CHAPTER VII.

DISTRIBUTION.

We have seen in the previous chapters how pure water may be recognised, how it can be obtained, and how it is to be stored. It remains to discuss the precautions which should be adopted in order to prevent contamination during the remainder of its journey to the consumer. That this frequently happens is a matter of common observation. During the East London inquiry in 1895, it was found, for example, that the water collected from the street hydrants issuing directly from the mains was of the ordinary character of the company's supply, but it was suggested on the analysis of private samples that the supply to houses was much inferior to the water in the company's reservoirs and in the large pipes. Collectors were therefore sent into the small alleys and dwellings, and samples taken from the house taps, after these had been cleaned, to represent the fluid actually drunk by the people. All these samples, when analysed chemically and bacteriologically, proved to have derived impurity from some source in their transit from the mains. The failure of the East London supply during the previous winter had been already attributed to leaks in the pipes, and it was

thus demonstrated that not only had water been lost but that dangerous matter from the soil of a populous district had diffused inward through the leaks.

At Eastbourne, in 1895, it was suddenly discovered by a private analysis that the water supply of a portion of the town had been contaminated by sea water, which had leaked through fissures in the chalk into a well.

It is, therefore, important that a householder, before going to live in a new locality, should become acquainted with the nature and pureness of the water supply, and when the pipes are found to be old, small, or shallowly laid, to either avoid a tenancy or have the defect remedied.

In Roman times pure water was brought from a distance to cities by aqueducts, many of which remain as ruins, while some are still utilised. These were of solid masonry, carrying a conduit lined with cemented bricks or tiles. Across the valleys often three tiers of arches, with a height in many places of more than a hundred feet, were constructed. Some of these structures were completed several centuries before the Christian era. Ancient Rome, with its nine aqueducts, served its people with 300 gallons a day per head, including the supply for the public fountains, baths, circus and amphitheatre, and for sanitary and trade purposes. A special State department administered the supply, and, as a result of these efforts, classic Rome was far more healthy than the modern city.

The water of the New River Company was originally brought to London by an aqueduct with several tunnels. The adoption of the built-aqueduct system was probably due to the fact that pipes of sufficient calibre and strength were not available. The ancients were certainly well aware of the fact that water will rise to its own level, and that, consequently, if pipes dip down in a valley, the water will rise to the same height on the other side, but in a clear atmosphere there is great advantage in an open aqueduct, as it can be easily cleaned and guarded, and allows of the beneficial action of light and air.

But in populous countries it is necessary that an aqueduct should be closed, to guard against contamination; hence a line of iron pipes of large diameter supersedes the old open channel. The pipes pass under rivers and canals by an "inverted siphon" (Fig. 29 : see *ante*), as mentioned in connection with the proposed London supply from Wales (p. 121). Sometimes it is advisable to cross an obstruction by a closed girder conduit (Fig. 30).* It must be remembered that iron pipes are proportionately weaker as their diameter increases. The inconvenience and loss attending their bursting were lately exemplified in the rupture of the Chelsea Company's twenty-four-inch main near Battersea Bridge in September, 1896.

* Details of the Bear River irrigation system at Utah are given in the *Engineering News of New York*, Feb. 13th, 1896.

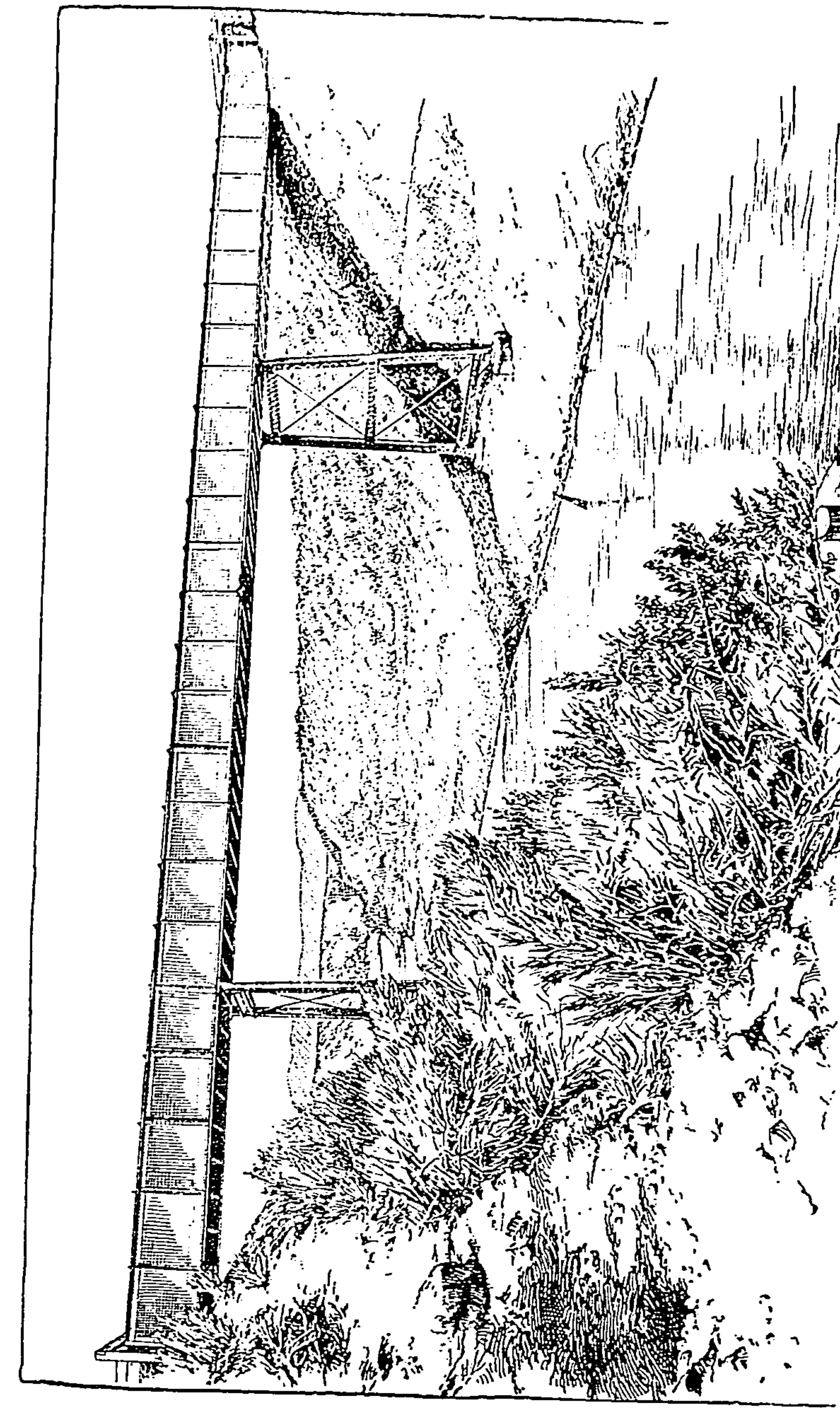

FIG. 30. 130-ft. Plate-girder Flume over Malad River.

One of the latest examples of the modern style of aqueduct is given in the Mourne water scheme for the city of Belfast. It is proposed to furnish an additional supply of 30,000,000 gallons per day by means of an aqueduct thirty-five miles long, comprising seven miles of tunnel (part of it passing under Slieve Donard, the highest of the Mourne range of mountains), with sixteen miles of covered conduit and twelve miles of cast iron siphon pipes, thirty-six inches in diameter. The service reservoir, about five miles from Belfast, will contain 90,000,000 gallons. From it the water will be conveyed under pressure in large mains to the city. The inlet ends of the siphon pipes will be controlled by automatic valves, so that the water is cut off immediately in case of breakage at any point in the siphon.

Some of the earlier water-pipes seem to have been constructed of wood.* During excavations at a brewery at St. Helens, in 1895, the workmen discovered a water-pipe line of considerable antiquity; the pipes consisted of trunks of trees about twelve feet long, chamfered at one end so as to fit in the end of the next pipe. A hole of about six inches diameter had been bored or burned through the irregular course of the trunk. The oak was in an excellent state of preservation, having been buried in clay.

Square wooden conduits are used occasionally in the

* In the engineer's estimate for the Liverpool waterworks in 1797, the following items occur:—"Elm pipes at 11s. per yard, £1,000; earthen pipes at 3s. per yard, £1,975."

Colonies; they should be tarred, or, at least, charred inside. There is no great objection to them beyond the liability to leakage and the bad taste they often communicate to the water. Iron pipes are now, however, generally used, the joints being either turned and bored, or run with lead, which makes a strong and watertight joint.

Pipes of too small diameter are frequently laid to save initial expense, but the friction of a fluid in small pipes is so great that the loss of pressure and the extra pumping more than counterbalance the first cost. The passage of 300 gallons per minute through 500 yards of four-inch pipe will absorb, by the friction of the water against the sides of the pipe, a head of 152 feet, whereas if a five-inch pipe be used only 49 feet will be lost.

Iron mains are used in all large towns, as they better support the jar of traffic in the streets. When buried in the earth they can neither be inspected nor repaired without the great expense and inconvenience of opening the ground. All mains for gas, water, electricity, and pneumatic parcel transit should be laid in a common tunnel so separated from one another that there be no danger of communication, and that every part of their surface be of easy access. Such a system is in practice in many Continental towns where all the supplies are under municipal control. The chief hindrance in England is the want of co-operation between private companies.

Effects of frost.—In an exceptionally severe frost the freezing of water mains has often led to great privations over large areas, as in the recent London water famine of 1895. It was proved that in most cases the mains and branch pipes were not laid at a sufficient distance below the surface. A depth of four feet for branch pipes and six for mains should be compulsory. It will be obvious to the consumer that in case of any damage to or defects in the pipes he has to pay for water that he does not receive.

Lead pipes of elliptical section have been proposed which when expanded by freezing become circular, thereby increasing the sectional area of the pipe. Such pipes, however, when once made circular do not return to the elliptical shape, so that a second freezing might cause their fracture.

Steel mains have been known to split without the action of frost. At Manchester, in 1893, a riveted steel pipe of twenty-six inches in diameter and seven-sixteenths of an inch thickness of metal, carrying water of about seventy pounds pressure from a well to a reservoir, ripped through five ten-feet lengths soon after being laid. The pipes had been tested for 400 pounds per square inch, and were said to be of good steel and of excellent workmanship. Cast-iron pipes seem to be safer and are less acted upon by the water.

The bursting of pipes by frost is commonly attributed to the thaw instead of to the pressure exerted by the water in freezing. That water on solidifying exerts a great pressure was shown by Major Williams in Canada, by filling a very strong iron bombshell completely with water and closing it tightly with an iron plug. On exposure to the frost the iron plug was forced out with a loud explosion and thrown to a distance of 415 feet, while a cylinder of ice eight inches long issued from the opening. In another case a screw plug that would not yield was used; the bombshell burst across the middle, and a sheet of ice spread all round the crack. In the bursting of lead pipes no explosion is heard, as the resistance is not so great, but the widening out of the portions that have not ripped testifies to the pressure exerted. In this way, water jugs, if left filled at night, are sometimes found in the morning split in long interlacing cracks, with a solid mass of ice within. In nature this action is the principal agent in the disintegration of rocks to form soils, and in the loosening and rendering porous the soils themselves by the freezing of the water contained in them.

Notwithstanding the frequent severe climatic changes in England, few precautions are taken against the grave inconveniences occasioned by frost. House pipes are often left unprotected, and so placed that a burst will cause considerable damage. Cisterns are frequently situated outside, and when they freeze solid are the cause of serious annoyance. The pipes should be run not less than four feet below the surface, right into the house, and should pass within about three feet of the kitchen grate before branching to other parts of the establishment. It is well known that water in agitation is less liable to freeze, as the crystals of ice have not time to consolidate: therefore a common precaution to prevent pipes freezing is to leave taps dripping. Outside pipes may be protected with a casing of rough wood three-quarters of an inch thick and seven inches square, extending three feet into the ground, and filled with sawdust.

In view of the explosions that have been caused by frost in domestic boilers, a circular of the Board of Trade, dated January, 1896, advises :—

1. That all cisterns from which boilers are supplied, and particularly the pipes communicating therewith, should be placed in positions where they are not likely to be affected by frost.

2. That a safety valve should be fixed on every boiler that has not a movable lid.

3. That should the water supply be interrupted from any cause the fire should be at once withdrawn until the boiler is cold and the water supply has been restored. It is very dangerous to put water into an empty boiler while hot.

Some waters deficient in lime, but containing a high amount of chlorides, have a very rapid action upon iron. Such waters corrode the pipes, and soon acquire a ferruginous taste, and throw down a

cloudy deposit of oxide of iron. Angus Smith proposed a coating varnish of pitch and coal tar oil as a protective film in such cases, but galvanised pipes are now very frequently substituted. Glass-lined pipes are also now manufactured, and avoid the chance of zinc poisoning which has sometimes been noticed when galvanised pipes are employed. Tin is sometimes used as a coating for both iron and lead pipes, but in the latter case, owing to galvanic action, the corrosion is sometimes more pronounced than when the pipe is left unprotected. So-called linings of pure tin have been found on analysis to consist of an alloy of equal parts tin and lead. Schwartz protects lead pipes internally with a film of lead sulphide formed by washing them with a solution of "liver of sulphur," but the coating is liable to blister, and is acted upon by soft water in presence of air. Iron pipes treated by the Bower-Barff process, or by the modification of Bertrand, have been highly recommended. The pipes or other iron articles are raised to a bright redness in a chamber into which superheated steam is passed. A hard black layer of magnetic oxide of iron is thus formed, which, as long as it remains intact, completely protects the iron from rust.

Action of water upon lead.—The noxious effects of lead compounds are so well-known that it is hardly necessary to draw attention to the importance of carefully guarding against the possibility of their presence in water. Lead has a cumulative poisonous action, so that even a minute quantity taken day by day accumulates in the system and remains in the organs of the body until serious illness, if not fatal consequences, ensues. One of the most characteristic symptoms of "plumbism" or *lead colic* is a blue line around the gums. Several instances have occurred in which an entire population has suffered from pronounced plumbism before the cause was traced, so that it is now universally admitted that no trace of lead should be allowed in a water used for drinking purposes.

Very few natural sources are thus tainted. In mining districts the metal is often found in issuing brooks, but is generally entirely precipitated by the sulphates, &c. in the water before it reaches the main stream. In a case which occurred near Hathersage, in Derbyshire, several effluents from lead mines were turbid with lead salts, and contained much of the metal in solution, but in samples of the river Derwent, at a point a quarter of a mile below the outlets of three of them, no lead could be detected in the examination of several gallons. It follows that when lead is detected in water it is usually to be attributed to the material of the pipes or cisterns with which the water has been in contact.

The capacity of waters for dissolving lead varies considerably. As a rule, the softer the water the greater the danger of that kind. In Dublin the soft moorland water of the Vartry was found to attack lead so easily

that tin-lined pipes were laid down when the new supply was inaugurated. The equally soft water of Loch Katrine, on the other hand, has little or no action upon this metal. At Sheffield the plumbo-solvent action of some of the public supplies have caused the authorities considerable trouble. These waters are peaty and of acid character, and rapidly attack lead, zinc, and iron. The difficulty has been overcome by the addition of powdered chalk to the extent of one-half to three grains per gallon. In many cases the addition of carbonate of soda, as in the process for softening water, has been found beneficial.

The Local Government Board have specially studied this subject, and have concluded that the action of water upon lead is determined by the presence of organic acids generated by special organisms which exist in most peaty soils. At Keighley, in Yorkshire, three coke filters, to remove the coarser impurities, and four sandstone and limestone filters have been erected to remedy this evil. It is believed that the limestone will neutralise the organic acids, and so cure the water of its plumbo-solvent properties. Some waters act so rapidly upon lead that standing all night in the service pipe is sufficient to determine the presence of lead in poisonous quantities in the water in the morning. It is therefore always desirable that the first water drawn should be allowed to run to waste. At Pudsey, in Yorkshire, for example, during the outbreak of plumbism in that town, Dr. Hunter found as much as half a grain of lead per gallon in the water supplied in the morning. In other cases, where the direct effects of lead poisoning have not been diagnosed, chronic illness has been noticed to disappear on the substitution of iron piping for lead. Dr. Tidy and others have contended that the plumbo-solvent action of a water may be prevented by means of silica, and that the best method of silicating was to pass the water over fragments of flint and limestone. Such treatment has been shown to be ineffectual at Sheffield and elsewhere by Dr. Sinclair White and Dr. Percy Frankland.

Contamination with sewage, involving the presence of nitrites and chlorides, increases the solvent action of water, as do also a high temperature and pressure and the presence of air.

Dr. Frankland recommends the following precautions to be adopted in those cases in which the use of a lead-contaminated water is for the time unavoidable :—

1. That no water should be collected for drinking purposes until after the tap has been allowed to run for such a length of time as will presumably clear the service pipe, and that drinking and cooking water may be advantageously collected immediately after a considerable quantity has been drawn for other domestic purposes.

2. That filtration through animal charcoal practically guarantees freedom from lead. It is important,

however, to bear in mind that the charcoal does not retain this power indefinitely, but requires to be renewed from time to time.

3. That hot water acts more powerfully than cold, hence that metal teapots and other soldered vessels should be avoided as far as possible.

New and bright lead is at first rather rapidly attacked by nearly all waters, but after a time the white coating of insoluble lead sulphate and carbonate to a great extent protects the surface from further action. When a lead cistern is cleaned out this coating should be allowed to remain, and cleaning with acids should never be practised, as such procedure has occasionally been attended with dangerous consequences. A method for testing waters for lead will be given in a subsequent chapter, but in all cases in which suspicion is aroused it is advisable that a full analysis of the water be conducted in order to ascertain what method for treatment should be adopted.

Zinc is easily attacked by most waters, and cisterns of galvanised iron have caused symptoms of irritant poisoning. The best material for cisterns is slate. Portland cement is also good, but is generally too heavy. It need hardly be said that with new cisterns and pipes the water is usually for some time unfit for drinking. Tanks of cast-iron plates, bolted together and well painted, are durable and inexpensive, but the water should be examined for lead, as sometimes it dissolves the latter from the paint.

Cisterns should be protected from frost, dust, and dirt, and be easily accessible for cleaning.

Constant Service.—Most towns have now a constant service, but in many parts of the metropolis an intermittent supply still obtains. Under a constant system, the pipes being always full and under pressure, pollution by the passage into them of drainage is less liable to occur, the pipes are less subject to corrosion, and have therefore a longer life, and the mains need not be so capacious. An intermittent supply makes the consumer dependent on a house cistern, and thus increases the danger of contamination, unless the precautions already alluded to and due attention to cleaning be observed. The penetration of sewer gas into cisterns has been shown by Parry Laws not to carry with it microbes, but it nevertheless renders the water offensive and unwholesome by the sulphuretted hydrogen and ammonia compounds which it communicates. Dr. Talbot, of Bow, has patented a self-cleansing storage cistern to be used with a constant service. It is of funnel shape, and is protected by a lid.

Water is liable to become contaminated in its passage through iron pipes. Certain vegetable growths, like *Crenothrix kuhniana*, possess the property of imprisoning oxide of iron within their tissues and of forming large matted growths, which may completely block up a pipe or communicate to the water a strong inky taste. *Cladothrix dichotoma*

also causes obstructions by absorbing calcium salts from the water. *Beggiatoa* reduces sulphates and gives an odour of sulphuretted hydrogen, and fresh water sponges communicate a bad taste. Green algæ cannot of course grow in the dark, but are met with in cisterns which are not kept covered. The presence of these organisms in the service pipes indicates imperfect filtration or faulty storage, as their spores should not have been allowed to penetrate.

Until recently the storage and distribution of the water supply of towns have been entirely in the hands of private companies, but the example of Glasgow, Liverpool, and other cities in purchasing these undertakings and placing them under municipal management, is being followed by other towns. A great deal of discussion has taken place in London on this point, and although vested interests are opposed to any change in this direction, it cannot be long before a matter of such importance to the public safety as the water supply of the metropolis will be under the control of a responsible and elected body.

Huddersfield, Yorkshire, is an example of a town where every large local service is under municipal control, and with conspicuous success. The capital expenditure on the waterworks, over £100,000, has produced an annual net profit of about £5,000. The storage capacity of their reservoirs is no less than 1,500,000,000 gallons. They are formed by embankments at the eud of valleys. Compensation water can be released from the reservoirs into the rivers (p. 63). The supply is chiefly moorland, from the millstone grit. It has been subject to the lead difficulty (p. 136), but experiments on the use of precipitated chalk are now in progress; and a local Water Act has been passed this Session (1896) without restrictions, notwithstanding that clauses as to filtration or treating have been inserted in the Barnsley and Sheffield Water Bills of the same year.

At present, as pointed out in the Report of the Select Committee of the House of Commons on the London Water Companies' Bills of 1896, there is in London no general legal control over the periods for pumping nor the proper carrying out of subsidence or filtration. The Committee consider that "the present system of the London Water Companies is not in accordance with the public interests."

In many respects, the United States are ahead of us in the care and management of water supplies. As an example, the regulations enforced by the City Council of Wilkes Barre, Pennsylvania, may be of interest:—

"Section 1. Any person, companies, or corporations wilfully or negligently furnishing to the people of this city water for domestic purposes in a state of impurity, or impregnated with the germs of disease, or any other matters dangerous to health, upon conviction thereof shall be required to pay for the first offence a penalty

of not more than $100, and for every subsequent offence a penalty of not more than $200.

"Section 2. It shall be the duty of all persons, companies, or corporations furnishing to the people of this city water for domestic purposes, through pipes located in the public streets, to adopt, use, and maintain in the most efficient condition, and without unnecessary interruption, for the purification of the said water, some system of filtration now employed in the cities of the United States or Europe, which experience has shown to be the most effective in freeing water from impurities, deleterious organic matters, and germs of disease, and rendering the same clean and wholesome.

"Provided, however, that the adoption of the system of filtration through sand beds, such as are used in London and Berlin, shall not be deemed a compliance with this ordinance, unless the said sand beds are at least five feet deep, and in working the same not more than forty gallons of water per square foot of area are allowed to pass through said sand beds per twenty-four hours.

"Section 3. It shall be the duty of such persons, companies, or corporations to adopt and use, without unnecessary interruption, and in the most efficient manner, such measures as may be necessary to prevent contamination of the water at its source, and at all places where it shall flow or be collected before reaching the places where it is filtered, in obedience to the requirements of the second section of this ordinance.

"Section 4. Any persons violating sections 2 or 3 pay a penalty of $100 for every day such violation is continued.

"Section 5. For the purpose of aiding the enforcement of this ordinance the office of water-inspector is hereby created; the incumbent thereof shall be an expert chemist and bacteriologist, to be appointed and his compensation fixed annually by an ordinance of the City Council; and it shall be the duty of the water-inspector to make bi-weekly chemical and bacteriological analyses of the water supplied, and immediately report the results of the same to the Sanitary Committee and to all persons, companies, and corporations furnishing the said water, and also from time to time inspect the system or systems of filtration adopted in obedience to this ordinance, and whenever the same are not kept and operated as herein specified, make report thereof to the parties aforesaid."

CHAPTER VIII.

PURIFICATION ON A LARGE SCALE.

Notwithstanding the fact that the necessity and, in most cases, the perfect possibility of obtaining a pure water supply has been insisted upon by hygienists for a great number of years, it is still a common practice to attempt the purification of polluted waters by cumbrous and expensive systems of filter-beds and reservoirs. Such systems, however, as notably in the case of Hamburg, are liable to accidental breakdowns, which then not only cause widespread inconvenience, but in many cases serious outbreaks of disease. Although such systems are wrong in theory and commercially wasteful, after they have once been started, the value of the plant and vested interests usually provoke such determined opposition to any natural scheme, that large populations are still persuaded to endure as their drinking water what has been described as "diluted and purified sewage." As compared with an artificial conduit for bringing water from an unpolluted collecting ground, a river is at once condemned on account of the certainty that it is open to drainage of all kinds, and that the so-called self-purification of a river in flow is of doubtful efficacy, and is in most cases