- The Necessity of a Pure Water Supply. -

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One of the great questions of economic importance is that of the purity of water, and, in order to understand this subject, it is necessary to have a knowledge of sources, means of contamination, and methods of purification.

Judging from records, the abundant supply of water has been considered of the highest value from remote antiquity.

In Genesis, wherever the people pitched their tents, there a well was dug, and quite often dedicated to a superior power, which certainly shows their estimation of its value.

In ancient times, centres of population sprang up around those points where water was readily available and great expenditures of labor and treasure were made to carry it to places where it was not naturally plentiful.

(Much of the larger constructions connected with ancient water supply were those built for the several systems of irrigation as is shown, in India, by the efforts to preserve and utilize the rains and rivers; and, in Beluchistan, the great Cyclopean dams of stone known as the Ghorbasta were erected (it is believed) 1800 B. C.)

By the construction of immense artificial lakes for the conservation of the flood waters of the rivers, the valleys of the Tigris and Euphrates were immense gardens of extreme productiveness.

A dam of hewn stone was built at Kosheish to divert the course of the Nile from the spot on which Meua desired to build Memphis, 5800 years ago. Hippocrates, who wrote upon the value of water over 1400 years ago, advised boiling and filtering a polluted water before using it for drinking. He thought that the consumption of swampy water produced enlargement of the spleen.

Pliny devotes large space to the discussion of potable waters.

Libavius (1595) refers to Pliny's works and adds the curious suggestion that the weight of water is proportional to its potability. Lascaris (1493) did not recognize the power to intensify and spread certain epidemics, yet it is interesting to observe that his teachings upon the origin of disease came very near the germ theory of today.

In Egypt, 2660 B. C., a canal was ordered by Usertsen III by which he sailed southward to crush Ethiopia. Lake Maeris, also in Egypt, was constructed, at least, 2000 years before Christ. Its dimensions were sufficient to regulate the annual inundation of the Nile.

On the site of ancient Carthage may still be seen the great cisterns for storage of water. Drinking water was supplied to this ancient city from a spring sixty miles distant.

It may readily be observed that, from these few references, more or less attention has been paid to water supply.

Its principal sources are rivers, lakes, springs, cisterns and wells. Springs may be defined as any water that comes to the surface of the earth, and, in some localities, the inhabitants depend largely on this means for the receiving of water.

In a country not thickly populated, they are usually very pure but when a country becomes densely inhabited, there is great danger of pollution by surface drainage, and thus becoming carriers of pathogenic germs. When the spring does not come to the surface, the ground is excavated to the spring and such an excavation is called a well.

If a boring is made through (in certain localities) an impervious stratum at a point considerable lower than the line where the water filters into the earth, the water rises to the surface giving rise to an artesian well. Although artesian wells are not in great numbers, yet the water is nearly always pure on account of the filtration in passing through the different strata.

Almost the whole of the rural population depend upon the wells for its supply of water, and much of the sanitary oversight, occurring in these districts, centres about this point.

Old wells are liable to be contaminated because of the infection of the ground water due to cess-pools or surface impurities.

The distance from a well at which a source of infection becomes dangerous cannot be definitely expressed as it depends wholly upon the character of the strata and the direction and velocity of the ground currents. Wells, at one time, furnished the best supply allowable even for a city, but, at the present day, are dangerous since with the increase of buildings and waste products, the soil has become saturated with impurities which thoroughly contaminate the water. The burial grounds, miles of sewers, gas-works, chemical and other manufactories whose proceeds are all injurious to well water.

The next in importance to the well in the rural districts is the cistern. These are small reservoirs for the collection of rainwater from the roofs of buildings. Their impractibility in the city can be readily seen; for there, the air is heavily ladened with smoke, dust, and impurities from the street and people, so that the water collected from the roofs is unhygienic.

A cistern is not of much practical value where the rain-fall if very slight but where the rainfall is slight and the precipitation is even moderate, water is available, for all that is needed, is a suitable collecting surface and a cistern.

In a district, where there is much rain, as large a cistern is not requited as where the rain-fall is but little; consequently, a corresponding increase in the size of the cistern and collecting surface is necessary to meet the requirements of a continual supply.

If the house has a roofage of 1000 square feet, the yearly yield will be, if the annual precipitation is thirty-seven inches, about 20,000 gallons, which at ten gallons per head per day is more than sufficient for the wants of an ordinary family.

A cistern, for this amount need not be excessively large; one ten feet deep and ten feet in diameter will hold 40,000 gallons which under usual conditions will last more then two months.

The construction of a cistern is of the greatest importance so as to keep the water from bacteria. One of the best methods is to finish the cistern in masonry either brick or stone and use good Portland cement: another method where the soil is of firm texture is to apply good cement directly to the earth.

The cistern should be supplied with a filter. There are many of these recommended, but very few of practical value. Charcoal and bone-black are quite satisfactory with frequent renewal. A highly recommended filter is a smaller cistern builded within a larger, the bottom of the smaller having holes into the larger cistern. In the smaller cistern is first placed large gravel or rocks, fine gravel, and then sand. The depth of this material should be at least twenty-four inches and is better to be more. The top layer of sand becomes covered with a film of nitrifying bacteria which are of great value in purifying the water.

One advantage is that this does not require frequent renewal of the sand as of the charcoal although it adds to the expense.

The leader empties into the central construction while the pump is placed in the cistern proper. Every farm should be provided with a cistern, but a city of any size should have a water supply from a river or lake. In the greater number of cases a lake is not accessible so river-water is used. Such a source seems necessary in many cases but extra precautions are necessary in order to free the water from the almost always present impurities due to using the river as a receptacle for waste materials.

An ordinary mountain stream with its clear, sparkling water would seem to furnish a pure and undefiled supply, but there are several points to be considered before selecting such a source; the amount of sewage emptied into the stream above the point to be used and secondly; the kinds of material that is on the ground from which the water is gathered.

Another peculiar fact about river water is the sudden and great changes that take place in it. Today it may be clear while tomorrow, it may be muddy, and consequently less fit for use.

When the water is taken from a river, the mouth of the suction pipe should face the way the water flows: by so doing, the best water will be drawn in and many of the impurities pass: when the water is taken from a lake, the pipes should face downward for the same reason. There are two general requirements which the intake works are designed to consider:- first, the reliability of the supply and of the works; second, that the point of intake should be so located as to obtain the best quality of water: therefore, the point of intake should be located above all sewer outfalls of the town in question. But the most important consideration regarding point of intake is that the water is free from local sources of pollution, this bringing us to the subject of contamination. Pure water should be colorless and free from all turbid material, but the presence of an odor, taste, and turbidity is an indication of the lack of purity and suggests the necessity of a closer analysis.

The turbidity is generally due to the presence of organic matter, but some vegetable growths, such as algae or diatoms, most frequently are concerned in such changes. Water may be made turbid by iron either in the form of iron bacterium, Crenothrix, or simple chemical oxidation of the ferrous salts to the ferric oxide.

The pleasant taste of water depends mainly on the oxygen and carbon dioxide dissolved in them, while the unpleasant taste or odor depends upon the foreign material in the water.

The physical tests of water aid us somewhat in deciding upon the purity or impurity of water, but the most reliable are the chemical and bacterial examinations.

The chemical analysis cannot tell if the specific disease producing organisms are present or not, but can tell if there is any sewage pollution, past or present. A water may be chemically bad yet not contain any pathogenic germs.

The chemist determines the amount of organic matter present by the loss in weight of the total solids before and after ignition, by the presence of nitrites and nitrates, by the amount of oxygen consumed, and by the free and albuminoid ammonia that is present.

It is impossible to tell the quality by one of these tests, but it takes all of them to ascertain a proof.

The bacterial test would seem a very definite one, but owing to the lack of mastery of this science, which is only a few decades old, the examination by this method may not be perfectly accurate.

When the methods are ableto be manipulated in this line with the aid of a greater understanding, much will be accomplished as with the little knowledge already possessed, great strides have been made in sanitary interpretation.

The bacteria are determined by adding a little water to the different media i.e bouillon, agar, and gelatine in which bacteria readily grow; thus obtaining general ideas about their number and character. After these grow in the media, a pure culture is made and the germ can be thoroughly studied. When water is known to be impregnated with foul material, it is desirable to know the cause, for though the source can possibly be renewed, in a majority of cases, water is contaminated by flowing over soil made impure by leaking sewers and cess-pool drainage.

The sewer contains the waste products, excretions, and secretions from man and other animals, and it is by means of these excreta that infection travels and so sewage can never be regarded in any way but dangerous.

The danger of water, acting as an agent for the transmission of disease, depends upon the possibility of such germs invading potable waters and the ability of bacteria to grow in water.

There are not many pathogenic bacteria that are able to preserve their vitality in water, but those specific microbes that are able to survive for a considerable extent of time are very dangerous to the public health.

Those germs that affect the alimentary canal are the microbes that are most dangerous to human organisms. Of these specific germs, Cholera and Typhoid are distinctively water-borne diseases. There are others but these two germs are the most common and most frequently effect water supply.

Neither of these diseases are contagious but must be introduced to the system by drinking water or food supply.

The disease organisms of typhoid multiply rapidly in the intestines, and is evacuated with the ejecta. Carelessness in the disposition of these discharges result in water becoming polluted.

While germs frequently gain admittance to the system by means of polluted water, milk is also a source.

In Stamford, Conn., (1893), there was a very severe epidemic of this fever. There were 386 cases that developed in a very few weeks, and all on the route of one milkman.

It was finally discovered that he rinsed his cans in the creek on the bank of which had been thrown the excrement from a member of his family suffering from typhoid.

The earliest, most famous, and the most instructive cases of the conveyance of ~~idea~~ disease by polluted water is that of the epidemic of Asiatic Cholera, connected with the Broad Streetwell (London).

This occurred in 1854. After the disease broke out in such fury, the vicinity was examined thoroughly, studying minutely the question of population, industries, previous sanitary history, meteorological conditions, and other general phenomena, common to London alone.

As the epidemic still continued in disproportion to the rest of the city, and these inquiries had given no information; they began to consider local questions such as soil, yard and cellars, ventilation and cleanliness, sewers and their overflow, and water supply. No explanation of the epidemic could be made through any of these except the water supply, consequently, this source was looked on with great suspicion as nearly all that were sick had taken the water from a certain well.

This well was thoroughly examined and startling conditions revealed themselves. The well was twenty-five feet deep, six feet in diameter, lined with brick, and contained on the average about seven feet of water.

The bottom of the main drain of house No. 40 was nearly three feet from this and nine feet above the water level. The drain was examined and was found to have but a slight fall and to be imperfect for the mortar had loosened. This drain led to a cess-pool a short distance off and its masonry was in the same condition.

The earth between the well and cess-pool was examined and the washed appearance of the ground and gravel gave evidence of communication of the cess-pool and well.

The well was ordered closed and the epidemic stopped.

In order to be able to use water that was originally impure, the modes of clearing water must be known.

The purification of water is not only to remove the pathogenic germs but to improve the appearance.

For this purpose, numerous processes have been devised, but in actual practice only a few have been found feasible.

Some of the methods are the result of a thorough study of the principles that underlie filtration in natural conditions, and others are the result of empirical testing.

Purification has improved along two lines: one for the removal of suspended impurities and the other for the removal of dissolved impurities.

The removal of suspended material is accomplished by either sedimentation or filtration.

Sedimentation is one of the processes that nature uses very effectively.

In streams, under favorable conditions, that would be considered as suitable sources of water-supply, the sediment usually consists of fine parts of sand, a small part of organic matter, and also a varying number of bacteria. The latter are too minute to render the water turbid but yet of great importance on account of their possible relation to disease.

When a body of quiescent water is sufficiently large and the period of repose is sufficiently long, the action of sedimentation becomes very marked. Artificially, this is accomplished by means of large reservoirs holding several month's supply, but this is not always practical as the cost is too great: but the reservoirs are of great value as large amounts of water can be stored.

For sewage - polluted water - sedimentation, no matter how thorough, is inadequate, as there is danger of all the bacteria not being eliminated.

The particles of clay and sand have a specific gravity of about 2.6, and, consequently, are held in suspension by the currents in the water. When the currents are retarded, the particles are deposited; the coarser first and later the fine silt.

The time required for the depositing of the sediments depends almost entirely upon the water. In some waters, the deposit may take place in three days, while in others, it may take months.

In this process, many of the bacteria are carried down with the particles of earthy material removing, it is estimated, from fifty to ninety percent of the bacteria.

In order to hasten the process of sedimentation, coagulants are often used. The chemicals, when added to the water, will combine with the certain substances ordinarily present, forming precipitates which have a more or less gelatinous characteristics.

When aluminum sulphate, added to the carbonates and bicarbonates of lime and magnesia, is decomposed and the S O_2 unites with the lime and magnesia while the carbon dioxide is set free: the alumina unites with the water forming a gelatinous hydrate. If more of the sulphate is added than is needed to combine with the quantity of carbonates present, the precipitate is redissolved, and this is a circumstance against which there must be a guard.

The amount of the chemical required depends entirely upon the character of the sediment and the degree of purification desired. It varies in practise from three-quarters of a grain to three or four grains per gallon.

There are other coagulants used such as potash and the various compounds of lime: these having about the same efficiency as the sulphate.

The method surer than sedimentation is filtration. There are many forms of filters but one of the most efficient is the sand filter.

The first filter of which we have any record was established by James Simpson (1829) for the Chelsea Water Company of London. Its object was to remove turbidity in which it was very successful, but the removal of bacterialoidal germs was not understood until some years later.

Filtration of water was made compulsory in London in 1855, however the chemical purification was very little but on the rise of the zymotic or germ theory of disease, it was found that the water was bacteriologically pure.

The sand or English filter-bed is a tight reservoir, properly under drained and containing some six feet of stratified filtering material: this varying from fine sand to quite large stones.

Much diversity exists in regard to the thickness of the different layers. Some have a very heavy sand layer and others very thin. An example of the last case is the Dutch filters which plan is not commendable as the fine sand layer has much to do with the filtering of the water.

One time, it was thought that the upper layer did all the purifying, but it was proved by Reinsch to be untrue. He found the unfiltered water to contain 36,320 microbes per cubic centimeter.

After passing the water through the sand or slime layer, there were 1,876 left, but on passing through the entire depth, there were 44 to the cubic centimeter. This proves that the lower layers have another office outside of the regulation of the flow.

For the best work possible, or in filters that have been the most successful, it has been found that the sand should not be less than twenty-four inches.

The engineering structures containing these beds have a great number of sizes, shapes, and methods of construction.

In London, from experience, they have decided that one acre is the proper size for a filter-bed and the inner wall surface is vertical or nearly so. There is one objection to this however; there is a possibility of impure water passing down between it and the sand. In the Holland filters, there is a notable exception; that the wall slopes very decidly. Usually the filter plants are left open, but where the winters are severe, they are generally covered with a layer of concrete supported by columns of the same material. In Germany (Stuttgart), both kinds of filters are used and the latter kind never freeze. When the filters become covered with ice, it is practically impossible to clean them, and, consequently, the water becomes very impure.

In Berlin (1889), there came an epidemic of typhoid fever, and it was traced to the use of the open filter as a small portion of the city was supplied with water from covered filters; and was free from the disease.

The filter-beds must be cleaned quite often: about every two months in summer while in winter, less frequently will suffice. They are cleaned by closing the sluice gates and the filter-bed becoming free from water, the upper layer of sand is removed, washed, replaced, and the sluice gates opened.

In some cases, fresh sand is used for first layer. The depth of the water depends upon the filter, however, the average is from three to three and one half feet and is kept constant.

Since the introduction of bacteriological methods, it has become possible to study the action and value of filters from an entirely new view point.

When cultures are made from the raw and filtered waters, a great difference may be noted in the number of bacteria.

Hazen has compiled the following data concerning the Lawrence City (Mass.) filter which uses the polluted Merrimac water.

	1896	1897	1898
Raw water	7198	10360	4850
Filtered water	91	61	46
(Each by c.c.)			
Efficiency of purification (in per cent)	98.72%	99.41%	98.95%

The amount that can be filtered through in a day depends upon the rate, but in all cases, it is found best to decide upon a rate.

The Hamburg works were designed on the basis of 1.6 million gallons per acre per day: at Berlin, the rate is about 2.6 millions;

and, at London, the average rate is about 1.8 millions; but some companies use higher than this but with less purity of water.

A notable exception is Zurich which has a rate of 8 million gallons per acre per day, but the unfiltered water is very clear and contain but a few hundred bacteria per cubic centimeter.

These modes of filtration have done much in diminishing the death-rate from infectious diseases.

After the introduction of this mode of sand filtration in Lawrence, Mass., the typhoid rates were reduced 90 percent, while in Hamburg, the death-rate was diminished over 70 per cent.

In 1862, Hamburg was stricken with the cholera, while its sister city, Altona, supplied with a sand filter, was afforded entire freedom with the exception of one case; this individual having partaken of Hamburg water.

This method of filtration has not been used so much in America as the mechanical filters. These are so-called only because machinery is commonly used in rakeing and agitating the sand during cleaning. These filters are designated to accomplish the same results as the sand filter but with a much smaller area of sand.

The construction of the bed is like the sand or English filter in having from two to four feet of quartz and sand; otherwise it differs greatly. The main differences are:- the very rapid rate of filtration (100 to 125 million gallons per acre per day), the use of a coagulant to aid in filtration, and the manner of washing the filter bed.

There are two well known types of the filters, all others being more or less adaptations of these plans.

In the first, the water enters the settling chamber at the bottom, passes up through the central tube to the top of the filter, then downwards through the sand to the collecting pipes located between the filter and settling tank. When a coagulant is used, it is introduced before admission to the filter bed. The agitators, which are operated in washing the filter, are raised out of the sand when not in use.

In the second, the settling tank is not connected with the filter, no agitators are used: but to loosen the sand, air is passed through the bed from below. In both of these forms, the method is by gravity.

The action of the coagulant enables high velocities to be used because the sediment is collected and forms a substitute for the organic coating on the sand grain.

To avoid frequent washing, the top layer of sand is often made as deep as ten or twelve feet, but deeper than this, the sand becomes clogged. The washing is comparatively easy. Ordinarialy, a run of twenty-four hours requires about twenty minutes to clean the sand.

The original cost of this filter is less than the sand filter but its after cost is in buying the coagulant and the diminishing value of the plant.

The sand and mechanical filters are the best devices for clearing large amounts of water but, where a small quantity is required, numerous methods have been employed. Lime is extensively used and possesses the greatest sedimentery power.

The Schuylkill, which receives the drainage of mines in the upper course, becoming heavily charged with iron salts and free mineral acids, is comparatively soft and pure by the time it reaches Philadelphia. It flows through extensive lime stone districts and receives waters charged with calcium carbonate.

The commingling of acids and lime-stone waters removes mineral constituents from each by the precipitating of gypsum along its banks, and, consequently, much of the organic matter is also deposited. Ferric chloride, potassium permanganate, and quite a number of other oxidizing agents have been used to destroy organic life, but, at present, these are less freely used than coagulants.

There are several methods that may be spoken of on account of their simplicity and effectiveness.

Ozone is one of the newer modes and is apparently one of the most successful and has been applied on a commercial scale.

The gas is generated electrolytically, the water is pumped into a reservoir, then allowed to flow slowly over stones coming in contact with air heavily charged with ozone.

The gas acts as a powerful disinfectant killing all pathogenic germs. As ozone is not readily absorbed by water, the pipes are but little acted upon and the ozonization of water adds no element of injury to health.

This is quite an economical method and more efficient than the sand filter and many believe it will be the filter of the future.

Fraube's method or the use of chlorinated water is a very simple and effective manner of rendering water germ-free. This disinfectant is composed of calcium hydroxide, calcium chloride, and calcium hypochlorite. It is rendered active by the free chlorine which it contains and it is extensively destructive to bacteria even in very dilute solutions. The excess of chlorinated lime may be neutralized by the addition of sodium sulphite or calcium bisulphite.

Peroxide of hydrogen is a very strong disinfecting agent. In solutions of 1:10,000, it will kill the cholera germ in five minutes. In the proportion of 1:1000, it will render the water practically pure in twenty-four hours, and not, in the least, effect the taste.

Aeration has often been tried but there are many cases where it has not been effective.

Electricity has also been tried but except for the manufacture of ozone, it has not been successful and is very expensive.

The revolving purifier, first invented by Anderson is becoming better known every year.

The process of purification, is, in reality, iron used as a coagulant followed by subsidence and filtration.

Metallic iron, in the form of either cast iron borings or steel punchings, is placed in a cylinder so arranged that, by slow rotation, the iron may be continously showered through the water which is being passed, at a moderate speed, through the same cylinder. The cylinder is provided with pipes whereby air may be introduced by direct contact with the iron.

The chemical action consists, in a great part, in the conversion of the iron into ferrous carbonate through the agency of the carbonic acid which partly dissolves in water and partly remains suspended in the form of a ferrous carbonate. When this is exposed to the air, it is oxidized into a hydrate which, settling rapidly carries down with it and oxidizes the organic matter.

The amount of iron dissolved per gallon has been found to be from 1/10 to 1/5 of a grain. This method of purification possesses high bacteriological effect.

The filters mentioned have been for town or city use, but filters are often needed for small amounts.

The Pasteur and Berkefeld filters have been found to be the best, for with proper care, they are very efficient. The Berkef eld is made of fine infusorial earth and is not as much used as the Pasteur which is of unglazed porcelain. These filters are comparatively porous and thus permit the water to flow through quite rapidly in which respect the Berkef eld is superior to the Pasteur. Both of these filters, when first put into service give a wholly germ-free filtrate but to keep them in the condition, they must be cleaned and sterilized, at least once a week, in boiling water.

The lower the temperature of water, the slower the bacteria multiply, and consequently, the filter will remain clean longer when supplied with cool water.

The pore spaces in the filters are not smaller than the bacteria, but there is a slime deposited which retards the bacteria so that the germs are prevented from being forced through the pores.

The Pasteur filter, in its simplest form, consists of a cylinder of fine unglazed porcelain called candle on account of its size and shape, this being enclosed by one of metal.

The supply pipe is connected with the iron cylinder: the water is forced through the porcelain which connects with the reservoir. One important fact connected with this filter is, that pressure is not needed in order to use it, often an important factor.

The value of this filter was proven at Auxerre, in 1892. There were 120 cases of typhoid, while, in 1893, after the use of the filter, there were no cases of this disease. Similar examples are to be found in Melum, Cherbourg, and Duian.

If a filter is not at hand, the water can be freed from germicidial life by means of boiling as bacteria are unable to stand heat and if water is distilled, it is as pure as can be produced.

With the prevailing amount of knowledge, there seems little excuse for the drinking of contaminated water; especially as an expensive apparatus is not necessary, for a tea kettle will provide a sufficient means of boiling water.

From the foregoing, the necessity of a pure water supply is seen. Each person should be interested for this question will never be thoroughly settled until every individual has a definite and scientific knowledge of it.

Every sanitary measure should be tried in order to ascertain the purity of the water, such as testing the soil from which it is collected, testing the water for impurities; but this is not sufficient: every woman should thoroughly understand water-supply, its liabiliaty of contamination, and its means of purity. When the mother is able to comprehend this subject, the nation, as a whole, will not have to consider the question as it will, then, have received sufficient attention.

Under the stress and strain of the present existence, too much value cannot be placed on hygienic living in order that the physique be kept in the best possible condition for "Health is the poor man's capital and the rich man's bank account."

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