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OHIO SOCIETY OF SURVEYORS AND CIVIL ENGINEERS.

A PAPER ON

Sewage Disposal and Water Supply,

BY

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SEWAGE DISPOSAL

— AND —

WATER SUPPLY.

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Works of drainage and sewerage are not of modern origin. Many of the famous cities of the ancients embraced methods for removing the sewage as well as drainage from the populous parts of the town, and some of these works exhibit great skill and ingenuity upon the part of the Engineers or Architects who planned them.

Nineveh, Babylon, Jerusalem, Damascus, Carthage, Rome, and many cities of lesser note, appreciating the sanitary advantages of works for the prompt removal of domestic offal, sought to expel from their midst the wastes of civilization by the most ready and certain means at command. Indeed these ancient governments seem better to have understood the essentials of health than those that followed during the so-called dark ages of European history, when many of the now celebrated and populous cities of that country were centers of filth; and the same renaissance in art and architecture which was inaugurated some centuries since can be said to have had its place in works of sanitation, although at a date much more recent than the revival by Raphael of the antique models in art. And the perseverance and ingenuity of modern engineers, in systematizing and perfecting the crude and detached works of the ancients, has contributed much to the advancement of sanitary science.

It should be remarked that these works of the ancients are scarcely to be compared with the sanitary devices of the present day, but this must be attributed rather to lack of skill and materials in construction, than to deficient knowledge of the importance of prompt removal from the habitation or the town of all decomposable organic wastes. Hippocrates, whose birth antedates the Christian era by 460 years, first pointed out the fundamental laws of health, viz.: pure air, pure water, and a pure soil, and so consistently did he observe his own precepts, that he lived to the ripe age of one hundred years.

To impure air may be traced diseases which have their origin in an impoverished or poisoned condition of the blood; to impure water may be traced diseases which attack the lining of the alimentary canal; and to impure and damp soil may be traced diseases of the nature of phthisis and some forms of tuberculosis.

Efficient drainage of the surface and subsoil of the grounds upon which a habitation or city is built, together with sewers which will certainly convey to a safe point all the sewage wastes of a community, combined with the prompt removal and destruction of garbage, will insure pure air to breathe, and a pure soil to live upon. And a public water supply, taking its source beyond the possible reach of contaminating influences, will satisfy the third requirement of health laid down by the " Father of Medicine."

It can be readily understood how personal habits will defeat any general efforts to improve the public health; and upon the other hand how it would be quite impossible for any individual system of sanitation to ward off the dangers from general unsanitary conditions. But, assuming that the mechanical adjuncts of sanitation are duly seconded by personal attention to the laws of hygiene, we will scarcely err in asserting that the most dangerous diseases which beset mankind will be then unknown.

Cholera, typhoid fever, diptheria, phthisis, and all forms of zymotic and enteric disease, can be traced to an utter disregard of the laws of health, or to bad sanitary arrangements of the home or the city. We are all aware that there was a time—not many centuries ago—when filthiness of person was taken as an evidence of virtue, and cleanliness regarded in the light of a crime. Dr. Lyon Playfair, in reviewing the habits of the people of Europe during the dark ages, asserts that "for a thousand years not a man, woman, or child in Europe, ever took a bath." And within a century the sanitary conditions of London and Paris were nearly as bad as at any time in their history.

It is not necessary with an intelligent audience to dwell upon the advantages to public health of the most perfect sanitary appliances. Neither do I think that it is required of a sanitarian to show that the money value of the works he proposes is more than counterbalanced by the improved health and earning power of a community, or by reduced costs for doctors' and undertakers' services, or by the greater number of days which wage-earners will be enabled to devote to their avocations. It is enough to say that without good sanitary works there cannot be good health, and health is wealth, as well as satisfaction in life. Although Mr. Baldwin Latham, one of the most eminent of modern sanitary engineers, is at great pains to prove by a complex and possibly accurate method of reasoning, that in a given instance the money value of the medical attendance, the cost of funerals of victims of diseases traceable to poor sanitation or no sanitation at all, the wages lost by illness of the patients, and occasionally of those forced to neglect their daily work and act as nurses to others, with the increased term of service which wage-earners could expect to have by reason of improved health, when spread through a term of years equal to the time the bonds to pay the cost of such improvement would run, was more than the outlay of taxation for the interest and sinking fund to redeem such bonds.

It is often held by the conservative citizen that the cost of sanitary works is an obstacle to their construction, but when a great work which will enhance the health and comfort of a community is under consideration too much stress should not be laid upon the cost, for "What will a man not give for his life?" And correct sanitation is life, health and happiness. And correct sanitation the world over means the complete extirpation of cholera, typhoid fever, diarrhœa, dysentery, diphtheria, and every other infectious and contagious disease. And if all communities were equally interested in advancing the condition of their sanitary arrangements, our bodily complaints would then be limited to those due to our personal habits.

* * *

On the invitation of your secretary, Mr. Charles A. Judson, I have ventured to present a few remarks on the subject of sewage disposal.

This question, although not confronting us with the serious aspect that it presents in many of the densely populated centers of Europe, and in a few peculiar districts in New England and Eastern States, is still worthy of some consideration at our hands at the present time.

The discharging of raw sewage into streams and rivers, some of which are now or soon will be sources of public water supply to cities and towns, will in due time be prohibited by law in every locality where offense to health or the bodily senses is liable to follow the pollution of the water by sewage discharges. Opinions will likely always differ upon the amount of sewage contamination which a stream may suffer without risk to the animal life which may be compelled to draw its water supply from such stream below sewage outfall, but the opinions of those whose views are re-inforced by long and careful observation, clearly point to the possible danger of discharging *any* sewage into a stream, the water of which is later drawn for drinking purposes, especially as the disease-producing bacteria which may come into the stream with the sewage are not easily detected, and may propagate and produce dire results before their presence in the water is suspected.

The recent frightful epidemic of cholera in Hamburg is ascribed to the water taken for public supply from the river Elbe, which is supposed to have been impregnated with the cholera bacilli, from a temporary settlement of Russian immigrants on the river bank above the water works intake.

Koch's investigation of cholera in India, demonstrated that the tank water, largely used for drinking purposes by the natives, was the natural carrier of the germ, and what is more likely, considering the rapidity with which bacteria multiplies, than that the Hamburg scourge may properly be traced to a few germs which found their way into the river Elbe from the band of immigrants mentioned. Cholera is classed in the Materia Medica, as the most dangerous of all diseases, partly from the rapidity with which it develops and partly from the heavy mortality that follows the attack. Statistics of its several trips through Europe, show a fatality of 50 per cent. of all having been stricken with the disease. The normal condition of the Elbe water may have had nothing to do with the propagation of the cholera germ, but investigation seems to show that disease germs will not live in wholesome water, possibly for lack of pabulum upon which to feed.

It was my intention originally to offer some remarks on "Sewage Disposal" as an independent topic, but when I began to arrange the sub-heads of the subjects and speculate upon the amount of ground to be covered and the necessity of many sketches to illustrate the methods of sewage disposal now in practice by foreign cities, it seemed to me to be too much of a task to undertake with the limited time at my disposal, and that it would perhaps be more satisfactory to you to briefly point out the dangers surrounding the present methods of getting rid of sewage, especially in the effects these may have on the present or future water supply of some organized community, and then to pass on to the real question which underlies the subject of sewage disposal, viz.: The quality of water supplies.

The attempts to recover from dilute sewage its theoretical value as a fertilizer have occupied the attention of sanitarians and chemists for more than forty years, and it can not be said that any very satisfactory success has attended their efforts. Some sewage farms and works aboard seem to pay something more than the cost of maintenance, but the majority are and have been operated at a loss to the municipal corporations which have adopted this means of sewage diposal.

Certain soils work very well for filtration of sewage, especially when the effluent is applied intermittently to respective areas of land, and time is given for the sewage to pass out of the filtering soil, and air to pass in and fill the interstitial spaces. In such instances, if the rate of filtration is properly proportioned to the filtering material in the grouud, the oxidation or combustion of the organic matter in the sewage is practically complete. But of course such a method of treatment assumes that no value is attached to the solid matter in the sewage for manurial purposes, and that the whole object it to obtain the best sanitary condition of the effluent. Sewage filtration can best be had by the use of the modern mechanical filter, with an arrangement of tanks or subsiding and intercepting reservoirs to retain the heavier solid matter, and the filters rotated and rested in service at frequent intervals.

The most approved and apparently the most successful solution of the question is found in a mode of treatment which combines subsidence or interception of the solid matter in the sewage in reservoirs or tanks, with chemical precipitation; the sludge which accumulates in the tanks to be pumped into filter presses, and the resulting solid sewage cake disposed of as a fertilizer, or dried and consumed as a fuel.

In those instances where sewage is used for irrigation purposes, it is applied directly to the land by a hand hose, through carriers or small channels cut in the earth, or by means of porous open-jointed drain tile laid from two and one-half to three feet below the surface; the liquid in this case being taken from the soil surrounding the carrier pipes to the roots of growing vegetation by capillary attraction. All these methods of application have their advocates, but Mr. Bailey Denton, one of the most experienced English engineers in this field of work, prefers the distribution of the sewage by the surface carriers. Mr. George E. Waring, however, condemns the surface carrier and prefers the underground tile system for distribution. One difficulty in the path of the successful disposal of sewage by irrigation schemes is the inability of the vegetation to assimilate at all times all the organic matter which may come to the sewage irrigated field. During winter the growth in plant life is practically *nil*, and the effect of irrigation then is simply to keep the ground saturated with sewage, and to depend upon such filteration as the soil is capable of furnishing to reduce the amount of organic matter in the effluent to safe proportions. It generally happens, however, that when the sewage-irrigated field cannot take the sewage effluent and produce the reactions due to the absorption of the nitrogenous compounds by active plant life, that the raw sewage can be discharged into a neighboring watering course with the least injury to the stream. The stream usually being in flood at this season, the dilution of the sewage is great enough to remove the present danger from pollution of the water course by sewage, unless the sewage effluent contains disease germs, when no amount of dilution will certainly remove the danger due to these.

Quoting from Mr. Santo Crimps' very excellent book on "Sewage Disposal Works:" "Land is prepared for the purification of sewage in two ways:" When the surface is relied upon as sufficient for the purpose, and broad irrigation is the mode in which sewage is applied, the surface should present a gentle slope, in order that the sewage may travel slowly forwards in a lateral direction and thus admit of the surface being equally wetted throughout, and also admit of the drainage and drying of the surface subsequently to the application of the sewage.

"When Intermittent Filtration is the method by which the purification is to be affected, the land is laid out in level beds, and the sewage applied to each bed passes vertically downwards through previous stratum from which, in a more or less purified condition, it escapes by means of drains or otherwise."

If the soil for intermittent downward filtration be open or porous no sub-soil drains will be required, but if the soil is heavy and retentive, as for instance clay soils and mixtures of clay and loam, sub-soil drains will become necessary to avoid a supersaturation of the ground, which will of course prevent proper filtration of the sewage, and in warm weather produce a nuisance and a menace to health which sewage disposal works for a principal object should aim to avoid.

In 1877 M. M. Schloesing and Muntz, concluded careful investigations of the purifying action upon sewage of the soil, and in their report, 1878, submitted the following theory:

"When a liquid, such as sewage, is applied to porous soil, the suspended matters are arrested at the surface; this is the first action. The water, freed of its insoluble matters, descends into the soil, and each particle of earth being surrounded with an extremely thin coating of liquid, an enormous surface of water is presented to the air contained in the soil. The second action of the soil now comes into operation, which is similar to slow combustion, the organic impurities are reduced to carbonic acid, water, and nitrogen, as in active combustion, but the organic nitrogen itself which is more difficult to oxidize than either carbon or hydrogen, is changed into inorganic compounds. The means by which these changes are effected are now understood and are doubtless due to micro-organisms."

The investigations of the Massachusetts State Board of Health, under the direction of Mr. H. F. Mills, at the Lawrence experiment station, clearly demonstrate the wonderful influence of micro-organisms in converting dangerous organic matter in sewage into harmless inorganic matter.

According to Dr. Tidy, 375,000 gallons, or 3,750,000 pounds of London sewage, contains 1671 pounds of organic matter, or 45-100 of

1 per cent. of the sewage is represented by the polluting agents. Reducing this to the average consumption of water per capita in American cities, which is quite twice that in London, the percentage of organic matter becomes 225-1000 of one per cent.

The experiments of the Massachusetts State Board of Health show the proportion of organic matter to be about 2-10 of one per cent., or substantially the same as London sewage reduced to the basis of our per capita consumption of water.

Of this 2-10 of one per cent. about one-half is mineral matter and can be neglected in discussing the treatment of a sewage effluent to render it fit for discharge into a stream of running water.

Considered from a sanitary standpoint it is the removal of this one part in 1000 parts of sewage that is necessary to prevent sewage pollution of a stream or other source of water supply, or of every 1000 parts of sewage coming from an outfall sewer, 999 parts might pass into any stream of water without risk to the water, if the other one part is properly intercepted and reduced to inorganic compounds or absorbed by micro organisms or plant life.

In providing a water supply for public or private purposes, two problems are presented for solution, one the quantity of water available during the period of extreme drouth, and the other the quality or potability of the water and the probabilities of the source remaining forever free from pollution.

Usually when the quantity of water has been assured, the second and more important problem—quality—is left to solve itself, very frequently at a cost of human life, or with an appalling amount of human suffering.

While earnest and unremitting attention has been bestowed on reservoirs, stand pipes, pumping machinery, water mains, and the numerous other adjuncts of water supply, but little has been done toward the improvement of the quality of water furnished for domestic consumption. I am not unmindful of the fruitful labors of the British Rivers Pollution Commission, of the splendid work of the Massachusetts State Board of Health, of the efforts of several local sanitary boards to prevent pollution of local streams by prohibiting the discharge of effluent sewage into them, nor of the work accomplished by the many excellent filters in limited service. But when the efforts of engineers in the construction of massive masonry dams, collosal impounding reservoirs, elaborate systems of supply mains, and ponderous and highly economical pumping machinery, are compared with the efforts of the same engineers to improve the quality of the water supplied to the communities which they serve, the truth of the assertion that small progress has been made in securing water for public supply from sources of known purity will be apparent.

One of the prime requisites of health is "pure water," and the the Romans in the construction of the fourteen aqueducts which supplied the city in the days of Nero, were careful to "head" all these in sources of supply known to be beyond the possibility of contamination. It might be urged that the only method of supplying Rome with water in the days of the Cæsars was by aqueduct from the surrounding lakes at higher level, but this will not alter the fact that the sanitarians of ancient Rome fully appreciated the necessity of supplying its citizens with a quality of water above suspicion.

How much of the courage and prowess of the Roman soldier, or of the wisdom and skill of the Roman statesman, was due to the excellence of their public water supply no one can say, but certain it is that with a polluted water comes a weakening of the powers of the body and mind, and no community can be brave and wise and persevering if disease and death are loitering at the threshold.

Every detail of water works constructions has been so fully exploited that little remains to be supplied in the direction of new principles of design, save in the field of increased purity of water furnished. And when it is considered that the use by a community of a polluted water will certainly kill—not all—but some of its citizens, and to save and develop human life is one of the noblest occupations of man, how very important then does it become, in selecting a source of water supply for public uses, to see that this source shall be beyond the reach of possible contamination. And how few cities can boast of a source of supply which fully answers the requirements of a wholesome water.

The recent work of the Massachusetts State Board of Health, in investigation of the sources of water supply for the several cities and towns in the State, which are provided with public works, is of inestimable value to engineers engaged in similar lines, and should be followed by other states, the relative population or development of which approximates that of Massachusetts. Many of the older and more densely populated states have lakes, ponds and streams, which are used for public water supply, the only information upon which is usually a few disconnected and incomplete analyses, and, in some cases coming under my own observation, even this limited test of the potability of a water supply for public use has never been made.

In the Massachusetts work, the analyses have been made as full and complete as chemical science permits, and these, with the biological examinations of the various waters investigated, together with a review of the topographical and geological formations of the watersheds of the several sources of supply, furnish a most complete and extensive compilation of statistics upon the quality of water for domestic and other uses.

How often it happens in adopting a source of water supply for a town that quantity instead of quality is sought, and this found, no attention is paid to the wholesomeness of the water until the question is raised by the local sanitarians, and then the investigations are usually crude and very unsatisfactory, either from unwillingness of the custodians of the water works to have such matters fully investigated, or from lack of means to properly conduct such investigations.

There are several large, and no doubt a multitude of small cities, pumping or otherwise supplying water to its citizens which is unfit for domestic use, and the continued consumption of which as drinking water means typhoid epidemics and many lesser ills which are directly traceable to polluted water supplies.

I have in mind an investigation made some four years ago of the water supplied to one of our lake cities, when several analyses showed the water to be nearly as high in chlorine and albumenoid ammonia as London sewage. The superintendent of water works stated that for several years typhoid fever was prevalent during the autumn and winter seasons. In this instance one large and several small sewers delivered their flow into a land-locked bay or cove where there was no circulation save that due to an occasional storm, and in the land end of which the intake pier for the water works was located.

Another personal experience is that of an impounding reservoir built on one of the highest points of land in the state, with an exceeding small water-shed which was sufficient to keep the reservoir of 10,000,000 gallons capacity full in the winter and spring, but entirely failed during the summer and autumn. During the first few years following the construction of water works, when the supply in the reservoir was so low as to require the stoppage of all use of water for the local railroad tanks and for street sprinkling, typhoid fever was prevalent, and an investigation ordered by the trustees of water works revealed the fact that the principal summer supply of the basin came from a six inch butt joint sewer running through and carrying off the drainage of a neighboring farmyard. Affairs were remedied here by abandoning the old sources of supply, the barnyard sewer included, and adopting a new one beyond the possible reach of sewage contamination, and which was competent to meet the most exacting summer requirements for quantity.

It may be accepted as an axiom that "There is enough wholesome water on the face of the earth to supply all the inhabitants thereof;" but the problem is how to distribute this in such a manner that each individual shall have his share. Usually there is a plentitude of satisfactory water where people are scarce, and where people are collected in masses the water is questionable in quality, and sometimes difficult to obtain in volume sufficient for the greatest demands. Rivers that heretofore have carried in their channels a supply of water acceptable for domestic uses, have by the development of their drainage grounds become large open sewers contaminated with human wastes and the refuse of factories.

The growth of the city, and the multiplication of towns, is followed by this contamination of lakes and streams, which sooner or later must become the sources of water supply for these and other towns, And, unless prudential methods of operation and rigid statutes for the disposal of sewage in some other manner than by its delivery into running streams and currentless lakes shall be adopted by all the states, it is only a question of time until water for public supply obtained in a wholesome condition at its source, will be a rare and costly commodity.

It may be urged that the modern mechanical filter, and the improvements which the ingenious will make in this as occasion demands, render it less important now than heretofore that sources of water supply be kept free from injurious contamination, and, that, whatever the condition of the water may be as it comes to or from the distributing plant, the filter will overcome all objections to its quality and convert it into a wholesome water. Without disputing this proposition the writer believes in a liberal factor of safety in water supplies for domestic uses, and while the mechanical filter is in its way a valuable adjunct of modern water works construction, it is not prudent to require too much of it. The better plan is to bring the water to the distributing plant in the best possible sanitary condition, and if filters must be used let them be used as a safeguard rather than as a necessity.

Water analysists are agreed that the source of pollution is rather to be considered than pollution itself. Thus, of two waters containing like amounts of free ammonia and of albumenoid ammonia, that water, which, by the chlorine present and from its known source, is supposed to derive its nitrogenous compounds from sewage contamination might be condemned as unfit for use, while the other water, analyzing the same in ammonias, might be passed as an acceptable drinking water. This is due not to the more harmful character of the ammonias found in the sewage contaminated water, but to the possibility of its containing disease bacteria from human sources In other words it is the knowledge of sewage pollution that condemns it, from the fear of its containing germs which chemical analysis does not reveal, the introduction of which into the human system might lead to disease and death.

The investigation of water supplies for sanitary purposes, so far as the chemist can pursue it, is embraced in tests for

Chlorine.

Nitrogenous compounds. { Free Ammonia. Albumenoid, or Organic Ammonia. Nitrites. Nitrates.

Residue on reduction of the solid matter in water to dryness at 100 degrees centigrade. { Organic, or volatile solids Inorganic solids.

Hardness. { Temporary. Permanent.

In addition to these, tests are made to determine the presence of metals and salts and natural oils which may have an effect on the quality of the water, The presence of these are usually manifest in degree, or are known by the source from which the water is taken, and sanitary analysis is usually limited to the general test mentioned above.

Chlorine, as chloride of sodium (common salt), is not an objectionable element in itself, and is sought by the chemist as an index of the source of pollution, if pollution be found, and care must be exercised in passing judgment on a water from chlorine alone. Waters, otherwise wholesome and potable, from sources near the sea may have an excess of chlorine above the normal, which is appropriated from the muriatic acid in the salt atmosphere, or waters from deep artesian wells may have an excess of chlorine obtained from subterranean sources, without indicating pollution. But water from inland streams, lakes and ponds, showing chlorine in excess, can safely be set down as having received sewage directly or through the soil. If the sewage comes directly into the stream, in addition to chlorine will be found high ammonias, but if the sewage has been filtered through the soil or artificially, the chlorine will still be present in quantity, while the filtration of the water has reduced the amount of ammonias, or advanced their condition to nitrates.

According to Prof. Wanklyn, the author of the "Ammonia Process," now in universal use by water analysists, the limitations in chlorine, free ammonia, albumenoid ammonia, and total solids, and hardness for safe potable water are as follows:

Chlorine	7 — 14	per 100,000 parts.
Free Ammonia	.000 — .001	"
Albumenoid Ammonia	.000 — .005	"
Total Solids	43 — 57	"

It will be understood that these quantities must be considered separately and not as whole. Thus, if in all other respects a water may analyze satisfactorily, as much as 14 parts of chlorine per 100,000 parts of water should not condemn it. But, taken in connection with more than .001 part of free ammonia, .002 to .005 part of albumenoid ammonia and nitrites or nitrates in quantity, such water would be condemned as utterly unfit for domestic use. To illustrate this the following is from deep artesian wells at Oshkosh, Wisconsin.

Chlorine.	Free Ammonia.	Albumenoid Ammonia.	Solids volatile.	Solids fixed.
8.24	.000	.000	13.12	62.52

This water is organically pure, but it is too high in total solids to be recommended for domestic use, and in connection with a total hardness by Clark's scale of 40.76, is utterly unfitted for use in steam-boilers, but it is absolutely free from pollution, and, excepting that it contains too high total solids, would make an excellent drinking water.

Another case is that of a water selected by a town council in Ohio, as a source for a public supply:

Chlorine	Free Ammonia.	Albumenoid Ammonia.	Solids volatile.	Solids fixed.
10.46	.0142	.0246	26.80	67 14

Here both chlorine and the ammonias are high, and these, in connection with the high volatile solids, stamp the water as town sewage which had leached through the drift (ranging from 0 to 20 feet in thickness) and followed the dip of the rock to the spring(?) from which the sample of water was taken. Can it be said that sources no better than this are not now in use for public water supplies to many towns in this country? It is to be hoped there are none, but the writer from his experience in these matters believes there are too many such.

The Massachusetts analyses and biological examinations of water from sources of public supply are peculiarly valuable because they extend through several years, embracing every month and generally every day of the month. The variations of chemical constituents, algæ and micro-organism by changes of temperature, by storing water in open and covered reservoirs, and the causes of unpleasant colors and odors where these have occurred in waters of public supply, are given with an elaboration of detail which is surprising, considering how few of the citizens or officers of the state will study these reports as they deserve to be studied. To the engineer engaged in similar pursuits the reports contain the abundance of riches and open a mine of information scarcely accessible through any other channel than a board like this made up of strong members and clothed with ample powers.

Certain states have a railroad commission, the object of which is to exercise such an espionage of railway construction and operation as to guard against accidents and prevent the loss of human life. Can any one doubt that a state board of health, such as Massachusetts has can do more good toward the preservation of health and life by the investigation and improvement of the public water supplies, than a railway commission? The late Prof. W. R. Nichols suggested: Each river basin should be under the control of some central authority by which conflicting interests should be harmonized. An accurate survey should be made of the whole area, and no town should be allowed to introduce a water supply without due consideration being given to the future of the supply, and to the question of disposing of the sewage of the town supplied. A state board of health, with powers such as are conferred by law upon the Massachusetts board, could effectually prevent the adoption by any town or city within its jurisdiction of a polluted water supply, and at the same time prevent injury to such supplies from future manufacturing or domestic wastes.

I have somewhere seen it stated that the use for a single day of water from a polluted well in the suburbs of Paris, caused the death from typhoid fever of nine out of a family of eleven persons. Upon the other hand the writer has personal knowledge of the continued used by family of four for years of a water for drinking purposes from as hallow driven well penetrating the pervius stratum a few feet under the soil, into which numerous privies in the neigborhood were also driven, the filth from the privies filtering through the sand and gravel and polluting the water of the well. This water was used for several years by the family, one of whom (the mother) contracted a most distressing case of typhoid fever, and recovered after nine or ten weeks illness, during which all the pronounced symtoms of typhoid were present. The mother was the only member of the family who used this polluted water exclusively (the father and children during the day being away from home and mixing their drinking water), and, upon the theory that one poison often neutralizes another, the constant change in their drinking water of the other three members of the family may have saved them from similar attacks.

Another instance of the influence of polluted water on systems peculiarly susceptible to it is that of a young man of 28, raised in an inland town and accustomed through infancy and youth to drinking water from cemented cisterns, who, after a short residence in Cincinnati fed upon the notoriously dangerous water supplied to this city, succumbed to typhoid fever and died after a few days' illness.

It is related by Dumas Pere, in his master work of fiction, "The Count of Monte Christo," how the system may be accustomed by degrees to strong doses of active poisons; and may not those illustrations of the long continued use of water known to be contaminated with human wastes without serious illness or death, be analogous cases? If the person dies in infancy from the use of such water, it is charged to summer complaint, inflamation of the bowels, or cholera infantum, and no note is made of the probable cause; and, if the tender years are passed in safety, the probabilities are that the system becomes accustomed to the specific poisons of the water of daily use. Thus, while one, accustomed all his life to a polluted water, may continue its use with impunity, a stranger to such water, or one who has been accustomed to an exceptionally pure water, may soon have the germs of a serious disease established in his system.

It must be that there are conditions of the human system when typhoid and other disease germs may be imbibed without risk in the drinking water; otherwise whole cities would be swept of their populations whenever the disease bacteria were abundant in the water. According to Mr. Chas. Watson Folkard, "there is and can be no safe drinking water except from deep sources," far beyond the reach of surface pollution. No river traversing a populous district can possibly be considered a "safe source of water supply," nor can any lake, upon the shores of which cities and towns are built and into which surface drainage and sewage are delivered, be regarded as a safe source for drinking water for a community, except the water be taken at considerable distance from the shore.

Prof. Wm. Ripley Nichols, who is to high attainments as a chemist united the good judgment of a man whose vision extended beyond the area of his personal labors, in discussing limitations for potable waters, said: "There always will be difficulty in deciding how near to any limit a suspicious water may come and still be used with a reasonable degree of safety."

If this be true, that no limitations can be fixed for drinking water within which its use is absolutely safe and beyond which danger may lie, then we are in a very deplorable condition indeed; for water like air, is an essential of human existence; we cannot dispense with either and live. And yet in the city and on the farm both are likely to be introduced into the system laden with the germs or bacteria of disease, and the first intimation of danger is disease itself.

There can be no doubt that all water is at some time in condition fit for drinking with absolute safety to the human system, when in a chemical and biological sense it is unpolluted. Chemists show us that fresh rainwater approaches in its conditions more nearly that of distilled water, and, notwithstanding the free ammonia and chlorine with such water in falling may appropriate from the atmosphere, such water is always safe, if used promptly after it has fallen from the clouds, and that it may be gathered in clean cisterns, from which light is rigorously excluded, and carried for weeks and months without injury to its condition. But it is impracticable to provide an organized community with such water for a continuous public supply, and some other source must be sought.

The water works of Rome are in evidence that its engineers thoroughly understood the value to a large community of a liberal supply of wholesome water, and that they also knew how to procure it. Lakes, the elevation of which was sufficient to supply water to city by gravity, and whose location and environment precluded the possibility of contamination from human or animal wastes, were selected as the sources of water supply, and, while our modern hydraulic devices were all unknown to them, it does not appear that their lack of our present facilities for water works construction stood in the way of the accomplishment of their purposes.

Water obtained from deep wells in the ground or in the rock, should never be stored in large quantities in reservoirs exposed to the light, but for best sanitary results should be delivered as quickly as possible to the consumer, or if stored at all only in small quantities in covered tanks or reservoirs from which light is rigorously excluded.

The development of the spores of bacteria and algæ found in water from deep underground sources, when exposed to light is much more rapid, and objectionable from a sanitary standpoint, than with water obtained from running streams, or lakes.

While deep well water upon analysis of fresh samples, may and usually does contain so low an amount of organic ammonia, nitrites and nitrates as to render it an eminently safe water for drinking and culinary purposes, it is also true that such waters must be promptly consumed after they are drawn from their original sources, otherwise their fitness for domestic uses is decreased, and in some cases coming under my own observation storage for several days of such waters has rendered then utterly unfit for domestic purposes.

Water impounded in deep reservoirs can be carried for days, months, and sometimes years, with an improvement in its condition, and the same is true of waters pumped from constantly running streams, where the reservoirs are deep and so constructed and managed as to discourage the growth of flora; but what in this respect is true of waters freshly stored from the drainage area, or pumped from running streams is strictly not applicable to waters taken from subterranean sources.

In concluding this brief discussion, of "Sewage Disposal" and "Quality of Water Supplies," I take the liberty of quoting a paragraph or two from a report which I made to the City of Zanesville, some two years since on the quality of water supplied to the citizens from its old Water Works.

"The difficulty of impressing upon a community the dangers lurking in a contaminated water supply lies in the fact that the use of such water is not followed by instant death. It does not kill like a stroke of lightning, but it will kill in due time, and often by a slow wasting fever in which the patient dies by degrees.

"The influence of a polluted water supply on the system is slow and insidious, and the victim never realizes the danger of his condition until his health is undermined and his system is a physical wreck. If polluted water killed its victim at once, there would be no difficulty in convincing a community of the danger, but it does not do this, and the apparent impunity with which some constitutions can use it, leads others to think there is no danger, and only an epidemic of typhoid or some other form of enteric fever, will carry conviction to some minds, and even then these doubt the cause, because they do not see it working.

"No fact is better established in sanitary science than that typhoid fever and fever of like nature, can in almost all cases, be traced directly to the use of polluted water."