SECTION II.

ENGINEERING AND SANITARY CONSTRUCTION.

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The President of the Section, Captain Douglas Galton, C.B., delivered the following Address:—

The President of the Congress, Dr. Richardson, has explained to you in his lucid address that the life of man on this globe might reasonably be expected to extend far beyond that to which he now ordinarily attains, provided he were removed from all the conditions unfavourable to long life which encompass him. Of these conditions some are hereditary, some arise from habits and are personal to the individual.

But there is another large class of conditions which are the direct result of the circumstances to which man is exposed in consequence of living in communities.

All living beings are in a continual condition of change, which results in their throwing off from the body matters which poison earth, air and water, unless space, time and opportunity are afforded for the counteraction of these deleterious effects.

Epidemic diseases are observed to occur in very different degrees of intensity at different periods, amongst groups of population exposed to certain unhealthy conditions. Sometimes they take the form of pestilences, and immediately afterwards, the conditions remaining the same, they subside and all but disappear, again to renew their ravages at some future period.

A careful examination of their phenomena has led to the discovery that whilst we have no knowledge of the causes which made these epidemics break out at one time and not at another, there are certain well-defined conditions which influence most materially not only their actual intensity, but also their frequency.

Thus, intermittent fever was observed to disappear from places which it formerly ravaged, after drainage of the soil and improved cultivation.

It was next discovered that by cleanliness, fresh air, and diminished crowding the worst forms of pestilential fever, which used to commit ravages similar to those of the plague, disappeared entirely from English gaols.

The breathing of foul air contaminated by the breath of other persons appears to be the special agent which predisposes people to consumption and diseases of that class.

Zymotic diseases, namely, fevers, diarrhœa, cholera, dysentery, &c. are most intensely active where there is overcrowding, and the repeated breathing of air already breathed, such air being further contaminated by moisture and exhalations from the skin; and where there are emanations proceeding from animal excretions, or from decaying vegetable matter, together with moisture, from the want of drainage from urinals, cesspits, and manure heaps. Moreover, cholera and dysentery are intimately connected with the condition of the water supply; while an epidemic prevails, the question whether a given population shall suffer or escape may almost be predicted from a chemical analysis of the drinking water.

It is to the physiologist and the chemist that we must look for the causes from which these baneful effects arise, and what are the conditions which should be altered to prevent or remove them.

The engineer steps in after these causes have been pointed out, and it is for him to design the methods of prevention or removal.

Five hundred years ago the population of the whole kingdom was only equal to the present population of the metropolis. When the first recorded census was taken in 1801, the population of England and Wales was less than 9,000,000; it has now reached nearly 25,000,000. We are crowded together as we never were crowded before; our pursuits are more sedentary, our habits more luxurious; houses increase in number, land is more valuable, the green fields more remote; our children are reared among bricks and paving-stones. It is daily becoming more and more impossible in the question of health for any one member of a community to separate his interest from that of his neighbours. If he places his house away from others the air which he breathes may receive contamination from the neighbouring district; the dirty water which he throws away may pollute the stream from which his neighbours draw their supply; and when a population congregates into towns the influence of the proceedings of each individual on his neighbour becomes strongly apparent.

In places where many dwellings are congregated together, the requirements for health may be classed as—first, those that are common to the community, such as the supply of good water, the removal of foul water, and the removal of refuse matter; and secondly, those which immediately concern the individual householder, such as the condition of his house and the circumstances of its occupation.

But the existence of some danger to health in houses in towns or villages may be a source of danger to the houses around. In my own case, illness was caused by my next-door neighbour having a defective soil-pipe, the sewer-gas from which passed through the wall. This was a danger from which perfect drainage in my house afforded no protection.

On these and similar grounds, it is the interest of every person in a community that every other member of the community should live under conditions favourable to health.

Each year as the population increases and as dwellings multiply, so does the importance of promoting these conditions increase; and so long as preventable diseases exist throughout the country, we must not delude ourselves with the idea that we have done more than touch the borders of Sanitary improvement.

There are few subjects in which so many professions of progress have been made in the last few years as in the theoretical knowledge of how to provide a healthy dwelling and a healthy town.

Books innumerable have been written upon the question. Physiologists have invented every conceivable theory; patentees have invented every conceivable description of apparatus; engineers, architects, and builders overwhelm you with professions of their knowledge of Sanitary principles, and millions of money have been spent in furthering the schemes they have devised; and yet, in spite of all these efforts, there are very few houses and very few towns where you would not easily detect some grievous Sanitary blunders.

I believe this to be due, in the first place, to the fact that the majority of men prefer anything to thinking for themselves. They like to obtain their knowledge as they do their hats—from a shop, ready-made. They will accept theories laid down by some one else rather than laboriously collect the facts and reason carefully upon them. The result has been that money has sometimes been expended upon theoretical suggestions which have later proved to be fallacies; the money has been wasted, and then discouragement has followed. There is perhaps no branch of public work in which onesidedness has done more mischief than in measures for so-called improvement of public health. If expenditure had only taken place on observed facts and experience, we should be now standing in a more advanced position than we at present occupy.

In the second place, the Sanitary education of the country has not been brought into a system. People seem to have thought that Sanitary knowledge could be picked up anyhow. Important questions of drainage, of water supply, of ventilation, have in many instances been committed to persons who had a good education in general architectural or engineering knowledge, in the nature and use of materials, and other such matters, but who had never received any special training in the Sanitary side of engineering. Yet the problems which the Sanitary engineer and architect are called on to solve require for their solution a knowledge of the higher branches of physics, chemistry, geology, meteorology, and kindred sciences, and entail as close habits of observation as any other branch of the engineering profession.

In the third place, it has always seemed to me that the system under which the Government advances money for Sanitary works, whilst of great *primâ facie* advantage in one point of view, yet has its disadvantageous aspect.

The facility with which Corporations and Local Boards have been enabled to borrow money at a low rate of interest has no doubt had the effect of inducing a more immediate expenditure for Sanitary works than would have taken place without this aid.

But the expenditure has not, in all cases, been so carefully considered beforehand as would probably have been the case if the towns had been left to raise the money without Government aid.

The result has been that much money has sometimes been spent where it has been subsequently seen that less money, carefully and judiciously applied, would have sufficed.

There has also been in the system of loans to towns a tutelage by the Government, which diminishes responsibility.

Where a loan is applied for, the plan upon which the money is to be spent is submitted for Government approval. The Government only lends the money after the approval of the proposed scheme of expenditure by one of their inspectors.

The Local Authorities of the towns to be drained cannot therefore be responsible for the plan selected; for the Local Authorities must alter their plans to suit the views of the inspector. The responsibility of the engineer is diminished, because he may be compelled to modify his plan in a manner of which he may not

thoroughly approve; and the inspector has no responsibility in the matter, because, after having approved of the general scheme, he has no control over the details or the execution of the work, nor can he be in any way held responsible if the result were a failure.

Indeed, after the money has been once borrowed, there is no certainty that it need be spent in accordance with the plans. I have heard a rumour that, in one instance at least, a scheme has been approved, the money has been borrowed, and never spent at all on the work on account of which it was borrowed.

Nor is there any apparent reason why the Government should have come forward to press money upon the Corporations.

The plan adopted by the Government in former times for promoting land drainage would have answered equally well in the case of sewerage works.

The Government commenced by assisting landowners, with loans granted on the security of their estates, the money being expended on a system of drainage approved by the Government inspector. But when the system had been initiated, private enterprise was allowed to take its place, and companies were formed who advanced the money and employed leading engineers to advise upon its expenditure; and the intervention of the Government was no longer necessary.

A similiar course of proceeding would have been applicable in the case of town drainage. If the Government, instead of becoming themselves money-lenders on so large a scale, and thus constituting their inspectors the sole advisers on matters of drainage, had passed an Act of Parliament enabling any town to borrow an amount of money, bearing a due proportion to the rateable value of the town, a sound security would have been created; and if large companies had taken upon themselves the function of lending to towns under a system similar to that in force for land drainage, viz., of satisfying themselves, through the advice of a leading engineer, of the probable efficiency of the plans for which money was advanced, a greater scope would have been afforded for progress in Sanitary Science. Indeed, I cannot but think that we should have reached a higher level of Sanitary improvement in this country than now prevails, if the Government had limited itself to its more legitimate functions, viz., first, the enactment of laws requiring Sanitary defects to be removed; and second, the promotion of measures for diffusing a sound education in Sanitary knowledge; instead of pursuing the course of endeavouring to dictate the exact measures to be followed in each case.

But it may be asked, What is Sanitary knowledge? It is frequently assumed that drainage and water-supply are the principal subjects which are embraced in the term; but these only make up a small part of the subject.

At the present time there does not exist any treatise which brings to a focus the various problems of mechanical and physical science, upon which Sanitary knowledge is based. The variety of these problems will be best illustrated by a few instances.

A sanitarian tells us that health depends on pure air and pure water. If a site is to be selected, it requires a consideration of its position with respect to its surroundings. It requires a knowledge of the temperature of the air and of the soil; what are the prevailing winds; what is the amount and incidence of the rainfall; and what is the percolative capacity of the soil.

The engineer cannot interfere with the general conditions of a climate, but he may produce important changes in the immediate surroundings of a locality; he may modify the condition and temperature of the soil; he may control atmospheric damp; he may arrange for the rapid removal of rainfall, or he may cause the rainfall to be retained in the soil, to be given out gradually in springs, instead of passing away in torrents to flood the neighbouring districts.

In the Island of Ascension, the power of retention of water in the soil exercised by the planting of trees was exemplified. That island formed a convenient point for ships to call at for obtaining water on their way home from the East Indies. It was a barren rock, to which formerly the water had to be conveyed in ships. About fifty years ago trees were planted on the island. These have thriven, and now the rain which falls, instead of passing away at once into the atmosphere by evaporation, is retained in a sufficient quantity to enable the water to be collected for the supply of the ships which call at the island.

The engineer may modify the incidence of disease. Algeria, perhaps, offers some of the best illustrations of the manner in which engineering operations have remedied the evils of the proximity of marshes. Bona stands on a hill overlooking the sea; a plain of a deep rich vegetable soil extends southwards from it, but little raised above the sea level. The plain receives not only the rainfall which falls on its surface, but the water from adjacent mountains, and is consequently saturated with wet. The population living on and near this plain suffered intensely from fever: entire regiments were destroyed by death and disease. It was at last determined to drain

the plain. The result of this work was an immediate reduction of the sick and death-rate.

Fondouc, in Algeria, is situated on sloping ground, immediately above the marshy plain of the Mitidja; mountain ranges rise immediately behind it. It was first occupied in 1844, and in the succeeding year half the population was swept away by fevers and dysentery. During the first twenty years the mortality was 10 per cent. The surrounding marsh has since been drained and cultivated, and the mortality now is 20 per 1000.

Similar instances may be quoted from our own possessions in India.

In the northern Doab districts in the north-west provinces of India the excessive fever mortality for which these districts were noted has been mitigated by extensive drainage works, by means of which the water which formerly stagnated in the land is now led away by continuously flowing streams.

When a site has been selected, it is necessary to consider the question of the subsoil.

The air does not cease where the ground begins, but air permeates the ground and occupies every space not filled by solid matter or by water. Thus, it is the same thing to build on a dry gravelly soil, where the interstices between the stones are naturally somewhat large, as to build over a stratum of air. The air moves in and out of the soil in proportion to barometric pressure, and with reference to the wind. If there is much water in the soil, the air carries with it watery vapours, and is cold, and such a site is called damp.

A site with a high water level is, as a rule, more unhealthy than a site with a low water level; but a site with a fluctuating water level is most unhealthy. The Sanitary engineer can control the water level in the soil, or construct works to remedy the evils of a wet site.

There is also a considerable quantity of carbonic acid in the soil. It varies at different depths; it has been found to vary greatly even in localities in close proximity. The processes going on in the soil in these several places are therefore probably very different. Each will have its influence on the ground air. One evil arising from a foul subsoil is very apparent. In cold weather the temperature of a house is warmer than that of the outer air. If a house is built on soil containing deleterious matters, the impure air will be drawn into the house by the action of the warm air of the house. The Sanitary constructor takes measures to check the passage of air between the house and the ground under and around it. The fact of this continual free passage of air in and out of the ground makes it important that not only should the ground lived on be free from water, but that it should also be free from impurities. It would be just as healthy (indeed, probably far healthier) to live over a pigsty than over a site in which refuse has been buried, or in which sewer water has penetrated, or over a soil filled with decaying organic matter; thus, before building on any ground, its nature should be carefully examined.

What then can be more dangerous, what more wicked, than the everyday proceedings, in the metropolis and elsewhere, of those persons who purchase a building site, who extract from it the healthy clean gravel and sand which it contains, allow the hole to be filled up with rubbish, and then proceed to build upon it?

When the site has been selected, the Sanitary architect has to consider how he will distribute buildings over it. The deteriorating effect of residence in towns has been frequently noticed.

The Registrar-General has shown that a population of 12,892,982 persons living on 3,183,965 acres in the districts comprising the chief towns of England, showed an average death-rate for ten years of 24·4 per 1000; whilst a population of 9,819,284 living on 34,135,256 acres in districts comprising small towns and country parishes showed an average death-rate for a similar period of 19·4 per 1000.

It has been calculated that of the adult population of London 53 per cent., of that of Birmingham 49 per cent., of that of Manchester 50 per cent., and of Liverpool 62 per cent., were immigrants from the country settled in the town, and that the majority of the incomers were men and women in the prime of life.

The mortality in these four towns averaged 26 per 1000 against 19 per 1000 in the adjacent country districts; the mortality of persons under the age of 15 being 40·7 per 1000 in these towns against 22 per 1000 in the country districts.

The marriages in the city population were four times as numerous as in the agricultural counties, but the births in the town population only exceeded those in the agricultural population by one-sixth.

When we consider the causes of low health in towns, it becomes apparent that the extraordinary degree of unhealthiness is unnecessary.

It will be found to result from absence of circulation of air through and between buildings, and from the retention near or in

houses, and in streets, of much polluting matter. The following figures illustrate this :—

St. Anne's, Soho,	with 331	inhabitants	per acre,	shows a death-rate of	24·16	per 1000.
Eltham,	„ 1·04	do.	do.	do.	18·8	do.
The Model Lodging-Houses, with .	860	do.	do.	do.	16·	do.
Do. do.	1140	do.	do.	do.	18·	do.

Thus some of the model lodging-houses are as healthy as a country district.

The superior healthiness of the model lodging-houses is due in a measure to the careful provision of Sanitary arrangements, but principally to the fact that the numerous stories in these buildings, whilst affording accommodation for a dense population on a limited area, are provided with free through ventilation, and allow of ample space all around for the circulation of air, as well as to the fact that impurities are not allowed to be retained on the open area around them.

The health of any building is dependent upon free and moving pure air, outside and inside its walls; anything which interferes with this first condition of health is injurious. And it follows that in towns, where land is dear and a large number of persons are crowded on a given area, better ventilation and circulation of air may be obtained by placing dwellings in stories one above the other, and leaving spaces between the buildings, than by placing them in one-storied buildings which would be too close together to allow of circulation of air round the building.

The next step in knowledge of Sanitary construction is to learn how to obtain pure air in a building. What is pure air? Where are the impurities which make the air of a town so different from the fresh air of the country? The volume of sulphuric acid from coal thrown up by our fires into London air is enormous. A cubic yard of London air has been found to contain 19 grains of sulphurous acid. The street dust and mud is full of ammonia from horse-dung. The gases from the sewers pour into the town air.

Our civilization compels us to live in houses, and to maintain a temperature different from that out of doors. What are the conditions as to change under which we exist out of doors?

The movement of the air is stated in the Registrar-General's reports to be about 12 miles an hour on an average or rather more than 17 feet per second. It will rarely be much below 6 feet per second.

Imagine a frame about the height and width of a human body, measuring about 6 feet by $1\frac{1}{2}$, or 9 square feet: multiplying this by the velocity of movement of the air at 6 feet a second, it will appear that in one second 54 cubic feet, in one minute 3240 cubic feet, in one hour 196,400 cubic feet of air would flow over one person in the open.

In a room the conditions are very different. In barracks, in a temperate climate, 600 cubic feet is the space allotted by regulation to each soldier; and when in hospital from 1000 to 2500 cubic feet to each patient.

If it were desired to supply in a room a volume of fresh air comparable with that supplied out of doors, it would be necessary to change the air of the room from once to five times in every minute, but this would be a practical impossibility; and, even if it were possible, would entail conditions very disagreeable to the occupants.

Hence, to maintain the comfort and temperature we desire indoors, we sacrifice purity of air. Therefore, however impure the outer air is, that of our houses is less pure; and it may be accepted as an axiom that by the best ventilating arrangements we can only get air of a certain standard of impurity, and that any ventilating arrangements are only makeshifts to assist in remedying the evils to which we are exposed from the necessity of obtaining an atmosphere in our houses different in temperature from that of the outer air.

On the other hand, why should we not do our best to obtain as pure air as we can? It has been recently shown that the soot and many deleterious matters from smoke may be easily removed by passing the smoke through spray on its way to the chimney. This would remove much impurity from town air; but until such a system of purifying town air is adopted, we can improve the air in our houses by removing the suspended matter from the inflowing air by filtration. Moreover, these suspended matters exist in much smaller quantities at an altitude; at 100 feet they are greatly diminished, at 300 feet the air is comparatively pure. In Paris the air for the Legislative Assembly is drawn down from a height of 180 feet, so as to be taken from a point above many of the impurities of the town atmosphere. That is a reasonable and sensible arrangement, and might be usefully adopted in public buildings in towns. In the Houses of Parliament, the so-called fresh air is taken from courtyards on the street level, from which horse traffic is not excluded.

The maintenance of the standard of purity, or rather impurity, in a building, depends on ventilating arrangements. Ventilation

chiefly depends on the laws which govern the movement of air, its dilatation by heat or contraction by cold; or, if ventilation is effected by pumps and fans, then upon the laws of the motion of air in channels, the friction they entail, and similar questions; therefore all these are matters for careful study.

But when we apply the study to practice, other considerations occur. We are told by theory that a room containing an air space of 1000 cubic feet, occupied by one individual, would require to be supplied with 3000 cubic feet per hour, in order to maintain it in a proper condition of purity and humidity. But in our temperate climate, a careful practical examination of the condition of barrack-rooms and hospitals, judged of by the test of smell, showed that arrangements which appear to provide for a volume of air much less in amount than that obtained by calculation will keep the room in a fair condition.

These results have pointed to about 1200 cubic feet of air admitted per man per hour in barrack-rooms occupied by persons in health.

This need not be set down to errors in calculation or in theory.

There are many data which cannot be brought into the theoretical calculation. For instance, the carbonic acid disappears in a newly plastered or lime-washed room, and could be recovered from the lime, therefore a newly cleaned, lime-whited room will present different conditions from a long-occupied, dirty room. Washing with quicklime destroys fungi in dirty walls; the same effect is produced by sulphurous acid fumigation. Air has the same property, especially dry air; and hence, opening windows, turning down beds, and all such measures, act directly on the subsequent state of the air. Therefore an enormous effect is produced on all the elements of the above calculation if the windows of a room are kept open for several hours a day, instead of being closed.

Besides this, the conditions under which the air flows in and out of a room are so varied. The walls and ceiling themselves allow of a considerable passage of air.

The ceiling affords a ready instance of porosity. An old ceiling, it will be observed, is blackened where the plaster has nothing over it to check the passage of air, whilst under the joists, where the air has not passed so freely, it is less black. On breaking the plaster, it will be found that its blackness has arisen from its having acted like a filter, and retained the smoky particles, while the air passed through.

Ill-fitting doors and windows allow of the passage of a considerable quantity of air.

In a temperate climate, where the changes of temperature of the outer air are rapid and considerable, these means of producing the outflow from and the inflow of air into a confined space are in constant operation. A sleeping-room is very warm when occupied at night, a rapid fall of temperature outside occurs, and at once a considerable movement of air takes place.

It may be summed up that, whatever the cubic space, the air in a confined space occupied by living beings may be assumed to attain a permanent degree of purity, or rather impurity, theoretically dependent upon the rate at which emanations are given out by the breathing and other exhalations of the occupants, and upon the rate at which fresh air is admitted, and that, therefore, the same supply of air will equally well ventilate any space, but the larger the cubic space the longer it will be before the air in it attains its permanent condition of impurity. Moreover, the larger the cubic space, the more easily will the supply of fresh air be brought in without altering the temperature, and without causing injurious draughts. One of the chief difficulties of ventilation arises from the draughts occasioned thereby. Everyone approves of ventilation in theory, but practically no one likes to perceive any movement of air.

These conditions point to the care which should be exercised in the form of rooms, the position of windows, doors, fireplaces, and other matters. We should study how the currents of air move in a room: what is the effect of the form of room on the circulation of these currents of air; for instance, a lofty room with the tops of windows some distance below the ceiling, and without outlets for air at the ceiling level, becomes dangerous, unless a constant circulation of air goes on, because the heated air, loaded with impurities, ascends, stagnates in the space near the ceiling, cools, and falls down, and re-mixes with the air in the lower part of the room, and thus increases in impurity.

These effects are modified by anything which causes circulation of the air. The open fireplace creates circulation of air in a room, with closed doors and windows. The air is drawn along the floor towards the grate; it is then warmed by the heat which pervades all objects near the fire, and part is carried up the chimney with the smoke, whilst the remainder, partly in consequence of the warmth it has acquired from the fire, and partly owing to the impetus created in its movement towards the fire, flows upwards towards the ceiling near the chimney breast. It passes along the ceiling, and, as it cools in its progress towards the opposite wall, descends to the floor, to be again drawn towards the fireplace.

Thus the open fire, whilst continually removing a certain quantity of air from the room, which must be replaced by fresh air, causes an efficient circulation of the air remaining in the room.

Moreover, a room warmed by an open fire is pleasanter than a room warmed by hot-water pipes.

A warm body radiates heat to a colder body near to it. The heat rays from a flame or from incandescent matter pass through the air without heating it; they warm the solid bodies upon which they impinge, and these warm the air.

Where the source of heat in a room consists of hot-water pipes, or low-pressure steam pipes, the air is first warmed, and imparts its heat to the walls. The air is thus warmer than the walls. When a room is warmed by an open fire, on the other hand, the warming is effected by the radiant heat from the fire, which passes through the air without sensibly warming it; the radiant heat warms the walls and furniture, and these impart their heat to the air. Therefore the walls in this case are warmer than the air. Consequently, in two rooms, one warmed by an open fire, and the other by hot-water pipes, and with air at the same temperature in both rooms, the walls in the room heated by hot-water pipes would be some degrees colder than the air in the room, and therefore colder than the walls of a room heated by an open fire; and these colder walls would therefore abstract heat from the occupants by radiation more rapidly than would be the case in the room heated by an open fire. And to bring the walls in the room heated with hot-water pipes to the same temperature as the walls in the rooms heated by the open fire would require the air of the room to be heated to an amount beyond that necessary for comfort, and therefore to a greater amount than is desirable. Moreover, warmed air contains less oxygen than cooler air, and as sick persons are more sensitive to such influences than persons in health, these may be the reasons why, in hospital wards, the warming by means of an open fire has been always preferred to warming by hot air or hot-water pipes.

With complicated buildings, such as theatres, legislative assemblies, prisons, &c., the problems of ventilation are more difficult and intricate, but all are based on the same principles of the movement of air.

Another group of questions relating to Sanitary construction are: What are the best materials for the house, and the best distribution of those materials? How can the less pure air from the ground be prevented from entering the house through the basement? What is the effect of the porosity of materials on the health of the inmates of a house? What is the law which regulates the loss of heat through walls and windows, skylights and roofs? For instance, if we assume that the loss of heat through a wall nine inches—*i.e.* one brick—thick, with a temperature inside the room two degrees above that outside, would be one unit for a given area of surface of wall, the loss of heat through a wall built of two half bricks—*i.e.* four-and-a-half inches—on each side of a central air space, would be two-thirds of the loss of the solid wall. Similarly the loss of heat through a double window would be about three-fifths of that through a single window. The laws which govern these questions are as complicated as those which govern the strength of materials, or the flow of water, and they form the alphabet of Sanitary building.

Whilst, however, I have limited myself to speaking of a theoretical knowledge, it is of essential importance that the Sanitary architect, builder, or engineer should have also practical technical knowledge of the subject. He should know what constitutes a good material and good workmanship.

One instance of the Sanitary importance of the quality of materials will suffice here. Dust and impurities adhere less to glass of a good quality than to glass of a bad quality, because the surface of the latter becomes rough much more rapidly than the surface of glass of good quality.

But there is one branch of work connected with water supply and drainage in which practical knowledge is especially necessary, and which has not been so prominently considered as it should be. I mean the details of the plumber's work, and the work connected with house drains. However well you may design your house drains, the whole of your design may be rendered nugatory by apparently trifling mistakes or carelessness in the details. Your trap may be excellent, but the junction with the pipe may be faulty. It is easy to conceal a bad joint; it is long before the defects in a badly-laid drain will become apparent if the drain is buried underground. Therefore, it is not only the officers of the army of Sanitary constructors who require knowledge and education, but the foremen and the labourers, each in his own degree.

I have thus specially called attention to these points of Sanitary construction, because they are not in general sufficiently dwelt upon; and the popular idea seems often to be that Sanitary engineering means drainage and water supply alone. I would not derogate from the enormous importance of these matters; but public attention has been so largely directed to water supply and drainage—especially here at Croydon, where your eminent townsman, Mr. Baldwin Latham, has done so much, and there are such eminent Sanitarians as vice-presidents of this section, Mr. Grantham, Mr. Bailey Denton, Mr. Rogers Field, and others—that I should only repeat what has been said, much better than I could say it, by many before, if I continued my *résumé* of what makes up Sanitary knowledge by saying much upon those branches of the subject.

I cannot refrain, however, from offering a few remaks upon these subjects, which at the present time necessarily fill the public mind.

We derive our whole water supply from the rainfall. If it falls on an impervious surface, it runs off in rivers above ground; if it falls on a pervious surface, it runs off underground in rivers whose direction of flow will depend on the geological formation. However much our population may grow, we cannot therefore increase our supply; but we may store it and utilize it if we obtain a knowledge of where it falls and where it flows to. It is thus the function of the Sanitary engineer to trace the course of these water supplies. But rain does not fall equally over the whole country. On the contrary, as has been so well shown by Mr. Symons, there is in some localities in England an enormous surplus, and in other localities a bare supply, and the incidence of these supplies has no reference to the spread of population over the country; thus it requires something beyond local organization to arrange for a distribution of the supply in accordance with the relative wants of the country. It is on these grounds essentially the duty of the Government to take up this question.

The Government have taken into their hands the more theoretical question as to when storms may be expected; but they have not taken in hand the question which has an enormously greater practical importance, viz., that of watching over our water supplies, although it is on the careful use of these that the health of the whole country depends. The first step towards obtaining a clear understanding of the question is to bring all the information on this subject to a focus. At the present time there are certain important public departments, the information collected by which bears materially on the Sanitary condition of the country; and yet these departments are scattered about indiscriminately, as if with the intention of preventing the information they already possess, and could so easily add to, from being brought to any useful focus.

The departments to which I allude are—

1st. The Ordnance Survey, which is under the First Commissioner of Works, probably of all departments of the Government the one least qualified to administer it usefully. The Ordnance Survey was originally undertaken on the one-inch scale for military purposes. The military map has long been complete. A survey was, however, commenced on an enlarged scale many years ago, which affords an admirable map for Sanitary purposes. But the progress is so slow, that a large portion of England remains unmapped, except on the old one-inch scale.

2nd. The Geological Survey, which is under the Privy Council, and whose progress also is very slow.

3rd. The Registrar-General's Department, which is attached to the Local Government Board.

4th. The Meteorological Office, which is under the Board of Trade.

The first step is to bring these departments under one general head, so that the information they can severally afford may be properly correlated. The Local Government Board would seem to be the department under which they would most naturally fall; and a department should be added for registering the distribution of rainfall over the British Isles on the plan initiated by the enterprize of Mr. Symons.

By means of this machinery the information bearing on the water supplies of the country, which is in existence, could be easily collected and made available, and the Government and Parliament would then be in a more favourable position for considering the necessity and, if such necessity exists, the means, of enabling the districts furnished with a copious water supply to assist the less favoured districts.

On the question of sewage, time would not allow me to enter; it is sufficient to say that this must remain always a problem for the Sanitary engineer, because no one system of sewage could be adopted universally; the peculiarities of different localities require different methods of treatment.

Where land at a reasonable price can be procured, with favourable natural gradients, with soil of a suitable quality and in a sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage.

In the case of towns, where land is not readily obtained at a moderate price, some of the processes, based upon subsidence, precipitation, or filtration, produce a sufficiently purified effluent for discharge, without injurious result, into watercourses and rivers, provided the volume of water into which it is discharged is of sufficient magnitude to effect a considerable dilution. But, as a rule, no profit can be derived at present from sewerage utilization.

With dry systems, where collection at short intervals is properly carried out, the result, as regards health, appears to be satisfactory.

For health's sake, without consideration of commercial profit, sewage and excreta must be got rid of at any cost.

My object in this *résumé* has been to endeavour to show how extensive is the field of knowledge which has to be traversed by those who undertake the duty of building healthy houses, and of watching over the arrangements for securing the health of towns.

The researches of the physiologist and the medical man into the laws which govern the prevalence of diseases have enabled them by the accumulation of information to lay down the principles upon which healthy construction should rest; it is the duty of the architect, the builder, the engineer, and the surveyor to apply these principles; and their correct application is as essential to the efficient construction of a dwelling as is the quality or strength of materials which are used.

The acquisition of Sanitary knowledge covers a vast area of ground, and requires special study.

The universities of Oxford, Cambridge, and London, instituted examinations in public health, but with little success; few candidates came forward, and indeed no candidates offered themselves for Oxford and London at the last examination. The reason is obvious. It is, in the first place, not sufficiently understood by the community that the Sanitary architect, builder, or engineer requires special knowledge. But if it were understood, there is, at the present time, no place or institution where this knowledge can be acquired.

The universities have instituted no chairs of Sanitary instruction. It is not taught in schools. But until some means of obtaining the education can be afforded, it is of little avail to establish examinations, or offer to give degrees.

The Sanitary Institute, whose *raison d'être* is to promote Sanitary progress, has from the first recognized the importance of developing Sanitary education, and has now decided to come forward as its champion. With this object the Sanitary Institute proposes to organize a course of lectures to be delivered, in the practical branches of this question, during the coming winter, and in this effort they are about to make for the public good the Council trust that they will receive the support of all those interested in Sanitary progress.

There is, however, a further step required in order to produce throughout the country a due recognition of the importance of Sanitary knowledge, and this step should be at once taken. The Medical Officers of Health, who are the advisers of the local authorities on questions connected with public health, have obtained a title to their position in the medical profession by virtue of certificates from qualified Boards of Examiners. But local surveyors, whose duty it is to advise local authorities on matters of Sanitary construction, are not required to produce any such certificate of qualification. In many instances, local surveyors, who should be the guides of the people in Sanitary matters, do not sufficiently appreciate the subject on which they should advise. If steady and continuous progress is to be made in Sanitary construction throughout the country, it is essential that the surveyors should receive a sound education on this special part of their profession.

The summary of the conclusions to which I would lead you in this address are, therefore—

1. That endeavours should be made to cause the adoption in educational establishments of courses of systematic education in Sanitary Science for those who undertake the business of Sanitary construction.

2. That no person should be appointed to the office of surveyor of a Local Board or Corporation without a certificate, from some duly qualified educational institution, of proficiency in practical Sanitary Science.

DOUGLAS GALTON, HON. D.C.L., F.R.S.,
President of Section.

Remarks on Certain Points in the Work of the Engineer which have a Direct Bearing on Public Health.

FOR some time past, I have been strongly impressed with the advantage to be gained from authoritative determination of certain points in Sanitary engineering, which would be accepted as conclusive by the country at large. I have been brought to this conclusion from finding that there still prevails a hesitation to adopt what the majority of experienced Sanitary engineers and medical authorities consider settled, and that this hesitation is not confined to local boards and local surveyors, but extends to influential persons whose opinions greatly prejudice the permanent character of works.

It can be well understood why the present Local Government Board, as the central authority, should refrain from imposing positive rules to override the judgments of independent engineers and local surveyors, for the experience gained since the Public Health Act of 1848 has brought home to all engineers alike the fact that the dicta then pronounced as fixed have led to conflicting results, and have deterred people from accepting as final certain principles and views which the experience gained since 1848 would long ago have established.

There are many points, indeed, upon which it is most desirable for the nation at large that this hesitation should cease to exist, and I will select a few illustrations—very different but equally important in character—to prove this statement, hoping that a means will be found of establishing some body in the shape of a council or commission, composed of the highest authorities that can be brought together, who shall conclusively decide them. I will place these few illustrations before you in the shape of questions, beginning with one of a fundamental nature, and at the same time state my own views, in the hope of eliciting discussion.

The questions will be as follow:

I. What are the sanitary objects which should be comprised in the duties of a River Conservancy Board?

II. Should surface-waters be excluded from sewers?

III. Should the public sewers of urban and rural districts be perfectly ventilated?

IV. Should all sewers be made water-tight?

I. The Rivers Conservancy Bill of last session had for its declared object (see sections 9 and 10) the conservancy of rivers and watercourses, and the prevention or mitigation of floods, with powers to enforce the Rivers Pollution Prevention Act, 1876. But although the Conservancy Boards to be created under the Act were to be bound to make periodical surveys of the watercourses within their district (see section 17), the Bill, when it left the House of Lords, contained no provision for securing a supply of water to the inhabitants of the river basins dealt with by the preservation of these watercourses in a pure condition, or by the storage of unpolluted surface-waters in substitution thereof, or by the raising from the water-bearing strata beneath, an equal quantity of the purest water.

The Bill excluded from its operations the two rivers, Thames and Lee, which are at present controlled by separate Conservancy Boards, and as the proceedings of these somewhat important bodies may guide future boards, I will endeavour to point out how the desiderata of river pollution and water supply are at this time being dealt with by them.

Since the first Act of 1857 constituted the Thames Conservancy Board, the length of river under the jurisdiction of the Board has been extended (by the Act of 1866) from Staines to Cricklade, while the breadth of area which was first confined (by the Act of 1857) to the width of the river itself, has been gradually increased to three miles on each side of the river by the Act of 1867; then to five miles by the Act of 1870; and, lastly, by that of 1878 to ten miles on each side of the river, making twenty miles by adding the two sides together. Reducing this present breadth of district to superficial area, it will be found that the control of the Board above the intakes of the Water Companies extends to a trifle above three-fourths of the tributary basin, leaving rather less than one-fourth—comprising about half a million acres—over which no conservancy jurisdiction exists, and from which the conservators have to submit to the influx of any polluting matter which may imperceptibly find its way into the river system. I say imperceptibly, because any defilement which was distinctly apparent would probably be met by independent action.

The work of the Thames Conservancy Board has decidedly been very considerable, and great improvement in the condition of the river has resulted from its supervision, but so long as there exists beyond control within the watershed such a wide margin as 800 square miles, you will agree with me that the duty expected of a Conservancy Board cannot be perfectly performed, and that this is the right conclusion is to be inferred from the fact that the Legislature itself, by five different Acts of Parliament, has gradually lengthened and widened the area of control in the manner I have stated.

The river Lee, which supplies two of the largest Water Companies furnishing London with water is not subject to the same restrictions as that which prevails in the Thames basin. By the Lee Conservancy Act, 1868,—which declares the duties of the Board to be the preservation of the purity of the water of the Lee and its tributaries, as well as the improvement of the stream and the maintenance of navigafion works—the tributaries over which jurisdiction is given are particularized without any reference to the minor streams and watercourses which feed those tributaries, and the consequence is that the control of the Board is considerably limited. If this is not the case by the legal interpretation of the Act, it certainly is so in a practical sense.

Upon this point I can speak positively, because I live within the

watershed of the Lee, and the village in which I reside has a population of about 2500 persons, which at this moment is discharging its sewage into a branch of one of the tributaries specified in the Act. This sewage, when it reaches the Lee—as reach it it must—is necessarily mixed with the water consumed by the inhabitants of London.

Other villages of less populations do the like, and the Lee Conservators evidently consider it no part of their duty to prevent such pollution. It will therefore remain until some authority, having jurisdiction over the whole watershed, compels all Sanitary authorities of districts within it to free their liquid refuse of foul and noxious matters.

Although the Local Board (Stevenage) to which I particularly refer was called into existence five years ago, it is the fact that up to this moment it has utterly disregarded the pressure of the Local Government Board, under a belief that, however peremptory the tone of communication may be, nothing will really be done by that Board to enforce compliance. The prospect of a writ of *mandamus* is held in perfect ridicule, and only those inhabitants are elected on the Board who will do nothing of a comprehensive character.

While this pollution of the stream is permitted, its waters still continue to be used for domestic and agricultural purposes by the people who live on its banks below. At the same time, the inhabitants of the village committing the wrong derive their own water-supply from wells of various depths, which are fed by percolation from the surface, although there exists immediately under their feet, at a depth of about 100 ft., the pure and never-failing supply of the great chalk basin. The consequence is, that while the Local Board by inaction is rendering the water of the stream into which the sewage of the district is discharged unfit for use by man and beast, the inhabitants live constantly liable to endemic maladies whenever dry seasons recur.

This homely illustration of the want of some presiding local authority is only one of many that I could quote as existing in the same watershed, but I hope it will suffice to show that any control by Conservancy Boards that does not extend from the main trunk and its tributaries up to the extreme margin of the river basin, and does not turn to use the subterranean sources of supply by the exercise of powers such as were embodied in the 26th section of the Rivers Conservancy Bill of which I have spoken, must fail to secure the sanitary benefit the country should demand. The section I refer to (the 26th) empowers a Conservancy Board to charge upon a part of a watershed—a private improvement rate to discharge any special outlay which may be authorized by the Act, and surely, as their duties extend to the preservation of the purity of water, the provision of water to villages should be one branch of duty. To tax the upland portions of a river basin (as intended by the 5th section of the Bill) towards the cost of improving main outfalls, on the ground that they throw down their surplus waters to flood the valleys—a charge which is perfectly right in itself—must strike everyone as unjust if the provision of pure water to the taxed population fail to receive from the Controlling Board the consideration due to so vital a question.

The use as well as abuse of waters feeding our rivers are objects so important to the nation that I trust you will be able to answer the question I have put to you, by declaring that the duties of a Conservancy Board should extend beyond the bed and banks of a river, and the maintenance of navigation works, to the protection from pollution, as far as practicable, of every stream and water-course within the watershed area, and to the substitution of either stored or subterranean supplies, where the purity of the running streams cannot be assured.

II. The next two questions have a somewhat intimate bearing upon each other, as one relates to the admission of surface-waters into the sewers, and the other to the ventilation of sewers.

The two objects may be considered to be related to each other; because, although all engineers know that the air existing in sewers is more or less affected by every fluctuation of the flow of liquid within them, we have ample reason for believing that, in many cases where unsatisfactory Sanitary results have followed the adoption of systematic sewerage, they have been due to the want of the proper ventilation of the sewers, and in no small degree to the escape of sewer-air into dwellings when forced out of them by the recurring influx of surface-waters, to say nothing of the escape of diluted sewage into the basements of houses, and into the ground adjacent to the sewers, which too frequently occurs when the sewers are overcharged.

When systematic sewerage was first adopted, under the Public Health Act, 1848, there existed no law compelling the Local Authorities to free the discharged liquid of foul and noxious matter. The rivers were then still recognized as the proper recipients of liquid refuse, and whether it consisted of the water consumed by the population, and converted into sewage, or the rain-fall thrown off the surface, it made no difference. The admission of suface-waters into sewers was therefore encouraged; first, because it was the readiest means of getting rid of a troublesome matter; and next, because the rain was thought to be the readiest means of flushing out the sewers. To make the sewers large enough to receive and discharge surface-waters as well as sewage, was represented as cheaper than the separation of the two; and so long as the rivers remained legally the proper recipients of foul as well as clean water, this treatment obtained general concurrence.

The obligation subsequently imposed upon all Local Authorities to free the refuse liquid they discharge into rivers from all foul and noxious matter has entirely upset this convenient arrangement, and we now find that, on all grounds, the separation of rainfall from sewage (as far as practicable) is desirable on Sanitary as well as economical grounds.

Of course, there will always exist flaws in both masons' and plumbers' work, however vigilant the supervision of local surveyors may be, and faulty traps will be found to admit sewer-air into dwellings and leaky sewers to let out liquid into the ground without

any extra pressure, caused by the influx of surface-waters; but every day's experience is proving, to those observant of facts, that on occasions of heavy rainfall, not only will sewer-gas find ingress into dwellings through faulty traps, but it will make a passage for itself, through water-traps, into kitchens and sculleries, even though they be in ordinary working condition. It not unfrequently happens, too, that upon extreme occasions, sewage diluted with storm-water will rise up the private sewers into the cellars and basements of houses; and I have seen instances where the deposit of sewer sludge in cellars has been considerable, and the effluvium arising from it most objectionable. All outlet pipes from sinks, &c. ought to be disconnected from the sewer, and then these evils cannot arise.

In the disposal of sewage, the advantage of separation is incontrovertible. This was made very clear in 1868, by the late Mr. William Menzies, and has since been forcibly shown to be the case, by Colonel Jones, as well as several other authorities on sewage utilization. As a sewage farmer, having to deal with different characters of soil, more or less absorbent, I can speak feelingly upon the immense difficulty of dealing with sudden augmentations of quantity.

But it matters not whether sewage is utilized upon land, or its solid ingredients precipitated by chemical processes, the sudden and copious increase of quantity, and the equally sudden and great variation in quality, will always convert the best designed arrangement into a work of disorder.

If, in addition to these drawbacks, the sewage has to be raised to the place of disposal, it is needless to say that every gallon of surface-water by which it is diluted, adds proportionately to the cost of pumping.

The only objection that in any way holds good is that the sudden admission of the rainfall into the sewers is an automatic mode of flushing them, and relieving them of deposit. But when it is remembered that surface-waters invariably bring with them road detritus, it will be granted that in the majority of cases the sewers are more likely to gain deposit than be freed from it by the admission.

Without going into any details to show that methodical flushing is superior to the occasional clearing of sewers by the rainfall, I am content to state, that with properly devised penstocks and valves, engineers may effect a perfect means of flushing sewers of deposit without the aid of the rainfall; though, in saying this, I would not reject the partial use of surface-waters, when they can favourably be brought to bear.

III. The ventilation of the public sewers of a district is the next object upon which I desire to express my opinions.

Engineers are constantly meeting with objections from the Local Boards they serve, from inhabitants of sewered towns, and not unfrequently from medical men, to the existence of ventilators, *i.e.*, the manholes and lampholes with gratings acting as such, when placed in the streets and other thoroughfares; and a medical journal, of high standing, recently pointed out that invalids, and persons of weak constitutions may inhale effluvia coming up from these outlets with very injurious results. These objections often assume, too, a substantial form by the outlets themselves being stopped up. We shall admit that a disagreeable stench meeting us as we pass a ventilator in the street, is not an agreeable thing, and we may readily conceive that a person sensitive from sickness might suffer from such cause: but, inasmuch as gases generated in sewers must escape somewhere, there can be no doubt but that it is far better that they should do so in the public streets and in the open air, rather than in private houses and confined spaces, from which there is no escape.

The problem to be solved is, how to effect such a system of ventilation as shall prevent the escape of objectionable stenches, either into the streets or into houses. Tall shafts, erected in selected places, have been tried, and are found incapable of effecting that concentration of foul air that was expected of them, while all attempts to purify gases rising up from street ventilation by the interposition of trays of charcoal, or any other material, have been found equally ineffective.

But the difficulties we experience are, nevertheless, to be overcome; not by adopting extraordinary scientific expedients, nor by reducing the number of outlets, or stopping up those that exist, but by increasing their number, and by insisting upon the ventilation of the soil-pipes of water-closets connected with the sewers, and all receptacles of putrescible matter into which sink-pipes, &c., may discharge, by sufficiently large pipes carried directly up above the roofs of houses.

Experience on all hands points to the advantage of diffusing the air of sewers by frequent ventilation at different elevations. This alone secures perfection. I, therefore, submit that a positive understanding should be come to, which should have the force of law.

IV. The next and last question I have to submit is, "Should all sewers be made watertight?" Upon this point it is quite as necessary for the public advantage that a positive rule should be laid down, as it is to come to a final decision on those objects which I have already put before you.

Although, as an abstract question, there can be no doubt that sewers should only discharge the foul liquid they collect, it cannot be denied that, in certain instances, sewers which have acted as drains, in consequence of their not having been constructed in a watertight condition, have produced such a good effect upon the health of the district they have traversed, by reducing the water-level in the ground, that a conflict of opinion has arisen, and to some extent still prevails, as to the desirability of having conduits, which shall perform the two services of sewerage and drainage at the same time. The adoption of what has been termed "drain-sewers," however, in the cases I have referred to, was not the result of deliberate design, but was due to the absence of a recognition of the actual difference between a drain and a sewer, the duty of the

former being to drain water out of the ground, while that of the latter is simply to discharge, as I have said, the filthy liquid it is intended to collect. These "drain-sewers" were, in fact, constructed with a disregard of the truth, that the same apertures which admit water into the sewer from the surrounding ground, under one condition of things, will let the filthy liquid out of the sewers into the same ground, to make it excrement-sodden under another condition of things.

If the effect of making a sewer act as a drain was simply to lower the water level in the soil, and secure the benefit which, in a Sanitary view, invariably follows the lowering of the subsoil-water in a populous town, nothing could be more desirable. But the consequence of doing so may not only be what I have just pointed out, but it will certainly be to dilute the sewage to such an extent as to increase its volume beyond the limits of economical treatment.

Within certain limits this dilution acts beneficially in keeping the sewers clean, but where, as in Liverpool, London, Dover, Leicester, and Torquay, the constant outflow from the sewers is more than doubled by the influx of subsoil-water, the difficulties of disposing of sewage is very greatly increased.

The difference between the admission of subsoil-water and surface-waters is, that the former increases the outflow, and the cost of treating that outflow constantly, while the effect of the latter is only occasional. In the first case, the whole of the outflow, however much it may be diluted, must be freed of foul and noxious matter; whereas, in the last case, relief may fairly be afforded by storm overflows, in times of heavy rainfall, when the rivers themselves are in a flooded and disturbed condition. Two evils, therefore, attend the use of sewers as drains, which may be avoided by making them watertight.

I am led to submit this point for public consideration, because it is not an unfrequent practice, in certain localities, to use clay for the jointing of sewer-pipes, under the plea of economy. In some parts of the north of England clay is more frequently used than any other material; and I have good reason for knowing that, although, in certain instances, that practice may be adopted without much disadvantage, in the majority of cases, it entirely fails, both in keeping the subsoil-water out of the sewer, and the "sewage proper" in the sewer. So difficult is it in the first place to prepare clay suitable for the purpose, in the next to get it placed equally within the socket, and afterwards to retain the jointing in its position, under pressure from without, when the soil is full of water, and under pressure from within when the sewer is overcharged with the rainfall, that I do not hesitate to say, after more than thirty years' continuous practice in the treatment of clay, that no amount of vigilance in supervision can render clay a perfect material for the jointing of sewers of any considerable length. I have, on several occasions, found that after a time the clay has been entirely washed from the joint.

With the facility that always exists of placing a subsoil open drain upon a watertight sewer, to keep the subsoil-water well below it during its construction, as well as to serve for a discharge of that water for all future time, it is hard to find a reason for uniting the two works in one.

The practice which now finds favour with our leading engineers, of jointing sewer-pipes with tarred hemp, or gaskin, and Portland cement, and having an independent drain beneath, with a layer of concrete between them, to support the sewer where it is of large dimensions, seems to leave nothing to be desired. I, therefore, submit that all sewers should be watertight.

Believing that the Government will not take upon itself to determine such questions as I have put before you, I would ask, is it not desirable that some seven or nine selected men should, with the approval of Parliament, form a Sanitary Council or Commission, somewhat of the character of the Railway Commission, who should consider and express a positive decision, when unanimous, upon all such points as may be deemed of national importance, so that Local Authorities may be assured that they are proceeding safely in the works they are required to execute?

BAILEY DENTON, C.E.

The Dangers of Bad Plumbing.

DURING the Exhibition which was held in Leamington in 1877, I contributed some remarkable specimens of mal-construction in plumbing, and also some curious examples of leaden pipes into which holes had been gnawed by rats while seeking ingress to a house. I also showed several pieces of sheet lead which had been completely perforated by worms that had previously destroyed the unseasoned roof boarding underneath. In the present Exhibition I have laid upon a table some still more remarkable examples of defective and dangerous plumbing; and I may add that each specimen which I exhibit has been associated with death and disaster in some shape or other. In the few remarks which I will now proceed to make, I will endeavour to classify under the heads of Imperfect Jointing and Improper Treatment of Wastes, the sources of some of the evils complained of, so that each specimen may point its moral.

IMPERFECT JOINTING.

These faults will mostly be found in soil-pipes. For instance, there is a slip-joint, properly so called, in which one portion of the soil-pipe has simply been dropped into another, without any filling-up material or solder. A necessary result of this is that the sewer-gas escapes at all times into the house, when the soil-pipe has to be erected in the interior of the house in the ordinary wall chases. Even when the soil-pipe had been led outside the house I have come across notable examples in which the sewer-air has escaped from these open joints, and found an entrance into the house by way of the open windows. Cases of death due to this improper delivery of soil are very common indeed, and the victims are mostly servants who sleep in attics, the windows of which open above these pipes. Sometimes, even when the joints have been properly made with solder, but when the soil-pipes inside the house have been insufficiently tacked to the wall or insufficiently supported, the weight of the soil-pipe has sufficed, by dragging action, to open the joints, with the usual bad consequences. It is not an uncommon occurrence to lay bare soil-pipe joints which have been made with putty, and tied over with canvas; or red-lead joints, without the slightest attempt at soldering; and when these joints were dry, an open annular seam has appeared, which has allowed an exit for the sewer-air. Joints of this description are almost invariably found in the older class of houses, and I have exhibited, on several occasions, pieces of soil-pipe, not more than 2 ft. in length, upon which could be noticed each one of these samples of improper jointing. I need hardly say that faults of this kind are mainly attributable to the carelessness of the workman, who has been content with the worst of patching, instead of insisting upon an entire replacement of the worn-out pipe, as was his duty. I am only too well aware that very often the builder has orders from the owner to carry out the very cheapest repairs; but this ought not to be a valid excuse, because it is neither workmanlike nor businesslike to treat so serious a matter as a soil-pipe in this way, and he ought to know very well that a soil-pipe cannot fulfil its duty properly unless it can sustain a column of water inside without trickling at the joints; and when the builder observes, upon taking down the casing, that a pipe has become eaten into holes by sewer-air, or abnormally thin, he should know that no amount of patching he can devise will remedy the defects, seen and unseen, in such a case.

The corrosion of soil-pipes into holes is almost entirely due to the action of sewer-gas, and will always be found present in some portion or other of an old soil-pipe which has never been ventilated. Where disinfectants of certain kinds are freely used, the decay of the lead is greatly accelerated. When a soil-pipe of this description is laid bare, the safest way is at once to remove it, and to replace it by a drawn lead soil-pipe of proper thickness, duly ventilated by a continuation of the same diameter of pipe up to the roof, remote as possible from windows and chimneys.

There is another thing which a builder has a perfect right to refuse to do, and that is to lead the soil from a water-closet into a rain-water pipe which descends inside the house, or has its extremity near any window. This is a very frequent cause of illness, even when such a rain-water-pipe, made to do double duty, is led outside the house; as, for the most part, it will be found that the upper extremity delivers foul air perilously near the inmates. During the past year I have known cases of death traced to this very fault. The evil factor in such improper treatment is multiplied when the pipe has not been made of lead, but only of lengths of thin cast-iron down-pipe, which cannot properly be jointed or made air-tight. I say that no responsible builder should ever consent to the erection of such inadequate soil-piping, or only upon the specification of an architect or engineer who dare risk it under certain conditions. Nor ought any one to make use of an iron soil-pipe outside the house, unless it be thoroughly disconnected at the foot, and a current of fresh air thus continually passed through it.

IMPROPER DELIVERIES OF WASTES.

A very large percentage of the waste-pipes of sinks are led direct into the drain, with only a bell-trap inside the room, which is oftener than otherwise broken, or with its upper portion removed for the convenience of passing down, quicker than is needful, the pantry and other sink wastes. As a result of this, and especially in butler's rooms, where he perforce sleeps, in order to be close to the strong room, a regular highway for foul air is established into the rooms, bringing with it sicknesses of many kinds. It is the same, too often, with housekeepers' rooms and servants' halls, in which sinks have been placed, and servants who are often obliged to pass the greater part of the day in such rooms suffer in consequence. The only remedy against this state of things is to cause the sink to deliver over the trapping water of an open gully outside the house, no matter what distance the pipe may have to go to reach the exterior of the building, and to provide, as well, a trap underneath the sink itself, in order to keep out the cold air and the effluvium arising from the decomposing wastes in the gully. This latter is a point which is often overlooked.

The above state of things is sufficiently bad, especially in a large household, too profusely equipped with sinks in the basement; but it is, perhaps, nothing to be compared to the improper entries of housemaids' sinks into soil-pipes or D-traps of closets. In nearly every instance when a foul smell is discernible upstairs, it will be found to arise from this improper connection between these wastes and the soil system. I am not now speaking of properly constructed housemaids' sinks, with ventilated traps underneath, which are purposely constructed for the removal of bedchamber slops of all kinds, because these may be allowed in such cases to enter a properly ventilated soil-pipe; but I refer rather to sinks merely intended to remove away the drips from hot and cold water taps, in which case the danger is greatly enhanced by the sinks being placed in passages close to bedrooms and in proximity to the great air-shafts formed by the staircases. These kinds of sinks should invariably deliver in the open air, and may sometimes be conveniently and safely led to the upper head of a rain-water pipe.

Another disgraceful system which obtains in many houses, even of very modern construction, is the leading of the cistern-waste or overflow into the trap of a closet. I have this year exhibited some startling examples of this dangerous practice, and I must most earnestly call attention to the fact that drinking-water is contaminated in this way to an extent which must be incredible to any one who has not made the Sanitary inspection of houses his special study. I have come to the conclusion that the wisest way to avoid the dangers consequent upon this improper treatment of a cistern-waste is to treat the latter as an overflow, and point it through the wall in all cases where a standing-waste cannot be led to deliver in the open air.

The few remarks which I have made upon the subject of the delivery of housemaids' sinks into the D-traps and P-traps of closets are equally applicable to the wastes and overflows of baths. An examination of my pilloried specimens will show that this practice is far too common. One can observe there the traps of closets, into one of which have been led the waste of a cistern supplying drinking and closet-flushing water, the waste of the housemaid's sink, and the waste and overflow of a bath. As may be observed there also, the wastes of baths, sinks, and cisterns have been taken into both cheeks of one D-trap. It is bad enough to place the bath in the same room as a closet, and I wonder how architects can persist in this evil association, but it is something horrible to think that the delivery of the bath-waste is into the very foulest conduit. And yet this latter mistake is one very constantly practised by plumbers who at least ought to know better, and who ought to feel themselves in a position to refuse to carry out such a practice, even if ordered to do so by a clerk of works. I have known instances in which death has entered a household by way of a bath-pipe thus dangerously connected, the danger being enhanced by the frequent contiguity of bath-rooms to bedrooms.

Nor can it be said that these errors of judgment, or worse, apply only to old houses, for I exhibit samples of closet-traps, with bath, cistern, and sink entries, which are palpably but lately from the plumber's hands. In the majority of cases the excuse cannot be urged that these mistakes have been perpetrated in order to save money or to scamp the workmanship, because many of these traps are really excellent specimens of skilled labour, and in some of them the wonder is how the painstaking workman could have brought his soldering-iron into play at the wiped joints in so small a space. The faults are entirely, in such instances, due to total ignorance of Sanitary principles, and to a slavish following out of the traditions of the workshop.

When we come to the water-closet itself, we are all bound to admit that there is a great deal still to be done in providing a faultless apparatus. Most horrible examples of death-dealing closets are to be found, especially in the area-vaults of our best town houses. I should, above all, like to see abolished the filthy D-trap, with its furrings of fæcal matter, the huge iron container, with its linings of ancient ordure, and the trap at the foot of the soil-pipe, with its excremental cess-pit. I would even like to see abolished all traps whatsoever to closets, and I am convinced that if plumbers would only follow the lead of our more advanced Sanitarians in this respect, or at least more largely patronize the earthenware closets, that much solid good and absence from disease would accrue to the community. It is almost criminal for builders still to persist in the use of the pan-closet, which, to my knowledge, was condemned by

Mr. Chadwick nearly forty years ago; and how they can insist on fixing this dangerous contrivance without a ventilating pipe, is more than I can fairly understand. I will not believe for a moment that its use is continued in order to sell the D-trap with it, the making of which occupies the time of the apprentices, or to provide for a regularly recurring bill of repairs; but those who persist in its use lay themselves open to the charge that they are introduced for no other purpose. I think the sole reason for the patronage it obtains is to be found in ignorance, and a false estimate of its economy and cheapness of erection. And I am persuaded that if our builders would only take to heart the lessons taught by the inspection of the much better articles seen at the present day in Sanitary exhibitions, they would refuse to have anything more to do with it.

There is another fault concomitant with the use of all closets, and that is the leading of the waste of the tray or safe under the apparatus into the closet-trap. It is almost invariably taken there in the commoner houses, and in a very large percentage also of the better class houses even yet, and one half the smells which encounter one on entering into a closet-room is due to this lamentable want of common sense and forethought in dealing with the closet essentials.

It is, perhaps, somewhat too much to expect that our tradesmen are all acquainted with the necessity for the disconnection of the house-drains from the sewer by means of any of the numerous disconnection traps, constructed on various systems, now in the market. But until such a trap is provided between the house and the sewer, at some part of the house-drain, the work has been only half done. Nor can there be obtained any absolute safeguard from sewer-air or house-drain gas, or any thorough ventilation of the horizontal drain or vertical pipes, until some method of absolute disconnection be practised, and fresh air taken in at such a trap in order to be discharged at the ventilating pipes. No plumber, however perfect his work, can hope to witness really satisfactory results from his labour until this disconnection has been achieved.

W. Eassie, C.E.

Mr. G. J. Symons asked: If sewer-gas is really so dangerous, why are men who work in sewers generally a healthy-looking class of men?

Professor F. de Chaumont being called upon by the President to reply, questioned the fact of the healthiness of sewer-men, and pointed out that evidence existed of the danger of sewer-gas, apart even from its forming a means of conveying specific poison. It was extremely dangerous in surgical diseases, rendering operations especially hazardous, unless special precautions were taken, giving rise to or aggravating child-bed diseases, erysipelas, ophthalmia, &c., and greatly increasing the danger of specific disease (syphilis). Dr. de C. had himself had occasion to see its influence in the production of ophthalmia in his own regiment. The evidence about sewer-men rested mainly on the statements of Parent-Duchâtelet in Paris, and on the state of health of the sewer-men of London. P. Duchâtelet's statements are hardly borne out by his own statistics, for the number of men examined was small, and even they suffered from rheumatism, ophthalmia, fever, &c. As regards the sewer-men of London, they worked in large, well-ventilated sewers, where the sewage was largely diluted. He had not been in the London sewers, but he had taken a journey down the great sewer of Brussels, where there was hardly any perceptible smell to be noticed.

On the Effects of the Long-continued Application of Sewage Water to the same Land.

The subject of this Paper was suggested by an observation in the Report on Sewage Disposal of Messrs. Rawlinson and Read to the Local Government Board. The observation occurs in their remarks (p. 36) upon Sewage irrigation, and is as follows:—

"We have also been assured by a gentleman of vast experience that the long-continued application of town Sewage to the same land fails to produce the like beneficial effects as when it was first used."

To assign a reason for this ought not to be beyond the powers of agricultural chemists, and it is to be hoped that when their attention is called to it, they will not keep Sewage farmers long in waiting for the explanation and the remedy. The failure is a very important matter for agriculture, and affects also the condition of our rivers and streams. It is certainly a question which calls especially for the attention of an Association like ours, when holding its meeting on one of the "classic sites" of Sewage irrigation, and near the dwelling-place of one of its most bitter opponents.

But for these circumstances, indeed, the author would shrink from putting forward his opinions on a subject concerning which he can neither pretend to have a practical experience as a farmer, nor to a knowledge as an agricultural chemist which is satisfactory even to himself. At the same time he considers that he need make no apology in bringing before you for discussion the experiments and observations of eminent men bearing upon the question, and if he draws deductions from them which science will not justify, he will willingly submit to being corrected.

One of the latest experimenters on the subject of manures, who has published his results, is so far as the author knows, M. Ville, who directed the experimental farm, established at Vincennes by the Emperor Napoleon III, with a view to regulating the effects of vegetation by means of the elements which chemistry discovers in plants. M. Ville gives the results at which he arrived in a series of lectures which have lately been translated by Mr. Crookes, and the work well merits the study of every intelligent farmer. It is on the facts and principles so clearly and simply put forward in this work that the author of the present Paper mainly relies for the support of his views, though additional evidence from the works of Liebig and Voelcker will not be wanting.

M. Ville found that wheat, when grown in calcined sand without any addition but distilled-water, acquired only a rudimentary development, the straw being hardly as large as a knitting needle. With 22 seeds of wheat weighing about 15 grains, a crop weighing somewhat over 90 grains was obtained. On adding the ten inorganic elements or mineral matters found in plants and without nitrogenous matter, the yield increased to 123 grains. With nitrogenous matter, but without mineral matter, it reached 138 grains. When lastly, both mineral and nitrogenous matters were added to the calcined sand the result was:—

"Almost magical. Previously the growths are languishing, precarious, and etiolated, but now the plants spring up rather than grow, the leaves are beautifully green, the stem straight and firm, terminating in an ear filled with good grains, and the heaviest weighed from 327 to 383 grains."

He concluded also from his experiments that one-half of the nitrogen required by the plant was derived from the air.

M. Ville next tried the results in calcined sand, with the suppression in turn of each one of the ten mineral elements which are found in plants. A fixed and invariable quantity of nitrogenous matter was mixed with the sand as a constant ingredient, and all the other elements were added by turns, omitting one each time.

1. When all the mineral ingredients, without any exception, were added to the calcined sand, to which the nitrogenous material (gelatine) had also been added, it was found that 22 wheat grains yielded prosperous plants which weighed 337 grains, and in some cases even 400 grains.

2. With the nitrogenous matter alone, omitting the minerals, the plants became miserable and stunted, but did not die.

3. When the phosphates were omitted, but all the other conditions remained as before, the plants sprang up and formed their first leaves, but these soon became yellow and withered, and the plants died. The yield, of course, being nothing.

M. Ville remarks upon these experiments:—

"We have proved that if the nitrogenous matter is retained, the plants become miserable and stunted, but they do not die. Death, on the contrary, invariably follows the addition of the mineral matter from which phosphates are excluded. This proves conclusively that the phosphates fill two distinct functions, viz., *they aid themselves in the nutriment of the plant, and determine the beneficial action of the other mineral ingredients.** Their function, therefore, is more important than that of the other mineral ingredients, since to their own peculiar action is added a secondary derived effect, that of determining the assimilation of all the other mineral ingredients."

* The italics are not in the original.

4. In the next experiment potash was excluded, and the stalk of the plant, instead of growing vertically, bent as if it wanted solidity. It did not die, but the yield scarcely reached 92 grains.

5. When magnesia was excluded the effects were nearly as disastrous as in the absence of potash. The yield fell to about 123 grains instead of 337.

6. The omission of *soluble* silica was very prejudicial to vegetable activity. From 337 grains the yield dwindled down to about 120.

7. The suppression of the lime produces a less sensible effect; the yield is then about 307 grains instead of 337.

Leaving the culture in calcined sand, Ville extended his investigations to various natural soils, and of these he says:—

"On submitting them to the same experimental system, we found that whatever might be their dissimilarity there was a distinct line of demarcation between the phenomena produced in them and those observed in the calcined sand; for to render vegetation flourishing in the latter material, a nitrogenous material and ten mineral ingredients were required, whilst in natural soil, however poor it might be, a nitrogenous ingredient and three mineral ingredients only—phosphoric acid, potash and lime—are sufficient. The yield is maintained at the same level as when sulphur, silica, soda, magnesia, iron, and chlorine are added."

"Experience shows, therefore, that the four ingredients—nitrogenous matter, phosphate, potash, and lime—are the only ones that need be admitted into manures."

"For myself, I never found any natural earths in which, with the help of these four substances, it was not possible to obtain a yield comparable to that obtained in the most favoured soils".

To the mixture of these four substances, M. Ville gives the name of "normal manure," but in so doing he does not intend to deny the utility of the other mineral ingredients. He excludes them from the manure simply because the soil is provided with them naturally.

In another series of experiments, undertaken to ascertain the action of humus, M. Ville found that with the help of all the mineral matter and a nitrogenous ingredient, the yield rose:—

In calcined sand	to	337	grains.
Sand and clay	„	337	„
Sand, clay, and limestone	„	337	„
Sand and humus	„	337	„
Sand, humus, and clay	„	337	„
Sand, humus, clay, and limestone ..	„	475	„

Humus, as is well known, originates in the actual substances of plants, being the result of a kind of spontaneous decomposition whereby a certain quantity of hydrogen and oxygen is lost in the form of water. It was originally considered as one of the most efficient of fertilizing agents, but though it is now recognized that this is not the case, it is found to exercise very good effects in the soil. An illustration of this fact is given in the above experiment with limestone, clay, and sand, in which a great increase of crop is gained by the combined action of the humus and calcic carbonate. Humus absorbs oxygen from the air, and afterwards undergoes a slow, inappreciable but real combustion, with the formation in the soil of carbonic dioxide,* which acts as a solvent of certain minerals, and especially of limestone and calcic phosphates. It, therefore, helps to supply to vegetables these ingredients in an available form. Humus, it may be mentioned, also fixes the ammonia in the soil, and thereby prevents it from being carried off by rains.

M. Ville subsequently inquires into the constitution and functions of farm-yard manure, and into the:—

"Connection between it and that law of restitution which we cannot escape from, and the disregard of which is fatal to the fertility of soil."

He finds it to consist—1st, of about 80 per cent. of water, which is certainly not the cause of its efficacy as manure; 2nd, of 13 per cent. of woody fibre (carbon, hydrogen and oxygen), in which the active principle of manure had previously been shown not to reside; 3rd, of 5 per cent. of the seven mineral ingredients which have been proved to be of very little value in a manure, because they exist in the worst lands; and 4th, of between 1½ and 2 per cent. of a mixture of the four bodies—nitrogen, phosphoric acid, potash, and lime—of which chemical manure should consist. Although, however, the carbon, hydrogen and oxygen of the woody fibre of farm-yard manure and of the solid dejections it contains are very slightly active at first, such fibrous matter acquires great efficacy by the decomposition it undergoes when brought into contact with the air, resulting in the conversion of the nitrogen, present with them, into ammonia, and, as is the case with humus, rendering the mineral matters more soluble.

After a long course of exhaustive experiments, M. Ville shows that, with farm-yard manure alone, great crops are impossible, because the total amount of substances capable of being assimilated is never sufficient, *but if the ingredients required by each crop are added yearly, the highest results will soon be attained.* If these are omitted and farm-yard manure alone be used, the fertility of the soil will be more and more impaired.

"We know by experience that in giving to the soil the moiety of nitrogen contained in the crops the soil is not impoverished."

"With phosphoric acid it is not the same, the soil loses 7 lb. per acre, the grass land returns 7 lb., but when the loss by rains is determined, the proportion of phosphoric acid which passes into the state of ferric phosphate and aluminic phosphate, both of them inactive compounds, constitutes a real loss, the effect of which must, in the long run, be severely felt."

"It is true that the soil receives notably more potash and lime than it has lost, but by reason of the deficiency of nitrogen and phosphoric acid, the increase of these two products is of no avail. With farm-yard manure alone farming is fatally arrested at the outset. . . ."

"Farm-yard manure owes its value to the nitrogen, calcic phosphate, potash, and lime which it contains, and, as one of these substances is always subordinate or predominant as regards the three others, according to the kind of plants we are growing, the nitrogen, which is the dominant constituent in the case of wheat, descends to the rank of a subordinate agent in the case of leguminous plants; but, notwithstanding this change, it is a noteworthy fact, on which I cannot too strongly insist, that this predominancy only manifests itself on the express condition that the soil is provided, to a certain extent, with the other three constituents of a normal manure."

Liebig, in his "Laws of Husbandry," tells virtually the same story:—

"Every field contains a *maximum* of one or several, and a *minimum* of one or several other nutritive substances. It is by the *minimum* that the crops are governed, be it lime, potash, nitrogen, phosphoric acid, magnesia, or any other mineral constituent; it regulates and determines the amount or continuance of the crops."

"Only those ingredients of farm-yard manure which serve to supply an existing deficiency of one or two of the mineral constituents in a soil, act favourably in restoring the original fertility to a field exhausted by cultivation; all the other ingredients of the manure which the field contains in abundance are completely without effect."

"No special argument is needed to demonstrate that where a wheat soil contains just so much phosphoric acid and potash as will suffice to afford the quantity of these two substances required for a full wheat crop, and no more . . . . an increase of phosphoric acid alone has just as little influence in making the returns greater as an increase of potash alone."

"The error of using too much manure arises from the mistaken notion that the action of the manures is proportionate to the quantities in which they are applied; this is true up to a certain limit, but beyond this all the manure is simply thrown away as far as any fertilizing action is concerned."

"A fresh store of nutritive substances brought up from the deeper layers of the soil may possibly accumulate again in the arable surface soil, but these deeper layers also will be gradually exhausted, and the accumulated store in the arable surface soil will also be consumed. *This is the natural termination of cultivation by the system of farm-yard manure.*"

Nor are there any reasonable grounds for supposing that continued applications of town Sewage would be free from the law which holds good with farm-yard manure.

Farm-yard manure consists of the excreta of animals and decaying straw and vegetable remains. Town Sewage consists of the excreta of human beings and animals, mixed with grease, paper, and other decaying vegetable refuse.

The elements which give value to farm-yard manure are the same in kind as those which give value to town Sewage, but, as compared with the phosphoric acid, the proportion of nitrogen is much greater in the Sewage. The potash and the lime, as well as the other ingredients, are in each case very variable, but on the whole the two manures may be regarded as not essentially differing in this respect. The carbo-hydrates, or woody fibre, bear a larger proportion to the nitrogen in farm-yard manure, but these play only a secondary part in vegetation, and as they are in a far more active condition in the town Sewage, probably the inequality in this respect is made up for. The grease in the Sewage has no fertilizing effect whatever. The great difference between the two forms of manure is in the quantity of water associated with them. Whereas, in farm-yard manure, it is from 80 to 85 per cent. of the whole, or about four parts of water to one of solid matter; in town Sewage it is from 2000 to 3000 to one of solid matter. Finally farm-yard manure need be applied only when crops require it, but town Sewage must be applied whether they want it or not, and during the periods when vegetation is inactive, many of the valuable salts are carried away in the drainage water. Dr. Voelcker has determined that although potash, nitrogen, and other salts are detained in the soil through which moderately strong solutions are filtered, the reverse action may take place when such dilute solutions as town Sewage are treated.

Now there is nothing in all this to encourage the hope that land under Sewage irrigation has its losses from cultivation more efficiently restored than if it had been manured with farm-yard manure. On the other hand there is much to excite the fear that the exhaustion will go on much more rapidly in this case than when farm-yard manure is employed. Sewage irrigation is most useful for the cultivation of grasses, and the growth of this class of plants being enormously increased by it, such crops must lead to the more speedy exhaustion of the minerals which especially feed them. In short, if, with farm-yard manure as our only fertilizer, we cannot dispense with the predominant element of each crop, much less can we do so with town Sewage alone.

This matter is so important that we will look at it in another aspect. It has been shown that there should subsist a certain relation between the phosphoric acid of a fertilizing compound and its nitrogen. Phosphoric acid is the element which, as we have seen, determines the action of all the other ingredients in manures. Without phosphoric acid plants die, but this is not the case if any other of the elements of plants be absent from the soil. The phosphoric acid, therefore, becomes the measure of the quantities of the other ingredients which it is useful to add to a manure for the growth of any particular crop. All supplies of such ingredients in excess of this, are of no avail, and will, in some cases, prove injurious.

For a general manure for agricultural and horticultural purposes, Dr. Voelcker is of opinion that the phosphoric acid should be to nitrogen in the ratio of about 100 to 50.

The mean of the six normal manures for different crops recommended by M. Ville gives the ratio of the phosphoric acid to the nitrogen as 100 to 74, varying between 100 to 130 and 100 to 33, according to the nature of the crops.

In farm-yard manure the ratio is as 100 of phosphoric acid to 200 or 300 of nitrogen.

And in town Sewage as 100 of phosphoric acid to 600 or 700 of nitrogen.

We see, therefore, how large a proportion of the nitrogen of Sewage manure must inevitably be wasted under the present system, if the above agricultural chemists approximate even to the truth in their conclusions, as to the quantity of nitrogen, a given proportion of phosphoric acid in a manure will render assimilable. A larger supply of phosphoric acid than the Sewage will supply at the critical periods of the growth of crops, is the author believes, the most efficient remedy for all this. This may of course be supplied in the shape of super-phosphate, and when potash is the constituent demanded by the crop, the deposits of salts of potash discovered a few years ago in Prussia, will yield a cheap supply of it. The calcic sulphate which would be added to the manure by the super-phosphate would of course supply any want of lime which might arise from the solvent action of the Sewage water upon the lime in the soil; and the lime deposit, where lime is used in the precipitation of Sewage, will, in conjunction with the decomposing organic matter of the sludge, afford a large supply of lime when lime is wanting in the soil. By the judicious application in fact of phosphoric acid, potash, and lime, dependent on the nature of the crop, no exhaustion of the land through Sewage irrigation need be feared. Indeed as far as phosphoric acid and lime are concerned, this addition may be made to facilitate greatly the disposal of that bugbear of all who are concerned with Sewage, viz., sludge. To dry sludge is, as it is well known, a formidable operation, and it becomes almost a hopeless task, unless mineral substances are abundantly mixed with it. The addition, however, of so much inert matter as is generally employed for the purpose, renders the sludge, by degradation, of so low a manurial value that it will not bear the cost of carriage. The author, however, has proved, by means of experiments conducted upon a large scale, that a comparatively small percentage of lime and phosphoric acid, not only renders the sludge less retentive of water and more easy to filter and dry, but it deprives it also, to a great extent, of its noxious smell.

It may be objected that to make phosphoric acid soluble and then to precipitate it, and again deprive it of its solubility by lime, is a waste of acid which must render the plan impracticable; but the author submits that this view has already been shown in this paper to be erroneous. Such calcic phosphate as is soluble to a scarcely appreciable extent in ordinary water, becomes fairly soluble when attacked by water in which carbonic dioxide is dissolved, and such carbonic dioxide must result from the decomposition of the carbo-hydrates which the organic matters of the sludge abundantly provide. Calcic phosphate is also dissolved by the ammoniacal salts which exist in Sewage water in sufficient quantities for the wants of vegetation. For Sewage irrigation, indeed, precipitated phosphate and decaying organic matter are better than phosphoric acid in the perfectly soluble condition; for in the latter state there is more danger of its being rendered less assimilable by plants, by being too readily converted into its inert combinations with iron and alumina. There is also the still greater danger of its being washed away altogether in the drainage water. Dr. Voelcker found that in operating with very dilute solutions of phosphoric acid, the proportion of the acid which was left in the liquid after passing through the soil was just as large as it was before it was applied.

By supplementing, in the manner which has thus been described, the action of the Sewage water, and by treating Sewage sludge with phosphoric acid and lime to be used as a top dressing, not only would the manurial effects of the Sewage water, when employed in irrigation, be greatly increased, but its application to land both fertile and unfertile would, the author believes, continue for all time as beneficial as in the first few years of its use.

Henry Y. D. Scott,
Major-General.

The Sanitation and Draining of Towns, and Disposal of Sewage.

The Sanitation of a town, and the disposal of sewage without creating a nuisance, and without polluting either river or the sea, are admittedly subjects of national importance; and as all the means of effecting these objects that have hitherto been employed have been more or less failures, practically and financially, I venture to bring to the notice of the Sanitary Institute a novel process of my own which, as it is based on one of nature's immutable and essential laws, must certainly be right in theory, and cannot therefore be wrong in practice, if properly carried out.

I start then with this assumption, that what the HEART, or, as I call it, the PUMPING STATION of the body for eliminating and purifying the blood, is to man, such would SEWAGE WORKS properly constructed on the plan I propose be to the purifying and disposing of SEWAGE.

This may strike you as a strange idea, but I undertake to work it out to your satisfaction I think.

I lay it down, too, as a law not to be disputed that a town cannot be healthy unless it be clean; and in order to be clean it is necessary to do much more than simply carry to the outside land the excretions of men and animals.

If these propositions be true, it is just as essential to dispose effectually of discarded house refuse and scavenged material as it is to get rid of sewage, if we wish to prevent the occurrence of

disease from an accumulation of things that foster corruption and decay.

But the efforts of Sanitarians have hitherto been confined to the disposal of sewage. This in my opinion is only half doing what is necessary to be done.

If we examine minutely the articles that compose a midden, or an ordinary manure heap, we find amongst them seeds of numerous weeds and larvæ of coleopterous insects.

I contend that a great deal of injury is now being done to land by putting the contents of middens and house refuse in a crude state to fields and gardens.

Much of the good that manure is able to do is neutralized by such means, because a crop of weeds and a host of destructive insects are the certain result.

What is there, let me ask, that takes more from the profit of a farm than a crop of weeds?

The labour to eradicate them thoroughly would be half the rent, and the loss on the corn crop as much.

If you ask me for evidence of the destructive power of insects, and the loss to society by growing weeds instead of food for man, I refer you to the daily experience of those who cultivate the soil—to occasional articles in the various journals—and other available sources of information. But no one proposes a permanent remedy.

I desire, therefore, to offer a remedy that cannot fail to be efficacious. For that purpose then I collect all refuse from houses and streets, such as bones, vegetable cuttings, cinders, ashes, manure from stables, cowsheds, slaughter-house offal, street sweepings, the droppings from birds, horses, and other animals, oyster shells, fish refuse, *clothes and bedding contaminated with contagious effluvium*—in fact, everything rejected from house, garden, and field, and subject them to combustion as a preliminary step to the sanitation of a town.

It is, as you know, the daily practice of certain local authorities in various towns to collect the discharges from men and animals in pails and middens.

But to do so, whether visibly to the eye or not, I say is a filthy and revolting process, fit only to be used by a primitive and barbarous people, in barbarous times, and is a disgrace to the civilization, refinement, and vaunted social progress of the present day.

Statistics of fever extending over two quinquennial periods from 1868 to 1877, given by a Medical Officer of Health at a Conference of the Society of Arts, were intended to show that pails are better than middens, but with what fractional benefit the figures themselves will prove.

In the first period up to 1872 there occurred in the town of Nottingham—a town not remarkable for cleanliness—748 cases of fever directly traceable to the pestilential influence of pails and middens. Of these 748 cases of fever 395 died.

This was with the "midden system prevailing." In the second period from 1873 to 1877 when "the pail-closet system prevailed," there were 549 cases of fever, and of these 256, or nearly one-half, again died.

Thus there were in all 1297 cases of fever, and of these no fewer than 651 died.

Such a state of things in a Sanitary point of view is to be lamented and wondered at, and whilst it is not at all complimentary to medical science, justifies the existence of such a society as a Sanitary Institute.

The Congress will no doubt have inferred that the mode of Sanitation which I urge upon them implies the existence of one or more Water-Closets in every house.

In fact I doubt if Sanitation will ever be much advanced till water-closets are universal, and all restrictions on the quantity of water supplied by companies are removed.

Assuming then that a town is drained by properly constructed sewers, and that water-closets are the mode by which excreta are discharged from houses to sewers, I come to the consideration of what means are best for the disposal and utilizing of sewage.

In the process invented by me, I have carefully abstained from the use of lime, or any chemical agent to effect precipitation, for the sufficient reason that lime is quite unnecessary.

Here I may observe that the precipitation of an article simply suspended in a fluid, as fimus is in sewage, is to all intents a mechanical, and not a chemical act. The active agent is gravitation.

It is then quite unnecessary to effect decomposition in order to precipitate fimus.

Therefore when sewage is collected in tanks, all that is required is to precipitate the feculence by a mechanical agent that will not only not destroy, but will add to the fertilizing character of the sewage, and at the same time absorb the superfluous moisture not otherwise disposed of.

The article I employ is finely pulverized calcined ash obtained from the combustion of the bones, house refuse, and scavenged matter spoken of before.

According to the size of the town to be drained, and the quantity of sewage formed, I construct a series of four, five, or six tanks.

Or one tank could be made, in an oblong form, sufficiently large to be divided vertically into six compartments.

Each of these would communicate with the adjoining division, about two feet from the top.

On the top of tanks Nos. 1 and 2 a furnace is built, large enough to contain several cartloads of refuse, and into this furnace everything that comes under the name of scavenging is placed to undergo combustion.

The furnace in which the combustion is effected being immediately over the tank, the finely calcined ashes fall through the floor of the furnace to the sewage below, and thus become the mechanical agent to produce precipitation.

When tank No. 1 is sufficiently filled, the sewage from the outfall pipe is diverted to No. 2, there to undergo the same process of precipitation.

Then, when deposition has proceeded to some extent in the first tank, the more or less clear supernatant fluid is drawn or let off into tank No. 3, to allow the finer portion of the suspended *debris* to deposit itself there.

But ashes will continue to fall or be deposited from the furnace to the first tank till any moisture that may remain has been absorbed.

The mass will then be stirred and assimilated by a mixer, or revolving wheel, till it is dry enough to be removed in sacks or carts. This is simple enough.

Here I may state that the outfall sewer pipe is made to enter the tanks a short distance below the floor of the furnace, which is composed of iron bars so closely put together that only the finest material can pass through.

From the furnace upward there will necessarily be a current of air, and as Nature never permits a vacuum to exist, it happens as an absolute result that any foul air or gas that may arise from the tank, or be attracted to it from the outfall pipe underneath the furnace, must pass to the fire and be there destroyed.

Having, as just stated, precipitated the solid part of the sewage, and passed the remaining fluid from one tank to another till everything suspended in it has become deposited, and the fluid clear and limpid, we come next to the mode of disposing of the effluent.

In order, therefore, to dispose of the effluent usefully, profitably, and to the permanent benefit of a town, I erect on the top of tanks Nos. 5 and 6 a capacious reservoir or cistern to receive the effluent, as shown on the plan.

Into that cistern I pump the effluent from the tank or tanks below by manual, steam, horse, or other power.

Then from the reservoir or cistern, as shown on the plan, I pass the effluent by gravitation through a pipe, tube, or channel running parallel with the outlying sewers, but on a higher level, by branches from the main to holes, or inlets, made at, or near to, the crown of the sewer.

The effluent thus made to pass into the sewers by a concentrated descending force, or fall, of perhaps four, five, or six feet descent, effectually agitates and stirs the sewage.

This mode of agitating and moving the sewage is, as you will see, a self-performing and continuous act, carried on simply by gravitation, without manual labour or assistance of any kind, and by it the sewers become thoroughly washed.

Thus the contents of the sewers are passed on by a steadily persisting, uninterrupted stream to the outfall pipe and tank again, partly by gradient descent, and partly by the *vis a tergo* force imparted to the sewage by the energy with which the effluent descends to the sewers.

The sewage then undergoes the same process of precipitation and purification as had been performed before.

Just then as the heart, or pumping station of man's body, sends the blood to the various and distant parts of the body by arteries or channels, and brings it back by the veins of the heart again, to be purified by the lungs, so does the arrangement of SEWERS, SINKS, and CISTERN circulate and purify sewage, and eliminate from it its poisonous parts.

The deleterious part of sewage, as you all know, is the gas that is produced and emanates from it.

But decomposition of sewage cannot occur, and gas consequently cannot be formed, unless sewage is at rest or stagnant.

Every wine-maker, every brewer, every chemist knows that rest is essential to produce fermentation in wort and must. So it is with sewage. At rest it ferments; kept in motion it does not.

But if from perversity of thought, or want of comprehending the principles here laid down on which draining should be done, an engineer constructs his sewers with insufficient gradient, then I say his sewers will be no better than elongated cesspools.

But whatever the gradient of sewers may be, sewage should be kept in steady circulation as the blood of our bodies is.

Then with a continuous flow of effluent into the sewers, as I have just described, the production of sewer-gas will be prevented, and one of the potent causes of zymotic disease will be certainly frustrated.

It will thus be seen how impolitic it is to adopt wrong principles in draining and disposing of sewage, and how foolish and pernicious it is to rely for relief on that phantom of misapprehension and absurdity, the VENTILATION of SEWERS.

When sewer gas has been formed, I contend the proper thing to do is to retain the sewer-gas in the sewer—I say the natural and true place for sewer-gas is the sewer—and then, by creating a vacuum at the outfall pipe, the gas will be attracted there, and destroyed by combustion at the furnace I have described.

But to discharge sewer-gas into streets and houses by what is called "ventilation of sewers," is, in my opinion, one of the grossest misconceptions of true sanitation and common-sense that it is possible to commit.

Yet certain Sanitary Authorities commit this mischievous act every day, and are unable to comprehend that disease and death can come as the result.

If you will allow me, I should like to mention one more point of importance before I conclude.

At given distances along the pipe that conveys the effluent from the cistern to the sewers, hydrants should be placed.

Anything like an overflow, or excess of effluent, would thus be prevented.

From those hydrants water could be drawn as necessity required to water streets and roads—in many cases to the saving of large sums to the rates.

From these hydrants water could also be conveyed for the service of water-closets, for washing carriages and horses, and for garden use.

In case of fire, too, these hydrants would always be available adjuncts to extinguish it, and could be employed also for many other purposes.

You are aware, too, that at the Society of Arts and other learned societies, there have been frequent discussions on the possible deficiency of our NATIONAL WATER SUPPLY, and HIS ROYAL HIGHNESS THE PRINCE OF WALES initiated action on this important subject at the Society.

Well, now, surely it is a rule prudent people should adopt when the ordinary sources of supply of an article of necessity are likely to be deficient, to take care that the supply already possessed should be economized and used in a way to prevent future possible want.

If that be true, then I say it is a suggestion for good to dispose of purified effluent in the way I propose; for not only would such disposal add to our present national water supply, *by saving the consumption of water in ordinary use*, but, taking the aggregate of towns, would represent an amount of money saved to the rates that very few persons have imagined, extending no doubt to several millions a year.

It will probably be inferred that, taking the average of seasons and the general character of land, it will be better, cheaper, and more fertilizing to deprive sewage of its effluent before it is applied to the soil.

I grant that there are in the Eastern counties and other places, some loose textured soils, to which sewage may be applied at any time, for in its natural state sewage is undoubtedly an agent admirably adapted to renovate a poor and thirsty soil.

But such soils are the exception and not the rule.

Even on these soils great advantage must necessarily result to the cultivator by having an unspoiled, unadulterated, natural manure, equal to the best guano, ready prepared to apply to the land at any time, freed from the noxious power of generating weeds and deleterious insects.

For although plants cannot absorb manure in its solid and dry state, but must have that manure dissolved by rain or other means, it is impossible to apply crude sewage to land in any quantity in such a summer as this of 1879, if due regard is to be had to the sanitation of the district where sewage is so applied.

The larger the quantity of sewage in its crude state that is applied to land, the more must be the evaporation from that land.

Consequently, the greater the evaporation the greater must be the dissemination of noxious matter throughout the atmosphere of the district.

If that be not the case the character of sewage as a poisonous agent has been much maligned, and it cannot be hurtful.

But facts and experience prove the contrary.

To sum up, then, I would say that no mode of draining and utilizing sewage can be worthy of NATIONAL regard and acceptance unless it be able to dispose of sewage by turning every part of it to use and profit, without discharging anything into river or sea.

It must also be able to dispense with the application of crude sewage to land except under special circumstances; must be able to destroy sewer-gas—exclude it from houses and streets, than which nothing is easier if right means be adopted; must also prevent the reproduction of sewer-gas, and by abstaining from spoiling sewage, keep the sewers clean.

No system of sanitation, I contend, will be worthy of national regard unless it can accomplish one and all of these things, and I am sure that the process I have patented can.

W. HEMPSON DENHAM,
SOC.COLL.CHIR., S.F.M., F.L.S., F.S.S., M.S.A.

A paper was read for Captain Liernur, in which he explained his system and his own views upon sewage disposal at considerable length. The paper is too long to insert in full; we must therefore confine our notice to the discussion which followed.

MR. DONALDSON expressed his surprise that the system of Liernur still found advocates in England. That system was not in reality a system for collecting and disposing of the whole of the polluted matter of an inhabited area, but a system for collecting only those ingredients which were richest in material value for the purpose of making a manure called *poudrette*. The inventor now called his system the double conduit system. The one conduit is the cast-iron pneumatic tube; the other is a gravitating sewer, discharging the whole of its contents directly into the nearest stream. Everything calculated to make the manufacture of *poudrette* difficult and costly is to be excluded from the pneumatic conduit and sent away by the gravitating sewer. Amongst the polluting liquids to be sent directly into the river, Captain Liernur himself enumerates the following:

(*a*) Manufactory water, cleaned by those who soiled it;
(*b*) Kitchen water deprived of all suspended matter;
(*c*) Bath and household water (minus sleeping-room wash water and fæcal matter) in its natural uncleansed condition.

That is to say, every manufacturer must successfully purify all his liquid filth on his own premises; and every drop of household filth, including soapsuds, with the exception of housemaids' slops and fæcal matter, is to be discharged directly into the river!! Such a system can never be adopted by any town in Great Britain and Ireland.

Financially speaking, the cost of Liernur's double conduit system is more than double that of a duplicate gravitating system in which the rainfall only is admitted into one set of sewers where the natural features of the ground are favourable, and is also in all cases more than double the cost of a duplicate system of sewers when the sewers proper are designed in accordance with the principles of Shone's ejector system. Captain Liernur states that the cost of the whole of the works at Amsterdam for collecting the sewage has averaged about 24*s* per linear yard of street. The *poudrette* works, nearly finished, will add 6*s* per yard more, or together 30*s* per linear yard of street for the pneumatic system. His estimate for the second conduit, 20*s* a yard, seems high, but as this sewer has to convey all household slops, it must be laid deep enough to drain cellars, and must be of the same lengths as the streets. If Stone's ejector system achieves success, which Mr. Donaldson is confident it cannot fail to do, nothing larger than a 9-inch pipe will be required, and the sewers, replete with every modern scientific requirement for ventilation and flushing, can be built for 10*s* a yard. In a scheme prepared by Mr. Shone and himself for the drainage of Cambridge, recently submitted to the Commissioners of that town, the estimated cost of the ejectors, mains for air and for conveying the sewage outside the limits of the borough, engines, air-compressors, and buildings, was a little under £16,000, which in the case of Cambridge is about 8*s* per head of the population, and about 6*s* per yard of street. As rain water only is to be conveyed in the most direct way into the nearest outlet, the sewers for this object will be shallow, and their length probably not more than two-thirds the total length of the streets; so that 6*s* per yard of street will be an ample estimate, including cost of gullies. A duplicate set of sewers, designed in accordance with Shone's system, would therefore cost about 22*s* per yard of street. Captain Liernur's estimate for his own duplicate system is 50*s*.

W. C. SILLAR, of Blackheath, said that it was difficult to separate the agricultural from the Sanitary aspect of sewage treatment, and that seemed to be the reason why the manurial value entered so largely into the discussions of this Institute.

There was, or ought to be, no doubt that sewage contained great agricultural value; and evidently it was only carrying out the intentions of nature in giving back to the land that which the land had first given to us.

It seemed to be needless to enlarge upon the products of a sewage farm. Shame upon them if they did not produce marvellous results, considering that they applied to a few acres the manurial wealth that ought to serve to enrich many hundreds. Still the difficulty seemed to remain of preserving in a proper form the sewage deposit without injuring it.

It seemed to be an accepted fact that sewage treatment could not be made to pay. That might be, but there was no reason why the sale of the deposit might not greatly reduce the working expenses; but this would depend upon the fact whether or not there was a market for the manure.

Anticipating that this question would be brought before the Institute, Mr. Sillar said he had taken the trouble to write to the manager of the Sewage Works at Aylesbury, asking how much of the sewage deposit of that town remained on hand now—after the three or four years that the treatment of the sewage had been carried on—and he had received the following reply:—

SEWAGE WORKS, AYLESBURY,
October 22, 1879.

DEAR SIR,—In answer to your inquiry I beg to inform you that at present we have no native guano in stock, our orders having entirely cleared us out; and I may mention that we have orders in hand for all we can make up to the end of April next.

Yours faithfully,

(*Signed*) W. STEVENS, *Secretary*.

One fact was worth more than much theory, and this letter proved not only that there was sale for the manure, but that it would bear, and bear well, the expense of carriage to a distance; a fact stoutly denied by many sewage authorities. And, moreover, it would be interesting to know, that this manure was largely sent abroad, not only to the vineyards of France and Italy, but to the coffee plantations of Ceylon. Indeed, the report of its efficacy in arresting the ravages of phylloxera among the vines was most remarkable, and, although it was premature to say that it was an infallible remedy, all the evidence received as yet was encouraging, though a second year's experience in confirmation was desirable. Whether this is received or not, there can be no doubt that the manure bears not only agricultural value, but very high agricultural value, and this may be verified by any one interested in the subject by a trial on any scale, from a single flower-pot to a large farm; and whilst on this subject he might say that whatever value was in it was from its own intrinsic qualities, and not directly or indirectly from any addition of fertilizing matter.

He submitted that the works at Aylesbury were a practical solution of the problem, and open to the inspection of any inquiry; and there, where the sewage was being treated day and night continuously, without offence of any kind, the value and character of the resulting manure was not only a practical solution to a great difficulty connected with agricultural depression, but also a solution to at least one-half of the Sanitary question.

On Heating and Ventilating.

THIS paper advocated a method of heating buildings by bringing in air at a high temperature through a large opening about seven feet from the floor. Immediate diffusion under such circumstances was said to take place, so that thermometers placed in various parts of the air-space read the same, irrespective of distance from the source of heat. The foul air was proposed to be taken out by openings near the floor (on the *supposition* that it was rendered heavier by vitiation) and carried up by tubes in the walls and the roof, and then discharged.

C. HENDERSON.

Observations upon Effective Ventilation.

A HOUSE-DWELLING should afford us shelter from wind and rain, and, while enabling us to obtain a comfortable temperature, should not deprive us of pure air for breathing.

The ordinary house-dwelling certainly provides us with shelter, but the requisite temperature, and the pure air, are obtained wastefully and with life-lowering insufficiency.

The warming and ventilation of buildings is an intrinsically difficult subject, requiring unusual thoroughness and comprehensiveness in experiment. An illustration of the danger proceeding from the neglect of strict experimental investigation was afforded by the very general misconception with regard to the work performed by cowls in ventilation, which prevailed, until the President of this Section, with his colleagues upon the Ventilation Committee, published the results of their experiments at Kew. It is to be hoped that the very great public benefit, conferred by that investigation, will not be limited to the dispersion of the unfounded pretensions of the cowl supporters, but that it will inspire an attitude of sceptical inquiry towards ventilating appliances, in general.

Perhaps, also, a lack of precision in language has contributed to obstruct our progress.

I may mention the word "draught" as an instance of this. In the popular sense of the word, a draught means a stream of air of highly uncomfortable and dangerous quality, and generally we find the effect of movement in the air and the impression derived from its quality are confounded one with the other!

Air perfectly at rest—stagnant air—though its quality may be good, is not agreeable to us, and perhaps not healthy. Mere movement in good air is agreeable and stimulating; fanning is so. Thus, in ventilation, a current or draught is distinctly an object to be attained, but of course the draught must consist of pure air, agreeable in temperature and in other qualities.

It will be prudent for me in order to secure a meaning identical in your minds and in mine for the loose expression, "the ventilation of houses," that I should at the outset explain my own understanding of it; I will, therefore, define the ventilation of houses to be *the maintenance of the atmosphere of a dwelling in that condition of purity, temperature, movement, and moisture which is found to be most agreeable to its inhabitants, and most conducive to their health and vigour.*

I think this definition is sound, although it goes beyond the limited sense in which the word is usually employed. The many modes of ventilating at present practised may, I think, be classified as belonging to three fairly distinct principles.

1st. We have ventilation by the natural or spontaneous method, or, as I prefer to call it, ventilation by the EXTERIOR WIND AGENCY.

2nd. We have ventilation by the operation of gravity obtained in ventilation by HEAT AGENCY.

3rd. We have ventilation by mechanical appliances, as blowers, fans, or pumps, which may be described as MECHANICAL AGENCY.

Ventilation, dependent upon the EXTERIOR WIND AGENCY principle, is the form commonly employed for the introduction of fresh air into house-dwellings in this country. The appliances for it are various in character. Among them are very numerous contrivances applied to holes in walls of buildings. To this principle also belongs the introduction of fresh air by tubes which convey it into the interior of dwellings in a manner to cause the least annoyance and discomfort. Tubes for extracting air open at the top, or surmounted by a cowl, whether used in conjunction with some mode for admitting exterior air or not, must also be placed in this class.

I am well aware that in many of these contrivances the action claimed for them as proceeding by their operation, from difference in temperature between interior and exterior air, does take effect to some extent, but such action is altogether inconsiderable when compared with the influence exerted by the exterior wind currents to which the tubes are exposed.

It is one object of my paper to ask your earnest consideration as to the value and expediency of relying at all upon the force of natural wind currents for a supply of air for breathing purposes, and it would be a great step in advance to acquire clear views upon the merit of this form of ventilation.

A leading cowl manufacturer in his prospectus says that the wind has an average velocity of 10 miles an hour in this country—it is easy to calculate an average, but to be of use for ventilation that average speed should have a reasonably enduring continuance, it should represent a normal condition of the wind force—the wind in this country actually varies from about 1 to 30 miles per hour, however seldom such extremes may be touched.

For the ventilation of sewers, cellars, and for what I can best describe as *air-cleansing work*, the fitful, but from time to time, powerful and thorough sweeping obtained from the full force of an exterior wind current, is most valuable; but our respiratory process is regular and uniform, and something like a corresponding uniformity in the quantity and quality of the air supplied to our dwellings is required by us. If this be conceded, I submit that the admission of the force of wind currents is pernicious, and must frustrate the attainment of reliable and uniform ventilation.

Ventilation on the second principle, by Heat Agency, is a great improvement on that obtained by exterior wind agency; but if applied to extracting air by chimney draughts, the admission of air is usually allowed to depend upon appliances largely controlled by external wind currents.

In summer the plan of propelling air by heat ventilation cannot well be carried out, and the stoves devised for it usually operate at that season of the year upon the external wind agency principle with its inaction during the hot calms of summer, and excessive action when the natural leakage of our houses introduces air enough.

I believe it is by the employment of the third principle, that of Mechanical Agency, that we can alone become masters of the situation—able to introduce air at any required rate, and, at the same time, do very much towards raising its life-sustaining value. By the use of fans, blowers, or pumps, the quantity of air admitted is placed under easy and immediate control, and its

condition can be modified so as to bring it to a near approximation with any desired standard. As the object I had in view when commencing some modest experimentation, was *to obtain the means of introducing air suitable for respiration, and of regulating the supply of it at will*, I have concentrated my attention on the modes of employing mechanical agency.

To furnish power for blowing or pumping air into large buildings is simple enough; but its application to the needs of private dwellings in a manner sufficiently simple, automatic, and inexpensive, is surrounded with considerable difficulty.

The ordinary means for the application of power appeared incapable of furnishing a flow of energy in a form sufficiently attenuated for a machine required to do work as undeviating, and as constant as the process of respiration within ourselves. The descent of heavy weights, governed by clock-work movement, affords an arrangement by which a considerable amount of energy can be stored and liberated with uniformity at any desired rate.

A descending weight of one ton might run in a shaft by the side of a house from the top to the bottom or from the basement downwards in a tube to any convenient depth, or by combining the two, a vertical fall of many feet would be obtained. The weight could be raised by multiplying pulleys by hand power, or by any form of engine, steam, wind, hot air or gas, but by using gas or hot air engines, it would probable not be difficult to contrive some continuous automatic arrangement for starting the engine to wind up the weight. I have made trials in ventilation by using the fall of a weight (2 cwt.) descending 30 ft. in connection with a small fan blower for the ventilation of a room, and I have also tried by means of the same machine the ventilation of a number of enclosed spaces representing in arrangement the rooms of a house. A mode by which power of a similar nature could be obtained might be devised by employing two cylinders of capacity sufficient to give the required force, running over pulleys, made to fill automatically with water at the highest cistern of the house, and to empty themselves into a lower cistern. The two cylinders would rise and fall alternately so as to offer a continuous exertion of power.

My results so far have been encouraging, but I am sorry to say that they are not as yet in a form which I could conveniently lay before the Section, though I hope upon a future occasion to place some definite results before the Sanitary Institute. A plan has been patented by Messrs. Verity and Co. in which a very small stream of water from a cistern at the top of a dwelling-house, or direct from the Water Company's mains, gives motion to one or more blowers. Wherever water is available, and the amount of ventilation required is small, this plan is exceedingly convenient and inexpensive.

Hot-air engines and gas engines are now manufactured for machinists of a power low enough to enable them to be employed to give direct motion to a fan or blower without the aid of any intermediary. By using hot-air engines heated by gas a considerable, down to a very small, exertion of power can be obtained, which, with some precautions, may be expected to act with the permanent and regular motion absolutely necessary in any arrangement for house ventilation.

After giving a good deal of consideration to the subject, and working at it in various ways by experiment, I came to the conclusion that we should not shrink from endeavouring to grasp, for an application to domestic buildings, the teaching afforded by the results of the best examples of ventilation in this country, such as the Houses of Parliament for instance. In short, that opportunities presented by a thorough and completely controllable system of air circulation should be utilized to the utmost, aiming at more than a mere replacement of breathed by unbreathed air.

Pure air united to the climatic conditions most agreeable and desirable for us is what is wanted. One process should enable us, in winter time, to secure a summer-like condition of air, as well as to maintain a high standard of purity in it throughout the whole of our dwellings.

Nothing but long habit could reconcile us to the extraordinary barbarism of the present ordinary provision for house heating. In each room we have a small patch of heat and a large space of cold, so that the arrangement of the dinner table and how to sit at work in one's study become problems it is impossible to solve; but such riddles are less serious than the important household question as to what condition or period of life, or what infirmity in health, constitutes a valid claim for the indulgence of a fire in the bedroom. The air of half our rooms is that of a cross between the atmosphere of a marsh and a glacier, and many of us leave a warm drawing room to undress and sleep and dress in the morning during winter under circumstances of pain and peril. Our houses surely cost us money enough to build or to rent, why should we not keep the whole of them in a habitable condition?

The labour, much of it of a very heavy and disagreeable kind, necessary for the average number of fires required in a large house is probably equal in the aggregate to the time and care which would suffice to produce with the proper appliances, any desired climatic condition throughout an entire house; and though the amount of attention required to carry out warming and ventilation in the form I contemplate may be too considerable for application separately to small houses, *why could not such houses, if built in rows or very near together, be supplied with pure air and summer climate from one source, taking precautions to prevent the loss of heat by the employment of non-conducting coats for the main pipes.*

The important item of saving effected by the avoidance of the destruction caused by stoves and open fires to the furniture, carpets, and hangings, must not be left out of consideration.

In point of original cost it is probable that the numerous stoves, with all their attendant paraphernalia of mantel-pieces, fenders, hearths, &c., in a house of twenty rooms, would cost as much in the first instance as the machinery for heating and ventilating, while in planning new buildings the arrangements for such a form of ventilation would not add materially to their cost.

I intend to apply these views to some buildings of different requirements I am about to erect. My endeavour will be firstly directed toward means by which the air used for circulation shall be endowed with qualities which will make those buildings comfortable and healthy at all seasons. The air will enter freely into a large chamber in which the whole of the appliances for heating the air, moistening it to obtain an agreeable dew-point, filtering it from dirt and blacks, and finally despatching it, by means of a blower or other mode, at any desired speed, will be carried on.

The details of arrangement for the circulation of air are, in some respects, those already well known, but in others they are of a special character. Great precaution is necessary to avoid any risk of injury to the quality or agreeableness of the air from the mode of heating it; but a chief cause of the difference experienced in the quality of air heated in various ways will commonly be found to be attributable to a neglect of its dew-point.

In conclusion, I submit that in experiment in ventilation we should keep in view, as desirable of attainment, the following:—

1. That the force of the current, the rate of supply, and quantity of air supplied for the purposes of ventilation of dwellings must be entirely under control.

2. That the quality of all the air supplied for ventilation of dwellings should be capable of easy approximation to any condition of temperature and moisture deemed desirable at any season of the year.

3. That greater influence should be exerted upon the circulation of air in dwellings by the apparatus for procuring inflow than by the means for outflow of air.

H. C. Stephens.

Ventilation: Position of Inlets and Outlets.

My object in introducing this subject, which is of the greatest importance if we want perfect ventilation, is that we may have brought before us such facts as are necessary for arriving at a right conclusion on this point.

In the first place, let us see what it is we desire to do. The products of respiration are of such a poisonous character that it is absolutely necessary that they should be allowed to pass away; then we have a certain amount of moisture and organic matter given off from the human frame which, when inhaled, has a most depressing effect upon us; and lastly, there are the products of combustion from lamps, gas, and other sources. The object of ventilation is to get rid of these, and to supply in their place pure air for our further support; for without this fresh supply man would be unable to perform his daily work.

Now these products have all one feature in common: they have all been warmed, and are consequently lighter than the atmospheric air which we wish to introduce and which tends, in consequence of its greater weight, to press them upwards.

This fact alone points out the natural and most economical method of proceeding.

Besides what I have just named there is another class of products which demands our most careful consideration at the present time, and which it would not be wise for us as Sanitarians to overlook. I refer to the volatile emanations met with in hospital wards, especially those set apart for infectious diseases; it is most desirable that these germs of disease should be carried away as speedily as possible, and with the least opportunity of contaminating the air of the rest of the room, and more particularly that which has yet to be breathed.—*See* Dr. R. Angus Smith ("Air and Rain," pp 491 and 492).

I think it must be clear to all thoughtful minds that the top of a room is the proper place for the outlet; this has been practically acknowledged, the difference of opinion varying more on the position of the inlets. The general objection to introducing air at the bottom of an apartment is the draught which has to be encountered. There have been many ingenious methods devised to overcome this difficulty, or rather to shirk it by endeavouring to obtain the same result by a roundabout process; they consist of various contrivances for admitting the air either at the windows, the sides of the room, or at the top; in every case above the breathing point, and with an expectation that the air would become diffused before reaching the people below. The objections which it must be plain apply to all these systems of introducing fresh air above the breathing point are these:—

1st. The diffusion is not always complete, the air often coming down in one column, to the inconvenience of those beneath.

2nd. When the air is admitted near the outlet, it is apt to be drawn out at once with the vitiated air; it may cause a little circulation at the top of the room, but leaves the bottom part nearly stagnant.

3rd. (And this I consider of the utmost importance.) The incoming air while becoming diffused with the air of the room is in reality undergoing a mixing process with the vitiated air which is ascending from the occupants, so that you cannot in this case obtain *pure air*, but a mixture of *pure* and *vitiated*.

In a room where you can admit a very large quantity of air at about the same temperature, this is not objectionable (except in hospitals, where in no case should the air be admitted above the beds, when it is intended to carry it away at a higher level), but this method becomes a very expensive one when the air, as in winter, is of a much lower temperature, and it is desirable to ventilate a room with the least quantity of air possible.

My investigations and experience have led me to the conclusion that the air can be admitted in ordinary cases at the bottom of the room, below the line of respiration, and that without the slightest

inconvenience. This I believe to be the natural system and certainly the most economical, as well as being the one which gives the most satisfactory results.

During the last winter, which was an exceedingly severe one, I introduced air directly into a number of rooms by the skirting, having cone-shaped openings. These were not supplied with valves, so that in no case were they closed, neither was the air warmed by warming apparatus, and yet it did not attract attention or elicit the least complaint.

If the current of air be reduced in its velocity by being duly regulated, or, what is better, by the shape of the openings, which cause it to be quickly diffused, then it can be admitted at a much lower temperature than is otherwise practical. This may even be carried to the extent of it entering at freezing point, as I have proved for weeks together, without experiencing any unpleasant movement. Further, the air at this position may be readily warmed by hot water or steam pipes placed in front of the openings, without that dryness which is felt when it is passed through a heated chamber.

J. E. Ellison.

Sir Antonio Brady next gave some explanations of how his house is provided with warm air.

Dr. de Chaumont mentioned that the bricks with conical openings, described by Mr. Ellison, had been placed in the wards of the General Lying-in Hospital, York Road, Lambeth, under the supervision of Mr. Eassie, C.E., and himself. The plan seemed to promise well as a means of renewing air without draught and introducing it in the proper part of the room—viz., below. Sufficiently high temperature would have to be provided by hot water pipes over which the entering air would pass; at the same time these openings would, like any others, be subject to the effects of wind, and might become outlets if they happened to be to leeward.

The President said that the plan of introducing warm air by means of the kitchen was good for small houses, and was suggested by Mr. Tredgold, but thought it could not apply so well to large houses. He then called for a vote of thanks to Mr. Ellison; who, in reply, stated that he did not object to the fresh air being admitted into a room above the breathing line when you could afford to introduce a large quantity of air at about the same temperature, though this arrangement has the objection that the fresh air becomes contaminated by diffusing with the vitiated air at the higher part of the room; but in cold weather, when it was not desirable to admit more air than was strictly necessary, the best result was obtained when it was introduced at the bottom of the room, and the vitiated air allowed to make its egress at the ceiling. This was most in accordance with natural law, and therefore the method which, when possible, should in all cases be adopted.

The President made some remarks showing that the best means of ventilating buildings is a very difficult problem, and suggested a plan for introducing fresh air under the floor to the grate, and so warmed before entering the room. On the whole, the President agreed with Mr. Ellison.

On the Necessity for an Improved System of Ventilating, Heating and Cooling Crowded Human Habitations or Places of Assembly; especially in Hot Seasons or Climates.

Illustrated by an example in the shape of detailed plans of a Model Barracks.

EPITOME.

THE first half of this paper is devoted to showing up the mistakes made by architects pretending to understand the "Exhaust System," as they phrase it; yet everywhere making air-passages that do not exhaust foul air, but contrariwise admit fresh air, too often when and where it is not wanted and far above the necessities of the case.

The last half is simply a statement of the leading points of the internal arrangements for heating, cooling, and ventilating, as seen on inspection of the plans.

[The plans were exhibited and described].

JOHN BALBIRNIE, M.A., M.D.
Member of the Council of the University of Glasgow.

Dr. Balbirnie's paper was illustrated by a numerous set of diagrams, but time would not allow of an explanation of them all.

At the end of his paper, the CHAIRMAN called upon DR. DE CHAUMONT, who spoke at some length, and pointed out many difficulties in constructing barracks on the plans suggested by Dr. Balbirnie. He paid a tribute of praise to the great care and labour bestowed upon the subject by the author, as shown by the elaborate diagrams he exhibited. He evidently had the improvements of barracks, hospitals, schools, &c. very much at heart, and had worked at the subject with enthusiasm. At the same time, Dr. de Chaumont did not think that the plans proposed would accomplish the desired end. It was a return to the construction of vast palatial buildings which experience had shown were both very expensive and also unadvisable in a Sanitary point of view. This was especially the case in the tropics, where the health of troops had been found to be greatly improved by scattering the

force in small buildings over a wide area. The arrangements of the individual rooms in Dr. Balbirnie's plans were objectionable, as they were side by side opening off a corridor. This resembled the arrangements of the permanent barracks at Aldershot, which Dr. de Chaumont had himself shown to be unfavourable for ventilation; it also resembled the mode of construction of Netley Hospital, the disadvantages of which he had daily opportunity of observing. Dr. Balbirnie's plan of ventilation, consisting as it did of an exhaust shaft, something on the plan of Sir J. Jebb as employed in Pentonville Prison, was one which could not be recommended. Dr. de Chaumont had practically tested the ventilation at Pentonville, and had found the result not satisfactory: the cells near the shaft were moderately well ventilated, whilst those further off were less so, and at the end of a wing the influence was practically *nil.* At present, independent ventilation for each room was apparently the best for barracks, and is undoubtedly essential for hospitals, the principle of whose ventilation ought to be the complete independence of each separate ward.

The CHAIRMAN then called for a vote of thanks to DR. BALBIRNIE; which he acknowledged, and replied to the remarks of Dr. de Chaumont, contending that the barracks he had proposed were in all their Sanitary arrangements, ventilation, heating of rooms in cold climates, and cooling them in hot countries, based on and in strict conformity with scientific principles enunciated by a Committee of Hygiene appointed in Paris for the service of the hospitals—that barracks implied and required precisely the same Sanitary conditions. The grand factor of a perfect ventilation was an "exhaust" chimney, or *aspiration* maintained by heat of fire or gas jets in the *cheminée d'appel.* That architects in England had but very partially turned their attention to this; and scientific men were prejudiced against it—entirely without foundation. The day would come that his plans of barracks, Board school, and hospital would be hailed as an immense improvement in all respects over the best buildings of the sort ever yet constructed.

The Necessity for a Permanent Registration of House Drains.

THE efforts of all who appreciate and promote the great branch of our art termed "Preventive Medicine" are directed towards creating throughout the length and breadth of the land a *systematic control* over all agencies and means known to generate or spread diseases which ought not to exist. The lower and middle classes have yet to learn to identify these diseases as results from their own infringement of nature's laws; but in this assembly no demonstration is needed to justify the assertion that for conveying from house to house, and consequently spreading from individual to individual, some of the most to be dreaded diseases, no agency is more powerful than defective sewers or house drains. Being so potent for evil they rank as one of the most important parts of a dwelling-house, and it follows that the aim of Sanitarians should be directed, not alone to secure a high degree of perfection in construction, but to provide means for *subsequent supervision* Admirable as are the regulations of the Local Government Act, it stops short of this latter point; it provides that plans of all new buildings must be submitted to the vestry or local authority; these after discussion by committee are further examined by the district surveyor; if he approves, the work is inspected, passed, and there supervision and record ends; the building when erected changes hands, possibly half-a-dozen times in as many years, and all remembrance of the course and position of the main drain is lost.

No need may arise for inquiry on this point till possibly sickness invades the house, sickness of such a type as to cause the medical man to inquire, "Can there be anything wrong with the drains of this house?" "Can there be any defect of construction, or is there any weak point which the time elapsed since the building was erected has developed?" The extent of information obtainable is in many cases reached by the master of house replying, "Oh, I don't think there can be anything wrong; I was assured by my predecessor all was perfectly right." But *where* does the house drain run? *Aye, where?* does it pass *under* the house? down the garden into the main sewer in front? or into the drain of the neighbour's house on the right, or that on the left? Cannot tell! Where are the plans of the house? Gone the way of all plans; nothing for it but dig, root, and explore in the most probable position, to the great detriment of garden, pleasure grounds, or such like.

Now this is not as it should be. The health of a house depends on the drains being pure; they must, from the nature of things, be hidden from sight; they will at some time or other require to be opened, therefore there should be a *permanent record* of their position, corrected at any time of change or alteration. The machinery for this is at hand. The plan to be effected *must be compulsory!* It is, that the local authority, vestry or board provide and keep up a *permanent register* of all drains, pipes, and channels of communication between a building and the sewer into which it drains. When the district surveyor approves the plan of a new building, he should append his signature to it, and this plan should then be inserted into a book, with a proper index, and retained for reference in the office of the local authority; half a dozen lithographed copies of this official plan should be handed to the owner of the property, and he should be required to affix one of these copies to the lease, agreement, or whatever form of document conveyed possession of the building to another.

By this means the owner of a house could at any time subsequent to the erection, ascertain without difficulty the exact position of the drains, and know precisely where to direct operations for examination of the same.

But not alone would it benefit one in possession, in the event of seeking to dispose of a dwelling-house, what an advantage for a hesitating purchaser! Unquestionably he would much prefer accepting one with which he received a certified copy of the drainage scheme, and on which he might obtain the opinion of a competent Sanitary engineer. Again, in the case of an epidemic invading a district, and necessity arising for a Government inquiry, what an immense assistance it would be if the commissioner or board of inquiry could have placed before them certified plans of the drainage of every house in the district under examination.

It may be objected that if this proposition were carried out, great space would be required to lodge all the documents; that as there are about forty thousand houses and warehouses erected annually in London district alone, these plans accumulating annually would be cumbersome. This is an objection which can carry little weight in comparison to the probable good. A central establishment might receive the records every five years, and the local officials keep outlines of same on Ordnance maps for daily reference. As to the outlay, it might be met by a slight fee for registration, and also for subsequent examinations, which fee might be increased according to the number of years elapsed since the first registration was received.

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