SECTION III.

PHYSICS, CHEMISTRY, AND BIOLOGY.

ADDRESS

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WITH the same regularity as the return of the seasons, the Annual Congress of the Sanitary Institute has again come round, bringing with it the large attendance of those devoted to the aims of this influential and useful organisation.

The perennial success of these Congresses is in itself eloquent testimony to the living interest which sanitary matters claim in this country; and there can, indeed, be no doubt that "cleanliness and godliness" are being brought into closer and closer juxtaposition by an ever-increasing section of the community, and I think the Churches may not unreasonably fear that the traditionally smaller of these two virtues will perhaps ere long take precedence of the greater in public estimation.

It is necessary that we should distinguish between the place taken by sanitation and by sanitary science in the eyes of the public; for whilst we may congratulate ourselves that in matters of practical hygiene we are unquestionably the leaders amongst the peoples of the earth, in sanitary science proper we unfortunately occupy a much less prominent position. Thus I have myself been in small towns on the Continent which rejoiced in the possession of a University Professor of Public Health and a Hygienic Institute, putting to shame anything of the kind existing at the time in the whole of our own country, but in which the practical sanitation would have outraged the feelings of even the most ignorant of our Rural Authorities.

In this Section of the Congress we are more than in any other interested in sanitary science rather than in practical sanitation, and it is of the highest importance, therefore, that we should exert ourselves to place England on a better footing

as regards the instruction given, and especially as regards the prosecution of research in the science of hygiene.

To those who have seen the magnificent opportunities afforded for study and original investigation in sanitary science on the Continent it is a matter of humiliation to reflect how inadequately we are provided with similar institutions in this country, and how steadily we are losing our reputation as pioneers in this department of knowledge.

Sanitary science, like the other sciences, is languishing in this country, not for want of men of capacity, for these we undoubtedly have, but simply because science does not appeal either to the ruling classes or to the masses of this empire. We are languishing for want of money, of which pence are grudged for higher education and research, where pounds in thousands are readily conceded for ironclads, torpedo-boats, and other warlike material. Far is it from my intention to deprecate the expenditure of money on what are still—and what will, in my humble opinion, long remain—the obvious necessities of imperial dominion; but if the same liberality be not extended to the promotion of higher knowledge and discovery one of our chief prerogatives and titles to such dominion will disappear.

Those who hold the purse-strings of this country have got to learn—and that without any further delay—that the progress of science is, even for political and commercial reasons, of as much importance as the perfection of our imperial defences, and that such progress forms, indeed, a national bulwark of equal strength, although invisible to the vulgar eye. It must be further recognised that the prosecution of scientific research is becoming annually more costly, and entails the provision of specially favourable conditions; that, in short, it depends no longer upon the man alone, but, also upon his opportunities and general environment.

These are matters which, curiously enough, appear self-evident in other countries, but cannot be sufficiently reiterated in our own.

As the scope of our section practically includes the whole of sanitary science, or the ultimate principles on which the entire practice of hygiene is based, it is obvious that our horizon is a very wide one, and that it is only possible in an address, such as that which I have the honour and privilege of delivering to you to-day, to touch upon a few of those matters in this vast field with which I happen to have come more particularly in contact myself.

One of the great engines in this country for the advance of general knowledge and of public opinion on many matters, is unquestionably the Blue-book of a Royal Commission or of a

Departmental Committee. The average Englishman believes in the contents of such volumes bound in blue paper with the same unquestioning and childlike faith as he accepts the verdict of a jury of twelve men, as to whose names, attainments, character, and position he is as ignorant as he is indifferent. To doubt the inspiration of a Blue-book, and to go behind the finding of a jury are to him two forms of heresy which strike at the foundations of British society, and merit, therefore, the severest condemnation, if not the most drastic punishment.

There can be no doubt that both are on the whole excellent institutions, and it is far from my purpose even to attempt to drag these idols from their pedestals, for in matters affecting hygiene and public health, the Blue-book has almost invariably been a beneficent agency, and it is only to be regretted that the actual powers of the commissioners and committeemen who compile the contents are limited to commanding outward respect, whilst their recommendations generally receive the same treatment as that which we are all in the habit of according to so much excellent advice which is daily offered to us by our neighbours.

In matters connected with hygiene and public health, the past year has been remarkably fertile in this inspired and blue-bound literature, for no fewer than three reports of three separate Committees have been issued, and the contents of each cannot fail to be of interest to the members of this Congress.

The matters dealt with in all three cases are in one respect of a similar character, for in each the Committee was requested to investigate an alleged conflict between certain industrial interests and the interests of hygiene.

In one we have a conflict between the interests of the gas manufacturer and the safety of the general public, in another a conflict between the interests of pottery manufacturers and the health of their employes, whilst in the third, again, it is an antagonism between the interests of the manufacturer of lucifer matches and the health of the work-people which forms the subject of enquiry.

The first of these enquiries is obviously the one which is of widest interest, affecting as it does practically the whole of the general public. This enquiry has been provoked by the recent introduction of modifications in the process of gas manufacture, leading to the circulation in many of our towns of an illuminating gas, appreciably richer in carbonic oxide, which, as is well known, is the most poisonous constituent of ordinary coal-gas. The enquiry is, in some respects, a very remarkable one, for it is admitted on all hands that the actual risk to the individual by this increased proportion of carbonic oxide is almost infinite.

simul, and it might therefore at first sight be thought hardly worth while to make this a subject of elaborate investigation. I believe, however, I am right in thinking that there is something fundamentally repugnant to an Englishman in the idea that even a single life should be unnecessarily sacrificed; it is an injustice to the individual, and injustice to a single unit is as opposed to our instincts and traditions of fair-play and equity as that which effects a whole community or even an entire race. Indeed, in some respects such individual injustice appears even more intolerable to British sentiment than an injustice affecting many.

The danger involved by the admixture of water-gas with ordinary coal-gas was investigated by a particularly competent committee, which actually numbered amongst its members one scientific man, Dr. Haldane, F.R.S., who had already previously devoted his attention with success to the subject.

A large amount of interesting information was collected by the committee, which is to be congratulated on having taken up a strong position in respect to this growing danger to the community entailed by the admixture beyond certain limits of water-gas to the ordinary household illuminant.

It has been conclusively shown by Dr. Haldane that, given equal conditions as to size of room, ventilation, flow of gas, and length of time to which a person is exposed to an escape of gas, the danger to life from such an escape is far greater in the case of gas containing any considerable proportion of water-gas than in the case of ordinary coal-gas. In fact, the really important point to bear in mind is that the danger increases at a much greater rate than the proportion of carbonic oxide; or, in other words, that a gas containing twice as much carbonic oxide as ordinary coal-gas is much more than twice as dangerous as the ordinary coal-gas itself.

In the opinion of the committee, convincing evidence of the danger attending the distribution of gas rich in carbonic oxide is to be found in the mortality statistics of Massachusetts. These figures show that in Boston—

1886	no water-gas	29,554 gas consumers	0 casualties.
1890	8 $\frac{1}{2}$ %	46,848	6 deaths.
1895	90 $\frac{1}{2}$ %	68,214	24 "
1897	93 $\frac{1}{2}$ %	79,893	45 "

These figures show that the unrestricted development of the water-gas industry must be viewed with grave apprehension. Fortunately there is not the same commercial advantage in this country for the substitution of water-gas for coal-gas to the extent which this has already taken place in America, and it should, therefore, be the more easy to control the proportion in

which it is distributed. The committee suggest that the distribution of gas containing more than 20 per cent. of carbonic oxide should be prohibited, a limit which would roughly correspond to a mixture consisting of equal parts of coal-gas and carburetted water-gas.

The question of the practical danger attending the distribution of water-gas is not a little complicated by the fact that a considerable number of the fatalities to which I have referred as having taken place in Boston were due to suicide—not to accident. Thus, whilst this circumstance shows that the danger from accident is less than would be indicated by the total number of deaths, it demonstrates, on the other hand, that a particularly seductive instrument of death is being distributed broadcast amongst the population.

The legislature of civilised countries interferes in the matter of the distribution of deadly poisons, solid and liquid; but perhaps it is too much, even at the close of the nineteenth century, to expect our rulers to possess sufficient scientific education to take cognisance of an invisible gas.

The other two Blue-books of sanitary interest, which deal with the dangers of the pottery and match industries respectively, may be perused with the same fascination as a number of the *Wide World* or the *Strand Magazine*; indeed, they might be advertised as readable from cover to cover. This is, however, not surprising when it is borne in mind that the contents of both are largely the work of Dr. Thorpe, whose high scientific attainments are so well known to be combined with an unusual degree of literary skill.

The inquiry into the employment of compounds of lead in the manufacture of pottery has revealed the fact that a very large number of operatives in this industry are victims to that subtle form of disease known as plumbism or lead-poisoning. Thus it appears that in the North Staffordshire district alone there were, in July 1898, 3,123 males and 1,580 females employed in processes where lead is used in the manufacture of earthenware and china; and that during the three years from 1895, when the Compulsory Notification Act came into force, there were no less than 1,085 cases of plumbism actually reported, 478 of these having occurred amongst men, and 607 amongst women; or, of the workers engaged in 1898 alone, 4.9 per cent. of the men and 12.4 per cent. of the women became so palpably affected with lead-poisoning during the year that they were actually reported to the inspector. These figures speak for themselves, and show that we are here face to face with an evil which the policy of *laissez-faire* and the principle of free contract can no longer be allowed to foster and promote.

Dr. Thorpe and his colleagues are not content, however, merely to point out the existence of this evil and its magnitude, but they have given the most careful attention to the possibility of mitigating, and, if possible, of wholly abolishing it. In doing so they have very fully considered the claims of industry; and their conclusions, which are most clearly and emphatically formulated, must be welcome reading to all who are interested in the welfare both of the workers and of the industries which have created them. Thus Dr. Thorpe and his colleague "have no doubt whatever that leadless glazes, of sufficient brilliancy, covering power, and durability, and adapted to all kinds of table, domestic, and sanitary ware, are now within the reach of the manufacturer. There are, however, certain branches of the pottery industry in which it would be more difficult to dispense with the use of lead compounds. But there is no reason why, in these cases, the lead so employed should not be in the form of a fritted double silicate. There can be little doubt that if lead must be used, the employment of such a compound silicate would greatly diminish the evil of lead-poisoning."

Further, Dr. Thorpe and his colleagues have had the courage to touch upon a question of enormous importance and extreme difficulty, viz., the propriety of prohibiting female labour in those parts of the pottery industry in which contact with lead is unavoidable. There appears to be no doubt that women are more susceptible to lead-poisoning than men, and that plumbism is attended with particularly disastrous consequences in the matter of producing healthy offspring. This is indeed so well recognised that at certain pottery works in Belgium there is a rule which is rigidly enforced, that the women engaged at these works lose their employment on entering into the matrimonial contract. All interference with the so-called rights of women is of course especially difficult in an age in which a powerful agitation is going on to place women on exactly the same footing as men in every particular. Now, whatever may be our views, sympathetic or otherwise, with regard to many aspects of what should, I suppose, be called the "Woman's Movement," we, as members of this Congress, which is devoted to the promotion of the public health, must be agreed that any rights, either of men or women, which are opposed to the welfare of future generations must be sacrificed without either hesitation or remorse. I take it that we are all at one in firmly believing that our most solemn duty is to see that our offspring shall, as far as lies in our power, be placed under more favourable surroundings, and have a better chance of healthy development than we ourselves have individually enjoyed. But the health and welfare of posterity is so intimately

connected with the conditions under which women and especially mothers live and carry on the most important industry of all—the production of men—that I venture to say that future generations will laugh to scorn our much vaunted civilisation of the Victorian Era, in which the State, whilst concerning itself with what will be regarded as all sorts of comparatively trumpery hygienic reforms, has almost entirely neglected the all important one of guaranteeing that each person entering this world shall do so under conditions which shall be a legacy, not only to the individual, but to humanity throughout all ages.

In recommending State interference with female labour, this Blue-book on the Pottery Industry will serve to show future generations that in the 19th century there were, at any rate, some who recognised, however dimly, the direction in which the most important of all hygienic reforms would some day be carried out.

This Blue-book has already produced some practical result, and it was with particular satisfaction that I read only a few days ago an advertisement for a large consignment of earthenware goods, in which the absence of a lead glaze was expressly stipulated.

Let us now turn to the third Blue-book of the year, which deals with the use of phosphorus in the match industry.

Here again we have evidence of mischief, much more terrible in its nature than that of lead-poisoning, done to human beings through an industrial occupation. As is well known, the unhealthiness of the match industry depends upon many of the workers being exposed to phosphorus fumes, which exposure may give rise to necrosis of the jaw, a most painful and loathsome malady, which, even when it does not end fatally, leaves the sufferer more or less permanently disfigured.

It has been found very difficult to obtain reliable statistics as to the danger attending the match manufacture, as it is notorious that many cases have been suppressed, a leading firm having but quite recently been convicted of this cowardly and criminal proceeding. As far as the statistics go, however, it appears that in the United Kingdom there were in 1897–8, 1,521 persons engaged in processes involving phosphorus exposure, whilst, during the five years, 1894–8, thirty-six cases of necrosis have become known. Dr. Thorpe and his colleagues, however, emphasize the fact that prior to the last year or two, the records cannot be regarded as at all complete, and the above number of cases of necrosis is, therefore, doubtless very much below the truth. But when the horrible nature of the malady is taken into consideration, even the mischief indicated

by the recorded figures represents a heavy responsibility, which weighs upon the match manufacturer and the match consumer alike.

As in the case of the pottery industry, so again here; chemical science has not been found wanting in ability to devise means of obviating the mischief, for the discovery of so-called amorphous phosphorus already in 1845, placed at the disposal of the match manufacturer a material which is entirely free from the dangers which surround the handling of the ordinary form of phosphorus. This amorphous phosphorus is, moreover, available for the manufacture of safety matches, which were invented in the same year, and were first made in this country in 1855. Even at the close of the century, however, the production of safety matches is quite an unimportant industry in this country compared with that of the "strike everywhere" match. The public can no longer plead ignorance as an excuse for demanding an article which annually causes terrible suffering and disease to a section of the producers, for the matter has on a number of occasions been well ventilated in the daily press; so that the newspaper-reading Englishman, and as far as my experience goes, the average Englishman reads little or nothing else, is well aware of the hideous selfishness of which he is guilty in purchasing any other form of match than the "safety." In this matter, as in many others, Switzerland leads amongst the nations, for within the territory of that little republic, the use of any matches excepting "safeties" is absolutely prohibited.

It is earnestly to be hoped that the admirable reports of Dr. Thorpe and his colleagues, on the mischief incidental to the manufacture of the common match, will lead the public to direct their serious attention to the removal of this scar on our civilisation. Meanwhile it is the obvious duty of every individual making any pretensions to the possession of a conscience, to forthwith banish for ever the common match, both from his house and his pockets. I would in this matter address my appeal especially to the fraternity of smokers, who are by far the largest consumers of matches, and I fear also the worst offenders.

The publications on water-gas, on pottery, and on matches, to which I have referred, show that chemical science has recently been most successfully enlisted in the service of hygiene, and, if only our legislators and the general public will act upon the carefully-considered recommendations which have been formulated by the eminent men of science to whom these investigations were entrusted, there can be no doubt that

another step will have been made in our victorious advance into the territories of disease, suffering, and death.

This section of the Congress is, however, also concerned with the applications of biology to sanitary science, and, with your permission, I will now proceed to say something of this side of the subject. Here, again, it is necessary that I should limit my observations to the discussion of a very few points with which I have been more especially brought in contact myself.

The department of biology which has for a number of years now been most prominent in its connection with public health is, of course, bacteriology; although recently biological investigations altogether unconnected with bacteria, such as the wonderful researches of Calmette and others on snake poison, have shown that there are other directions in which biological science can be of signal service in diminishing the dangers with which life is surrounded.

The science of bacteriology is now so firmly established in public estimation, and its utility to man is so fully recognised, that it is no longer necessary to introduce it with an apology, nor does its mention now evoke the smile of contempt which some of us can well remember on the faces of our audiences, when both the science and we ourselves were but some ten or fifteen years younger than we are to-day. Time and ceaseless toil beget lines and wrinkles, which impart dignity and command respect; and this has been the case with bacteriology. Its reputation is assured, although much of the elasticity and hope of its youth have gone. Some of the expectations which were entertained of this new science have proved illusory. Take, for instance, the application of bacteriology to the hygienic aspects of water supply. How many enthusiasts for the new science thought that a revolution in our methods of dealing with the problems which present themselves in connection with water supply was at hand, and that the guarded opinion of the chemist recommending or condemning the use of water, on review of all the circumstances connected with it, would be substituted by the authoritative pronouncements of a bacteriologist, who would be able to declare, "This water is absolutely safe, because it is free from all pathogenic bacteria," "This water will cause cholera," and "This one typhoid," &c. Far from the introduction of bacteriological methods having proved the dawn of such a new era as was anticipated by the sanguine and misguided enthusiasts in question, time and the more careful study of micro-organisms have shown the insuperable difficulties in the way of arriving at any such clean-cut and definite conclusions. Indeed, the detection of specific pathogenic bacteria in drinking water is now known to be almost

beyond the range of practical politics, and the search for such bacteria is, in general, only carried on in deference to the special request of the layman, the uninitiated, or the hopelessly ignorant, whilst it cannot be repeated often enough that any feeling of security which may be gathered from an unsuccessful search for pathogenic bacteria is wholly illusory, and in the highest degree dangerous. Notwithstanding these misconceptions, which still linger long in places, the real and great value of bacteriology to water hygiene is now very generally recognised.

By far the most important service which has been rendered by bacteriology in this connection is the means which it affords of controlling the efficiency of filtration and other purification processes. Such bacteriological control is now systematically and regularly exercised at a number of our more important water-works where filtration is carried on, and the result is a highly beneficial one, as the slightest irregularity or defect in the process of filtration is at once laid bare, and brought to the notice of the engineer in charge. The water engineer has now a standard of efficiency to aim at, and receives a stimulus and encouragement in his work, the former absence of which must have been in the highest degree disheartening.

The bacterial purity of well-waters can also be satisfactorily controlled, any departure from their normal character being at once detected, whilst again the great bacterial improvement which surface waters undergo by storage and sedimentation has been ascertained, and has led to the further extension of this important means of purification.

Again, the water expert is now being guided in the formation of his opinion by the qualitative nature of the bacteria which he discovers; the presence of indol-producing bacteria, and bacteria which grow in broth and jelly containing a certain proportion of phenol, affording indications of considerable value to the skilled and experienced observer.

In short, the bacteriological methods which some of us welcomed fifteen years ago as invaluable adjuncts to the chemical methods of water examination, have brought forth abundant fruit, and have been of the greatest assistance in that work of making provision against water-borne disease, which was first inaugurated on scientific lines by those classical labours which are recorded in the Sixth Report of the Rivers Commission in 1874, and form a landmark in the hygienic annals of the present century.

From the bacteriology of water we have in the last few years passed to the bacteriology of sewage, and hardly a day goes by without opinions being publicly expressed with regard to the

bacterial purification of sewage. From the terms in which the majority of persons discuss this subject, it might be supposed that the bacterial purification of sewage was a discovery possessing the same kind of novelty as the Röntgen rays or wireless telegraphy, whilst as a matter of fact, of course, practically the only purification of sewage which has ever taken place in the past, or ever does take place at present, is entirely due to bacterial action; in short, we have been all along bacterially purifying sewage, like M. Jourdain spoke prose, without knowing it.

Again here, as in the case of water hygiene, it is to the work of the Rivers Pollution Commissioners of thirty years ago that we must turn, not only for the first indications of how sewage purification should be carried out on scientific lines, but for the most complete instructions as to how the real purification of sewage must be conducted.

The classical investigations of the Rivers Pollution Commissioners showed already a generation ago that the purification of sewage by chemical means alone is an *ignis fatuus* and a chimera, but that by distributing sewage over porous materials, which are alternately bathed with the sewage and atmospheric air, a degree of purification is obtainable which a generation of eager investigators has been unable to improve upon.

The extraordinary possibilities of purification attained by land irrigation and intermittent filtration were fully established before the advent of bacteriology, and this new science has not given us any new method of sewage purification at all, but has only furnished the explanation of the marvellous achievements described in the Reports of the Rivers Pollution Commissioners.

If then the purification of sewage through the agency of porous surfaces had been fully established before the work of Pasteur, Schloesing, Müntz, Winogradsky, and many others, had revealed the essential factor in these porous materials to be the legions of bacteria with which these materials are swarming, what is the novelty attaching to that which at the present moment is commonly understood by the bacterial treatment of sewage?

The important departure which has been recently made and with which we especially associate the name of Mr. Dibdin, is not the discovery of a new principle of sewage purification, but the adaptation of an old and well established one.

The merit of this important new departure lies in its providing for the display of the activities and powers of these countless legions of bacteria a more suitable field than that which is afforded by the natural soil in which they had formerly been constrained to carry on their operations.

As so distinctly pointed out by the Rivers Pollution Commissioners, it is not only necessary to have soil of a suitable character for the efficient purification of sewage, but this soil must be supplied with a sufficient quantity of air. Now, the adequate aëration of ordinary soil is always more or less a matter of accident, is difficult to regulate, and requires a very considerable amount of time, owing to the close texture of the material. These difficulties have provoked the attempt to obtain the bacteriological purification of sewage more expeditiously and under more perfect control by substituting artificial beds of porous material for the soil—always more or less haphazard in character—which Nature provides. The advantages gained by the use of such artificial beds in place of the application of sewage to land are almost comparable to those which are realised by the substitution of steam for wind and water power. The gain is in compactness and manageability of the machinery involved, and not in the amount of energy required to produce a given result.

The degree of purification, again, can be more perfectly regulated than in the case of land treatment, for if the purification achieved in a single bed is not sufficient the effluent can be brought in contact with a second, and even a third or a fourth; and, again, the number of such contacts and the length of time during which the beds are allowed to remain idle for aëration can be varied according to the variable nature of the sewage which has to be dealt with in different places, or even at the same place during the twenty-four hours and at different periods of the year. In short, we have in these bacteria beds a very beautiful piece of biological machinery, which, however, like all delicate appliances, requires careful management, and is subservient to the law of the conservation of energy. It cannot perform the impossible, and all attempts to exaggerate its powers will only check progress and bring it into disrepute.

It does not either follow that such artificial beds for inducing the bacteriological purification of sewage are the best adapted for use under all circumstances. The more delicate the machinery, the more careful is the management required for its successful operation—and such management, of course, involves expense. Thus, whilst in the case of large towns the provision of an adequate area for efficient land-treatment is often an insuperable difficulty, and the additional cost involved in managing bacteria beds a minor consideration, there are many smaller places where land in plenty and of suitable character can be inexpensively obtained, and where consequently the construction of artificial beds, with their more costly management, would be a move in the wrong direction.

The bacteriological purification of all refuse organic matter has, since the classical researches of Pasteur on the functions of bacteria, been known to take place in two phases, of which the first consists in the breaking down of complex organic compounds by bacteria, which flourish in the absence of air, and were named by Pasteur *anaërobic organisms*; whilst in the second phase the process of purification is completed by the agency of bacteria requiring the presence of air for the exercise of their functions, to which, therefore, the name of *aërobic organisms* has been given.

In the ordinary course of nature, both of these phases of purification are taking place side by side, and are governed by purely accidental circumstances. Thus, if we consider the case of a small particle of solid refuse organic matter, we should find that in the interior of such a particle anaërobic processes were at work, whilst on the surface aërobic bacteria would be exercising their purifying functions. The question naturally arises as to whether it is desirable that these two processes should thus be going on in close juxtaposition, or whether it is not more advantageous to provide the conditions most favourable for the first class of bacteria in one place, and the conditions most favourable for the work of the second class of bacteria in another.

It is obvious that the indiscriminate mingling of different classes of operatives in one place is entirely opposed to the principles of organisation which are universally adopted in all industrial establishments. If we go into any well-conducted manufactory, we shall find each class of the employes carrying on their particular work in a separate room, or even in a separate building altogether, and only in an ill-regulated establishment do we see the different classes of workmen jostling each other, and interfering with each other's duties.

In the purification of sewage, similarly, the necessity is more and more forcing itself upon experts of adopting the usual industrial plan of separating as far as possible the different classes of the myriads of microscopic hands which a sewage works has in its employ, and of providing for each a separate and suitable place in which they can carry on their particular line of business without interference.

The recent experimental work on the bacterial treatment of sewage, which has been conducted with a thoroughness and an attention to detail quite unprecedented in the history of sewage purification, shows most conclusively that the best results are achieved by separating the phases in which the bacterial purification takes place, allotting distinct premises to

the anaërobic and the aërobic organisms respectively engaged on the works.

We are all aware of the difficulties attending the management of human labour, these difficulties being one of the great social problems of the day, but no less harassing difficulties are encountered in the management of the microscopic artisans of the sewage works. The anaërobic bacteria are supplied along with the sewage, and practically no difficulty arises in retaining their services on the works, beyond that of providing them with space and time in which to carry on their labours; the aërobic bacteria, however, demand air in addition to space and time, and if this air be not provided in sufficient quantity, they go on strike and leave the works, their place being taken by their less exacting anaërobic brothers who are, however, unable to finish the work of purification. There is thus the constant tendency for the overflow of the anaërobic bacteria into the aërobic department of the works, if there be any stinting of the air in the latter. In order, therefore, to insure the services of the aërobic bacteria being retained on the premises, it is desirable to provide for the aërobic bacteria at least two workshops through which the sewage, on coming from the anaërobic department, is made to pass. The first of these aërobic workshops it may be difficult to always provide with adequate ventilation, the result being that both anaërobic and aërobic bacteria will here be found competing with each other, and that the aërobic bacteria will be unable to finish the work of purification. The sewage, however, on passing into the second and better ventilated workshop, will there fall almost exclusively into the hands of the aërobic bacteria, which it will under proper management, leave as an inodorous, almost pellucid liquid incapable of putrefaction.

This is, in outline, the method of septic treatment, followed by double or even multiple contact on bacteria beds, which would appear to constitute the most rational principle on which to organise those bacterial legions which nature so lavishly provides for the destruction of refuse organic matters.

The modern sewage works must, however, not only be prepared to deal with the ordinary or normal contents of the sewers, but those extraordinary volumes of liquid which make their appearance after sudden showers and heavy rain, and commonly go by the name of *Storm Water*, must be provided for and subjected to some purification before discharge into the nearest water-course.

Artificial beds obviously offer particular facilities for dealing with these enormous volumes of liquid, which from time to time come down to the works and demand the immediate attention

of the manager at any hour of the day or night. For the artificial beds being under perfect control, the quantity of liquid which can be passed through them in a given time admits of regulation with the greatest nicety. At first sight it might be supposed that this storm water, being the ordinary sewage plus a large volume of rain water, would be a very weak sewage, and that it could, therefore, be sufficiently purified by passing it at a comparatively high velocity through the bacteria beds. Experience, however, shows that for some time after the commencement of a storm, the increased volume of sewage is by no means exceptionally weak, but, that on the contrary, it brings down with it a large amount of highly polluting solid matter, the washings of the streets and sewers, which is calculated to have a most prejudicial effect on the beds. It is, in fact, only after the rain has been falling for some time, the length of which depends upon local conditions, that the storm water becomes dilute, and that it can safely be subjected to an accelerated process of purification.

These circumstances point unmistakably to the necessity of very carefully purifying the first instalment of storm water, instead of hurrying it at once into the nearest stream, as is the general practice at present. The exact manner in which this first instalment of storm water should be dealt with must be regulated by local considerations, but a reasonable plan of action would consist in providing a sufficient spare tank capacity to impound the necessary volume of highly polluted storm water, to then deal with the weak storm water on the bacteria beds by accelerated treatment, and finally, when the storm is over, to purify the impounded first instalment at leisure, by gradually adding it to the normal sewage flow.

I have, however, already trespassed long enough on your patience in the matter of this subject of sewage purification, but I would plead its ever-increasing importance and urgency in justification of my having done so. From what I have said, however, it will be evident that sewage purification must now be regarded as a fermentation industry, ranking with brewing, distilling, and vinegar manufacture in the nature and complexity of the scientific principles involved, and the skilled attention and control which its successful exercise entails. But whilst the industry of sewage purification ranks in respect of its scientific foundations with the other fermentation industries, it differs entirely from them in one detail, and that unfortunately under the present conditions of society the most important of all. We know that breweries and distilleries are amongst the most remunerative concerns in which investment for capital can be found on the Stock Exchange, but for

the present, at any rate, science is not in a position to extend even the hope that the industry of sewage purification can be carried on at any profit at all. Who shall, however, venture to predict what science, with her limitless possibilities and resources, may not conjure from the lap of the future?

In conclusion I would again repeat—for in this country it cannot be sufficiently reiterated—that it is by the devoted prosecution of those pure sciences with which in this Section we are especially concerned that the health, the wealth, and the happiness of man are advanced and promoted. A single scientific discovery—which to-day may appear of so little importance that it entirely escapes public notice—may within a few years effect a revolutionary transformation in the habits, in the comforts, and in the fortunes of mankind. The present century alone bristles with examples of the most wonderful and unexpected blessings showered upon the world by the application to practical life of discoveries made in the secret interrogation of Nature by the man of science, whose sole object was to raise one small and apparently insignificant corner of that thick and heavy veil which shrouds the unknown.