cannot dispense with European culture, because we refuse to separate ourselves from the mighty past which has settled there in forms of human life unrepresented among us. We cannot step out of the world's current, though it looks sluggish beside our rushing stream, because there is a spiritual demand in us which cries louder than the thin voice of a self-conscious national life. This demand is profoundly at one with the deeper, holier sense of national being which does not strut upon the world's stage. The humility of a great nation is in its reverence for its own past, and, where that is incomplete, in its admiration for whatever is noble and worthy in other nations. It is out of this reverence and humility and this self-respect that great works in literature and art grow, and not out of the overweening sensitiveness which makes one's nationality only a petty jealousy of other people.

The patriotic school-master who in the dark twilight of his country's new institution turned to the making of elementary school-books might well find his reproduction at the present time. A certain instinctive sense of nationality, poorly disclosed in his thin pleading for the mere signs of national life, led him to tasks which have been of profound value. He made a speller which has sown votes and muskets; he made, alone, a dictionary which grew, under the impulse he gave it, into a national encyclopædia, possessing now an irresistible momentum. His failures we may smile at; the substantial success remains. So, doubtless, in the more complex life of the present day, when gloom overcasts the political landscape, when literature seems a spiritless thing, and no great names or works rise above the horizon, the humbler elements at work may some day be proved to have been laboring more efficaciously than we now guess. We are all making ready for a new start in history, but history has an inconvenient way of disregarding the almanacs, and it may be that while we are beating our centennial drums no great deeds or great books will come to the call. Yet in the somewhat desperate encounter with that worst form of ignorance which is ignorant of its own ignorance, literature in the person of its knights may take courage from the growing resolution to make the most of our own past. Certain it is that a sturdy belief in the nation as a divine fact is the condition of hearty literary work, and the patriotic school-master of to-day, whether holding the pen or the ferule, has the advantage over Webster in being able to look before and after from a point a little further along in the nation's course.

*Horace E. Scudder.*

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# THE SANITARY DRAINAGE OF HOUSES AND TOWNS.

## I.

It is proposed in these papers to consider a subject which, one might almost say, was born — or reborn — but a quarter of a century ago, and which has contended with much difficulty in bringing itself to the notice of the public. Indeed, it is only within the past ten years that it has made its way in any important degree outside of purely professional literature.

Happily men, and women too, are fast coming to realize the fact that humanity is responsible for much of its own sickness and premature death, and it is no longer necessary to offer an apology for presenting to public consideration a subject in which, more than in any other, — that is, the subject of its own healthfulness and the cleanliness of its own living, — the general public is vitally interested.

The evils arising from sanitary neglect are as old as civilization, perhaps as old as human life, and they exist about every isolated cabin of the newly settled country. As population multiplies, as cabins accumulate into hamlets, as hamlets grow into villages, villages into towns, and towns into cities, the effects of the evil become more intense, and in their appeal to our attention they are reinforced by the fact that while in isolated life fatal or debilitating illness may equally arise, in compact communities each case arising is a menace to others, so that a single centre of contagion may spread devastation on every side.

It is not enough that we build our houses on healthful sites, and where we have pure air and pure water; we must also make provision for preventing these sites from becoming foul, as every unprotected house-site inevitably must — by sheer force of the accumulated waste of its occupants.

Houses, even of the best class, which are free from sanitary objections are extremely rare. The best modern appliances of plumbing are made with almost no regard for the tendency of sewer-gas to find its way into living-rooms, and for other insidious but well known defects. So generally is this true, that it is hardly an exaggeration to say that unwholesomeness in our houses is practically universal. Hardly less universal is a curious sensitiveness on the part of the occupants of these houses to any suggestion of their short-comings.

Singularly enough, no one whose premises are subject to malarial influences seems willing to be told the truth with regard to them. No man likes to confess that his own well and his own cess-pool occupy the same permeable stratum in his garden; that the decaying vegetables in his cellar are the source of the ailments in his household; or that an obvious odor from his adjacent pig-sty, or from his costly marble-topped wash-stand, has to do with the disease his physician is contending against.

That the imperfections of our own premises are a menace to our neighbors is a still more irritating suggestion, and such criticism seems to invade the domain of our private rights. Yet surely there can be no equitable or legal private right whose maintenance jeopardizes the well-being of others. It is not possible, in a closely-built town or compact neighborhood, for one to retain in his own ground (either on the surface or in a vault or cess-pool) any form of ordure or festering organic matter, without endangering the lives of his neighbors, through either the pollution of the common air or the poisoning of wells fed from strata underlying the whole ground and more or less tainted by household wastes. Even if he might be permitted to maintain a source of injury to his own family, his neighbors may well insist that he shall not endanger them.

It being important for all that each be made to live cleanly, and the requirements of all, so far as the removal of the wastes of life is concerned, being essentially of the same character, the question of drainage is one in which the whole public is interested, and should be decided and carried out by public authority, — so that all may have the advantage of the economy of organized work and the security of work well done.

The drainage question is essentially a question of health and life. Dr. George Derby stated the whole case when he said, "The well are made sick and the sick are made worse for the simple lack of God's pure air and pure water."

Yet, neither this statement nor the most perfect modern development of the art of cleansing towns by water-carriage has the merit of novelty. Hippocrates gave as the cardinal hygienic formula, "Pure air, pure water, and a pure soil," and after all these centuries we know nothing to add to it. Our modern sewerage works are thus far only taking us back to the cleanly condition of the most prosperous ancient cities; only lifting us out of the slough of plague-causing filth that marked the darkest periods of the Middle Ages; only continuing the wholesome revival that the Mahometan Moors introduced among the unwashed Christians of Europe. It is a revival that has grown slowly, urged on by the harsh whip of disease and death. So late as the middle of the brilliant nineteenth century it had only begun to command the aid of the law, and as a subject of popular interest it can hardly yet be said to command the attention of even the more intelligent members of society.

Yet, when the subject is once considered, every thoughtful person must appreciate the fact that in seeking the advantages of civilized life we necessarily depend at every turn upon our fellow-men, and that in this communion we lay ourselves open to the consequences of the neglect of others, while we equally threaten others with the consequences of our own neglect. The influence of thoughtful persons cannot long be withheld from a movement whose object it is to popularize the knowledge of good and evil in the conduct of the daily life of the household and of the community, and to make the public at large insist that each shall so regulate his action as to secure the greatest safety for all.

Public sanitary improvement is not the affair of the philanthropist alone, nor is the interest of the individual satisfied when he has made his own immediate surroundings perfect. Everything that can affect the health of the poorest and most distant of our neighbors may affect us; and, practically, the spread of disease in closely-built towns is more often than not from the poorest classes upward, so that many a patient falling ill of contagious or infectious disease in the back slums of the city becomes the centre of a wide infection. The health of each is important to all, and all must join in securing it.

The great aim of all sewerage work is to secure to every member of the community his full supply of uncontaminated air, and, where wells are used, of pure drinking-water.

Referring to the lower quarters of the city of Boston, Dr. Derby asks us to consider "what would be the effect upon the annual mortality in a community like Boston, if the wretched cellars and crystal palaces and rookeries and dens in which the extremely poor and improvident live could be depopulated, and their occupants transferred to well drained and lighted and ventilated buildings, of however cheap and simple construction; if all the foul fluids could be made quickly to depart by force of gravity through ventilated sewers; if all the foul solids could be removed without delay in carts provided with means for arresting putrefaction; if the blind alleys and narrow streets were opened to the admission of the air and of sunlight; if the old vaults were removed, the old cisterns torn down or filled, and the general principle of *cleanliness in its broadest sense* applied to air, water, and food." The picture would have been complete, had he suggested the well-known fact that the danger to the community from the class of diseases known as "pythogenic" (born of putridity) is not confined to those who live amid these filthy surroundings, but that the very sewers with which the better houses are drained are too often subterranean channels for conveying poisonous gases from the places of their origin to quarters which, without this transmission, would remain free from contamination.

Self-preservation is the first law of our nature; but it is a law which we ignorantly and constantly disregard in laying our life and health at the mercy of the foul conditions of life prevailing among our neighbors.

We roll up our eyes and stand aghast when contemplating the horrors of war; yet the mortality of war is trifling as compared with the mortality by preventable disease. England, in twenty-two years of continuous war, lost 79,700 lives; in one year of cholera she lost 144,860 lives.

We look idly on and see our population decimated by an infant mortality so great that its like among calves and colts would appall the farmer, and set the whole community energetically at work to discover a remedy.

It is estimated that for every person dying, twenty fall sick (Playfair estimates it at twenty-eight), and — to turn the argument in a direction best understood by many of our more influential neighbors — that every case of sickness costs on the average fifty dollars.

Dr. Stephen Smith says, "Man is born to health and longevity; disease is abnormal, and death, except from old age, is accidental, and both are preventable by human agencies."

Disease is not a consequence of life; it is due to an unnatural condition of living, — to neglect, abuse, or want.

Were any excuse needed for the constant reiteration of such truths as are known concerning the origin and spread of infectious diseases, it is to be found in the hope that by creating a public realization of the danger of sanitary neglect we may obviate the necessity that now seems to exist for the appearance of occasional severe epidemics, acting as scavengers and inducing the performance of sanitary duties whose continued neglect would lead to even more serious results.

Dr. Farmer speaks of pestilence as the angel "with which it would seem it has pleased the Almighty Creator and Preserver of mankind" to awaken the human race to the duty of self-preservation; plagues "not committing havoc perpetually, but turning men to destruction and then suddenly ceasing, that they may consider. As the lost father speaks to the family, and the slight epidemic to the city, so the pestilence speaks to nations."

The death-rate in the healthiest broad districts in England may be fixed at about fifteen per thousand per annum, but taking the whole kingdom into consideration, the death-rate is thirty-five per thousand, over one fourth of the deaths being due to preventable diseases. It is estimated that eighteen deaths take place every hour which might have been prevented by proper precaution. In addition to this, account must be taken of the lowering of the tone of health of those who survive, and of the existence of a vast number of weakly persons who are a tax on the community, and who transmit an inheritance of physical weakness to their offspring. Infants are most susceptible to unhealthful influences, and one half of the population of Great Britain dies before attaining the age of five years.

An ordinary epidemic any modern community will bear almost with indifference. The few who know the close relation between the disease and its preventable cause will generally maintain their accustomed indifference until their own circle is attacked, and even then they are powerless to arouse the authorities to the necessary action. It is only when an outbreak of more than ordinary malignity occurs that even the sanitary authorities of most of our towns bestir themselves in the matter; but if the prevalence and the malignity be sufficient, there follows a most active cleansing of streets, purification of drains, and investigation of the private habits of the lower classes of the people.

Then only is such attention given to the most obvious duty not only of the sanitary authorities but of every man in the community, as, had it been exercised in advance, would have prevented every death and every case of sickness that has gone to swell the aggregate needed to attract public attention.

Nothing so arouses the alarm of a people as an epidemic of cholera, yet it is a singular fact that even during the most severe cholera epidemics the deaths from this disease are less than from many others which attract no attention and excite no apprehension. During the epidemic of 1849–50 there were 31,506 deaths from cholera in the United States. During the same period there were more than this number of deaths from other diseases of the intestinal canal, and more from fevers alone.

That a proper use of known sanitary appliances is competent to remove the causes of a large class of fatal diseases is hardly disputed, and it is clearly proven by experience here and abroad.

Mr. Baldwin Latham, in his excellent work on Sanitary Engineering, gives the following table, showing the effect on health of sanitary works in different towns in England: —

| Name of Place. | Population in 1861. | Average Mortality per 1000 before Construction of Works. | Average Mortality per 1000 since Completion of Works. | Saving of Life per Cent.[1] | Reduction of Typhoid Fever Rate per Cent. | Reduction in Rate of Phthisis per Cent. |
|---|---|---|---|---|---|---|
| Banbury . . | 10,238 | 23.4 | 20.5 | 12½ | 48 | 41 |
| Cardiff. . . | 32,954 | 33.2 | 22.6 | 32 | 40 | 17 |
| Croydon . . | 30,229 | 23.7 | 18.6 | 22 | 63 | 17 |
| Dover . . . | 23,108 | 22.6 | 20.9 | 7 | 36 | 20 |
| Ely . . . . | 7,847 | 23.9 | 20.5 | 14 | 56 | 47 |
| Leicester . . | 68,056 | 26.4 | 25.2 | 4½ | 48 | 32 |
| Macclesfield . | 27,475 | 29.8 | 23.7 | 20 | 48 | 31 |
| Merthyr . . | 52,778 | 33.2 | 26.2 | 18 | 60 | 11 |
| Newport . . | 24,756 | 31.8 | 21.6 | 32 | 36 | 32 |
| Rugby . . . | 7,818 | 19.1 | 18.6 | 2½ | 10 | 43 |
| Salisbury . . | 9,030 | 27.5 | 21.9 | 20 | 75 | 49 |
| Warwick . . | 10,570 | 22.7 | 21.0 | 7½ | 52 | 19 |

When the improvement of sewerage was actively undertaken in London some twenty-five years ago, it was found that the death-rate was so much reduced, in some of the worst quarters of the town, that if the same reduction could be made universal the annual deaths would be twenty-five thousand less in London, and one hundred and seventy-seven thousand less in England and Wales; or, by another view, that the average age at death would be forty-eight instead of twenty-nine, as it then was.

The early registration returns of England developed the fact that the prevalence of fatal diseases was in the case of some three times, of some ten or twenty times, and of others even forty or fifty times greater in certain districts than in others, and that these diseases raised the mortality of some districts from fifty to a hundred per cent. higher than that of other districts, the death-rate of the whole country being from thirty to forty per cent. above that of its healthiest parts.

The effect of sanitary improvement has been nowhere better shown than in the British navy, where in 1779 the death-rate was one in forty-two (this of able-bodied, picked men), and the sick were two in every five. In 1813, after the means and appliances of health had been furnished, the death-rate was one in one hundred and forty-three, and the sick two in twenty-one.

Less than a generation ago the idea prevailed that it was of doubtful propriety to ask why we are sick, and even at this day many believe that such an inquiry savors of irreligion. Happily this condition of otherwise intelligent minds is passing away.

While we know, thus far, comparatively little of the exact causes of disease, our knowledge at least points to certain perfectly well-established truths. One of these is that man cannot live in an atmosphere that is tainted by exhalations from putrefying organic matter, without danger of being made sick — sick unto death. It is true that not all of those who live in such an atmosphere either fall sick or die from its effects; but it is also true that not all who go into battle are shot down. In both cases they expose themselves to dangers from which their escape is a matter of good fortune. Fewer would be shot if none went into battle, and fewer would die of disease if none were exposed to poisoned air. Our adaptability is great, and we accustom ourselves to withstand the attacks of an infected atmosphere wonderfully well; but for all that, we are constantly in the presence of the danger, and though insensibly resisting, are too often insensibly yielding to it. Some, with less power to resist, or exposed to a stronger poison, or finally weakened by long exposure, fall sick with typhoid fever or some similar disease, that springs directly from putrid infection. Of these, a portion die; the community loses their services, and it sympathizes with their friends in mourning that, "in the wisdom of a

[1] It is to be remembered that even this great saving of life has been effected by works that are very far from perfect.

kind but inscrutable Providence, it has been found necessary to remove them from our midst."

In this way we blandly impose upon Divine Providence the responsibility of our own short-comings. The victims of typhoid fever die, not by the act of God, but by the act of man; they are poisoned to death by infections that are due to man's ignorance or neglect.

Pettenkofer states that, so far as the city of Munich is concerned, typhoid epidemics bear in their frequency or rarity a certain fixed relation to changes in the soil, which can only be surmised, but which correspond with the differences of elevation of the water-table, or line of saturation in the soil. The greatest mortality coincides with the lowest state of the water-table, and the least mortality with the approach of this to the surface of the ground.

Fifteen years' observation showed that the prevalence of typhoid was indicated by the water-level in the wells. This careful investigator believes that the cause of the disease exists not in the water, but in the soil; that it is due to certain "organic processes" in the earth.

The English investigators say that when the water in the well is low its area of drainage is extended, and it draws typhoid poison from a greater distance.

Neither of these theories is inconsistent with the hypothesis that the disease is due to organic matter reaching the soil from house-drains, cess-pools, etc., and finally either carried into the well to poison the drinking-water to a degree that becomes apparent when, during drought, it is reduced to a small quantity and its impurities are concentrated, or else left in the soil after the withdrawal of the water, and there exposed in such quantities to the action of the permeating air that poisonous gases are generated by their decomposition.

It is very clear that no system yet applied has been so generally efficient in lessening and weakening the attacks of typhoid as the English system of water supply and impervious drainage, which gives drinking-water free from contamination, and leaves the air untainted by the decomposition of organic matters in the immediate vicinity of dwellings.

Whether the London theory or the Munich theory be correct, the general result of all investigations shows that typhoid fever stands in a certain relation to the amount of neglected filth permitted to poison water and air.

The Massachusetts Board of Health published in 1871 a copious report on the causes of typhoid as occurring in that State. It concludes that the propagation of the fever is occasioned by a poison "as definite as that which causes vaccine disease;" and divides the means of propagation under three heads: first, drinking-water made foul by the decomposition of any organic matter, whether animal or vegetable, and specially by the presence in such water of excrementitious matters discharged from the bodies of those suffering from typhoid fever; second, propagation by air contaminated by any form of filth and specially by privies, cess-pools, pig-sties, manure-heaps, rotten vegetables in cellars, and leaky or obstructed drains; third, emanations from the earth, occurring specially in the autumnal months and in seasons of drought.

So far as Massachusetts towns are concerned, the contamination of wells, though a prominent, was not found to be a preëminent cause; numerous instances show this to have been active, but other causes, such as foul drains, sewer-gas, etc., are more important. It appears that the attack is more frequently received through the lungs than through the intestines. While it may be necessary that a marked quantity of impurity should exist in drinking-water before it can do us harm, an extremely small proportion of impurity in air is greatly to be apprehended; for we drink but a comparatively small amount of water, while we inhale, every twenty-four hours, from one to two thousand gallons of air.

There is reason to suspect the poison to be sometimes, if not quite generally, odorless, and the danger seems to be the greatest where the natural process of decomposition is secluded from air and light. The decay of vegetables in dark and unventilated cellars, and of house wastes or street wash in unventilated sewers, are especially to be feared.

In the town of Pittsfield, when the Board of Health assiduously attended to the removal of all nuisances, there was a very decided falling off in the number of cases of typhoid fever.

Derby says, "Whether the vehicle be drinking-water made foul by human excrement, sink drains, or soiled clothing, or air made foul in inclosed places by drains, decaying vegetables or fish, or old timber; or, in open places, by pig-sties, drained ponds or reservoirs, stagnant water, or accumulations of filth of every sort, — the one thing present in all these circumstances is decomposition."

If anything has been clearly proven with reference to the whole subject, it is that nearly all of the causes of typhoid fever are strictly within human control.

Dr. Benjamin Rush, an eminent physician of the last century, was so satisfied that the means of preventing pestilential fevers are "as much under the power of human reason and industry as the means of preventing the evils of lightning or common fire," that he looked for the time when the law should punish cities and villages "for permitting any sources of malignant or bilious fevers to exist within their jurisdiction."

No dense population can hope to escape recurrent pestilential diseases unless the inhabited area is kept habitually free from the dejections and other organic wastes of the population.

The instance of the "Maplewood" young ladies' school, at Pittsfield, Massachusetts, has been so often quoted in sanitary writings during the past ten years, that it must seem almost an old story to those who are familiar with the literature of the subject; but it is at the same time such a striking instance of the possibilities of the evils with which we are contending, that it can never lose its interest, and it is to be hoped that it may always remain the worst instance of its sort in our country's record.

The house was a large one, built of wood, closely surrounded by trees, with a foul barn-yard near it containing water in which swine wallowed, and emitting offensive odors. The cellar of the centre main building was used for storing vegetables, and its private closets connected by closed corridors with the main halls of the building. The kitchen drain opened eighty or ninety feet away from the building. The vaults of the private closets were shallow and filled nearly to the surface with semi-fluid material (they received the slops from the sleeping-rooms). The house seems to have been beset with danger on every side, and it was often necessary in the heat of summer to close the windows, to keep out offensive odors. The whole case was examined after the attack by Drs. Palmer, Ford, and Earle, of the Berkshire Medical College, and they took, so far as possible, the testimony of every member of the household and of the relatives of those who had died after being removed to their homes. Their investigation fixed the origin of the Maplewood fever (which was clearly marked typhoid) unquestionably upon the unhealthfulness of the air of the house, made impure by the causes above specified.

This Maplewood fever is one of the most fatal ever recorded. Of seventy-four resident pupils heard from, sixty-six, or nearly ninety per cent., had illness of some sort, and fifty-one, or nearly sixty-nine per cent., had well-marked typhoid fever. Of the whole family of one hundred and twelve persons, fifty-six had typhoid fever, and of these fifty-six, sixteen died. These proportions applied to the eight thousand people living in Pittsfield would have given four thousand cases of typhoid fever within the space of a few weeks, and of these eleven hundred and forty would have died. The outbreak was, however, so entirely local that some physicians in Pittsfield had no cases, and others only two or three. The Maplewood fever was a sudden explosion. It broke up the school in a very short time, and the pupils scattered to their homes, where, under the influence of pure air, many recovered.

Dr. Palmer says of this epidemic, "Before the investigation, the matter was spoken of as the act of a mysterious Providence, to whose rulings all must submit. Looking with the eye of science upon the overflowing cess-pools and reeking sewers as inevitable causes, and with the eye of humanity upon the interesting and innocent victims languishing in pain and peril or moldering in their shrouds, I could but regard such implications of Providence, though perhaps sincerely made, as next to blasphemy; especially when uttered by the agents who were to be held responsible; though the prayer of charity might have been, 'Father, forgive them, they know not what they do.'"

A century ago epidemic diseases carried with them only calamity, not culpability; but now, when their occurrence is chargeable to willful ignorance or to wicked neglect, Dr. Rush's prophecy should be fulfilled, and the law should hold the community responsible for every death permitted to occur from preventable disease within the area that it controls.

The sanitary reforms recommended by the examining physicians being carried out, Maplewood became, and still remains, free from malarial disease.

Dr. Anstie, in his Notes on Epidemics, after describing the fouling of wells by the escape of cess-pool matter, and the fouling of the interior air of houses by reason of imperfect drain-traps, says, "In short, all observers arrived at the conclusion that it would be possible, by rendering our drinking-water absolutely pure, and by disinfecting our sewage at the earliest moment, entirely, or almost entirely, to suppress typhoid fever."

Dr. Austin Flint says, "Typhoid fever is very rarely if ever communicated by means of emanations from the bodies of patients affected with the disease. It does not spread from cases in hospitals to fellow-patients, nurses, and medical attendants. Isolated cases are numerous, occurring under circumstances which preclude the possibility of contagion. Its special cause may be a product of the decomposition of collections of human excrement."

The agency of tainted water was enunciated by Canstatt, in Germany, in 1847, and many later medical writers have confirmed the theory.

Dr. Flint investigated an outbreak of typhoid fever in a village in Western New York, in 1843. No case of typhoid fever had ever been known in the county. The community numbered forty-three persons; twenty-eight of these were attacked with fever, and ten died. All of those affected obtained their drinking-water from a well adjoining the tavern; but one family, living in the midst of the infected neighborhood, owing to a feud with the tavern-keeper did not use this water and escaped infection. Two families lived too far away to use this well. This immunity on the part of the enemy of the tavern-keeper led to a charge that he had maliciously poisoned the well, a charge which led to a suit for slander and the payment of one hundred dollars damages. At this time the idea that typhoid fever might be communicated by infected drinking-water had not been advanced, but its truth receives strong confirmation from the fact that a passenger, coming from a town in Massachusetts where typhoid prevailed, and traveling westward in a stage-coach, having been taken ill, was obliged to stop at this tavern. Twenty-eight days after his arrival he died of typhoid fever, and thus, doubtless, communicated in some way to the water of this well the germs of the disease, which speedily attacked every family in the town, except the three which did not resort to it for their supply. Dr. Flint states it as his opinion that "in typhoid fever the contagion is in the dejections, and this fever may be, and generally is, caused by a morbific matter produced in decomposing excrement from healthy bodies." And he believes that "the spontaneous occurrence of this disease is to be avoided by a complete precaution against the pollution of water or air by the dejecta from healthy persons."

In the summer vacation of 1874, ten students from Oxford went on a reading party to a rural retreat in Cornwall, which was recommended as of undoubted healthfulness and of quiet seclusion. They fell into a fever trap. The water and the soil of this village were polluted until it equaled the worst slums of Liverpool. Detecting the sanitary shortcomings of their retiring-place, they beat a hasty retreat, but they carried with them the germs of the disease, and before many days six of the party were down with typhoid fever: one has since died.

The Local Government Board of England lately deputed Dr. Thorne to investigate an outbreak of typhoid at Brierly. He found that the spread of the fever was due to the poisonous dejecta of the patients. Wherever those dejecta went, poison and disease went also. The original case was in the person of a dairy-man, and was of a mild type; but it was followed by two other cases in the same house, and, by the tainting of the milk vessels, the infection was carried to thirty-eight houses in the village, in twenty-three of which the fever appeared. From these centres it spread by excremental contamination until nearly the whole village was attacked. Dr. Thorne "wished it to be distinctly understood that he by no means attributed all the cases occurring to the use of milk from the infected dairy; for when once the disease was started another powerful means for distributing it came into operation;" and he proceeds to show a very defective condition of the vaults and drains. His irresistible conclusion was that the outbreak had been due, primarily, to the use of milk from an infected dairy, and that bad drainage and bad disposal of excrement had done the rest.

During the autumn of 1874 there was an outbreak of typhoid fever in the town of Lewes, about four hundred and fifty cases occurring. The town is divided into three sections, each having its own water supply, and the disease was confined almost entirely to the division supplied by the Lewes Water-Works Company. This company furnished an intermittent supply of water, the head being turned on for three or four hours in the morning and for the same time in the afternoon. When the head is taken off, the pipes empty themselves, sucking in air at every opening. Examination showed that there were many water-closets, some of them used by fever patients, which were supplied by pipes leading directly from the water-mains into the soil-pan, and that it was a common habit to leave the taps open so that the closets should be flushed whenever the water was turned on. There were leaks in some of the old mains, and many of these were laid in soil fouled with the overflow of vaults. In one case a leak was found in a water-main where it passed through a sewer. The lead service-pipes of houses were frequently honey-combed, especially in the immediate vicinity of vaults, and in one case a leak was found directly under a vault. In seeking for this while the water was subsiding in the mains, the opening was exposed, and the whole contents of the vault were sucked into the water-pipe. In short, on every occasion of the subsiding of the water supply, air was drawn in violently at every opening, and the pipes thus received air contaminated by closets and vaults, and air from within a public sewer, so that in some cases at least, particles of excrement were drawn in from closet pans. In one section of the town only sixty houses out of a total of four hundred and fifty-four were supplied by the water-works company, and in this section, with the exception of two infants, every case of typhoid fever occurred in these sixty houses, to the total exclusion of the other three hundred and ninety-four. Even after the epidemic became rife, and there were many other means for its extension, it was found that twenty-seven per cent. of the town-water houses had been attacked, and only six per cent. of all the others.

There has recently been an investigation into the origin of an outbreak of "filth fever" in Over-Darwen, England, the origin of which for a long time eluded the careful search of the authorities. It was finally worked out by a sanitary officer dispatched from London. The first case was an imported one, occurring in a house at a considerable distance from the town. The patient had contracted the disease, came home, and died with it. On first inquiry it was stated that the town derived its water supply from a distance, and that the water was brought by covered channels and could not possibly have been polluted by the excreta from this case. Further examination showed that the drain of the closet into which the excreta of this patient were passed emptied itself through channels used for the irrigation of a neighboring field. The water-main of the town passed through this field, and although special precautions had been taken to prevent any infiltration of sewage into the main, it was found that the concrete had sprung a leak and allowed the contents of the drain to be sucked freely into the water-pipe. The poison was regularly thrown down the drain, and as regularly passed into the water-main of the town. This outbreak had a ferocity that attracted universal attention; within a very short period two thousand and thirty-five people were attacked, and one hundred and four died. The report of this investigation closes as follows: "If an inquest were held on every case of death from typhoid fever, as we have long contended there should be, a similar relation of fatal effect to preventable cause could nearly always be traced, and may always safely be presumed."

Thus much attention has been given to the subject of typhoid fever because it is universally recognized as the typical pythogenic disease, and the most prominent of those which are believed to be entirely preventable by human agency.

Two other prevalent scourges, not ascribed to organic uncleanliness but connected with the question of soil-water removal, — consumption and fever and ague, — must have a prominent place in any discussion of sanitary drainage.

The scientific world has been quick to accept the suggestion of Dr. Bowditch, of Boston, that the genesis of pulmonary disease seems to be connected with excessive moisture arising either from a wet soil, from a clay subsoil, which is usually a cause of damp and cold, from springs breaking out near the site of the house, from sluggish drains, damp meadows, ponds of water, and other sources of fog and atmospheric moisture, or from too close sheltering by trees. To one or more of these causes it is now thought that we may ascribe the origin of a large proportion of the cases of that painful disease which, more than any other, characterizes New England.

Dr. Bowditch says, "Private investigations in Europe and America have in these later times proved that residence on a damp soil brings consumption; and second, that drainage of the wet soil of towns tends to lessen the ravages of that disease."

In 1865–66 the British government instituted an examination into the effect of drainage works on public health. Twenty-four towns sewered by the modern system were examined. "It appeared that while the general death-rate had greatly diminished, it was most strikingly evident in the smaller number of deaths from consumption." As Bowditch had pointed out, the drying of the soil as an incidental effect of sewerage had led to the diminution of this disease.

Those ailments which are caused by the influence of stagnant water or excessive wetness of the soil — consumption in its most fatal form being one of them — may be much alleviated by the simple removal of the drainage-water, through exactly the same process that is employed in farm drainage.

The connection of fever and ague with soil moisture and with the obstructed decomposition of vegetable matter in saturated ground or in moist air is almost universally recognized.

The improvement resulting from drainage is fully attested by wide areas in England where whole neighborhoods have been drained for farming purposes, and where, as a consequence, malarial diseases have entirely disappeared.

In the report of the Staten Island Improvement Commission (1871) it is stated that where the foundations of the dwelling and the land about it for a certain space have been thoroughly under-drained, and where considerable foliage interposes between such space and any exterior source of malaria, the liability to disease is greatly reduced, and there is little danger that fever and ague would be contracted by the inmates of such a house except by exposure outside their own grounds. An instance is cited where four adjoining farms, near Fresh Kills, were drained. Close to each of these farms there has been much malarial disease, but the seventy people living on them have had scarcely a symptom of it. In another quarter formerly very malarial, the occupants of which carried to other residences the disease there contracted, those who remained after the thorough drainage of the land have recovered, and have not suffered at all since; while those who moved to them after their drainage have lived there for years without injury. In this case as in the first, the neighborhood beyond the influence of the under-drains is still highly malarial.

Pulmonary diseases, especially the early stages of consumption; all continued fevers, especially typhoid fever; degenerative diseases, such as scrofula and cancer; and uterine diseases, both of tissues and of function, are stated by the Staten Island commissioners to become less severe with the natural or artificial reduction of the level of the ground-moisture.

The Secretary of the General Board of Health (England) published in 1852 Minutes of Information collected in respect to the drainage of the land forming the sites of towns, etc.

He says: "When experienced medical officers see rows of houses springing up on a foundation of deep, retentive clay, inefficiently drained, they foretell the certain appearance among the inhabitants of catarrh, rheumatism, scrofula, and other diseases, the consequence of an excess of damp, which break out more extensively and in severer forms in the cottages of the poor, who have scanty means of purchasing the larger quantities of fuel and of obtaining the other appliances by which the rich partly counteract the effects of dampness. Excess of moisture is often rendered visible in the shape of mist or fog, particularly towards evening. An intelligent medical officer took a member of the sanitary commission to an elevated spot from which his district could be seen. It being in the evening, level white mists could be distinguished over a large portion of the district. 'These mists,' said the officer, 'exactly mark out and cover the seats of disease for which my attendance is required. Beyond these mists, I have rarely any cases to attend but midwifery cases and accidents.' Efficient drainage causes the removal, or at least a diminution of such mists, and a proportionate abatement of the disease generated or aggravated by dampness.

"After houses built in the manner described have been inhabited for some time, and especially if crowded, fevers of a typhoid type are added to the preceding list of diseases, in consequence of emanations from privies and cess-pools. The poisonous gases, the product of decomposing animal and vegetable matter, are mixed with the watery vapor arising from excessive damp (such vapors being now recognized as the vehicle for the diffusion of the more subtle noxious gases), and both are inhaled night and day by the residents of these unwholesome houses. A further consequence of the constant inhalation of these noxious gases, which have an extremely depressing effect, is inducing the habitual use of fermented liquors, ardent spirits, or other stimulants, by which a temporary relief from the feeling of oppression is obtained."

In the English Sanitary Report for 1852 the following propositions are laid down: —

1. Excess of moisture, even on lands not evidently wet, is a cause of fogs and damps.

2. Dampness serves as the medium of conveyance for any decomposing matter that may be evolved, and adds to the

injurious effect of such matter in the air; in other words, the excess of moisture may be said to increase or aggravate excess of impurities in the atmosphere.

3. The evaporation of the surplus moisture lowers temperature, produces chills, and creates or aggravates the sudden and injurious changes of temperature by which health is injured.

The copious evidence taken by the Metropolitan Sanitary Commission, in 1848, concerning the effect of ordinary agricultural land-drainage, as practiced in England, upon the improving healthfulness of men and animals and upon climate, resulted in the production of a vast amount of evidence of the most telling character, to review which, even briefly, would be impossible in this limited space; but it clearly showed that all the benefits that the advocates of land-drainage have claimed for it had already been fully sustained by English experience.

The agricultural drainage of the land in and about the sites of towns, and the soil-drainage which is usually effected, even where no especial provision is made for it, by the ordinary works of sewerage, has fully demonstrated the sanitary benefit arising from the removal of stagnant water, or water of saturation, from the soil. The earth acts upon foul organic matters much in the same way that charcoal would do, having, though in less degree, the same sort of capacity for condensing within its pores the oxygen needed to consume the products of organic decomposition. But no soil can act in this way so long as its spaces are filled with water, and in order to make it an efficient disinfectant it is necessary to withdraw its surplus moisture and thus admit atmospheric air within its pores.

It is now generally believed that in addition to the many other evils of excessive soil-moisture, its effect in rendering a dwelling-house cold and unwholesome is especially marked in encouraging the formation of tubercles in consumptive subjects; and the various forms of malarial fever, neuralgia, influenza, dysentery, and diseases of the bowels, are thought to be aggravated by excess of moisture in the soil immediately about human habitations.

During the past thirty or forty years very large contiguous areas have been drained in England for agricultural purposes, and an invariable result of the improvement has been a great decrease of malarial diseases, such as fever and ague and neuralgia. The vast fen-lands of Norfolk, Lincolnshire, and Cumberlandshire were formerly the seat of very wide-spread diseases of a malarial type. Since the drainage of the fens these diseases have become comparatively rare and mild in form; and it is asserted with regard to England generally, that such diseases "have been steadily decreasing both in frequency and severity for several years; and this decrease is attributed in nearly every case mainly to one cause, — improved land-drainage."

The well-known Mr. James Howard, of Bedford, England, says, "In my own county, ague and fever thirty or forty years ago were very common in certain villages; since draining has been carried out the former has quite disappeared, and the latter has greatly decreased."

So far as the question of social prosperity is concerned, it is quite proper to consider the financial aspects of the question of health. The body politic has perhaps no compassion for the sufferings of the poor invalid or the bereaved mourner, but it has a quick and a vital interest in everything affecting its worldly prosperity, and the deepest foundation of its worldly prosperity lies in the strength and efficiency of its members.

Dr. Boardman, of Boston, in the sixth annual report of the Massachusetts Board of Health, enters into a calculation, based on numerous data, which seem to be sufficiently proved.

In the metropolitan district, including Boston, the average loss of time from sickness for each individual is twenty-four days in the year. In the western district, including Berkshire County, the loss is about fourteen days; and the average for the whole State is nearly seventeen days for each member of the population. This was in 1872; a similar computation for the previous eight years shows an average of fourteen days for each person. Calculating the cost of nursing, medical attendance, etc., and the loss of time to persons of a productive age, he finds that the loss to the State from the sickness of working people alone is over fifteen million dollars; and the same computation for the entire population would amount to nearly forty million dollars.

Assuming that out of the nineteen persons in every thousand who die annually in the whole State of Massachusetts, four might be saved by the avoidance of preventable diseases, — and this is certainly very low, for it may be reasonably assumed that eleven per thousand is the *natural* death-rate, or the lowest that can be attained, — the following saving to the State would result: the annual mortality being 26,619 with a death-rate of nineteen per one thousand, it would be, with a death-rate of fifteen per thousand, 21,015, or an annual saving of 5604 lives. Good grounds are given for assuming that every death represents a total of 730 days of sickness and disability; the aggregate saving from sickness therefore would be 4,090,920 days, which would amount to $8,181,840, or for the working population alone $3,190,916, which latter sum would represent the interest on more than fifty million dollars. The practical question then which the commonwealth should consider is whether an investment of fifty million dollars in the improvement of the sanitary condition of its population, and in their enlightenment as to means for preserving health, would result in a reduction of the death-rate from nineteen to fifteen. If it would do so, then the investment would be a profitable one. That it might do this, and even more, is proven by English experience, and no one can doubt it who will give even casual attention to the degree to which human life, in even our best communities, whether in town or country, is hourly endangered by the unwholesome conditions under which it exists.

In every household in which a pronounced case of typhoid occurs, it may fairly be assumed that the value of the whole family to themselves and to the community is distinctly lessened; and the large proportion of "debilitated and weakly" persons found in all our communities are but half-way victims struggling against the assaults of foul air and contaminated water. Their lives are permanently dulled by a malaria they are in part able to withstand.

In this ever-waged battle there are wounded as well as killed; and in England it is recognized that "convulsions" and many attacks of nervous ailments are marks of excremental poisoning.

There are several diseases which are now known to indicate more or less definitely unfavorable sanitary arrangements, and as the knowledge of hygiene extends, other diseases are being added to the list. Nervous toothache, neuralgia, scarlet fever, cholera, dysentery, diphtheria, cerebro-spinal meningitis, and consumption are among those which are either generated by foul air or foul water, or which are made worse because of unhealthy surroundings.

Dr. Derby says, "That an obscure internal cause — which, in our ignorance of its nature, is called a proneness of disposition to receive the poison — is necessary for its development does not affect the truth of the fact that without filth the disease is not born. . . . The improvement of public health as expressed by that unerring guide, the death-rate, corresponds with all the means by which air and water are kept free from pollution."

Typhoid fever is the most conspicuous type of the class of zymotic diseases, all of which are clearly pythogenic, and none of which can originate under conditions fit for proper human habitation.

A fertile soil or an impervious subsoil is especially favorable to typhoid poisoning; while deep gravel or sand, well drained and offering free access to the air, are the least so. Rock near the surface is bad in the same way that a clay subsoil is bad.

As a rule, new residents in an unhealthy locality are more subject to disease than those who have become accustomed to the unfavorable influence; yet when typhoid contagion appears, it attacks first those whose systems have been debilitated by the insidious influences of foul air or water.

One naturally argues from circumstances with which he is most familiar, and as I have given more especial attention to the sanitary short-comings of my own town, I take it as an example, believing, however, that its interior arrangements are not less favorable than those of the average of our prosperous country places, and recognizing the important fact that its position (on a neck of land hardly a mile wide and sloping in one direction to the Atlantic Ocean and in the other to Narragansett Bay, without a hill or a forest to intercept the free-blowing winds from every quarter) makes Newport *naturally* a perfectly salubrious town. The population in 1870 was 12,521, the larger number living in a compactly built district facing the west and drained into a deep cove of Narragansett Bay. At the north and at the south the land is flat, but nearly all of it lies high enough for tolerable drainage. It is underlaid with stratified rock, and has a heavy clay subsoil interrupted by fissures of gravel sloping similarly to the surface of the ground.

There is no public water supply, and probably a large majority of the population drink water from wells only, although there are many filtering cisterns. Nearly all the houses of well-to-do people have the usual plumbing arrangements, which discharge into cisterns or into cess-pools in the ground. Some of these drain themselves through the gravel streaks of the subsoil, and a very few are absolutely tight, so that they require hand emptying. A rude sort of sewerage has been attempted here and there, laid without system and constructed apparently without the least reference to the well-known requirements of all town drains.

These sewers have the advantage of being at every opening so noisomely offensive that persons living near them are warned by the odor to keep their windows closed when the wind comes from a certain direction, and passers-by do not loiter in their vicinity. There is less insidious sewer poisoning here, as the exhalations are blazoned to the dullest sense. Usually where a sewer is available, the private cess-pool overflows into it, but in a great majority of cases the removal is by hand, with carts trundling into the country and making winter days and summer nights more than hideous.

If the best winds of heaven did not blow almost constantly through our streets, we should probably be as badly off as a country town can be, but apparently this free ventilation will for some time continue to stave off the epidemic that awaits us, and which alone probably (here as elsewhere) will be able to secure the needed reform.

With these advantages and disadvantages Newport had a death-rate in 1863 of 34.16 per thousand (even supposing the population not to have increased between 1863 and 1870); a death-rate in 1873 of 25.76 per thousand, and an average death-rate for eleven years ending 1873 of 21.05 per thousand.

The town of Worthing, on the south coast of England, is probably more nearly like Newport in its climate, population, and uses than any other sea-coast town with which it can be compared. Like Newport, Worthing is more or less a resort for invalids and persons seeking a beneficial change of air, but unlike Newport it has an excellent and abundant supply of pure water, and its drainage is said to be perhaps the most complete in Great Britain, every cess-pool and surface drain having been suppressed and a main sewer emptying into the sea two miles away. The sanitary effect of this difference is shown by the fact that Worthing has the lowest death-rate ever recorded — 14.5 per thousand (during the second quarter of 1874 it was only 12.9 per thousand); and *a death-rate of* 14.5 *means an average longevity of nearly sixty-nine years for the whole population.*

It is probably as nearly certain as any such speculation can be, that could Newport have the simple advantage of a pure water supply and the perfect drainage that could so easily be given it, its average death-rate could be reduced to that of Worthing, causing us an annual saving of nearly one third of its deaths, with the enormous amount of costly and wearying illness and of debility and inefficiency that these deaths imply. Viewed in another light, could the questionable reputation under which Newport now suffers be replaced by one like that of Worthing, it would lead to such a growth of "stranger" population in summer and in winter as would gladden the hearts and overflow the coffers of all its eager army of purveyors.

Nor are our cities better provided with sanitary appliances than our smaller towns. Even Boston, which congratulates itself on its refinement and civilization, is assiduously planting the seeds of future trouble.

The newer parts of the city, especially the district toward the mill-dam, may serve as a very good illustration of what it is possible to do in the way of providing unfit habitations. The annoyances caused by the imperfect sewerage of this district have long been a ground of complaint even among persons who would accept the ordinarily defective drainage of higher-lying town-districts as quite satisfactory.

In this case the remedy though radical is simple, and it would be much less costly than would be supposed by those who are not acquainted with the artificial pumping system largely in use in England. Indeed, this district is especially well adapted for such drainage, for the reason that all its houses are occupied by a class who use water very liberally, so that there need be no fear that there would not be an ample flow to remove all solid matter reaching properly made drains.

All street-wash and the rain-water falling on the roofs, court-yards, etc. (beyond what would be needed for occasional flushing of the house sewers), may be removed by surface gutters or by a system of shallow drains discharging into Massachusetts Bay, and flushed, whenever needed, by water admitted to a flushing reservoir from Charles River. The house drainage itself should be disposed of through an independent system of small sewers laid at least three feet below the level of the lowest cellars, collected at one point and lifted by steam power into a sewer leading to Massachusetts Bay.

Nothing but the fact that it is surrounded by wide stretches of water and great areas of unoccupied land could account for the preservation of the city in a state of even tolerable healthfulness, in the face of the circumstance that the water system is only partially introduced, and that fully one half of its night-soil, or about five thousand cords per annum, is still removed by carts; and it should be borne in mind that this five thousand cords is only what has been retained in the vaults after enormous volumes of its liquid parts have soaked away into a soil covered with a dense population.

Reference has been made to the fact that there is often less danger from impure well-water than from impure air, and some of the Massachusetts investigations indicate that in that State contaminated wells are not a very prominent source of infection. At the same time, the fouling of well-water by organic impurities is a very frequent source of fatal disease, and probably the reason why it does not appear relatively more serious in Massachusetts is that so much of the soil of that State is of a light character to a very great depth, there being less lateral movement of excessive soil-moisture than where strata of hardpan, or impervious soil, and seams in stratified rocks are more prevalent.

The reason why well-water is often bad and unwholesome is, in plain English, because sink-drains and vaults empty their foul contents into it. A well may be good for a long time and subsequently become poisoned, because the soil lying between the source of the impurity and the well itself has a certain amount of cleansing power. While this is effective, every impurity is withheld, but by degrees the soil becomes foul farther and farther on, until at last there is no grain of uncorrupted earth to stand between the sink and our only source of the pure water without which we cannot live in health.

The well is in effect a deeper drain, toward which the water from the surrounding earth finds its way, and in time, as impurities will follow water to any outlet unless the filter that holds them back remains always active, the foulness of the earth within the drawing range of the well is carried into the water, which it renders unfit for human use.

In 1847 typhoid fever broke out nearly at once in the thirteen houses of a single terrace in Clifton, England, which took their drinking-water from a certain well. Other houses in the same terrace escaped entirely, and it was found on investigation that in every house supplied from the well in question the disease was severe, while in no other house of the terrace did it appear. The infected houses were considerably scattered, and the only connecting link between the inmates was the use of the same drinking-water.

A very striking case in point which occurred in Williamstown, Massachusetts, was well and skillfully investigated. A house-drain became choked, and its contents mingled with those of a field-drain that was near a well. The season was wet, the ground was thoroughly saturated, and surface water oozed into the well. The house was a boarding-house, with from thirty to thirty-five persons, mostly students, at table. Within two weeks most of the boarders were affected, and twenty or more of the students fell sick. At this time there was one case of typhoid fever in town, and this patient had been removed from his lodgings in the college to this boarding-house, where, probably by means of the escape of his dejections from the imperfect drain, his disease was communicated through the water of the well to all or nearly all of those who drank the water unboiled. Those who drank no cold water escaped: but a family in an adjoining house supplied from the same well were attacked, except one member who habitually drank no cold water. All who drank that water unboiled had the disease; all who avoided it in that state escaped.

Dr. Stephen Smith describes a visit to a country clergyman, a former schoolmate, who told him of a family, five of the members of which had died, while another was then fatally sick with typhoid fever; and he had not thought of attributing it to anything else but a "visitation of Providence." An investigation showed that during a busy harvest the valve of the pump had got out of order, and there being no time to replace it, water had been taken from a brook which received, higher up, surface water and the drainage from several barn-yards. Of the entire family but two escaped attack, and they had not used the water.

The Broad Street pump in London is now famous in the annals of epidemics. During the cholera visitation in 1848–49, it killed five hundred persons in a single week. And many of the better classes, who fled the town and went to reside five miles farther up the Thames, were there attacked with cholera, it being found that they had been in the habit of sending to the Broad Street pump for their tea-water.

Having been instrumental in introducing the dry-earth system of sewerage into this country, it is proper for me to say here that my faith in the ability of that system to accomplish all that it has ever promised remains unabated, and that, under circumstances where its application is practically feasible, I should never recommend water sewerage; yet, in the present state of its development, it is so inapplicable to a large majority of cases, or so distasteful to a mass of persons whose necessities demand immediate relief, that, without in any way receding from its advocacy, I freely acknowledge that the practical good which is to come of early sanitary reform is to be sought through other means.

The drawback, so far as towns are concerned, lies in the inability of this system to deal satisfactorily with copious amounts of water. Twenty-five gallons of waste running from a kitchen sink would require for its absorption from four hundred to five hundred pounds of earth. Still, earth sewerage can be perfectly depended on in village and rural establishments where there is a sufficient amount of lawn or garden to absorb the waste by underground irrigation; such irrigation beginning at a point sufficiently far from the house or the well. Disposed of in this way, and made to feed a vigorous vegetation, all of the liquid waters of the house may be safely treated in a small lawn or garden.

The evidence as to the sanitary completeness of this system is all as conclusive as the following recent report from a very unhealthy quarter: Before 1868, dysentery and fever were very prevalent in the convict-prison of Labuan, Borneo, and the old system of water-closets and cess-pits was abolished, earth-closets being substituted. Hereupon the sickness and mortality declined. In 1870 a great mortality broke out among the troops of the station, and a government inquiry developed the fact that in the barracks, where the earth system had been neglected, thirty per cent. of the troops died per annum; the deaths in the prison, where it had been assiduously used, amounted to but two per cent. In Sierra Leone, where the commanding officer had taken efficient measures to provide earth-closets for the troops, the health of the officers and men was maintained "at the very time when fever and dysentery were carrying off twenty per cent. per annum of the European population residing in the town."

A novel system of sewerage by pneumatic action, invented a few years ago by a Dutch engineer named Liernur, has been introduced on a large scale in parts of Amsterdam, Leyden, and other towns of Holland, and is now being much discussed by those interested in sanitary matters in England. The accounts given of the success of this method, of the entire absence of odor in all its processes, and of the complete saving for agricultural use of almost every part of the household waste, indicate that it is most efficient, economical, and admirable. It has just been adopted for the entire sewerage of St. Petersburg, where it is to be introduced at a cost of over twenty million dollars.

It has been attempted, in this preliminary paper, to bring within the scope of a magazine article some of the leading considerations which make the subject of sanitary drainage seem well worthy of more attention at the hands of the public than it has thus far received. It seemed advisable to offer such an introduction to the later articles of this series, — which will treat more particularly of the better methods of dealing with such of the wastes of human life in and about dwelling-houses, whether isolated or in towns, as lead to the evils herein referred to; and of the safest means for removing from inhabited town-areas the accumulated waste of its individual houses.

*George E. Waring, Jr.*

Of the sands of gold in the palm-leaf's shade,
And the strange, high jewels all these have won.

You dare not doubt it, O soul of mine!
And yet, if these vacant eyes could see
One, only one, from that voyage divine,
With something, anything, sure for me!

Ah, blow me the scent of one lily, to tell
That it grew outside of the world, at most;
Ah, show me a plume to touch, or a shell
That whispers of some unearthly coast!

*Mrs. S. M. B. Piatt.*

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# THE SANITARY DRAINAGE OF HOUSES AND TOWNS.

## II.

"The house is the unit of sanitary administration."

Whatever means may be adopted by the board of health of town or village for the removal of the wastes incident to the life of its population; whatever facilities for such removal may be offered by the natural surroundings of isolated country houses; and whatever the public or the individual may do toward rendering the natural character of the ground dry and salubrious, the first aim of the householder himself should be to secure a perfect means for carrying safely beyond the walls of his domicile everything of a dangerous character that is generated or produced within it, and to secure his living-rooms against the entrance of any manner of foul air, impure water, or excessive dampness.

It would not be possible here to consider the very great variety of circumstances attending the location and arrangement of different houses. It will suffice for our general purposes to assume that all liquid or semi-liquid drainage from the house should be delivered either into a public sewer, into a private cess-pool or vault, or directly into a natural water-course. If we arrange a safe means for discharging our outflows into one or other of these, for the exclusion from the house of gas arising from their decomposition, and for preventing filtration from them into the source of our domestic water, we shall, so far as exterior surroundings are concerned, accomplish the most important aim. General rules and principles, of which the modifications needed in particular cases will quite naturally suggest themselves, are all that can here be given.

The individual householder has these problems to solve: —

1. To secure his house against excessive damp in its walls, in its cellar, and, where practicable, in its surrounding atmosphere.

2. To provide for the perfect and instant removal of all manner of fluid or semi-fluid organic wastes.

3. To provide a sufficient supply of pure water for domestic use.

4. To guard against the evils arising from the decomposition of organic matter in or under the house.

5. To remove all sources of offense and danger which may affect the atmosphere about the house.

6. (And almost more important than all the rest.) To prevent the insidious entrance into the house, through communications with the sewer, cess-pool,

or vault, of poisonous gases resulting from the decomposition of the refuse of his own household, or of other households with which a common sewer or drain may bring him into communication.

The first item implies a dry cellar, an impervious foundation wall, and, if the soil be heavy and liable to be wet, or if it be underlaid too closely with rock or clay, "thorough drainage," of the sort employed in the agricultural improvement of land. So far as this matter of drainage is concerned, it will suffice to refer to the well-known works on agricultural drainage; but the drying of the cellar and foundation receives so little attention at the hands of both owners and architects, that explicit directions seem advisable. If the house is founded on well-drained gravel or on a dry bed of sand (which is the best of all foundations) no further draining will be necessary; but even here it is always advisable to cover the floor of the cellar with an impervious concrete, to prevent the exhalation of moisture that arises from even the dryest soil; and in all cases where the foundation wall is not built with hard and impervious stone, it should be furnished with a course of some impervious material, whether hydraulic cement, asphalted brick, bluestone, slate laid in cement, or sheet-lead. Even with this precaution, if the foundation wall below the impervious course is of brick or soft stone, the inner surface of the wall should be well washed with pure hydraulic cement, which will lessen the escape of the moisture that penetrates the stones during driving rain-storms, or soaks into them from the earth.

If the ground is at all inclined, even in the wettest seasons, to be wet or springy, whatever other precautions are taken, a drain should be laid all round the cellar inside of the wall, and at least a foot lower than its lowest bed-stone, and carried away to a free and sufficient outlet. This drain may be made of gravel or broken stones, but ordinary land-drainage tile with open joints is usually cheaper and always better, especially as preventing the ingress of vermin. For the largest private house, the smallest-sized land-drain tile will be sufficient. If the soil is unduly wet, at any season, similar drains should cross the cellar at intervals of not more than fifteen feet. All of these drains should have a slight but continuous fall toward the outlet, and should be securely covered by having earth well rammed over them, the whole cellar bottom being then coated with concrete. For small houses, where cobble-stones or gravel are plenty, if the foundation rests on a layer of this porous material a foot or more deep, and if a good outlet be provided at the lowest point, the tile is not needful.

The complete drainage of the house, that is, the instant removal of the impurities incident to human life, is the crowning work of the whole system of sewerage. In towns, street drains, main sewers, outlets, and the whole paraphernalia of the system have for their main purpose the furtherance of the ultimate object of the sanitary drainage of the house; and the effect of sewerage on the health and decency of the population must depend very much upon the manner in which each house is provided with the necessary drainage system and is connected with the public sewer.

In the country, whatever the final means of removal, the house drainage, whether partial or complete, must be equally guarded. If there is only a kitchen drain, this should be perfectly well made and arranged.

When we consider its immediate proximity to the windows of the room in which the family of the average farmer passes most of its time, the kitchen drain probably heads the list of all the agents by which our ingenious people violate the universal sanitary law; and it doubtless carries more victims to the grave than do all other sources of defilement combined; for with an enormous majority of our population this one pipe still represents the whole drainage of the house.

Receiving daily supplies of organic matter ready to pass into dangerous decomposition, drenched with sufficient water to soak far into the ground, and kept warm enough for putrefaction to proceed rapidly throughout a large part of the year; sending its exhalations into the kitchen and living-room windows, and with a favorable summer breeze throughout the whole house; and leaking, too often, through a light surface soil, or through a porous stratum in a clay soil, into the adjacent well; it attacks the family through the lungs and through the stomach with an almost unremitted assault, soon achieving, in the case of those who live mainly in close, stove-heated rooms and sleep on the ground floor with a window opening over the back-yard, its various measures of debility, disease, or death.

No house drain can be made which may not be carelessly obstructed by the admission of substances for which it is not intended. Shedd enumerates, among the articles that have been found in such drains, "sand, shavings, sticks, coal, bones, garbage, bottles, spoons, knives, forks, apples, potatoes, hay, shirts, towels, stockings, floor-cloths, broken crockery," etc.

House drains in towns should of course be laid at the expense of the owner; but, as they are a part of the system by which the health of the community is to be protected, and as the obstruction of a single house drain may establish a centre of infection for a large district, the work should be done in accordance with an established rule and under the immediate supervision of the engineer having charge of the sewerage work.

Latham gives a velocity of three feet per second as the least that should be allowed for the outlet drain of a house. A four-inch drain to secure this flow should have a minimum inclination of one in ninety-two; a six-inch drain, one in one hundred and thirty-seven; a nine-inch drain, one in two hundred and six; and to attain a velocity of three feet per second at these inclinations *they must run at least half full;* that is, the four-inch drain must discharge 7.85 cubic feet per minute; six-inch, 17.66 cubic feet per minute; and nine-inch, 39.76 cubic feet per minute. It is very seldom indeed that even a large boarding-house discharges a flow equal to 7.85 cubic feet per minute, and in practice, while too large outlets should always be avoided for house drains, any such drain should have considerably more than the minimum rate of fall indicated above.

The main outlet drain from a house may be small, and even for the largest private dwelling need not be more than four inches in diameter, if proper precaution is taken to prevent its being choked by the accumulation of kitchen grease; while, without such precaution, were it even a foot in diameter, this same influence would cause it to be ultimately obstructed by gradual accumulation. In other words, with a proper grease trap, a four-inch drain will furnish an ample outlet, while without such grease trap no drain can be relied upon to remain permanently effective.

There are various forms of grease trap, some with open gullies for ventilation at the surface of the ground, and all of them depending upon the congealing of the grease and its accumulation at the surface of water which has its outlet at a point below the surface. The best form that has come to my notice is that shown in the accompanying diagram.

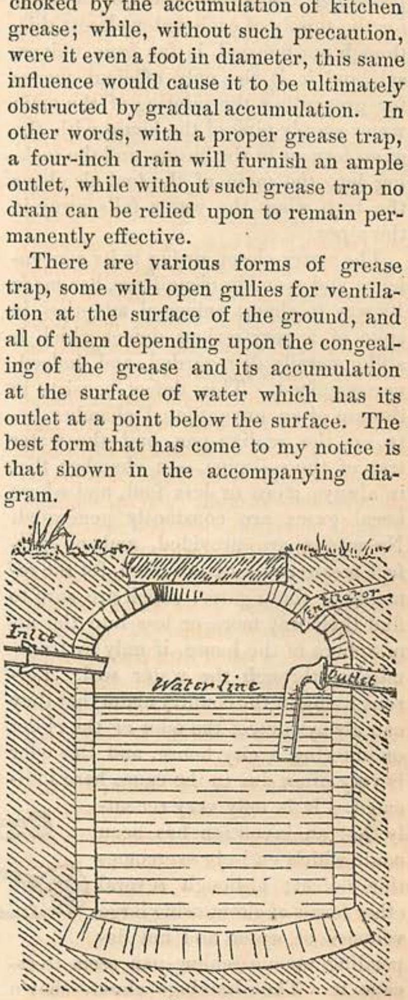



Figure 1.

The removal of organic wastes is the chief purpose of all house drains, whether a wooden pipe from the kitchen sink or the soil pipe of a house fitted with all the modern plumbing appliances. It is this part of the work that first suggests itself when the question of house drainage arises, and it is too often to this only that attention is given.

The accompanying diagram shows the simplest form in which the plumbing and draining of a house can be arranged to render it absolutely safe. An important feature of the plan here shown is that of providing a separate reservoir of water for the supply of each water-closet; this, though not unusual, is far from universal, and it is the only efficient means for preventing the tainting of the main water-supply pipe of the house with the gases formed in the basins, and the sucking into the main of the foul air above the trap when the water falls away in the pipes.

The water-closet, owing to its convenience and seeming cleanliness, has made its way to almost universal adoption, in spite of a very serious defect which is still generally disregarded, and, indeed, unrecognized. This defect consists in the use of an unventilated chamber between the sealing-pan and the water trap of the soil pipe, — a chamber that is always more or less foul, and where fæcal gases are constantly generated. No means are provided, and no perfect means could be provided, for the removal of these gases, which are sure to find their way more or less into the atmosphere of the house, if only by transmission through the water seal. Persons living in the country claim that they can always detect the odor of the closet on entering a city house, and this odor is very often due to the cause here indicated. It is only very recently that an invention has been made which entirely overcomes this defect; although several other forms of closet using large volumes of water and not depending upon a sealing-pan seem to escape it. The Jennings closet, shown herewith, has the peculiarity that it contains directly under the seat the whole charge of water to be used for the flushing at each operation of the closet.

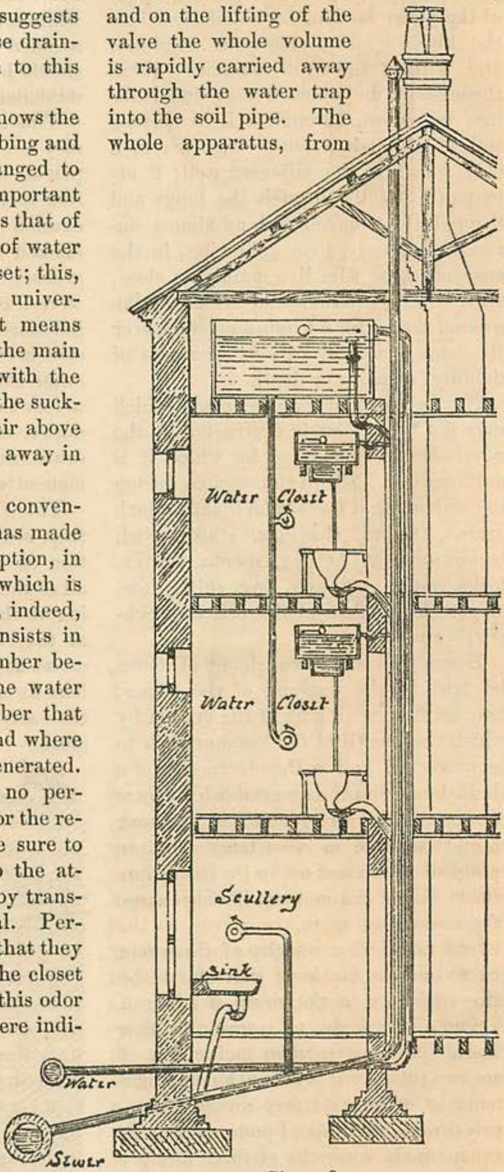



Figure 2.

Fæcal matters are immediately immersed and so at once somewhat disinfected, and on the lifting of the valve the whole volume is rapidly carried away through the water trap into the soil pipe. The whole apparatus, from the seat to the soil pipe, is a single piece of earthenware, and the valve is held so firmly in its place by its own weight and by that of the water bearing upon it, that if proper vent is given to the soil pipe itself, so that the pressure of sewer air cannot be brought to bear upon it, there is no probability of the least escape into the room.

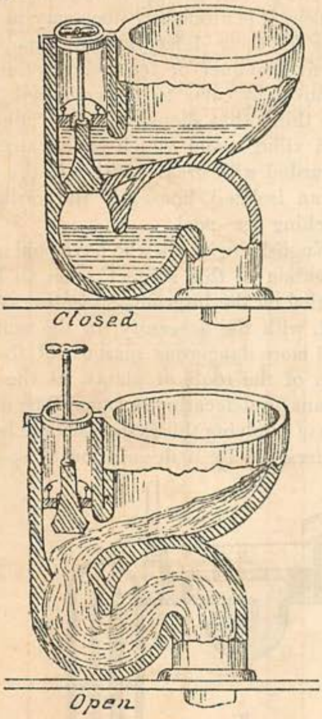



Figure 3.

Referring to the diagram which shows the general arrangement of plumbing, etc., it is to be said that from a sanitary point of view the most important feature there shown is a complete ventilation of the drain leading to the sewer, so that by no possibility can there be a forcing back into the house of gases formed in the sewer or in the main drain. As already stated, a small water trap, no matter how deep, does not suffice to secure this. A water trap having a bend of even two feet would resist a pressure of only about one pound to the square inch, while the sudden filling of the sewer, by rising tide or falling rain, to such an extent as to reduce its air space one half, would bring to bear a pressure of fifteen pounds to the square inch; and whether the filling be sudden or gradual, the degree to which the increased pressure would affect any given outlet would depend on the facilities offered elsewhere for the air to find vent. In our ordinary town sewage works, it is never safe for the householder to depend on other vents than his own connecting drain being available; he must in self-defense assume that his own drain is the only channel of escape, and make it impossible that air escaping there should find its way into the house.

Where severe frosts are not to be guarded against, this may be accomplished by discharging the water of the house into a receptacle that is open at its surface, and from which a drain passes to the sewer with some form of trap; into this surface opening, for greater cleanliness, a rain-water pipe from the roof should discharge. Under this arrangement, if sewer gas is forced from the drain it will escape into the outer air. The chief objection to the plan lies in the fact that such escape would too often take place where it would be offensive, and sometimes too near an important window. A much better plan is to have the drainage discharged into some form of covered grease trap, similar to the one shown in Figure 1, and to carry a ventilator not less than four inches in diameter, and by the straightest available course, from the grease trap to a point well above the highest dormer windows. If in addition to this there is an opening for fresh air in the cover of the grease trap, so that there shall ordinarily be an upward current through the ventilating pipe, the arrangement will be quite complete.

Some of the minor devices of modern plumbing seem as objectionable as they are convenient: for example, the ordinary fixed wash-basin having a plug at its bottom effects a complete separation between the water in the basin and the foul, soap-slimed escape pipe below it; but the more convenient shut-off cock placed some distance below the basin is a most ingenious arrangement for tainting the water in the basin, which is in free communication with the water in the unclean escape pipe. How readily impurities are diffused through still water is shown by the rapid clouding of the contents of a tumbler to which a used tooth-brush has been returned; the invisible solution from an unclean waste pipe spreads with equal ease.

It is now quite usual, also, to ventilate the lower chamber of the ordinary water-closet, and this is to a certain extent effective for the purpose intended; but it does not accomplish a proper ventilation of the soil pipe, and it alone should by no means be depended on. Indeed, this lower chamber is always objectionable, sending forth such a whiff of fetid air, whenever the water pan is emptied, as could come only from a confined, dark, and wet vessel where the most offensive matters are undergoing decomposition. The cheap and simple siphon-closet, with a copious flow of water, or, better, the Jennings closet previously described, are types of the only satisfactory forms. It would be beyond the scope of this article to describe and illustrate the minor points of complete house drainage, but it is believed that enough has been said to set forth the general principles which should govern the construction and arrangement of each of these. So far, therefore, as the town house is concerned, nothing further need here be said.

In the country and in villages, where each house has to be provided not only with the ordinary interior arrangements, but also with means for the disposal of its drainage after this has passed beyond its own walls, a serious further difficulty arises. The usual practice, where plumbing is introduced, and very often where only the water of the kitchen drain is to be provided for, is to discharge the whole mass into a cess-pool not very far away, and often very near to the well, trusting to the permeability of the earth to afford an outlet through the uncemented wall. The objections to this have been sufficiently stated, and the remedy is not in all cases an easy one.

There is no royal road of escape from the responsibility that the production of effete matters entails upon us. If they can be run by a cemented drain into a water-course, or elsewhere, far enough away from human habitations to be unobjectionable, this course may be allowed; but in the great majority of instances it is absolutely necessary to provide for their defecation in some inoffensive manner or for their inoffensive removal by carts to the country. The one thing that should never be allowed in a village, and which should even be regarded with great caution in the case of an isolated house, is the ordinary leaching cess-pool.

English engineers who have paid much attention to this subject seem to have settled on the intermittent action of the soil, with the accessory, in the warmer and more dangerous seasons, of the action of the roots of plants, as the best means for defecating sewage. The methods of applying this system will be better understood by a description of specific

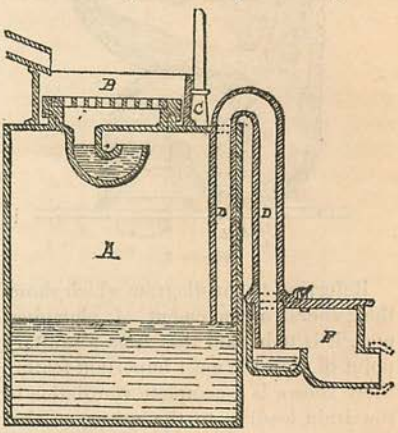



Figure 4.

processes. The accompanying illustration, Figure 4, shows the construction of Field's patent self-acting flush-tank, which is intended to be placed immediately outside of the walls of the house and to receive all of its liquid wastes. It is made entirely of earthenware or cast iron. The liquids pass through the grating of the pan *B*, and are discharged through a trap that prevents the contained air of the vessel from escaping at the surface. *C* is a ventilating pipe to carry this contained air to the top of the house. *A* is a vessel holding a certain amount of water which has no escape save through the siphon *D.* When the chamber is entirely filled, the pouring in of a few extra quarts of water, which is sure to occur sometime during the day, brings the siphon into action, and it flows copiously until the chamber is empty to the depth below which solid matters are permitted to accumulate, to be occasionally cleared out on raising the pan *B.*

The purpose of this apparatus is to prevent the constant trickling away of the small stream usually flowing from the house with too little movement to carry forward obstructing matters, such as are sure sooner or later to clog any ordinary house drain. It also furnishes a sufficiently strong flow to secure a wide distribution of the liquid instead of allowing it to soak slowly into a small area of soil. From its intermittent action, also, it fills the ground for a short time, and then as the liquid subsides fresh atmospheric air enters the soil and assists, by its oxidizing action, in the work of purification. Whether the irrigation be on the surface or by means of underground pipes, this copious intermittent discharge is in every way preferable to the steady small flow.

This flush-tank would be a great improvement on the system which I have had in successful operation at my own place during the past five years, and which has been more satisfactory than any other plan that I have seen applied.

The house drainage is discharged into a tightly cemented tank four feet deep and four feet in diameter, entering near its top, which is arched over and closed by a tightly fitting stone cap, and thoroughly ventilated. This tank is similar to that shown in Figure 1. Its outlet pipe, starting from a point one foot below the surface of the water and about two feet below the capstone, passes out near the surface of the ground and is continued by a cemented vitrified pipe to a point about twenty-five feet farther away. Here it connects with a system of open-jointed drain tiles, consisting of one main fifty feet long, and eight lateral drains six feet apart and each about twenty feet long. These drains underlie a part of the lawn and are only about ten inches below the surface. During the whole growing season their course is very distinctly marked by the rank growth of grass over and near to them, the difference of growth in their immediate vicinity being so great that were the work to be done over again I should place the lines but three feet apart. The slope of the ground is very slight, probably not more than fifteen inches between the extreme ends of the systems, yet, judging by the growth, the distribution is very uniform through all the pipes, — main and laterals.

I supposed, when I first adopted Mr. Moule's suggestion to make this disposition of the house sewage, that some other arrangement would be necessary for the winter season, but even during the winter of 1874–75, — the coldest for many a long year, — the liquid has been perfectly disposed of, and has apparently found its outlets equally in all parts of the drainage.

Successful though this experiment has been, I am now arranging to adopt a small Field's flush-tank, in the belief that the system will be improved by having the discharge made intermittent, so that the flow of water being more copious will saturate the ground for a greater distance, and that, with considerable intervals during which there is no flow, there will be a complete aeration of the ground.

Field's apparatus is intended only for the use of private establishments. For mills, hotels, and even villages, a modified and much larger apparatus (being the adaptation of the well-known engineer, Mr. J. Bailey Denton) is capitally suited to the intermittent surface irrigation of large fields, enabling the agricultural use and purification of considerable quantities of sewage which are yet too small in their regular flow to be properly applied without such device.

The importance of a close attention to these details of household drainage cannot be overestimated. In a paper on The Health of the Farmers of Massachusetts, Dr. Adams, of Pittsfield, says, "There is no dwelling in the State, of any class, which possesses an absolute immunity from these causes" (the vicinity of putrescent animal and vegetable matter); "for they are often so hidden and subtile as to elude the search not only of the landlord, but also of the most vigilant health officer."

The securing of pure drinking-water for the household can hardly claim full attention here, except so far as drinking-water wells are concerned; although the extent to which water coming from public works is contaminated by an injudicious arrangement of supply pipes and soil pipes is often alarming, as was suggested in the preceding article.

Quite generally, country houses and houses in villages and towns depend entirely upon drinking-water wells for their supply, and the degree to which these wells are rendered dangerous by what is called "surface water" — that is, rain-water passing over or through a surface soil made foul by house slops, kitchen refuse, etc. — is more than alarming. The purity of the water in any well depends almost entirely on the ability of the earth through which it descends to deprive it, by filtration, of its organic impurities. It is always a question between the amount and character of the filtering material, and the amount and character of the impurity. In a deep, porous soil, where the water-table lies at a great depth, and where the rain-water descends vertically to the line of saturation below, there is little danger, unless the grossest fouling of the surface in the immediate vicinity is constant and long-continued; but where the water level is near the surface of the ground, where the soil has an impervious stratum a few feet below the surface, or where the well is supplied through rock fissures or gravel seams which open near to the surface of the earth, the most scrupulous cleanliness is needed to prevent contamination.

Fresh earth is a capital purifying filter, and the rapidity with which its filtering power is renewed depends upon the freedom with which air circulates within it, the purification being in nearly all cases a process of oxidation. In a deep and porous soil, as the water of a rain-storm settles away, it is immediately followed by the entrance of air from the surface, and the oxidation may be complete; but in clay and in other impervious soils, the entrance of air being much more slow and difficult, the impurities accumulate and the foulness increases and too often becomes permanent. In soil of this character the curbing of the well should be laid in cement for some distance below the surface, and wet clay should be closely puddled round the curbing, to prevent the trickling down of water beween this and the solid earth. The greater the distance between the surface of the ground and the point at which water first oozes from the earth into the well, the greater the safety.

The above refers only to the fouling of wells by the leaching down of impurities thrown upon or accumulating in the surface soil. A much more frequent and much more serious source of mischief is their contamination by foul water leaking from badly made house drains or flowing laterally from cess-pools or vaults, — our own or our near or distant neighbors', — or the trickling down through gravel seams in heavy soils or porous fissures in rock of the surface liquid of adjacent or remote barn-yards. When porous strata in rock or earth bring the site of the cess-pool into communication with the site of the well, the danger is immediate and constant until the cess-pool is made absolutely tight.

The more insidious process is that of the gradual fouling of the semi-porous earth lying between the source of the impurity and the drinking-water well. In such cases the exudation is usually quite or nearly constant; there is no opportunity for the air to restore the filtering power of the soil, and it becomes saturated with impurity inch by inch, until, perhaps after a month or perhaps after several years, the saturation reaches the well; then every drop oozing in from this source carries with it its atom of filth. While the supply of water in the ground is copious, and while there is more or less circulation through the water veins, the foulness may be too much diluted to do harm; but in dry seasons, when the supply recedes to a depth of only a few feet at the bottom of the well, the contribution of drain water continuing the same, the dose becomes sufficient to produce its poisonous effect.

The dangerous character of the water of such wells is often manifested by no odor or taste of organic matter; the chemical changes in this matter seem to have been carried so far as to yield little more than vivifying nitrates to the water, their organic character having entirely disappeared. Indeed, some of the most dangerous well-waters are especially sparkling and refreshing to the taste. But the chemical processes which have effected this change appear to have had no effect on the germs of disease, — if germs they be, — which retain their injurious character to such a degree that the worst results have often come of the use of water that was especially sparkling and pleasant as a beverage.

The bad effects of organic decomposition are nowhere more manifest than when it takes place in an unventilated cellar.

That large part of the American people who were born and bred in the country will appreciate the following quotation from Judge French, describing childhood's experiences with New England cellars: "You creep part way down the cellar-stairs, with only the light of a single tallow candle, and behold by its dim glimmer an expanse of dark water boundless as the sea. On its surface, in dire confusion, float barrels and boxes, butter firkins, washtubs, boards, planks, hoops and staves, without number, interspersed with apples, turnips, and cabbages, while half-drowned rats and mice, scrambling up the stairway for dear life, drive you affrighted back to the kitchen." This will seem to many like exaggeration, but probably throughout all America one half of the population which lives over cellars at all, lives over cellars which, at some time during the year, approach the condition described.

All this nastiness and wet and confined moldiness and stagnation must inevitably foul the air of the whole house, rendering it impure to a degree that makes us wonder how human beings, if they can live at all, can live in even tolerable health in such abodes.

A medical correspondent of the Massachusetts Board of Health gives an account of the cellar of a house in Hadley, built by a clergyman, which had an uncovered well within it, and into which a sink drain with its deposit-box had full opportunity to discharge its gases, there being no proper ventilation to the drain or box. The cellar was also used for the storage of vegetables, and its windows were never taken out. There was no escape for the damp and foul air of the cellar save through the crevices of the floors into the rooms above.

"After a few months' residence in the house, the minister's wife died, of fever, so far as I can learn. He soon married again, and within one year of the death of the first wife the second died, from, as I understand, the same disease. His children were also sick. He lived in the house about two years. The next occupant was a man named B——. His wife was desperately sick. A physician then took the house. He married, and his wife died of the fever. Another physician was the next occupant, and he, within a few months, came near dying of erysipelas. All this time matters had remained as before described with reference to ventilation." After this a school-teacher took the house, and made some unimportant changes. "The sickness and the fatality of the property became so marked that the property became unsalable. When last sold every sort of prediction was made as to the risk of occupancy, but by a thorough attention to sanitary conditions no such risks have been encountered."

It is hardly necessary to recur to extreme instances of cellar foulness, such as those above described, to convince any person of ordinary intelligence that in a confined and dimly-lighted atmosphere, like that of an ordinary cellar, all decomposition of organic matter must result in the production of gases unfit for human breathing.

We especially need a condition of air that can be maintained only under the influence of light and free ventilation. The great difficulty with our cellars is that as they have a more or less complete communication with the house through open doors, imperfectly laid floors, etc., and as the law of the transfusion of gases is constantly operating even though the means of communication may be imperfect, their unceasing tendency day and night is to communicate their impurities to the air of the house. Where floors are deafened and where the ceiling of the cellar is lath-and-plastered, the danger is much less than where there is only a single thickness of boards with imperfect joints to check the communication; but no matter how perfect the separation may be, everything like the decomposition of vegetable or animal matter should be studiously avoided, and there should be at all times a free (though slight) circulation of air in the cellar.

To live in a house standing amid offensive and dangerous surroundings is under no circumstances either necessary or excusable. It has been well said that no man is so poor that he need have his pig-trough at his front-door, or that he need throw his slops under his dining-room window. No place is so small that it need contain a fermenting manure heap within dangerous proximity to the house; either the fermentation must be arrested or the accumulation must be entirely avoided. No yard is so flat that the slops of the house may not be drained away to a sufficient distance for safety. In short, there are in this world no circumstances unfit for wholesome living which may not be either overcome or run away from.

To live wrongly is a danger and a disgrace to the individual. To permit such wrong living is more than a danger and a disgrace to the community; it is a criminal menace to its own health and life. No special rules and regulations need be given here for the avoidance of palpable sources of danger; all that is necessary is studiously to avoid the retention of accumulations of organic filth of whatever description.

In the living of every family there is a certain necessary production of waste organic matter. In the economy of nature all such waste is destined to return to its elementary condition and to become a part of the air or soil or sea, awaiting its renewed use in feeding plant life. Man has learned how to avail himself of nature's organic products to supply his demand for food and clothing. He seems not yet to have learned how to hand back to the realm of nature the refuse that is not useful to him, in such a way as to avoid the injury with which its neglect threatens him. Were each man dependent only on the conditions in and about his own house, it would be safer than it now is to leave the needed reformation to individual action; but unfortunately all in the community are dependent for life and health more completely than they realize on the condition and surroundings of their poorest and most ignorant neighbor.

The public has long asserted and exercised its right to abate nuisances, but its definition of the term "nuisance" begins at a point far removed from the stricter sanitary limit. Our communities seem not yet to realize that they have a clear right to the health and strength of their individual members, and especially to insist that no man shall, by incurring the risk of disease in his own family, endanger others to whom his disease may be communicated. The stamping-out process must extend to the very bottom of society, and if we apply ourselves to the stamping out of causes, the effect (infectious disease) will not demand our attention.

If slops thrown out at the kitchen door of the poorest house in the town threaten the health of those living in that house, all who may eventually suffer from the sickness beginning in that family have as clear a right to prevent the cause as they would have to put the family in quarantine were they suffering from small-pox.

The art of purveying has been brought very near to perfection, and it may well be left to the commercial instincts of those whose business it is; but the hardly less important art of scavenging has received from the outset nothing but the sheerest neglect. It is as yet hardly in its infancy; if we can hide our filth away underground, shove it down the gutter to our neighbors' premises, or secrete it in one of those fermenting retorts, a public sewer (as usually constructed), we think we have done all that our own safety requires of us, and the safety of others we have not yet learned to regard. But our own safety is by no means secured; we are always in danger from our neglected wastes, and in proportion as we and others use the common sewer do they endanger us and we them.

That precursor of the sewer, the receptacle in our own yards, is certainly less dangerous than its modern substitute, but it is usually very far from being a safe neighbor to even an isolated house. As houses accumulate, the risk from it increases.

I was recently conversing with an intelligent builder about the construction of a contemplated cess-pool.

"It is useless to suppose that in such heavy ground a filtering cess-pool can very long answer a good purpose."

"I don't know how that is, but my own cess-pool in similar ground has been in constant use for eight years without being cleaned out, and it works all right yet."

"How do you know that it is not leaching into your well?"

"Because I put my well a good distance away from it, on the up-hill side."

"How about your neighbor's wells, down the hill below you?"

"Oh, I don't know anything about them; that 's their lookout."

The fact is that the whole hill-side near the top of which this man lives is supplied with alternate cess-pools and wells, and there is every reason to suppose that the porous strata through which the cess-pools are emptied are the very strata from which the wells are filled.

It is not to be understood that the ordinary outhouse vault is necessarily a source of danger; there is enough to be said against this arrangement on the score of convenience and of decency to serve as an argument for its abolition; but if it be cemented perfectly tight, and if its contents be daily disinfected with carbolic acid, sulphate of iron, or other suitable chemical addition, there is no fear of either the poisoning or the dangerous fouling of the air.

So, too, if it be used only for its legitimate purposes, if no liquid matter of any sort be poured into it, and if it have a copious daily sprinkling of ashes or dry earth, it will be equally free from sanitary objection.

But if these precautions are not adopted and carried into effect under a rigid supervision, there is certainly no single appurtenance of the life of an ordinary household so fraught with danger and annoyance to all who live within reach of its influence.

In all towns and villages where this expedient is allowed to remain in use, the strongest and most persistent effort of the board of health, reinforced with full power for the infliction of penalties, should be devoted to the regular, frequent, and efficient supervision and inspection of every out-of-door closet of whatever description. The removal of contents should never be left to the uncontrolled action of the proprietor, but should be carried on by well-directed workmen in the employment of the board, or at least under its direct inspection.

However perfect the ventilation of sewers or cess-pools, the safety of individual families and of all to whom they may communicate disease demands a careful attention to the ventilation of the house drain. It is chiefly through this drain that cess-pool and sewer gas finds its way into the house, and the house drain itself will be relatively more foul than will the public sewer which takes the wash of streets. Dust and foul matters of various sorts are very apt to accumulate with the congealed grease that so frequently coats the sides of the drain. Therefore, so far as the house itself is concerned, its greatest source of danger lies in the return to its rooms of the emanations from its own offscourings, entering through the water traps or through leaks in the pipes, whether such return be caused by their own expansive force or by the pressure of the sewer air behind them.

It is by no means enough to establish even the most perfect water trap in the line of a house drain. It is of at least equal importance that there should be a free vent for the escape of all air from the sewer and all gases generated within the house drain or in the soil pipe, not into the attic of the house nor at its eaves, near sleeping-room windows, but well up through and above the highest point of the roof.

House-drain ventilators are often introduced into chimneys, but they are nearly as often removed after a short trial. So long as there is a constant upward draft in the chimney, this disposition of the gases is good enough, but when no fires are used the chimney frequently becomes a down-cast shaft, or when gusts of wind drive the smoke or the soot-smelling air into rooms, the ventilator gas is sure to accompany it.

House drains are even more liable to changes of temperature, and therefore more subject to a varying pressure of the air within them, than are sewers themselves.

Ventilating pipes should be made of some permanent material. Earthenware is the best, but lead and cast-iron are good and reasonably durable. Zinc — and consequently the zinc coating of galvanized iron — is very subject to decay under the action of the corrosive gases issuing from soil pipes.

What is known under the general term "sewer gas" is the emanation from waste matters undergoing decomposition in the absence of free air and light, and in the presence of water, whether in a sewer, a house drain, a cess-pool, a vault, or a foul, wet, and unventilated cellar. It frequently exists in the case of a detached country house, and is never absent from a town sewer, though it is possible in the case of these, by perfect ventilation, greatly to lessen its production, and so to dilute it as to prevent its doing serious harm.

Poisonous sewer gas cannot be clearly defined. It is known chiefly by its effect; even its odor is rarely a marked one, and danger is believed to lurk not so much in those foul stenches which appeal to our senses, as in the odorless, mawkish exhalations which announce themselves first by headache and debility. This gas, in its most dangerous form, is believed to be some product of organic matter undergoing decomposition in the presence of superabundant water, and in the absence of light and free ventilation.

It may be present without detection; and, in addition to its frequent passing of the usual water traps, it is largely drawn into our living-rooms by the draught of heated chimneys when their demand for air is not abundantly supplied through other and easier channels of ingress.

Furthermore, soil pipes, as frequently constructed, crack or open their joints, by the frequent expansion and contraction that alternate floods of hot and cold water occasion, and thus give vent to their gases.

It is well known that leaden waste pipes decay and frequently become so perforated as to allow the escape of gas into the house. This decay always takes place from the inside, and generally at the upper sides of a pipe running in a horizontal or oblique direction; that is, in the horizontal pipe leading from a closet to the descending soil pipe more often than in the descending soil pipe itself. If there is a bend in the pipe the perforation occurs in its upper part. It usually occurs first in the highest pipes in the house. The perforation is very much the most rapid in the entire absence of ventilation. If the ventilation is by means of free and clear openings above and below, the corrosion amounts to very little.

The fact that the point of attack lies in that part of the pipe which is not covered with water, and more especially in the higher portions, — to which heated sewer gas at once rises, and where it accumulates, — indicates clearly that the corrosive action is due to the resultant gases of fæcal decomposition and not to the liquid contents of the pipe. As the corrosion begins on the inside of the pipe, and at a point where perforation would not ordinarily cause leakage, it is very likely to be overlooked, even when sought for by a plumber applying the usual tests for leakage.

The diseases resulting to the inmates of the house from this condition of the pipes, and from other means for the admission of sewer gas, are those usually caused by excrementitious poisoning: namely, typhoid fever, diphtheria, diarrhœa, cerebro-spinal meningitis, scarlet fever, etc.; and it is always safe to advise any one in whose house such diseases appear, to uncover his soil pipes and have them thoroughly examined. Dr. Furgus says, "For some years back I have insisted on the careful examination of the soil pipes wherever I have had cases of diphtheria or typhoid, and *in every case where I could get this carefully carried out* I have detected sewer gas getting into the house through perforated pipes or in some other way."

One of the other ways he believes to be by the transfusion of the gas through the water of the trap, which he seems clearly to have detected. In experiments with glass pipes having bends or water traps it was found that the light gases passed through by the top of the bend, and the heavy gases by the bottom. "The action of the gas was curious. It was found, first, to saturate the surface of the water next to it in the trap; then to sink down in a fine stream, and then gradually travel through to the other or house side of the trap, when it again spread out and began to diffuse itself both into the atmosphere above it and downward through the water also."

Dr. Carpenter, of Croydon, England, says: "The demands of air for fires and for respiration must be supplied from some source, and as the easiest means of access is often the communication between the house and the sewer, the poisonous gases which are lightest, and therefore in the highest parts of the drains nearest at hand, are first drawn in."

He gives the following means by which its admission is obtained: through the water-closet trap when the soil pipe itself is unventilated; through defective joints or fissures in the soil pipe, resulting from bad workmanship, accident, or decay; through the waste pipes of house-maids' sinks, butlers' sinks, kitchen sinks, and untrapped bath outlets; through the overflow pipe from wash-basins, etc. He especially emphasizes the emptying of the traps by siphon-like suction, or, where the trap is not constantly used, by the evaporation of the sealing water. He thinks that not one trap in ten thousand is properly protected, and that without protection they are worse than useless.

The healthful arrangement of the water supply and drainage of the house in its minutest details should be a chief care of the architect, whereas, in practice, it is almost invariably left to a plumber, doing the work too often by contract, and having no conception of what is needed, — only of what has hitherto been done.

Evils resulting from the admission of sewer gas into living-rooms are popularly called "accidents," but they are accidents which may always be foreknown and the prevention of which is perfectly understood; they are no longer accidents, but gross faults of commission.

Until lately, in applying the water system, it has been considered sufficient to interpose what is called a water trap — usually an inverted siphon, in which water is supposed to be always standing — between the house and the waste pipe leading to the sewer. These traps, as commonly constructed, are in every way defective: even a light wind blowing into the mouth of the sewer often increases the pressure sufficiently to send the sewer gas bubbling through them into the house; a great rush of water into the sewer during heavy rains, by lessening the air-space, often similarly forces the traps. The same effect is produced in a marked degree by the rise of the tides into the mouths of outlet sewers in sea-side towns, the air being compressed into a smaller space and forced to find a vent. Even did these difficulties not exist, the fact that water transmits aeriform matter would always remain as an objection; sewer gas is absorbed by the water of the end of the trap which is toward the sewer, and is given off to contaminate the air at the end which has a communication with the interior of the house.

The ordinary soil pipe has a trap at its lower part, and, if unventilated, its air stagnates often for hours together. When the pipe is used, every gallon of water poured down causes a displacement of some of the contained gas, which will seek its easiest means of escape, probably into the house. When a current is set up in the siphon-shaped trap below, its contents necessarily vibrate back and forth for a certain time, giving an impulsion to the confined air above that will tend to force it through fissures or feeble traps.

Instances of fatal disease arising from imperfect plumbing have been and still are numberless, many of them as glaring as the following, described by Hakerman, who says that in the prisons at Brest the apartments which were supplied with water-closets were filled with sewer gas when the southwest wind drove the air through the sewers and forced the traps. In these apartments the cholera raged with great intensity, while those parts of the prison not supplied with closets remained free from it.

Dr. Furgus asserts that diarrhœa, cholera, diphtheria, and dysentery have increased fourfold since the introduction of the water-closet system with its numerous inlets for sewer gas into houses and water-supply cisterns.

In 1872 the Medical Officer for Edinburgh reported that wherever water-closets were introduced, "in the course of one year there were double the number of deaths from typhoid and scarlet fever, and any epidemic fever occurring in these houses assumed a character of malignant mortality." In our own cities it is known that the fatal prevalence of typhoid, and it is believed that frequent epidemics of diphtheria and cerebro-spinal meningitis, are due to faulty drainage alone.

In doing away with cess-pools and substituting sewers, unless proper precautions are taken, we simply make an elongated cess-pool, rarely sufficiently cleansed, and often grossly foul, and communicating with the interior of every dwelling-house. If typhoid excreta are thrown into a sewer a mile away from us, we have no security against the danger that its poisonous organisms will float in the gas of the sewer and enter our own living-rooms. Grave as this difficulty is, it may be almost entirely removed by a proper arrangement of the drainage works of the house itself.

How slight a change in temperature in a sewer or cess-pool suffices to force a water trap may be seen by experimenting with the simple apparatus illustrated herewith.

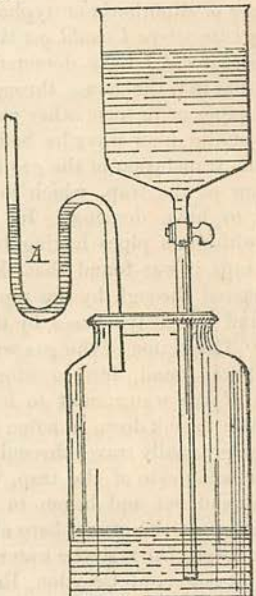



Figure 5.

The bend in the pipe A, filled with water, represents the common trap of house plumbing; the flask is filled with air. If the hand be simply placed upon the flask, the bodily heat will expand the air sufficiently to throw the water quite out of the pipe, although its upper arm may be several inches long. In like manner, on opening the cock in the pipe leading from the vessel above, containing water, the contents of this vessel will flow into the jar and bring to bear upon its contained air such a pressure as will force the water out of the bent tube. This represents precisely the condition of things when the quantity of water in the sewer is materially increased by sudden rains or by the rise of the tide into the outlet.

Another cause of changing pressure upon the air of the sewer is the frequent ebb and flow of the volume of sewage, now only a thread of water along the floor, and now an amount sufficient to fill it to half its height.

The ventilation of soil pipes is not only needful to carry away sewer gas which would otherwise be forced through the traps or transmitted by their water, but also to prevent the formation of a vacuum when large volumes of water are poured down them. The vacuum thus formed is quite sure to suck open one or more of the water traps, — which, until it is filled at its next use, will remain free for the passage of the gas from the pipe into the house.

A soil pipe in untrapped communication with a sewer has been described by Dr. Carpenter as an elongated bell-glass, affording a certain depot for the lighter products of decomposition and putrefaction; if the soil pipe has a free ventilation by a direct channel to the outer air above, these gases will escape harmlessly, but unless such outlet is provided, they will themselves seek out (or create) defective spots through which to find their way to the interior of the house.

Unused water - closets are especially dangerous, as the water in the trap, which was their only feeble barrier to the communication between the inside of the sewer and the inside of the house, is soon removed by evaporation; and as ordinarily arranged, the overflow pipes of little used bath-tubs and stationary wash-basins have their traps empty and open during a large part of the time.

In the very complete sewerage work of Croydon, Dr. Carpenter early insisted upon the compulsory ventilation of soil pipes, but his opinion and advice had to be reinforced by a long list of deaths traceable to the lack of ventilation before the authorities adopted the rule. The work was systematically carried out by Mr. Latham, who was then a director of the Croydon board, and who has since become a leading authority in matters of sanitary engineering. Although he had himself given full credence to Dr. Carpenter's belief, he was astonished at the result. "Typhoid was sprinkled here and there before him; but as the work progressed it entirely disappeared from behind him and has not returned."

It is especially important that soil-pipe ventilators should be as nearly straight and vertical as possible; a crooked ventilator pipe will not "draw" any more than will a badly built chimney flue, nor even so well, as it lacks the heat of a fire to set up a current.

Incidentally to the seclusion of sewer air from our houses, we have to consider the subject of general ventilation, — a subject that has been more bemuddled and befogged by *quasi* scientific treatment than any other connected with domestic life, unless it be the much vexed and generally misunderstood subject of sewerage itself.

The best practical statement I have met about ventilation was contained in the remark of a mining engineer in Pennsylvania: "Air is like a rope; you can pull it better than you can push it." All mechanical appliances for pushing air into a room or a house are disappointing. What we need to do is to pull out the vitiated air already in the room; the fresh supply will take care of itself if means for its admission are provided.

It has been usual to withdraw the air through openings near the ceiling, that is, to carry off the warmer and therefore lighter portions, leaving the colder strata at the bottom of the room, with their gradual accumulation of cooled carbonic acid undisturbed. Much the better plan would be to draw this lower air out from a point near the floor, allowing the upper and warmer portions to descend and take its place.

An open fire, with a large chimney throat, is the best ventilator for any room; the one half or two thirds of the heat carried up the chimney is the price paid for immunity from disease; and large though this seems from its daily draft on the wood-pile or the coal-bin, it is trifling when compared with doctors' bills and with the loss of strength and efficiency that invariably result from living in unventilated apartments.

The admission of fresh air to supply the place of that which is withdrawn is an imperative necessity, and in tightly built modern houses cracks and crannies for this purpose are wanting. It is not unusual in modern houses supplied with furnaces, especially where there is no public sewerage, to find such an arrangement of closet and kitchen drains as permits the escape of some of their dangerous gases immediately into, or in the vicinity of, the cold-air box which supplies the furnace, and the flues which furnish the interior of the house with its heated air.

In a house warmed by a furnace the supply from the registers is usually sufficient to feed the chimney, and if the furnace chamber draws its air from the outer atmosphere, from an unfouled locality, and by all means *not* from a cellar, the only objection lies in the character of ordinary furnace heating. Concerning this it need be said here only that iron heated by hot water is better than iron heated by the direct action of fire, and that, if water-pipes be not used, wrought iron is a much safer material than cast-iron for the transmission of the heat.

In all houses which are connected with public sewers or cess-pools, especial pains should be taken to supply enough fresh air for the fires through some efficient means of communication with the outer atmosphere. Otherwise, there is danger that they will feed themselves from badly trapped communications with the drain.

Sunlight is the handmaiden of ventilation and fresh air. Indeed, ample sunlight and the avoidance of a damp soil may be taken as the very fundamental conditions of healthy living.

In the lying-in hospital in Dublin the mortality of new-born infants during twenty-five years preceding its ventilation was one in six. In the twenty-five years following the supply of pure air by better ventilation, it was one in one hundred and four.

It seems almost incredible that such striking changes should have taken place so recently, but it is to be remembered that it is only about one hundred years since oxygen was discovered, and hardly fifty years since the physiology of respiration was made known; while the fact of injury from breathing foul air is indeed a very recent discovery.

Popular attention is now being resolutely drawn to these important sanitary considerations, and we may reasonably hope that we have fairly entered on an era in which the improvement of sanitary conditions will be an important attendant of advancing civilization.

*George E. Waring, Jr.*

# THE SANITARY DRAINAGE OF HOUSES AND TOWNS.

Dr. Bowditch says, "All filth is absolute poison."

It should be the first purpose of town sewerage to remove the unclean refuse of life rapidly beyond the limit of danger; the second, to prevent it from doing harm during its passage; and the third, to regulate its final disposal.

The channel through which the removal is effected — the sewer — whether large or small, must conform to certain conditions, or it had better never have been built: —

*a.* It must be perfectly tight from one end to the other, so that all matters entering it shall securely be carried to its outlet, not a particle of impurity leaking through into the soil.

*b.* It must have a continuous fall from the head to the outlet, in order that its contents may "keep moving," so that there shall be no halting to putrefy by the way, and no depositing of silt that would endanger the channel.

*c.* It must be perfectly ventilated, so that the poisonous gases that necessarily arise from the decomposition of matters carried along in water, or adhering to the sides of the conduit, shall be diluted with fresh air, and shall have such means of escape as will prevent them from forcing their way into houses through the traps of house drains.

*d.* It must be provided with means for inspection, and, where necessary, for flushing.

*e.* Its size and form must be so adjusted to its work that the usual dry-weather flow shall keep it free from silt and organic deposits.

A sewer that is deficient in *any one* of these particulars is an unsafe neighbor to any inhabited house, and a fair subject for indictment as a dangerous nuisance. Frequently, when the systematic sewerage of a town is undertaken, there comes up the question of private drains, which have been built by individual enterprise and are really the property of private owners; but owing to this complication, and to the fact that they are thought to be good enough for temporary purposes, they are often left to the last.

This is entirely wrong. *So far as circumstances will permit, the first action of the authorities should be to stop all connection of house drains with these sewers.* The next should be to stop all connection of house drains with private cess-pools. This may seem to those who have not considered the subject like an extreme statement; but all who have studied the evidence as to the means of propagation of infectious diseases will recognize its justice. The health of the community would really be less endangered if the offensive matters sought to be got rid of were allowed to flow, in the full light of day, in roadside gutters, than it now is by their introduction into the soil from which the water of house wells proceeds, and by the accumulation of putrefying masses in unventilated and leaky caverns, whence the poisonous gases sure to be produced find their way through the drains into our houses, or into their immediate vicinity. In the open air, their offensiveness would make us avoid them, and their poisonous emanations would be dissipated in the atmosphere. In the cess-pool and in a leaky sewer (which is but an elongated cess-pool) they too often find only one means of escape — through the drains into houses.

It is an almost invariable rule, in this country, to hold the question of sewerage in abeyance until after a public water supply has been provided. This is in every way unwise. It is a sufficient tax upon the soil of any ordinary village to receive its household wastes and subject them to a slow process of oxidation, so as to keep them, even under the most favorable circumstances, from doing great harm; but when the volume of these wastes is enormously increased by the liberal use of water from public works running free in every house, the case becomes at once serious. The soil is over-saturated, not only with water, but with water containing the most threatening elements of danger.

On the other hand, no system of sewerage arranged to accommodate an abundant water supply should be introduced until enough water is provided to secure the thorough cleansing of the drains.

Both branches of the work should be carried out at once, so that the over-saturation of the ground and the danger of sedimentary deposits in the sewer may alike be avoided. Where the introduction of water is not contemplated, the local authorities of towns and villages should regard it as their most important duty to provide and maintain sufficient and absolutely impervious sewers wherever these are needed.

Nor is the simple foul-water sewerage enough, save where the soil is so dry as to be free from such sources of malaria as do not depend on the wastes of human life. Malaria is a poison in the atmosphere which is recognized only by its effects on health. It often accompanies foul-smelling gases, but it is not necessarily heralded by any form of appeal to the senses, unless it be in the way of nervous headaches and a general feeling of debility.

Its presence is often marked by a disturbance of sleep, uneasiness, lassitude, and digestive irregularity. Sir Thomas Watson, who has made one of the best statements of the case, says, —

"For producing malaria it appears to be requisite that there should be a surface capable of absorbing moisture, and that this surface should be flooded or soaked with water and then dried; the higher the temperature and the quicker the drying process, the more plentiful and the more virulent the poison that is evolved."

If malaria come from cryptogams, then drainage may prevent the germination of these, just as it prevents the germination of the seeds of the cat-tail flag.

The districts soaked by hill-waters about Rome were malarious for many centuries. Tarquin, by a system of deep subterranean drainage, collected this stagnant water and turned it into the Tiber. The lands became at once healthy, and were occupied by a large population. After the Gothic invasion the drains were neglected, became obstructed, and so they still continue; and for hundreds of years these once fertile and populous districts have remained almost uninhabitable.

In addition to the frequent examples of sanitary drainage in Europe, and conspicuously in England, there are some instances in our own country which are sufficiently striking.

The town of Batavia, in New York, became at one time so malarious that it was almost threatened with destruction. It was decided to drain some saturated lands near the town. The first work was carried on by subscription, but the agricultural profit demonstrated was enough to induce land-owners to continue it at their own expense. The malaria was immediately mitigated, and for the past twenty years the town has been practically free from it.

Shawneetown, in Indiana, was formerly exceedingly unhealthy. One seventh of the men engaged in building the railroad there died of malarious disease. The draining of the surface water by a ditch (which at one point had to be cut to a depth of forty feet) removed the cause of the difficulty, and the town has remained healthy ever since.

Embryo towns and paper cities — their surface being obstructed by partly finished roads, and the land being withdrawn from cultivation and left to the care of no one in particular — are often much more unhealthy than their sites would have been had the same population planted itself in the open fields.

Stagnant pools on which cryptogams grow are frequent sources of disease. Most surface ponds have their areas contracted in summer by evaporation, and their newly-exposed, foul margins are quite sure to poison the atmosphere.

The increase of population in malarious districts always exerts an especially bad influence, because the organic wastes of human life accumulate in the soil and aggravate its insalubrity.

Closely allied to the malarious influences of saturated soils (especially in densely built districts) are those which attend the escape of sewer gas. The pernicious action of this gas is especially felt in the higher districts of sewered towns. As a rule, sewer air finds its escape in the higher-lying districts, and often conveys the germs of diseases originating in the lower and poorer parts of the town.

The Medical Officer of Glasgow says: "It has been conclusively shown that houses presumed to be beyond suspicion of any possible danger from this cause — houses in which the most skillful engineers and architects have, as they believed, exhausted the resources of modern science — have been exposed in a high degree to the diseases arising from air in contact with the products of decomposition in the sewers. And this for a very obvious reason. Such houses are usually built on high levels, where the drains have a very rapid fall."

Thon says that in Cassel, in the higher part of the town, which one would suppose the healthiest, typhoid fever was brought into houses by sewer gas which rose to them by reason of its lightness. In Oxford, in 1850, cholera, by the same action, appeared in several houses in the higher and healthier parts of the town.

In Berlin, in 1866, in those parts of the city where there were no sewers or water-closets, the deaths amounted to 0.37 per cent. of the population, while in the Louisenstadt, where sewers and water-closets were in general use, the deaths reached 4.85 per cent. Owing to errors in the construction of the sewers of Croydon (England), their early use was followed by a violent outbreak of typhoid fever, which attacked no less than eleven per cent. of the population.

The evidence is almost universal, that wherever sewerage works are badly executed, and where proper precautions against the invasion of houses by sewer gas are not taken, typhoid fever and diseases of the bowels are quite sure to be increased in intensity, and to appear in parts of the town which, before sewerage was undertaken, were comparatively healthy.

In 1856 there was an epidemic of typhoid fever in Windsor, England. Four hundred and forty persons, or five per cent. of the whole population, were attacked, and thirty-nine died. The disease affected the rich quite as much as the poor, but it confined itself entirely to houses that were in communication with a certain defective town drain. Windsor Castle had its own drain, and its inmates were entirely untouched; in the town, places only a block apart suffered severely or escaped entirely according as they were in communication with the town drain or with the castle drain.

It should be understood that sewage matters, though offensive, are not dangerous until two or three days after their production. The great point sought to be gained in the water system of sewerage, and that which constitutes its chief claim to confidence, is the instant removal of all organic refuse, everything being carried entirely away from the vicinity of the town before decomposition can have begun. Any plan not effecting this is entirely inadequate, and, on sanitary grounds, objectionable.

In many towns where there is no water supply, a rude system of sewerage is adopted, with the precaution of prohibiting water-closet connections. This is really hardly a precaution at all. Investigations made in towns where the earth and ash systems prevail, as in many of the large manufacturing towns of the north of England, show that the ordinary contents of the public sewers are in all respects not less foul and offensive, and probably little less dangerous, than are the contents of those which receive all of the ordure of the town with a copious flow of water. That is to say, the kitchen wastes and house slops when mixed with the wash of the streets constitute so prolific a source of offensive sewer gases that the night-soil is not especially marked, save as a specific vehicle for the spreading of epidemics.

It is not the least benefit of the water supply in towns and villages that it sooner or later compels proper attention to the sewerage question; for a liberal supply of water running free of cost in every house soon leads to a great increase in the amount of water used and allowed to run to waste, and the result is that the people are awakened to the only argument by which average communities are at all affected, — the argument of life and death, — and are compelled, often in spite of themselves, to adopt more complete sewerage. It would show a wiser forethought, and lead to ultimate economy, if our towns would at once, on agitating the question of the introduction of water, couple with the scheme a plan of complete sewerage. It is a very ostrich-like blindness which hopes to escape the sure consequence of the beginning of the work. If it is undertaken at all, the double expense is inevitable, and it had better be honestly acknowledged and sufficiently provided for at the outset, especially as it is in every way better that the two operations should proceed simultaneously.

If the supply of water is ten gallons per head per day, the quantity of sewage to be removed will be about one hundred pounds daily for each person, of which the closet flow will constitute about one third. This assumes that the use of the water-closet is universal, that vaults are entirely done away with, and that the water is employed for all domestic requirements.

Nearly the most important item in connection with the arrangement of a plan for sewerage, and one in which professional experience is especially important, is the regulation of the sizes of the different main drains and laterals. This involves a consideration of the amount of sewage proper; the customary rain-fall of the district; the grade or inclination of the surface, as indicating the rapidity with which storm waters will find their way to the entrances of the sewers; and the extent to which, in order to avoid the flooding of cellars and other injury during copious rains, it is advisable to increase the sizes of the conduits beyond what is needed for ordinary use.

It is doubtful whether even large cities can really afford, in arranging their sewerage, to provide for the underground removal of the water of heavy rains, and certainly in smaller towns and villages it would be far cheaper to pay for repairing whatever damage might be caused by occasional heavy floods in the streets, or to provide for the removal of the water of these storms by surface gutters, than to make the size of the whole system of sewerage adequate for such work. Not only this, but sewers large enough to accommodate the water of very heavy storms would usually be too large for perfect cleansing with their daily flow, and would require expensive flushing appliances, which with smaller pipes would not be needed. In country towns it would not generally be wise to provide for removing through the pipes the flow of a heavier storm than one quarter inch per hour. Gutters are much cheaper than sewers, and there is usually no objection to their being depended on to remove the surplus water of sudden showers.

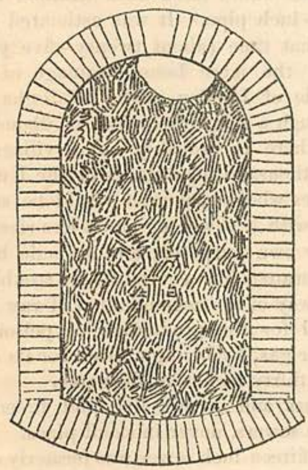
It is not unusual to provide in cities for a rain-fall of one inch per hour, and to assume that one half of this will reach the sewer within the hour. Even this is far more than is necessary, if any other provision can be made for exceptional storms. For example: In Providence, one hundred and eighty-five storms were recorded in twenty-six years. Of these, one hundred and fifty-eight were of one half inch or less, and one hundred and thirty-one were of one fourth inch or less. One half inch per hour equals thirty and one fourth cubic feet per minute per acre.

In Brooklyn, it is estimated that, aside from rain, the sewage equals one and one fourth times the water supply, or fifty million gallons per day, the half of which running off between nine A. M. and five P. M. gives 3,125,000 gallons per hour, escaping during eight hours. This, from twelve hundred acres, gives two hundred and sixty gallons or thirty-three cubic feet per acre per hour, being less than one hundredth of an inch in depth over the whole area.

It is a safe rule to estimate all sewage except rain-fall at eight cubic feet per head of population per day. Of this, one half will be discharged between nine A. M. and five P. M., equal to a flow of five hundred cubic feet per hour for each thousand of the population.

Sewers choke and overflow during heavy storms mainly because they are too large for the work they are ordinarily called on to perform. If a sewer is so small that its usual flow is concentrated to a sufficient depth to carry before it any ordinary obstruction, it will keep itself clean. But if, as is almost always the case where the engineer lacks experience or where he defers to the ignorance of the local authorities, it is so large that its ordinary flow is hardly more than a film, with no power even to remove sand, we may be quite sure that its refuse solid matters will gradually accumulate until they leave, near the crown of the arch, only the space needed for

Fig 1



Cross section of a large sewer filled by the gradual accumulation of silt until only sufficient waterway is left for the smallest constant flow.

the smallest constant stream. And, in order to make room for a rain-fall flow, the whole sewer will have to be cleared by the costly and offensive process of removal by manual labor. A smaller sewer would have been kept clear by its own flow.

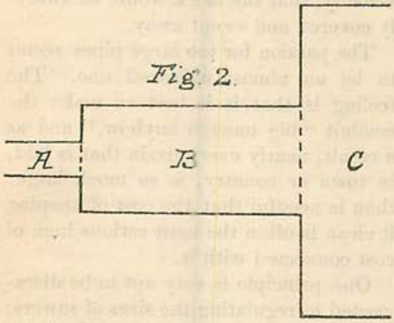
The shallower and broader the stream, the more the friction against the bottom and sides and the greater the retarding of velocity. A brick will stand unmoved in a shallow stream of water running sluggishly through a fifteen-inch drain, while if the same stream were concentrated into a five-inch drain it would have so much greater depth, force, and velocity, that the brick would be entirely covered and swept away.

The passion for too large pipes seems to be an almost universal one. The feeling is that it is best to make the conduit "big enough anyhow," and as a result, nearly every drain that is laid, in town or country, is so much larger than is needful that the cost of keeping it clean is often the most serious item of cost connected with it.

One principle is very apt to be disregarded in regulating the sizes of sewers: that is, that after water has once fairly entered a smooth conduit having a fall or inclination towards its outlet, the rapidity of the flow is constantly accelerated up to a certain point, and the faster the stream runs the smaller it becomes; consequently, although the sewer may be quite full at its upper end, the increasing velocity soon reduces the size of the stream, and gives room for more water. It is found possible, in practice, to make constant additions to the volume of water flowing through a sewer by means of inlets entering at short intervals, and the aggregate area of the inlets is thus increased to very many times the area of the sewer itself. Where a proper inclination can be obtained, a pipe eighteen inches in diameter makes an ample sewer for a population of ten thousand.

It was formerly the custom with architects and engineers to enlarge the area of any main pipe or sewer in proportion to the sectional area of each subsidiary drain delivering into it. But this is no longer done, since it has become known that additions to the stream increase its velocity, so that there is no increase of its sectional area. For example, the addition of eight junctions, each three inches in diameter to a main line of four-inch pipe, did not increase the sectional area of its flow, but made the flow only more rapid and cleansing. Ranger thus illustrates the average architect's method of draining a house and court. The reason for making *B* so large is to *prevent* its choking, an effect that its extra size is quite sure to produce.

Fig. 2.




*A*, 3-inch drop or soil-pipe.

*B*, 9-inch intermediate drain (9 times the area of *A*).

*C*, 26-inch sewer (8½ times the area of *B*, and 75 times the area of *A*).

The main sewer in Upper George Street, in London, is five and one half feet high and three and one half feet wide. In the bottom of this sewer there was laid a twelve-inch pipe five hundred and sixty feet long. A head-wall or dam was built at the upper end of this, so that all the sewage had to pass through the pipe. The whole area drained was about forty-four acres (built area). The velocity of the water in the pipe was found to be four and one half times greater than on the bed of the old sewer. The pipe contained no deposit, and during rains stones could be heard rattling through it. The force of water issuing from the pipe kept the bottom of the old sewer perfectly clean for about twelve feet below its mouth. From this point bricks and stones began to be deposited, and farther on sand, mud, and other refuse, to the depth of several inches. In one trial a quantity of sand, bricks, stones, mud, etc., was put into the head of the pipe; the whole of this was passed clear through the pipe, and much of it was deposited on the bottom of the old sewer some distance from its end. *The pipe was rarely observed to be more than half full at its head.* It was found that the sum of the cross sections of the house drains delivering to this half-full twelve-inch pipe was equal to a circle thirty feet in diameter.

Another experiment was made with a sewer in Earl Street, which took the drainage from twelve hundred average-sized London houses, the area occupied being forty-three acres of paved or covered surface. It was three feet wide and had a sectional area of fifteen feet, with an average fall of one in one hundred and eighteen. The solid deposit from the twelve hundred houses accumulated to the amount of six thousand cubic feet per month (two hundred and twenty-two cart-loads). A fifteen-inch pipe placed in this sewer, with an inclination of one in one hundred and fifty-three, kept perfectly clear of deposit. The average flow from each house was about fifty-one gallons per day, and, apart from rain-fall, the twelve hundred houses would have been drained by a five-inch pipe. It was estimated that at that time (about twenty-five years ago) the mere house drainage of the whole of London might be discharged through a sewer three feet in diameter; yet there is probably not a village of five thousand inhabitants in the United States whose magnates would be satisfied with a sewer of much less size for their own purposes; and a single hotel in Saratoga has secured future trouble in the way of the accumulation of raw material for the production of poisonous sewer gas, by laying a drain for its own uses thirty inches in diameter.

Rats and vermin live and breed in large sewers, never in small pipes.

A fifteen-inch sewer was formerly considered the smallest size admissible for the drainage of a "mansion." Such a sewer, with a fall of one in one hundred and twenty, or one inch in ten feet, would drain nearly two hundred of the largest city houses; and a nine-inch drain with the same inclination would remove the house-drainage *and storm water* from twenty such houses.

A curious example of the capacity of

small pipes was furnished in a case where a six-inch pipe was laid for the drainage of one detached house. One after another, as new houses were built, new drains were connected with this same pipe, until, after a time, it was found to be clean and in perfect action, though carrying all the drainage of one hundred and fifty houses. In a second instance a workman by mistake used for the drainage of a large block of houses a pipe which the architect had intended for a single house, and it was found to work perfectly.

It may be taken as a rule that, with even a slight fall, a well-constructed eighteen-inch pipe sewer is ample for the drainage of an ordinary village area containing seven or eight hundred houses. In one instance a sewer of this size, having a fall of one in one thousand, accumulated but little deposit, and this was always removed by storms. In Tottenham (London) a main sewer of nine-inch pipe, widening to twelve-inch and afterward to eighteen-inch, and having a fall of one in one thousand and sixty-two, drained an area containing sixteen hundred houses. Its ordinary current was two and one half miles per hour, and brickbats introduced into it were carried to the outlet. During ordinary continued rains it was not more than half full half a mile from the outlet, and at the outlet the stream was only two and three fourths inches deep.

During the preparation of these papers the Sewer Commissioners of Saratoga (the writer being employed as their consulting engineer) have completed a main sewer more than two miles long, for the removal of the entire sewage, rain-fall, and spring-water drainage of that village. The experience with this work affords so pertinent an illustration of the principles here advanced that it seems worth while to refer to it. The village is large and scattered, has an abundant water supply, is so inclined that during showers its storm waters concentrate rapidly, and has, aside from its regular population, five or six enormous hotels, entertaining, when full, about as many thousand guests. The village brook itself, being mainly supplied by spring water flowing from various points over a wide district, is always a considerable stream. As it flowed through its old channel — a conduit with rough, loosely-laid stone side-walls, and with a more or less irregular bottom — its sectional area was about five feet. During heavy rains it was sometimes thrice this.

From the very beginning of the work we encountered the most violent opposition on the part of many citizens, who believed that the sewer contemplated (circular, three feet in diameter) would be entirely inadequate, not only for the removal of the water of heavy rains, but even for the drainage of the hotels alone, or the carrying of the storm waters alone; and throughout its construction this main sewer has been derided as a "cat hole." We were constantly reminded that one hotel had a main drain eighteen inches in diameter, and another a drain two and one half feet in diameter, and that it was madness, with these drains as our guide, to attempt to accomplish the whole work with a three-foot sewer; especially as our fall was said to be slight, one foot in four hundred feet.

On the 9th of July, 1875, the connections were made with all of the hotels; the village brook itself was turned into the sewer at its head, and its insufficiency was to be demonstrated. After every available source of water had been drained, the depth of flow in the upper part of the sewer was six and one half inches. Nearer the outlet, where the water had acquired its maximum velocity, it was only four and one half inches. As this was not sufficient to wash out the few loose boards carelessly left by the workmen who had done the final pointing of the joints, a hydrant was turned on at the upper end of the sewer, with a full head, and it had the effect only of raising the flow one inch at the upper end and less than half an inch at the lower end of the sewer. On the 10th there fell a violent thunder-shower, flooding the street gutters until the water ran to the top of the curb-stones, and when this flood had reached the catch-basins and the open brook that discharged into the head of the sewer, its only effect was to raise the flow, at the highest point, less than two inches, justifying my original opinion that a two-foot sewer would have been more than adequate for all that was required of it. On the 30th day of August the entire village brook, with its tributaries and its many springs, was turned into the three-foot sewer, near the water-works, about one half mile beyond the outskirts of the village. The effect of this addition was to increase the depth of flow in the sewer from about six inches to nine inches, and to increase the velocity of its stream from one hundred and fifty feet per minute to one hundred and eighty-five feet per minute. I can excuse my course in recommending so large a sewer as one of three feet, only by the fact that in the state of public opinion then it would have been entirely impossible to secure the making of anything smaller. Before the introduction of the brook I examined the outlet of the Grand Union Hotel, which had then about eight hundred and fifty guests and four hundred and fifty servants, or about thirteen hundred inmates in all. There can hardly be fewer than one hundred water-closets in the house, and the use of water in this hotel seems to be in every way as copious as possible. The hour of examination was ten in the morning, at which time, as the landlord supposes, the largest flow is running. By the most careful measurement and estimate that I could make, the amount of sewage then flowing from that hotel measured four and one half inches in sectional area, and might have all been discharged by a two and one half inch pipe.

The pipe sewer has been so long in successful use that there is no further question of its value. Even ten years ago, fifty miles of such pipe were made per week in Great Britain alone.

Accuracy in form and joints, and smoothness of surface, are very important. A perfectly round pipe, accurately laid at the joints, will deliver, under the same circumstances, fifty per cent. more water than one of distorted form or with ill-fitting joints.

Any roughness of surface, as in even the best made cement pipes, tends to catch hair and lint and thus to form nuclei for accumulating obstructions, sometimes so hard that they can be removed only by forcible mechanical means.

With a well-constructed system of pipe sewers, not too large for the work required of them, of good form and surface, with perfect joints, with only curved junctions, and with a well regulated even if slight fall, every particle of the sewage of the town may be delivered at the outlet, far away from the built-up districts, long before any decomposition of the refuse matter has set in; though occasional flushing may be necessary to cleanse the sides of the pipes from slimy matters adhering to them.

In New York, the cost of flushing and cleansing sixty miles of pipe sewers was found to be only fifty dollars per year.

The material of the pipe should be a hard, vitreous substance, not porous, since this would lead to the absorption of the impure contents of the drain, would have less actual strength to resist pressure, would be more affected by frost or by the formation of crystals in connection with certain chemical combinations, or would be more susceptible to the chemical action of the constituents of the sewage. The best pipe known in our market is the Scotch; but some American work is very nearly as good.

Sewer pipes should be salt-glazed, as this requires them to be subjected to a much more intense heat than is needed for slip-glazing, and thus secures a harder material.

Pipes having a socket at one end should be furnished with a gasket before being cemented, in order that no cement may be pressed through into the bore of the sewer, to cause a disturbance of the flow. Where there is danger of the penetration of roots, as near elm-trees, the sewer should be bedded in a sufficient thickness of concrete to prevent the entrance of rootlets, which are sure to find and to penetrate the smallest aperture. An entrance once effected, a mass of fibres soon forms, sufficient to retard or entirely to arrest the flow.

A chief argument in favor of the use of pipes rather than brick sewers lies in their greater essential cleanliness. Brick sewers are always offensive, even though small, because their porous walls are more or less permeated by the filth of their contents. If (as is almost always the case) they are too large, there will be the additional annoyance of accumulations of refuse as foul and dangerous as the contents of any cess-pool, producing poisonous gases which are free to travel through the sewer and all its branches.

The first question to be considered in arranging the plan for the sewerage of a town or village is that of an outlet, at which the foul sewage of the streets and houses may be delivered without danger of polluting water-courses or destroying their fish, or of silting up harbors or navigable streams; and without forming within dangerous proximity to the town a deposit of offensive sewage matters which might constitute a source of annoyance or of insalubrity.

In all cases where this part of the problem presents difficulties, it should be considered whether a separate direction or a shorter outfall may not be given to the storm-water drainage, allowing the sewers to deliver at their main outlet only the ordinary drainage of houses and the street-wash of very slight rains. The cases are frequent where the removal of the sewage proper may be best and most economically secured by artificial pumping; though, in the majority of instances, it will be practicable, by the use of intercepting sewers, to deliver by natural outfall the drainage of all except the very lowest portions of the town. It is in the adjustment of this part of the work that the experience and judgment of the engineer in charge will be the most severely tested; in all matters of construction, ventilation, house connections, etc., certain rules and explicit directions can be applied, but the arrangement of the outlet varies with nearly every new undertaking, and with reference to this branch of the subject it is possible here to give only general indications.

It would often be practicable to take the small ordinary flow of public sewers to a remote point, when the cost of providing such an outlet for storm water would be so great as to make it impracticable. In such cases there may be carried from the point of outlet to the distant point of discharge the smallest pipe that will accommodate the usual flow, so arranged that whenever, as during storms, the volume is increased beyond the capacity of this pipe, it shall overflow and be carried directly into the stream or harbor at hand. At such times the amount of water in the sewage will so dilute it that no bad effect need be apprehended.

The great danger in nearly all the towns of our Atlantic seaboard lies in the fact that they discharge some of their most important sewers below high-water mark, so that at each rise of tide not only is the flow at these points checked, and foul silt allowed to collect in the stilled water, but the closing of the vent at this end of the sewer and the rise of water within it, whether by the action of the tide or through the accumulation of the flow from above, brings a pressure to bear upon the contained air and forces it to escape at the higher points; so that the state of the tide is often made perceptible by the forcing of water traps a mile or more distant from the outlet.

Outlets, especially of large sewers, exposed to strong winds, are likewise very objectionable, the pressure of the wind forcing the tainted air to find vent too often through badly trapped drains leading into occupied houses.

Where necessary to secure a constant flow of sewage, pumping should always be resorted to. With coal at nine dollars per ton, the cost of lifting thirty thousand gallons ten feet high with a twenty-five horse-power engine would not exceed seventy-five cents, while with a larger engine and a larger flow the relative cost would be much less. It was estimated that to lift the whole sewage and rain-fall from a low-lying district in London, occupying four thousand acres, to a height of thirty-one feet would cost about five cents per annum per head of population. Whatever the cost of pumping, it may be made in level districts to do away with any outlay for cleansing or flushing sewers, which without pumping must have been laid nearly level.

There are few cases yet in this country where it is necessary to discharge the sewage of a town into a stream from which other towns receive their water supply, though the towns along the Schuylkill River still stand in this relation to the city of Philadelphia. The time is probably not very distant when this question will become here, as it now is in England, a very serious one.

Tidal estuaries and bays receiving the drainage of a town are sure to have those parts of their bottoms and sides which are alternately covered and exposed by the changing tides fouled with organic matter, and to become thereby seriously offensive.

Recent sewage floats in water. After maceration it sinks in still water and in currents having a less velocity than one hundred and seventy feet per minute. Its specific gravity is 1.325.

The condition of Newtown Creek, Wallabout Bay, and the Gowanus Canal and Bay, near Brooklyn, are examples of the subsidence of sewage in eddies and slack water.

Tides may be made extremely useful in the flushing of sewers in level lowlands, but care should be taken to carry the outlet to a point where the inconvenience from subsidence will be reduced to the minimum.

All sewers must at least be *vented*, and for perfect security all ought to be well ventilated. It is of the first importance to provide openings for the escape of the contained air and gases when these are compressed, either by a wind blowing into the outlet or by the increase of the quantity of water in the sewer from the rise of the tide or from heavy rain-fall. Unless such precaution is taken, house traps will surely be forced and sewer gas will surely escape into dwellings. It is, however, hardly less important that there should be such a free circulation of air through the sewer as will prevent the formation of those poisonous, mephitic gases which are especially generated in the absence of a sufficient supply of oxygen.

Latham says that unventilated sewers are far more dangerous than steam-engines without safety-valves. They contain in their air some quality that is pestilential and dangerous to health, and this can be disposed of or neutralized only by giving the air of the sewer a free communication with the atmosphere. Typhoid fever is said rarely to be absent from towns with unventilated sewers. The constantly changing pressure upon the confined air within these conduits acts in connection with the draughts of chimneys and the force of winds to cause the bubbling of house traps, accompanied with an entrance of more or less of the sewer emanations.

When the sewerage works of Croydon were nearly completed and the town was visited by an epidemic of typhoid fever, the mortality rose from 18.53 per thousand to 28.57 per thousand. Although it is probable that the only matters decomposing in the sewer were such as adhered to the pipes (which were well flushed), there were frequent outbreaks of fever until 1866. Diseases which had formerly made their haunts in the lower parts of the town traveled by means of the sewers and infected the higher districts. In 1866 the sewers were systematically ventilated, and since that time there have been no periodical outbreaks of fever, and, with a doubled population, "the rate of mortality rarely exceeds eighteen in the thousand, which is a standard of health unparalleled in the history of sanitary science for a district having so large a population."

The principle of the ventilation of a sewer is practically the same as that adopted by builders for the prevention of dry-rot. The fungi which cause this rot in timber cannot produce their germs in a current of air, and if a sufficient number of ventilating openings are made, communicating with each other, the action of the wind from one side or the other will cause a sufficient current. So in a sewer, a continuous movement of the air in one direction or the other carries away and dilutes sewer gases, and if they contain germs of organic disease capable of infecting the human blood, these are believed to be destroyed by oxidation or otherwise.

A safe sewer always has a current of air passing through it, and if it contains sewage matters at all, these also must be in constant motion. On this incessant movement of the air and the liquid must we rely for our only security. A solution of sugar in water, remaining stagnant, and protected from a free circulation of air, will enter into a vinous fermentation. If well ventilated and agitated, no such fermentation takes place. The excrement of a typhoid patient, continually agitated in contact with fresh air and a fair admixture of water, passes through a series of complete chemical changes, with no injurious product; but if allowed to remain stagnant, if not freely exposed to the air, or if it gain access to human circulation before a certain oxidation, it will, like a ferment, reproduce itself, and give rise to the conditions under which it was itself produced. Motion and aeration are therefore needed to prevent infection, which is sure to be generated when typhoid evacuations are confined and stagnant. Unventilated and badly-constructed sewers are sure agents for the propagation of the disease.

The resulting gases of sewer decomposition are the vehicle or medium for the conveyance of infection, and from their lightness they give rise to a rapid diffusion owing to the eagerness with which they seek means of escape at the higher parts of the sewer system, that is, in house drains, soil pipes, etc. It may not be possible entirely to prevent the development of the poison in even the best arranged sewer, but it is possible, by a free admission of air, to supply the oxygen which will take away its sting and render it harmless. Sewers which have large and frequent openings at the street surface, and through which the liquid contents have a constant flow, may give forth offensive smells, but, if they have proper attention, sanitary evils do not often result.

Sewer gas, when largely diluted on its escape (at frequent intervals) into the air of the street, is probably nearly or quite innoxious, but when it forces its way into the limited atmosphere of a closed living-room, the poison, or the germs of disease accompanying it, may work their fatal effects.

Sulphuretted hydrogen is found in all sewers in which the sewage itself or the mucous matters adhering to the pipe assume a certain degree of putridity. This gas is extremely poisonous; so much so that one part of the gas to two hundred and fifty parts of atmospheric air will kill a horse. At one half this intensity it will kill a dog. A rabbit was killed by having its body immersed in a bag of it, although its head was not inclosed and it could breathe pure air freely.

One of the most frequent sources of pressure upon the air within a sewer is the increase of temperature arising from the hot water escaping from kitchens and baths. The repeated expansions and contractions caused by the admission of hot and cold water produce a constant effect on all water traps connecting with unventilated sewers. With ventilation, the breathing in and out, as the air of the sewer contracts or expands, does not affect the water traps, because an easier passage is found through the ventilators.

The constantly changing volume of water in many sewers, as has been before stated, exerts a powerful influence on the confined air. As the water rises it reduces the air space, and if it reduces this to one half, it brings to bear upon the air a pressure equal to a column of water thirty-four feet in height, and this pressure is relieved by a forcing out of air through the most available channel, — the channel where there is the least resistance; if there is no other vent, a sufficient number of water traps must be forced to allow the pressure to become reduced. It being reduced, and the water falling again to a lower level, a vacuum is created which must be supplied by air forcing the traps in a reverse direction, and in either case the forced trap may remain open for the free passage of foul air until another use fills it with water. In the ebb and flow, too, a part of the perimeter of the sewer is made alternately wet and dry, with an accompanying production of vapor and gas.

As the chief domestic use of sewers is between morning and noon, and as at this time the most hot water passes into them, the pressure on the air in the sewer is during this period increased both by an elevation of the temperature and by a reduction of the air space. Then, from about noon until the next morning, the quantity of the flow decreases, the air-space increases, the temperature falls, and more air must be admitted to supply the partial vacuum created. Such fluctuations are constantly occurring, accompanied with a drawing in and forcing out of air, for which ample passage *must* be made independently of the water traps of houses, or sewer gas will surely enter them. Where proper air vents are provided, this ebb and flow of the sewer may be increased, with great advantage in the matter of ventilation, by artificial flushing arrangements which will allow the water to be dammed back and released at frequent intervals.

The movement of the air in and out of the sewer is also affected by barometric changes.

Where proper ventilation is furnished there will be an advantage in exposing the outlets of sewers to the direct action of the wind, but where there is not sufficient vent for escape, such outlets should, as has been stated, always be screened against strong currents of air.

Numerous experiments have been made with tall chimneys and fires, having for their purpose the creation of a strong draught from the sewer, but these have never worked satisfactorily, and are in no case to be recommended, being both expensive and troublesome. By reason of the causes constantly at work tending to the increase and decrease of the pressure of the air in the sewer, this variation may safely be depended on to furnish all needed ventilation, if only sufficient openings are provided from which air can pass in and out at frequent intervals.

Ventilation by rain-water pipes from the eaves of houses has often been recommended, but experience has shown that it is unsatisfactory, not only because it frequently discharges sewer gas near the windows of sleeping-rooms, but because at the time when ventilation is most needed these pipes are not available; either being filled with a rush of water or else having such a rapid downward current as to move the air toward the sewer rather than away from it, or because, from the position at which rain water inlets are often introduced into sewers, these are entirely closed when there is a large amount of sewage flowing, — as during heavy rains, when ventilation is especially demanded.

This system was adopted during the early days of the Croydon work, and was rigorously pursued. In 1860 such ventilation was compulsory in all cases. The mortality was very much increased until a better system was adopted in 1866, when the death-rate fell again to its old standard.

In Hints on House Drainage, by Dr. Carpenter, of Croydon, we are told, with reference to fatal epidemics of typhoid fever, that the illness dated from two distinct times, at both of which, with a high temperature and a stifling atmosphere, there was a heavy fall of rain. "I do not mean to assert that each case commenced immediately after the rain-fall, but in upwards of twenty fatal cases into the history of which I examined, the commencement curiously ran up to two distinct dates, and of many slighter cases the patients stated that they had not felt well about the same periods." One case occurred in his own house. The water-pipe ventilators being closed by the rain water, and the air in the sewers being compressed by the increased volume of the flow, the gas forced the water trap of his soil pipe and escaped into his tank room, where the upper end of the ventilator was used as an overflow pipe for the cistern. This air ascended to a room occupied by two persons, both of whom were attacked with typhoid fever. There were no other cases in the house.

After all the experiments that have been tried with shafts, furnaces, mechanical blowers, steam jets, electricity, etc., the most experienced engineers have settled upon more frequent ventilation, by means of man-holes and lamp-holes opening at the centres of streets, as in all respects the best and safest. If these openings are sufficiently frequent, there is such an easy and thorough circulation of air in the sewer that the concentration of poisonous or of offensive gases is prevented, and their escape into the open air takes place at a point where they will be more diluted before reaching the sidewalks or the houses than if withdrawn by any other means yet devised. By the use of the excellent charcoal ventilators described below, so arranged as to give free vent at their openings, all practical danger or objection may be obviated.

The great safety, however, lies in the dilution of the gases by the free admission of air, and by their escape, when they escape at all, into the open air as far as possible from the house line. The effect of dilution is fully shown in fever hospitals: formerly, the mortality among both patients and attendants was frightful to contemplate; but now, although the ventilation is often far from complete, the condition of the patients themselves is much improved, and contagion is almost done away with; so much so that if an attendant contracts the disease it is taken as clear evidence that there has not been a sufficient dilution of the exhalations from the patients, or, in other words, that the ventilation has been imperfect.

The absorbing and disinfecting power of charcoal fully sustains its popular reputation. Latham quotes the following from Professor Musprat: "The absorbing powers of charcoal are so great that some have doubted whether it is really a disinfectant. This opinion has probably arisen from imperfect views of its *modus operandi*, since it not only imbibes and destroys all offensive exhalations and oxidizes many of the products of decomposition, but there is scarcely a reasonable ground of doubt remaining that it does really possess the property of a true disinfectant, acting by destroying those lethal compounds upon which infection depends."

Strictly speaking, the charcoal is simply an apparatus by which a natural process is carried on in an intensified form. It has the two important qualities of condensing upon the surfaces of its inner particles eight or ten times its volume of oxygen, and of attracting to itself all manner of other gases. It is not necessary that sewer gas be brought into direct contact with it by external pressure. By the operation of the law of the diffusion of gases, the impurities of the air next to the charcoal being absorbed, remoter impurities flow to this space and are in turn taken up, until the contents of a close room may be entirely purified by a small dish of charcoal. The oxygen that consumes or burns up the organic matter is speedily replaced from the atmosphere, and the constant efficiency of the apparatus is thus maintained.

The clogging of the pores of the charcoal with dust, or their saturation with water, prevents this action, and charcoal that has become wet or foul must be dried or burned in a retort before it becomes again perfect in its action. If charcoal ventilators are so situated as to keep dry and free from dust, they will not require changing or reburning more often than once a year.

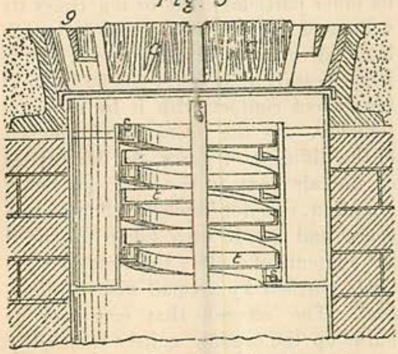
The efficiency of even a small quantity of charcoal will be understood when we remember Liebig's statement, that a cubic inch of beech-wood charcoal contains a surface of interior particles equal to one hundred square feet.

The capital adaptation of charcoal to use in sewer ventilators is further shown by the fact that it absorbs gases contained in or accompanied by the vapor of water (as they always escape from the sewer) much more readily than those which are dry.

All manner of chemicals used for disinfecting sewer gas are objectionable, from their unpleasant odor, their own injurious character the constant attention their use demands, and their expense; nothing has yet been discovered that can at all compare with the simple use of wood charcoal.

Several forms of charcoal ventilators have been devised. The best of them seems to be that of Mr. Baldwin Latham, which is a type of the class, all of which work on essentially the same

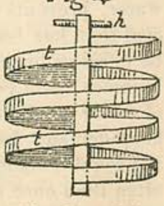
*Fig. 3*



Latham's charcoal ventilator for sewer and man-holes.

principle. It is illustrated in the accompanying diagrams. The central cover, *C*, which is of wood, protects the charcoal from rain or water used in sprinkling the streets; *g* is a grating outside of the closed part, through which the air escapes from the sewer or is drawn into it. Under this grating is a dirt-box surrounding the ventilator and intended to catch dirt falling through the grating. There is an overflow (*S*) arranged to carry to the sewer all water reaching the dirt-boxes. The spiral tray *t* is made of galvanized wire-cloth and is filled with charcoal; it is screwed into the ventilator over the spiral trough *S* by means of the handle *h*.

*Fig. 4*



The charcoal tray for Latham's ventilator.

The arrangement of this disinfector is such that all air escaping from the sewer must pass either through the charcoal or through the spiral passage between layers of charcoal. If the layers become so obstructed by dust that a free passage through them is not afforded for the air, there is still an easy vent through the spiral open spaces. The charcoal is thoroughly protected against dirt and wet, and will remain effective for a long time, and the arrangement is such that there can be no interruption of the working by the accumulations in the dirt-boxes, nor by the overflow of the water escaping from them. The sewer gas is all brought into close contact with charcoal, and has no possible means for escape except through the protected channels intended for it. The spiral tray should be filled with charcoal broken to about the size of marbles, and if care is taken in screening out its finer dust, it will afford a very permeable passage for gas. The dirt-box can be easily taken out and dumped, and readily replaced.

Ventilators should be closer together in the lower and filthier parts of a town than on higher lands or steeper inclines. Mr. Latham thinks that they should never be more than two hundred yards apart. He advises renewing the charcoal once a month. Five hundred and sixty-two sets of his apparatus were used in Croydon. Their total cost, including labor, new charcoal, fuel for reburning, etc., made a charge of less than one dollar and twenty-five cents per annum for each. The charcoal is reburned in iron retorts having small pipes to carry away the escaping gases.

The usefulness of the charcoal ventilators is demonstrated by the fact that in Croydon the written complaints of smells from certain sewers coincided with the absence of the trays (taken out for repairs), and the cause of the complaint was removed by replacing them.

On steep grades, where there would be a tendency for the air of the sewer to be drawn toward the ventilators on the highest land, discharging at this point an amount of gas that should be distributed along the whole street, it is therefore well to place a light hanging valve in front of each outlet into a man-hole. Such a valve will not obstruct the flow of the sewage, while it will prevent the air below from finding its way up the drain, compelling it to escape at its own ventilator.

Where ventilators are used not in connection with man-holes, they should rise, not from the crown of the sewer itself, but from a recess or chamber carried up to the height of a foot or more. Into this recess the sewer air will naturally rise instead of passing on up the line, as it would be likely to do were there only a small ventilator-opening to arrest it.

With a free ventilation through the soil pipes at every house, there is an immense preponderance of area in favor of the vertical escapes, and these are frequently so placed that they become sufficiently heated to create a strong upward current. In a district containing a population of fifty thousand there would probably be ten thousand of these vertical openings, with a combined area equal to from twenty to forty times the area of the sewer at its mouth, so that their action would result more or less generally in the drawing in of air at the street openings; a fact which is sufficiently proved in Croydon, by the accumulation of dust in dry weather in the charcoal-baskets with which the ventilators are furnished. Where the orifice is a continuous exit, — that is, where there is no inward draught of air, — the charcoal remains black in spite of dusty streets.

Concerning the rate of fall necessary for the removal of ordinary road silt from sewers, Adams gives the following table of inclination for pipes of different sizes *running half full;* based on careful calculations and practical trials in connection with the sewerage works of the city of Brooklyn.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| For 6-inch | pipes | a grade | of | 1 | in | 60 |
| " 9 " | " | " | " | 1 | " | 90 |
| " 12 " | " | " | " | 1 | " | 200 |
| " 15 " | " | " | " | 1 | " | 250 |
| " 18 " | " | " | " | 1 | " | 300 |
| " 24 " | " | " | " | 1 | " | 400 |
| " 30 " | " | " | " | 1 | " | 500 |
| " 36 " | " | " | " | 1 | " | 600 |
| " 42 " | " | " | " | 1 | " | 700 |
| " 48 " | " | " | " | 1 | " | 800 |

When the direction changes, the friction is increased, and the fall must be increased to compensate for this.

When the lay of the land permits it, the most rapid fall should be given at the upper end of the sewer, where the quantity of water is least, and where the greatest velocity is consequently needed to secure a cleansing flow.

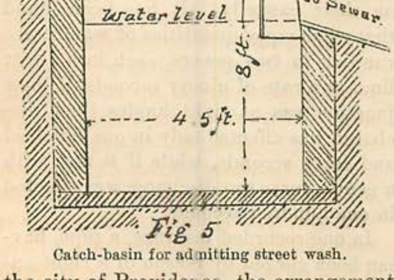
The object of giving an inclination or fall to the sewer is to secure the velocity necessary for the removal of such solid matters as may exist in the sewage, but *if the amount of water flowing is proportionate to the size of the conduit*, sewers of different sizes give the same velocity at different inclinations: for instance, a ten-foot sewer with a fall of two feet per mile, a five-foot sewer with a fall of four feet per mile, a two-foot sewer with a fall of ten feet per mile, and a one-foot sewer with a fall of twenty feet per mile, will have the same velocity, provided they are filled in proportion to their capacity; but the ten-foot sewer will require one hundred times as much sewage as will the one-foot sewer, *and unless it carries a volume of water proportioned to its capacity, the velocity of its stream will be correspondingly lessened.* It becomes, therefore, especially important that the *size of the conduit* be adjusted to the *volume of the stream*, this being as important as the rate of inclination in securing a cleansing flow, and being so little understood that it cannot be too much emphasized in any attempt to bring the mechanism of sewerage works to the notice of the general public.

The character of the junctions of main and tributary sewers has much influence on their capacity. It has been found that when equal quantities of water were running in two sewers, each in a direct line, at a rate of ninety seconds, if their junction was at right angles their discharge was effected only in one hundred and forty seconds, while if it met with a gentle curve the discharge was effected in one hundred seconds.

In one recorded instance, a pipe, having been gorged by reason of a right-angled junction, which kept the velocity of its flow down to one hundred and twenty-two feet per minute, had its flow increased to two hundred and eight feet per minute and the difficulty entirely removed by making the junction on a curve of sixty feet radius. The same objection holds with right-angled junctions falling vertically into the sewer. In this case, as in the other, the inlet should be on a curved line; but vertical junctions are usually objectionable.

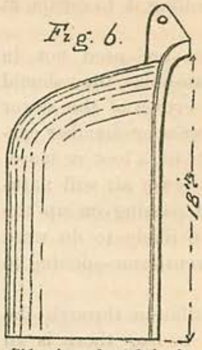
Frequent junctions are of great advantage. Experiment has shown that, with a pipe having a fall of one in sixty, its capacity, with junctions at frequent intervals, is more than three times what it would be if flowing only from a full head at the upper end of the pipe. In sewers of larger sizes the capacity is increased more than eight times.

Various devices have been adopted to secure the admission of surface water from street gutters to the sewer without allowing the escape of sewer gas. These are usually arranged with a deep recess below the outlet for the accumulation of sand and silt washed from the roadway, and with some form of water trap. Their construction in our northern climate should have careful reference to a severe action of the frost, and no plan that has come under my notice seems so well adapted for this as one used by Mr. Shedd, the engineer of the sewerage in



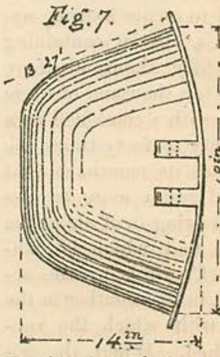

Catch-basin for admitting street wash.

the city of Providence, the arrangement of which is shown in the accompanying diagrams. The trap for sealing the outlet is made of cast-iron, hinged with a copper bolt. It is firmly attached to the side of the basin with cement, and, if disturbed by frost, is simply torn loose from the brick-work, and can be easily cemented to its place in the spring.




Side view of catch-basin trap.

All sewers should be provided with man-holes for ventilation and for service during examination; and pipe drains should have, between the man-holes, and at every point where the vertical or horizontal direction of the sewer is changed, lamp-holes, at the bottom of which lanterns may be suspended which will enable the line to be examined from the nearest man-hole. The removal of all such obstructions accumulating in pipe drains as cannot be washed out by flushing is effected by various instruments attached to jointed rods, like chimney-sweep tools, which serve as handles, enabling them to be used even at a distance of several hundred feet.




Top view of catch-basin trap.

It was formerly supposed that with pipe sewers not too large for the amount of liquid they were to carry, there would be no necessity for flushing, and so far as sedimentary deposits are concerned this is usually true; but a slimy coating often forms on the wall of the pipe and enters into decomposition, generating objectionable sewer gases. For this reason, all pipes used for house-drainage only should be so arranged that they can be occasionally flushed out with a good flow of fresh water; but where rain-fall is admitted from roadways and from the roofs of houses, additional flushing will not generally be needed, except during epidemics, or in dry, hot seasons. At such times there is always a great advantage in frequent flushing, and occasional disinfection.

It cannot be too often reiterated that the great purpose of modern water sewerage is to remove immediately, entirely beyond the occupied portions of a town, all manner of domestic waste and filth before it has time to enter into decomposition; thus preventing an accumulation of dangerous matter, and obviating the necessity for employing men in the unwholesome work of hand-cleansing of cess-pools and of sewers of deposit, *which all sewers are when materially too large for the work they have to perform.*

The public sewer or drain may properly afford an outlet to the land drainage of private property, but before reaching the public drain this should pass through at least two rods of sub-main drain laid under the direction of the public engineer, and trapped as he may direct for the exclusion of silt or refuse. This sub-main should deliver its water into the public drain as nearly as possible in the direction of the flow of the latter, so that the streams may run together without confusion, and the danger from eddies be obviated. Drains from houses and all private establishments should be connected with the sewer under similar official regulation.

It is a frequent practice with engineers to admit house drains at a very low point in the wall of the sewer, where they will ordinarily be entirely submerged. This renders such connections inoperative as a means for ventilating the sewer, and the ventilation of the soil pipes of houses so connected will consequently be of no avail as a part of the public system of ventilation. If the drain has no ingress for air at its lower end, the ventilation of the soil pipe itself will be much less complete; the pent-up gases arising from the decomposition of the contained organic matters may escape, but there will be little of the needed circulation of air in the pipe. With a free sweep of air from below, this decomposition would not take place in a pent-up condition, but would be carried on with a full supply of constantly changing atmosphere. Under these circumstances the ventilation of the street sewer would have to depend upon its street openings alone. In a perfect system these should even play a somewhat secondary part, acting more as a means for the inlet of fresh air to supply the higher ventilators than as a means of escape for the air of the sewer itself.

The question of cost should be taken into very early consideration, and it will not be slight; but *pari passu* there should be a due estimate of the benefits to accrue. These are not of such a character that they can be very readily calculated in dollars and cents, but there are few cases, in towns of five thousand inhabitants and over, where their importance will not be very fully appreciated.

The construction of a proper system of sewerage is at best expensive, but it may be much more cheaply done if taken in hand at once and carried on systematically until the whole is complete, than if done piecemeal, here and there, as property-holders may elect, which is the general custom in America. I do not know that the English method of paying for the cost by distributing principal and interest over a period of years has been adopted with us, but it seems the most just and the least oppressive. It is more fair to posterity, without bearing heavily on the present generation, than payment by interest-bearing bonds to be redeemed twenty or thirty years hence.

Latham, in his inaugural address as President of the Society of Engineers, made a calculation of the cost and value of the water-works and sewerage of the town of Croydon, as follows: —

Cost: purchase of land (for sewage utilization), £50,000; water-works, £70,000; sewers, irrigation works, baths, abattoirs, and general improvements, £75,000. Total, £195,000. The money savings during thirteen years since the completion of the work, he estimates to have been:

2439 funerals, which would have cost £12,195; 60,975 cases of sickness prevented, £60,975; value of the labor for six and one half years of 1317 adult persons whose lives were extended, £166,-930. Total, £240,100. He says, "Although it has been attempted to put a money value on human life, we individually feel that life is priceless, and we may look to the 2439 persons saved from the jaws of death in this single town as the living testimony of the great value of sanitary works."

It is well known to physicians that their chances of success in the treatment of disease are very much reduced with persons living in unhealthy places.

The cost of sewerage works is often made unnecessarily great with the idea that it is the duty of the public to furnish an outlet for factories, slaughter-houses, and all manner of establishments which are carried on for individual profit, and in which the cost of removing the resultant refuse is fairly chargeable on the business rather than on the public purse.

So far as the community is concerned, it should be compelled to construct sewers only for the removal of such waste matters as are incident to the daily life of all classes of the population. If breweries, chemical works, and other manufactories producing a large amount of liquid waste, are to be provided with a means of outlet, this should be done entirely at their own charge; their profit and convenience should not be advanced at the cost of every member of the community. And more than this, the wastes of factories being often pernicious, not only on reaching the outlet of the sewer, but by the generation of gases within them which may pervade all their ramifications, it is a serious question whether such establishments should not be compelled to secure independent outlets at their own expense, or at least to render their wastes innoxious before discharging them into the public drain; paying even then an extra sewer-rate proportionate to the extra service they require.

The sanitary authority of every town should have entire control over the sewers, with power to decide what shall be admitted to them and what excluded, and to levy an additional tax in all cases where an undue use is made of the public convenience.

In the limited space of a magazine article it would be out of place to go very largely into the question of the economical use of the organic wastes of the house or town. The utilitarian question, important though it is, is but secondary. At the same time, as an accessory, the matter of economy is very important, and in every *perfect* system of sanitary improvement the arrangements must be such that there shall be a complete utilization of all the valuable constituents of the wastes of domestic life; and practically our arrangements should be so nearly perfect that nothing shall be lost that can be economically saved.

In our climate, sewage irrigation cannot be carried on in winter, but it may be made very useful during the growing (and sickly) season.

In sewage irrigation the amount of land appropriated should not be less than one acre to one hundred and fifty of population, and should lie not more than a mile from the town. The same land should not receive sewage two days in succession, and each area should have occasional periods of rest for a whole growing season.

If the land is of a very retentive character, even if well underdrained, it would be better to allow an acre to one hundred of population.

Bailey Denton objects to the disposal of large volumes of sewage by sub-irrigation, but where the ground is covered with vegetation, and where the flow is evenly and intermittently distributed in that part of the soil occupied by roots, especially if not in too close proximity to wells, it must be, under many circumstances, the best system.

Under favorable conditions, the utilization of the manurial matter contained in sewers is more easy by the system of irrigation than by any other in general use.

Where the earth-closet is used, and

where there is no system of sewers for the removal of liquid wastes, some provision must necessarily be made for disposing of slop water before it can generate dangerous products of decomposition. This may be best effected in many cases by the use of some device like Field's flush tank (described in the preceding paper), in connection with the subirrigation of the lawn or garden.

The "general conclusions" of the English Board of Health, after a thorough investigation of the whole subject of sewerage, were as follows: —

1. That no population living amidst aerial impurities arising from putrid emanations from cess-pools, drains, or sewers of deposit, can be healthy or free from attacks of devastating epidemics.

2. That as a primary condition to salubrity no ordure or refuse can be permitted to remain beneath or near habitations, and by no other means can remedial operations be so conveniently, economically, inoffensively, and quickly effected as by the removal of all such refuse dissolved or suspended in water.

3. That the general use of large brick sewers has resulted from ignorance or neglect; such sewers being wasteful in construction and repair, and costly through inefficient efforts to keep them free from deposits.

4. That brick and stone house drains are "false in principle and wasteful in the cleansing, construction, and repair. . . . That house drains and sewers, properly constructed of vitrified pipe, detain and accumulate no deposit, emit no offensive smells, and require no additional supplies of water to keep them clear."

5. That an artificial fall may be cheaply and economically obtained by steam pumping, and that the cost of the whole system to each house is much less than the cost to that house of removing its refuse by hand.

6. All offensive smells proceeding from any works intended for house or town drainage indicate the fact of the detention and decomposition of ordure, and afford decisive evidence of malconstruction or of ignorant or defective arrangement.

*George E. Waring, Jr.*

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## RODERICK HUDSON.

### XI.

#### MRS. HUDSON.

Of Roderick, meanwhile, Rowland saw nothing; but he immediately went to Mrs. Hudson and assured her that her son was in even exceptionally good health and spirits. After this he called again on the two ladies from Northampton, but, as Roderick's absence continued, he was able neither to furnish nor to obtain much comfort. Miss Garland's apprehensive face seemed to him an image of his own state of mind. He was profoundly depressed; he felt that there was a storm in the air, and he wished it would come, without more delay, and perform its ravages. On the afternoon of the third day he went into Saint Peter's, his frequent resort whenever the outer world was disagreeable. From a heart-ache to a Roman rain there were few importunate pains the great church did not help him to forget. He had wandered there for half an hour, when he came upon a short figure, lurking in the shadow of one of the great piers. He saw it was that of an artist, hastily transferring to his sketch-book a memento of some fleeting variation in the scenery of the basilica; and in a moment he perceived that the artist was little Sam Singleton.