SEWAGE DISPOSAL

INTRODUCTION

THE SANITARY DEMAND FOR SEWERAGE AND SEWAGE DISPOSAL

The Wastes of Human Life. The human body is a biological machine which requires food for fuel and which produces in its operation a considerable amount of waste material. Like the ash from a furnace, this waste consists partly of mineral matter and partly of incompletely oxidized fuel. The excretions of the kidneys, representing the end products of cell metabolism, still contain a large amount of organic matter in the form of urea; the discharges from the alimentary tract consist largely of undigested, or partially digested, foods which have not been absorbed by the body. All these substances undergo further change after they are excreted from the body, breaking down into simpler or more stable compounds, and during this change compounds are formed which are characterized by the penetrating noxious odors of putrefaction.

Besides the organic waste materials from digestion and excretion, the excreta contain a host of microscopic living organisms, and this fauna and flora is of even greater practical importance than the lifeless substratum upon which it subsists. The surfaces of the human body, within and without, are parasitized by micro-organisms, which find their most favorable conditions for multiplication in the digestive tract. MacNeal, Latzer and Kerr (1909) report an average of 33 million million bacteria per day in the feces of normal adult men;* and Proto-

* Complete references to all literature cited will be found in the bibliography at the end. References in the text include the name of the authority (the initials in the case of the British commissions) and the date of publication, with a distinguishing letter in case more than one volume appeared in a single year. This serves simply to identify the article or book, the full title of which is given in the bibliography.

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zoa, though not so ubiquitous, are by no means rare. Most of these microscopic parasites are harmless, putrefactive forms; but in the excreta from a patient suffering with typhoid fever, or dysentery, or cholera, or any other intestinal malady, the specific germ of the disease may at any time be present.

The discharges from the alimentary canal and the kidneys do not of course exhaust the catalogue of human wastes. The washings of the outer skin, and the wash water from cooking and house-cleaning, are included in the wastes from the household. In more closely settled communities, street washings and the wastes from industrial establishments are also added. With the exception of factory wastes and street washings, which are of various composition and require special treatment, the excretions of the body may be taken as a general type. The important constituents in every case are the intermediate products of organic decomposition plus the living micro-organisms, which may at any time include specific pathogenic forms.

**Primitive Methods of Dealing with Excreta.** Under primitive conditions excretal matter ultimately finds its way to the water or the earth. Direct discharge into watercourses is eminently satisfactory to the persons immediately concerned, if the flow be sufficient to prevent local accumulations. The effect of this procedure upon individuals and communities on the watershed below may, however, be serious. This is an aspect of the larger problem of sewage disposal and stream pollution which will be discussed more fully further on; as far as the polluting individual goes, direct discharge into water is an efficient method of disposal. The earth, too, is able to assimilate decomposing organic matter with success, as demonstrated yearly by the manuring of the fields. Mixed with a sufficient quantity of earth, and with reasonably free access of air, excreta are quickly disintegrated and oxidized to stable and innocuous forms.

The difficulty with the method of earth disposal lies in its application. Its success demands prompt and complete mixture with clean dry earth; and this is rarely attained. The
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conditions which actually exist are various. The most primitive houses are provided with privy vaults for the excreta, but discharge sink and other wastes directly on the surface of the ground, with or without the medium of a drain. Combinations of privy vaults for excreta with cesspools for sink drainage lead up to a better class of houses provided with cesspool connections for all wastes.

The privy vault is certainly the most objectionable of these contrivances. It stores up quantities of human excreta in a slowly decomposing condition. It is generally loosely built, and the material which it contains is more or less freely exposed to the air and to the distributing agency of insects and higher animals. It is subject to overflow and surface discharge at times of heavy rain; and the material which it contains must generally be removed and otherwise disposed of at intervals, the process of handling causing fresh nuisance and menace to health. A well-constructed cesspool is free from many of these objections. The material in it is, or should be, closed in, so that air-borne odors and the access of insects are prevented. The liquid contents of the cesspool must go somewhere, however. If the surrounding soil be of a suitable sand, the liquid may so filter through it as to be efficiently purified. Such a cesspool may operate for years without filling up and without causing pollution of water or earth. Where, however, a rocky or clayey soil is traversed by fissures, a leaching cesspool may constitute a serious menace to well waters, even at considerable distances. A tight-walled cesspool, on the other hand, resembles a privy vault in the danger that it may overflow and in the certainty that it must be emptied and the material in it removed and carted away.

The Dangers from Accumulations of Excretal Material. Accumulations of excretal matter are not merely objectionable on account of the unpleasant odors due to their decomposition. The nuisance from an individual cesspool or sink-drain is seldom sufficient to be obnoxious, except in the immediate vicinity. The real danger lies in the disease germs which
may be present. Typhoid fever and dysentery are unfortunately still common diseases; and in the discharge of persons suffering from these, or other, intestinal disorders the specific parasites may be present in great numbers. Even with patients patently suffering from such maladies it is rare that proper precautions are taken for disinfection. Unrecognized cases of a light nature may spread the most virulent germs; and occasionally "typhoid carriers" are found, infected with pathogenic organisms, though not themselves suffering from the disease. Wherever excretal are present the germs of intestinal disease are potentially present also.

If excretal matter carrying disease germs is kept exposed in privy vaults, or is discharged from overflowing cesspools, the transfer of the infection to susceptible human beings is one of the most probable of events. Flies, which impartially affect privies and larders, offer perhaps the most convenient mechanism for transferring fecal matter to the mouth. Rats and chickens and other animals play their part. Children may easily acquire more direct infection. The carelessness which is encouraged by the uncleanly environment of the privy vault increases the danger to all who use it; and, finally, the emptying of privy or cesspool and the transportation of the contained material to its point of final disposal, spreads infection in a hundred ways.

The statistics of typhoid fever in the Spanish-American war offered striking proof, if any were needed, of the relation between that disease and the care of excreta. The chief cause of the scandalous prevalence of typhoid (which affected one-fifth of all the troops in the national encampments of the United States) was camp pollution. The official report of Surgeons Reed, Vaughan and Shakespeare (1904) concludes, "It may be stated in a general way that the number of cases of typhoid fever in the different camps varied with the methods of disposing of the excretions." In the Seventh Army Corps, for example, the First Division had a water-carriage system of disposal and developed 173 cases of typhoid fever per regiment, on
the average. In the Third Division regulation pits were used, in which the excreta were supposed to be promptly covered with earth. This method is fairly satisfactory, though inferior to water carriage. There were 185 cases per regiment in this Division. The Second Division used the tub system of disposal, by which "infected fecal matter was scattered all through the camp," and had an average of 299 cases per regiment.

Sanitary Dry Closets. Where a water supply is not available it is obviously impossible to secure the immediate removal of excreta, and the only thing to do is to minimize as far as possible the dangers which have been discussed in the preceding section. For this purpose various methods of dry disposal have been devised, dating back at least to the excellent sanitary regulations in the twenty-third chapter of Deuteronomy.

In a temporary camp the pit system of disposal is probably the best available. Here, the excreta are received in an ample trench and at once covered with a few spadefuls of dry earth or ashes. At frequent intervals the trenches should be filled in and new ones excavated. This is of course merely a modified privy vault with provision for covering in the excreta. In connection with permanent dwelling houses the pail system, (fosses mobiles of the French), should be installed. In this system tight pails or tubs are placed under the closet seat to receive the excreta and are removed and emptied at frequent intervals. A supply of ashes and earth should be at hand for absorbing liquids and exercising a deodorant action.

In many German cities the pail system has attained a considerable development and the excreta from large communities are handled in this way. For final disposal, the material collected from an isolated house may be carried, tightly covered, to some point at a distance from the dwelling and dug into the ground. Where larger settlements use the pail method, the collected excreta may be used in their crude condition for manure or they may be worked into artificial fertilizer, or they may be burned in a cremator designed for the purpose.

The following sanitary essentials for a dry-closet disposal sys-
tem are enumerated by Blasius (1894), in connection with an excellent discussion of German systems of this type.

1. Pails of adequate capacity and complete impermeability.
2. Tight connection between pails and closets.
3. Constant ventilation of closet rooms and closets.
4. Regular and frequent removal of pails.
5. Hermetrical closing of pails in transport.
6. A pail chamber under the closet, protected from frost and from the heat of the sun and provided with an impermeable floor. This chamber should open from outside the house.
7. Complete cleansing and disinfection of the empty pails before they are replaced.

The Water-Carriage System. The pail system of removal is a makeshift at best. It may operate well under rigid supervision, but it involves too much machinery and too much handling for constant sanitary efficiency. The ideal method of removing excreta is by the water-carriage system. With water supply and sewerage and proper plumbing the excreta are at once washed away into a system of closed pipes and removed promptly and completely from the vicinity of the dwelling. Wherever water is available and the construction of sewers is economically possible, no other system of handling fecal matter should be tolerated by sanitary authorities.

The recognition of these facts is a comparatively recent event and the use of the water-carriage system for removing excreta is essentially a modern one. The Cloaca Maxima and the other so-called sewers of antiquity were rather drains than sewers, and their function was to lower the ground-water level and to carry surface water rather than to remove excreta. Until 1815 the discharge of any waste but kitchen slops into the drains of London was prohibited by law, and the same regulation persisted in Paris up to 1880. Sewerage and sewage disposal properly date from the epoch-making report of the health of towns commission of Great Britain in 1844, which revealed the accumulation of such an astonishing amount of decomposing organic matter and filth of all kinds in the cities that it aroused
British sanitarians to a strong movement for the amelioration of these conditions. Public and private cleanliness was taught and practiced as never before. The midden system and the pail system rapidly gave way to the water-carriage system. Whereas in 1815 the sewers of London were simply drains to carry off the storm water, in 1847, only three years after the report of the health of towns commission, it was made obligatory to discharge all sewage into those drains.

In other countries the example set in England was more or less promptly followed. In the United States numerous drainage systems existed,—one in Boston, for example, dating from the seventeenth century; but the first comprehensive sewerage project was designed by E. S. Chesbrough for the city of Chicago in 1855. On the continent of Europe a sewer system was constructed at Hamburg after the great fire of 1842, by Lindley, an English engineer. Berlin began her sewerage in 1860 and other German systems quickly followed.

**Efficient Sewerage Systems and the Death Rate.** The new method of dealing with excreta quickly justified itself by its results. A marked decline in the death rate, and particularly in the typhoid death rate, has followed the introduction of sewerage systems. In many cases simultaneous improvements in water supply complicate the results; but in a number of instances it seems clear that the removal of excreta was the main force at work. Thus Pettenkofer (1874) shows that at Munich the typhoid death rate was 242 per 100,000 between 1852 and 1859. Improvements in privy vaults and the construction of sewers began between 1856 and 1859. From 1860 to 1867 the typhoid death rate fell to 166. New water supplies and other reforms have since reduced the death rate to a very much lower point; but this first diminution of one-third was primarily the result of sewerage.

In Berlin, Weyl (1893) records similar phenomena. The introduction of a public water supply in 1856 produced a rapid decrease in typhoid fever; but the opening of the first considerable system of sewers in 1876 caused the curve of typhoid to
take a much steeper fall than its previous course would have indicated. The curve for the ratio of typhoid deaths to total deaths in Berlin, during this period, is plotted in Fig. 1.

Fig. 1. — Effect of water Supply and Sewerage on the Typhoid Death-rate of Berlin (Blasius, 1894).
Parkes and Kenwood (1907) cite the case of Nottingham, England, in illustration of this point. In that city, "where middens, pails, and water closets are in use in different parts of the town, Dr. Boobyer has shown that the greatest prevalence of enteric fever is to be found in the houses with middens, and the least in the water-closeted houses, those with pails occupying an intermediate position. In 1902 there were twice as many cases of enteric fever proportionally in 'pail' houses as in 'w. c.' houses, and 14 times as many cases in 'midden' houses as in 'w. c.' houses."

The Sanitary Significance of Drainage. There is another aspect of the sewerage problem which deserves some consideration,—the sanitary importance of drainage, pure and simple, as distinct from sewerage. A sewerage system not only carries away excreta; it furnishes also, if desired, an opportunity for the removal of surface water; and it may be so constructed, or so supplemented by subdrains, as to effect a permanent lowering of the ground-water level. The removal of accumulations of surface water is obviously of much sanitary importance, since stagnant water offers an opportunity for the Anopheles mosquito to breed and thus promotes the spread of malaria. The lowering of subsoil water is also a sanitary desideratum under certain conditions. In the classic investigations of Buchanan in England (Buchanan, 1867) it appeared that where sewerage systems led to an appreciable drying of the soil a marked diminution of tuberculosis followed, whereas in towns where no such drying took place the tuberculosis death-rate was stationary. In this case the direct effect of a drier air on vital resistance was no doubt the efficient cause.

The New Problem of Sewage Disposal. Water carriage is clearly the ideal method of sewerage for the individual householder. It removes excreta and all other liquid wastes promptly and completely from the region of habitation; it prevents contamination of water and earth; and it offers an opportunity for the drying of surface soil and subsoil. The problem of ultimate disposal is, however, merely shifted from the individual to the
community. The unsanitary condition surrounding the dwelling is relieved, but at some point on the outskirts of the city the concentrated filth from the entire population must be delivered and must be taken care of by municipal authorities, and the problem is rendered all the more difficult by the large amount of water which carries this filth through the sewers to the point of discharge. The proper disposal of the combined waste of the community so that it shall not cause offensive or dangerous conditions, is the problem of sewage disposal. The magnitude of this problem may be realized by the simple statement that from the sewers of the Metropolitan District of Boston 186 million gallons of sewage containing 19 tons of nitrogen are discharged each day into Boston Harbor; and the extent to which this problem is still unsolved is indicated by a statement of Fuller's (1905 a) that in 1905 only 28,000,000 of the inhabitants of the United States were served by sewerage systems, and only 1,100,000 were served by sewerage systems connected with sewage purification plants. Since that time certain large cities, as, for instance, Columbus, have constructed sewage disposal works, but Fuller's figures still remain approximately true; and it is with the hope that the methods by which sewage can be prevented from causing a nuisance, and from being a source of potential danger, may be brought to the attention of students of sanitary science, that the following pages have been written.