toilet, and may cause odors; the reducing action of the bacteria in the upper layers of the soil is lost. Just how important the two latter are is not positively known. Experience has shown that a dry pit is more satisfactory than one containing water, but the benefit from the soil bacteria in reducing the pit contents will depend as much on local conditions, it is likely, as on the depth. However, the depth of the pit should not exceed sixty inches in most localities.

Sheeting of the inside of the pit will be necessary in soils subject to caving, as sand or loose loam. In most
places an inside curbing or lining of boards, extending eighteen inches down from the ground surface, will be sufficient (Fig. 10). This lining need not be watertight,

but should fit the hole snugly and should extend above the ground surface four to eight inches, forming a curb around which earth should be banked to prevent the inflow of surface water. Such a lining is valuable in all types of soil, for even the hardest clay may cave or slip
in wet weather. In some places a large tile, usually about thirty-six inches in diameter, set into the ground has been used to form the sheeting and the curb. When the pit is filled, the tile is pulled and placed in a new pit. A well-made wood sheathing is cheaper, easier to handle, and just as satisfactory.

To construct a pit privy, select a site on dry, well-drained ground, if possible. Dig the hole to the dimensions chosen—three feet square and five feet deep is a good size. Let the sides of the pit slope a little to minimize caving. Line the pit as directed, and with the dirt from the pit build a mound around the curbing to serve the double purpose of turning rain or surface water and forming a resting place for the privy house. Place the privy house over the pit, letting it lap fairly evenly on all sides, but placing the seat hole over the centre of the pit. Board the privy building to the ground, making fly-tight all possible entrances to the pit.

An improved form of the pit privy has been used very largely in Alabama. The hole is of the same dimensions, but the privy floor is of concrete, and the seat riser of cast iron, equipped with a seat, seat cover, and flue. The floor is four inches thick, and is cast around the riser, giving a unit construction of unusual strength, well fitted to withstand abuse or hard usage. This variation of the pit has made a considerable impression on health workers, due to its all-around good qualities. The cost is somewhat greater than the usual wood construction, but the permanency and high sanitary qualities, which persist under hard service, make it a good investment (Fig. 11).

In constructing the improved type of pit, any one of several methods may be used. Probably the best way is to build around the pit a concrete curb, the inside flush
with the pit walls, and the top a little above the ground surface, and on this curb place the floor, already cast around the riser. In some places the curb is omitted, and

![Diagram of a pit privy](image)

**Fig. 11.**—Pit privy with concrete floor and metal seat riser, fly-proof and durable.

the floor slab set in a prepared place over the pit; it is also possible to cast the floor over the pit, afterward removing or sawing out the supporting boards (Fig. 12).

The cost of the pit privy depends very largely upon local conditions. If the owner is willing to do the work, the cost may be very small. At Brookside, Alabama, 147 pits were installed in May, 1922, at an average cost of less
Fig. 12—Steps in installing pit toilet with concrete floor and iron riser. 1, hole is dug and curb constructed; 2, floor and riser in place; 3, earth banked up ready for construction of privy house.
than $2 each. In this case, most of the property owners did their own work, or all but digging the pit. At Brighton, Alabama, in the spring of 1923, over 500 pits were installed by contract at a cost of $15 each, these being of the concrete floor and iron riser type. At Rosedale, Alabama, 357 pits were installed in 1923, wooden installations costing about $8, and the concrete and iron type from $12.50 to $15.60. This work was done by contract. Thus, the pit privy may cost from $2 to $15, depending upon the type installed, and the amount of work that the owner wishes to do. This cost does not cover the construction of a privy house.

In health work, annual cost is frequently more important than first cost. The average pit privy will last from three to five years, experience shows, before it requires attention. With cleanings from time to time as required, the concrete and iron pit should last indefinitely; it is
rare to find a wooden privy of any sort that remains very sanitary for more than two or three years, unless exceedingly well constructed and maintained, after which period reconstruction is necessary.

When the pit fills to within eighteen inches of the ground surface, attention is needed. The pit may be cleaned out, or the privy moved to a new location, a new pit dug (Fig. 14), and the old one filled. The latter method is usually cheaper and easier than cleaning the old pit. If cleaning is to be done, some of the disagreeableness of the task may be eliminated if a strong deodor-
ant, or disinfectant chemical, is added to the pit contents a day or so before the work is to be done. Pine tar deodorant, or caustic soda are usually most satisfactory. If a new pit is to be dug, and the old one filled, the contents should be well covered with chloride of lime before filling.

Several styles of construction have been devised with a view to easy moving of the seat and privy house when the pit becomes filled. Houses, built of light material, may be provided with handles; in some sections the house and seat raiser are mounted on skids or runners, and handled with a team of horses. Moving the iron riser and concrete floor type is difficult because of its great weight.

Pits scarcely can be used under all conditions of soil and ground water conditions, though there is no doubt but that the average person, and to some extent the trained man, have grossly exaggerated the possibilities
of ground-water pollution. Studies recently made on the spread of pollution from privies have shown that while there is need for care, there is a wide field of usefulness for the pit. This subject of the dissemination of contamination from a pit or similar source of pollution, and the distance of travel of pathogenic bacteria with ground water and through soil is fully discussed in Chapter XVI. Where the ground water is ten feet below the bottom of the pit, or where the water supply is from a city system, or from deep wells, there can be little question as to the safety of the pit.

The main advantage of the pit is its initial cheapness. It costs less, also, for upkeep. Properly constructed, it provides a high degree of sanitation. From the adminis-
trative point of view, it is valuable, for it requires little after attention. It can be installed with home material, and, if necessary, with home labor. Its installation requires less oversight and trouble than any other type.

Proper construction, however, is important and must always be insisted on.

Even though primitive in type, and subject to many disadvantages, the installation of a pit privy in every home would mark a tremendous advance in sanitation, and probably, if these pits were kept in a proper condi-
tion, the virtual elimination of typhoid fever, hookworm, and the other filth-borne diseases.

Among the disadvantages of pits is the danger of water pollution, already mentioned, the lack of general applicability and the chance of their acting as fly and mosquito breeders after losing their flytight qualities. In the summer there is a possibility of odors, especially where water stands in the pit. Over an undetermined period, the soil is left loaded with a charge of pollution that cannot be removed.

Operation is simple, for little attention is demanded.
SEWAGE DISPOSAL FOR UNSEWERED SECTIONS

The seat lids should be kept down, and flytight. By means of proper construction, and with the aid of protecting ditches if necessary, surface water should be prevented from entering the pit. Screens must be kept in good condition. Prompt attention must be given the cleaning problem when the pit becomes filled to within eighteen inches of the top. If mosquitoes breed in the pit, a cup of oil poured over the pit contents every week will give relief. Certain types of mosquitoes are able to pass through the average commercial screen, so that mosquitoes may be present even though the pit is flyproof. If odors are troublesome, the application of chloride of lime may help.

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Special Bulletin No. 178, August, 1919, North Carolina State Board of Health, Raleigh, N. C.
CHAPTER VI
THE DOUBLE COMPARTMENT CONCRETE VAULT

The double compartment concrete vault privy consists of a concrete box built in the ground, a central wall dividing it into two compartments, the rear wall sloped to allow for easier cleaning, a seat riser and seats on top, and the whole covered with a privy house. Each compartment has a capacity of 75 to 100 gallons, or theoretically sufficient to provide storage for the wastes of the average family for three to six months. Scavenging is through the rear, where a removable cover is provided.

Only one compartment is used at a time, the other being closed completely. As soon as the vault or compartment in use is filled, the seat cover is fastened down, and the other compartment used. The contents of the first compartment are allowed to stand quiet during the period required to fill the second. The first compartment is then scavenged and put into use, and the other side allowed to cure or dry in turn. It was thought that this treatment would result in a dry, inodorous substance, free from pathogenic bacteria. In practice, however, the tendency has been to liquefy, rather than to dry out. This makes the scavenging very difficult, and probably does not eliminate all danger from disease germs in the excreta. It should be noted, also, that even if the tendency should be to dry out, hookworm eggs would not be killed, and the promiscuous scattering of the dry excreta would tend to spread this disease.

The concrete vault was developed just before the entrance of the United States into the World War, and
in the hurry attending the sanitary work in and around the cantonments, was installed in large numbers during 1917 and 1918. Although built without proper knowledge of its capabilities, which since have been found to be very limited, the concrete vault did prevent soil pollution and the spread of the filth-borne diseases in those places where it was installed.
In other words, the concrete vault is very efficient over a short space of time, as a year. The trouble comes when the work of scavenging becomes necessary. Most of the places where these vaults were installed as a war measure are now having difficulty in solving the problem of scavenging and maintenance.

The most important part of a privy of this type is the vault itself. Care should be taken to have this tight, as a leaky vault, by allowing the entrance of water during wet periods and the filtering out of contamination during dry seasons, tends to defeat the purpose of the installation.

The average interior dimensions of the concrete vault are: Length over all, thirty-six inches; depth, twenty-four to forty inches; width from front to back on top,
about forty inches. The rear wall is given a slope of about sixty degrees to aid in cleaning. The walls and bottom are four inches thick. The floor and superstructure may be of concrete or of wood. The former is more durable; the latter is cheaper.

If the vault is to be built in firm ground, where the earth will stand vertically, the excavation should be made of the same dimensions as the exterior of the vault, so that the earth will then act as the outside form of the concrete. Where the earth is sandy or loose, and will not stand vertically without support, both exterior and interior forms must be used and the excavation made larger so that the forms may be placed and removed easily.

Interior forms for constructing the concrete vault are rather complicated. The forms should be built fairly tight so that there will be no leakage, but so constructed that they can be removed easily. After the concrete has been poured, the forms should be left in place at least forty-eight hours in warm weather, and seventy-two hours in cold weather. The mixing, pouring, and placing of concrete is described in Chapter XV.

There will be some difference in the upper part of the form, according to the style of seat riser determined upon. The vault may be built to a point about six inches above the ground, and a wooden seat riser built on this; a concrete top may be poured, and individual concrete seat risers built on this; the walls of the vault may be carried up twelve or fifteen inches above the floor, forming a riser and the seats placed directly on this. This latter method, though not the cheapest, probably combines economy and good construction to the greatest extent, while retaining simple forms. The use of individual seat risers neces-
situates the construction of special forms, circular or elliptical in shape, which are rather difficult to place and use. A wooden superstructure is cheaper, but rarely as durable or as fly-proof as a concrete one.

Forms should be made of planed timber, and should be well oiled or soaped before being used to prevent the concrete from sticking to them. If more than one vault is to be built, the forms, when handled carefully, may be used over and over again. Especial care must be taken with the inside forms or they will extract moisture from the concrete, swell, and crack the vault. Concrete, while setting, has little strength, and cannot resist such pressure. It is necessary to place expansion joints in the forms, or to soak them thoroughly before the concrete is placed, which will cause them to expand at once.

For the ordinary concrete vault, seven sacks of Portland cement, half a cubic yard of sand and three-quarters of a cubic yard of broken stone or gravel will be needed. The lumber and material required for the privy building will be the same as that for building any other privy house.

Scavenging the concrete vault has been the most difficult problem to solve. If the vault had worked as it originally was intended to work, and the contents had become dry and inodorous, it would have been easy to dispose of the contents, as, for instance, by adding kerosene after removal and burning. In the great majority of cases, however, the vault contents are liquid or semi-liquid. This necessitates totally different methods of cleaning.

In most of the places where concrete vaults were installed, the problem of scavenging was left unsolved. As a consequence, the scavenger, who originally cleaned the surface closets of the community once or twice a year
generally fell heir to the work, and applied his old methods to the new installations. The usual plan has been to bail or shovel the vault contents into cans, barrels, or boxes. These containers are usually neither tight nor covered, with the result that pollution is splashed and dripped throughout the entire length of haul. It is not too much to say that all the sanitary qualities of the vault are nullified by such methods of cleaning.

The problem has also been intensified because of the lack of foresight and common sense in locating the vaults. These have often been put in inaccessible places, as in back gardens, enclosed by high fences. It is not hard to picture the results of the efforts of the scavenger, after bailing out the vault, to pass the buckets over a high fence.

It is a not uncommon happening in a sanitary campaign that the old dumps and disposal places are eliminated, without substituting new ones; or the new ones are unhandy. In such cases, most householders bury the vault contents alongside the vault, thus losing the benefits of this particular type of construction.

In most cities the regular charge for cleaning such a vault is $5 to $8. In a few cities the charge is $2 per compartment. Other methods of cleaning than the scavenger have been tried out. Pumping has been fairly successful where the vaults are accessible, which is not generally the case. Either hand or power pumps may be used. A usual trouble is that the vault contents are too thick to handle readily; again, the sticks, old clothes, old shoes, slippers and other rubbish commonly found in the vaults, tend to injure or clog the pumps. Where pumping can be used it is somewhat cheaper than hand cleaning.

A machine built by the Springfield Engineering Company for cleaning catch-basins was tried out on the vaults at Fayetteville, North Carolina. It was very successful
in handling the vault material, and demonstrated its ability to clean vaults at from sixty to seventy-five cents per compartment, but the high first cost of the apparatus, and its great weight, preventing it from negotiating many of the alleys and unpaved streets, militated against its general use.

One of the disagreeable features of this type of privy is its almost universal tendency to odors. This tendency, which seems almost inseparable from any process of storing the excreta without treatment, is a very serious one, especially in the summer. It has been found almost impossible to keep the vault fly- and mosquito-proof, as the rear cover warps in the sun and rain. Even where good construction is secured, it is usually nullified by the carelessness of the user in leaving the seat lids up, thus allowing the entrance of flies.

About a year and a half after several hundred concrete vaults had been installed in the area around Petersburg, Virginia, an inspection was made to determine how well this type of privy was performing in actual service. One hundred privies were examined, fifty in rural sections, and fifty in a small unincorporated town. The results of the examination of the fifty installed at rural homes were:

<table>
<thead>
<tr>
<th>Care of toilets:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Covers on seats kept flytight</td>
<td>24</td>
</tr>
<tr>
<td>b. Covers on seats not kept flytight</td>
<td>26</td>
</tr>
<tr>
<td>c. Rear door closed flytight</td>
<td>31</td>
</tr>
<tr>
<td>d. Rear door not closed flytight</td>
<td>19</td>
</tr>
<tr>
<td>e. Cleaned recently</td>
<td>14</td>
</tr>
<tr>
<td>f. Needing attention or overflowing</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nature of vault contents:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Semi-solid</td>
<td>12</td>
</tr>
<tr>
<td>b. Liquid</td>
<td>38</td>
</tr>
<tr>
<td>c. Fly larvae present in contents</td>
<td>25</td>
</tr>
<tr>
<td>d. Fly larvae not present in contents</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of time toilet had been used:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Under one year</td>
<td>1</td>
</tr>
<tr>
<td>b. One year to one and a half years</td>
<td>49</td>
</tr>
</tbody>
</table>
SEWAGE DISPOSAL FOR UNSEWERED SECTIONS

Only 28 per cent. of the vaults were being cleaned as often as appeared necessary. In half of the vaults, fly larvae were present, though whether or not these would hatch out under such conditions is not known. Only two of the fifty privies examined were perfectly satisfactory. In several places it appeared that kitchen wastes and garbage were being emptied into the vaults.

Conditions were about the same in the fifty privies examined in a small town not far from Petersburg. The tabulated results were:

Care of toilets:
- Covers on seats kept flytight: 33
- Covers on seats not kept flytight: 17
- Rear door closed flytight: 26
- Rear door not closed flytight: 24
- Cleaned recently: 40
- Needing attention or overflowing: 10

Nature of vault contents:
- Semi-solid: 29
- Liquid: 21
- Fly larvae present in contents: 29
- Fly larvae not present in contents: 21

Length of time toilet had been used:
- Under one year: 9
- One year to one and a half years: 41

During the period between the installation and examination of these vaults, a sanitary officer had been in charge of the district, inspectors were available for seeing that proper care was taken of the toilets, and a campaign of education had been carried on. Despite these facts, the loss in sanitary qualities was at least 50 per cent. The vaults in this section were up to, if not above, the average in excellence.

In some sections a modified form of the concrete vault, often called a "tight pit" is used. This consists of a hole, usually rectangular in shape, and about three feet wide, three feet deep, and five or six feet long, lined with concrete. Such construction costs less than the double
compartment vault, owing to the simpler design. It has practically all the advantages and disadvantages of the regular form of vault.

While filling, theoretically, in a high degree three of the four main requirements of sanitation, the concrete vault has few advantages outside of great durability and low cost of maintenance. Well built, it is fly- and animal-proof, and prevents ground water contamination. If it never had to be cleaned, it would also prevent soil pollution, but usually so much filth is scattered about at the time of cleaning, that most of the other sanitary qualities are nullified. Carefully constructed and cared for, the concrete vault has a high sanitary value, but it seldom gets the necessary care.

High cost, difficulty in maintaining proper cleaning service, and rapid deterioration of flytightness are important disadvantages. When not carefully constructed, the vaults frequently leak. Odors are a serious handicap in using this type of privy. In large numbers, the cost will average above $30 each; in individual installations, the cost will be $40. These costs do not include the privy house.

Odors cannot be prevented entirely, but may be reduced somewhat by the liberal use of dust, ashes, lime, or other absorbent material added immediately after using the privy. Keeping the privy flytight will reduce fly and mosquito breeding. Oiling may be necessary for the latter.

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Special Bulletin No. 178, August, 1919, North Carolina State Board of Health, Raleigh, N. C.
CHAPTER VII

THE BOX AND CAN PRIVY

The box and can type of privy is so-called because it is essentially a flyproof box, within which is contained a waterproof receptacle or can for the catchment of the excreta. The system combines simplicity and a fair compliance with sanitary laws; cheapness and ease and rapidity of installation. It is especially fitted for rapid and thorough sanitation of the unsewered areas of cities and large towns.

The cleaning or scavenging of the filled cans is accomplished by means of a scavenger with a collection wagon, making regular rounds, usually at weekly intervals. The wagon starts out with a load of empty, clean cans. As each privy is reached, the filled can is removed, covered with a tight lid, and loaded onto the wagon. A clean, empty can is put in its place. When a load has been collected, the filled cans are hauled to the dump or other disposal place, emptied, cleaned, and disinfected. A variation in the method of scavenging is the use of a tank or tank wagon into which the can contents are dumped.

The disposal of the can contents is, where there are sewers, usually accomplished by dumping through a riser or manhole into the sewer. At other places some of the means described in Chapter X are used. After the cans have been emptied and washed, a small amount of disinfectant is often placed in them.

The box and can is not new, for it has been used for many years in Europe, but in the past few years its general features have been considerably modified in this country, and the system adapted to wider uses. The
modern box and can may be said to date from the installation at Jasper, Alabama, in 1915, when the idea of quantity production of boxes at some convenient point, and their later installation in old privy houses, was originated by Dr. L. L. Lumsden. During the past few years there have been no radical changes from this standard type insofar as fundamental principles are concerned, though variations have been tried from time to time in the matter of openings for the removal of cans, hinges for seat covers, flues, and other details.

The present standard seems to be a square or nearly square box, with one seat hole, a flue of wood or metal, with the can to be removed through the top of the box by lifting the lid. The can usually employed is of galvanized iron, 26-gauge or heavier, with proper reinforcing, and of about nine gallons capacity (about fourteen inches deep and fourteen inches in diameter). Wood boxes are most commonly used, but recently concrete and metal boxes have been tried out.

The box and can system is one of the most important methods of excreta disposal, and probably serves as many or more people than any other one type of privy. In the state of Alabama, alone, according to the figures of the State Board of Health, there are 30,000 of this type of privy, serving 150,000 people. It is the most popular type in all cities for use in the unsewered fringe. Its importance is enhanced, from the health point of view, by the fact that it usually serves regions of congested population, where typhoid would normally be epidemic if no means of sanitary excreta disposal were in use.

A proper scavenging system must be provided, but this is not economically possible with less than 200 homes, so that no boxes and cans should be installed in communi-
ties with less than that number of houses. Even with this number, the scavenging charge must be high.

For the box and can system to succeed, from a sanitary point of view, it must be conceived, operated, and maintained as a public business, and it must be conducted along lines of business efficiency. Its management must be the duty of some specific, paid, and responsible city official, who is directly responsible for the work. The scavenging must be regular. All individual installations, to secure best results, must be uniform in construction, operation, and maintenance. A thoroughly good job of installing is nearly a necessity if the system is to be satisfactory.

The general tendency in recent years has been to use only single seat boxes, installing two, if necessary, in one privy. One box will serve five or six people (Fig. 21). Where more must be provided for, extra boxes and cans should be furnished. Single boxes are usually made seventeen inches deep, twenty inches wide and twenty-two inches long. Double boxes, when used, should have the same width and depth, with a length of forty-two inches. These sizes are not absolute, and larger or slightly smaller boxes may be substituted.

The method of removal of the can is most important. There are two principal methods: Through the top and from the rear. Owing to the practical impossibility of finding any way of making the rear door flytight over any considerable period of time, this method is not much used, though it has many advantages. Where the can is removed through the top, the entire cover of the box is usually lifted.

When removing through the rear, the door either slides or is hinged, the hinges being at either top or
THE BOX AND CAN PRIVY

bottom, and the door fastening with a button or other catch. No one has yet developed a hinge that will remain long in operation under the rough usage and exposure to the weather that it has to undergo. Even before the hinge becomes useless, however, the door may warp and crack from the sun and rain, and thus lose its flytight qualities. The sliding door sticks after a short period of operation, and is also subject to the same weathering influences as the hinged door. A striking variation from this general rule is the box and can in use in Birmingham, Alabama. This box has a hinge with a non-rusting pin,
and a well-designed rear door which gives very little trouble, though it usually does not remain flytight for more than six months to a year after installation.

When the method of removal through the top is used, the cover may be hinged or merely rest on the top of the box, overlapping on all sides and held in place by cleats nailed on the under side. The greatest disadvantage of this method is that the scavenger must enter the privy to reach the can, which may be spilled in removal, soiling the privy house. Also, the scavenger must enter the back yard from the alley, and this necessitates an opening in the fence. All this takes more time than removal from the rear of the house, but nevertheless it has generally proven more satisfactory.

The seat cover is important, for the seat hole is one of the most important means of entrance for flies. Some maintain that a self-falling lid is necessary. Others hold that the user will tie back the lid if it interferes, and that the best way is to educate the user to keep the lids down. There is no doubt but that education is the best way, but it is slow and difficult, and it is likely that the appearance of a self-falling lid will suggest the fact that it is meant to be kept down. The lid should extend over the hole in all directions for about two inches and should be hinged. A block should be nailed on the wall behind the cover, so that the cover will be just off balance, and will fall forward if not supported.

Boxes may be of wood, metal, concrete, or other materials. They may be built locally or purchased ready-made, but in any case, strict attention must be paid to the quality of the material. It is of little use to install boxes that lose all flyproof qualities through warping or crack-
ing within six months. Specifications in regard to the
construction of boxes will be found in the Appendix.

The wooden box lends itself easier to home manufac-
ture, as it may be built locally by almost any good car-
penter or wood worker, or constructed by day labor. The

Fig. 22.—Rear opening box in use in Birmingham, Ala. Pail is reached by
raising hinged cover, and can be removed from the rear.

first essential is good lumber. Tongue-and-groove mate-
rrial is best, already seasoned and free from knots, one
inch thick, with one or both sides planed or finished.
Pieces of 1 x 2 or 2 x 2 may be used in the corners to
stiffen the box and to nail to. The box may be made first,
and the seat hole, seat cover, and box cover
added afterward.

The advantages of the wooden box are home manu-
facture, with consequent ability to duplicate later, opportunity of thorough inspection, and, in some cases, economy. It must be remembered, however, that the work of constructing a large number of boxes is no light job, and should be undertaken only if it is impossible to secure good boxes otherwise at a reasonable cost.

The average cost for wooden box installations made by nine large cities in 1918 and 1919 was $8.75 each, ranging from $5 to $20. Twenty-eight cities in Alabama, according to figures from the State Board of Health, had costs varying from $3.50 to $15 for boxes alone, with an average of $7.14, the installations being made during the years 1915 to 1920. The better installations will usually average a little above these figures, generally from $10 to $12 each. Cans in the nine cities mentioned above averaged $1.85 each, which made the complete average installation cost $10.60, not including disposal facilities.

Concrete makes good material for boxes, but costs more than wood. Either round or square boxes may be used, though the round box is easier to cast. Either wood or concrete may be used for the top, but wood is generally preferable. The concrete box used at Talladega, Alabama, is twenty-two inches square and sixteen inches deep. It is made of cement mortar, mixed one part Portland cement to one part of sand, and is in the single-seat style only. In making this box, the slabs were cast separately and put together afterward. One of the several companies turning out commercial privies has made an elliptical concrete box, with copper screens cast in place. The cover is of concrete, with a watercloset seat. This has been sold for $13 complete with vent.

Sheet-iron boxes should be more popular than they are, and in greater use. Various styles of these boxes
are on the market at prices considerably lower than wooden boxes can be made for, while they excel other types of boxes in lightness, durability, and sanitation. Probably the general dislike of the health officer for a
commercial article has been a powerful factor. A cast-iron box has been used in one or two places, but as a rule, the galvanized or enameled metal box, with its lighter weight and lesser first cost, is more popular. A sheet-metal box, complete with can and vent pipes, can be purchased for as little as $8.

Various attempts have been made to make boxes of resistant, non-warping, and non-absorbent materials, such as porcelain, vitrefied tile, or similar materials, but these attempts have not met with much success.

A box may be ventilated by means of holes bored in front near the bottom, and by a vent pipe or flue extending from the top rear of the box to a point above the roof. A flueless box has been used very satisfactorily in Birmingham, Alabama. This does away with all vent troubles and makes maintenance much easier. The absence of the vent has no apparent effect upon the odors given off by the privy contents.

When a flue is used, a metal flue is better than a wooden one, for it will not warp or leak, and is more durable. Likewise, copper or monel metal screening should be used throughout on the box and flue, for galvanized iron screening is rapidly attacked and destroyed by the acids given off from the can.

The can usually used in this work is from fourteen to fifteen inches in depth and the same in diameter, giving a capacity of ten to fourteen gallons. It is built with straight sides, preferably, and must be of strong and durable construction. The top should be bound with a heavy wire, and the bottom protected by having the sides carried down beyond it for about half an inch. The metal ought not to be lighter than 22-gauge, though 24-gauge, and even 26-gauge are used. With the light metal
the life is much shorter. Rust-resisting iron, such as Toncan or Armco, increases the resistance to corrosion and lengthens the life.

Cans may be secured from hardware dealers, from manufacturers of sheet-metal products, or may be constructed locally by tinsmiths. This latter method is more costly, but very good cans are usually secured. In purchasing in the open market, cans will average about $1.50 each. Cheaper cans may be secured, but it is not economical to buy them.

Data collected in 1920 from several cities indicate that the life of a can is but little in excess of a year. It has been noted that the cause of trouble is the same in almost every case. Wear and handling cause little trouble, but the cans corrode through. Usually the first sign of trouble, as well as the final break in the can, comes on the side walls at a point about five or six inches from the bottom. This corresponds roughly with the top of the can contents for the average can, as it is usually filled. It probably also corresponds to the line of the greatest amount of splash while the can is being used.

With the exception of a few cities in Alabama, no place is known where any protection is used to lengthen the life of the can, though this is feasible, since rough usage alone rarely puts a can out of use. The Alabama cities include Florence, Birmingham, Huntsville, Tuscaloosa, and some smaller towns. The usual protection in these places is a mixture of asphaltum and varnish, into which the cans are dipped. A better plan, though more costly, would be to coat the cans only on the inside, for the outside coating makes them harder to handle. There is now on the market, such a pail, coated only on the inside, and guaranteed against both flaking and chipping.
The coating is a thin bituminous enamel and the cost is little greater than for the uncoated pail.

One can is needed for every single privy or group of five persons or less, and in addition enough to operate the scavenger service. This will require from 5 per cent. to 12 per cent. more, depending upon the type of wagon and method of scavenging. The usual practice in regard to furnishing cans is for the people to install the necessary cans in the privies, and for the municipality to replace them as they wear out. This is necessary because of the continual interchange of cans under most systems of scavenging. Covers are needed while handling the filled cans. These must be close-fitting to prevent "sloshing" of the can contents. There are several types of covers, none of which gives universal satisfaction. A few cities have used a wooden cover, which was intended to be wedged down into the pail, but such absorbent material quickly became very disagreeable to handle. Metal covers are of two types, those that fit inside the pail, and those that come down over the outside. The latter are usually cheaper, but there is little to choose otherwise between the two types.

Only as many covers will be needed as there are extra cans, that is, from 5 per cent. to 12 per cent. of the number of cans installed, as covers are not supplied for cans in privies. These will last for a long time, and rarely need replacement. The average cost is about 50 cents.

In the matter of administration and installation, the box and can privy differs widely from other types. Such other types are usually installed at scattered homes, where the use or maintenance of one privy has little effect upon another. Conversely, the box and can is installed in large numbers, where success depends entirely
upon uniform operation and scavenging. To secure a fair degree of sanitation the enforcement of certain rules, and the carrying out of certain policies are necessary.

The first step is the education of the community, if this is necessary in order to secure the installation. Such a campaign will follow the usual lines in regard to health matters, and should point out the dangers to health from improper excreta disposal. Following this, the necessary ordinances must be enacted. These should specify the approved type of privy, set scavenging fees, and provide a method of collecting them, provide personnel for the system, and require the imposition of a fine for non-compliance with the ordinance.

In the work of installing the system, a map of the city on as large a scale as possible, preferably 400 feet to the inch, will be found helpful, in fact, almost indispensable. On such a map, can be spotted by pins or other means every privy to be installed, shown in its exact location. The map should also show all streets, alleys, streams, sewers, and water mains.

This map will indicate at a glance those homes that ought to be connected with the sewer, will give the best possible idea of the work to be done, and will allow a graphical method of keeping up with the work of installing privies. For instance, every house to be sanitized may be shown by a circle, or by a colored pin. When the privy is installed, the color of the pin may be changed, or the circle filled in. The map is valuable for showing the progress of the work to city officials, reporters, and citizens, and is extremely handy for reference purposes.

The boxes and cans should be available in sufficient quantity before work begins. The workmen may then begin the installation of the boxes in the old buildings,
the surroundings of which must first be thoroughly cleaned and disinfected. Such work should be done by a force of city workmen, and not entrusted to the property owner. If possible, work should be started at one end of the town and carried through to the other, so that when scavenging starts, regular routes may be followed from the beginning.

The work is best financed by the city, the citizens paying for the toilets after they have been installed. The charge may then be based on a proportionate amount of the entire cost of the system, including overhead that may be necessary. In some places, the city can handle the entire matter, while in other localities, other means may be better. The city often can obtain the necessary credit from a local bank, or it has been suggested that boxes and cans be purchased from commercial firms on ninety-day basis of credit, the city collecting from the citizens within this time.

Maintenance after installation is most important, and some provision should be made for this. A tax of $1 a year may be levied, in addition to the scavenging fee, upon every box and can, in return for which the city will keep it in repair; or the scavenger fee may be set high enough to take care of this. The ideal way is to have a man devote his whole time to the work. In smaller cities, the same man may be a repairman or carpenter, superintendent and inspector.

Scavenging is probably the most important point in the operation of a box and can system. Collections must be made regularly, preferably at intervals of not more than one week. The scavenging must be carried on carefully. Rigid inspection and follow-up are necessary. The town or community too poor to afford a competent
inspector and a proper scavenging system is entirely too poor to lose the money that is certain to be wasted on a box and can system without these requisites.

Prompt scavenging is necessary, especially in the summer when odors develop rapidly, and when fly-breeding is most intense. Flies will scarcely develop from egg to imago in less than ten days, so that weekly scavenging of cans, with proper disposal of the can contents, is a considerable aid in the reduction of fly-breeding. It will be found that flies will gain access to a majority of the cans, especially after the system has been in use for a year or more. Weekly scavenging and proper disposal then become important. Burial of the can contents will not kill the flies, for they have been known to emerge when buried as much as six feet underground. Dumping into a sewer or tank will usually kill the larvae by drowning.

There are two ways of handling the scavenging prob-
lem, by contract or by city forces. In the rare cases where a first-class contractor can be found to take the work, this method is best; otherwise the collection by city forces will give better results. In contracting the work, the city does not have to furnish the initial equipment for collection of the cans, but ultimately, of course, the proceeds of the work will have to pay for these. The city, no matter what the method of scavenging, should assume the collection of the scavenging fees. Placing this burden upon the contractor is entirely unsatisfactory.

The amount and type of equipment needed for scavenging depends upon the topography of the country, the nature of the districts to be served, the average hauling distance, and the number of cans to be scavenged, as well as on other and various local conditions. Single and double wagons (Fig. 25), double-deck wagons, and
motor trucks are used in various places. The double team or truck with an average haul is capable of handling about 1000 cans a week, when three men are employed on the wagon. Single wagons with one or two men will handle 400 to 600 cans weekly, if the haul is not too long.

It is necessary to know the type of box and can to be used and the method to be employed in operating the system in order that the cost of equipment and the probable expenses of operating may be estimated, and the best adapted system of scavenging selected.

No matter what the type of box adopted, the cans should be uniform in size and construction in every case. In the can replacement system of scavenging, uniformity is positively essential in order that any can may fit into any box, and in order that the same set of lids may be used. In the tank system, where cans are partially washed and filled, cans replaced with clean, empty cans carried to the privy, the same necessities for uniformity exist. In any system, it is of advantage to avoid the use of odd-sized or peculiarly-shaped cans. Covering of the cans between the privy and the conveyance is most desirable, and again the uniformity of cans is essential.

In the can replacement system, where the wagon sets out with a full load of empty cans and exchanges these for filled cans, a spring wagon is usually used to minimize the jostling and spillage of cans. This type of wagon may be fitted with a single bed, approximately four feet wide and fifteen feet long, or with a double deck. The single wagon will hold thirty to thirty-five cans, and the larger wagon twice as many.

In operation, an empty can is taken from the wagon to the privy and exchanged for a full one, the lid being transferred to the full can, and the empty can being placed
in the privy box. With a double-deck wagon there is usually a driver and two men. Where a single wagon is used, one man is most often employed, but occasionally two.

When the wagon is loaded with filled cans, it is covered with a tarpaulin and driven to the dumping station, where the covering is removed, the cans and wagon washed with a hose, and the cans unloaded and dumped. After being dumped, the cans are washed and placed on a drying platform, or may be returned to the wagon. The lids are washed by piling on the floor and spraying thoroughly with a hose. In some places a quart or more of disinfectant is placed in each can after it has been washed.

A later development in scavenging this type of privy is the use of a steel tank for hauling can contents. This may be horse-drawn or motor-driven. One to three men are employed in operating it. The filled can is removed from the privy to the conveyance, and the contents dumped through an opening in the top of the tank, usually a manhole with a tight-fitting, but removable lid. In some places, the can is returned to the privy box without washing, while in others, an auxiliary water tank is carried in which the can is partially washed before being replaced. The water used for washing is emptied into the main tank, and the can charged, if desired, with a small quantity of disinfectant. In case the sewage is treated in a septic or Imhoff tank, the effect of the use of disinfectant on the action in the tank should be noted.

A variation of the above described tank method of scavenging is to carry a few reserve clean cans when starting out. The filled can, when removed from the privy is at once replaced with a reserve can, thus saving one full round trip to the privy. When the filled can has
been emptied, washed, and placed in the reserve, it is available for return to another privy.

When filled, the tank may be taken to a dumping station or sewer manhole, provided the sewer is of sufficient size, and emptied by means of a valve in the bottom. Many cans, usually most of them, contain bottles, rags, sticks, or tin cans, which should not be permitted to enter the sewer. A bar strainer or screen will usually exclude these, which requires that emptying shall be done only at specially-equipped manholes. The tanks must have a funnel for directing the flow, and the valve in the bottom ought not to be less than six inches in size.

The size of the tank to be used is determined by the weight, as this is limited by the roads and alleys that are to be traversed. A convenient size, and one that can be handled by two mules or placed on a Ford truck, is a tank of 150 to 160 gallons capacity, and an auxiliary water
tank of about one-third this capacity. The can contents will vary somewhat with the season, but will average around four gallons each, so that an outfit of this size will serve thirty-five to forty cans. The contents will weigh, when the tank is full, about 1300 pounds, to which must be added the weight of the tank and the vehicle (Fig. 26).

All the above methods are in use in Alabama, where the box and can system seems to have reached its greatest development. A recent bulletin of the Board of Health of that state describes the installations in twenty-eight

<table>
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<tr>
<th>City</th>
<th>Population</th>
<th>No. Boxes</th>
<th>Unit Cost of Installation</th>
<th>Scavenging Equipment</th>
<th>Cans Washed</th>
<th>Annual Fee</th>
<th>Who Collects</th>
<th>Per cent. of Collection</th>
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<td>722</td>
<td>9.50</td>
<td>1 Tank</td>
<td>Part</td>
<td>6.00</td>
<td>Cy. Clk.</td>
<td>98 1/2</td>
</tr>
<tr>
<td>Townley</td>
<td>800</td>
<td>333</td>
<td>8.25</td>
<td>1 Tank</td>
<td>No</td>
<td>4.00</td>
<td>Police</td>
<td>99</td>
</tr>
<tr>
<td>Tuscaloosa</td>
<td>11,996</td>
<td>1,800</td>
<td>3.50</td>
<td>1 Wagon</td>
<td>Yes</td>
<td>5.00</td>
<td>&quot;</td>
<td>80</td>
</tr>
<tr>
<td>Tuscumbia</td>
<td>3,857</td>
<td>305</td>
<td>7.75</td>
<td>1 Wagon</td>
<td>Yes</td>
<td>12.00</td>
<td>Cy. Clk.</td>
<td>90</td>
</tr>
<tr>
<td>York</td>
<td>1,630</td>
<td>55</td>
<td>4.00</td>
<td>1 Tank</td>
<td>Yes</td>
<td>6.00</td>
<td>Mrshl</td>
<td>100</td>
</tr>
<tr>
<td>Total and average</td>
<td>369,458</td>
<td>29,418</td>
<td>7.14</td>
<td>5.80</td>
<td>78.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
cities which are using the box and can system. Full information of these installations is presented in the foregoing table, which is extracted from the above-mentioned bulletin.

In the case of contract scavenging, payment should be for the work done. With properly laid out routes, and with the aid of an inspector, the number of cans collected daily by the contractor should be known. Payment should be made only for the number of cans actually collected. This provision protects both city and contractor. It is human nature with most people that the work will not be done well unless there is profit in it. On the other hand, under the usual methods of payment, whereby a scavenger is paid so much per can per year, the fewer collections made, the greater the profit. That is, if payment is made for collecting weekly, but if the scavenger collects only twice a month, he is being paid double. This problem is solved by having the city collect the scavenging fees and pay the scavenger a certain amount for every can collected. It is a very serious error to impose on the scavenger the duty of fee collection.

It will be noted that, according to the above table, only 78.2 per cent. of the fees due are actually collected. This factor must be borne in mind in planning the finances of any system.

The scavenging system is the crucial point in the entire sanitary organization. If this part of the system operates properly, it will cover up many defects in other parts, but a careless and inefficient scavenger will wreck the best installed system. With this in mind, every effort should be made to install the scavenging system so that it will operate with a minimum of difficulty.
The preliminary work should include the selection of the areas for the disposal of the excreta, the laying out of the scavenging routes and the furnishing of the necessary equipment for scavenging. One week after the first toilets have been installed, scavenging will be necessary.

It is necessary for efficient operation that each wagon have a definite route to follow each day. Just as soon as a driver is allowed to cruise about at will, there is trouble. Routes should be laid out and adhered to rigidly.

The map already mentioned will be found a great aid in selecting the disposal areas, as well as in laying out the scavenging routes. The disposal areas should be as handy as possible to the largest number of cans, but far enough away from any homes so that there will be no nuisance. In the case that sewers are used for dumping, the disposal places can be located very accurately on the map, but should be checked up in the field afterward to make sure that they can be reached by teams; that the grade, size, and volume of flow of the sewer is ample; that water is available, and that houses are not near.

Tentative routes for the wagons may be laid out on the map, and then gone over on the ground. In laying out the routes, several points must be borne in mind. Where cans are scattered, or where the hauls are uphill, an empty wagon should be used, completing the load from more favorable areas. The ending of the route should find the wagon near a good road, as near as possible to the disposal station, and in such a location that the haul to the disposal station is as easy as topographical features permit. The route should be of such length that in traversing it a full load is secured. Bad streets or alleys should be avoided with a heavily-loaded wagon or truck.
As soon as a route has been tentatively planned, and its relation to other routes assured, it should be followed out in the field to see that there are no impassable obstacles, as unbridged streams or unopened streets, not shown on the map. Often, on account of such obstacles the tentative plans must be abandoned and new ones made. This is easily done on the map, and the same checking process is followed until the routes have been so located that they cover the ground with the least possible expenditure of time and energy.

An inspector is necessary to any system, though it may not always appear possible to have one, especially in the smaller systems. Where a thousand or more privies are in use, he will pay for himself several times over in the course of the year. His duties include checking the wagons, receiving and investigating complaints, inspections of the sanitary conditions of the toilets, and, in the smaller towns, the work of superintendence.

There is usually some difficulty, owing to the disagreeable nature of the work, in getting good men for the scavenging work, and more in keeping them, once they are secured. The bonus system of payment aids materially in this. Enough work is allotted to each team to take them, ordinarily, five and a half or six days to complete, and the men are paid a full week's wage when this is done. Such an allotment or task is easy, with the routes laid out and rigidly followed. Most men will do the work in four-and-a-half days. As a rule, there is little trouble in slighting the work.

The Alabama State Board of Health, in its excellent bulletin on the box and can system in Alabama, summarizes the experience in that state in regard to can and tank wagons as follows:
The exchange of full and empty cans was the first system adopted in Alabama, and the first wagons used were of the platform type. With rolled edge lids, tightly lidded cans, fairly good roads, and level terrain, the can replacement system has been found to operate with a fair degree of satisfaction. The running gear of a spring wagon already in use can be converted into a can wagon at comparatively little expense. When the full time of a horse- or mule-drawn can wagon is not required in scavenging, the animals may be used otherwise, when the can wagon is not in use. The cleaning of the soiled cans, made possible by the exchange of cans, distinctly in favor of the system. On the other hand, the adoption of this system necessitates the building of a washing station which may cost $200 or upwards, depending upon the proximity of a water supply under pressure. When only one wagon is required in the operation of the system, some time will be taken up in can washing; when two or more wagons are employed, a special man may be hired to empty and wash the cans, permitting the wagons to unload full cans and proceed immediately. The routes of the wagons may be then so arranged that they will reach the washing stations at scheduled intervals. Such a system requires a full extra set of cans for each wagon, and the hire of one man is added to the operation costs.

The platform type of can wagon is not adapted to use in hilly country or over rough roads, and this militates against the can replacement system under these conditions of topography. It is never feasible to motorize the platform type of wagon because of the excessive bouncing due to greater speed, thereby causing spillage of the can contents. After a certain period of use, the lids do not fit tightly on all cans, and sloshing occurs when the wagon jolts. On steep hillsides, the contents of well-filled cans spill. A wooden wagon absorbs the material thus spilt, soon acquiring a permanent odor. The latter condition may be met by placing on the platform of the wagon a metal lining. With proper maintenance and the use of
a tarpaulin in transit, objectionable odors may be reduced to a minimum.

"A double-team wagon complete costs about $750. The cost of feeding stock is estimated roughly at $1 per head per day. The cost of labor is determined by local conditions. A single wagon with one man should remove 400 cans or more per week, and a double-deck wagon with three men a minimum of 1000 cans a week.

"The use of a closed metallic tank eliminates much of the objection to the transportation of fecal material through streets and alleys, though there is sometimes cause for complaints while the cans are being loaded. If the haul is long, a motor vehicle is less expensive in operation than one drawn by animals. Unwashed cans used in connection with the tank are not so satisfactory as washed cans in the exchange system, though semi-washed cans have given general satisfaction. The length of haul may usually be shortened with a tank, especially where there are sewers, for any manhole not too public may be used, as previously stated, for dumping. Where sewers do not exist, a dumping vat is necessary, but the cost of such vat is usually small, as no shed, screen, platform or water need be provided. This is also true where the material is dumped into a stream of ample flow. There is little odor noticeable in emptying the tank, nor is it unsightly. The cost of the tank and motor truck is about the same as that of the two-deck mule wagon fully equipped, or about $750. On the whole, the tank is more economical in operation, less objectionable, and reduces or eliminates the cost of washing or dumping stations required by the can replacement system."

No matter whether the collection is by contract or municipal forces, the fees for scavenging should be collected by the city at the City Hall, just as are water bills and taxes, or the fees may be paid from the general fund of the city. In some cities, where house to house collection of fees by the superintendent, inspector, or police-
man, is in force, an average of three calls is necessary at each house, and the cost of collection often averages 25 per cent. of the fees received. In some cities, the contractor does the work of fee collection. About his only method of enforcing payment, is to discontinue collections from cans, with the result that the system loses most of its sanitary efficiency. The city suffers no financial loss, and is therefore not so willing to enforce the law regarding payments and nuisances, as when it collects the fees.

Fees should be collected by the clerk of treasurer of the city, quarterly for three months in advance, and with a discount for prompt payment. This method ensures a good percentage of collections at a reasonable cost, in the great majority of cases, but with cities having a high percentage of floating population, some additional precautions must be adopted. Probably the best way is to make the owner of the property pay the scavenger fee. This acts as an additional inducement to make sewer connections. The owner may or may not add the scavenging fee to the rental.

There are many elements that enter into the amount of the scavenging fee. The Alabama figures vary, generally, from 75 cents to $3 per quarter, with an average just under $1.50. These figures are lower than experience has shown to be necessary if the cost of can replacement, interest, and overhead are included. Following are the annual charges from a number of cities:

<table>
<thead>
<tr>
<th>City</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zion City, Ill.</td>
<td>$5.00</td>
</tr>
<tr>
<td>Chapel Hill, N. C.</td>
<td>6.00</td>
</tr>
<tr>
<td>Charlotte, N. C.</td>
<td>3.60</td>
</tr>
<tr>
<td>Montgomery, Ala.</td>
<td>6.00</td>
</tr>
<tr>
<td>Phoebus, Va.</td>
<td>12.00</td>
</tr>
<tr>
<td>Hampton, Va.</td>
<td>12.00</td>
</tr>
<tr>
<td>Cambridge, Md.</td>
<td>13.00</td>
</tr>
<tr>
<td>Anniston, Ala.</td>
<td>3.00</td>
</tr>
<tr>
<td>Tuscaloosa, Ala.</td>
<td>5.00</td>
</tr>
<tr>
<td>Fort Worth, Tex.</td>
<td>$9.00</td>
</tr>
<tr>
<td>Greenville, S. C.</td>
<td>3.00</td>
</tr>
<tr>
<td>Chattanooga, Tenn.</td>
<td>6.00</td>
</tr>
<tr>
<td>Columbus, Ga.</td>
<td>9.00</td>
</tr>
<tr>
<td>Kecoughtan, Va.</td>
<td>9.60</td>
</tr>
<tr>
<td>Newport News, Va.</td>
<td>6.00</td>
</tr>
<tr>
<td>Alexandria, Va.</td>
<td>13.00</td>
</tr>
<tr>
<td>Birmingham, Ala.</td>
<td>6.00</td>
</tr>
<tr>
<td>Bessemer, Ala.</td>
<td>4.20</td>
</tr>
</tbody>
</table>
Collection wagons have already been discussed to some extent. They are an important item in any system. They must be neat, as odorless as possible, and inoffensive to the sensibilities of the people. Popular favor is necessary for a box and can—or any other privy system—to yield best returns. Good wagons are a factor in securing and holding this popular favor.

The wagons used in cities where the hauls are long and the number of cans to be handled large, will usually be designed to carry more cans than would a wagon for a smaller city. Below is given information from several cities as to the number of cans, capacity of wagons, cans collected per day, and kind of wagon.

<table>
<thead>
<tr>
<th>City</th>
<th>No. of Cans</th>
<th>Wagon Capacity</th>
<th>Cans per Wagon Daily</th>
<th>Kind of Wagon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlotte, N. C.</td>
<td>1,900</td>
<td>24</td>
<td>90</td>
<td>Closed</td>
</tr>
<tr>
<td>Greenville, S. C.</td>
<td>1,100</td>
<td>16</td>
<td>80-90</td>
<td>Platform</td>
</tr>
<tr>
<td>Chattanooga, Tenn.</td>
<td>6,000</td>
<td>44-66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montgomery, Ala.</td>
<td>6,750</td>
<td>48-66</td>
<td>200</td>
<td>Covered</td>
</tr>
<tr>
<td>Huntsville, Ala.</td>
<td>1,400</td>
<td>44</td>
<td>88</td>
<td>Open</td>
</tr>
<tr>
<td>Columbus, Ga.</td>
<td>3,500</td>
<td>48</td>
<td>190</td>
<td>Covered</td>
</tr>
<tr>
<td>Alexandria, Va.</td>
<td>1,800</td>
<td>20</td>
<td>60-80</td>
<td>Open</td>
</tr>
<tr>
<td>Fort Worth, Tex.</td>
<td>4,200</td>
<td>70</td>
<td>140</td>
<td>&quot;</td>
</tr>
<tr>
<td>Hampton, Va.</td>
<td>490</td>
<td>40</td>
<td>80</td>
<td>&quot;</td>
</tr>
<tr>
<td>Phoebus, Va.</td>
<td>380</td>
<td>30</td>
<td>60-90</td>
<td>&quot;</td>
</tr>
<tr>
<td>Newport News, Va.</td>
<td>1,880</td>
<td>35</td>
<td>70-105</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

A closed wagon has some advantages from an administrative standpoint. There is a distinct decrease in odor as compared with the open wagon. If the closed wagon is tight, the drippings or splashings from the cans are held in the wagon, instead of leaking over the streets. The objection to closed wagons lies mainly in their small capacity, and the extra time required for operation, but a slight increase in cost is of little importance compared to the attainment of sanitation or the goodwill of the citizens.

It must be admitted that no wagon yet devised is
perfect. The wagon used at Charlotte, N. C., is one of the best where the can replacement system is in use. Where it is not necessary to wash the cans before replacing them in the privy, the tank wagon system works well. The open wagon should be used only where nothing else can be adopted. Local conditions in regard to streets, alleys, the amount of mud in rainy weather, hills, and other topographical features, will have a considerable effect upon the design of the wagon. Generally, this should be closed and tight, preventing leakage from splashing, and eliminating odor as much as possible.

Where sewers of sufficient size to carry away the excreta from the can dumpings are available, dumping stations may be built in the form of risers over manholes. Where sewers are not available, burial, dumping or burning may be adopted as the disposal means. The problems of disposal, and the advantages and disadvantages of the various methods, are discussed in Chapter X.

While there is some variation due to season and color and class of inhabitants, the average amount of can contents per week per family is slightly under four gallons, according to several thousand observations made in Virginia, North Carolina, and Alabama.

The sanitary life of a well-constructed box and can system, with a reasonable degree of maintenance, is about five years. Where there is no follow-up, and where no attention is paid to the system after the initial campaign, the sanitary life varies from six months to two years, depending largely upon the quality of the initial work and the construction of boxes. A very few of the better built systems will retain their qualities of sanitation for a longer period than five years.
The following hints on operation, which are given by the Alabama State Board of Health, will be found useful:

"If a deodorant is not used, a quart or more of water should be placed in the cans to facilitate the removal of the solid contents. A teacupful of kerosene may be poured into the cans weekly to reduce odor.

"Can wagons or tanks must be thoroughly washed at regular intervals to get rid of odors and to avoid objectionable appearance. Can wagons must be equipped with brakes. An umbrella or hood over the driver's seat is of advantage in securing continuous service in bad weather.

"A trestled plank driveway over a concrete catch-basin or apron, from which water may be drained to the sewer, makes an excellent washing station for wagons and tanks, and avoids excessive mud around the washing or dumping station. Scavengers should be equipped with knee boots and aprons.

"The coating of cans lengthens their life and facilitates the removal of the contents. A dark interior to the boxes tends to inhibit the entrance of flies."

Next to the pit, the box and can is cheapest to install. Where several hundred are to be placed in service, a central point of manufacture can be selected, the boxes made uniform in materials and dimensions, and built at a decided advantage in cost. Control can be had of the quality, materials, and workmanship.

Combining, as it does, three of the principles of sanitation in a marked degree, and a fourth, prevention of soil pollution, depending only on proper scavenging, with low first cost and rapid rate of installation, this system offers a high degree of sanitation with a low first cost. If the existing privy is in good shape, the box may be installed in the old house, thus utilizing the material at hand, and so further reducing the expense.
Boxes and cans, representing a low first cost, do not delay the extension of sewers, but rather tend to hasten such construction because of the monthly payment of scavenger fees. Geologic and topographic conditions play a lesser part with this than with any other cheap system. Not much expensive equipment is necessary.

The box and can is not suited to individual installations, nor to communities too small for proper scavenging service, as very few individuals may be relied on to care properly for the scavenging. This limits the field greatly. The cost of scavenging is high, running, in most cases, from $7 to $10 per year.

The capacity is limited, and without proper scavenging at frequent intervals, the system becomes little better than open-back privies. In fact, its successful operation depends almost entirely upon the scavenger service and the type of scavenger employed.

In most of the systems, as now designed, the scavenger has to enter the privy to remove the cans, and upon his care depends the cleanliness of the privy. In many cases where the city is not laid out with alleys, it becomes necessary for the scavenging wagon to pass along the streets in front of the residence and for the scavenger to enter and leave the premises through the front yard. At times, where alleys do exist, weather conditions are such as to delay the scavenger with disastrous results to the efficiency of the system.

In cold climates, winter scavenging is made more difficult by the freezing of the can contents, while in warm climates, summer conditions sometimes result in decomposition of the pail contents, and the liberation of unpleasant odors in the privy building.
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CHAPTER VIII
THE SEPTIC CLOSET

The septic type of closet depends for its action upon the same general principles as does the septic tank, that is, the retention of the fecal matter, and its storage under such conditions as to allow a process of sedimentation and septic action. Water is added to aid in the bacterial action. The overflow from the tank must be treated further to prevent it from spreading disease.

This closet was developed by Drs. Lumsden, Roberts, and Stiles of the Public Health Service, and at once sprang into much favor. It was, most unfortunately, advertised widely as a type of privy requiring no care, or at the most a very small amount of care, and commercial interests have since furthered the idea. So widely has this impression been spread, that of the thousands of this type of privy installed, comparatively few are giving proper returns in sanitation. This is due almost entirely to neglect.

The privy is operated by use, and by the addition of water. The water is usually poured through the seat hole, but occasionally is provided by means of a spout gathering rainwater from the roof. This type of privy requires regular attention, and the latter plan does not provide this. Therefore, it cannot be recommended.

The importance of the septic privy (Fig. 27) is exceeded only by the pit with its great application in the rural sections, and by the box and can with its widespread use in the unsewered sections of cities. Its importance is especially great in the South. Recommended by Federal
THE SEPTIC CLOSET

officials, and with the sale pushed by several companies engaged in their manufacture, great numbers of these tanks were installed in cotton-mill and coal-mining villages. Most of their value, from the sanitary standpoint, has been lost through the utter lack of attention that has been their portion, and the general sanitary return has been small. Added to this lack of attention is the fact that some of the firms engaged in their manufacture sold tanks entirely inadequate in size for the work they were called upon to perform.
With so many of this type of privy returning inadequate interest on their investment, the question may arise as to the conditions under which the septic closet will work well. These required conditions include proper installation under suitable local conditions of soil, and proper care or operation.

Just as some of the tanks sold have been inadequate in size, so has the installation of others been hasty and lacking in care. To secure good service from the septic closet, the tank should be carefully installed, after an inspection to determine that it is entirely watertight. Especial attention should be paid to the construction of the tile line for the disposal of the effluent.

There are some conditions of soil and ground water under which it be best not to use a septic closet, as where the ground water level is within a short distance of the top of the ground, which may prevent the effluent from soaking into the soil. In limestone regions, caution should be observed because of the danger to local water supplies. Where water is taken from shallow wells or springs, and the ground water is within a few feet of the ground surface, the septic closet should be at least 200 feet from any such source of water supply.

Daily attention is needed in order that the tank may operate properly. Water must be added every day, preferably to the amount of about ten to fifteen gallons. No garbage, dishwater, bottles, rags, or old clothes should be thrown into the tank, lest clogging occur and cleaning become necessary. The mat or scum on the tank contents must be broken from time to time as the top of the tank becomes covered. If these attentions are given, the septic closet will operate satisfactorily and with a high degree of sanitation.
Sufficient size is an absolute necessity. Just what may be termed sufficient size will depend in each case upon the particular circumstances of that case, as the number and character of users. Men engaged in hard work, eating meat two or three times daily, will require greater storage capacity than will an equal number of women or children. It is impossible, however, to foresee the conditions under which every installation will operate, so it is necessary to provide a factor of safety in the shape of extra capacity.

The following capacities will be found to be reasonable from the standpoint of first cost, and adequate for the average installation in regard to size, providing a margin for extra duty:

For seven persons or less........ 200 gallons working capacity
For eight to ten persons........... 250 “ “ “
Over ten persons.................. Add twenty gallons per person

The above sizes are designed for use in homes, hotels, and similar places where people live. For schools, the load is somewhat lighter, as school is in session only six or eight hours a day, five days a week. Moreover, most of the school sewage, at least a considerable part of it, is urine. The following requirements will be found sufficient for the rare cases where septic closets are installed at schools:

For one to ten pupils.............. 200 gallons working capacity
Eleven to twenty pupils............ 400 “ “ “
Twenty-one to forty pupils........ 600 “ “ “

For more than forty pupils, the tank may be designed on the basis of fifteen gallons per pupil.

The septic closet is not well suited to mill or factory installation, where it generally receives little care and
much hard usage. When so installed, the following capacities are recommended:

<table>
<thead>
<tr>
<th>No. of Men Contributing</th>
<th>Working Capacity in Gallons with Plant Operating Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 10</td>
<td>300 gallons</td>
</tr>
<tr>
<td>11 to 15</td>
<td>450 &quot;</td>
</tr>
<tr>
<td>16 to 20</td>
<td>600 &quot;</td>
</tr>
<tr>
<td>21 to 25</td>
<td>700 &quot;</td>
</tr>
<tr>
<td></td>
<td>600 gallons</td>
</tr>
<tr>
<td></td>
<td>900 &quot;</td>
</tr>
<tr>
<td></td>
<td>1200 &quot;</td>
</tr>
<tr>
<td></td>
<td>1400 &quot;</td>
</tr>
</tbody>
</table>

For more than twenty-five people, the capacity should be increased about twenty gallons per person.

A tank of such size will be used rarely, however, for it will be found cheaper and easier to install several small tanks than to build a single one of such capacity.

While it is not only possible, but probable, that in a great majority of cases capacities less than those recommended above will give good service, there is always the chance that tanks will be subjected to overloading and abuse. The sizes given above provide a reserve to care for such cases. The additional capacity costs but little more, and this extra expense is usually saved many times over in better service and less frequent cleaning.

Some states have regulations providing for various capacities. Where such local regulations are in force they should be observed, as they take into account local conditions. The recommendations herein given are based on a general experience in which the outstanding fact is the number of failures on the part of tanks, most of them commercial, largely because of lack of capacity. Only two states, so far as is known, make definite requirements as to the size of septic closets. North Carolina provides for a minimum of 165 gallons and Virginia a minimum of 200 gallons.

The shape of the tank is not so important so long as the excreta does not short circuit or find its way directly
to the outlet without adequate storage. Circular and rectangular tanks are most generally used. In the case of the rectangular tanks, while it is not so required, a width of about two-fifths to three-fifths of the length gives the best results. The overhead clearance between the top of the liquid in the tank and the top of the tank, must not be less than eight inches, and ought not to be less than twelve inches in any but the smallest tanks. This provides sufficient space for the scum.

The effective or working depth for the smallest tank should be not less than thirty inches, and it is better to have a minimum depth of thirty-six inches of sewage. For the larger sizes, the depth should increase somewhat, but in interests of economy will generally not exceed about five feet. Proper depth is needed to care for the sludge in the bottom and the scum at top, while still providing ample space for septic action.

The outlet pipe should have a down bend or some suitable substitute so that the overflow from the tank will be drawn from some point about two-fifths to one-half the distance from the top to the bottom. This point will be found to yield the clearest effluent and to be least liable to stoppage. The baffle, or partition, should be so placed as to divide the tank into two compartments, sludge and effluent. The effluent chamber should have from one-third to one-fourth of the total tank capacity. For a 200-gallon tank, this rule would give a sludge chamber capacity of 133 to 150 gallons, and an effluent chamber of fifty to sixty-seven gallons. The baffle, or partition, may be arranged in a number of ways. Either the baffle may be solid, with an elbow or siphon bend reaching down twelve or fifteen inches below water line to convey the liquid from one chamber to the other, or there may be two baffles,
placed an inch or two apart, one acting as a skimmer, and the other as a weir or overflow. Some baffles have only a hole cut through them at the required depth. As a rule, any device that allows the passage of the liquid from one chamber to another without stoppage from sludge or scum is satisfactory.

It is good practice to allow some means of getting into the tank in case of trouble. Commercial septic closets are provided with removable covers or with manholes. In building a home-made tank, it is wise to build a manhole in the top so that both compartments may be reached in case of trouble, or for the purpose of cleaning.

Septic closets are made of concrete, metal, brick, vitrified tile, and various other materials. Concrete has been, in the past, the most popular type of material, due to the general familiarity with it, its comparative cheapness, ease of handling, and almost universal availability. It is also very durable. Most of the septic closets in use are of concrete.

In the case of septic closets built in place on the ground, the concrete should be mixed one part of cement, two parts of sand, and three parts of broken stone or gravel (a 1:2:3 mix). The walls should be not less than four inches thick for the smaller tanks, and six inches for the larger. Portland cement must be used, and the
mixture should be left rather dry, and tamped into place, care being taken that no airholes or other spaces are left. Airholes or pockets will often form in the walls if too much water is added to the mixture, and these may cause leaks. Where concrete tanks are built at a central factory, as is the case with commercial tanks, and shipped to the point of installation, the mixture is of equal parts of Portland cement and sand. The walls, top and bottom, should be made two inches thick. Such tanks must be reinforced and it is well to reinforce all tanks. Further information in regard to the use of concrete will be found in Chapter XV.

Concrete tanks are very heavy. When built in place they cannot be moved or added to except at excessive cost. Commercial concrete tanks are also heavy, and the freight charges are high. Many are damaged in transit. Cracks may be repaired by filling with plaster of paris, which expands upon setting, thus completely filling the crack. Cement mortar contracts slightly and makes an unsatisfactory repair job.

The average commercial concrete tank will cost about $60 delivered, or $100 installed, depending somewhat upon the local conditions as to distance from factory, labor, and soil.

Metal tanks are a comparatively recent production, but have met with much favor. Experience has shown that tanks constructed of pure iron or copper-bearing steel, protected from outside corrosion by some proper covering, will last indefinitely. Metal tanks are much lighter than concrete tanks, and have the additional advantage of not cracking or leaking. Such tanks are generally made of fourteen-gauge metal, which is about an eighth of an inch thick, and are furnished in various sizes to suit almost any requirements.
While hot, these tanks are dipped into a gilsonite or asphaltic compound, which adheres tightly to the tank and prevents corrosion or rusting. The weight is generally in the neighborhood of 200 pounds, while a similar tank of concrete weighs 1400 pounds. The cost of the metal tanks is a little less than of the concrete tanks, about $50 delivered or $90 installed.

Some tile septic closets are on the market (Fig. 29), while many people purchase their own tile and build tanks. As a rule, tile tanks are satisfactory though there may be a filtration or leakage through the tank causing a considerable loss of water, which is bad, inasmuch as lack of water is the main cause of trouble in non-leaking tanks. Tile is heavy, and is very easily cracked or broken in handling or shipping. The cost is slightly less than either concrete or metal tanks.

Septic closets may be built of other materials, as brick, which makes a very satisfactory tank if it is watertight. The cost is usually high, except in special places where labor and material are low.

The septic closet occasionally generates odors during the summer and a flue may be provided to carry off, to as great extent as possible, the gases given off by the process of decomposition. There is, however, some question as to the necessity for a flue, if the riser be ventilated with
well-screened holes. Experience in several Alabama cites indicates that a flue aids but little in the reduction of odors.

Scores of firms have been in the business of manufacturing and selling cement septic closets. Thousands of tanks have been built by the home owner, or for him by a contractor. One of the strongest points in favor of this type of privy is the fact that, given proper instructions, almost anyone familiar with the use of concrete, and able enough with a saw to cut out the form, can build himself such a tank. It must be realized, however, that the job of constructing such a tank is greater than it appears to be, and most people will do better to purchase a tank suitable for their needs from a reputable firm which has been approved by their own state board of health.

The Kentucky State Board of Health improved the design of the original septic privy and developed the Kentucky Sanitary Privy, which is described in a Bulletin issued by that Board of Health. This Bulletin explains the various steps in the construction of a tank, and gives full directions for operating. The Virginia State Board of Health also publishes a Bulletin giving a full description of the method of building a similar tank. The directions given in the Kentucky Bulletin are abstracted below:

"Select the location, and dig the hole five feet long, four feet wide and three feet deep. It is best to mark out the size of the hole with a string, and then dig inside the string, and slightly smaller, later cutting to the exact size. Close cutting to measurements saves cement and makes the work easier. If the hole is dug in sloping ground, make it three feet deep at the deepest point.

"Pour into the hole enough concrete to make the bottom four inches thick. Level this off and let it set.

"A study of Fig. 30 will show there are seven differ-
ent sizes of pieces for the forms. If these are cut accurately to the sizes shown, there will be no trouble in putting them together. Care should be taken to nail the battens on the inner side, and to put the hole for the out-

| A. 12 Pieces. For Battens. Each 1" x 3' x 36" |
| B. 2 Pieces. For Sides. Each 1" x 8' x 32" |
| C. 2 Pieces. For Sides. Each 1' x 12' x 32". Can be Made of 2 or More Boards if Total Width Equals 12" |
| D. Each 14" Long For Sides. |
| E. Each 36" Long. For Ends and Baffles. |
| F. 2 Pieces. Each 1' x 2' x 32". For Top of Form on Sides. |
| G. 4 Pieces. Each 1' x 2' x 36". At Top of Ends and One Baffle |

Make First The Two Sides, Using Pieces A, B, C and D. When Making The Other Side Be Sure To Reverse So All Battens Will Be On Inside.

Fill in Baffles and Ends with Pieces E. 6 Inch Opening For 4" Tile Elbow. Center of Circle 6 Inches From Top.

Fig. 30.—Lumber and forms required for Kentucky Sanitary Privy, with directions for making forms.

A concrete of 1:2:4 mixture should be used for the work. The best sized batch, and the one easiest handled, is composed of one sack of cement, two cubic feet of sand, and four cubic feet of broken stone or gravel. Specifi-

let tile elbow in the end next to the standing baffle. The centre of this hole should be eight inches from the top of the form, which will bring the bottom two inches below the top of the baffle. Six-penny nails should be used for putting the forms together, and the ends should not be clinched, thus making removal of the forms easy.

A concrete of 1:2:4 mixture should be used for the work. The best sized batch, and the one easiest handled, is composed of one sack of cement, two cubic feet of sand, and four cubic feet of broken stone or gravel. Specifi-

Courtesy Kentucky State Board of Health.

Courtesy Kentucky State Board of Health.

Courtesy Kentucky State Board of Health.
cations for sand, stone, and cement, will be found in Chapter XV.

"The mixing board should be about six feet square and tight enough to keep the liquid cement from running through, though small cracks may be stopped with sand. A measuring box exactly one foot square inside, and one foot deep, will be found valuable.

"If the form and pit have been made as directed, it will be found, when the form is properly placed, that there will be a space of about five inches all around between the form and the walls of the pit. The top of the form will extend about five inches above the ground. Level the form carefully. If the bottom is still soft, leveling can be accomplished by tapping the form on the high side.

"The tile elbow should be placed with the bell end against the earth wall, and the curved end extending down into the tank. It is well to put a wad of paper into the bell end to prevent concrete from flowing into it, but this must be removed later.

"The concrete should be poured evenly all around the form. As it is poured, it should be tamped and spaded so as to give a good, smooth face after the forms are removed. When this face is rough or porous, it should be plastered with a cement mortar coat, mixed 1:1.

"The concrete should set for twenty-four to forty-eight hours before removing the form. In the meantime, the tank should be covered to prevent too rapid drying and to protect the concrete. The form should be taken out before the concrete is entirely dry, and all holes or imperfections should be plastered up.

"The seat riser is made of good, dressed lumber of such size as to fit exactly on the shoulder provided for it over the first compartment. It should be about twenty-one inches high. Over the balance of the tank, one- or two-inch planks should be laid as a support for the concrete top. These are left in place.

"Two inches of concrete should be placed on these planks. Reinforcing of wire mesh, iron bars, or similar material should then be placed, after which additional
concrete should be poured to secure a thickness of five inches. While the concrete is still soft, iron bolts should be placed head down in the concrete and in such a fashion as to provide anchorage for the foundation of the privy house.

"The top of the tank acts as the floor of the privy and should be finished with a rich mixture, as one of equal parts of cement and sand, and made perfectly smooth.

"Until the top of the tank has thoroughly set, it should be protected by covering with wet sacks, over which a layer of planks is placed. The wet sacks furnish water to replace that lost by evaporation and prevents the concrete from cracking while seasoning.

"The ultimate disposal takes place in the ground outside the tank. The liquid leaves the tank by means of the curved tile elbow and enters the tile line provided for distribution. This line should be laid as directed in detail in Chapter XIV.

"The tank should be completely filled with water and allowed to stand for twenty-four hours to determine its watertightness. If the tank leaks, it should be emptied and repaired. If it is tight, add a few shovelsful of well-rotted horse manure, a cake of yeast, or sludge from another tank. Provide a good quality of toilet paper, as any other kind is liable to clog the tank.

"Two buckets of water must be poured through each seat opening every day. Not only does the privy require the daily addition of water, but floating masses should be broken up. There should be very little odor from a properly constructed and operated septic privy."

The tank above described, which is the standard septic closet of the Kentucky Board of Health, has a capacity of about 260 gallons, and is suitable for the use of one family.

In the summer, such a tank will begin bacterial action within two or three weeks after it is put into use. In the fall or winter months, the cold weather may retard
this action for as much as two or three months. No disinfectants of any sort should be thrown into the tanks.

Fig. 31 shows plans and forms for a simple tank, which was designed by the author for a quantity installation at Leeds, Alabama. Special attention was paid to simplicity in the construction of the form, with a view to repeated use. Some of the forms on this work were used as many as twenty-five times, though it was generally not found economical to use a form over twenty times, owing to the longer time required to place old forms. The timber baffle and the removable floor slab, doing away with the necessity of a manhole, considerably reduced the cost, which averaged $22 complete. Larger tanks may be built along the lines of any of the designs shown, the same relative dimensions being retained, but the tank increased in width, length, and depth.

The basic principles of all septic closets are the same and the commercial septic privy has all the advantages of the home-made one except that it may cost more. This extra cost may be regarded as an insurance against those defects that are very liable to creep in when construction work is done by persons unskilled in such work. Home-made tanks frequently leak. Where only one tank is being built, the various concrete mixing jobs entail a considerable waste of time, as the concrete must be allowed to set between each operation. The commercial tank can be purchased and installed in one day. Most manufacturers guarantee their tanks to operate satisfactorily.

Metal tanks are rapidly rivaling the concrete tanks in favor. Both types work equally well, and the advantage lies in the cost and ease of handling. The metal tanks are built with a bolted-on cover, upon which is mounted a
Fig. 31.—Septic closets and forms for 270-gallon septic closet constructed at Leeds, Ala. Materials required: A, pieces 12, 1x8x18; B, pieces 12, 2x4x54; C, pieces 2, 2x4x28; D, pieces 2, 2x4x17; E, pieces 1, 2x4x4; F, pieces 2, 2x2x30; G, pieces 12, 1x8x26; H, pieces 24, 1x8x16; I, pieces 4, 1x4x48. Total materials (not including lumber for seat and house). Lumber: 80 running feet, 1x8; 65 running feet, 2x4; 16 running feet, 1x4; 5 running feet, 2x2. 5 pieces, 2x6x40 for baffles; 5 pieces, 2x8x30 for top forms. Concrete: 1 cubic yard broken stone; 1/2 cubic yard sand; 8 sacks cement; 4 bolts, 3/4"x6".
commode, while the concrete tanks carry the tank sides up an additional fourteen inches, and mount seats directly upon the top of the tank. In nearly all the tanks, whether of metal or concrete, a baffle divides the tank into two compartments. Fig. 32 shows a specially designed tank with a slanting baffle somewhat after the fashion of the Imhoff tank.

The method of starting the tank has already been explained. The tank is filled with water, and horse manure, yeast or sludge from another tank added, and the tank put into service. Bacterial action soon begins, the length of time required depending largely upon the temperature.

The operation process is that of septic action. The excreta is retained in the tank in the presence of bacteria, which results in the breaking down of the complex compounds found in excreta, with reduction to simpler forms. Some liquefaction takes place during the operation, and gas is generated, with the final division of the sewage into two parts, sludge and effluent. The sludge is the solid part, which sinks to the bottom of the tank, while the effluent is the liquid which flows off through the tile line and soaks into the ground. The action follows the general lines already described in Chapter III.

At least two pails of water are needed daily for each seat hole. Care should also be taken to prevent the formation of a solid scum or mat on top of the tank contents, as excreta may be deposited thereon, out of reach of bacterial action, and cause odors. No rubbish or other waste should be thrown into the tank. At intervals of from six months to five years, the tank must be cleaned out, the frequency of the cleaning depending very largely upon the amount of care or abuse it has received.
SEWAGE DISPOSAL FOR UNSEWERED SECTIONS

Plug to be furnished
To be used when tank is used
as a "Sanitary Privy"

Fig. 32.—Tank with slanting baffle. Seat riser fastens to top of tank.
The sludge in a tank that is working well is, after a few months, a well-digested substance, which usually has some odor and contains B. coli. When the tank is cleaned, the sludge must be disposed of by burial, burning, or other means. Methods of sludge disposal are described in Chapter XIV.

The effluent or liquid overflow from the tank is about equal in volume to the liquids entering the tank, less the loss from evaporation. This must be given an additional or secondary treatment to prevent nuisance and the spread of disease. Contrary to the statements of some of the firms manufacturing this type of privy, this effluent, which is a dark-brown liquid, having some odor, contains millions of bacteria, and must be regarded as extremely dangerous to health. It is usually disposed of by underground filtration or similar means whereby the bacteria are killed and the chemical compounds reduced to simpler and more useful forms.

Unless considerable care is taken in the operation of the septic closet, troubles will occur from time to time. The most usual forms of trouble are clogging, flies, worms, and odors. While some of these may not be serious, they are extremely disagreeable.

Clogging is almost always due to abuse, such as the presence of rags, rubbish, bottles, or tin cans in the tank, the use of other than toilet paper, or the lack of water, which may be due to leakage from the tank, or to lack of care by the user. If it is due to lack of water, this may be determined by stirring the tank contents. If below the scum, the contents are fairly liquid, and if the scum is not more than six to twelve inches in thickness, lack of water is probably not the difficulty. This diagnosis
will be verified to a considerable extent if there is no serious odor.

If the scum is thick, the middle depth of the tank mushy, or fairly solid, and the sludge in the bottom deep, lack of water is probably the trouble. Add at least two or three pails of water per seat per day, noting that the outlet line is not clogged. This can be determined by digging down to the end of the tile line, and pouring water into the tank until it overflows down the outlet elbow. If water comes through the tile line, and the treatment, when continued for several weeks, does not remedy matters, the tank must be cleaned and started over again.

If clogging is due to throwing rubbish in the tank, to the use of newspaper instead of toilet paper, or to similar abuse, the only remedy is to clean the tank. If the trouble is lack of water, due to a leak in the tank, it is usually cheaper to buy a new tank, though it may be possible to dig up the old tank, find the hole, and plug it.

Sometimes stoppage is caused by poor work in installation, whereby cement mortar is allowed to run through the joints of the tile line, of which the first two or three are concreted, and form plugs in the line. If upon digging up the line it is found that no liquid reaches the end, the tile should be followed up until the trouble is located.

Flies and worms may be somewhat troublesome in the summer. To prevent the entrance of flies, all screens must be tight and the seat lids kept down. The flue must be screened, as otherwise many flies will pass down it to reach the tank contents. Worms often appear, occasionally in disagreeable numbers. Most of these are fly larvae of one or another species, many of which will hatch out under the conditions obtaining in a septic tank. Kero-
Fig. 33.—Simple form of tile septic closet. Not enough capacity for general use, but might be suitable for camps.
sene or other oil poured over the tank contents once a week, and attention to the screens is about the only remedy. Mosquitoes sometimes breed in septic tanks. The ordinary 12- or 14-mesh screen will not keep out mosquitoes, but the use of oil in small quantities, as directed, will prevent them from breeding. The oil should be applied about once a week.

At times odors will be noticeable, especially in hot weather, even though the tank is working properly. Little can be done to counteract this, though scrupulous cleanliness in and around the privy, and the addition of plenty of water to the tank, will alleviate the nuisance.

Under no circumstances should any form of disinfectant be added to a septic closet. Such disinfectants will kill the bacteria and stop all septic action, resulting in clogging or odors, or both.

The sludge problem needs no attention unless the tank needs cleaning, when it will be necessary to remove the sludge. It is then burned or buried, or it may be used for fertilizer, though not on vegetables that may be eaten raw. The liquid overflow of the tank, the effluent, must, however, be taken care of at all times, as it continually trickles from the tank. Usually an open joint tile line is laid,
bedded in cinder or other porous material, and the effluent allowed to seep into the soil through this. A fuller description of the various methods of secondary treatment of both sludge and effluent, will be found in Chapter XIV.

The septic closet meets most of the requirements of sanitation. Well constructed, it is flyproof; it protects the excreta from animals; there is no chance for soil pollution, nor may water pollution take place, provided that proper location of the privy is insisted upon. The septic closet, therefore, possesses a high theoretical sanitary value, and this, combined with its long life, low maintenance cost, and the comparatively small amount of attention really needed, make it a favorite with many sanitarians. An important administrative advantage is that, when installed, the septic closet may be made large enough and so constituted as to function as a septic tank if desired. If later the home is equipped with running water and a flush toilet, a small amount of work will convert the old septic closet into a septic tank capable of handling the sewage of the home.

The initial cost of the septic closet is rather high, and even though only a small amount of attention and care is needed, this minimum is imperative. Proper operation is rare in any but home installations; most of the septic closets installed rapidly lose their sanitary qualities. Part of this is due to the unfortunate advertising this type of privy has had in regard to operation and care. The septic closet needs attention every day in the year, if the user hopes for sanitation. Any rough usage, even the use of other than toilet paper, will often cause trouble. There are possibilities of odors and nuisances in the summer. Seat lids carelessly left open invite the
entrance of flies and mosquitoes, which may find ideal breeding places in the privy tank.

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CHAPTER IX
THE CHEMICAL CLOSET

The chemical toilet operates through sterilization and deodorization of the tank contents by means of a chemical solution. The excreta are caught in a metal tank and retained there in the presence of a strong caustic solution, until the tank is filled, when it is emptied and again charged with the chemical. Chemical toilets are made in various sizes and styles, the most common being the 125-gallon tank, with china bowl. This furnishes sufficient capacity to provide the average family about six to nine months without emptying. The installation resembles very much the ordinary water flush toilet, and is the only substitute for the water flush toilet that may be installed within the house. This is possible because the chemical destroys all odors.

The chemical toilet was first brought out about twelve years ago as a commercial proposition. It has always remained in that place, mainly because of its construction, which requires an extensive plant. Largely for the reason that it is a commercial proposition, health officers have stood aloof, preferring to recommend types of closets that could be constructed at home. On the other hand, the method of operation of the chemical toilet, and the results obtained with it, have been approved almost universally by health officers.

The importance of the chemical toilet is not as great as some of the other types that have been discussed. The price, which has always been rather high, has prevented a wide use. It is of considerable sanitary importance,
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however, for it is the best of the sewer substitutes where money is available, but running water is not. It is especially valuable in school sanitation. Cheaper chemical types are being developed, and sanitarians are beginning to recognize that its many valuable qualities make it worthy of recommendation under nearly all conditions of use.

The prerequisite of successful operation of a chemical toilet is proper installation. Care and attention are necessary after the toilet is put into use, but if the outfit has not been properly installed, most of the after care will be wasted. The routine attention required is a daily working of the agitator, thus helping break up the excreta in the tank, and allowing the chemical solution a full chance to operate.

When the tank is filled, it is emptied by opening a valve which allows the contents to flow out into a previously prepared seepage pit, and again charged with chemical.

There are two types of chemical toilet, the commode (Fig. 35), and the tank, or storage, system. The commode consists of a metal container or box, equipped with an ordinary water closet seat, and furnished with a can or pail of about ten gallons capacity. The container is usually enameled neatly in white or gray for indoor use. A small charge of chemical is placed in the can, which is then used in exactly the same manner as a box and can privy.
The can must be emptied, just as with the box and can, at intervals of a week or ten days, but the contents are sterile, if the privy has been properly operated, fairly liquid, and odorless. Caustic soda is the chemical most generally used, but phenol and pine tar disinfectants are also used. The applicability of a commode is limited, but if well operated, it has considerable sanitary value. The initial cost depends somewhat on the style, and varies from $7 to $15. The cost of operation is about eight cents a week for the average family.

The standard tank chemical toilet is of 125 gallons capacity, and is well finished, with a china bowl, and good seat and seat cover. The cost is about $70 each, and the annual operating cost about $4.50 per year for the average family. Multiple tanks are also furnished, equipped with any number of seats up to six, with 125 gallons of tank capacity allowed for each seat. These are especially suited for use where more than one bowl or seat is required in one place, and where one seat, as the the nearest to the door, may receive more use than the others. Tanks of eighty gallons capacity are also furnished. These are built on the same plan as, and have all the advantages and disadvantages of, the larger tanks, but cost about 25 per cent. less. Owing to their smaller capacity, they require more frequent cleaning.

The tank of the ordinary chemical toilet should be of pure iron, or copper-bearing steel of about 14-gauge thickness, with all seams electrically welded. There should be a manhole to allow access to the interior, and for recharging. In the bottom is a drain valve to empty the tank when it becomes full. Most of the tanks are cylindrical, about four feet long and twenty-eight inches in diameter. While one or two companies do nothing
more than protect their tanks with a coating of graphite or asphalt paint, most manufacturers dip their tanks into a hot asphaltic enamel and thus render them proof against corrosion. The base of most of these enamels is gilsonite, and the enamel, when well applied, effectually prevents corrosion.

The caustic soda or other chemical employed rarely has any effect upon the tank metal, but outside causes may tend to injure the tank metal. For instance, the bedding of a tank in coal cinders, subject to frequent wettings, would speedily destroy the tank if unprotected. The life of a properly protected tank is indefinite. Most firms guarantee their tanks to have a life of fifteen years, or agree to make replacement on a basis of yearly use, in case of failure.

Some method is necessary to break up the masses of excreta and allow the chemical to act upon them. Otherwise the tendency is for the excreta to raft, or pile up, on the surface beyond the reach of the chemical, and protected from it by floating paper. This is accomplished
by mechanical agitation. An agitator must be simple and sturdy, while affording the greatest amount of motion to the tank contents. The elimination of as many moving parts from the tank interior as possible is an advantage. Old clothes, rags, newspapers, and other wastes are often thrown into the tank. The agitator must be such that these will not put it out of commission.

The agitator should be operated frequently—at least once a day. Rafted excreta, if allowed to float on the surface, may cause odor, will attract flies, and subtracts from the efficiency of the system. A tank working properly will show only a dark liquid inside. Too much agitation cannot be given.

The closet bowl is usually of vitreous china, resembling very much the ordinary water flush toilet bowl. This is placed on the floor, and an enameled vent pipe run through the roof or into the chimney to carry off objectionable gases and to provide a circulation of air through the tank. A drop tube connects the bowl and tank. This is a metal tube about twelve inches in diameter, of sufficient length to connect the bowl and the tank. It should be enameled or otherwise protected on the inside.

In the tank systems, all manufacturers use caustic soda for the sterilizing and deodorizing agent. Nothing else will act as efficiently. It is fairly cheap, readily obtainable and has but one defect, its corrosive qualities. While very few complaints are received, according to the records of the various manufacturers concerning burns from this chemical, there is no doubt but that quite a number of users have suffered from small splashes. Vinegar or lemon juice are antidotes for these burns and should be applied at once.

In the commodes, some companies use caustic soda,
while others employ a phenol or pine-tar disinfectant. It should be remembered that complete sterilization is seldom or never effected by the use in chemical toilets of any chemical other than caustic, and while it may be permissible to be rather careless in the disposal of the contents of a chemical toilet in which caustic has been used, extreme care should be observed with other chemicals. The pine tars are little more than deodorants under the conditions of use in a commode. The phenols rarely completely disinfect, as they cannot penetrate into the lumps of organic matter. Other chemicals, such as sodium chromate, have been tried out, but with little success.

The cost of chemical, when using caustic, is about $4.50 per year for the average family. One charge of twenty-five pounds, mixed with fifteen gallons of water will operate the standard tank system for six to nine months, at a cost of $3 to $3.50. The cost of the pine-tar disinfectants is about the same, while the phenol costs vary with the strength.

The principal points to be observed in installing a chemical toilet are the setting of the tank and bowl, and the construction of the seepage pit. In the setting of the tank and bowl, the tank should be placed under the floor so that it is at least eighteen inches beneath the bottom of the bowl. Especial care must be taken to see that the valve fits well and that the valve packing is in place and seated properly. A defective seating of the valve will allow the chemical to leak out, and conditions then simulate the double compartment concrete vault, with odors becoming extreme.

In the construction of the seepage pit, sufficient capacity must be provided. A good allowance is 50 per cent.
to 100 per cent. greater than the size of the tank it is to serve, and this capacity must be available below the tank outlet. A tile or iron line may be used to carry the contents from the tank to the pit. The shape of the pit is immaterial, but usually it is more economical to build and cover when made square or oblong. Sometimes boxes or barrels having the requisite capacity are buried; the pit being walled up with loose stone, or with brick laid with open joints. A strong cover should be placed over the pit to prevent accidents.

It is imperative that the pit be not filled with cinders, broken stone, or other similar material, as such an arrangement will invariably clog after one or two charges have been turned into it. Sometimes the pit may be placed on a steep hillside, which allows a rather better diffusion of the tank contents. Tank contents should not be discharged upon the ground surface.

In localities where the ground water level is high, as within eighteen to twenty-four inches from the ground surface, the seepage pit cannot be used. If the chemical toilet is to be installed under these conditions, other arrangements must be made for scavenging. The contents may be pumped or bailed out and buried, burned, or used for fertilizer. The fertilizing value is high, but the material should not be applied directly to vegetation, and extreme care should be taken if used for enriching a garden.

The seepage pit may be installed close to the tank. In fact, this has certain advantages in shortening the length of pipe line and reducing clogging troubles. In the case of home installation, the pit may be built close alongside, or even under the house. It should not be
placed within 100 feet of the well, if this is possible, and in every case the drainage should be away from the well.

The scavenging of the chemical toilet is accomplished by opening the valve, thereby allowing the tank contents to drain into the previously prepared seepage pit. After the tank has been emptied, it should be flushed with one or two buckets of water, and after the valve has been carefully cleaned, and properly seated, the valve packing inspected, the valve closed, and a new charge of chemical added.

In recharging, the powdered chemical should be dissolved in from fifteen to eighteen gallons of water, for the standard size tank, before pouring into the toilet. If the chemical is poured into the tank dry, and the water then added, the chemical will not dissolve, and results will not be satisfactory.

While the chemical toilet is very nearly fool-proof, it does require some care and attention. The matter of daily use of the agitator has already been mentioned. With ordinary use there will be little if any fouling of the bowl or drop tube. Where such fouling does occur, it should be removed with a wet mop, dipped in disinfectant solution. Properly operated, there will be no odor. If odor does occur, the toilet is not working properly and the manufacturer should be notified. The proper amount of ventilation is furnished with each toilet. This should be installed carefully, with the top extending above the highest part of the roof.

The operating difficulties of the chemical toilet are usually due to one of two causes, or to both causes. The most frequent source of trouble is the leaking out of the chemical, usually through a defectively closed valve. The other usual source of difficulty is lack of agitation. The
latter trouble is one that the users only can remedy. Automatic agitators are being tried out and may ultimately be successful. In the meantime, the chemical toilet, or any other toilet, is not fitted for installation where there will not be available some care and attention.

Leakage of the chemical is almost always due to a poor seating of the drainage valve. Often after emptying the tank, the valve is replaced with some dirt under the seat. Not closing tightly on account of this obstruction, the chemical and the liquid parts of the excreta seep away. The result is much odor and the absolute stoppage of any chemical action. The tank must be cleaned out, the valve cleaned and replaced tightly, and the tank recharged with chemical. Occasionally in shipping the tank, rough handling may cause a crack near the valve, or in one of the seams at the end of the tank. When this occurs, the tank must be returned to the factory for repairs.

This action of the chemical toilet is positive and it will operate without regard to such abuse as use of newspapers instead of toilet paper, or the throwing of garbage or refuse into it. In the summer, when evaporation becomes heavy, it may be well to add an occasional pail of water to the tank, and to follow this with vigorous agitation. Where one tank serves a large number of men, as in a factory, it is sometimes dosed with a double charge of chemical in order to care for the stronger sewage received.

The chemical toilet is sanitary so long as chemical is added. When this is not done, the chemical toilet becomes such a nuisance that it cannot be used. Flies are repelled or killed by the chemical and breeding inhibited. There should be no odor. Disease germs are killed when the tank works properly, and the sewage
rendered harmless. Of all the sewer substitutes treated so far, this is the only one available for indoor installation. It thus combines convenience with sanitation. The indoor installation can be counted on to receive better care than an outdoor one. The lasting qualities of the chemical toilet are high. Probably the mechanical life is greater than the actual. There is always the inevitable desire for something better, which often ends in running water and sewers or a small septic tank.

The cost of operation will average eight to ten cents a week for the family of four to seven persons. The type or size of toilet has practically no bearing upon the cost of chemical, which remains the same for all types.

The chemical toilet is practically independent of local and geological conditions. It is an indoor installation and possesses high sanitary value. All dangerous germs are killed so that final disposal is without danger. It also has a health value in that bad weather does not prevent the use of the privy. The first cost is high, in the case of the standard chemical, and the operating cost may also be classed as high, though not so high as the box and can. Attention is needed, and considerable nuisance will develop if anything goes wrong. Lack of chemical might, under some circumstances of careless disposal, lead to danger.

**BIBLIOGRAPHY**

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CHAPTER X

DISPOSAL OF EXCRETA

In the operation of the box and can or concrete vault types of closets, it is necessary to provide some means for the disposal of the excreta collected by the scavengers. Various such means are available for use. Among the cheaper and more commonly-used methods are burying, and dumping into sewers. Other less used methods include dumping into streams, which cannot be condoned on sanitary grounds except under unusual conditions, burning or incineration, tank treatment, and utilization. The choice of these methods will depend upon the amount of material to be disposed of, the presence or absence of sewers, the type of soil, and other local conditions.

Burial is, perhaps, the method most frequently used where sewers are not available for disposal. In some places, disposal by burial has been used with considerable satisfaction. There are two methods of disposal by burial, plowing under or shallow burial, and burial in trenches or pits.

Plowing under is accomplished by plowing a furrow, dumping into it a certain amount of excreta and covering at once with another furrow. Usually this cover is not complete and it becomes necessary for a man to follow the plow and complete the covering with a hoe. The second furrow is then filled and covered in the same way.

Dr. L. L. Lumsden, in Public Health Bulletin No. 89 (1917), gives the following directions in regard to disposal by plowing under:
For disposal by burial, a field should be selected which is not more than a mile or two distant from the points of collection and which is not to be cultivated for at least a year after use as a disposal field. In such a field, a furrow about eight inches deep is run with a plow. The receptacle contents are spread along the furrow in a layer not more than two or three inches deep. Then a parallel furrow is so run that the earth from it is thrown over the matter in the previously made furrow. Spots not covered with the plow should be carefully covered with a hoe or shovel. The soil covering the excreta should be at least three inches deep. By this method 3000 bushels of privy contents can be buried on each acre of land. The matter is in the upper active layer of the soil and undergoes rotting with destruction of whatever disease producing agents may be contained within it. The excreta are high in valuable fertilizer principles and poor land used as a disposal field becomes markedly enriched and consequently of increased value. At least twelve months should elapse after burial before the disposal field is cultivated or otherwise used. In this time all danger from the buried material is past. The field selected should be one that is at a safe distance (at least 400 yards) and preferably downhill from any source of water supply used for drinking purposes. In using a field for burial, provision must be made for washing and disinfecting the cans."

At the rate of 3000 bushels to the acre, one acre of land would be required weekly for every 6000 to 7000 cans. The average amount of excreta to the can, when collections are made weekly, is slightly less than four gallons. Three thousand bushels are equal to about 24,000 gallons. If there are 1000 cans to scavenge, an acre will be needed about every seven weeks, or at the rate of seven to eight acres a year. This seems a rather large amount of land, and its acquisition within a couple of miles of the average town of 20,000 to 40,000 would
entail a rather large expenditure. Burial, therefore, will be more practical for the smaller towns. Most of the larger places have sewer systems into which the cans may be dumped.

From a sanitary standpoint, burial by plowing under is not all that can be desired. There are always odors and large numbers of flies. Flies having a flight range of several miles may bring dangerous pollution to homes located near the disposal field. The can contents are scarcely ever completely covered, and if they are, animals or wind may more or less uncover them. In fact, animal spread of pollution is an important factor and one to be considered in disposal by plowing under. Rain or surface water may wash the excreta into streams, wells, or other sources of water supply.

In the average box and can or concrete vault privy system, a considerable percentage of the privies are not fly-tight which results in the presence of a large number of fly larvae in the excreta. Such fly larvae will emerge, even if buried to a depth of several feet in loose earth, so that the shallow covering secured by plowing under is no hindrance to their development.

On the other hand, burial by plowing under has some real advantages. It disposes of the excreta with a comparatively small amount of real nuisance and usually in a fairly safe manner. The valuable fertilizing elements are preserved. It is doubtful whether typhoid bacilli live more than a couple of months in the soil, although hookworm eggs may survive for a long time. If no better means of disposal are available, such as dumping into a sewer, burial must be used. It is far better, even if carelessly done, than to dump into a stream or to use surface privies.
Burial in pits or trenches is another means sometimes employed for the disposal of can or vault contents. Trenches and pits of various sizes and depth are used. Generally, it is not desirable to make these pits more than three to four feet deep.

In the experiments at Wilmington, North Carolina, excreta were buried in pits in dry, sandy soil, and in wet soil, the pits in all cases being about three feet deep and three feet square. Little change, except for a slight drying out was noted during the first year. It undoubtedly requires at least two to four years, possibly longer, for the pit contents to digest completely.

If pits or trenches are used, they should have a cover of at least twelve inches of soil. In this case, a trench three feet deep would have twice the capacity of a trench two feet deep, and one four feet deep would have a still greater capacity. On the basis of trenches four feet wide and three and four feet deep, spaced six feet apart, the three-foot trench would allow ten weeks to the acre for 7000 cans, whereas the four-foot deep trench would give fifteen weeks, and plowing under about one week. Undoubtedly the trenches could be placed somewhat closer together than six feet, but it is equally certain that the field could not be used again for at least three years, and probably not for a longer period. If pits three feet square and three feet deep are used, with a row every nine feet, the capacity per acre is still further diminished and there are no corresponding benefits. Very narrow trenches, one foot wide and four or five feet deep, might give good results.

If trenches or pits are used in cold climates, they must be dug in the fall before the ground freezes, and must be backfilled or covered with earth before the spring
thaws. Plowing under is impossible all year around in those sections where the ground freezes.

The main advantages of burial in pits or trenches are less attraction to flies, less nuisance, better covering, and the reduction in the chances for surface wash or mechanical pollution. The field remains useless longer, but the work is probably slightly less than that entailed by plowing under.

Some few places dispose of excreta by dumping it into a sinkhole or pit. There is little to commend this practice, except such local economies as may be effected by its use. In regard to this method of disposal, the Alabama State Board of Health in their bulletin on the box and can privy state:

"In certain instances where sewers or streams are not available or are not of adequate size, cans may be emptied into a pit and washed elsewhere where the wash water may be carried away by a house sewer, storm sewer or small stream. Such a pit may be constructed in the following manner: It should be located on a hillside. The capacity should be 1.5 cubic feet per person per year. Construction should be such as to prevent caving. If built in impervious soil, the pit should be subdrained into a secondary gravel or cinder-filled pit one-tenth the capacity of the main pit, which should also be subdrained. The main pit should be closely covered with 2-inch planks. In the median line of the pit cover a number of bottomless feces cans should be set, and fitted with tight lids. These cans form the openings through which the pit is filled."

The capacity suggested for the pit seems very small. The average content of the can scavenged weekly is about one-half cubic foot, or slightly less than four gallons. In most soils not more than 50 per cent. of this is drainable moisture, and probably not nearly so much. According to this data the pit would fill in about six
months. More space is probably needed. It is also probable that the cost of such a pit over a term of years would not be much less than that of a treatment plant.

Except in the comparatively rare cases where a stream large enough to care for all the material dumped is available, dumping into water should not be practiced. Even where there is a large flow throughout the entire year, this method of disposal should be adopted with caution and only under the advice of the State Board of Health.

Where a line of sufficient size is available, dumping into sewers is usually the best method of disposal. The requirements, in addition to having a sewer of sufficient size to carry off the can contents, are isolation, or a reasonable distance from the nearest home, an ample water supply, and convenience to the most privies possible, thus shortening the haul.
DISPOSAL OF EXCRETA

The Alabama State Board of Health recommends a sewer not less than eight inches in diameter, and a grade great enough to prevent any deposits. It is better to use a larger sewer. Plenty of water is a necessity. A screen must be provided to exclude sticks, stones, tin cans, bottles, and other débris that is found in cans, and in vaults. Usually, these acquirements are combined in a can dumping and washing station.

The following abstract from Reprint No. 532, U. S. Public Health Service, by E. B. Johnson, Chief Sanitary Inspector, describes a can washing and dumping station installed at Montgomery, Alabama, and gives the salient points to be considered in the design of such a station (Fig. 38):

"The location chosen for the disposal station was such that, though no buildings were within 300 feet, there were 3300 privies within a radius of one and one-half miles from the station. The station was placed in the centre of the available plot of ground to secure all possible ventilation. The chief consideration in regard to size was the platform room necessary to accommodate the 700 cans per day that would be brought to the station. The assumption was made that not over 200 would arrive at one time, but provision was made so that expansion to provide capacity for 480 cans could be made.

"The unloading platform was seven feet wide and thirty feet long. On the opposite side of the plant was a loading platform of the same size. A width of six feet was provided around the washing and dumping hoppers, making the structure thirty by twenty feet. In Fig. 38 are shown a floor plan and end elevation of the station.

"The floor of the station was elevated thirty to thirty-six inches above the driveway to permit of easy handling of the cans. Floor stringers are 4 x 6; floors are of 2-inch plank; the roof is twelve feet high at the
ridge, and nine feet at the eaves. Only the centre six feet were covered by the roof. Experience has shown that it would have been better to have covered the entire platform, to provide shelter for attendants and protect equipment from theft.

"A concrete hopper was provided leading to the sewer, and the cans were emptied into this hopper. Bars
DISPOSAL OF EXCRETA

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built into the hopper about seven inches from the top act as screens. The hopper is seventeen inches in diameter at the top and narrows gradually to eight inches at the point where it enters the sewer. A quick-opening valve on a water line to the centre of the hopper provides for washing the can while it is in the perpendicular dumping position in the hopper.

"There has been little complaint concerning odor at this station due to the rapid dumping and washing of the cans, and to the fact that all filled cans are tightly covered until they are ready to be placed in the washing hopper."

The disposal station was erected during the war at a time when the cost of labor and materials was unusually high. The items of expense connected with the erection and operation of the main disposal station are as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot of ground</td>
<td>$1,500.00</td>
</tr>
<tr>
<td>Station and hoppers</td>
<td>768.40</td>
</tr>
<tr>
<td>Sewers, water pipe, and fixtures</td>
<td>931.60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$3,200.00</strong></td>
</tr>
</tbody>
</table>

Cost of operation daily:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreman</td>
<td>4.50</td>
</tr>
<tr>
<td>Two laborers at $2.50 per day</td>
<td>5.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$9.50</strong></td>
</tr>
</tbody>
</table>

This force handles 700 cans daily, and could, if necessary, care for 1200 cans in the same time.

While the station described is considered to have served very well the purpose for which it was intended, certain changes are indicated as desirable. These would be:

1. A concrete floor with a centre drain.
2. A roof over the entire building.
3. Inclosed sides to the building, so that the laborers may be protected in stormy weather and the property protected from theft. Sliding or rolling doors should
be used, thus permitting free ventilation while cans are being discharged and washed.

Figures 24 and 39 illustrate dumping stations used at Fort Worth, Texas. These were simply concrete risers over sewer manholes, with a bar screen installed to remove the grosser solids. Water was made available from the city mains for can washing. About half of the stations in Forth Worth were covered. The difference in odor was very noticeable, the covered stations being much less objectionable, though delaying the work of unloading slightly. The cost of the Forth Worth stations ranged from $200 to $500 each.

Figure 40 shows a plan proposed by the Alabama State Board of Health for a can dumping and washing station. In Birmingham, Alabama, tank wagons are used
which are emptied by the opening of a valve. The stations consist of a shed covering a concrete floor, in the
centre of which is a manhole into the sewer. Bar screens protect the sewer from the heavier refuse.

In cities where the can exchange system is in use, the collection wagons bring the cans to the dumping station. Here they may be unloaded onto a platform or unloaded and emptied directly into the hopper. The can is then washed and returned to the wagon. When all have been emptied and cleaned, the rags, bottles, cans, and other débris caught on the screen are thoroughly washed, and then removed and burned or buried. Such stations are usually odorous; or at least the nearby property owners claim them to be. Covering the station will usually reduce the odor, and also the number of complaints.

The advantage of dumping into a sewer is that, once the cans have been emptied into the manhole, there is no further problem. In very rare cases does the extra amount of sewage have any effect upon the method of disposal. The only cost, after the initial installation of dumping stations, is for labor and water. In any place where boxes and cans are used, every effort should be made to secure this means of disposal in preference to burial or dumping into pits or streams.

Very few places practice incineration. For a time, Ranger, Texas, incinerated its can contents by the use of natural gas, there little more than a nuisance because of its frequent occurrence in the oil wells. International Falls, Minnesota, also employed incineration for some years. A few cities which use incinerators regularly for garbage and rubbish disposal, mix the can contents with the combustible refuse and so burn it. Unless some practice of this sort is followed, odors are very liable to result, and the method will be found very costly. There
are very few incinerators that will burn excreta without nuisance and without a great deal of extra fuel. Therefore, except in the few sections where natural gas or other cheap fuel is available, incineration cannot be recommended. Such lack of recommendation is solely upon the basis of cost, for with proper operation, odors can be prevented and sanitary requirements complied with.

In those cities where sewage is treated by tank methods or other means of treatment, the can contents dumped into the sewers will eventually reach the treatment plant, and, mixed with sewage, pass through the usual processes. In such places, care must be taken to see that the disinfectant sometimes placed in the cans is not in sufficient quantity to interfere with the bacterial action of the plant.

The United States Public Health Service constructed three tanks near Newport News, Virginia, for the treatment of excreta collected in the can systems near there. These tanks were designed to operate on the principles of separation of the soluble and non-soluble elements of the sewage, the digestion in special tanks of the latter portions and the chlorination and discharge into tide-water of the former, along with the water used in washing the cans.

None of these tanks ever gave satisfaction. The original design was apparently sound, but improper and unskilled operation, coupled with poor construction work, precluded any chance of success. The method of operation necessary was never followed by the unskilled employees selected to run the plant, with the result that the tanks repeatedly clogged, causing much trouble. Finally the separating tank was omitted in the opera-
tion cycle, and the cans dumped directly into the digestion tank. It is apparent that such tanks rarely can be successful owing to lack of intelligent operation.

The Tennessee Coal, Iron & Railroad Company, which operates extensively in Alabama, uses tanks in several places for treatment of can-type excreta. These tanks are designed on exactly the same basis as ordinary septic tanks, the same capacity per person being allowed. Furthermore, every effort is made to convert the can material to a sewage basis. Much water is added; the can dumping station is at some distance from the tank, so that the excreta are well broken up by the passage through the sewer before reaching the tank. Enough water is added to the can contents to dilute them to approximately the same consistency and strength as sewage.

An installation of this company at Ishkooda, Alabama, consists of a dumping station, septic tank, and sprinkling filters. This operates without trouble and yields a very good effluent, which is discharged into a small stream without nuisance.

Tanks, when properly built and operated, will handle excreta from cans or vaults, if the latter are not too dry, without difficulty. Proper construction means that the same *per capita* volume should be allowed as for sewage treatment; proper operation means that enough water is added to the material flowing into the tank so that it is practically sewage in strength and volume, meanwhile observing the rules given in Chapter XI regarding the operation of small septic tanks. In some places, tank operation seems to be aided by having a small stream of water flowing into the tank at all times.

The successful design of tanks for the treatment of excreta requires the services of a skilled engineer, just
as does the construction of any septic tank larger than that required for a small house. In the larger cities or towns, an engineer often will be able to fit such a tank into a scheme whereby later, when sewers are available for that section, it may be used for sewage treatment. Nearly every installation should be studied separately, and for that reason no data are given here in regard to the details of designs of such tanks.

The value of excreta is entirely in its fertilizing power, wherein it differs from sewage, which possesses some fats and greases. However, the popular mind has grossly exaggerated its value in this respect, as well as the value of sewage and of other municipal wastes. The entire value of the waste products per person, if all this value could be utilized, would be about $1 per year; but not all of it is available. Probably it is cheaper to buy commercial fertilizer than it is to accept excreta or sewage without cost. The same is very generally true in regard to utilization of sludge.
PART THREE

THE TREATMENT OF SEWAGE

Heretofore we have discussed treatment or disposal of excreta by means of the privy, but the privy is no longer adequate when running water has been installed in the house, and bath, toilet, kitchen sink, and other connections are contributing to the wastes from the household. These wastes now consist of a mixture of a large amount of water and a small amount of fecal and other organic matter. This relatively small amount of organic and fecal matter is sufficient, however, to render the entire mixture objectionable and subject to putrefaction. The sewage may also contain disease germs. Some treatment must be given to prevent nuisance and the spread of disease.

The main methods of treatment followed are dilution, or the mixing of the sewage with water sufficient in quantity to prevent nuisance and accomplish purification and clarification, which consists of separating out as much as possible of the organic matter and then treating further, if this is necessary, the partially purified sewage. Tank treatment, screening, and other methods are available for the removal of the organic matter.

Dilution is one of the important methods of municipal sewage disposal, but it is not important in home sewage disposal. Few homes are located near to a stream large enough to handle the wastes without nuisance; there are legal limitations to this method of disposal in most of the states; and the cost of a small
treatment plant will rarely be more than the cost of a sewer line to the stream.

The most generally used process of primary treatment or clarification, so far as the field covered by this volume is concerned, is tank treatment. The sewage is passed through a tank or chamber which slows up the velocity of flow sufficiently to cause the coarser suspended matter to settle to the bottom or rise to the top. The partly-treated sewage, now called the effluent, passes on out of the tank to undergo further, or secondary treatment, if this is deemed necessary.

Septic tanks are most commonly used in the treatment of sewage from homes, institutions, and small communities, though in some places, and under certain conditions, Imhoff or two-story, and plain settling tanks may also be used. Dilution has already been mentioned, and will be discussed more at length in Chapter XIII along with the leaching cesspool, screening, filtration, and other less-used methods of treatment.
CHAPTER XI

THE SMALL SEPTIC TANK

The septic tank treats sewage by sedimentation and septic action. The sewage passes through the tank so slowly that the lighter solids may rise to the top, and the heavier solids sink to the bottom. In addition to this mechanical action, there is a bacterial action, mainly in those solids which have settled out. Bacteria multiply rapidly in the interior of a septic tank, and certain types disintegrate the solids in the absence of oxygen with a reduction both in volume and offensiveness. In this process, the lighter and gaseous portions rise to the top to add to the scum, and the heavier portions, changed to a more stable form, sink to the bottom. The sewage loses its oxygen. The finer matters, and the matters in solution in the sewage, are carried out of the tank for further purification. Gas is formed by the action in the bottom of the tank, and gas bubbles rise, carrying with them particles of the solid material. Some of these particles are caught by the current flowing through the tank, and also carried out.

The work of purification is not completed in the tank. Only the primary process of disintegration goes on there. Technically, this process of septic action may be described as sedimentation, coupled with conditions which allow the sewage to undergo anaërobic decomposition in contact with decomposing solids or sludge. Anaërobic decomposition is that carried on by anaërobes, or bacteria which work in the absence of air. This treatment takes the sewage on its first step toward purification.
The organic matter has been changed to simpler, but not to stable forms.

The next step in treatment is oxidation, or the combination of oxygen with the organic matter present, forming stable compounds. This is accomplished through the action of aerobic bacteria, or those which work in the presence of air and require oxygen for their life processes. The aim of secondary or aerobic treatment is to furnish favorable conditions for oxidation, just as the septic tank aims to provide the most suitable conditions for decomposition. Chapter XIV gives information on those methods of secondary treatment which are applicable to home sewage disposal.

The results of
septic action are the settling out and change of the solid matters to the form of sludge, and the production of a partly purified sewage, called the effluent. This becomes offensive in a few days, especially in the summer, contains much bacterial life, and needs further treatment to render it harmless and inoffensive.

Several causes operate to produce a reduction in the volume of solid matters. A portion of the solids are actually turned into gas or liquids; the changes in the character of these solids are such as to make them compact and reduce the actual space occupied; a considerable amount of the solid matter entering the tank is carried out by the effluent in the shape of finely-divided particles which have been caught up by the current flowing through the tank.

In larger tanks, where sludge removal is frequent, the reduction in volume is about 25 per cent., but may range considerably higher in some cases. In small plants, where the same care in operation is not available, sludge is often allowed to accumulate until it occupies enough space to increase materially the rate of flow of the liquid passing through the tank, thus increasing with the velocity, the carrying power of the current, which takes out more and larger sludge particles. Equilibrium is reached when the flow becomes rapid enough to remove as much sludge in the shape of suspended matter as will balance the inflow of solids. Needless to say, the sewage passing through the tank receives but little treatment when this is the case.

Though the sewage from the single home or small group of homes bears a considerable resemblance to the sewage of a city, there are some important differences. Among these are the greater strength of home sewage,
for city sewage is often diluted by wastes from manufacturing plants, while the usually greater water pressure in a city means a greater use of water; the home sewage is fresher, for the sewage of a city often flows for miles through a network of sewers before it reaches the treatment plant; the flow of sewage from the average home is compressed, almost entirely, within twelve hours of the day, and is variable from hour to hour. Saturday evenings and Monday mornings are periods of especially heavy production of sewage. The greatest hourly rates usually occur between seven and nine in the morning, twelve and two in the afternoon, and six and seven at night.

The amount of sewage per person or per house varies greatly. Much depends on the water pressure, the size of the house, the number of persons contributing sewage, and the number of bathrooms and water-using fixtures. Possibly the flow of sewage from the average home will amount to about 300 gallons per day, or about fifty gallons per person per day.
Factors which must be considered in the design of the small septic tank will include, therefore, the greater strength of sewage, its freshness, and its variable and unknown quantity. Possibly more important yet is the amount of care that each plant may be expected to receive. The average city plant is operated by a skilled attendant; the average home plant receives practically no attention. Reserve capacity should be provided to care for these factors, and sufficient storage provided to equalize the abnormal hourly flows and allow a certain minimum retention period for the sewage. The installation should be as nearly automatic as possible, and should be designed to operate practically without attention.

Many people confuse cesspools and septic tanks. There are actually two distinct types of cesspools, the open or leaching, and the tight. The latter is really but a variation of the septic tank, and the processes going on in it are the same as those which take place in the septic tank.

The cesspool is usually considered as a larger, deeper, and rounder type of construction, and the processes going on in it are not so subject to the control of the operator. In other words, when the cesspool is provided with an outlet and equipped with partitions and trapped overflows it becomes a septic tank. Greater efficiency is attained by these improvements and with an overflow initial capacity becomes less important, so the septic tank is smaller. The septic tank has all of the advantages of the tight cesspool and few of its disadvantages. In fact, there are few places where the tight cesspool can be used economically. The leaching cesspool, which cannot be considered a sanitary means of sewage disposal,
will be considered in Chapter XIII, along with other less important means of treatment of sewage.

A small septic tank is usually designed to provide a storage or retention period of twelve to twenty-four hours, which is considerably longer than the period of retention for the larger tanks, such as those in use in municipal treatment plants.

Given a variable flow such as occurs in homes and institutions, the actual size of the tank needed is open to considerable difference of opinion. It is not considered good practice to install tanks of a capacity less than 200 gallons for any home. Where there are more than seven persons contributing, this should be increased to about 300 gallons, and for more people, still greater capacity is needed. The requirements of the Virginia State Board of Health, which are given below, may be followed in the absence of state or local requirements. These required capacities are as follows:

"The minimum allowable working capacity (volume of sewage below the water line) shall be 200 gallons for families of six persons or less, where not more than one bath and one toilet are used. Required capacities for homes and similar installations shall be:

<table>
<thead>
<tr>
<th>Working Capacity</th>
<th>Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six people or less</td>
<td>200</td>
</tr>
<tr>
<td>Seven to ten people</td>
<td>290</td>
</tr>
<tr>
<td>Eleven to fifteen people</td>
<td>400</td>
</tr>
<tr>
<td>Sixteen to twenty people</td>
<td>500</td>
</tr>
</tbody>
</table>

"For every person in excess of twenty, twenty gallons should be added to the tank capacity. For each additional bath or toilet, add fifty gallons."

Less capacity is required for factories working on a ten-hour basis, and for schools or other places where the tank is not subject to use throughout the entire twenty-
four hours. The regulations of the North Carolina State Board of Health on manufacturing plants and schools are:

"For manufacturing plants with shower baths, working on a ten-hour basis, septic tank capacity is required as follows:

<table>
<thead>
<tr>
<th>Per Capita</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to twenty persons</td>
<td>25 gallons</td>
</tr>
<tr>
<td>Twenty to sixty persons</td>
<td>20 &quot;</td>
</tr>
<tr>
<td>Over sixty persons</td>
<td>18 &quot;</td>
</tr>
</tbody>
</table>

"Where shower baths are not used, the following capacities are required:

<table>
<thead>
<tr>
<th>Per Capita</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to twenty persons</td>
<td>20 gallons</td>
</tr>
<tr>
<td>Over twenty persons</td>
<td>15 &quot;</td>
</tr>
</tbody>
</table>

"For schools (not including boarding schools, which are rated the same as homes), fifteen gallons per pupil are required, with a minimum of 200 gallons."

Many state boards of health have their own requirements with respect to the capacity, size, and arrangement of tanks, and these may differ from those just quoted on account of local conditions or for other reasons. Local or state requirements should always be followed, though the capacities recommended here will usually give excellent results.

Tank sizes as required or recommended by various states are as follows:

Wisconsin requires four cubic feet of tank per person contributing to the tank. On a basis of a twenty-four-hour retention period, this means thirty gallons per capita. Texas requires a minimum retention period of twenty-four hours, but makes no statement in regard to the allowance per person. The Kentucky State Board of Health requires not less than twenty-four hours or
more than forty-eight hours' retention period for the sewage. For single houses the tank is limited to not more than five feet in depth and width. Ohio requires a minimum of 560 gallons for four to ten persons, and fifty gallons per person for all other sizes. Illinois requires a twenty-four-hour retention period and specifies forty-five gallons *per capita*. Virginia requirements have already been given, as have the North Carolina specifications for schools and manufacturing plants. For homes, the North Carolina regulations call for thirty gallons per person up to twenty persons; over twenty persons, twenty gallons *per capita* are required, but for twenty persons the tank shall be not less than 600 gallons capacity. The minimum allowable capacity is 200 gallons.

There are many different opinions in regard to various points of design in connection with the septic tank, such as the shape, length, width, depth, number and location of baffles, depth of outlet, shape and size of compartments, and method of ventilation. Generally speaking, the septic tank will work under almost any conditions of installation and operation, and for this reason it is easy to find an installation bearing out almost any claim. The best course to follow in the construction of such a tank is to avoid extremes and pursue a middle road.

Although it is not likely that best results are obtained where septic tanks are less than about forty-two inches in depth below the waterline, it is often necessary to make them shallower, especially in the smaller sizes, in order to retain proper proportions and to minimize the cost of construction. In the very small tanks, the matter of depth is not extremely important, though too shallow a tank should be avoided. Tanks should not be more than five feet in depth unless the capacity be in the neigh-
borhood of a thousand gallons or more. The Virginia State Board of Health regulations in regard to depth are:

<table>
<thead>
<tr>
<th>Capacity (gallons)</th>
<th>Minimum Depth (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>30</td>
</tr>
<tr>
<td>290</td>
<td>30</td>
</tr>
<tr>
<td>400</td>
<td>36</td>
</tr>
<tr>
<td>500</td>
<td>36</td>
</tr>
<tr>
<td>900</td>
<td>42</td>
</tr>
<tr>
<td>1,500</td>
<td>42</td>
</tr>
</tbody>
</table>

So long as sensible proportions are observed, the shape of the tank is not very important. Circular tanks have given good results. In the case of rectangular tanks, the width should usually be from 40 per cent. to 60 per cent. of the length. Too much width results in dead corners and possible short-circuiting, or direct passage of the sewage from the inlet to the outlet. Too narrow tanks do not permit proper settlement of the sewage, as the velocity of flow is not slowed sufficiently.

The Virginia requirements call for a clearance between the flow-line and the top of the tank of seven inches in tanks up to 500 gallons capacity, and of twelve inches for larger tanks. Where possible, a 12-inch clearance should be obtained. The general practice is to locate the outlet, usually by means of an elbow, in such a way as to draw sewage from a point about eighteen inches below the waterline of the tank.

Almost every kind, shape, location, and type of baffle and partition has some advocates. Slanting baffles have been tried out, after the fashion of the Imhoff tank. In general, the baffle will best be placed so as to give the effluent chamber from one-third to one-fourth of the total capacity of the tank. The shape of the baffle is not very important, so long as the division of the compartments is proper, and the sewage is allowed to pass freely from one compartment to the other. The methods most used are a wall or partition with a hole, bend, or slot in
it, or two baffles, one hanging and one standing. The opening should be about the same depth as the tank outlet, that is, about eighteen inches below the waterline, so as to prevent stoppage from scum.

Many tanks work well which have but one compartment, with a submerged inlet and outlet. Notable among these are the tanks built by Fletcher of the New Hampshire State Board of Health in the summer resort regions of that state. Figure 43 shows a tank after the plans of Fletcher. The general practice, however, has been to divide the tank, by some sort of a wall or baffle, into two compartments. Such tanks work very well. A few designs call for more than two chambers, but such plans require an extra expense without corresponding increase in efficiency.

A variation of this is the battery method, where a number of small tanks of 200 or 300 gallons each are
placed in a row or battery. There is one such installation in use that numbers over sixty tanks. This is generally done to avoid the construction of a large tank, or for purposes of convenience. The result is that the first tank gets all the heavier parts of the sludge, until it becomes filled, when the process is transferred to the second tank, and so moves on down the line. Also, this installation is similar in action to a long, narrow tank, in which the velocity in the small channel remains great enough to prevent proper sedimentation. Under no circumstances should an installation requiring more than four such tanks in a row be approved. The Virginia requirements fix a maximum of three tanks in a battery, and such a restriction is a very wise one.

The question as to the distance a septic tank or its subsurface disposal system should be located from a well or spring, is an important one. Several states specifically limit the minimum distance to fifty feet, but allow a tight line to be used in case it is necessary for the line carrying the sewage to the tank or from it to the subsurface disposal system to pass closer to the water supply than this. If possible, it is better to limit the distance to not less than 100 feet, except where a tight line, preferably iron, is used. Septic tanks, though watertight, should not be permitted closer than fifty feet, as in case of stoppage, they may overflow.
To operate properly and to prevent pollution of the ground or the ground water, septic tanks should be watertight. Any material is permissible, so long as it is durable and does not leak. Concrete, cement mortar, brick laid in cement mortar, and metal are the most popular materials. Vitrified tile is generally not so satisfactory because it is not strictly watertight, and may sweat or leak under a small head. However, many excellent tile tanks are in use.

The Virginia State Board of Health has adopted the following requirements as to materials of construction:

"Concrete Tanks Cast in Place."—Where tanks are to be cast in place, the walls and top shall be not less than four inches in thickness, and the bottom six inches. The mixture shall be of Portland cement, sand, and gravel or broken stone, properly graded, and in the proportions of not less than one part of Portland cement to two parts of sand and four parts of stone or gravel. Broken stone or gravel shall be clean, sharp, and free from foreign materials. Where no gravel, stone, or coarse aggregate is used, the mixture shall be one part of Portland cement to three parts of sand or less. Cinder concrete shall not be permitted.

"Precast Concrete Tanks."—Precast concrete tanks shall be not less than two inches in thickness, it is recommended, and be properly reinforced. The mixture shall be one part of Portland cement to one part of clean, sharp sand. Watertightness must be guaranteed.

"Metal Tanks."—These shall be made of iron or copper-bearing steel, not less than 14-gauge in thickness, and shall be protected by a paint, asphalt, enamel, or other protective covering, all metals and coverings to be
THE SMALL SEPTIC TANK

approved by the State Board of Health. Metal tanks must be guaranteed as to life and watertightness."

As a general rule, concrete for septic tanks should not be mixed leaner than 1:2:4, and should be placed carefully to avoid leaks in the tank. Portland cement must be used, as other cements are not sufficiently strong for the work. All concrete or mortar tanks should be reinforced. Metal tanks should have the seams or joints electrically welded to insure tight and permanent joints. Brick septic tanks, with the brick laid in cement mortar, and lined on the inside with a coat of the same mortar, are very satisfactory, but costly, and there is usually little reason for their use, as cheaper materials are usually available. They have no special advantages.

There is a difference of opinion on the matter of ventilation, some engineers and sanitarians holding that the tank should be tight, so that the gas generated by septic action will build up a slight pressure inside the tank. Others hold that ventilation is necessary. Actually, many tanks of both types are in satisfactory operation, and it is doubtful if the matter is a very important one.

<table>
<thead>
<tr>
<th>Piece No.</th>
<th>Diameter</th>
<th>Piece No.</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>1x8x18 inches</td>
<td>F</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>2x8x26 inches</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>24</td>
<td>1x8x15 inches</td>
<td>H</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>2x4x18 inches</td>
<td>I</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>2x4x20 inches</td>
<td></td>
</tr>
</tbody>
</table>

Material for making tank:
9 sacks cement, 
1/2 yard sand, 
1 yard broken stone or gravel.
As in the case of the septic closet described in Chapter VIII, anyone familiar with the use of a saw and hammer and able to mix and pour concrete, can construct a septic tank. The description of the method of constructing the Kentucky Sanitary Privy also applies to the work of building a small septic tank, and the forms used in that work can be applied, with small changes, to the construction of a septic tank.

The points of difference to be observed between the septic closet construction described on pages 93 to 96 and a septic tank of the same size, are that an additional elbow must be provided at the rear end of the tank nearest the house to take the sewage coming from the house through the sewer line and that a flat top can be built over the entire tank. This top eliminates the rather complicated construction of the seat riser and seat. No house is needed for the septic tank, but it should be constructed somewhat deeper in the earth than the septic closet, so that the discharge elbow will be twelve to eighteen inches underground. In some cases, it will have to be deeper than this, as it must be placed on the same level as the house sewer.

The size of the tank described on pages 93 to 96, when used with running water and flush toilets, is sufficient for the average household of five people. For more
than five people, a larger tank should be built. The forms for such a tank may be of the same general construction as those shown. Figures 44 and 46 show plans and forms for a simple 270-gallon tank suitable for five to ten people.

The same firms that manufacture septic closets turn out septic tanks. These are made of cement mortar and of iron. The same advantages are possessed by commercial septic tanks as by commercial septic closets. They are cheap, in the case of the individual installation, easy to install, and built from good designs. The cost for these is generally slightly less than for septic closets, as the seat and vent are omitted. Metal tanks retail for $50 to $65 each, and the cement tanks at a slightly lower price. Extra freight charges, on account of the weight of the cement tanks, make the final price about the same. The smallest size manufactured is 200 gallons. Larger tanks may be purchased for about the same proportionate prices.

Septic tanks, especially the larger ones, discharge large quantities of water. This discharge is in the shape of a continual trickle or overflow, with the result that the first few sections of the tile line will receive more than their share of sewage, and soon may
Fig. 49.—A complete installation for a large rural home. General layout on a contour plan and construction drawings. Note abandonment of old cesspool near the well and garden and removal of sewage to a lower and safer location in the pasture, where the treatment is subsurface distribution, aided by numerous filter wells about 4 feet deep filled with coarse gravel. Note that sludge is removed from the bottom of the settling chamber by opening the gate on the sludge drain.
Fig. 50—Layout for septic tank and secondary treatment.

The small septic tank

Courtesy Virginia State Board of Health.

This type of trench may sometimes be used in heavy soils not hard-pan or impervious clay.

Sub-surface tile: Two methods of laying.

In filling the trenches with gravel or cinders aids in the absorption of the liquid not necessary when soil is light and porous.

Detail of siphon with water at level of fill with water of sufficient depth to allow backwash of siphon after cleaning.

Outlet from sump tank.
become overdosed. A dosing tank and siphon should be installed.

The dosing tank is a tank having a capacity of one-third to one-tenth of the septic tank capacity, into which the trickling overflow of the septic tank discharges. A siphon is installed in this tank and when the sewage rises in it to a predetermined height, the entire accumulation is flushed out or discharged rapidly and distributed by the sudden flow to every part of the tile line, thus ensuring that all parts of the distribution area receive equal doses of the effluent.

The additional cost is small. The siphon for the ordinary small tank will cost from $15 to $25, while the cost of the additional small tank will be even less. The siphon is entirely automatic in action and has no moving parts to wear out.

At rare intervals, as once in two or three years, the smaller septic tanks will need cleaning out. The sludge taken from the tanks should be buried. In the larger tanks, sludge removal is necessary at intervals of six months to a year, and a sludge drying bed is often furnished for curing the sludge. This usually consists of a gravel or cinder bed, underdrained, upon which the sludge is spread to dry. The effluent or liquid wastes from the tank must be given further treatment, either by subsurface irrigation, sand filters, or others of the methods described in Chapter XIV.

Figure 51 illustrates a septic tank designed by the Maryland State Board of Health for the use of five to ten persons. This is an elaborate and rather costly design, though an excellent one, and will give good service. Capacity somewhat in excess of 1000 gallons is provided, which is sufficient for about twenty persons. A siphon chamber
is built as a component part of the tank. A pipe is arranged for sludge removal, which is another good point in design, as cleaning is made easy. It is necessary only to open the valve in the pipe, as the hydrostatic pressure in the tank forces the sludge out. The extension of the...
pipe allows a rod or hose to be pushed down for breaking up the sludge if it should tend to plug the pipe. A wooden cover is provided in the plans, but the construction of a concrete cover would be easy, if desired.

A tank suitable for twenty persons or less is shown in Fig. 43, after the design of Fletcher, but taken from Public Health Reprint No. 625, by H. R. Crohurst. The most noticeable characteristics about this tank are the tight cover and the depth, which is fifty-four inches. The inlet pipe discharges sewage from a depth of thirty-six inches beneath the surface, while the outlet pipe takes sewage from a depth of thirty inches. Both of these figures are somewhat in excess of usual practice. A notable feature is the entire absence of baffles. The capacity is about 700 gallons, or thirty-five gallons per person. This type of tank has been in successful use in New Hampshire summer resorts for more than ten years. Two simple septic tanks of 270 and 405 gallons capacity each are shown in Figs. 44 and 45. These tanks have been built quite freely in Alabama, and have been very satisfactory in operation. The forms necessary for the construction are shown in Figs. 46 and 47, and the material needed for the forms listed.

Commercial tanks must be designed with a minimum of excess size in order to keep the price as low as possible. Figure 48 shows a metal tank with a capacity just over 200 gallons. The tank is suitable for families having not more than five or six members, though a larger tank is better. The tank is very light in weight and easy to handle and install. Tanks of this general style have been sold in large numbers.

Commercial cement mortar tanks of about 200 gallons capacity are also popular. In order to keep the unit
weight down, these tanks are generally made in two sections, one tank acting as effluent and the other as sludge chamber. Larger tanks, up to nearly 400 gallons, are also made. The tank shown in Fig. 32 makes use of a slanting baffle, somewhat after the fashion of the Imhoff tank. This design allows more space in the bottom for the digestion of the sludge, while at the same time allowing a greater surface area for scum on the top. No special advantage appears in this tank in operation.

Considerable difficulty is sometimes caused in the operation of small septic tanks by the presence of grease. This may come from the kitchen, or from the use of large amounts of soap in washing or bathing. It soon forms a scum upon the surface of the liquid in the settling tank and may eventually become thick enough to flow out through the effluent line and clog the disposal field. Septic action has no effect upon this grease.

The best way to avoid grease trouble is to prevent the grease from entering the tank. This can be accomplished by the use of a grease trap on the lines from the kitchen or other grease-producing places. A grease trap is merely a small tank which will retard the flow of the wastes while the grease rises to the top. The liquid waste is drawn off from beneath, and the grease skidded
off at intervals from the tank. Figure 54 shows several simple forms of grease traps.

The presence of appreciable quantities of disinfectants and acids in the sewage will kill off the bacteria causing septic action and stop the working of the tank. Nothing that might interfere with the action going on inside the tank should be allowed to enter the sewage.

Ordinarily very little attention is required to maintain a septic tank in good working condition, though it should be observed frequently to see that it is operating properly. There should be no odor more serious than that of stale dishwater; and usually none. The effluent

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**Figure 53.**—Typical two-chamber concrete septic tank. Recommended dimensions and quantities are:

<table>
<thead>
<tr>
<th>Number of persons</th>
<th>Quantity of sewage in 24 hours (Gals.)</th>
<th>Capacity below flow line (Gals.)</th>
<th>Length (Ft. In.)</th>
<th>Depth (Ft. In.)</th>
<th>Width</th>
<th>W.</th>
<th>X.</th>
<th>Y.</th>
<th>Z.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>180-280</td>
<td>240</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>320-480</td>
<td>420</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
<td>520-680</td>
<td>620</td>
<td>5</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>3</td>
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<td>720-960</td>
<td>860</td>
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<td>0</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>
Ready-made grease trap, vitrified earthenware. Temporary sealing of putty.

Homemade grease trap, Concrete or well-plastered brick work, elbow, cross and increaser to be recessed drainage fittings.

Type of grease trap used at U. S. Army camps.

Fig. 54.—Three styles of grease traps.
THE TREATMENT OF SEWAGE

should be fairly clear and odorless. The presence of a large amount of suspended particles of black sludge in the effluent will indicate that some sludge should be removed. If no means of sludge removal by pipes or drains is provided, it will be necessary to remove it with a bucket or a pump, bailing out the entire tank if that becomes necessary.

The sludge may be buried, burned, if any provision for doing this is at hand, used as fertilizer, or dried. If deposited upon a sand or cinder bed, it will gradually become dry and lose most of its offensiveness. It is then in better shape to use as fertilizer than when first taken from the tank. In neither state should it be used as fertilizer for crops eaten raw. From time to time if the scum on the tank appears to be too thick and heavy, it may be broken up by a stream of water from a hose, or by a stick.

With careful treatment of the effluent from the tank, this means of sewage treatment is a very safe one. Very little care is required, and the cost of maintenance is practically nothing. The life of the tank is almost unlimited. In convenience, economy, and compliance with sanitary requirements, this method of sewage treatment leads all others so far as the problems discussed in this book are concerned.

The rather high first cost, when the installation of running water in the home is also considered, and the necessity for care in the final disposal of the effluent are practically the only disadvantages worth mentioning. The final disposal of the effluent is a simple matter in sandy soils; in tight clay soils it is a real problem; in limestone sections it offers a chance for dangerous pollution. This is discussed more fully in Chapter XIV.
THE SMALL SEPTIC TANK

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CHAPTER XII

SMALL IMHOFF TANKS

The Imhoff or two-story tank is a variation of the septic tank principle, by which sewage is allowed to undergo active bacterial decomposition. Compared to the septic tank, two new principles are introduced. Provision is made so that all matters in the sewage which will settle or float are separated from the remainder of the sewage. These matters compose most of the objectionable elements of the sewage, and their elimination is a big step forward. The sludge is allowed to decompose away from the sewage passing through the tank, which eliminates a large part of the odors and makes the final treatment of the effluent easier.

This is accomplished in Imhoff tanks by dividing the tank into two compartments, one above the other. On top is the settling chamber, which is connected by means of a trapped slot with the lower or digestion chamber. The sludge, settling out of the sewage which flows slowly through the settling chamber, drops down into the lower or digestion chamber, is trapped there, and undergoes decomposition in the absence of oxygen.

The Imhoff tank, which was developed in Germany by Dr. Karl Imhoff, has been used extensively in the United States and Europe. The tank is patented, and American users are obliged to pay a small royalty. The Pacific Flush Tank Company, New York, N. Y., are the American agents for the Imhoff tanks.

The Imhoff invention marked a considerable advance in sewage treatment. The disadvantages of the plain septic tank when used for treating city sewage are
important, but in smaller installations, as in homes and institutions, these disadvantages are much less marked. Odors and the difficulty of sludge disposal and treatment are among the principal handicaps of the septic tank. The Imhoff tank sludge is far easier to treat than septic sludge, and the odors of operation are largely eliminated. There are usually some advantages in the quality of the effluent as well, these including less suspended matter and greater freshness.

As a consequence of the disadvantages of the septic tank, the Imhoff tanks were rapidly taken up, and since their introduction into this country, very few large septic tanks have been built. The importance of the Imhoff tank in the field of municipal and similar large installations is much greater than it is in the case of residential and institutional sewage treatment. There are few advantages in their installation for small homes or groups of homes, as the operating results in these cases are not much better, and the cost almost always higher than small septic tanks.

Where not less than twenty people must be served, it may be economical to install the small Imhoff tank; at least such installation may not be much more costly than a septic installation. The two-story tank requires much more attention in operation that does the septic. Odors are reduced, which in some communities is an important item. Otherwise the selection of this type is largely dependent upon the judgment of the engineer as to its practicability and its place in the scheme of sewage treatment.

The principle and method of operation of the Imhoff tank are described very clearly by Frank and Rhynus in Public Health Bulletin No. 101. The following descrip-
tion of the operation of the Imhoff tank is abstracted from that bulletin:

The Imhoff tank (Fig. 55) is divided into two compartments, the upper or settling, and the lower or sludge digestion chamber. These communicate only through a long narrow slot at the bottom of the upper chamber. The sewage flows quietly through the settling chamber, permitting the lighter solids to float to the surface, and the heavier solids to settle to the bottom of the chamber and slide through the slot into the sludge digestion chamber below. Here these solids decompose in the absence of oxygen and finally form a deep black sludge of a very uniform consistency, which may be removed from the tank and dried without offense. During the process of decomposition gas may develop within the sludge particles, causing many of them to become lighter than the water surrounding them. These gas-laden particles disengage themselves from the heavier sludge and rise into the scum chamber above. Some of them remain permanently in the scum chamber, while others give up their gas, and becoming heavier than water, sink again to the sludge chamber. It will be noted that none of the rising sludge particles or gas bubbles can find their way into a settling chamber, as the overlapping of the slot prevents this. It is this complete separation of the digesting sludge from the through-flowing sewage that keeps the latter from becoming septic and generating unpleasant odors. All sewage, even in its freshest state, contains anaerobic organisms, but considerable time is required before the anaerobic process reaches the stage at which unpleasant odors are produced. Samples of raw sewage may be kept for several days at ordinary room temperature without becoming offensive, though
Fig. 55.—Perspective and sectional views of Imhoff or 2-story tank. Sewage passes through settling chamber, solids settling out and sliding through slot into sludge chamber, where reductive bacterial action takes place.

**PERSPECTIVE**

**MINIMUM**

**CROSS SECTION**

**SECTION A-A**

**PLAN-COVER REMOVED**

- Sludge pump and pipe in place
- Sludge Chamber
- Slope 15 to 10
- Chamber
- Outlet
- Sludge Chamber
- Water level
- Put in place
- Inlet
- 6" Plank Cover
- 6" Pipe
- 6" Baffles
- 16"
they eventually will become so. But if the sewage is inoculated with large amounts of anaerobic sludge, as is the case when sewage enters a septic tank, the process is hastened and odors develop much sooner. For this reason, the Imhoff tank will yield an effluent free from odors where the septic tank effluent would cause nuisance. The separation into two compartments also prevents the disturbances of the settling action by means of the rising gas bubbles.

With the Imhoff tank there is no unpleasant odor from the tank itself; the effluent is fresh and may be exposed to the air without producing nuisance; the sludge is greatly reduced in volume by the process of decomposition; and the decomposed sludge may be removed from the tank and dried without offense.

Factors in the design of the small Imhoff tank include the capacity of the settling, scum, and sludge chambers; the depth of the tank; the design of the slot and overlap; and the inclination of the inner surfaces of the settling chamber. Essential points in regard to each of these will be taken up in turn.

The capacity of the settling chamber will depend upon the amount of sewage to be treated. In larger plants, capacity is such that the retention period of the sewage in the tank is not more than two and one-half or three hours, usually less. As pointed out in the preceding chapter, the flow of residential sewage is, however, compressed within twelve hours of the day, and even then is highly variable. To care for such conditions, the settling chamber must be made proportionately larger. Too great a capacity will tend toward septicization or staleness of the sewage, but this point is not so important in dealing with house sewage, which is fresh. Therefore,
a capacity great enough for a mean retention period of five to six hours may be adopted. This would give a retention of two and one-half to three hours at the time of greatest flow.

Shape is also important. The settling chamber should be of such dimensions that the sewage will pass through evenly, with the least inclination to short circuit or to stand in dead corners. A width of one-third to one-half of the length is generally satisfactory for the settling chamber.

The size of the sludge chamber, as recommended by Frank and Rhynus in Public Health Bulletin No. 101, is 3.5 cubic feet per person contributing to the tank, this volume to be available below the lowest edge of the inclined surface of the settling chamber. There is little information available regarding per person capacity of sludge chamber for small tanks, though data are plentiful for large installations. For Imhoff tanks serving cities, from one and one-half to two and one-half cubic feet per person are allowed for sludge chamber capacities. The sludge is drawn off more frequently in the case of large tanks than with small ones.

There is also a minimum size for sludge and settling chambers in small tanks, below which it is not economical to go, from a construction viewpoint. This is one of the factors that limits the economical use of small Imhoff tanks to installations where not less than twenty to twenty-five people are served.

The scum chamber is that part of the tank above the sludge chamber, excluding the settling chamber. Particles rising from the sludge chamber are prevented from passing into the settling chamber by the trapped slot, but are diverted to the scum chamber. This must be large
enough to care for the floating sludge particles, without overflowing. Frank and Rhynus recommend about one-third square foot per person area, and about twenty gallons per person volume above the slot. The tendency of late has been to increase the scum chamber area.

The depth of the tank is important. Large Imhoff tanks, until recently, have been designed for a depth of twenty-five to thirty-five feet. Small tanks cannot have such a depth. Recent installations of large Imhoff tanks have shown satisfactory operating results with depths much less than those given above. Small tanks may be six to twelve feet or more in depth. Greater depth tends to produce a better sludge, but increases the cost.

The slot connecting the settling and sludge chambers must be large enough to allow free passage of all settling substances, and to prevent clogging. It must also have an overlap or trap to prevent matter from rising into the settling chamber. The opening of the slot in small tanks should be not less than four inches, while five inches is better. The slot overlap should be about two inches.

The inner surfaces of the settling chamber must have sufficient inclination to cause the settling particles of solid matter to slide off through the slot. Much will depend upon the material of construction. Smoothness is desirable. In some late installations, wire-glass panes have been used for the sloping surfaces. They have the advantages of not corroding and of being easily cleaned. The inclination should be at least 1.5 vertical to 1 horizontal, and 2 to 1 slope is better. A steep slope has the disadvantage of requiring a deeper tank for the same sludge capacity.

From a study of these points in design, it will be
seen that the total capacity of an Imhoff tank must be much greater than that of a septic tank to handle the same volume of sewage. For a family of six people, the settling chamber capacity would be seventy-five gallons; the sludge chamber capacity 160 gallons; the scum chamber 120 gallons; or a minimum total capacity of 355 gallons. A septic tank of 200 gallons would handle the same volume of flow.

An Imhoff tank has been designed by the Illinois State Board of Health to care for the wastes from a household of ten people. Owing to the uneven rate of flow in such small installations, the retention period advised is five to six hours, or two to three times the period of larger Imhoff installations. This tank is one of the deeper of the small designs, and calls for a depth of sewage of about twelve feet, and a total depth of fifteen feet or more. The total capacity of the tank is nearly 1000 gallons, which is considerably more than is considered necessary for a septic tank for the same number of people.

This tank is three feet wide, with the settling and scum chamber areas equal, and four feet long. Scum boards are placed six inches from the inlet and outlet pipes. A sludge removal device is provided, so that the sludge can be drained easily by the opening of a valve.

There seems no reason why this tank could not be constructed with a depth about four feet less than recommended by the State Board of Health. This would make the construction cost much less, but sludge removal would be necessary more often.

A tank of about the same capacity, but shallower, is that shown in Fig. 56, designed by the Ohio State Board of Health. The tank is planned to care for the wastes
Fig. 56.—Two-story tank for 10 people.

Courtesy Ohio State Board of Health.
of ten people. The depth of sewage is nine feet six inches, the width of the tank three feet eight inches, and

the length, four feet six inches. Scum boards are placed ten inches from the inlet and outlet, and the scum chamber has an area of 45 per cent. of the surface of the tank. A smaller chamber is provided for receiving the dis-
charged sludge which is handled by the usual form of sludge removal pipe.

A third small Imhoff tank is shown in Fig. 57. It was designed by Leslie Frank and C. P. Rhynus, and is described in Public Health Bulletin No. 101. It is built to handle 150 gallons of sewage daily, has a settling chamber of sixty gallons capacity, and provisions in the sludge chamber for five cubic feet per person. The tank is three feet wide, four feet long, and six feet deep, with a depth of sewage of five feet. Scum boards are placed twelve inches from each end. For a family of six persons, discharging 320 gallons of sewage, the same tank is used in combination with a different form of secondary treatment. Various designs of small Imhoff tanks and secondary treatment combinations are shown in the bulletin mentioned above, and valuable information is given in regard to design.

The Ohio State Board of Health has also designed a two-story tank for school use. This tank will care for the sewage from 250 pupils, the basis of design being a flow of fifteen gallons per pupil per day. The flow may be passed through either or both settling chambers, with a detention period of four hours when sewage is passing through both channels in series, and half that time when the channels are used in parallel. The total flow of 3750 gallons is assumed to take place in the eight hours in which school is in session. Slots and overlap are both six inches. The sludge compartment has a capacity of 200 cubic feet, which is estimated to be sufficient for the sludge accumulation of the entire nine months of school so that sludge removal will be necessary but once a year. The gas vent or scum chamber has an area of about 17 per cent. of the total surface area. The extreme depth of
the tank is twelve feet four inches, and the total capacity about 5000 gallons. The usual form of sludge discharge pipe is provided.

No figures of cost are given for the tanks just mentioned, and such costs will vary for local conditions, while costs for the past five years are nearly worthless, as far as comparisons go. However, in practically every case, the cost of a two-story tank will exceed considerably the cost of a septic tank of sufficient capacity to care for the same number of people. Extra depth of excavation, more intricate form and concrete work, and greater capacity per person are among the important elements in making the cost higher. There is no doubt but that the above tanks, or tanks similarly designed, will operate well and produce good effluent and sludge, but it will be necessary to decide for every case whether the extra cost of Imhoff construction and the greater care necessary in operation, will be balanced by better results.

The same secondary treatment must be given to the effluent from Imhoff tanks, as with septic tanks. Sludge from an Imhoff tank, while treated in the same manner as septic sludge, will be found to be much easier to handle and dry. Further data on treatment of sludge and effluent will be found in Chapter XIV.

The Imhoff tank requires considerably more attention and care in operation than does the small septic tank. The slot at the bottom of the settling chamber must be kept open, and it is well occasionally to squeegee or scrape the walls of the settling chamber with a horizontal strip nailed to the end of a pole. The scum on the gas vent or scum chamber must be broken up and allowed to sink to the bottom at intervals. If this tends to foam and rise, and cannot be controlled by breaking up, sludge
Fig. 58.—Isometric view of Imhoff tank and lath filter plant for 10 people. Sewage enters through influent, D₁, and passes under partitions A₂ and A₃. Solids, settling out, fall through slot E₁ into digestion chamber below. Rising gas bubbles and solid particles cannot interfere with sewage, as they are deflected by ledge F₁. Secondary Imhoff tank is shown under lath pile. This removes additional suspended matter after secondary treatment by lath filters.

must be drawn off from the bottom of the tank. It is necessary to observe precautions against disinfectants entering the tank, as any large amount of such will stop
the action of the tank, by killing off the bacteria in the tank and preventing the reducing and stabilizing actions normally taking place there.

The Imhoff tank is usually not covered, though a board top may be constructed. This allows inspection. Bubbling in the settling chamber is a sign of trouble and slots and walls should be cleaned, and it should be ascertained that the sludge chamber is not too full.

The advantages of the Imhoff tanks have already been detailed. They include a better sludge and effluent, with less odor, as well as easier final disposal of the sludge. The only disadvantages are those of greater cost and the need for greater care in operation. The two-story tank cannot be built by the ordinary person, owing to the many factors entering into the design, and an engineer with special knowledge along this line is needed, both for design and construction.

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CHAPTER XIII
OTHER MEANS OF TREATMENT

In the eight chapters immediately preceding, the various types of privies in most general use, and the simpler methods of sewage treatment have been described, and their advantages, disadvantages, and limitations pointed out. In this chapter short descriptions will be given of other methods of treatment not in such general use nor possessing such advantages for the average home, institutional, or small community installation. Many of these methods are in more or less general use in the treatment of sewage from cities, but with rare exceptions, they have no place in the field covered by this volume.

A cesspool is a basin or pit in the earth for the reception of effluent from a flush toilet or, more rarely, for the catchment of excreta. Cesspools have already been classified in Chapter XI as open or leaching, and tight, and the tight cesspool has been discussed under the head of septic tanks, where it rightly belongs, since the processes in the two are practically identical. The open or leaching cesspool is commonly made by digging a hole from six to twelve or fifteen feet deep, and ten or twelve feet in diameter, and walling up to prevent caving, if this is necessary. The walls are loosely laid so that as much as possible of the liquids discharged into the tank will seep out into the soil.

The subsoil in the vicinity of such a cesspool becomes heavily polluted, the distance of travel of such pollution depending upon the type of soil and the depth of ground water. (See Chapter XVI.) The depth is usually great
enough to place dangerous contamination within reach of the ground water, thus increasing the danger. It will be noted that the better the cesspool works as a distributor of sewage, the more dangerous it becomes as a possible source of pollution to water supplies. It is the custom in some sections to shatter the subsoil beneath the cesspools with dynamite in order to get a better distribution of the sewage. This practice greatly increases the danger. The open cesspool should be prohibited. As ordinarily constructed, it is a distinct menace to the health of the community.

Two forms of tank treatment have already been described in the two preceding chapters. In addition to septic and Imhoff tanks, various other types of tanks are used in municipal sewage treatment, one of the most important being the plain settling tank. Settling or sedimentation tanks are plain chambers through which the sewage flows quietly, while the same settling action as already described in the case of the septic tank takes place. The essential difference between settling and septic and Imhoff tanks is that in the former the sludge is removed at intervals of a week or ten days, while in the two latter the sludge is allowed to remain and digest or undergo bacterial action. In the settling tanks, the scum which rises to the top and the sludge which settles to the bottom are in a fresh state, sticky, foul-smelling, and difficult to handle and dry. The final disposal of these wastes is a difficult matter, as well as a disagreeable one. Sludge removal is necessary at frequent intervals, or septic action takes place, and the sedimentation tank becomes a septic tank.

Regular attention is necessary, as the sludge and scum become septic in a week or ten days in the summer.
Because of the need for this attention and the disagreeable nature of it, plain settling tanks are rarely suitable for home use. Without this necessary attention the plain settling tank loses its only advantage, that of having an effluent fresher and carrying less suspended matter.

The biolytic tank employs the general principles of septic action, and is really a modified form of the septic tank. Its design is based on the belief that the more or less solid sludge in the ordinary septic tank interferes with the process of decomposition, and that continuous agitation, with continuous removal of the products of decomposition, would render the process of decomposition more nearly complete. This agitation is usually accomplished by means of the incoming stream of sewage. The biolytic tank has been operated mainly, if not entirely, under experimental conditions and is not suited, in its present stage of development, for home or institutional sewage treatment. The tendency of the action is to intensify the natural aptitude of the septic tank for odors, and unless expertly and carefully operated, it is very liable to become a nuisance.

Dilution is a very important and widely used means of sewage disposal, but it is much more important in the large plant field than it is for home sewage disposal. More than four-fifths of the people served by sewerage systems discharge their sewage untreated into water. As a means of treatment for a city, under expert engineering advice, dilution may be permissible, but the indiscriminate discharge of sewage into small streams, with no regard to the ultimate effect upon people living farther down stream, should not be allowed. Most states through their Boards of Health do prohibit such use of the streams except by special permit after investigation.
Many formulae have been given in regard to the volume of flow of streams necessary to carry off without nuisance the wastes per person. Generally, no nuisance will result where the flow of water is thirty or forty times as great as the flow of sewage. Other conditions favorable for successful disposal by dilution are thorough mixture with or diffusion through the water, swift currents to aid in dilution and mixing, and removal of the objectionable solids from the sewage.

Home sewage is generally fresh. By passage through a septic or Imhoff tank the coarser solids easily can be removed. The other qualifications depend largely upon the stream itself and generally can be replaced by one condition, which is ample dilution. Under these conditions of fresh sewage, already partly treated, and ample dilution, this means of treatment may be practiced, if the permission of the State Board of Health has been secured. Under no condition should untreated sewage be discharged into a small stream.

Irrigation is practiced but little in this country, about the only places being those sections where the moisture conditions are such that the water in the sewage is valuable. Irrigation has no place in home sewage disposal methods as it causes odors, may permit and cause dangerous soil and water pollution, requires a large area, and demands a considerable amount of attention.

Intermittent sand filtration is another of these methods of sewage treatment which are highly effective in cities, when planned by a trained engineer and operated by a skilled attendant, but which are of doubtful value in small installations made without the benefit of experience in construction and operated without skill or care.

Intermittent sand filters furnish a cheap and excellent
method of sewage treatment in those sections where soil conditions are such as to allow their use without costly construction. Natural formations occur in Massachusetts, for instance, and many of the cities of that state use this method for treating their sewage. The requirements are a sandy or gravelly soil, with ground water some distance below the surface. In most places, artificial underdraining of the beds is necessary.

Sewage should be given some preliminary treatment, as screening or sedimentation, with or without septic action, to remove the grosser solids. Careful operation, with frequent rests for the beds, is necessary. The results, under such conditions, are excellent.

In the small-plant field, a handicap is the attention necessary if the plant is to operate properly. Sand filters may cause odors if improperly operated, and therefore are not wholly suited for use in thickly settled regions. Indeed, this method is scarcely ever one for the home, though it may be used in institutional sewage treatment, where large areas of land and proper care are available.

One method of disinfection has already been described, the chemical toilet. Disinfection, whether by the chemical toilet or by other means, is an extremely efficient means of elimination of pathogenic bacteria. For primary treatment it is costly. It is coming more and more into use as a means of final or secondary treatment of tank effluent. Preliminary treatment, as in a tank, or by screens, is necessary. Properly operated, all, or practically all, bacteria are killed. Liquid chlorine and hypochlorite of lime are the favorite disinfecting agents. Disinfection is not generally necessary for the small
OTHER MEANS OF TREATMENT

plant, but if desired may be installed at a moderate cost and operated with a small amount of attention.

The activated sludge method of sewage treatment is one of the later developments, and is not yet in general use for municipalities, though gradually becoming so. In this method, air is discharged into the sewage. The object is two-fold. An abundant supply of oxygen is furnished to support the aërobic action of the bacteria, and the passage of the air produces agitation of the tank contents, assuring the continuous and intimate contact of the particles of activated sludge with the sewage. The main advantages are the good and highly purified effluent, and the condition of the sludge, which is easily dried and which has some fertilizer value.

At present, the activated sludge process is confined to cities of considerable population, and has no place in home, institutional, or small-town sewage treatment. One of the smallest installations to date is that at Gastonia, North Carolina, a town of about 20,000 population.

German engineers have used the fine screen for removing the coarser solids from sewage. In this country there are several screen installations, most of these being used for clarifying sewage before discharge into streams or into the ocean. The disposal of the screenings offers some problems. Like the activated sludge method, screening is rarely, if ever, applicable to residential or institutional work.

The sewage treatment plant for the domestic field must be one that will operate with a minimum of attention and care, and it is useless to endeavor to use any other type, except in those few places where these requisites will be available. The great problem of sanitation
is to supply the greatest number of people with sanitary means for the disposal of their bodily wastes. The idea should be to concentrate upon and improve the simpler and better types, rather than to install too complicated and costly methods at the risk of failure and loss of confidence.

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SECONDARY TREATMENT OF SEWAGE

Various methods of treatment of sewage from homes equipped with running water, flush toilets, baths, etc., were described in Chapters XI, XII, and XIII. The method most generally used was shown to be the small septic or Imhoff tank. The process of treating sewage by means of tanks results in the production of wastes which must be given further treatment. These wastes are the sludge and the effluent.

The sludge is the digested heavier, or solid, parts of the sewage. The treatment of this will be considered later. The effluent is the partially purified liquid waste resulting from tank treatment of sewage. It contains much organic matter and numerous bacteria. Before it can be turned safely into a watercourse, or upon the soil, most of these bacteria must be killed and the organic matter converted into stable forms which will not cause odor.

In reality, this effluent is but a less objectionable form of sewage. The coarser solids have been removed and the first stage of decomposition has set in. The oxygen content is low, as all, or nearly all, the available oxygen has been used up in the partial purification which has already taken place. More oxygen must be supplied to prevent nuisance, as decomposition without oxygen causes odors.

The bacteria present are in almost as great number as in the raw sewage. In fact, it is not unusual for the number to increase, as the interior of a septic tank is a
breeding place for them. The number present will vary greatly, just as it does in sewages. Much depends upon the method of primary treatment, temperature and characteristics of the sewage.

Secondary treatment must oxidize or reduce the organic matter to more stable forms, so that decomposition with odor will not take place. It must also reduce the number of bacteria. The reduction of the organic matter must be such as to eliminate the chance for nuisance. The reduction of the bacteria required will depend almost entirely upon local conditions. They may be eliminated completely, if desired, but this may be costly, and rarely, if ever, is necessary.

Secondary treatment methods include subsurface irrigation, sand filters, trickling filters, contact beds, secondary tanks, leaching wells, and other less important types. The choice as to which method shall be used for any place will depend largely upon the following: (a) amount of attention available for operating plant after construction; (b) amount of money available for construction; (c) local topographical conditions; (d) degree of treatment desirable or necessary.

Subsurface Irrigation

Subsurface irrigation, as the name implies, consists of discharging the effluent from the tank into the earth beneath the ground surface. This is usually accomplished by means of a line of open-joint tile laid in one or more rows, twelve to twenty inches under the ground surface. The effluent from the septic tank overflows into the tile line and seeps through the open joints of this into the soil.

As the partially purified liquid passes through the
joints of the pipe into the soil, it is subject to more than one method of treatment. There is, of course, the mechanical straining action resulting from the passage through the soil. There are in the upper layers of the soil great numbers of nitrifying bacteria, which attack the organic compounds and reduce them to simpler forms. The action resulting from these changes produces an unfavorable environment to the sewage bacteria. The result of these processes is a rapid reduction in their number and a decrease in the offensiveness and harmful properties of the sewage.

Subsurface irrigation is the most popular method of treatment for the small plant. It is the only method, excepting dilution, which requires practically no care from year to year. Probably more than 75 per cent. of the small septic tanks and nearly all of the septic closets in use are equipped with subsurface irrigation systems.

Broadly speaking, this method of treatment may be used in any place where the ground is porous enough to absorb the liquid, and where there are no conditions tending to cause pollution of ground water. It works best of course, in a sandy or gravelly soil, but may be used, with proper precautions, in tight soils. The tighter the soil, the greater the amount of tile needed, and the more care required in construction.

The use of a siphon has been mentioned. While not absolutely necessary in the small plants, a siphon should be installed whenever possible. Without it, the overflow from the tank will trickle through the first few lengths of tile and overload the soil along these places, finally stopping the pores with suspended matter. This action follows down the pipe until it is all out of action. The siphon discharges enough at one time, so
that the entire pipe line is filled with liquid, thus evenly dosing the entire field. In the large plants, a siphon must be used.

Where the ground water is within two or three feet of the ground surface, there will be little purification of the effluent, and pollution of the water is almost certain to follow. In general, there is danger of pollution if the ground water is less than eight or ten feet beneath the tile. There is especial danger of such pollution in limestone regions where there is considerable opportunity for the passage of water through underground cracks and crevices.

Finally, there is an economic limit to the use of this method of secondary treatment. Depending upon the availability of local materials, conditions of the soil, etc., a point will be reached where other methods will be found more economical. The great field for the subsurface irrigation lies in the small plant, and where the flow of sewage
reaches any considerable volume, other methods may be found to be as cheap or cheaper.

For the average small installation, four-inch pipe should be used throughout; in the larger plants, six-inch pipe may be used for the mains, and four-inch for the laterals; in the largest plants it occasionally may be necessary to use an eight-inch main and six-inch distributors with four-inch laterals.

The first few feet of line out from the tank should be of regular glazed sewer pipe, with the joints cemented. The distribution pipe should be of unglazed, agricultural tile, without bells. This is generally cheaper than the bell and spigot glazed tile. For the main lines, the bell and spigot pipe may be used, but for the laterals the unglazed tile is cheaper and more desirable.

In sandy or gravelly soils, a trench twelve inches wide and twelve inches to eighteen inches deep is dug, the pipe laid carefully to grade, and the joints covered to prevent infiltration of sand and mud. The pipe may then be covered. Sometimes the pipe is protected by covering it with poles or boards, laid lengthwise of the trench, and directly on top of the pipe, or by straw or brush (Fig. 61).

There are few soils, however, so well suited to this means of treatment. In most localities it will be necessary to provide a layer of porous materials around the pipe to aid in the diffusion and absorption of the liquid. In these tighter soils, the trench is dug with the necessary width and depth and is then filled with six to eighteen inches of cinder, gravel, broken stone, or other porous material. Upon this bedding of porous materials the tile line is laid carefully to grade, the joints protected, and the earth replaced, after covering the line with a thin layer of the absorbent material.
The upper part of the tile usually should not be less than twelve nor more than eighteen inches from the ground surface. The depth of the trench will depend, therefore, upon the amount of porous or absorbent material, which in turn depends upon the porosity of the soil.

In extremely tight soils, a variation of the above method may be used. A trench is dug about four feet deep and two feet wide. In the bottom of the trench a line of four-inch open joint tile is laid, the joints being unprotected. The trench is then filled with porous material to a depth of three feet. On top of this filling the effluent pipe from the tank is laid as described in the foregoing paragraphs.

One end of the bottom tile line should discharge into a stream or ditch as shown in Fig. 61. The end of the tile line leading from the septic tank should also be vented.

The effluent from the tank flowing through the upper tile line seeps through the open joints and percolates or trickles downward through the filtering media to be collected by the pipe below. Considerable purification is effected in the downward flow and the resulting effluent is not usually objectionable and may be discharged into most streams.

Where, as is always the case in subsurface irrigation systems, the joints in the tile are left open, they must be protected or downward flowing water will carry dirt and sand into the pipe and ultimately stop or clog it.
Strips of burlap, composition roofing, or similar material should be placed over the joints as shown in the accompanying figures. If properly done, this work will prevent stoppage.

No definite statement as to the amount of tile can be given, for the soil conditions may vary so as to make it necessary to install three or four times as much tile in one place as in another, even if all other conditions are the same. Sandy and gravelly soils, of course, will require a minimum of tile, and tight clay soils a maximum.
On another page are given the requirements and recommendations of the various state boards of health. In case of any doubt in any installation the advice of the State Board of Health should be secured.

The septic tank, with its much larger volume of water, will, of course, require much more tile and a much greater area of distribution field than the septic closet. Under average conditions, the author recommends one-fifth to one-sixth foot of drainage tile per effective gallon of tank capacity for septic closets and nine inches of drainage tile line per effective gallon of septic tank capacity. More than this amount will be required in tight soils, and less may be sufficient in sand or gravel. Greater care must be observed in laying the tile and in preparing the drainage bed in the case of the septic tank.

In level sections, the tile may be laid out in one continuous line, though it is better not to have any one line over 100 feet in length. Parallel lines, or as many branches as may be desired, can be used. In fact, the matter of layout is largely one of personal choice where it is not indicated by requirements or limitations of space or slope.

In hilly sections, the slope or contour of the ground will determine almost entirely the layout of the lines. Since the amount of fall is limited, and the line must be laid nearly level, it must often follow the curve of a hill, or hug the side of a valley. In some cases there will have to be parallel lines of tile at different elevations on a hillside. These are usually constructed after one of the methods shown in Figure 62, which is taken from the bulletin of the New York State Department of Health.

The amount of fall required is small. It should range from three to four inches per hundred feet, or about two
Fig. 62.—Layout of tile lines in hilly country.
inches in fifty feet, depending somewhat upon the porosity of the soil. A loose soil will require a greater fall than a tight soil. The amount of fall is discussed more fully in the following paragraphs, where the requirements of the various state boards of health in regard to amount, manner of laying, fall, and other details are given.

The Louisiana State Board of Health Bulletin states that the distribution of the sewage through the soil from a septic tank is best effected by lines of tile drains laid with uncemented joints about twelve to eighteen inches below the surface of the ground. The lines need not be straight, but should follow the contours of the ground, with a fall of two to three inches in a hundred feet. The area required for the treatment depends upon the nature of the soil, and may be determined by allowing one-half foot of pipe per gallon of flow per day in sandy soil, and one foot in fairly dense loam. In tight or clay soils the absorptive power may be increased by excavating trenches two feet wide and a couple of feet below proposed grade, and filling these with porous materials, as gravel, cinders, and sand. In extreme cases it may be necessary to underdrain the lines with tile drains. In very sandy soil, one line may be enough, but it will usually be better to place the lines three feet apart, or five feet in dense soils. The ends of the pipe should be turned up to permit the flow of air. Two systems of drains should be laid and operated a week at a time. In sandy soil, tarred paper or pieces of pipe of a larger diameter should be placed around the joints. These lines of drains should not be laid within a hundred feet of a well.

The Virginia recommendations are to select a sandy or gravelly soil. When the soil is heavy clay or impervious, or where the ground water is only two or three
feet below the surface, the system will not be satisfactory. Much depends upon how accurately the distributing lines are laid. The grade should be two inches per hundred feet. Parallel lines are usually spaced four feet apart. If the area is not to be plowed, the depth of the pipe should be reduced to twelve or fifteen inches. Four-inch tile is usually best. A space of one-fourth inch is left at each joint and to prevent earth from falling into and stopping the lines, the joint is covered with tar paper or an earthenware cap. Gravel or cinders may be placed over the joints. A double system of drains is recommended for the larger tanks. The amount of tiling required will depend upon the porosity of the soil and the volume of the sewage. For installations of septic closets serving less than fifteen people, five feet of tile per person is required, with a slight reduction per person above fifteen persons. For school installations serving less than ten pupils, sixty feet of tile must be laid; for eleven to twenty pupils, ninety feet; for twenty-one to forty pupils, 120 feet. For a ten-hour basis, plants, mills, and factories must provide ninety feet for ten men or less; 100 feet for eleven to fifteen men; and 110 feet for sixteen to twenty men. For plants operating on a twenty-four-hour basis, twenty feet of tile must be added to each of the above lengths. For septic tanks, owing to the widely varying conditions of soil throughout the state, no direct requirements are made, the factor of soil conditions entering more into the disposal of septic tank effluent than is the case with septic closets. The following recommendations are made:

<table>
<thead>
<tr>
<th>Number of People</th>
<th>Sandy Soil</th>
<th>Medium Soil</th>
<th>Heavy Clay Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six or less..................</td>
<td>80 feet</td>
<td>100 feet</td>
<td>210 feet</td>
</tr>
<tr>
<td>Seven to ten people..........</td>
<td>100 &quot;</td>
<td>140 &quot;</td>
<td>350 &quot;</td>
</tr>
<tr>
<td>Eleven to fifteen people....</td>
<td>140 &quot;</td>
<td>210 &quot;</td>
<td>525 &quot;</td>
</tr>
<tr>
<td>Sixteen to twenty...........</td>
<td>160 &quot;</td>
<td>280 &quot;</td>
<td>700 &quot;</td>
</tr>
</tbody>
</table>
The California State Board of Health, Bulletin No. 39, recommends a uniform fall of two inches per hundred feet, for when a steeper slope is used, the water will rush to the lower end and defeat the desire to distribute evenly the burden over the entire length. It is desirable to keep the drains near the surface, but they must be sufficiently deep to escape injury by a plow if they are in cultivated ground. If the top is fifteen inches below the surface, they will usually be safe from disturbance. Drains may be of small agricultural tile, laid with open joints, and surrounded with a little gravel, or of redwood. Either type is serviceable and satisfactory. The necessary length of drains must be determined more or less by experiment. It will vary greatly with different soils, a short line serving as well in a coarse porous soil, as a longer line in fine-grained soil. From twenty to one hundred feet should be provided for each person contributing sewage. Later, if water begins to appear on the surface of the ground, additional capacity will have to be provided. Drains must not be laid below ground water. If the ground water is high, it is sometimes feasible to lay the drains on top of the ground and then haul in sufficient soil to cover them. It is not advisable to make individual drains more than 100 feet in length, but rather provide a number of lines branching from the main distributor, keeping the separate lines at least six feet apart. If the disposal system is large, serving fifteen people or more, or if it must be laid in tight soil, it is advisable to provide two or three separate systems fed from a switch.
box, which is merely a small wood or concrete box into which the effluent of the tank flows and from which, by manipulation of the stop planks, it can be diverted into any or all of the drains. By this means a drain system may be cut out of service and the soil around it allowed to drain and aerate. With such an arrangement, one drain system should be kept resting all the time, switching a different one out of service every week or two.

The Montana State Board of Health stresses the fact that tight clay, impervious, and waterlogged soils are not suited for this system. Where the land is suitable, four-inch tile should be used, laid with the joints open, but protected with tar paper, linoleum, or other materials. The grade should be one-sixteenth inch per foot in sandy soils, and one-thirty-second of an inch per foot in tighter soils. In sandy or gravelly soils, twenty to thirty feet of tile per person will be sufficient, whereas in tight soils sixty feet may be necessary. It is preferable to use two short lines rather than one long line. Where more than one line is employed, they should be at least six, and preferably ten, feet apart. The top of the tile should be at least twelve inches from the ground surface, and a covering of twenty inches is preferable in cold climates.

New York does not give definite requirements, but states that ten to twenty feet of tile per person will usually suffice in sandy soil; forty to sixty feet per person in light loams; but in clay soils the method is not applicable. Three- or four-inch lines are recommended, laid twelve to fifteen inches beneath the ground, the joints being left open, and the lines being at least four feet apart. The grade suggested is six inches per 100 feet. Care is recommended in protecting the joints. Stress is
also laid on the arrangement of the tile line, several methods being shown on page 189.

Kansas recommends a grade of three inches per 100 feet, and a depth of about eighteen inches. If the soil is open and sandy, 200 feet will be sufficient for the average home, while if of closer texture, 300, 400, or more feet may be needed to adequately care for the flow. The system is not well adapted to tight and retentive clayey soils, though it has been used successfully for a time under such conditions. One or more lines may be used. In case more than a single line is laid, great care should be taken to see that every line receives its share. A desirable, though costly, modification is a trench about four feet deep, with the lower three feet filled with cinders or gravel, then laying the tile line on the surface of the porous filling.

North Carolina does not make any specific recommendations at present. Conditions in that state differ widely. In the eastern part there is a great deal of sand; in the western part the soil is a very tight red clay. Every installation is a matter for individual study.

The Maryland recommendations for tile lines for septic tanks, as made in 1916, are:

<table>
<thead>
<tr>
<th>Number of Persons</th>
<th>Feet of Drain Tile Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light Soil</td>
</tr>
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The Department of Agriculture recommends that the capacity of the tile lines about equal the siphon discharge, and states that the ends of the lines should be laid flat, or nearly so.

Frank and Rhynus, in Public Health Bulletin 101, recommend a dual system of lines of three-inch agricultural tile laid with open joints about one-fourth of an
inch wide. Forty lineal feet of tile per person is recommended, though the varying types of soils are recognized to have a bearing on this recommendation. The grade suggested is two inches per 100 feet.

The recommendations of the State of Washington are 160 feet per family, with a fall of two or three inches per hundred feet. Mississippi suggests a fall of one inch in every twenty-five feet of line. Illinois recommends about 100 feet of tile for each member of the household. The Maine Health Bulletin states that thirty-five feet of tile per person will usually give good service in sandy

Fig. 64.—Four methods of protecting open joints in distribution lines. Sketches show cross-section and longitudinal views; the depth from the surface of the ground to the top of the tile is about 10 inches.

1. a, subsoil ground; b, 3- or 4-inch drain tile; c, strip of tarred paper about 6 inches wide and extending three-fourths the distance around the tile, allowing sewage to escape at the bottom; d, coarse sand, gravel, broken stone or brick, slag, cinders, or coke, the coarsest material placed around the tile (where the ground is naturally very porous and well drained, special filling in the trench may be omitted); e, natural soil.

2. Drain tile covered with a board laid flat, leaving the entire joint open.

3. Drain tile laid in stoneware gutter pieces and the joint covered with stoneware caps; gutter and cap pieces are inexpensive commercial products; their radius is longer than that of the outside of the tile, thus leaving open most of the joint space; the gutter aids in keeping the tile in line.

4. Vitrified sewer pipe with hubs facing downhill; the spigot end should be centered in the hub with a few small chinks or wedges.

Unless the ground is rather porous, more sand, gravel or other porous material than is shown in cuts will be needed. As a rule, in tight soils 4 to 5 cubic yards are required for each family.
or gravelly soils, if the tile is laid properly. In tighter formations, the length per person must be increased up to eighty or ninety feet. In clay sections, a modified form must be used. The laterals should be spaced at least six feet apart, and preferably double that distance. The depth of the tile line should not exceed twelve inches. Where only clay soils are available, trenches forty-two inches deep are dug and filled to within a foot of the top with cinder or other porous materials. Sometimes a second tile line is placed at the bottom to carry away the effluent.

Ohio recommends a double system, each part connected to its own siphon, and each part to have a capacity of at least 10 per cent. in excess of the dosing chamber. The distributing lines may be six or eight inches in diameter, preferably the latter, to reduce the cost of trenching. For the distributing lines, hard-burned tile is preferable. These should be laid with one-quarter inch joints and surrounded with gravel. Small strips of heavy paper may be placed over each joint to prevent washing full of dirt. Underdrains are recommended about three feet below, and between the lines of distributing tile.

Wisconsin recommends the filter trench for the small home. The distribution tile should be five-inch, or six-inch, laid with a grade of four inches per 100 feet. The pipe should be laid in broken stones or gravel. The ordinary tile surface system may be used in sandy or gravelly soils. The lines must be laid fifteen or more feet apart, with a grade of two inches per hundred feet. The joints are left open one-fourth inch and are protected with burlap or broken stone. The amount of tile should vary from twenty feet to 100 feet per person, according to the soil.

At first glance, especially, it will appear that there
SECONDARY TREATMENT OF SEWAGE

Fig. 65. — Layout of tile subsurface drainage lines, with method of underdrainage.

Courtesy Ohio State Board of Health.
are too many differences in the recommendations of the various authorities. Most of these, however, may be accounted for by local differences of soil, climate, and similar factors, all of which have some effect upon the methods of sewage disposal.

The cost of subsurface disposal is dependent so much upon local conditions and prices that no fair estimate can be made without taking these factors into account. In figuring such costs, the tile cost will be known, the labor cost will depend largely upon the soil. It will cost more to dig in clay than in sand.

This method of secondary treatment is usable except where the soil is very tight and impervious, or in regions of high ground water or other conditions tending to cause ground water pollution. It is more adapted to sandy and gravelly sections, but may be used in less favorable places at an added cost.

Subsurface disposal is foolproof, once it is installed, for operation is entirely automatic. No attention is needed until, after a period depending upon the soil, care
in construction, etc., the system must be relaid. The first cost is low, especially in sections with open soil. There is no odor and little danger of pollution. Subsurface irrigation cannot be used economically in tight soil, in areas of high ground water, or where the volume of liquid to be treated is very great.

**Leaching Cesspools or Wells**

Unfortunately, leaching cesspools, a variation of subsurface disposal, are a rather common form of secondary treatment. In a few types of soil, where the ground water is very low and the soil strata porous, they may be used with safety. In most cases, however, there is an ever-present danger of water pollution. A cesspool should never be used in a section of high ground water.

The rather low first cost, the simplicity of construction, and the small amount of care and attention required where soil conditions are favorable, have been largely responsible for the popularity of this method. The usual
program is to sink a well three to five feet in diameter, or larger if the occasion demands, to a depth of ten to fifteen feet, and wall up the sides, loosely or tightly as local conditions demand, leaving the bottom open. In some cases the well is filled with cinders or gravel. Figure 67 shows leaching wells according to the plans of the Ohio State Board of Health, while Figure 68 is a well shown by Crohurst in Public Health Reprint No. 625. The leaching cesspool should be abandoned in favor of subsurface disposal or some other form of secondary treatment.

Intermittent Sand Filters

For those localities where subsurface irrigation is not applicable owing to unfavorable conditions, but where a considerable degree of purification is necessary, sand filters may be used. Beds of sand are underdrained to carry off the flow of sewage which is applied at intervals, or intermittently, to the surface. Purification is effected by two means. First, by bacterial action in the interstices of the bed as the sewage passes downward; and second, by the mechanical straining action of the sand.

This method of secondary treatment is a very popular one for larger home installations, and for institutional plants where the volume of sewage is too great for subsurface disposal. It yields an excellent effluent. Intermittent sand filtration is also a popular method of treatment for partially purified sewage in municipal plants.
Certain limitations may prevent the use of a plant of this type. From thirty-six to fifty-four inches of fall or head are necessary to provide for the operation of the various devices in the plant; the sand filter requires considerable land area; in a built-up section, such a plant may become somewhat of a nuisance; an economic limitation is the fact that sand filters are generally not suited to installations serving less than twenty-five people.

Operating care is necessary for proper results. Inspections should be made by the owner or operator every few days and the flow of sewage should be changed from one bed to another at about weekly intervals. At periods of a month, the beds must be raked and scraped. In the winter additional special attention is necessary. Sand beds should not be installed where proper operation is not assured.

A dosing chamber with siphon is necessary with sand beds as the sewage must be applied in such quantities as to spread evenly over the entire surface of the bed and dose all parts at the same rate. The size of the siphon depends upon the amount of sewage to be treated. In the smaller plants, a three-inch or four-inch siphon is large enough. The dosing chamber should have a capacity of about one-third to one-fifth of the total daily flow of sewage. Frank and Rhynus, in Bulletin No. 101, Public Health Service, recommend two and one-half cubic feet of siphon or dosing chamber capacity per capita for flows of twenty gallons per person per day, and 3.7 cubic feet for flows of 100 gallons with proportionate capacities for intermediate flows.

Inasmuch as sand beds must have considerable rest between doses, it is necessary to have at least two or
three beds, and to discharge the sewage alternately upon two of them while allowing the remainder to rest. This calls for two siphons or for some device to allow for the alternating discharge. If two siphons are used, they may be set in the same chamber and arranged to discharge alternately, each upon its own filter. Valve arrangements should be such that the flow may be diverted to or from any bed. Plans for a dosing chamber are shown in Figure 69.

Usually sand beds are contained within concrete or masonry walls or curbs, or within earthen embankments. They may or may not have a concrete or other tight bottom, but they must be underdrained. A tight bottom is desirable.

The depth of sand is dependent upon the amount of fall available, but should not be less than twenty-four inches. Ordinarily a depth of thirty inches is desirable. The filtering material should be of a good grade of sand, clean and sharp, and for best results should have an effective size of 0.30 to 0.50 mm. The bottom of the beds should be sloped to a centre drain, and six or eight inches of gravel or broken stone should be placed over and around the underdrains, and spread on the bottom of the bed. The lower layer of gravel should be one-quarter to one inch, and on this should be a two-inch layer of finer materials, about the size of small peas, to prevent the washing down of the filter sand.

The underdraining in the smaller beds, such as are used for residential sewage treatment, is usually accomplished by one line of tile, which should be covered, as before mentioned, by gravel or broken stone. The underdrains should have open joints. The bottom of the beds,
SECONDARY TREATMENT OF SEWAGE

Figure 69 — Typical layout of sand filters.
whether of concrete or of earth, should be sloped toward this central tile line to aid in drainage. Discharge may be into a ditch or stream. The effluent from properly operated sand beds will be of good quality and will not cause nuisance.

If clean sand is not available, ordinary sand may be washed in exactly the same manner as is done in preparing it for concrete or other work.

Various units are used whereby the size of the bed necessary may be determined. A common basis is a rate of filtration of 100,000 gallons per acre per day, which at 100 gallons per capita per day gives 43.5 square feet per person. Another somewhat commonly used basis is 750 to 1000 people per acre, which gives forty-three to fifty-five square feet per person. As a general rule, forty square feet per person will give satisfaction, though where the flow of sewage is small, less may occasionally be used. Where only a few people contribute, the beds should be built with a rather large per capita allowance.

The cost of sand beds varies so much with local conditions that no adequate estimate can be given. From three to four and one-half cubic yards of sand are needed per person, and to the cost of this in place should be added the costs for sidewalls, excavating, and underdrains.

It is important to apply the sewage so that the sand is not disturbed by too rapid application, while at the same time it is necessary to distribute the charge as evenly as possible all over the bed. Wooden troughs with holes bored in the sides every ten or twelve inches are frequently used; in other plants the distribution is from a concrete apron.
SECONDARY TREATMENT OF SEWAGE 205

As the name indicates, sewage is applied to the filters intermittently. This is accomplished by the dosing chamber and siphon. The dosing chamber should be of such size that a single dose or discharge will cover the sand bed to a depth of about two inches. The retention of this liquid upon the beds for any considerable time may result in odors. It is therefore necessary to keep the beds clean and in such condition as to permit the sewage to seep readily through the sand. A pooling of the liquid on the surface is a sign that the bed needs cleaning. When this occurs, the bed should be thrown out of service and allowed to dry out. The mat or scum found on the surface must be removed by scraping and the beds raked to a depth of about one inch. When pooling occurs frequently, as within a couple of weeks after scraping, the scraping should be supplemented by the removal of the upper crust of the sand to a depth of about an inch, a raking of the sand to a depth of two inches, and a releveling of the bed.

During the winter months, when the surface of the filter bed is liable to freeze, the beds should be furrowed. This is done with a shovel or a spade, on the small plant, furrows being turned about twelve or fifteen inches wide and five or six inches deep. Ice will form over the top of these furrows and protect the remainder of the bed, allowing the sewage to pass along the trough of the furrows and soak into the sand. In the spring, the beds should be allowed to dry, and raked, scraped and leveled.

At each cleaning some sand will be lost. Where sufficient head or fall is available, the sand should not be allowed to become less than twenty-four inches in depth. New sand should then be added to secure the required depth.
Weeds growing upon the beds is a common cause of clogging, so the beds should be kept clean of weeds, grass, or other vegetation. If earth embankments are used to contain the filter, they should be protected from washing by rain or surface water. If possible, they should be sodded.

Sand filters are available for use wherever there is sufficient fall, and when proper maintenance is assured. Other limitations to their use include cost, the area of land, and the possibility of odor in built-up sections. For the institution or estate where personnel is available for proper upkeep and care, sand filters provide a most excellent means of secondary treatment, yielding an effluent of very good quality. Where local sand is available, the cost may not be much greater than subsurface irrigation.

The main advantage is the highly purified effluent, which may be discharged without further treatment into any stream not used for water supply. Continual care is required for proper operation, and without such care the plant will not work well and may even become a nuisance. The first cost is rather high, and the cost of personnel for proper operation also is high.

Trickling Filters

Another popular method of secondary treatment is the trickling filter. The partially purified sewage from the septic or Imhoff tank is allowed to trickle through a bed of broken stone, gravel, coal, coke, slate or laths, being acted upon by aerobic bacteria in the downward passage. At the bottom of the filter are collecting drains just as in the sand bed. From six to ten feet of fall or head are required.
This method of treatment does not produce quite as good an effluent as does the sand filter, but the attention required is somewhat less. Not so much ground area is needed, but a greater head or fall must be available. Like the sand filter, trickling filters, though used to some extent in residential sewage treatment plants, are far more popular in large municipal installations. The reason is the same in both cases. The care and attention so rarely given in small plants are required for their proper operation.

As with sand filters, the bed may be contained within concrete or wooden walls, and may have a bottom of concrete or of clay. This bottom should slope to the central open joint drain as with the sand filter.

Clean, sharp stone in sizes about two to three and one-half-inch is best. All fine material should be excluded. The depth of the bed generally should not be less than four and one-half or five feet and may be as much as eight or nine feet. In general, the amount of stone rather than the area of the bed determines the amount of sewage to be treated.

The method of application of sewage to the bed determines to some extent the shape of the bed. It is necessary that the application be uniform in volume, but intermittent, so that the bed will work under the same general conditions as the sand filter, though usually the intervals between applying the doses, as well as the time of dosing, are shorter. Several methods of dosing are in use, including spray nozzles, splash plates, and boards. The spray nozzles discharge a circular spray under a small head; with the splash plate, the flow is discharged from a height of about a foot onto a concave circular plate which causes the liquid to splash out in the shape
of a circular spray; with the tapered board system of distribution, the sewage effluent is usually applied from a trough or tank. For the first two methods, in the case of the small installation, circular or hexagonal tanks are best; with the tapered boards, a rectangular tank works best.

The size of the filter needed depends upon the number of people it serves and upon the volume of sewage flow. The sub-committee on Rural Sanitation of the American Public Health Association recommends not over thirty-six gallons per square foot of filter surface daily, and not less than eight cubic feet of filter bed per capita. Frank and Rhynus, in Bulletin 101, Public Health Service, recommend eight cubic feet per capita. For a family of five persons, this would require a filter bed four feet by four feet and five feet deep. The same capacity rules will generally apply, no matter whether the filter material be brush, stone, coal, coke, lath, or slate.

In the case of lath filters, the laths are placed in courses or layers, three inches on centres, each layer being at right angles to the layer below, and every other course placed with the lath centres directly over the openings of the second course below. Brush filters are made up of tightly-bound bundles of straight brush, with the leaves removed, packed in layers eight or ten inches in thickness, with each layer at right angles to the layer below.

The effluent from filters made of any of the above materials is fairly good in quality, if the filters are properly operated and cared for, but such treatment does not remove all dangerous bacteria.

The trickling filter, when properly installed, probably requires as little operating attention as any other form
Fig. 70.—Imhoff tank and lath filter plant for 120 people, showing distributing boards and tippers.
of secondary treatment, excepting subsurface irrigation. A moderate amount of attention is, however, absolutely necessary. If spray nozzles are used, they should be looked after every few days and cleaned when necessary; splash plates also need frequent attention; the tipper and taper board arrangement, as shown in Fig. 70, requires somewhat less attention, but will not operate when neglected. Moreover these devices are installed only in connection with some form of primary treatment, usually passage through a tank, and such method of primary treatment also requires attention.

Trickling filters may be used anywhere that the requisite amount of attention is available, and where the contour of the ground is such that the necessary fall or head is available. On account of the possibility of odor, they should be recommended with caution in a built-up section, especially where the best attention is not assured.
Trickling filters provide a means whereby a good effluent can be secured at a moderate initial cost and with a moderate degree of attention. Intelligent care, however, is too often lacking in the average plant. Improper installations are not uncommon, because of the fact that a sanitary engineer is usually not available for the design of such small plants, though designs for these plants really call for a greater degree of skill and care in construction than a medium-sized plant. The cost of trickling filters is somewhat greater than the average small plant owner can afford.

Contact Beds

Contact beds work upon the same principles as do the trickling filters, but instead of allowing the sewage to trickle down over the bed of material, it is held in the contact bed for a period of time, usually one to four hours, and then drawn off, after which the bed is allowed to rest for the same period. Thus a schedule of operation may be: Filling the bed, two hours; bed standing full, two hours; bed draining, two hours; bed resting, four hours. This method of operation requires that the filter material be contained within a tight tank or receptacle. Most contact filters are contained within a concrete box or reservoir, the size depending, of course, on the amount of sewage to be treated. (Fig. 72.)

The depth of the filtering material and the amount required per person, or per unit volume of sewage, is not the same as with the trickling filters. The depth is generally not quite so great, while the volume required is somewhat greater. More attention and more complicated machinery are required for operation. The filling and draining is performed by automatic siphons or by
Fig. 72.—Typical installation of double contact beds. The sewage should be settled before delivery to the beds, but a dosing chamber is not necessary.
other self-acting machinery. Distribution of the sewage is usually by means of troughs or from aprons, much as with sand filters.

Trickling filters have quite largely taken the place of contact beds within the past fifteen to twenty years, having practically all of the advantages and not so many disadvantages.

Secondary Tank Treatment

Where a high degree of treatment is required, a secondary settling tank is sometimes employed to take out as much as possible of the suspended matter before final discharge. Usually the secondary tank is so placed as to receive the sewage after treatment by primary settling tanks and trickling filters or contact beds. Tanks of the ordinary Imhoff or septic styles may be used. In general, the same principles of design will govern secondary tanks as apply with primary tanks, except that the capacity per person will be about half as great, the sludge chamber is smaller in comparison with the remainder of the tank, and in the Imhoff design, the slot clearance may be much less.

Disinfection

Disinfection is practically never used, except as a final treatment prior to discharging the sewage effluent into a stream, lake or ditch from which there may be danger of pollution. Disinfection is not very generally used in the smaller plants, but may be applied to plants of any size.

The most generally used disinfecting agent is chlorine, which may be employed either in the form of liquid chlorine, or as bleach or hypochlorite of lime. Liquid chlorine is applied directly to the sewage effluent by
means of chlorinating machines. These are costly but efficient. Hypochlorite of lime is mixed with water, and the solution added to the sewage effluent. Figure 73 shows a homemade chlorinating plant for applying chlorine from hypochlorite of lime.

**Sludge Disposal**

We have discussed somewhat fully the methods for further treatment of one of the wastes resulting from tank treatment of sewage. The other waste, sludge, must also be given some treatment before it can be disposed of finally.

Sludge is the settled and digested solids which collect
in the sludge chambers of septic or Imhoff tanks, generally speaking, though strictly this definition is capable of much broader interpretation. Disposal of these solids is necessary, or the tank fills up, losing its efficiency as it fills, until the flow through the tank is so rapid that no treatment at all is given the incoming sewage. No tank is so efficient as to destroy all the solid matter entering it, and a tank not cleaned becomes, within a year or so, almost worthless insofar as sewage treatment is concerned.

In larger municipal plants, the volume of sludge is so great that the problem of disposal is a serious one, and the cost a considerable item. In most plants, the sludge that comes from the tanks is 2 per cent. to 4 per cent. solids and 98 per cent. to 96 per cent. water. Sludge may be valuable as a fertilizer, but the cost of handling so much useless water makes its transportation impracticable in most cases. An idea of the amount of water may be gained by comparing the volume of sludge with 96 per cent. water and with 98 per cent. water, as mentioned above. For a given amount of solid matter, a sludge with 98 per cent. water has just twice the volume of a sludge with 96 per cent. water. A sludge with 90 per cent. water has just one-fifth the volume of a sludge with 98 per cent. water. Even the 90 per cent. of water must be reduced very much if the sludge is to be commercially usable.

Such problems as these will not bother the owner or operator of the small plant. His main object will be to get rid of his sludge in the easiest manner possible. Usually it is not worth while to attempt to use it as a fertilizer, though it has some value as such, especially when well dried.

The amount of sludge to be expected in the larger
plants can be computed with considerable accuracy, but owing to careless operating conditions in the smaller plants, and the lack of knowledge of the exact amount of sewage treated, the same figures will not apply. In larger plants, about 0.0035 cubic foot of sludge will be deposited per person per day. This is at the rate of about 1 1/4 cubic feet, or ten gallons per person per year. In smaller plants the amount will vary from the figures given to two or even three cubic feet per person per year.

The sludge has been so acted upon by bacteria in the tank that it has changed into fairly stable forms. In some cases it still retains considerable odor, though sludge from properly operated two-story tanks rarely does so. There is much difference in the sludge from septic and Imhoff tanks. The sludge from the latter is not so sticky, greasy and heavy, and dries much more rapidly.

There are several ways of treating or disposing of this sludge. It may be drained off into a nearby stream or ditch; it may be buried; it may be used as a fertilizer while wet, or it may be dried and then used as a fertilizer.

When turned into a stream or ditch, a good flow of water is necessary in order to carry away the sludge without stoppage or nuisance. If buried, the same general rules should apply as for the burial of excreta. When plowing under is used, it should be spread in an open furrow to a depth of not more than three or four inches, and covered with not less than three inches of dirt. Where trenches or pits are used, three feet will be found to be a handy depth. The area required will depend upon the amount of sludge. If used as a fertilizer as it comes from the tank, the sludge should be kept away from vegetables that are to be eaten raw.

Where it is desired to dry the sludge, sludge beds must
be constructed. The general plan of the sand filter is followed, but the beds are neither so deep nor so large. Over the central drain tile, which is laid with open joints, should be placed six or eight inches of broken stone or gravel, with a somewhat finer layer of this material on top. On top of the gravel or stone should be placed eight or ten inches of sand.

A drain pipe may carry the sludge from the treatment tank to the beds, or it may be transported in barrels, or by other means. In the former case, the tile may be laid to the centre of the sludge bed, preferably with an elevation of about a foot above the bed, and discharge upon a small concrete apron. The beds for the small plant will not be of any considerable area, and no other form of distributor is needed. Where mechanical transportation is used, the sludge should be poured on the bed, care
being taken not to damage the bed by pouring from too great a height.

The area required for the average installation will be one or two square feet of bed area per person contributing to the tank. A school installation, recommended by the Ohio State Board of Health, is shown in Fig. 74. One square foot of sludge bed area is allowed per pupil.

The sludge may be run on the bed to a depth of eight to twelve inches and allowed to dry thoroughly. The time required for drying will depend upon the quality of the sludge and upon the weather, and will vary from a couple of weeks to a couple of months. When dry, the sludge may be forked off the bed and used as fertilizer, or thrown away. The effluent from the sludge beds should be collected, wherever possible, and given the same treatment as the tank effluent.

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PART IV

PROBLEMS IN FIELD SANITATION

In this part, three problems, that at times are extremely important to the health worker, are taken up. Many non-technical men are unfamiliar with the intricacies of concrete work, and do not know how to estimate the quantities of cement and concrete aggregate needed. Called upon to present plans or specifications for constructing privies, or other sewage treatment apparatus, they are unable to enumerate clearly fair and reasonable requirements. It is the aim to provide in Chapter XV some elementary information along this line, and to refer the reader to works that give greater detail and treat the subject more fully.

Time and again in health work the question of underground travel of pollution arises. The installation of pit toilets, for instance, brings on this question. The information available on the subject has been canvassed pretty thoroughly and combined into Chapter XVI. It may be said that present data on the subject appears to indicate rather convincingly that surface travel or fly carriage of pollution are more important than underground travel, especially where the contamination is not placed directly in the ground water.

Fly control is important, but difficult. In few places have really complete and effective fly control campaigns been carried on; but this is possible. Such work, however, will generally be carried on under the direction of experts in the subject, so it has been the idea to give only so much information within the narrow limits possible
here, as would enable the reader to comprehend fully the problems in fly control, the need for fly control, and the essential points to bear in mind in inaugurating or planning such a campaign.

Naturally it has not been possible to go into detail on any of these subjects, important though they be. The plan has been to present the subject simply; to give to as great extent as possible the fundamentals and a few of the applications most liable to be encountered. In the bibliography following each chapter are listed some of the sources of information available for those who desire greater detail.
CHAPTER XV

CONSTRUCTION DETAILS

In the great majority of cases where improved privies are installed, it is possible and necessary to utilize the old privy house, repairing and rebuilding it as may be needed to make it meet sanitary requirements. While such a policy should be followed to as great extent as possible in order to reduce costs, it must be remembered that no privy will receive the care, attention, and use that it deserves unless housed in a decent building. Moreover, unless protected by a good roof, seat covers and other wooden materials will warp and crack, losing all qualities of flyproofness. Protection of the user from the weather is necessary to allow use during wet or cold days.

The privy should be located not too far from the house. If it is a sanitary privy, properly constructed and operated, fifty feet will afford convenience without danger or odor. If it is an open-back privy, or similar insanitary substitute, the farther from the house the better.

Where a new privy building is constructed, it should be not less than four feet square; larger buildings will be required if more than two seat holes are needed. The building should be at least six feet high in the rear, and seven feet to seven feet six inches in front. It is a good policy to have the roof overhang about eighteen inches at the rear to get rainwater away from the privy. This is especially desirable in the case of the pit privy. Where more than two seat holes are desired, two feet of additional width should be allowed for each seat.
The North Carolina State Board of Health, Special Bulletin No. 178, August, 1919, gives the following recommendations and regulations for the construction of privy houses:

"Frame: The frame should be constructed of pieces at least two inches by four inches in cross-section.

"Walls: The walls should be covered with lap weather-boarding, tongued and grooved, or other closely fitting boards.

"Roof: The roof should be constructed of one-inch boards, covered with shingles, tar paper, or other roofing material.

"Floor: The floor should be constructed of concrete or of planks tongued and grooved or otherwise closely fitting.

"Housing of Excreta: All cracks or holes in that part of the building which surrounds or houses the excreta shall be so covered and screened as to exclude all flies from the filth.

"Lumber: Green or unseasoned lumber should not be used in any part of the privy building. This is especially true of the box, seat, or other portions of the building housing the excreta, because green lumber will shrink, producing cracks."

For the seat an overall width of twenty-four inches is recommended, with a hole twelve inches long and nine inches wide. The front edge of the hole should be about three inches back from the front riser, and this puts the rear of the hole nine inches from the rear wall. The seat lid hinges should be about six inches back from the hole, and the lid itself will therefore be about twenty inches long. A good width is twelve inches.

The privy house shown in Fig. 10 was designed by the
CONSTRUCTION DETAILS

North Carolina State Board of Health. The materials required are:

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<td>&quot; 10 &quot; x &quot; 16 &quot;</td>
<td>14</td>
</tr>
</tbody>
</table>

This gives a total of 256 board feet. Additional material needed includes four yards of roofing material, two pairs of hinges, and nails. The ground around the privy should be graded up to the privy building to a height of about six inches, to aid in turning away the surface water.

To be of value in preventing the access of flies to the excreta, the seat covers should be self-falling and fit closely. The self-falling feature is easiest provided by some device which will prevent the cover from attaining quite a vertical or balanced position. A wooden block or rail nailed in the proper position in the rear of the seat will usually care for this.

Wooden seat covers are generally used. Old belting twelve inches or more wide, cut into lengths of eighteen to twenty inches, makes excellent seat covers. These lend themselves to the contour of the seat, making it flyproof; they are durable and cheap.

Hinges are very important. They must withstand rust and hard usage. The ordinary metal strap or butt hinge is not satisfactory. They soon corrode around the pin and stick; if force is applied, the hinge breaks; hard usage will put these hinges out of business in a short time. However, a heavy hinge of this type, equipped with a non-rusting pin, has been used very satisfactorily in Birmingham, Ala., on a large number of box and can outfits.
Many hinge devices have been tried, but few have the necessary requirements as to strength, durability, and cheapness. A very satisfactory hinge is made from two staples driven in the cover and the seat, respectively, and connected by means of an iron ring. A section of a discarded automobile outer casing, with the concave side down, makes a durable and cheap hinge. In using any hinge, care must be taken to so construct the hinge that it will allow complete closure of the lid.

The necessity for a vent pipe or flue is an unsettled question. They were formerly thought indispensable, but
experiments in Birmingham, Ala., by Dr. J. D. Dowling, the health officer, indicated no difference in odor with or without the vent pipe, so about half the 6500 boxes and cans installed in that city are without vent pipes. This represents a saving in first cost and in upkeep.

Some means of ventilation are, however, usually considered necessary, and such vents or openings must be protected by screens to prevent ingress of flies. The screen should be placed inside the seat riser or box, so as to protect it from kicks or rough usage. Galvanized iron screen of not less than sixteen meshes to the inch may be used. Copper or monel metal screens have a much longer life than the iron screens and are cheaper on the basis of life and service, though their first cost is greater. The finer mesh (sixteen to the inch) should be used, if possible, as the coarser screen will allow the entrance of mosquitoes, which may breed in pits, septic closets, or other types of privies which contain water.
The principal objections to flue pipes or vent pipes are that they are hard to maintain, and if they pass directly through the roof, it is almost impossible to make the roof tight. If the roof leaks upon the seats and seat covers, warping results, and the privy is no longer flytight. Where the vent passes out through the rear or side walls of the privy, and thence up, the main objections are liability of breakage and the constant necessity for repairs.

If a flue is used, a metal pipe is better than a wooden flue, as it is more durable, and usually is fairly flytight. The metal flue should be not less than three inches in diameter. If a wooden flue is preferred, one may be made by nailing together two pieces of 1" × 4" and two pieces of 1" × 6" to form a flue pipe four inches square on the inside. This must be kept free from cracks and should be screened at top or bottom. Experiments at Wilmington, N. C., by the Public Health Service, showed that flies were attracted by the odors emanating from flue pipes, and would readily enter and pass down them in search of food or breeding places. Generally, flues should be built under the same rules as chimneys in order to secure a good draft, without which they are useless. In other words, they should project well above the ridge of the roof.

Where flues or vent pipes are not used, a row of holes should be bored in the front of the seat riser, about two inches above the floor, and a few holes in the top of the seat riser. All the holes should be protected by screening on the inside. The holes in the riser should not be placed in a direct line with either of the seat holes.

Directions for mixing and handling concrete, insofar as such work is necessary for the construction of the
septic closet, have been given in Chapter VIII. Some additional information may be of value for those planning installations in quantity, or desiring to build large tanks. It should be remembered, however, that to do first-class work, care, a knowledge of cement and concrete materials, and experience in such work are required.

To make concrete, cement, sand, water, and broken stone, gravel or other similar material are mixed together. Sand is sometimes called “fine aggregate” and the broken stone or gravel “coarse aggregate.”

The ordinary Portland cement, obtainable at almost any hardware or building materials store, is used. The proportion of cement used to the sand and stone determines largely the quality of the concrete, though the cleanness of the sand and the care used in mixing are also highly important. Usual mix proportions are 1:2:3, 1:2:4, and 1:3:5. The first figure represents the proportion of cement, the second the proportion of sand, and the third the proportion of stone or gravel.

Cement will usually be found in good condition when purchased, but cement too old or badly caked is not good and should not be used. Lumps should be broken up into dust before using.

The storage of cement is very important. It must be kept in a dry place. Once wet it becomes useless. If the lumps are caused by pressure in storing, they may be broken up by a blow with the back of a shovel. In storing cement, place blocks on the floor, and upon these place boards. Pile the cement on the boards and cover with a piece of canvas or roofing paper. Never keep cement on the bare ground or pile it directly against the outside walls of buildings.

Sand should be clean, sharp, and coarse, and the
grains should be composed of durable materials. Usual sand specifications require merely that the sand shall fill these requirements. Sharpness is desirable, for angular grains offer better holding places for the cement than do round grains. Cleanliness is necessary to give strength to the concrete. A good way to judge if the sand is clean enough is to rub a little in the palm of the hand; if the hand is nearly or quite clean after throwing out the sand, it is probably good enough to use. Another method of testing the cleanliness is to pour some sand into a pail of water, noting the discoloration of the water; or a fruit jar may be filled to a depth of four inches with sand then adding water to within an inch of the top of the jar. After the jar has been well shaken, the contents should be allowed to settle for a couple of hours. The mud will form a distinct layer on top of the sand and if this layer is more than half an inch thick, the sand should be washed before using. Coarseness of the sand is desirable, for coarse sand requires less cement than fine sand.

Gravel is often found locally and may be much cheaper than broken stone. Naturally mixed bank sand and gravel are sometimes found in the right proportions, but this is generally not the case. Unless the mixture is correct and runs very evenly throughout the bank, it is better to screen the sand out of the gravel and use in the usual way. Durability is required in a gravel, as easily broken gravel makes an easily broken concrete. Cleanliness requirements are the same as for sand. Variety of size is necessary so that the smaller pieces may fill the chinks or voids between the larger pieces, thus using less cement and giving a concrete of greater strength.

Broken stone should be fairly angular and the stone hard and durable. It should be broken small enough to
be handled conveniently and easily mixed. Usually stone which will pass through a three-quarter-inch or a one-inch ring is most suitable for such work as is described in this book. Best results are obtained by a mixture of sizes, graded from large to small, such a condition resulting in a more compact concrete and the use of less sand and cement.

Cinders from soft coal are not suitable for making septic tanks owing to their tendency to leak. Slag from blast furnaces, when crushed to proper size, makes a good coarse aggregate.

Water for use in making concrete should be clean and free from strong acids and alkalies. The amount needed will vary with the richness and with the wetness of the mixture desired. Roughly, one gallon per cubic foot of concrete will be used. If there is any doubt about the quality of the water, a test-block of concrete may be mixed, which will show whether or not the concrete sets up properly.

The proper proportioning of the various parts of a concrete mixture is important. Watertightness and cost are two of the most important factors depending upon proper proportioning. Proportions are usually made on the basis of a bag of cement which holds approximately one cubic foot, and loose sand and loose stone by volume. One sack of cement weighs ninety-four pounds, and four sacks are packed to the barrel. Sand, when dry, weighs eighty-five to ninety-five pounds to the cubic foot. Crushed stone weighs about the same. One cubic yard, the basis upon which most measurements are made, contains twenty-seven cubic feet.

The following table is reproduced from *A Treatise on Masonry Construction*, by I. O. Baker. It shows the
cement, sand, and stone required for different mixtures for a cubic yard of wet concrete.

<table>
<thead>
<tr>
<th>Proportions</th>
<th>1 2 3</th>
<th>4 5 6</th>
<th>1 3 4</th>
<th>5 6 7 8 9</th>
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<tr>
<td>1 2 3</td>
<td>6.5 0.45 0.68</td>
<td>7.5 0.53 0.80</td>
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<tr>
<td>4 5 6</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>6 7 8</td>
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<td>5.3 0.37 1.11</td>
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</tr>
<tr>
<td>1 3 4</td>
<td>4.8 0.51 0.68</td>
<td>5.7 0.60 0.80</td>
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<tr>
<td>5 6 7</td>
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<tr>
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<td></td>
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<tr>
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<td>8 9 10</td>
<td>2.7 0.38 0.86</td>
<td>3.4 0.47 1.06</td>
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</tr>
</tbody>
</table>

The Portland Cement Association in their Bulletin No. 26, which contains valuable information in regard to the use of concrete, give the following information in regard to proportioning concrete:

- **Mixture**: Quantities of material in 1 cu. ft. of concrete
  - 1:2:4 Concrete: .058
  - 1:2.5:5 “: .048

Figure the number of cubic feet of concrete that will be needed. Then by multiplying this number by the number under the proper column and required mixture, the amounts of stone, sand, and cement can be found. It should be remembered that one barrel equals four bags of cement.

Sometimes it is desirable to use cement mortar instead of concrete. This may be the case where plenty of sand but no stone or gravel are available. Cement mortar is stronger and more compact and less is needed. Thus, walls of septic tanks when made of concrete should be four to six inches thick; when made of cement mortar they may be as thin as two inches.
For various proportions, the cement and sand required for a cubic yard of cement mortar is, according to I. O. Baker, in *A Treatise on Masonry Construction*:

<table>
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<tr>
<th>Proportions</th>
<th>Materials Required</th>
</tr>
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<tr>
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<td>Bags of Cement</td>
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<td>17.7</td>
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<td>1</td>
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<td>1</td>
<td>7.4</td>
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<tr>
<td>1</td>
<td>6.1</td>
</tr>
<tr>
<td>1</td>
<td>5.1</td>
</tr>
</tbody>
</table>

In general, reinforcing for strength is not necessary in the concrete construction required in this book, except in the case of covers for tanks. These should be strengthened with reinforcing bars, if these are available; if not, with old pipe, wagon axles, and scrap iron. Reinforcing for such covers should be placed in the lower or under half of the concrete forming the cover, generally about two-thirds the distance from the top to the bottom of the concrete to be reinforced.

Reinforcing may be used to prevent or reduce cracking, such as may occur in sidewalls. For this purpose, woven wire netting, or chicken wire netting is suitable. This may be purchased in flat strips, or as fencing. Black iron metal is better for reinforcing than the galvanized. Such reinforcing should be continuous around corners, and from the bottom into the sides.

Cracks may occur from several reasons, such as lack of water while setting, tearing down forms too early, etc. They are best repaired, if small, with plaster-of-Paris, which expands slightly upon setting, and so fills the crack. Cement mortar will not make such a tight repair job, but must be used for large cracks. If there are many holes or cracks to be repaired, it may be easier to plaster the entire structure with cement mortar mixed 1:1 or richer.
If the cracks are very small and numerous, a coat of cement mortar mixed to the consistency of thick cream may be applied with a brush.

Where forms are to be used several times, it will pay to use surfaced, seasoned timber. If they are to be used only once, any sort of lumber may be used.

After use, particles of concrete stick to the forms. In order to prevent this give the surface of the forms a coat of oil or soft soap. Upon removal of the forms, immediately clean off all pieces of concrete adhering. A short-handed hoe and a wire brush will be found handy for this work. Dry forms placed inside wet concrete will absorb moisture from the concrete and expand, cracking the concrete. Forms should be thoroughly wet before using.

Green concrete should not be exposed to the sun for several days after it has been placed. Considerable water is required in the process of setting, to prevent a harmful amount of drying out. Each day, for several days, the concrete should be wet both morning and evening, this water replacing that evaporated from the outside of the concrete. The concrete should also be covered with burlap, sheeting, old timber, or other protection until well hardened and thoroughly set.

With care, concrete can be placed in freezing weather, though ordinarily it is not good practice to attempt this on the smaller jobs. Freezing of setting concrete usually destroys the strength.

Several methods are available to prevent freezing. The sand and stone used in the mixture may be heated, and hot water used. This causes the hardening action to be accelerated, and prevents freezing for a time, at least. Salt, soap, or other solutions may be added to the
concrete to lower the freezing point. A good rule for the use of salt is to add it to the amount of one-fifth of 1 per cent. of the weight of water used per degree Fahrenheit below freezing. This works out to about one pound of salt to sixty gallons of water for every degree below 32. For 20 degrees F., twelve pounds of salt would be added to every sixty gallons of water used in mixing. Some protection may be secured by covering the freshly laid concrete with straw, boards, canvas, or other covering. This is most effective in the case of mass concrete, and not very valuable when small amounts only are placed.

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CHAPTER XVI

SOIL AND WATER POLLUTION

All of the filth-borne diseases are caused by the pollution of our food or drink by excreta containing germs of one or more of these diseases. The manner in which and the conditions under which this pollution takes place are important, and in order intelligently to fight such diseases we must know these. How far apart must we place the privy and the well? How long does a filled privy pit retain its death-dealing powers? Is pollution largely through carelessness, or is it unavoidable? These and many other questions must be answered, if we are to be efficient in our fight against these filth-borne diseases.

We may classify pollution, generally, under two heads—surface and subsurface. Surface pollution is caused almost entirely by carelessness in the disposal of dangerous wastes. Excreta left unprotected and exposed to rain, the wash of surface water, animals, birds, etc., are the main, if not the sole, cause of surface pollution. The remedy is plain. Human wastes must be protected by means of privies built to fulfill the principles, outlined in Chapter II, of watertightness, prevention of access of flies and animals, and the prevention of soil pollution.

The distance that pollution will travel overland is surprising. Animals may transport germs of disease in their bodies several miles from their point of origin, though this is not very common. Flies travel rapidly for long distances, going as far as ten to fifteen miles in a
few days. Water is a most rapid carrier of pollution and often carries it for miles, as in the case of brooks and streams, or by the flow of surface water after rains.

Subsurface pollution has the stronger appeal to the imagination. The invisible and the unknown always attract, and because of the very uncertainty and lack of knowledge regarding underground pollution, it often has been convenient to attribute to it many cases of disease that might as easily have come from other sources.

It must not be concluded, however, that the underground travel of pathogenic bacteria is the exception to the rule, and that such sources of disease spread are unimportant. Experiments, as well as experience, have shown that dangerous pollution often travels for considerable distances with underground waters. The possibility of the spread of disease by this method is always present where there are opportunities for ground water pollution, provided the water supply is from shallow wells or springs.

The chances of such spread of disease are largely dependent upon the life of pathogenic bacteria under the conditions they will encounter in septic tanks, in the soil, in privy pits, and in other places. Many experiments have been conducted on this subject. Typhoid and dysentery bacilli will rarely live more than five to seven days in septic tanks; in soil they will survive for a much longer period, even up to two or three months, if conditions are really favorable; in masses of feces, as in privies, the life will rarely exceed two or three weeks.

This information must be used with caution. For instance, in the case of the septic tank, "short circuiting" may cause sewage to pass through a tank in as little as
fifteen or twenty minutes, in which case the effect upon the bacteria present will be practically nil, and the effluent may be found to contain many dangerous forms of bacterial life. Around privies, soil conditions may be so favorable that germ life will persist for two or three months, instead of the two or three weeks expected in feces.

Moreover, present-day sanitary technique considers the presence of B. coli as a dangerous indication. We must, therefore, conclude that their appearance is an evidence of danger, irrespective of whether or not the above conditions as to the life of typhoid and dysentery bacilli have been met.

During the past few years the increasing popularity of sanitation has intensified the interest in the possibilities and probabilities of subsurface pollution from privies, septic tanks, and leaky sewers. Considerable research has been carried on by various bodies to determine, if possible, the limit of travel under the various conditions of use, and the probability of such pollution.

The Public Health Service, through an experimental board headed by Dr. Charles Wardell Stiles, has been making a thorough investigation into this problem. The results have shown that the distance of travel through soil from a pit or similar source of pollution is small, lacking water to transport the bacilli, but that where water is present, as in leaky sewers or septic tanks, the area polluted may be relatively large. Furthermore, once the pollution reaches the ground water, the probable distance of travel becomes considerable and very uncertain. In some soils it may reach as much as 200 or
SOIL AND WATER POLLUTION

300 feet, possibly more under most favorable conditions. In some cases, pollution appears to travel against the flow of ground water as well as with it. In dry soil, pollution will rarely travel, without the aid of water, for more than a few feet.

Perhaps one of the most thorough investigations is that made during the period of 1917 to 1919 by Dr. Israel J. Kligler of the Rockefeller Institute. In his report, published by the Institute as Monograph No. 15, he summarizes the results of the work as follows:

"The problem was approached both from the experimental and the practical standpoint. In the laboratory, repeated tests were made to determine (1) the viability of the typhoid and dysentery bacilli in soil and excrement under different conditions; (2) their ability to penetrate through columns of soil of different porosity; (3) their viability in septic fluids and effluents; (4) the nature of the antagonistic factors in soil and septic material which influence the viability of these microbes. In the field work various types of privies of different ages were examined, particularly with regard to (1) the extent of pollution of soil surrounding these privies; (2) their relation to well pollution; (3) the passage of material through the soil from privies to adjoining wells.

"The main conclusion arrived at on the basis of both the experimental and field observations was that, in moderately compact clay and sand-clay, or sandy soil, free from cracks, the possibility of subsoil pollution of the ground water is negligible, provided that the ground water level is more than ten feet below the polluted area.

"The following facts were established:

"1. The typhoid and dysentery bacilli succumb rapidly on an exposure to an unnatural environment.

"(a) Both typhoid and dysentery bacilli die out in one to five days in septic tanks.

"(b) In solid feces, the typhoid bacilli may survive
for a period of ten to fifteen days, while dysentery bacilli rarely survive longer than five days. The paratyphoid bacilli are the most resistant members of the group. The Shiga dysentery bacilli are the least resistant.

"(c) The survival period of these organisms in soil is greater than in either septic fluids or feces, and varies particularly with the moisture and reaction of the soil. Temperature does have some effect on the viability, but the two main factors are moisture and reaction. In moist, natural soil the typhoid and dysentery bacilli may be recovered up to seventy days. In the same soil dry, the bacilli are not recovered after two weeks. In moist, acid soils, 90 per cent. of the bacilli inoculated die out within the first ten days. Others may survive as long as thirty days.

"(d) The antagonistic action of soil bacteria on typhoid and dysentery bacilli is due largely to the alkaline reaction resulting from their metabolism. Specific inhibitive substances are, however, elaborated by some soil bacteria, notably B. fluorescens and B. proteus.

"2. The spread of pollution from a focal point is limited in scope.

"(a) Typhoid and dysentery bacilli under experimental conditions were not observed to spread laterally to any appreciable extent, although they were carried vertically through a column of two feet of porous soil. In denser soil, they failed to penetrate through one foot of soil.

"(b) In the field, where subsoil was free from pollution, either near pit privies or near tile pipes, from septic tanks, contamination extended downward to a depth of three to five feet, and laterally only about two feet.

"(c) Heavy rains or constant dripping of water may carry surface pollution to a depth of ten feet.

"3. Pollution of wells is usually surface in origin.

"(a) There was no correlation between the type or proximity of the privy to the degree of contamination of
the adjacent wells. The purity of the well water varied rather with the condition of the well. Driven shallow wells with pumps were, as a rule, free from contamination, while dug wells with pumps or buckets were more or less grossly polluted.

"(b) Experiments with fluorescein failed to show subsoil pollution of wells from privies, but proved in some instances, at least, the possibility of surface contamination."

It appears from the results of this investigation that the pit and septic privies, if properly constructed in regions where the ground water is at least ten feet below the bottom of the privy, are safe so far as intestinal infections are concerned. This supposition is borne out fairly well by the work at Wilmington, N. C., by the Public Health Service, and by work at other places by other men. Whether or not the above holds true in regard to hookworm infection is as yet undetermined.

Dr. Kligler in his report also refers to some work done by P. A. A. F. Eyken and G. Grijns along similar lines in the tropics. In general, the results were very similar. It was found that pollution of the subsoil around pits was very slight. In only one case was it possible to trace pollution as much as five meters (sixteen feet) from the pit. In dry soil, B. coli were not found at a depth greater than twenty inches; in wet weather the penetration was about three times as great. In the case of high ground water, these authorities seem to think that much pollution is from the soil directly into the ground water and thence to the well, with the privy having no part in the process. This would appear to fall under the head of surface pollution and illustrates how mechanical (or animal) transportation of pollution may be an important factor in the spread of disease.
C. L. Pfau of the Public Health Service made some tests in 1919 around various sanitary privy installations in Kentucky. In substance, he found that pollution from effluent pipes of septic closets extended two or three feet on each side of and about ten feet below the point of discharge. Therefore, in case ground water is within ten feet of the point of pollution, contamination may occur. No data are given for the distance of travel of pollution with the ground water.

The report of the Commission on Additional Water Supply for New York City, made by Burr, Hering and Freeman, records some experiments on this same subject. The tests were made at Elmont, L. I. While it is stated that the passage of polluted water at low velocities through twenty-five feet of the finer sands, such as are found in Long Island, will render the water safe to use, it is also shown that, under severe conditions sewage bacteria and B. coli may pass through soil for a considerable distance. In most cases, a lesser distance than twenty-five feet may be considered safe, it is stated.

In these tests, a circle of wells was sunk around each of two latrines at a distance of ten feet, with a test well for each latrine, fifty feet away. The latrines were six feet deep. The water table was thirteen and one-half feet below ground surface, which allowed seven and one-half feet between the bottom of the pit and the ground water. The wells were so placed as to take ground water at two feet, seven feet, and seventeen feet, respectively, below the top of the water table.

Samples collected from these wells at intervals showed all water heavily polluted. The nitrogens were
high, especially in the form of free ammonia and nitrates, indicating active decomposition. The bacterial counts were also high, some of the samples containing numbers comparable to those found in sewage. The effect of rainfall on the number of bacteria was great. B. coli, however, was not present as often as might have been expected. Out of 110 samples of water tested, only 1.8 per cent. showed positive B. coli in 0.10 cc.; 9.1 per cent. were positive with 1 cc.; and 22.7 per cent. positive with 10 cc. Five other wells driven at distances of 130 to 220 feet showed indication of active decomposition or organic matter, and two of the wells showed some positive tests for B. coli in 10 cc. samples.

The investigations of the Public Health Service at Wilmington, N. C., followed the same general plan as that of the Long Island tests. Pits were sunk and surrounded by wells, usually two or three circles or rings of wells being placed.

Where the pits were so located that seven to ten feet intervened between the bottom of the pit and the ground water, there was practically no sign of pollution in the ground water, provided that the pit was protected from surface water. Pits which were allowed to fill with surface or rain water carried pollution fairly rapidly to the ground water below. Pits, the bottom of which reached into ground water, were the cause of widespread pollution, B. coli being found as much as 200 feet away. These results appear to agree very closely with those of Kligler, and fairly well, considering the differences of soil and water conditions, with those made in Long Island.

Dr. C. T. Nesbitt, at that time Health Officer of New Hanover County, N. C., made a series of tests in 1917
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at some mill villages near Wilmington. He found pollution of the ground water from effluents from septic closets, in some cases up to twenty feet from the effluent pipe, beyond which distance he made no tests. The results in this case were generally such as to indicate that the sand-clay soil of that region does not fully protect the ground water from fecal pollution, nor prevent the travel with underground water of such pollution for uncertain distances.

This indication was borne out by the bacteriological examination of about 700 shallow driven wells located in the city and county. The only wells of this kind free from pollution were those located 200 to 500 yards away from any concentrated source of pollution, as stables or privies. The bacterial counts in those wells not so located were extremely high, and the presumptive tests for B. coli were almost unfailingly positive.

Judging from the above investigations and findings, a pit privy or septic closet or tank should be fairly safe in regard to subsurface pollution, provided it is located in soil fairly compact and free from cracks, and further, in the case of the pit privy, that the construction be such as to exclude surface or rain water. At least ten feet of soil should intervene between the bottom of the pit and the ground water.

Apparently less study has been given to the problem of surface pollution of domestic water supplies, though this is exceedingly important. Probably most of the pollution of wells and springs comes from surface contamination from open privies, carelessly placed excreta, or improper disposal of privy contents.
The open-back privy can hardly fail to cause widespread pollution. The contents are exposed to rain, which may transport the contained bacteria for miles through streams of water, flies, and animals.

Surface pollution is probably more dangerous than subsurface pollution because it is more general. Prevention, however, is easy. The use of privies which meet the simple requirements of sanitation will prevent the dissemination of the contents, and will protect the health of the user and his neighbors.

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CHAPTER XVII

FLIES AND THE FILTH-BORNE DISEASES

Flies have for so many centuries been regarded solely as household pests that it is hard to convince many people that they are a real menace to health. The important part they play in the spread of disease and the dissemination of pollution is not appreciated, except to a very small extent, by the majority of people, and probably not very well by most of those engaged in health work.

It is hard indeed to trace squarely to the fly the blame for an epidemic of disease. There is a volume of evidence showing the culpability of the fly in disease transmission, but the fly is not usually to blame for such spectacular and explosive outbreaks as characterize water- and milk-borne epidemics. His warfare is one of attrition, with sporadic cases of disease, rather than of grand assault.

There are few bacterial diseases that the fly cannot spread. A large number of organisms have been found on flies, including those from tuberculosis, typhoid fever, dysentery, diarrhea, and enteritis. Such a possibility is indicated by the habits of flies, which pass freely from the open privy to the sickroom, and from the sickroom to the pantry or dining room. It does not take scientific statistics to prove the danger; a mere inspection of the habits and behavior of this pest will indicate how easily they become such important disease-carriers.

There are, of course, many kinds of flies. For our purposes they may be divided roughly into two groups—those which bite and those which do not bite. Among the
non-biting flies, or flies which sip or suck their food, are to be found the principal house flies. The most common, numerous, and widely distributed of all flies is the house, or typhoid fly (*Musca domestica*). The favorite haunt of this fly is houses and it is found all over the world, wherever people live.

The blue-bottle blow flies are others with which we are familiar. The name comes from the noise made by the flies in flight. They have a strong liking for fresh meats and fruits; they also frequent houses.

The green-bottle blow fly bears a strong resemblance to the blue-bottle fly, but differs in color, as the name indicates, and is slightly smaller. It is often found near rotten meat, and in dead animals. When the larvae hatch
out in either flesh or filth, they are especially voracious. The fact that these flies alternate between human excreta and food products renders them extremely dangerous. They are not numerous, as flies go, and not especially indoor flies.

There is a small fly which much resembles the house fly, called the "lesser house fly." Next to Musca domestica, it is the most common indoor fly, and its habits are much the same.

The biting stable fly differs from the above, which are all non-biting flies, in that, as the name implies, it bites. It does not frequent filth as freely as the house fly, but its blood-sucking proclivities afford an opportunity for direct inoculation of disease germs.

There are a great many varieties of flies other than those mentioned, but these are the most common and the most culpable in disease transmission. Moreover, data in regard to these apply largely to other flies, insofar as they are concerned with the spread of filth-borne diseases.

The every-day habits of flies are well known. They frequent filth, garbage, decaying vegetable matter, and manure, and then come to the kitchen and dining room, laden with pollution. They are pests and nuisances, but most of all they are carriers of disease.

While it is probable that many flies live out their lives within a short distance of the place where they were born, there is no doubt as to their ability to travel many miles. Bishopp and Laake, of the Department of Agriculture, by experiments in Texas in 1916, proved that flies will travel as much as fifteen miles. The summary of their report states:
"The maximum distance of spread from the point of release as recorded in these tests was as follows for the several species: *Musca domestica*, 13.14 miles; *Chrysomya macellaria*, 15.1 miles; *Phormia regina*, 10.9 miles; *Lucilia seratica*, 1.2 miles; *L. Caeser*, 3.5 miles; *Synthesiomyia brasiliana*, 0.5 mile; *Sarcophaga spp.*, 3 miles; *Ophyra leucostoma*, 7 miles; *O. aenescens*, 4.1 miles."

The report further states:

"These tests show that the house fly, the screw-worm fly and the black blow fly spread rapidly for many miles. *Chrysomya macellaria* was recorded about eight miles from the point of liberation in less than twenty-four hours and ten miles away in less than forty-eight hours. *Phormia regina* was recovered eleven miles away in less than forty-eight hours after release. *Musca domestica* was recovered over six miles away from the point of release in less than twenty-four hours.

"Males as well as females of the principal species used in these experiments may travel many miles.

"The maximum longevity of the marked flies after liberation as shown by the records of the capture was: *Musca domestica*, fifteen days; *Chrysomya macellaria*, seventeen days; *Phormia regina*, ten to eleven days; *Ophyra aenescens*, six to eight days; *Sarcophaga spp.*, eleven to twelve days.

"While in the fourth experiment no marked flies were captured in the more distant traps (about seventeen miles from the point of release), it is the authors’ belief that the limits of dispersion were not reached in that test, and that where great numbers of flies are emerging constantly, the distance traversed may be much further than the maximum here recorded.

"The facility with which flies travel many miles emphasizes the importance of the general application of sanitary measures looking toward a suppression of breeding."
It already has been shown that the fly is able to carry many kinds of disease organisms, a large number of which are to be found in this country. Typhoid fever, dysentery, diarrhea, and intestinal parasitic disease are the most important common ailments, and of these typhoid fever is most typical and best known.

Disease may be transmitted by the fly by biting, thereby inoculating with the germ and by spreading pollution by vomiting or regurgitation, or by mere mechanical transmission. The least important method in this country is from biting or the actual injection into
the blood of disease germs. Biting flies only may transmit disease in this way. In some tropical countries, this method is important.

Flies feed upon filth or garbage, or discharges from sores, and later vomit this material upon food, dishes, walls, etc. This is especially the case with flies born in filth or manure. These take up with them upon emergence a mouthful of this material, later to regurgitate it upon some convenient place. Flies may also swallow material containing bacteria and then void these bacteria upon food. Such bacteria are usually unchanged by their stay within the body of the fly and retain all their original power to cause disease.

Mechanical transportation or transference, whereby the fly becomes contaminated with disease germs from walking or crawling over filth and excrement, and then carries these to articles of food or drink, is the most common means by which flies spread disease. All flies may act as disease carriers in this way, but the house fly is the principal offender owing to its prevalence and its tendency to frequent filth and excreta. The body of the fly is covered with stiff hairs and bristles which are very well adapted to gather and hold pollution, later to smear it upon articles of food, or to wash it off in milk.

A single instance will show typically the part that flies may have in the transmission of disease, especially where they have access to excreta. In Manchester, England, in 1906, flies were caught daily and counted, and the catch compared to the deaths in the city from diarrhea. There was a remarkable agreement in the incidence of flies and the prevalence of diseases. Fig. 77 shows how the deaths from typhoid and other filth-borne diseases increase during the fly season.
From ten to twelve days in average weather are necessary for the development of the fly from egg to adult. In colder weather the development is slower and may take weeks or even months; under the most favorable conditions of weather, warmth and moisture, the fly may emerge in eight or nine days. The development takes place in four stages or periods: Egg, larva, pupa, and adult.

The female may lay eggs within a few days after emergence and lays a hundred or more eggs at a time, selecting for a breeding place decaying vegetables, human excreta, manure, or other organic filth. Three conditions are necessary for fly propagation—proper temperature, moisture and food supply.

The eggs of flies are small, white, cylindrical objects, about a twentieth of an inch long, rather larger at one end than at the other. If conditions are not too unfavorable, these hatch out in about twelve hours into maggots or larva, probably very familiar to most people. These are white, half as large again as the eggs, and have considerable motility, though they have no legs. During the
course of their growth the maggots pass through two changes, constantly feeding upon the material in which they live. Maturity is reached in from three to five days and after arriving at maturity, the maggots migrate, burrowing into the soil, at times for as much as three or four feet, or traveling overland for quite a considerable distance.

The third or pupal stage is marked by inactivity, contraction, and a change to a darker color. There is a disintegration of the larval parts and a development of the wings and other adult parts. This stage continues for about three days, when the adult, fully-grown fly emerges. In a few minutes the wings dry and the fly is ready to take the air.

Flies multiply very rapidly, so that an enormous increase in the fly population takes place in a very short time. The breeding season varies with the climate, from late April or May in the northern states to September. In more southern climates, breeding may begin in March. After September, the number of flies diminishes very rapidly.

There are two general ways of fighting flies. Active campaigns can be carried on against breeding places with the object in view of preventing the growth and development of the fly; or palliative measures, such as traps, poison, fly-paper, and similar means are employed, the fly being allowed to propagate or breed unmolested. Both methods are of value, but efficiency and safety demand that the fly be fought while breeding, or its breeding prevented. It has then no chance to spread disease.

In instituting any anti-fly campaign, provision should be made for a continued fight. A "Swat-the-Fly" drive, or a cleanup campaign covering a week does not accom-
plish much. It is only by united work on the part of the entire community, efficiently directed by a man familiar with the life and habits of flies, that real progress in fly eradication is possible.

The time of the year has an important bearing upon the success or failure of the campaign. As a rule, anti-fly campaigns are initiated too late to be really efficient. In the north, where breeding does not start so early, work should begin not later than April; in the south, where breeding begins much earlier as a rule, the fight should be under way in March. The chances of attaining any noticeable success diminish rapidly as the months pass.

Control or repressive measures are far more efficient and successful than palliative campaigns.

The first points of attack are the fly-breeding areas. As long as these exist, other repressive measures are almost useless. Therefore, control of these places is an absolute necessity. Fly-breeding areas include manure heaps, garbage dumps, open-back privies, and similar accumulations of refuse and waste. These must be eliminated as breeding places.

Horse manure is the favorite breeding place of flies, though they also breed in the manure of other domestic animals. Control must therefore be had over manure, either so treating it as to make it unfit for flies to breed in, so protecting it as to render it inaccessible to flies, or by taking other steps to prevent breeding in it.

The United States Department of Agriculture has made careful studies into chemical treatment of manure to render it unfit for fly-breeding, while at the same time not injuring its fertilizing value. Fresh manure may be treated with powdered borax at the rate of one pound of borax to sixteen cubic feet or thirteen bushels of
manure. This will kill about 90 per cent. of the fly larvae and is not harmful to the manure. Water extract of hellebore, prepared by making a mixture of one-half pound of hellebore and ten gallons of water, is very effective at the rate of one gallon per cubic foot of manure. Either borax or hellebore, in greater quantity than recommended, will injure the manure, or rather the soil upon which the manure is placed. Creosote has been used to prevent breeding, but it also affects the quality and fertilizing value of the manure.

Maggot traps, whereby the migrating habits of the maggots are turned to their disadvantage, are familiar. The manure is placed or piled upon a slatted platform, under which is a basin or tank of water. The maggots burrow through, or migrate from the pile, fall into the

Courtesy Dr. W. K. Sharpe, Jr.

Fig. 80.—Ideal fly-breeding conditions.
water and drown. Manure may also be stored in fly-tight bins. This is a good method of temporary storage until the manure can be removed finally. Stacking in a compact pile will greatly reduce the amount of breeding, especially if the edges of the pile are oiled or treated with borax. On farms, if manure is spread over the ground thinly, especially in such a way as to let it dry out, breeding will be prevented, since moisture is a necessity in the life cycle of the fly.

The privy which allows flies to reach the contents is a prolific producer of flies, and must be eliminated if fly control is to be effective. Moreover, flies which develop in or frequent human excrement are far more dangerous than those which frequent other places. This source of breeding should therefore receive especial attention.

The various types of privies most used and best
suited for the majority of homes were described in Chapters V to IX, inclusive. The installation and careful operation of any of these types will not only reduce the fly incidence, but will also protect the excreta, so that it cannot be carried to food or drinking water by flies, animals, or surface wash, or scattered over the soil to cause hookworm, typhoid fever, or dysentery.

Flies also breed freely in garbage. To reduce this, garbage should be kept in tight cans and collections should be made at least twice weekly in the summer; every-day collections are better. Still more important is the final disposition of the garbage. If dumped, flies will breed freely in the dump; if fed to pigs, the feeding pen may become a heavy producer. Dumping is permissible from a sanitary point of view only when the garbage is covered with at least two to three feet of earth, or is so treated as to prevent breeding. The hog-feeding pens should have a concrete floor and the remains of each day's feeding should be collected and burned. In the larger cities, reduction of the garbage is sometimes employed. This, of course, permits of no breeding, nor does incineration, which method is quite popular with cities of medium size, though often beyond the means of the smaller towns. Burial, as usually practiced, will allow the emergence of the larvae already in the garbage, so in case of disposal by this method, the flies should be prevented from reaching the garbage and laying their eggs in it.

Flies will also breed in rotting vegetable matter, accumulations of trash, street sweepings, packing-house and other trade wastes, and in almost any other place providing the three requisites of warmth, moisture, and food supply. In general, the application of the principles already mentioned will control production, but more
detailed information will be found in the various publications of the Department of Agriculture or in entomological books or pamphlets, various of which are listed in the bibliography following this chapter.

As has been shown by Bishopp and Laake, flies may travel long distances. Therefore, though all local fly-breeding places be eliminated, some flies may still be present. The campaign must then be directed against adult flies, as well as against breeding places. Screening is undoubtedly the most important of the measures directed against the adult fly, though this is a defensive and not an offensive measure. Fly-traps are useful, as are poison and fly-paper.

Traps have the advantage of reducing the population, even though this reduction is small. The use of traps is most effective at places where flies tend to congregate, as meat markets, packing plants, restaurants, etc. Many good fly-traps are on the market. Proper baiting is very important. Bananas, meat, fish scraps, sour molasses, and similar materials make good baits, though any kind of bait to be effective must be changed frequently and kept attractive.

Sticky fly-paper is useful in reducing the number of flies in a house, and should be used freely where no better means of control are available.

Poison is a very valuable adjunct in the fight against adult flies, but caution must be observed so that children are not poisoned. Formaldehyde in a 0.5 per cent. to 1 per cent. solution is very efficient. Arsenical compounds are dangerous, and fatal cases of poisoning are not rare. Formalin diluted with about forty parts of water is a useful poison. Hygienic Laboratory Bulletin No. 108, Public Health Service, gives full data on poisons for flies.

The unscreened house and the open-back privy make
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Fig. 82.—How to make a fly-trap.

Courtesy Provincial Board of Health of Ontario.

Pattern for construction of cone

Conical fly trap

Door placed under cone

Bottle hoop

Screen wire galvanized

Opening at apex cone with 1½" screen wire

15 to 20 mesh circular slab

Removable barrel head or

Thread-square
a very dangerous combination. Screening does not keep out all flies, but when properly done, about 90 per cent. to 95 per cent. are excluded, and the danger and nuisance reduced accordingly. Screening of the kitchen and dining room, and the living room is most important in the order named. In case of sickness, screening is important in preventing further spread of disease, especially in the most communicable or "catching" diseases.

Just as it is very important to screen the kitchen and the dining room, so should bakeries, meat markets, stores, and other places where food is exposed for sale, be carefully screened.

Screening of the average small home will cost in the neighborhood of $40 to $50. Just as in the case of a similar expenditure for a sanitary privy, this amount of money invested in screens will yield big returns in health and comfort. Screening, when properly done, keeps out mosquitoes as well as flies.

The following directions for screening houses is from Reprint No. 170, Public Health Reports, by Surgeon R. H. Von Ezdorf:

"To be of proper construction, a door frame should be made of cypress or other seasoned wood one inch to one and one-half inches thick, well braced and painted. The wire should be sixteen to eighteen mesh. The lower panel should be covered on the inner side with a one-fourth-inch mesh wire guard to protect the screening. If this is not provided, two or three strips of wood, one inch wide, set three inches apart should be nailed across the lower panel and two or three such strips of wood placed over the lower portion of the upper panel. This provision is made for the protection of the screening in pushing the door open.

"It is not an unusual experience in certain climates to have doors, even the best, swell or warp, so they will not close. After planing them so they will close, the wood
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will shrink in warm weather leaving a crack of half an inch or more where flies or mosquitoes might enter.

"An easy-fitting door, fully one-fourth inch clear all around the edge is best, and to make it mosquito-proof it is necessary only to tack a strip of light canvas one inch wide around the top and one side of the door facing on the outer side (not on the screen door), so that when the door closes this canvas will take up all the lost or extra space.

"Some use strips of wood nailed to the inner side of the door jambs against which the screen door strikes. This is usually satisfactory, but doors will warp lengthwise, so that the tops and bottom will not strike such facing strips, thus leaving spaces at the top and bottom. The door should, of course, have a spring which will keep it closed firmly.

"Windows are probably the most common place of entrance for mosquitoes or flies. Windows are frequently screened with a view to easy removal of the screen for opening or closing the shutters. For this reason, telescoping and adjustable screens are most commonly used and sold. This type of screen is made of wood or angle iron material for the frames and furnished with twelve- or fourteen-mesh iron wire. At best, these screens are not effective. The half-window sliding screens provided with guides, well made, are efficient, but costly. When using this type, the window must be kept wide open so that the sash will fit close to the frame of the screen.

"The most efficient method of screening a window is to screen the entire opening. A well-fitting screen frame, which is screwed into place so that it can be removed at the end of the season, is probably the best.

"Another method, less expensive than that of constructing a frame, is to cover the window with wire netting tacked to the window facing, and cover the edges of the netting with narrow strips of wood, nailed down to keep it flat and to hold it firmly. Cotton mosquito netting, which will serve for a time, possibly for a whole season, might be used in this way."
It must be remembered, though, that trapping, poisoning, and other palliative measures are practically worthless unless carried on in conjunction with active repressive measures. Screening has a high health value and should be recommended from this point of view, as it protects against mosquitoes and flies. Screening is valuable even where anti-fly and anti-mosquito campaigns have been successfully carried on.

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APPENDIX

There are some matters which, while important, it has not seemed best to include in the text. These include certain specifications in regard to construction, and ordinances suitable for use in towns and cities of various sizes. In order that these may receive treatment in an adequate manner, they have been included in the Appendix.

Ordinances

The first ordinance presented is a very complete one adopted by Leeds, Alabama. In fact this is more of a health code than an ordinance. It may well serve as a model for other towns and cities which desire to provide for the future in the matter of sanitation—a point which is especially important in health work. Experience has shown that it is much easier to secure satisfactory legislation on health matters before the customs of the community become settled along insanitary lines. Such a health code provides for future policy in sanitation.

AN ORDINANCE

To protect the public health and to provide for the disposal of human excreta, the installation of sanitary privies, toilets, and water-closets, and to regulate their construction, maintenance, and use, and to regulate the maintenance of open wells and other sources of water supply in the town of Leeds and its police jurisdiction.

BE IT ORDAINED by the City Council of Leeds, Alabama, as follows:

SECTION 1. After the passage of this ordinance, all buildings, premises or other places in the town of Leeds, Alabama, or its police jurisdiction where human beings live, are employed or congregate shall be provided with adequate facilities for the disposal of the bodily discharges of such persons, the method, type and location of which facilities shall be approved by the Board of Health of Jefferson County.

SECTION 2. The Board of Health of Jefferson County is hereby empowered and directed to regulate and control the type, construction, capacity,
location, use and maintenance of all privies, toilets, water-closets, and all appurtenances thereto, or used in connection therewith, in the town of Leeds, Alabama, and its police jurisdiction, and it shall be unlawful for any person, firm, or corporation to use or maintain in said town or its police jurisdiction any privy, toilet, water-closet or other method of sewage disposal not approved by, or in accordance with the regulations and specifications of the said Board of Health.

SECTION 3. For the purposes of this ordinance the word "sanitary" when used in connection with, or as alluding to a type or character of toilet, privy, water-closet, or other appliance or method used for, or in connection with the disposal or handling of human excreta shall be interpreted to mean toilets, privies, water-closets or other appliances or methods used for, or in connection with such purposes, the type, construction, capacity, location and character of which have been approved by the Board of Health of Jefferson County.

SECTION 4. It shall be unlawful for any person, firm, corporation or association owning or controlling property, or for tenants or occupants of such property or premises, in the town of Leeds, Alabama, or within its police jurisdiction, to dispose of or to permit the disposal of human excreta on or about such property or premises except in a sanitary toilet or privy or otherwise in such a manner as may be approved by the Board of Health of Jefferson County, Alabama.

SECTION 5. Whenever used in this ordinance for the purposes thereof, the following words, terms or names shall be construed as follows:

Dwelling. A "dwelling" is any house or building or portion thereof which is occupied in whole or in part as the home, residence or sleeping-place of one or more human beings, either permanently or transiently.

Private Dwelling. A "private dwelling" is a dwelling occupied by but one family alone.

Two-family Dwelling. A "two-family dwelling" is a dwelling occupied by but two families alone.

A Multiple Dwelling. A "multiple dwelling" is a dwelling occupied otherwise than as a private dwelling or a two-family dwelling.

Classes of multiple dwellings. All multiple dwellings are dwellings and for the purpose of this ordinance are divided into two classes, viz., Class A and Class B.

Class A Multiple Dwellings. "Class A multiple dwellings" are dwellings which are occupied more or less permanently for residence purposes by several families, and in which the rooms are occupied in apartments, suites, or groups, and includes tenement houses, flats, apartment houses, apartment hotels, bachelor apartments, studio apartments, duplex apartments, kitchenette apartments, and all other dwellings similarly occupied whether specifically enumerated herein or not.

Class B Multiple Dwellings. "Class B multiple dwellings" are dwellings which are occupied as a rule transiently, as the more or less temporary abiding-place of individuals who are lodged, with or without meals, and in which, as a rule, the rooms are occupied singly. This class includes hotels, lodging houses, boarding houses, furnished room houses, lodgings, club houses, convents, asylums, hospitals, jails, and all other dwellings similarly occupied whether specifically enumerated herein or not.

SECTION 6. There shall be provided for each and every private dwelling in said town or its police jurisdiction, one separate sanitary privy, toilet or water-closet and for each two-family dwelling and for each multiple
dwellings of "Class A" there shall be provided for each family, a separate sanitary privy, toilet or water-closet. In multiple dwellings of "Class B" there shall be provided one separate toilet or water-closet, or separate privy seat for each fifteen occupants or fraction thereof.

SECTION 7. In all buildings or places other than dwellings where persons are employed or congregate, there shall be provided one separate toilet or water-closet or separate privy seat for every twenty persons or fraction thereof. Provided that in all such buildings or places and in multiple dwellings of Class B separate privies, toilets or water-closets within separate and complete enclosures, having separate entrances, shall be provided for males and females. Provided further, that where two or more toilets, water-closets or privy seats are located within a single or common enclosure, each shall be separated by a wall or partition so constructed as to obscure the vision or contact between persons during ordinary use thereof.

SECTION 8. It shall be unlawful for dwellings or other buildings or premises which are not provided with sanitary privy or toilet facilities in accordance with the provisions of this ordinance, to be leased, or rented, for the purpose of residence or occupancy by human beings or to be used or occupied for such purposes.

SECTION 9. It shall be the duty of the Board of Health of Jefferson County to prohibit the use or occupancy of all such dwellings, buildings or premises not so equipped, and, when necessary, to order or cause such dwellings, buildings, or premises to be vacated.

SECTION 10. It shall be unlawful for a person to use or permit the use of a privy, toilet or water-closet which is defective or for any reason insanitary, and each use thereof shall be deemed a separate offence.

SECTION 11. When water under suitable pressure is or becomes available, a flush toilet shall be provided which shall be connected with a sewer or septic tank, the design, construction and location of which shall be approved by the Board of Health of Jefferson County. No water flush toilet shall be located out of doors or outside of the principal building, the equipment of which it is intended to become a part, without written approval from the Board of Health of Jefferson County. No toilet shall be placed in a cellar without written approval from the Board of Health of Jefferson County.

SECTION 12. When an approved public water supply under suitable pressure is or becomes available within reasonable distance from any dwelling, building or other place in the town of Leeds, Alabama, or its police jurisdiction, where human beings reside, are employed or congregate, a water flush toilet connected to a sewer or septic tank shall be immediately substituted for other types of toilets or privies, provided that when a sanitary sewer becomes available within a reasonable distance all such water flush toilets as may have previously been connected to septic tanks or otherwise shall forthwith be connected to said sewer.

SECTION 13. The provisions of this ordinance with reference to sewer connections and water supply shall be deemed to apply only where connection with a public sewer or with public water mains or pipes is or becomes reasonably accessible and such connection shall be deemed to be reasonably accessible when such public sewer or public water pipes or mains are within a distance of two hundred (200) feet of any outside line of the lot upon which such dwelling or other building is located, provided that when such property or premises is not subdivided into lots, and so designated on available surveys or maps of record, then the distances
specified above shall be deemed to apply to the nearest portion of said dwellings or other buildings.

SECTION 14. When water suitable for use by human beings, the source and quality of which is approved for such use by the Board of Health of Jefferson County or of the State of Alabama, becomes available on any premises in the town of Leeds, Alabama, or its police jurisdiction, the maintenance of or the use of water from open wells or other sources on such premises not so approved is hereby declared to be unlawful.

SECTION 15. The cost of providing sanitary toilets, privies, or other methods of excreta disposal required by the provisions of this ordinance shall be borne by the owner or agent of the property upon which said privies or toilets are located.

SECTION 16. In case of the failure of any person, firm, association, or corporation, or their agent, in the town of Leeds, Alabama, or the police jurisdiction thereof, to comply with the provisions of this ordinance by or before April 15, 1922, the town of Leeds, Alabama, shall order and execute the necessary improvements, the cost of the same to be assessed against and to become a lien upon the entire premises upon which such installation is made, in accordance with law.

SECTION 17. All privies, toilets, water-closets and appurtenances thereto or on any premises within the town of Leeds, Alabama, or its police jurisdiction, not constructed and maintained in accordance with the provisions of this ordinance are hereby declared to be a menace to the public health, and a nuisance, and same shall be abated.

SECTION 18. Each and every violation of the provisions of this ordinance shall constitute a separate offence for each day such violation occurs or exists, except as provided in Section 10.

SECTION 19. Any person violating the provisions of this ordinance shall, when convicted, be punished as provided in Section 1216 of the Code of Alabama of 1907, except that the fine in every case shall be not less than $5.

SECTION 20. All ordinances and parts of ordinances in conflict herewith are hereby repealed.

SECTION 21. If any section, clause, provision or portion of this ordinance shall be held to be invalid or unconstitutional by any court of competent jurisdiction, such holding shall not affect any other section, clause, or provision or portion of this ordinance which is not in itself and of itself unconstitutional.

The Alabama State Board of Health issues the following suggested model ordinance for the guidance of municipalities contemplating the installation of a box and can privy system, with boxes of any type.

This ordinance describes a sanitary privy in a general way, and must be amplified by specifications promulgated by the Health Officer or agency responsible for the operation of the system.
Note.—Where the term “Health Officer” appears, the title of the officer charged with the administration of the system may be substituted.

AN ORDINANCE

To provide for the regulation, maintenance, inspection, and operation of privies in the City of................., Alabama; to provide for a scavenger fee for cleaning of same; and to provide a penalty for the violation of said ordinance or any section thereof.

BE IT ORDAINED by the City Council of the City of................., Alabama:

I. That on and after................., it shall be unlawful for any person, firm, or corporation to own, maintain, or operate in................., Alabama, or in the zone of police jurisdiction thereof, a privy or dry closet for the reception of human excreta, unless said closet is built, rebuilt, or constructed as hereinafter provided.

II. It shall be unlawful for any person, firm, or corporation, to permit a privy or dry closet of any kind or description, for the reception of human excreta, to be maintained or to exist upon any property in ................., Alabama, or in the zone of police jurisdiction thereof, where any of said property is adjacent to the public sewer system of said city.

III. It shall be unlawful for any firm, person, or corporation to throw out, deposit, or bury within the city limits of................., Alabama, or in the zone of police jurisdiction thereof, any excreta from human bodies, solid or liquid, or to dispose of such excreta in any manner other than into a properly sewered water-closet or a properly constructed sanitary privy.

IV. All buildings or other places in said city where human beings live, are employed, or congregate, shall be provided with a properly sewered water-closet or a properly constructed sanitary privy for the catchment or receiving of human discharges, which will properly dispose of and safeguard such matter.

V. It shall be unlawful for any person, firm, or corporation to construct, maintain, or permit a privy to exist on any property or properties under their control, where sewer connection has not been made, unless said privy is sanitary, or is constructed as hereinafter provided.

VI. A sanitary privy is one so built, rebuilt, or constructed that
(a) the excreta deposited therein will not fall upon the ground, but enters some watertight receptacle, the same to be contained in a fly-tight compartment;

(b) the contents of which receptacle shall be inaccessible to flies, fowls, or small animals at all times.

(c) The can compartment or box shall be of such design and constructed of such materials as are approved by the City Council and Health Officer, all joints being made tight. Said can compartment or box shall be provided with a closely fitting top or seat. In this top or seat there shall be a smooth beveled hole of suitable size. This hole shall be covered by a lid built as a true plane, of the same material as the seat, reinforced to prevent warping, provided with grooves or a hand clip for opening, and
of such size as to extend over the outer rim of the hole at least one and one-half inches and provide at all times a flytight joint. The lid shall be so hinged or fastened to the top as to permit its being easily raised. The seat and lid shall be varnished and polished or treated with an enamel paint, so as to be smooth and impervious to water. The compartment or box shall be so designed that the can will at all times be suitably located in relation to the seat hole, allowing the proper air space between walls.

(d) Ventilation of the compartment shall be provided for by screened openings. There shall be a screened opening near the top of the back wall of the compartment into which shall fit an elbow of four-inch galvanized iron pipe, connected with a vertical riser or flue of the same material. This riser shall be seven feet in length, and capped so as to exclude rain but permit proper ventilation. All screens shall be of sixteen-inch mesh, copper, bronze, or brass.

(e) The watertight receptacle shall be cylindrical or oval, constructed of No. 24 gauge galvanized iron, and shall have a cubical content of approximately nine and one-half gallons when full. Heavy bails or handles for handling shall be provided. The watertight receptacle shall be so constructed as to permit a rolled or pressed lid to fit tightly.

(f) Such privies shall be so located as to be easily accessible to the scavenger for cleaning.

VII. The Health Officer of .................., Alabama, shall prescribe, by specifications, proper sizes and methods of construction of such privies, and such other details as will render this ordinance effective and its application uniform. All such privies must conform to such specifications.

VIII. The contents of all privy receptacles shall be removed by the owner of said premises, occupants, or tenants thereof, or family or member thereof using the said privy, whenever necessary and at least once every week, and a failure to do so shall subject such party, or parties, to the penalty provided in this said ordinance. Said person or persons shall have the right of paying in advance to the city ............ per quarter for each privy, containing one receptacle, located at a private home, and twenty-five cents for each additional receptacle; in which event the city scavenger shall make removal of said privy contents, and said person or persons shall not be liable for the penalties provided if such provision is not carried out, for the quarter for which such advance payment was made.

IX. All sanitary privies in said city, and in the zone of police jurisdiction thereof, shall be kept in clean condition at all times, and so used that all excreta deposited therein will fall in the receptacle provided. Such receptacle shall be used only for the purpose of a privy, and no wash water, garbage, or other refuse matter, other than human excreta, shall be deposited therein.

X. No privy receptacle shall be permitted to become filled to overflowing. If emptying of privy receptacle becomes necessary oftener than hereinbefore provided, it shall be the duty of the occupant of the property to notify the .........., and such privy shall be cleaned, and an additional charge of fifteen cents shall be made for each receptacle so emptied.

XI. All privies existing or maintained in said city, or in the zone of police jurisdiction thereof, after the date on which this ordinance takes effect, which do not conform to the requirements of this ordinance, or to the specifications of the City Health Officer issued under this ordinance, shall be and are hereby declared a nuisance, dangerous to the public health,
and the city of .........., Alabama, shall proceed to abate such nuisance in accordance with law, or in accordance with the ordinances of said city.

XII. The city shall have the further right, after five days notice, to make, or cause to be made, such alternations or additions to such privies as are nuisances as will render them sanitary, and the entire cost of such work shall be charged against the person creating or maintaining the nuisance, all such alterations or constructions being prescribed and approved by the Health Officer.

XIII. All receptacles for sanitary privies in the city of .........., Alabama, or in the zone of police jurisdiction thereof, are to be considered the property of said city, which shall make renewals when said receptacles are no longer suitable. It shall be unlawful for any person, firm, or corporation to remove, destroy, misplace or misuse any of such receptacles.

XIV. The Health Officer of the city of .........., Alabama, or a duly appointed inspector, shall personally inspect all privies in .........., Alabama, or in the zone of the police jurisdiction thereof, as often as such inspection shall be deemed necessary by such Health Officer or Inspector. The Health Officer, or duly appointed Inspector, is hereby empowered to enter all premises in the discharge of his duty.

XV. It shall be unlawful for any person, firm, or corporation to fail or refuse to comply with the provisions of this ordinance.

XVI. Any person, firm, or corporation violating any of the provisions of this ordinance or the specifications issued by the Health Officer under this ordinance, or any person, firm, or corporation, in any way obstructing the Health Officer, or his duly authorized agents or the scavenger, in the proper discharge of the duties prescribed in this ordinance shall, upon conviction, be fined in a sum not more than one hundred dollars ($100.00), and may also be sentenced to hard labor for the city for a period of time not exceeding six months.

XVII. All ordinances, or parts of same, in conflict with the provisions of this ordinance are hereby repealed.

Attest: .......................................................... Mayor.

.......................................................... City Clerk.

The anti-fly ordinance is modeled after the general ordinance of the Pennsylvania State Board of Health:

SECTION 1. No privy, cesspool or other receptacle for human excrement shall be constructed, maintained or used so that flies have or may have access to the excrementitious matter contained therein.

SECTION 2. The transportation of human excrement shall be effected in watertight containers with tight-fitting covers. Containers shall be thoroughly cleansed after each use.

SECTION 3. No human excrement or material containing human excrement shall be placed on the surface of the ground or buried or otherwise disposed of, where it is likely to gain access to any waters of the state, unless subjected to treatment by a method approved by the Health Officer.

SECTION 4. The contents of privies, cesspools or other receptacles for human excrement shall not be used on ground within the corporate limits of any city or borough, or within 700 feet of any habitation, unless subjected to treatment by a method approved by the Health Officer.
Section 5. No kitchen or laundry water shall be allowed to discharge or flow into any gutter, street, roadway, or public place.

Section 6. No garbage, offal, pomace, dead animals, decaying matter or organic waste substance of any kind shall be thrown or deposited in any ravine, ditch or gutter; on any street or highway; into any waters of the state or be permitted to remain exposed upon the surface of the ground.

Section 7. Manure shall not be allowed to accumulate in any place where it can prejudicially affect any source of drinking water, or as a source of fly breeding, it may become a menace to public health.

Specifications

Section VII of the model ordinance proposed by the Alabama State Board of Health provides that:

The Health Officer of Alabama, shall prescribe, by specifications, proper sizes and methods of construction of such privies, and such other details as will render this ordinance effective and its application uniform. All such privies must conform to such specifications.

These specifications of the Health Officer are determined by the type of box decided upon by the members of the city government. Model specifications, prescribing the construction of an inside-opening wooden box, are given below. Specifications for rear-opening boxes may be drawn up in a similar manner.

(A) All sanitary privy can-boxes shall be made of sound, seasoned lumber, free from knot-holes and cracks, not less than seven-eighth inch in thickness, and tongued and grooved or ship-lapped. The front and sides of every box shall be constructed of lumber dressed on one side, planed side out. All joints in the boxes shall be made tight, and all boxes shall be strong and durable.

The four sides of the box shall be nailed to $2 \times 2 \times 17$-inch pieces of lumber, located in each lateral corner when the box is completed, upon the upper end of which the cover shall rest firmly.

(B) The use of a single-can privy shall be limited to five persons; larger families or groups of persons shall require a two-can privy or a larger multiple of the single-can privy.

The inside dimensions of a single-can box shall be:

Length, 22 inches; width, front to rear, 20 inches; height, 17 inches.

These specifications were prepared by the Engineering Department of the Alabama State Board of Health.
The inside dimensions of a two-can box shall be:
Length, 42 inches; width, front to rear, 20 inches; height, 17 inches.
Boxes for larger multiples of cans shall be 20 inches longer for each additional can.

All boxes shall be thoroughly saturated with a creosote solution, either by dipping or painting. This does not include the seat and seat-hole cover, both of which shall be painted or varnished.

(C) The top of the box shall be hinged and shall form the seat. This top shall consist of dressed, kiln-dried lumber, and shall be reinforced on the under surface, with $3 \times \frac{3}{4} \times 16$-inch strips of wood to prevent warping. The lid shall extend beyond the front face of the box, to permit it to be easily raised. The lid shall be hinged to the rear face of the box with two four-inch strap hinges for a single-can box, and at least three hinges of the same size for a two-can box. A one-inch molding shall be nailed on the under surface of the lid where it makes contact with the inner surface of the front and end walls, in order to prevent the access of flies, in case of slight warping.

In a two-can box a brace shall be placed midway between the ends, to strengthen the box and serve as a support for the seat. This brace shall not be a solid partition, and shall be placed so as not to interfere with the screening of the flue and air vents.

(D) The seat-hole shall be oval and shall measure 11 inches from front to rear and nine inches laterally. The edges of the seat-holes shall be beveled. The forward edges of the seat-holes shall be four inches from the front outside surface of the box. In single-can boxes the hole shall be placed in the median front and rear line; in two-can boxes the centres of the holes shall be 10$\frac{1}{2}$ inches from the inside lateral surfaces of the box. The cans are to be kept in proper position with relation to the seat-holes by cleats nailed to the floor of the box in such a manner as to guide the can, when placed in the box, to a position in which its forward edge is one inch from the front wall of the box, and the lateral edges are equidistant from the ends.

(E) Every seat-hole shall be provided with a cover or lid of dimensions sufficient to overlap the hole in all directions by at least 1$\frac{1}{2}$ inches. The cover shall be well made of kiln-dried lumber, shall be reinforced to prevent warping, and shall lie flat over the hole so as to exclude flies when in this position. The cover shall be so shaped that the rear edge, at which it is hinged, shall extend at least five inches back from the rear edge of the seat-hole. Parallel to the rear face of the box, and five inches from the rear edge of the seat-hole, a $1 \times 2$-inch bar of wood, extending laterally across the box from end to end, and securely and permanently fastened thereto with two-inch wood screws or nails which have been clinched, shall be placed. The seat cover shall be hinged in a manner to avoid binding, to this strip of wood with two-inch harness rings, fastened to cover and box with heavy staples, sufficiently long to be clinched on the under side.

(F) Every box shall be equipped with a ventilation flue. These flues shall be seven feet long, four inches in diameter, shall be constructed of 24-gauge galvanized iron, securely riveted and soldered, and shall be provided with a suitable cap over the top to prevent rain from entering the flue. This cap shall cover the entire top of the flue, but its lower edge shall be not less than two and one-half inches above the top of the flue, to permit free exit of gases at all times. The flue shall be provided with
an elbow. This elbow shall be not more than twelve inches, nor less than ten inches in length, in order to allow the flue to fit snugly against the rear of the privy when the box is installed.

Each flue shall be provided with a strip of 28-gauge galvanized iron, three and one-half feet long and one inch wide, to be used to fasten the flue to the rear wall of the privy.

(G) Every box shall be provided with a round hole, four inches in diameter, for the snug admission of a four-inch flue pipe. This hole shall be centered five inches from the top of the box, equidistant from the ends. A 6 x 6-inch frame of 1 x 1/2-inch wood strips, and an 8 x 8-inch square of copper, bronze, or brass wire screen, with at least eight small wire nails, shall be included in the equipment of each box, for permanent placing over the flue opening when the flue has been placed.

(H) Inlets for air shall be provided by one-inch holes in the front wall of the box, three inches from centre to centre, on a line two inches above the inside floor of the box. Holes shall be bored at an angle of 45 degrees to the front plane of the box, so they open upward and inward. The inside opening of the ventilating holes shall be covered with a strip of 16-mesh copper, bronze, or brass wire screen, securely fastened on all edges, at least one inch from the edges of the holes, by means of wood strips nailed with small wire nails. The air inlets in two-can boxes shall be of similar size and similarly located, but four inches from centre to centre.

(I) The privy cans shall be of 24-gauge galvanized iron, watertight and well soldered, fourteen inches in diameter and fourteen inches deep, and uniform in every dimension. Each can shall be reinforced at the top and bottom with a hoop or band. The circumferential walls of the cans shall extend beyond the bottom, so the cans may not rest on their bottoms. Each can shall be fitted with a substantial, well-riveted handle on each of opposite sides, three inches from the top.

(J) All boxes, cans, and flues which do not meet these specifications shall be rejected by the Health Officer or his duly appointed agent.

.................................................................
Health Officer.

Approved by the City Council................................

.................................................................
Mayor.

Attest:

.................................................................
City Clerk.
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