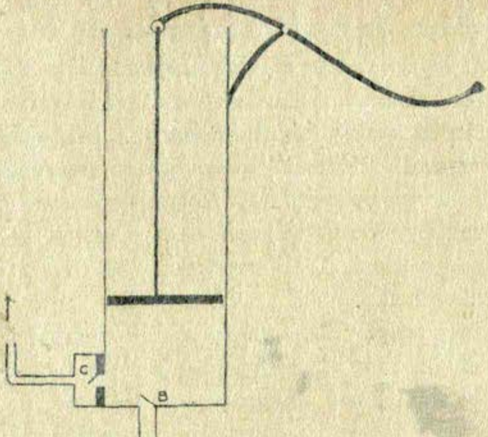
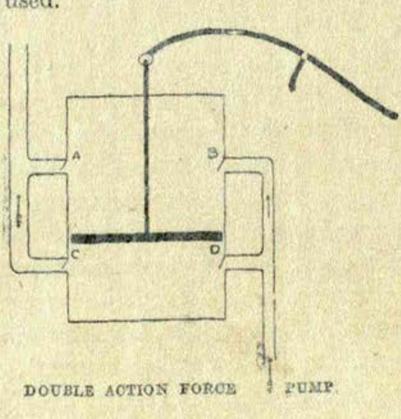


SINGLE ACTION FORCE PUMP.

THE DOUBLE ACTION FORCE PUMP.

This pump forces up water both at the up and down strokes. At the up stroke the water above the piston is forced through the valve A, while that below enters the cylinder at the valve D. At the down stroke the water is forced through the valve C, while it enters above the piston at the valve B. In all force pumps, the packing of the piston or box is of the utmost importance. It is commonly made of waste tow soaked in tallow rammed tight, but for great pressures cup leather packings are used.



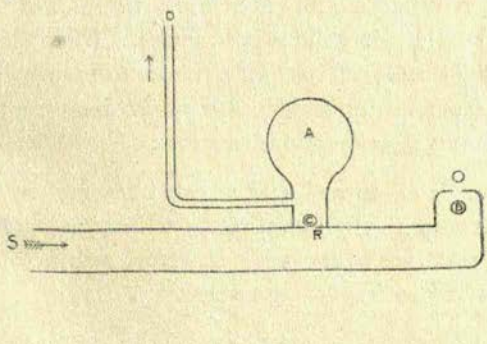
DOUBLE ACTION FORCE PUMP.

CENTRIFUGAL PUMPS.

These pumps contain no valves and no pistons. They work by the revolution of a series of blades contained in an iron casing. A partial vacuum is produced behind the revolving blade and water is drawn in due to atmospheric pressure upon it, while the water in front of the blade is forced into the rising main. These pumps are very good up to 25 feet. Some are made which are capable of raising water up to 100 feet.

THE HYDRAULIC RAM.

Rams are used to lift water to heights as a rule not exceeding 150 to 200 feet, but special rams are made for greater heights. The principle on which they work is as follows (*vide* Diagram) :—The water working the ram is supplied through a pipe S and it escapes through the opening O until



it has gained a velocity sufficient to raise the valve or ball B, which suddenly stops the current in this direction and causes an excess pressure in the ram R which results in the valve C being raised. The water is then pressed into the air chamber A and finally through the delivery pipe D to its destination. When equilibrium of pressure is established between S and R, the valve B falls and the operation is repeated. The ram, depending on its size, can make as many as 200 strokes per minute. The intermittent flow through C is converted by the pressure of the air in A into a constant flow in the pipe D. The length of the supply pipe may be ten times the height of the fall or more, but it must not be less than 5 times the height.

Any working fall from, say, 18″ up to 100 ft. will do to work a ram, but the more the fall obtained up to about ⅓ of the total height that the water has to be raised above the ram, the less will be the cost to raise a given quantity and the less will be the driving water required to lift that quantity. Rams will force water to a point several miles distant. The quantity of water required to work a ram depends on the fall available, the height it is required to raise the water and the quantity desired to be raised. Under favourable circumstances, rams can be made to work with less than one gallon of water per minute. When giving the quantity of water available to work a ram, it is necessary to state also the velocity and flow in gallons per minute. When the working supply is not sufficient to work a ram continuously, the water may be dammed up and discharged at intervals; the ram thus working in intermittent manner.

The ram is cheap and well adapted to small villages and country houses. The elevation to which the water has to be raised must not be too great, otherwise repairs to the working parts will be frequently needed.

In actual practice, it may be said, that water falling from any height between 4 and 40 feet may be made to raise a portion of itself to any greater height up to 10 times the amount of fall available.

A well-made ram is very durable and requires but little attention, and its cost should not exceed £50 to £60.

HARDNESS OF WATER.

The provision of a hard water supply for a town reacts in various ways. In the first place a very great waste of soap occurs. The constant use of a hard water for drinking purposes causes gastro-intestinal troubles; vegetables boiled in hard water lose much of their colour and flavour. The same amount of nutriment is not extracted from meat, nor flavour from coffee or tea, with a hard as with a soft water. Hard water used in boilers may cause an explosion due to the deposition of salts, which usually occurs in the following order :—

1. The carbonates of calcium and magnesium.
2. The sulphates of calcium and magnesium.
3. Salts of iron, if present.
4. Silica or alumina, if present.

The incrustation formed causes much waste of coal.

The total hardness of most water is caused by salts of calcium and magnesium with some free carbonic acid ; hence waters from chalk, oolite, limestone, dolomite, and new red sandstone are hard. Rain water is soft.

It is estimated that every degree of hardness means waste to the extent of one pound of soap for every thousand gallons of water used.

Hardness of water is of two kinds, (1) temporary and (2) permanent ; the former is capable of being removed by boiling or by the employment of caustic lime or soda.

Temporary hardness is due to the presence in the water of the carbonates of calcium and magnesium held in solution as bicarbonates by carbonic acid chiefly. Salts of silica, iron and alumina, if present, may also add to the hardness. The bicarbonates of calcium and magnesium cease to be soluble at 212° F. and after treatment of the water with caustic lime or soda, as they are robbed of a portion of the carbon dioxide which holds them in solution, and they are deposited as mono-carbonates.

The permanent hardness is due to calcium and magnesium sulphate, chlorides, phosphates and nitrates with some magnesium carbonate which re-dissolves as the water cools. The salts of iron, silica and alumina, if present, also add to the hardness. All these salts are unaffected by boiling, thus constituting the difference between temporary and permanent hardness. To determine the amount of hardness present, a solution of soap is used. Soap is a salt, the base of which is a metal and an acid, one of the fatty acids, *i.e.*, soap is an alkaline oleate, soluble in water forming with it a lather. If lime, baryta, alum, magnesium or iron be present, oleates of these bases are formed and no lather is given until the earthy bases are thrown down or used up. Free carbonic acid has the same effect. The precipitate formed with calcium comes down direct, but that formed by magnesium comes after a slight delay, hence an apparent lather may form only to disappear later. Many of the salts contributing to the total hardness are held in solution by carbonic acid, *e.g.*, the carbonate and some salts of lime and magnesium and some of silica, alumina and iron if present.

The amount of hardness may be expressed in terms of grains of calcium carbonate per gallon. This is known as Clarke's system, where each grain equals one degree Clarke; or it may be expressed as parts of calcium carbonate per 100,000. This is known as the metrical scale. When they are compared, $1°$ Clarke $= 0{\cdot}7°$ metrical.

The total hardness of a water should not exceed $30°$ metrical and of this the permanent hardness should not exceed $5°$ metrical.

Hard waters vary from $20°$ to $30°$ metrical and soft waters from $8°$ to $15°$. A very soft water may contain from $6°$ to $8°$ metrical. The greater the permanent hardness the more objectionable the water.

TREATMENT OF HARD WATERS.

Temporary hardness can be dealt with by caustic lime or soda, which robs the bicarbonates of one molecule of carbon dioxide and reduces them to monocarbonates.

A water containing carbonate of magnesium :—

$MgO + 2CO_2 + CaO = MgCO_3 + CaCO_3$.

A water containing only bicarbonate of calcium :—

$CaO + 2CO_2 + CaO = 2CaCO_3$.

Water treated by caustic soda :—

$CaO + 2CO_2 + 2NaOH = CaCO_3 + Na_2CO_3 + H_2O$.

A water containing sulphate of lime can be dealt with by carbonate of soda, with the result that a monocarbonate of lime forms and sulphate of soda, a soluble salt, remains in solution.

$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$.

A water containing both bicarbonate and sulphate of calcium :—

$$CaO + 2CO_2 + CaSO_4 + 2NaOH = CaO + 2CO + CaO + Na_2SO_4 + H_2O = CaCO_3 + CaCO_3 + Na_2SO_4 + H_2O.$$

When the bicarbonate exists in greater proportion than 144 to 136 of the sulphate, the difference in excess must be dealt with by caustic lime.

One must know the exact degree of hardness in the water and use only so much lime, etc., as will combine with the carbon dioxide holding the chalk in solution—otherwise lime will pass out into the distributing pipes.

The average amount added is about 1 oz. of lime per 100 gallons of water for each degree of temporary hardness.

In the Porter-Clarke process the suspended matters are removed by passing the water under pressure through linen cloth. This process does not touch the permanent hardness.

For the reduction of permanent hardness, the addition of lime, sodium, or sodium carbonate is necessary.

ACTION OF WATER ON LEAD PIPES, ETC.

Certain waters act on lead and also on zinc.

Those waters which act most are—

- the purest and most highly oxygenated, *e.g.*, rain water, and the soft waters of lakes and upland surfaces;
- those containing any organic matter, nitrites or nitrates from sewage pollution;
- waters containing much of chlorides which dissolve the coating of carbonates which may have formed;
- waters containing any free acid, *e.g.*, peaty water.

Water containing mud and mortar appears to act more on lead. Moorland gathering grounds are usually rich in peat. Moist peat is invariably acid in reaction, and water draining from peat is always acid. The degree of acidity depends chiefly on the amount of peat and the length of time the water has been in contact with it; the cause of it is the growth in the peat itself of acid producing bacteria.

Those waters which act least on lead are—

- those rich in the earthy salts, *e.g.*, hard waters from deep wells containing carbonates, phosphates and sulphates, especially calcium carbonate: when sulphates are in excess, they increase the solvent action;
- those containing free carbonic acid. If the CO_2 is in excess or the water is charged with it under pressure, then the coating of protective basic carbonate is dissolved and the solvent action of the water is increased.

Silica is said to have a protective influence.

New lead pipes yield more lead to the water than do old pipes. The length of time the water is in the pipe also influences the result: for the first 24 hours the amount dissolved increases, but afterwards some is deposited and after the lapse of about 6 days less is found. Hot water in pipes takes up more lead than cold. Increased pressure upto 140 lbs. per square inch helps the solvent action of the water. The juxtaposition of other metals to lead increases the solvent action owing to galvanic action ; this is seen when iron, zinc or tin is mixed. Bending lead against the grain is said to increase the risk. Zinc pipes, which often contain a mixture of lead, may yield that metal to the water.

The amount of lead necessary to cause illness varies very greatly according to the personal idiosyncrasy of the individual concerned. Angus Smith quotes a case where water containing $\frac{1}{100}$ grain of lead per gallon caused poisoning. Adams also records a similar case. Any quantity over $\frac{1}{20}$ grain per gallon (*i.e.*, 0·07 per 100,000 parts) is to be considered as bad. As different observers report water analysis in different terms, *e.g.*, some in terms of grs. per gallon, while others do so in terms of parts per 100,000, it is convenient to remember that to convert grains per gallon into parts per 100,000, one must multiply by 10 and divide by 7.

To prevent the absorption of lead various devices have been proposed, including acting on the water before it enters the pipe and acting on the pipe itself :—

1. Limestone, lime, or bicarbonate of soda is added to the water in order to lessen its acidity.
2. Lead pipes lined with tin have been recommended, but as the lining is liable to fracture, galvanic action may be set up and lead dissolved. Block tin pipes besides being expensive are liable to corrosion if the water contains nitrates. Tin lined iron pipes have been used in many places. On the whole, the best is to have good iron pipes protected in one of the various ways in vogue. Filtration through sand, charcoal, or spongy iron will remove much of the lead.

ACTION OF WATER ON IRON PIPES.

The action appears to be energetic at first but diminishes later. Soft waters act freely on cast iron, causing corrosion and consequent turbidity of the water and diminution of the lumen of the tube. Waters with little lime but high chlorides act rapidly on iron. They acquire a ferruginous taste and leave a deposit of red oxide of iron in vessels. Different methods have been adopted to protect iron pipes from corrosion.

Angus Smith's protective process consists in coating the interior of the pipe with a mixture of pitch. As a result the corrosive action of the water is lessened. The pipes are heated to 310° F. and are then immersed in a bath of pitch for some time. This bath must be kept at a temperature of not less than 310° and the pitch used must be distilled until all the naptha has been driven off the coal tar. To the pitch about 5 % to 6 % of linseed oil is added. The pipes must be perfectly clean and free from rust before immersion.

Barrf's protective process consists in raising the temperature of the pipes to 1200° F. in a suitable chamber through which superheated steam is passed for several hours—after which treatment a coating of oxide of iron is formed.

In some parts of the United States of America, iron pipes lined with hydraulic cement are used.

On the whole, iron sizes are best for the larger sizes required, and, under the pressure of the constant system, for the smaller sizes also.

QUANTITY OF WATER REQUIRED PER HEAD OF POPULATION.

This must of necessity vary according to circumstances of climate, the presence of trades and large institutions, etc. Water is required for ordinary domestic purposes including personal ablutions, cooking, cleansing of the house and clothing and for water-closets and baths. Municipal requirements must be met, as water is needed for the streets, for cleansing drains and sewers and for extinguishing fires. Provision must also be made for animals, *e.g.*, horses, cattle and dogs. Finally, trade requirements and an allowance for waste must be met. It is not possible to lay down any hard and fast standard of requirements; a rough guide, which however must vary according to circumstances, is for domestic, municipal and trade purposes 10 gallons each per head. The following table shows the average allowance per head in each of the following towns :—

London	35	Edinburgh	38
Liverpool	31	Dublin	35
Manchester	29	Bristol	23
Glasgow	50	Newcastle	38
Paris	44	Rome	220
Berlin	22	Calcutta	35
Vienna	22	Madras	18
Bombay	40		

In the case of Calcutta, Madras, Bombay and other towns in India, the amount of water actually used per head is greatly in excess of the amount provided by the respective Municipalities, as a large amount of water is extracted from private wells and public tanks for ordinary domestic purposes, washing and for the watering of gardens.

In Bombay it is beyond question that a reckless waste of public water is practised by the poorer classes.

THE COLLECTION AND STORAGE OF WATER.

Where the water supply is derived mainly from surface waters, it is necessary to provide sufficient storage where any aggregation of population occurs, in order to meet the demands for water in the dry seasons. Water is therefore collected in what is known as an "impounding reservoir," which is usually constructed by damming the lower end of a valley.

Many considerations have to be weighed before settling on any particular site as suitable for an impounding reservoir, and though these fall more particularly within the duties of a Water Engineer, brief reference may be made here to a few of the main points.

(i) In the first place, one must know the amount of rainfall experienced in the area under examination, its seasonal distribution, the greatest annual rainfall, the least and the average, and also the length of the dry season.

Hawksley has estimated that, speaking generally, the average of 20 years' rainfall less $\frac{1}{3}$ may be taken as the amount of rain in the driest year, that similarly the average of 20 years plus $\frac{1}{3}$ equals the amount in the wettest year, that the average of the 3 driest years in 20 is a fairly safe basis to work upon, and that this may generally be taken to be about $\frac{5}{6}$ the average rainfall. We may assume that about $\frac{6}{10}$ of the actual average rainfall is available for use.

(ii) The extent, configuration and nature of the catchment area must be carefully ascertained. The nature of the soil influences the loss by percolation, which is greatest where the soil is porous, *e.g.*, sand and gravel. A steep rocky surface occasions least loss by evaporation and percolation. The ground must be examined to ascertain the nature of the underlying impervious stratum and its distance from the surface and, if possible, the presence or absence of any fissures should be ascertained.

It is most desirable that no part of a catchment area should be under cultivation, nor should any human habitations be permitted in the area. The houses necessary for the Water Engineer's permanent staff should be so situated as to preclude any risk of drainage from them entering the lake. The area should be fenced in to prevent cattle straying into it and it should be covered by evergreen trees to protect the soil from being washed away.

(iii) The extent of the demand (if any) for compensation waters must also be ascertained and provided for.

The sides of reservoirs should slope rapidly, and preferably should have a rubble-covering to a depth of 6 to 10 feet below low water mark. In very large reservoirs, however, this is often impracticable.

The margins should be kept free from weeds and long grass.

In impounding reservoirs the growth of chara and nitella may cause an offensive smell and taste to be imparted to the water. Soft waters and those with ammonia in them aid the growth of these low forms of vegetable life.

Blue and green algæ frequently grow along the sides and diatoms and desmids on the surface.

To destroy algæ, etc., copper sulphate in the strength of 10 lbs. for every million gallons of water is of great value. It is usually mixed with the water by towing canvas bags over the lake behind a small boat or boats.

The decay of blue algæ causes an objectionable smell, which is noticeable also when the oil sacs in them are ruptured. After water containing blue and green algæ has been treated with copper sulphate, the smell may appear to be worse, but in a week the water will be found to be quite free from smell, sediment and any trace of copper. Filtration through polarite removes copper, as will also many mechanical filters, *e.g.*, Jewell's.

Water from reservoirs, rich in bottom vegetable growths, frequently has an offensive odour, for which the only remedy is thorough æration.

A method of getting a very rough estimate of the amount of reservoir space required is as follows:—Divide the number of gallons of water used daily by 6·23; this gives the number of cubic feet consumed per day, and that multiplied by the number of days for which storage is required gives the reservoir space necessary. Hawksley introduced a formula whereby one can ascertain the number of days' supply that should be stored in any particular instance. Let F equal the mean annual rainfall in inches, say $\frac{5}{6}$ of the average annual yield, and let D equal the number of days for which storage is required, then $D = \frac{1,000}{\sqrt{F}}$

e.g., the mean annual rainfall is 25 inches, then

$$D = \frac{1,000}{\sqrt{25}} = 200 \text{ days.}$$

In England, the minimum number of days for which storage should be provided is usually about 150 days.

From impounding reservoirs the water is taken to storage reservoirs, from whence it may pass to filter beds, or in some instances direct to the consumer through street mains and service pipes, etc. Pumping stations and settling tanks may or may not be necessary, according to the elevation of the impounding reservoir and the purity of the water. As far as possible all storage reservoirs should be covered in and ventilated, they should be deep, and not extended and shallow, so as to lessen evaporation and keep the water cool. They should be periodically cleansed. Further reference will be made to the importance of storage reservoirs under the heading of "Purification of Water."

When the supply of water is derived from a river, the intake should be where the stream is constantly flowing, avoiding stagnant and shallow places. It is best situated some feet below lowest summer level. Screens should be provided to exclude gross matter entering. The water may have to be pumped to subsidence and storage tanks, passing thence to filter beds and to the clear water storage reservoir and thence to the public.

DISTRIBUTION OF WATER.

There are two main systems, and several subsidiary methods of distributing water, such as by water carts, *pakhals*, etc. The main systems are (1) the constant and (2) the intermittent, the essential difference between them being that in the latter there must be provision made in the house for the storage of one or more days' supply of water, whereas in the constant system the storage required is only to the extent of the cisterns necessary for the water-closets and kitchen boilers.

In the constant system, the taps in the houses deliver water direct from the service pipes. This system necessitates a good supply of water, good pipes and fittings and strong taps. Any wastage is generally due to leaks in the pipes resulting from fracture and drawn joints or defective taps. Such leakages are generally detected by sight or by the use of waste-water meters. Among the objections raised to the constant system are the waste that may occur and the loss of control in times of shortage of water. The former can and should be controlled to a great extent by waste-water inspectors and by the compulsory use of strong fittings, and the latter is capable of control by curtailment of hours of supply should necessity arise.

The intermittent system is open to many objections : in the first place it causes corrosion of the pipes, resulting in diminution of supply and turbidity of the water.

The cutting off of the water tends to create a vacuum in the pipes ; consequently, if there is any fracture in the pipes or leaking joint, there is great risk of foul air or coal gas or even sewage being sucked into the pipes. In actual practice, outbreaks of disease have been traced to this very cause.

The intermittent supply is in itself a great source of waste, as people leave the taps open on finding no supply on. Consequently, when the supply does come much waste may result.

Another very serious objection is that this system necessitates the use of cisterns for the storage of water during non-supply hours. Cisterns are apt to get foul, are costly and moreover the water is apt to stagnate in them and absorb impure air. Besides, in many of the homes of the poorer classes there is no room for cisterns. Where cisterns are necessary, they should be so placed as to be readily accessible for purposes of cleansing, which process should be carried out at regular intervals. They should be covered so as to keep out dust, insects, vermin and the droppings of birds, etc., and also to prevent the breeding of mosquitoes. Provision can be made for ventilation by means of a curved pipe. They should be placed at the top of the house, and if this be a high one, provision must be made for filling them by a force pump worked either by hand or by electricity.

No cistern supplying a water-closet should be allowed to supply the drinking water of the house as well. Here one may add that on no account should a tap from a service pipe ever be allowed to directly flush a water-closet.

Every cistern should be supplied with an overflow pipe opening directly into the open air, so as to give timely warning of any waste. This pipe must never open either into or over a drain or sewer.

Frost may interfere with the action of a cistern, and if the kitchen boiler is supplied direct from the cistern at the top of the house, much trouble may result from a severe frost such as is experienced in certain parts of India. A separate cistern placed at the back of the range should always be provided in places exposed to severe frosts.

Cisterns are constructed of various materials : stone, cement, brick, slate, tiles, wood and lead, zinc and iron, etc. Of these, slate is perhaps the best, but it is liable to leakage ; it should be set in hydraulic cement or in Spence's metal ; common mortar should not be used as it may cause the water to become hard. Lead cisterns are open to the objection that certain waters act freely on them. Zinc and galvanised iron cisterns are liable to corrode, and if the water is rich in nitrates, zinc salts may be dissolved in the water. Wooden tanks should not be allowed. Iron cisterns are apt to corrode.

Spence's metal is made by melting the three sulphides of iron, zinc and lead with sulphur. It expands in congealing and so is very useful for jointing water pipes, etc.

Sources of Impurity in the Water Supply.

These may have their origin in the geological strata from which the water is derived, or from the manner of storage or distribution.

Impurities from Geological Strata.

Mountain limestone yields a clear palatable water, which however is rather hard and therefore unsuited for many trade and domestic purposes. So also water from hard oolite, cretaceous rocks and chalk is hard. Water from magnesium limestone contains a large amount of permanent hardness. That from gravel is very variable and usually contains much organic matter. Shallow wells in alluvial and gravel soils generally yield an impure water, containing calcium carbonate and sulphate, sodium carbonate and chloride, magnesium sulphate and traces of iron and silica and often much organic matter. From cultivated land, the water contains much organic matter and salts. The water of marshes contains much vegetable organic matter. Wells near cemeteries may yield a water containing ammonium and calcium nitrites and nitrates and sometimes fatty acids and much organic matter. That from old cemeteries contains less organic matter, but much nitrates and chlorides, and speedily becomes putrid. Wells near the sea may give a brackish water.

Impurities of Storage.

One of the great objections to the intermittent supply of water is that this system necessitates the presence of cisterns. These are very apt to become neglected and be a source of danger, as already mentioned. Storage in underground tanks, which are not properly constructed so as to exclude surface drainage or drainage from leaking cesspools, also permits of pollution of the water. The material of which the tank is constructed may also have this effect. Open tanks are very liable to pollution from the habits of the people bathing there and washing their clothe therein; moreover, many are so insufficiently protected as to permit of surface drainage gaining access.

POLLUTION DURING DISTRIBUTION.

Distribution by means of open conduits is attended with considerable risks, as such are liable to be fouled by surface washings, leaves and branches of trees, dead animals, house and trade refuse and human and animal excrement.

The possibility of water dissolving iron, lead and zinc when passing through pipes composed of those metals or stored in cisterns thereof has been discussed elsewhere. Defective pipes and joints may admit of pollution, if water pipes are permitted to be laid in the vicinity of cesspools and drains, etc.

Sewer gas, sewage and coal gas may all be drawn into water-pipes when the intermittent system of supply is in vogue.

DISTRIBUTION BY SKINS (*Mashaks*).

Leathern receptacles made of the skin of the goat or calf are used.

The sources of pollution are more or less obvious, as the skins are unclean to commence with and cannot be made or kept clean. Moreover, during non-working hours the *mashaks* are deposited anywhere, and, should an outbreak of Cholera or Typhoid occur in the house of the *bhisti*, the chances of infection of these receptacles are very considerable.

DISTRIBUTION BY WATER CARTS AND BARRELS.

The chief risk in such cases lies in the difficulty of keeping such receptacles clean. As a general rule, precautions are absolutely neglected and the carts become very foul.

Periodical cleansing and strict inspection tend to minimise the risk.

EFFECTS OF AN INSUFFICIENT SUPPLY.

The effects of an insufficient supply are more or less obvious. Personal cleanliness of body and clothing diminishes. Eating utensils are not properly cleansed. The cleanliness of the house suffers. The streets are not watered, increasing thereby the nuisance and danger from dust. The sewers and drains are not flushed, and these add to the vitiation of the atmosphere. The result of all these factors is a lowering of the general health. Skin and eye diseases spread. Typhus, Enteric, Diarrhœa and Relapsing Fever increase. The danger from an outbreak of fire is also increased in the case of a shortage of water.

EFFECTS OF AN IMPURE SUPPLY.

The diseases which are associated with the use of impure water are Cholera, Enteric, Dysentery, Dyspepsia, Diarrhœa, Goitre, Metallic Poisoning, and Parasitic diseases.

Diarrhœa may be due to suspended mineral matter, *e.g.*, clay, marl, etc., examples of which may be seen in the effects of the waters of the Ganges, Missisippi and the Orange Rivers.

Suspended animal and vegetable matter and also dissolved organic and mineral matters may also cause diarrhœa, *e.g.*, hydrogen sulphide, calcium and magnesium sulphate, calcium and potassium nitrate.

That Dysentery may be caused by impure water there is ample evidence to prove ; in most instances the water was polluted with fæcal discharges.

Ova of parasitic worms are frequently found in water and may gain access to the stomach in this way. The more common forms are Bilharzia Hæmatobia, Ascaris Lumbricoides, Oxyuris Vermicularis, Filaria Medinensis, Distoma Hipaticum, Ankylostoma Duodenale.

(1) Bilharzia Hæmatobia or Schistosomum Hæmatobium. This trematode gains access to the human system through drinking water, or by its miracidia, from the evacuated eggs, penetrating through the skin of man while in the process of bathing. It lives in man in the portal vein and its branches and is distributed to the veins of the abdomen, particularly those of the pelvis or bladder and rectum. The manifestation of the disease, most frequently, is in the bladder, where at first there is catarrh, followed by sanguinous urine or hæmaturia.

(2) Ascaris Lumbricoides, or the round worm, sometimes enters the system through drinking water infected with its eggs.

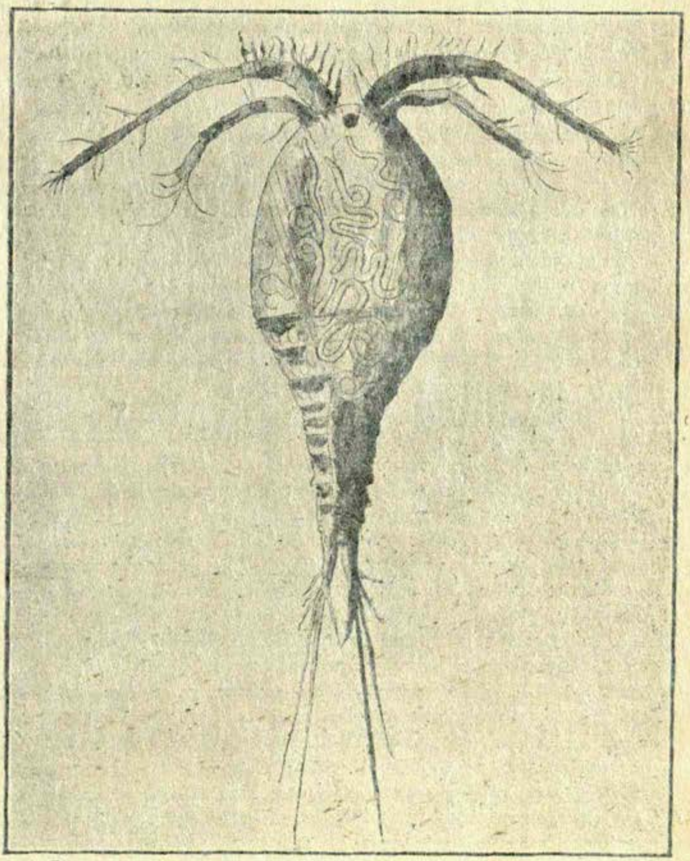
"At Moulmein in Burmah during the wet season, especially at its commencement, natives and Europeans, both sexes and all ages, were in former years so affected by lumbrici as almost to constitute an epidemic. The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon" (Notter and Firth). The normal habitat of this worm is the small intestine. It however wanders all over the alimentary tract, and may be discharged by vomiting or by the stools. The ova of this worm develop in water or moist earth, after a long period of incubation. In medium temperature it takes about 30 to 40 days for the embryo to become formed. The spirally rolled up embryo never leaves the egg shell in the open. In this condition it gains access to the intestine of man and takes about 4 to 5 weeks to develop into young worms. The infection occurs partly through water but principally direct from the soil.

(3) Oxyuris Vermicularis, or the thread worm, is one of the most frequent and widely spread parasites of man. It occurs principally in children and its normal habitat is the large intestine. There the male and female oxyuris live and reproduce. The male rapidly dies and disappears, and that is why it is rarely met with in the excrement. The female remains very active and often leaves the tract through the anus and causes very troublesome itching. The ova also pass out and may infest man through water or be transferred directly from person to person by the hand and re-introduced into man *per os*.

(4) Guineaworm or Filaria Medinensis is very common in tropical climates. It was known to the ancient Arabs, and is most prevalent in Medina (Arabia), Persia, Turkestan and India. The Medina worm is widely distributed in Africa and is identical with what is generally known as guinea-worm. In adult stage it lives beneath the surface of the body, most frequently under the skin, in the lower extremities, chiefly about the ankles. It may also occur in other parts of the body. The male worm is very small and generally dies after attaining maturity. It is the female worm that burrows under the skin. When the worm tries to come out, a blister forms on the skin; this blister soon bursts leaving a superficial ulcer with a central depression through which the head of the worm protrudes.

When the ulcer comes into contact with cold—and this happens when an affected individual walks into the water of a steep-well or bathes in it—the worm discharges her embryos into the water. Dr. Max Braun, in his book "Animal Parasites of Man," says "it was known since the most remote period. 'The fiery serpents' that molested the Israelites by the

Red Sea and which Moses mentioned were probably filariæ." The larvæ of the worm reach the open after the bursting of the mother's body. They live in water and moist soil. The larvæ enter the body of a cyclop through its integuments and there undergo development and are thus taken in with drinking water. When such infected cyclops are swallowed by human beings through their drinking water, the gastric juice kills the cyclops and liberates the contained embryos which are at this time 1-50th of an inch in length. Their further life-history in man is not known until about a year afterwards when we find them fully matured and with a length of from 2 to 3 feet; they are then ready to make their appearance on the surface of some part of the human body.



CYCLOPS QUADRICORNIS (AFTER LEUCKART).

The guineaworm disease, although it does not endanger life, is still productive of much suffering and is sometimes the cause of permanent deformities.

The prevention of the disease is a very simple affair. It is only necessary to prevent the embryos from entering the drinking water, and this can be done by not allowing any infected persons to have access to the well water reserved for drinking purposes. But the habits of the people and their general indifference in this respect make this an extremely difficult matter. Children and even grown-up people often jump into these wells for a swim or for bathing purposes and infect the water.

Straining the drinking water through fine muslin will keep back all cyclops and prevent the disease; but this must always be done.

Boiling the water will also kill the cyclops and prevent infection.

The best measure and the one certain to give the most permanent result is to cover up the well and draw the water through a pump.

(5) *Distoma Hipaticum*, or the liver fluke, inhabits the bile ducts of numerous herbivorous animals, chiefly sheep, ox, goat, buffalo and horse. It occurs equally in all climates. In India it is chiefly found in the liver of the buffalo and in Burma in that of sheep. In the latter animal it produces a disease known as 'sheep rot.' Its habitat is the liver which it gradually atrophies. The eggs of liver-flukes develop in water and the larvæ miracidia penetrate into a water-snail common in fresh water and become sporocysts, and these are further developed into young redia which become encysted on the meadows and are taken up by herbivorous animals with their food. The liver fluke is extremely rare in man; only 23 cases have so far been observed. It feeds on blood.

(6) *Ankylostoma Duodenale* is also called the tunnel-worm or hook-worm. The American hook-worm is called Uncinaria Americana. The ankylostoma is found all over the world. It is very common in India. It is also most frequently found in warm, damp mines where sanitation is defective; hence miners and pitmen suffer most from it and the disease is commonly called Tunnel or Miners' Disease. The normal habitat of the worm is the duodenum, and more rarely the first part of the jejunum. It is parasitical in human beings. The disease is due to the manner of nutrition of the parasite. The worm sucks blood with its head sunk deeply into the mucous membrane of the intestine. It constantly leaves the spots it has attacked, so secondary hæmorrhages occur; in addition to the diseased condition of the intestine, it has considerable effects on the nutrition of the patients; possibly also, toxins are produced which have a pernicious effect on the host. It produces Chlorosis. Recently, during the construction of the tunnel St. Gothard, the labourers suffered severely from Ankylostomiasis. The male worm is smaller than the female but both attack the host by their buccal end which contains claw-like hooks, through which the worm sucks the blood. The female produces a very large number of eggs, which reach the open through the fæces. The larvæ are then developed, which consist of minute organisms, very mobile and

active. In the larval stage it lives in muddy water or wet, damp soil. The larvæ may gain entrance into the alimentary canal through the drinking of such water, or through food eaten with soiled or dirty hands. Recently, Loos has discovered that larvæ of ankylostoma enter the human body through the skin. The larvæ placed on the skin with a drop of water penetrate the hair follicles in a short time. When they attack the skin in large numbers, inflammation of the skin occurs—a dermatitis commonly known as "cooly itch." They gain access to the venous system directly or through the thoracic duct and are then conveyed to the lungs, where they develop further, and are conveyed by the mucous secretion into the bronchi and trachea and out of the glotis, passing down into the œsophagus and lastly into the duodenum, where they further mature and develop into full worms.

The American hook-worm or Uncinaria Americana differs from the ankylostoma duodenale in the following particulars. It is shorter and more slender with the buccal capsule smaller, and instead of the four ventral hooklike teeth, it is provided with a ventral pair of semi-lunar plates, similar to those of the dog hook-worm (Uncinaria stenociphala); deep in buccal capsule are one pair of dorsal and one pair of ventral sub-median lancets. This worm is also called Necator Americanus, and is said to occur in Madras, Burma and Assam.

The disease caused by these worms is termed "Ankylostomiasis."

PURIFICATION OF WATER.

The purification of water may be necessary in order to remove excessive hardness, suspended mineral or vegetable matters, dissolved organic matter, or for the removal or lessening in number of micro-organisms.

Various methods are employed, *e.g.*, distillation, boiling, chemical agents, storage and filtration.

DISTILLATION.

Distillation unquestionably produces a very pure water which is soft. It is only rarely employed on land but is frequently applicable at sea. Its use as a means of purifying water on land is obviously restricted to comparatively small demands owing to the expense involved. Distilled water is often flat and dull owing to loss of dissolved gases. In hot countries it has indifferent storage qualities. The lack of aeration can be partially remedied by passing the water through a clean sieve or by pouring in from one vessel to another, 2 or 3 times repeated, or by charging it with CO_2 gas under pressure.

BOILING.

All vegetative forms of bacteria are killed by boiling. Those bacteria which form endogenous spores withstand, of course, for the most part, the process of boiling.

The pathogenic varieties coming mainly into consideration, Cholera and Typhoid form no such spores, and consequently boiling forms a safeguard against those diseases.

Boiling is limited to the purification of water in small quantities.

The chief objections to this method of purification are the expense involved, the water is rendered flat and insipid and the difficulty of getting the purified water in a cool state.

Besides killing vegetative bacteria, boiling also lessens the hardness of water; on the other hand, it does not remove any suspended matter. To overcome the difficulty of cooling the water, special apparatus in a variety of designs have been invented on the heat exchange principle. By this, use is made of the fact that, with a sufficient area of metallic surface of good conducting capacity and sufficient time, a given quantity of hot liquid will yield nearly all its heat to an equal amount of cold liquid of similar nature.

By adopting this principle, large quantities of water can be rapidly treated and as rapidly cooled. The majority bring the water to the boil and depend on the expansion of the boiling water for the maintenance of the circulation of the water through the machine.

Many patterns exist, and the one in general use in the army is the Griffith which is capable of sterilizing considerable quantities (350 gallons per hour), with the expenditure of a small amount of fuel.

For drinking water for domestic purposes, boiling forms a certain method of killing most disease germs; and has the advantage of requiring no special apparatus.

If, however, larger quantities are required, *e.g.*, for hospitals, schools, factories, mineral water works, ships, armies etc., some special apparatus is necessary.

In the absence of any efficient means of sterilizing water by boiling, distillation or filtration, it may be necessary to fall back on chemical methods.

CHEMICAL METHODS.

(1) *Alum* is very frequently used to purify water from suspended matters. It has a very good effect in clarifying water, specially if calcium carbonate be present. This forms calcium sulphate and this with aluminium hydrate forms a bulky precipitate which sinks to the bottom, bringing down a certain number of organisms with it. Alum does not act well if the water is very soft; consequently, when such is the case, a little calcium chloride and sodium carbonate should first be added.

In all cases the alum should be well stirred up in the water and the mixture then set aside to allow the suspended matter to subside.

(2) *Potassium Permanganate* is of great use in cases where the water is impure and foul smelling.

It forms a precipitate of manganic oxide and carries down suspended matters. Some organic matter, both animal and vegetable, is oxidised. A solution of the crystals should be made before adding the chemical to the water.

It is advisable to supplement the potassium permanganate treatment by alum purification and if possible filtration may be added.

If the water is very soft, add calcium chloride and sodium carbonate. No definite quantity of permanganate is used, the custom being to add sufficient solution to make the water pink and retain its pink colour for about ½ hour.

(3) *Sodium Bisulphate.*—Rideal and Parkes suggest the use of sodium bisulphate in the proportion of 15 grains to one pint. It causes a somewhat acid taste in the water but Cholera vibrios and the Enteric and Dysentery bacilli are killed by ½ hour's contact.

Notter and Firth have devised a tabloid containing 2 grammes of 70 per cent. bisulphate sweetened with saccharine and flavoured with oil of lemon. One tabloid for every 1¾ pints of water sterilises the water in 20 minutes.

(4) *Calcium Hypochlorite.*—Thresh, experimenting with chalk water, rain, tap and well water and using Typhoid and Bac. Coli communis, found that very minute quantities sufficed for sterilization. In most cases one part of chlorine in one million of water was sufficient in a few minutes. In no case, however, should less than this quantity be used. The amount of chlorine required to sterilize filtered water varies exceedingly, not only with waters from different sources but with water from the same source at different times.

METHOD OF USE (*Thresh*).

(*a*) Obtain a supply of good quality chlorinated lime in ¼ lb. sealed tins. Add the contents of a tin to one gallon of water and shake until uniformly mixed.

(*b*) A gallon of this mixture will now sterilize 8,000 gallons of any ordinary clear well or river water in 15 minutes.

(*c*) Obtain also, a corresponding supply of ½ lb. packets of sodium hypo-sulphate, which is nearly tasteless and combines with all the available chlorine in ½ its weight of chlorinated lime.

Add one packet of this hypo-sulphate to one gallon of water and shake until dissolved.

(*d*) At the expiration of the treatment of the water with hypochlorite for 15 minutes, the gallon of hypo-sulphate solution is added and an excess of chlorine is thereby removed.

In encampments the water would require to be sterilized in the water carts and these vary in size usually from 100 to 150 gallons.

As one gallon of the chlorine solution mentioned above is sufficient for 8,000 gallons of water, one fluid oz. would suffice for 50 gallons. This being remembered, the quantity to be added can readily be calculated. Waters containing organic matter, such as peaty moorland waters, require more chlorine.

(5) *Iodine.*—Vaillards red, white and blue tablets form a valuable method of rendering water safe in districts, where no other form of protection is available. The red tablet consists of tartaric acid, the white of sodium hypo-sulphate and the blue of potassium and sodium iodide. Method of use:—For one litre of water dissolve one red and one blue tablet in 2 or 3 tablespoons of cold water and add this solution to the litre of water, shake and mix well. The water becomes yellow due to free iodine. After 10 minutes, add one white tablet when, as a result, the water becomes colourless, due to the formation of iodide. The amount of iodine liberated in the above process is 60 m.m., and iodine in the strength of 25 m.m. per litre of water will kill with certainty the bacillus of Typhoid, the B. Coli communis and the Cholera vibrio in from 5 to 10 minutes. It is essential that the operation be carried out as above described.

The red tablet contains 0·1 gramme of tartaric acid; while the blue, 0·1 gramme of potassium iodide and 0·016 gramme of iodate of sodium. The white tablet contains 0·12 gramme of sodium hypo-sulphate.

PURIFICATION OF WATER BY OZONE.

Ozone, the so-called active oxygen, which is formed from the oxygen of the air by the silent discharge of high tension electricity through perfectly dry air, has proved to be a good medium for sterilising water. When dissolved in water, it kills the greater part of the bacteria and then escapes again from the water, without influencing the taste or smell, since it decomposes to ordinary oxygen. Many designs of plant have been proposed and used.

The general principle is that the water is treated with aluminium sulphate before entering the purification chamber and the air drawn into the ozone producer is first of all dried by the use of calcium chloride or by refrigeration. After treatment with alum, the water is passed through mechanical filters.

PETROGRAD WATER WORKS.

To this filtration plant is attached the actual ozone plant which consists of two parts, the ozone batteries and the steriliser.

In the ozone batteries, the oxygen of the air is converted into ozone by high tension discharges. The concentration of ozone amounts to about 1 grain per cubic foot of ozonised air.

The movement of the air through the ozone batteries and pipes takes place by the aid of the so-called emulsifiers (Otto's system). These emulsifiers are water-jet air pumps, which by means of a water pressure of about 160 inches, suck the ozonised air out of the ozone batteries and bring it mixed with water into the steriliser.

The absorption of the ozone and the consequent sterilization of the water takes place partly in the emulsifiers placed near the sterilisers, and partly in the agitators, from the bottom of which the ozonised air rises to the top in a very fine state of division, and therefore in very intimate contact with the water. From the emulsifiers and sterilisers the water passes over a cascade to a pipe which leads it to a pure water reservoir, from whence it passes to the city main.

In order that the plant may work satisfactorily, it is necessary that the water to be sterilised contain no suspended matter and not too large an amount of organic matter, or ferrous oxide.

Where such are present, the ozone is in great part consumed in the oxidation of the dissolved substances or of the iron.

As a result of treatment with ozone, the water undergoes an improvement in taste and colour, its chemical composition does not alter essentially, its temperature is not raised, and the ozone dissolved in the water disappears after 10 minutes. Bacteriologically, experiments made by many observers show that practically all bacteria, except the more resistant spores, are destroyed.

Chemically, according to Sanna, nitric acid is completely destroyed, 15-43 per cent. of organic matter is oxidised. Ammonia present in the water is oxidised.

Sulphates, carbonates and chlorides are not affected. Nitrates and free oxygen show an increase. Hydrogen peroxide is not formed. By using suitable amounts of ozone, complete sterilisation of the water takes place.

Cost.—At Paderborn, with preliminary filtration from 0·66 to 1·94^{D}.

At Paris 0·33^{D} per 1,000 gallons.

At Petrograd 0·87^{D} to 1·0 gallons.

According to Schreiber, the cost of sand filtration in comparable cases amounts to 1·05 to 1·87^{D} per 1,000 gallons.

STERILISATION OF WATER BY THE ULTRA-VIOLET RAYS.

The physicist has known the ultra-violet rays and has produced them in his laboratory by different methods.

It is well known that if white light be analysed into its components by means of a prism, beyond the extreme violet end of the pectrum, there can be indicated certain rays which cannot be perceived as light rays, and are therefore invisible, but to which there belong powerful chemical activities, *e.g.*, towards a photographic plate. That these ultra-violet rays also possess the power of killing bacteria has long been known.

Ultra-violet rays are to-day generated by means of the quartz mercury-vapour lamp.

An electric current is sent through the mercury-vapour which is enclosed in an evacuated quartz tube; the mercury vapour thereby glows and sends out ultra-violet rays, which have the property of passing through quartz though they are retained by glass.

Nogier in conjunction with Mr. Thevenot and M. J. Courmont made researches in the power of the ultra-violet rays emitted from a mercuric vapour electric lamp to sterilise drinking water. The earlier experiments showed that the rays have little penetrative power in non-limpid waters and that the presence of colloidal matters practically nullified the action. Further experiments showed that water which contained 100,000 B. Coli communis per c.c. was completely sterilised in one minute. A similar result followed double this dose of B. Coli communis.

The lamp is immersed in the water so as to bring it in close contact and to enable the rays to be used up on all sides and also for the purpose of keeping the lamp cool.

Only clear water, without turbidity or colour, is sterilisable in this manner.

It was formerly thought that the action of the ultra-violet rays rested on the formation of hydrog n peroxide or ozone. Such is not the case however. Such compounds have never been shown to be present. The taste, smell, temperature, and chemical properties of the water are in no way appreciably altered by the rays, and many experiments on animals have demonstrated the complete harmlessnes of the waters so treated.

This method has a promising future if the cost can be reduced.

SPECIAL TREATMENT OF PEATY WATERS.

Very many peaty waters have a plumbo-solvent action and various devices have been adopted to overcome this difficulty. Previous reference has been made to this subject. The following is the method adopted in Paignton. The water supply to this town comes from a moorland gathering ground on Dartmoor and, though otherwise of good quality, it had formerly, in common with more or less all moorland waters, a very solvent action on lead. In 1909 special filters were installed, and continuous tests since made show that the water is now non-plumbo-solvent and fit for dietetic purposes. The special filters first remove from the waters the peaty solids in suspension, and afterwards render it non-plumbo-solvent by passing it through a chamber containing magnesium oxide, a material which has, after exhaustive trials, been found to be the most reliable substance yet discovered for destroying plumbo-solvency when used on the system of the Candy Filter Company of Westminster. Finally, the water is oxidised and purified by a layer of polarite (also contained within the filter) and then discharged into the clean water tank. Magnesium oxide, which is a hard granulated substance prepared by the Candy Filter Company, dissolves very slowly and in terms of hardness is more efficient than lime or chalk. The depth of the layer of magnesium oxide in the filter is in proportion to the acidity of the water and the filter is so arranged that, as the oxide is slowly taken up by the water, it can be replenished at intervals (once every week or two is sufficient) by a little more being added through a special charging door provided in the filter for such purpose. The filtered water was subjected to the usual chemical tests and showed free alkalinity with phenolphthalein, as compared with free acid with the untreated water, and 3 degrees of hardness in the treated water as compared with ·6 in the water direct from the impounding reservoir, thus satisfactorily indicating that the soft character of a mineral water may still be retained and yet the water be rendered non-plumbo-solvent by passing through the Candy special filter. The system is extremely simple and a distinct advance on the usual chemical processes for the removal of plumbo-solvency, as it entirely does away with the trouble, uncertainty and unreliability attendant upon the ordinary chemical mixing and gauging appliances, machinery, small pumps, etc., and it has the great advantage of combining in one filter three different processes, *viz.*, straining, rendering non-plumbo-solvent, and filtering and oxidising the water.

REMOVAL OF IRON.

Certain waters may contain iron in greater or less quantities. When freshly drawn, the water may be quite clear but later it becomes turbid owing to the separation of a brown precipitate due to conversion, by the oxygen of the air, of the ferrous salt into an insoluble ferric hydroxide with evolution of carbon dioxide.

Although not really objectionable so much from the point of view of effect on health, it is so from that of appearance and on account of the deposit in the pipes and reservoirs. Three methods of removing the iron are used based on the following principles :—

(*a*) By contact with air of the ferrous salt, the oxygen in the air oxidises this salt into an insoluble ferric salt. Consequently, the water may be well aerated and subsequently filtered.

(*b*) Since carbonic acid keeps the iron in solution, the precipitation of the iron may be effected by neutralisation of the carbonic acid with lime.

(c) If the iron is present in the water in a colloidal form (organically combined), a coagulant such as aluminium sulphate or ferric chloride may be employed.

REMOVAL OF MANGANESE.

Manganese, like iron, can be removed by aeration, but it separates out with greater difficulty, since in the process of aeration some soluble manganese compounds form.

For the removal of manganese (and also of iron) permutit has recently been recommended. It is a complex compound of sodium, aluminium and silicic acid, occurring in nature. It is artificially produced by melting aluminium silicate with sodium carbonate (Tillmans).

It will remove lime, magnesia, manganese or iron from water when such water is slowly filtered over it.

REMOVAL OF FREE CARBONIC ACID (*Tillmans*).

If water contains much free carbonic acid, it may have a deleterious action on the concrete walls of storage reservoirs and on iron pipes. Three methods can be used for its removal :—

(a) The water is allowed to flow through limestone. The free carbonic acid is thereby converted into calcium bicarbonate.

$Ca\,CO_3 + H_2\,O + CO_2 = Ca\,(HCO_3)_2$.

(b) Caustic soda or sodium carbonate is added to the water in calculated amount, according to the estimated amount of carbonic acid. The free carbonic acid is converted into a bicarbonate.

$CO_2 + H_2\,O + Na_2\,CO_3 = 2\,Na\,HCO_3$.

(c) Allow the water to rain down in a fine state of subdivision, or to trickle slowly over coke, glass or gravel.

The disadvantage of this system is that it increases the amount of oxygen in the water and this causes severe rusting of iron pipes.

THE FILTRATION OF WATER.

This must be considered from two points of view depending on whether the filtration is required on a large or a small scale.

The researches of Houston have shown that efficient storage and filtration are very intimately associated. The objects of filtration are to remove turbidity, taste and odours, to remove very fine suspended matter and to remove low forms of animal and vegetable life and bacteria and also to remove organic matter in solution. Filtration on the large scale may be by the more usual slow sand process or by the method so frequently seen in America—by the agency of mechanical filters. Sand is the most usual filtering medium and many experiments have been carried out to determine the best conditions under which such filters should work.

A filter consists of a masonry tank containing sand, gravel and metal in varying proportions. The bottom of the tank is sloped and underdrained to permit the clear water to flow away in the required direction. Valves are provided at the inlet and outlet so as to regulate the flow of water on to and through the filters. At the inlet a cushion wall is provided to break the force of the flow of water on to the filter and so permit its gentle passage on to the sand.

In Bombay the Malabar Hill beds are 8,546 square yards in area and comprise 7 beds varying from 1,425 square yards to 1,006 square yards in area.

The filtering medium consists of

Sand	Black	12 inches.
	White	12 ,,
Gravel	Fine	3 ,,
	Coarse	3 ,,
Bricks	.. ..	6 ,,

Average depth of water on filters .. 3′-6″

Maximum rate of flow .. .. 8″ per hour.

Minimum rate of flow ..	.. 3″ per hour.
Average period of use ..	.. One month.
Amount of sand removed..	.. One inch.
Head of water on the Filters	.. From 6″ to 2′-6″ according to condition of the filter.

At the Bhandarwada works there are nine filters varying from 1,701 to 1,835 square yards in area and amounting in all to 15,632 square yards. The depth of water over the filters varies from 2 to 3 feet. The filters are composed of shingle 6 inches and fine sand 2 feet 6 inches.

At Vehar there are five filters giving a total area of 3,044 square yards. The head is 3 feet and the filters resemble those of Bhandarwada, *viz.*, shingle 6 inches and fine sand 2 feet 6 inches.

The maximum rate of filtration is 624 gallons per square yard per day. The rate of filtration is controlled by means of regulating valves, penstocks at the outlet end of each filter and sluice valves at the intake end.

Considerable variation exists in the details of construction of the filters of different cities.

In the Metropolitan Water Boards Works, the water passes from storage reservoirs on to filter beds composed of layers of gravel (fine and coarse) above which is 3 feet of fine sand. The depth of water on the filter is about 2 feet and the average rate of filtration is 1,600,000 gallons per acre per day.

FACTORS TO BE CONSIDERED IN CONNECTION WITH SAND FILTERS.

(1) *Influence of depth of sand.*—Within certain limits the depth of sand exerts but little influence. The Massachusetts experiments showed that, with moderate rapidity of filtration, one foot of sand appeared as effective as five. The sand however should not be less than one foot in depth.

(2) *Size of sand grains.*—The larger the size of the sand grains, the more quickly does the water pass through, but

the coarser sand does not yield such pure germ-free water as does the finer.

There are, however, practical limitations preventing the use of too fine sand. If the sand is too fine, the rate of filtration is very slow, the filters soon clog and require frequent scraping; this is the case whether the filtration be continuous or intermittent—though filters used continuously require less frequent scraping than those used intermittently.

Mr. Hagen, in summing up a series of experiments, says:—Both the quality of the effluent and the cost of filtration depend on the size of the sand grains. With a fine sand, the sediment layer forms more quickly and the removal of bacteria is more complete but, on the other hand, the filter clogs more quickly and the dirty sand is more difficult to wash and the expense is thereby increased. With very fine sand, it is almost impossible to drive bacteria through and the filtrate is practically sterile but the rate is too slow. With a coarse sand, the suspended matter including bacteria penetrates further and consequently thicker layers have to be removed. The minimum expense for cleansing will be secured with a sand which does not allow this deep penetration.

Thresh's specification for the effective size of sand is that the whole of the sand should be of such fineness that it will pass through a wire sieve having 400 meshes to the square inch, and 80 per cent. of it will pass through a sieve having 900 meshes to the square inch, and none of it through a sieve having 3,600 to the square inch.

Further, similarity of form in the size of the sand is important. The more dissimilar the particles of sand are, the more erratically the filter works.

(3) *Rate of filtration.*—Koch after many experiments came to the conclusion that the maximum rate of filtration should be fixed at 2,000,000 gallons per acre per day.

The more slowly filtration takes place, the purer, as a general rule, is the filtrate. The rate varies greatly in different water works but on average it amounts to about 4 inches (100 millimeters) per hour (*i.e.*, 60 gallons per square foot of surface per day.)

(4) *Filtering agents.*—Water in passing through a sand filter is subjected to two processes: (*a*) mechanical and (*b*) chemical, as a result of which improvement in its quality is effected.

The chemical action is slight but a certain amount of oxidation of the organic matter present in the water does take place. This action is probably due to the presence of a nitrifying organism in the sand itself as well as to the presence of air in the interstices of the sand. The mechanical process however is the more important. In this the substances which have not subsided, but remain suspended in the water, are kept back.

The real effective agent in removing organisms from the water undergoing filtration is the layer of gelatinous organic matter which forms on the surface, and if this surface be removed by scraping, or its continuity be affected in any way, the number of bacteria which pass through increases. Frost, water rich in vegetable growths, insects, eels, too great a rush of water, etc., may cause loss of continuity of this surface layer, which consists of diatoms, green and blue algæ, bacteria, desmids and animalculæ.

Hagen states that in the winter it is chiefly of diatoms, and in the spring green algæ appear, whereas blue algæ are more numerous in the hottest months continuing into autumn and disappearing in winter.

This layer is charged with microbial life, and it is by these organisms that the nitrification of organic matter is effected, and the whole layer assists in arresting microbes which may be present in the water. The continuity of this surface layer is essential to the efficiency of the filter.

Certain experiments carried out showed that over 80 per cent. of the bacteria removed by a sand filter were found in the upper inch of sand and 55 per cent. in the upper ¼ inch.

(5) *Frequency of scraping.*—After a certain period of time which varies according to circumstances, it is found that the output of a filter lessens considerably, in consequence of which it is necessary to put it out of action in order that it may be scraped and cleansed.

This is done by scraping away a thin layer of sand from the top of the filter, the amount removed varying in different works but on average is about one inch. In some works, after the removal of the top inch, the underlying sand is loosened to a depth of about 8 inches and the filter allowed to remain unused for a day or so to permit the access of fresh air.

The effect of scraping the filter to remove the clogged layer is to permit an increased number of organisms to pass through when the water is first turned on to the filter again. Consequently, after scraping, water should be allowed to stand on the filter bed for about 24 hours and the first water to pass through after that may be rejected. The object of this wait is to allow the filter to mature again.

The frequency of scraping depends on the character of the raw water, sediment basins being essential to the successful treatment of turbid river waters, also on the size of the sand particles, the smaller the size the more frequently is scraping necessary. The rate of filtration and the maximum loss of head allowed also have an influence.

(The " head of water " is the difference of water level in the filter and in the pure water reservoir.)

A uniform discharge of water from the filter is most desirable, but as already stated, owing to the gradually increasing clogging of the filter, the velocity of discharge becomes lessened and the filter can be kept up to its work only by gradually increasing the " head of water." This is best done by diminishing the water pressure in the pure water reservoir rather than by increasing the amount of water in the filter.

Apart from scraping the surface, from time to time the sand must be replaced by fresh or washed sand. The filter is removed down to the layer of gravel, new sand is filled in and in some instances this is covered by a layer of the lower portion of the old sand which has a sticky nature and accelerates the formation of the surface sediment layer.

The interval between scrapings must, as has been stated, vary largely. In Bombay on an average it is about once a month.

(6) *Sand washing.*—In London and Antwerp the sand is washed, on an inclined plane surrounded by a wall, by means of a hose. The sand is kept to the upper part of the plane while the water and dirt flow off. In Germany it is washed in a revolving cylinder.

In Bombay City it is washed in pits provided with perforated false bottoms through which water is introduced. The sand is agitated by workmen standing in the pits. After prolonged washing, the sand is removed and exposed to the action of the sun for a period of time.

There are numerous other systems.

(7) *Depth of water on the Filters.*—In most European cities, the depth of water on the filters varies between 36 and 52 inches. In Bombay it is about 3 to 3½ feet.

GENERAL REMARKS ON SAND FILTERS.

Filters are either covered or uncovered. Open filters have the disadvantage that during frosty weather cleansing is made more difficult, owing to the freezing of the moist sand.

Covered filters are far more costly, the gelatinous layer is formed much more slowly as it is composed in part of organisms containing chlorophyll and consequently needing light. On the other hand, in some instances this slower growth of algæ, etc., is not a disadvantage.

In countries abounding in mosquitoes, covered filters with mosquito-proof openings are desirable, and for this reason and to exclude the droppings of birds it is an advantage to have covered filters in India.

In order to permit the air in filters to pass out, so that it is not constrained to rise to the top, thus causing a disturbance of the filtering agents, tubes for the removal of air are let into the side walls.

In practice, the filters are frequently filled with water from below to just above the surface of the sand, then the impure water is allowed to flow in from above, and to remain at rest for a period of time during which the formation of their gelatinous layer is accelerated.

The filter is then allowed to work and the filtrate is allowed to flow away until the germ content has reached a certain limit.

Then the filtrate is permitted to pass into the clear water reservoir.

Each filter bed should have a separate contrivance to regulate the pace of filtration, each bed should be small, never exceeding one acre in extent, and it is most desirable that all filter beds should have separate filter wells for sampling purposes in order to see that the bed is working satisfactorily. It is not sufficient that the quality of the mixed filtered water is good ; each of the units filtering should be in proven and perfect working order. The total area of filter beds required in any case is calculated from the quantity of water required for all purposes, the rate of filtration, plus an allowance for filters out of use for purposes of cleaning.

Investigations have been carried out at the King Institute, Guindy, since 1913, to discover the most efficient method of water filtration best suited to the conditions in the Madras Presidency.

The water was drawn from a river which, in the rainy season, shows countless organisms per c. c., lactose fermenters being present in ·00 1 c.c., whereas, in the hot weather the total microbic count may be reduced to 4,000 per c. c., and lactose fermenters may be absent in less than ·1 c.c.

Prior to filtration the water was subjected to storage for a short time so as to permit of sedimentation of suspended matter.

As a result of a large series of experiments with sand filters it was found that :

(1) the total bacterial count was reduced twelve-fold, the lactose fermenters being eliminated more readily ;

(2) the length of life of a filter was 6 to 11 weeks, the maximum rate of filtration being 4 vertical inches per hour. It was noticed however that at intervals there was a sudden deterioration in the purity of the filtrate, due to breaks in the biological film covering the surface, caused by movements of frogs or aquatic insects, heavy rain, excessive growth of algæ, &c.

In order to obviate these disturbing causes, the filters were covered over so as to keep away animals and prevent other mechanical disturbances and it was found that when the filters were protected in this manner, the results were much more satisfactory than when the filters were uncovered.

(1) Bacteriological test showed that uncovered filters yielded a filtrate containing 250 to 400 microbes per c. c., whilst in the covered filters the filtrate contained only 50 to 90 microbes per c. c., there being in the latter case a still further reduction in the number of lactose fermenters—they being absent in 300 to 1,000 c.c. samples.

(2) The life of the filter was increased from 11 to 21 weeks, and the rate of filtrate from 4 to 6 vertical inches per hour.

(3) The texture of the filtering skin in the covered filter was more uniform and not so thick as in the case of the uncovered one.

Numerous experiments have been tried to vary the thickness and texture of the various layers of the filter, compatibly with giving a sufficient support to the biological film. It was found that by placing flat tiles on the bond system in these layers between the coarse and fine sand, good results could be obtained with a thickness of 18 or even 12 inches of sand. The sand retained in a sieve containing 40 meshes to the inch proved to be the best.

As the biological film formed on the surface of the water was found to be independent of the amount of suspended matter in the water, the addition of alum to the water prior to sand filtration was attempted but the filters clogged rapidly and the results were not satisfactory.

As regards the relative merits of sand and "gravity mechanical filters," the conclusions are that the sand filters give far better results. Slow sand filters yield a purer filtrate than gravity mechanical filters and exert a special influence upon the lactose fermenters whereas mechanical filters show no such action. The efficiency of gravity mechanical filters was variable as it depended on the condition of the raw water, whereas in the case of the sand filters it did not so depend.

INFLUENCE OF STORAGE OF WATER PRIOR TO FILTRATION.

The recent researches of Dr. Houston, Director of Water Examinations, Metropolitan Water Board, have demonstrated the great value of storage prior to filtration. In his third report to the Metropolitan Water Board, Dr. Houston states that adequately stored water is probably incapable of causing epidemic disease. He does not advocate supercession of filtration, but rather storage plus filtration, and in support of this view he advances what is termed the triple plea in favour of the safety of stored river water.

The three processes which make for the purification of water under storage conditions are chiefly (1) Sedimentation, (2) Equalisation and (3) Devitalisation.

(1) *Sedimentation.*—This *per se* is insufficient to produce the desired results, but settlement even for less than 24 hours has a considerable purifying effect.

(2) *Equalisation.*—If the water destined to be stored were, to begin with, of uniform composition and contained the organisms of water-borne disease in uniform distribution, no equalisation in the sense meant could take place. But, as judged by the usual chemical and bacteriological tests, the quality of a river water varies enormously from time to time ; it therefore need scarcely be said that mere storage, on purely physical grounds, undoubtedly smooths over (levels, as it were) abrupt fluctuations in its quality.

Moreover, even sewage polluted rivers do not uniformly, or of necessity, contain (in ascertainable numbers) the microbes usually associated with water-borne diseases (*e.g.*, Typhoid).

(3) *Devitalisation.*—This is a factor of supreme importance. The destruction of the microbes of epidemic disease in water is merely a question of time. It is known to vary with the temperature, and no doubt is also influenced by many other factors, such as the prevalence of competitive organisms or their products.

To secure the absolute elimination of these pathogenic bacteria, several weeks' storage may be required, but for all practical purposes provision for 30 days' real storage is ample, that is when dealing with sources of supply comparable to those of London. Strong confirmation of the beneficial effect of storage has lately been obtained by the experimental proof that "uncultivated" bacilli succumb in *raw* river water at a more rapid rate than their "cultivated" brethren. It is strikingly obvious from experiments that temperature is an important factor bearing on the vitality of the Typhoid bacillus in river water, and the lower the temperature, within the limits stated, (0°C to 37°C), the longer does this bacillus show evidence of its existence or vitality. During the cold months, therefore, it is specially desirable that the water should be adequately stored antecedent to filtration.

SUMMARY OF THE CHIEF POINTS SHOWING THE ADVANTAGES ACCRUING FROM THE SIMPLE STORAGE OF RAW RIVER WATER.

(1) Storage reduces

(*a*) The number of bacteria of all sorts.
(*b*) The number of bacteria capable of growing on agar at blood heat.
(*c*) The number of bacteria, chiefly excremental bacteria, capable of growing on bile-salt medium at blood heat.
(*d*) The number of coli like microbes.
(*e*) The number of typical B. Coli.
(*f*)* The amount of suspended matter, colour, ammoniacal nitrogen and oxygen absorbed from permanganate.
(*g*) The hardness.

(2) Storage alters certain initial ratios, *e.g.*,

(*h*) It reduces the number of typical B. Coli to a proportionately greater extent than it does the bacteria of all sorts.
(*i*) The colour results improve relatively to a greater extent than those yielded by the permanganate test.

(3) Storage, if sufficiently prolonged, devitalises the microbes of water-borne diseases.

(4) Storage produces a marked levelling or equalising effect.

(5) An adequately stored water is to be regarded as a safe water.

(6) The use of stored water permits of a constant check being maintained on the safety of a water supply antecedent to and irrespective of filtration.

(7) The use of adequately stored water renders any accidental break-down in the filtering arrangements much less serious than might otherwise be the case.

While these are the advantages, there are certain real or potential disadvantages.

(x) Sometimes algæ develop to such an extent in storage reservoirs as to interfere seriously with filtration processes and in some cases the water may acquire a fishy taste and odour. These troubles may be combated by the use of copper sulphate (2-10 lbs. per 1,000,000 gallons) under skilled supervision. In certain cases Houston found that the use of permanganate of potash (2½—5 lbs. per 1,000,000 gallons) in the case of London's supply destroyed the taste in a few minutes. Such treatment, however, requires expert advice.

The results observed in connection with the storage of London water quoted by Houston must not be read as necessarily applicable to cases in general, especially if climatic conditions are not comparable.

Experiments conducted by Colonel Clemesha prove that within a period of 8 days the beneficial effects of water storage become evident. Experiments made in Madras to distinguish between the effect of storage alone, and storage in combination with sunlight, have proved that during the first 4 days of storage there is a very considerable and rapid diminution in the number of bacteria, the maximum reduction reaching about the 8th day. There was similarly a great reduction in the number of lactose fermenters. There was no consistent difference between the combined action of storage and sunlight and storage alone. It would appear that under tropical conditions storage for a short period of 5 to 8 days has beneficial effects.

DOMESTIC FILTRATION.

There are two systems of domestic filtration, *viz.*, the low and the high pressure system. In the latter, the filter is directly attached to the water pipe and the pressure is derived from the main. In the former the pressure is merely that derived from the water lying on the filter bed.

The best high pressure filters are the Pasteur-Chamberland and the Berkefeld.

The Pasteur-Chamberland consists of a candle or cylinder of fine grained unglazed porcelain enclosed in a metal jacket. The cylinder is closed above and terminates below in a nozzle. Between it and the metal jacket there is a space both above and on all sides. The water under pressure from the main enters the metal jacket and circulates round the cylinder and passes from without into the interior of the candle to be delivered *via* the nozzle as purified water. The rate of filtration depends on the pressure.

The Berkefeld is somewhat similar in design. It is composed of compressed infusorial earth. It is thicker but at the same time more porous and much more liable to fracture than the Pasteur-Chamberland.

After prolonged use, the filtering capacity of both types becomes much lessened and the filtrate ceases to be so good in quality. The former is due to the clogging of the filter by suspended matters arrested on the surface and the latter to organisms growing through the filter.

The cylinders should be periodically cleansed (every 3rd day) by brushing them in hot water and subsequently sterilising them by steam or in the flame of a Bunsen burner or large spirit lamp.

Clarification of the water prior to filtration greatly prolongs the life of the candles.

It should, perhaps, be unnecessary to state that the development of the slightest crack in the candles renders them useless as filters ; yet one often sees cracked candles in use. This point should always be carefully attended to and one must always remember that the candles require careful handling.

The water pressure should not be more than one or two atmospheres, and should not act jerkily, since such pressure assists the passage of bacteria through the filter.

SLOW FILTRATION WITHOUT PRESSURE FROM THE MAIN.

Of recent years the Berkefeld and other companies have placed such filters on the market. They require most careful attention to cleanliness and the preliminary use of coagulants if the water is at all muddy.

The number of different forms of domestic filters is legion. They are all based on the filtration of the water through some porous material, with or without the employment of increased pressure. Many old pattern filters are still sold, the majority of which are more or less useless.

For example, the old carbon filter; which is composed of plastic retort carbon or finely sieved charcoal. The charcoal filter oxidises organic matter but does not sterilise the water but rather favours the growth of bacteria by adding nitrates to the water as well as phosphates, both of which act as nutrient media. It attacks putrifactive organic matter but allows fresh to pass. Also, as regards removal of turbidity these filters are of little use.

STONE FILTERS OF SANDSTONE, PUMICE, ETC.

The stone is burnt from coarse or fine sand, quartz, lime, and magnesium silicates. The clarification of the water may be rather good, but the bacteria pass through fairly readily, at the latest after 2 or 3 days.

They are slow in action (1 litre per hour) and even this yield falls off rapidly.

Asbestos of very fine fibre is used, as a pulp, or compressed or mixed with other materials. They retain bacteria fairly well, but choke up very quickly and this necessitates frequent cleansing and sterilisation.

Polarite, magnetic carbide and spongy iron have all been used.

RAPID FILTRATION ON A LARGE SCALE.

This is done by means of "mechanical filters." The general principle is that water is introduced into a tank containing a filtering medium and passes through at a rapid rate. Where turbid waters are treated, a coagulant such as alum is added to clarify the water before it passes through the filter. This assists in forming an artificial filter layer as it re-acts with the alkaline earths present in the water.

$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = Al_2(OH)_6 + 3CaSO_4 + 6CO_4$

Most of the flocculent, gelatinous aluminium hydroxide sinks to the bottom, and the suspended matter travels with it. The flakes still remaining in the water form a sediment layer on the filter (Tillmans.)

There are a large number of different systems.

(1) *The Candy Filter* is a filter in which sand and polarite (a magnetic oxide of iron) form the filtering medium. A closed tank is divided into compartments containing polarite and sand. The unfiltered water enters under slight pressure and in doing so is sprayed so as to become charged with compressd air. Each compartment of the cylinder is a separate filter. A considerable portion of the organic matter is oxidised and bacteria are removed. By occasionally reversing the current, the suspended dirt which has been stopped by the filter is removed. The filter is successful in removing iron and lead from waters.

In this system no chemical coagulants are used.

(2) *The Jewell Mechanical Filter* consists of a steel cylinder containing the filter bed which is encased in a second cylinder of somewhat larger diameter, leaving an annular space between the two. This space is closed underneath, and into it comes the raw water which has been previously treated in sedimentation tanks and passes on to the filter bed which is composed of sand.

After passing through the sand, the water is collected in a series of tubes and passes thence to the pure water basin.

There is a regulator to keep the rate of filtration constant. To clean the filter, filtered water is passed through in a reverse direction under pressure, the filter bed (sand) being well stirred at the same time so as to effect a thorough cleansing of the sand. It is claimed that these filters occupy only a small area of ground, they are easily and rapidly cleansed, and that objectionable growths cannot take place in the filters and there is less risk, therefore, of the water acquiring odour and taste. The sand can be easily sterilised if required.

EXAMINATION OF WATER.

COLLECTION OF SAMPLES.

The collection of samples of water for chemical and bacteriological examination requires very great care if the results are to be relied upon.

For chemical examination the water may be collected in a Winchester quart bottle which has been thoroughly cleansed previously. Glass stoppers should be used for closing the vessel.

If for bacteriological examination, it is best to use a Pasteur's bulb which consists of a glass tube blown out at one end to a bulb and drawn out at the other end to a fine point. These bulbs are supplied perfectly sterile. They contain a partial vacuum and when about to be used they are held under water and the thin sealed drawn-out end is broken off, thus allowing the water to enter the tube. When the specimen has been obtained, the drawn-out end is again sealed by means of a spirit lamp and the bulb is replaced in the special metal case provided.

When taking a specimen from a hydrant or tap, the water may be allowed to run for a few minutes before taking the sample, unless in the case of the latter, the object is to test for lead. If from wells with pumps, the pump should be worked for a few minutes before taking the samples. In collecting samples from a tap or pump or hydrant, it must be remembered that the tap, etc., may be dirty and care should be taken to obviate this source of error.

If the sample is from a reservoir, then it should always be taken from the windward side and from not too near the bank, as the sediment there may contain many organisms. The bulb should be held well away from the bank by means of a rod, and it will be quite easy to fix up an arrangement to enable the sampler to break off the fine drawn-out end. The bulb should be held below the surface so as to avoid the surface contaminations.

In taking a sample from a deep well, use a perfectly clean weighted bottle provided with an arrangement for pulling out the stopper when required. Under no circumstances should the stopper be removed from the bottle, or the fine drawn-out end of the bulb be broken except for the purpose of taking a sample. The part of the stopper which goes into the bottle and the drawn-out broken end of the bulb should not be touched by hand during the process of collecting the sample. Having obtained a sample, from whatever source, it is most important that no time be wasted and that the sample, packed in ice, be at once despatched to the analyst. The ice is to prevent undue multiplication of the organisms present.

Any delay in forwarding the sample may entirely vitiate the analysis and give an erroneous impression of the quality of the water.

It is most important that the whole operation should be conducted in such a manner as to exclude any possible extraneous contamination.

In the event of a supply of water becoming polluted, it may be necessary to examine the whole of the collecting ground in order to ascertain the source thereof. To do this, one must follow up each stream feeding the reservoir to the spring or moorland surface from which it is derived and apply the following test to each stream in succession. Obtain a sample at the source and also just at its entry into the reservoir and examine both bacteriologically and chemically : if the latter sample is found to be more impure and to contain organisms indicating sewage contamination, then follow up the stream and note all contributory streamlets and take samples just above and below the point of entrance of all such. In this manner one may ascertain the source of contamination. This method is possible only in the case of small streams.

Minute inquiry must also be made into any history of illness of any of the employès and others who have occasion to frequent the gathering ground.

Inspection must also be made to ascertain the presence or otherwise of small villages or isolated houses on the catchment area. If such be found, one must ascertain the method of conservancy adopted and where the liquid refuse matter is disposed of. Most frequently it is the nearest stream, where also washing of clothes, &c., is carried out. This should be ascertained and samples taken from this stream and also from the lake or reservoir close to the point of entrance of the stream. One should also ascertain the kind and number of the animals kept by the villagers.

One cannot dogmatically state what should be the composition of a good drinking water or give an absolute value to the significance of any one analytical datum. The analysis must be considered as a whole and in relation to the source of the water.

The chlorine in a water is nearly all in the form of sodium chloride. An average of a series of examinations in England is as follows :—

Rain water contains ·22 per 100,000, upland surface 1·10 per 100,000, spring water 2·5 and deep well water 5·0 per 100,000.

SOURCES OF THE CHLORIDES.

Rain water, especially that falling near the sea-coast, often contains chlorides. Certain geological formations may contain strata bearing chloride of calcium and soda.

Alkali works and mines may contribute some, wells near the sea are often brackish, and finally they may be present as the result of admixture with liquid excreta of men and animals, as urine contains about 1% of chlorides. In considering, therefore, the significance of chlorides, these possible sources must be borne in mind. If they come from strata containing sodium and calcium chloride, the water may be found alkaline from the presence of sodium carbonate, the oxidised organic matter may be absent or nearly so and often there is much sulphuric acid. The characteristics are common in deep well water. The amount present may vary considerably according to the strata, and it is necessary to know the amount normally present for such district, and any variation from this would indicate the need for a further investigation. When due to admixture with sea water, much magnesia and but little evidence of oxidised organic matter may be found ; examples of such are sometimes seen in wells sunk near the sea shore or tidal rivers. When present, due to recent contamination with sewage, they will generally be present in marked quantity but not necessarily so. And there will probably be evidence of nitric and nitrous acids and ammonia and sometimes of phosphoric acid, and, if the contamination be recent, of oxidisable organic matter. A stream fouled by sewage may show different amounts of chlorine at different periods of the day. As a general rule, contamination of a water with sewage can never take place without increase of chlorides, unless it be by some gaseous emanations, or unless the normal amount of chlorides in that particular geological formation is very high, in which case admixture with contaminated surface water or sewage may cause an actual decrease in the percentage of the chlorides present. It must also be remembered that the presence of chlorides does not necessarily signify present pollution : the organic matter originally associated with them may have been completely oxidised and destroyed. Most good waters contain only 2 to 3 grains per gallon of common salt, and Wanklyn is of opinion that when 5 to 10 grains per gallon are present there is reason to become suspicious. Thresh is of the opinion that more than 50 grains of salt per gallon is objectionable and that 70 grains should condemn it absolutely.

NITROGEN IN WATER.

The nitrogen present may be in the form of free nitrogen, ammonia, nitrites, or nitrates or as organic matter.

NITRITES AND NITRATES.

Nitrogenous organic matter undergoing putrefaction produces ammonia, and this is oxidised into nitrous and nitric acids by organisms in the soil. These acids unite with the lime, soda, and potash present, displacing the carbonic acid. Some geological strata contain a considerable proportion of nitrates, but a large proportion is by no means so common as in the case of chlorides. A water may be free from unaltered animal and vegetable contamination, but may contain oxidised products derived therefrom, either as the result of remote contamination, or due to oxidation which has occurred in the soil intervening between the source of contamination and the source of the water. The nitrates are the chief of these, but much care must be exercised in drawing conclusions from the amount of nitrates present. They may at times be derived from the soil, the contamination of which is very remote, and, on the other hand, in very bad waters the nitrates may be lessened as a result of the impurity, the organic matters present reducing these salts to a less oxidised form. Again, the amount present may be reduced by the fact that growing crops take up ammonia, nitrites and nitrates, and further it must be remembered that animal matter decomposing in the absence of air or of free oxygen, tends to destroy nitrates liberating nitrogen. The Rivers Pollution Committee found that animal organic matter produced much nitrites and nitrates and that vegetable matter produced but little, not being highly nitrogenous and decomposing but slowly. The coincidence of easily oxidised organic matter, of ammonia, and of chlorine in some quantity would point towards contamination by animal organic matter. If the water shows the presence of nitrates, but of no nitrites, and of but very little ammonia, then either potassium, sodium or calcium nitrate is present, probably derived from soil impregnated with animal organic matter at some anterior date. Nitric acid is the ultimate state of the oxidation of nitrogenous organic matter, and when present it is always the result of pollution of the water itself or of the stratum. The process of nitrification is due to organisms. In some soils, especially sands and gravels and in ferruginous soils, the process goes on very rapidly and consequently one must never omit the test for nitrates, as otherwise organic pollution may be overlooked.

The presence of nitrites indicates the existence of organic matter undergoing a change. It may either be a stage in the oxidation of such matter, or a retrogression from nitric acid as a result of the latter having yielded up some of its oxygen. It is rare to find any of the higher forms of life in a water rich in nitrites, though bacteria may be abundant. The presence of nitrites in the water of shallow wells or rivers is always of grave significance. In deep wells nitrates may be reduced to nitrites, due to iron, salts or other innocuous constituents of the soil and, as Thresh points out, nitrites may also be formed from nitrates by metal, such as lead or iron forming the tube of the pump or the lining of the well. The presence of nitrites is always suspicious of sewage contamination, except when it is known that the water is of peaty origin.

As a general rule, water ought to contain not more than 0·5 per 100,000 of nitric nitrogen and no trace of nitrites. The coincidence of easily oxidised organic matter, ammonia and chlorides would point to organic matter of animal origin and if nitrites are present, the contamination is probably of recent origin. The presence of high nitrates in the absence of nitrites and a low quantity only of organic matter does not necessarily mean that the water is injurious, as unpolluted sub-soil water may give this analysis.

SALINE AMMONIA.

The exact significance of this is difficult to briefly discuss; generally speaking, the ammonia found in river, spring and well water is derived from pollution by animal matter, but the mere presence of ammonia in a sample of water cannot be held to indicate contamination with either vegetable or animal organic matter. All rain waters nearly contain ammonia, the quantity being considerable near large towns, and especially in the first portion of a downpour. Many deep wells also contain ammonia, which is generally held to result from the reduction of nitrates and nitrites by ferruginous soils.

ALBUMINOID AMMONIA.

Albuminoid ammonia does not exist as such in water; it is purely a laboratory product, the result of reducing the nitrogenous matter in the water by boiling with alkaline permanganate solution. Waters from deep wells do not, as a rule, yield much albuminoid ammonia. The presence of much albuminoid ammonia with but little free ammonia is supposed to indicate vegetable contamination, often peaty, especially if the chlorides, nitrates and nitrites are low. Peaty waters often give much albuminoid ammonia but give it slowly. The purest water-supplies yield either no albuminoid ammonia or more usually form a trace up to 0·002 grain per gallon. A water which is safe for drinking purposes will seldom yield more than 0·005 grain per gallon, but in certain instances this limit may be exceeded, *e.g.*, in upland surface waters of peaty origin, which in general are beyond the reach of zymotic contamination. When the stratum may be excluded as a source, the nitrogen as nitrates should not exceed 0·1 per 100,000 ; in other cases the total combined nitrogen, including free and albuminoid nitrogen, should not exceed 0·4 per 100,000.

OXYGEN ABSORBED.

The amount of oxygen required to oxidise the organic matter in safe waters will not in general exceed 0·1 gramme per gallon, though here again the limit may be exceeded by upland surface waters in which organic matter of an innocuous nature may exist. A good well water does not often absorb more than 0·001 gramme per 100,000. Certain other substances absorb oxygen, *e.g.*, iron salts, sulphuretted hydrogen and peaty upland waters. Slight variations in temperature, acidity and alkalinity influence the readiness with which the permanganate parts with its oxygen. Tidy considers that in the first fifteen minutes the more or less easily oxidised animal matters are oxidised, while the oxidation of the vegetable organic matter does not take place for four hours or so. The ease of oxidation is not a very reliable index of the real amount of pollution present. The water must be regarded as suspicious, if within 15 minutes the amount absorbed exceeds 0·1 per 100,000 and in four hours if it exceeds 0·3 per 1,00,000, in both cases deduction being made for any nitrites or iron salts present. The permanganate does not act upon any fatty substances —starch, sugar, gelatine, urea, hippuric acid or creatinine present.

Wanklyn is of opinion that if the chlorides exceed 5 or 10 grains per gallon, there is reason for suspicion and enquiry.

If free ammonia and chlorides exist, but no albuminoid ammonia, the water may pass, and the same may be said even if albuminoid ammonia is present in amounts approaching 0·002 but less than 0·005 per 100,000 ; but if there is much free ammonia and the albuminoid ammonia reaches 0·005 per 100,000, the water should be looked upon with suspicion. If free ammonia is absent, or present in very small amounts only, and the albuminoid ammonia is less than 0·01 per 100,000, one need not condemn the water, but in all cases where the albuminoid ammonia exceeds 0·01 per 100,000 the water should be condemned.

BACTERIOLOGICAL EXAMINATION.

This is of great value in ascertaining the suitability of a water for drinking purposes, and by it one can obtain data which give information not only as to existing conditions but from which deductions can be drawn as to recent harmful pollution. The object of a bacteriological examination is to ascertain the presence or absence of any organisms and, if present, to determine their number and whether they belong to the class of micro-organisms which, though not of necessity hurtful to man, are yet indicative of animal contamination, or whether they are in the class of actual disease-bearing organisms, *e.g.*, Cholera vibrio and Typhoid bacillus.

The detection of these latter in a public water-supply is a matter of some difficulty, and in many instances one has to rely on the evidence afforded by the presence of organisms usually associated with fæcal contamination, either human or animal. In reporting on a water analysis. the bacteriological and chemical results must be carefully considered in relation to one another. As it is only under exceptional circumstances that zymotic poisons gain entry to a water-supply without associated decrease of chemical purity in general, it will be found that a water thoroughly pure chemically will also be found pure bacteriologically. On the other hand, a supply which gives bad results on chemical analysis should be condemned, as, if free from pathogenic organisms on any particular occasion, it must be held to be at least liable to contamination with these and must form a good medium for the growth and dissemination of bacteria. It is in the case of waters of intermediate purity that a bacteriological examination becomes of the greatest importance, as though the amount of contamination may be such as to produce only a small amount of chemical impurity, yet it may be sufficient to produce marked bacteriological impurity. In both chemical and bacteriological examinations, great assistance is afforded by a knowledge of the exact source of the water, and for this reason it should be an invariable custom to give full details when sending a sample for examination.

The covering letter should state—

(*a*) The date and the hour of taking the sample.

(*b*) Source of water, well, lake, spring, etc.

(*c*) Filtered or unfiltered.

(*d*) If from tap, pump, etc., how long the water was allowed to flow before taking the sample.

(*e*) If from a tap, whether it was direct from the house main or through a storage cistern. Nature of cistern.

(*f*) If from a well, state whether apparently properly constructed and protected, the distance away from nearest visible source of contamination. Also how the water is raised from the well.

If any authentic records of former analysis of water from the same source exist, they should be furnished, as information may be gleaned from them as to any departure from the normal.

As already stated, the isolation of pathogenic bacteria from water is frequently attended with the greatest difficulty, and water may be grossly polluted with sewage without any specific disease-germs being present at all. All sewage polluted water is however potentially dangerous, as there is the possibility of disease-germs appearing at any time. Bacteriologists have therefore mainly to rely on the detection and isolation of excretal and sewage organisms which though not dangerous in themselves are significant as indices of the probable presence of disease-germs. The three most frequently used indicator organisms for this purpose are "the B. Coli group, Streptococci, and Bacillus Enteritidis Sporogenes and closely allied Anærobic Bacteria" (Savage). A water supply however should be finally judged on a summation of verdicts (geological, geographical, physical, bacteriological and chemical). According to Savage, the conditions of a perfect bacterial indicator are—

(1) It should be abundant in the substances, for which its presence serves as an indicator.
(2) It should be absent, or at least relatively absent, from all other sources.
(3) It should be easily isolated and numerically estimated.
(4) Its characteristics should be definite and not liable to variation, whereby its distinctive characters might be impaired.

The three indicators referred to by Savage are extremely abundant in both human and animal excreta and in sewage.

As regards human excreta, the B. Coli group are present to the extent of 100 to 1,000 million or more per gramme. Streptococci are equally numerous, while about 1 million to 10 million B. Enteritidis Sporogenes are present per gramme.

These organisms also occur in immense numbers in the intestines of all the domestic animals and apparently of all mammals.

The B. Coli group has been found to be abundant in the excreta of many birds and fishes.

Dr. Houston has laid down the following requirements, which must be conformed to by any microbe indicator suggested as an indicator of pollution of water :—

(1) It must be superabundant in excremental matters.

(2) It must be absent, or present only in comparatively small numbers, in water free from undesirable pollution.

(3) It must be a decadent microbe when divorced from the animal body.

Throughout his observations, Dr. Houston has chosen the B. Coli test as the indicator of water pollution. The typical B. Coli recognised by him is one yielding gas in lactose cultures and indol in peptone water cultures, *i.e.*, lactose and indol. +.

Now B. Coli conforms to all the requirements mentioned above :—

(1) Since at a low estimate there are 100,000 B. Coli present per cubic centimetre of crude sewage, or 1,000,000 per gramme of human fæces.

(2) Of 1,331 samples of Kent deep well waters examined, 94 per cent. showed no B. Coli in 100 c.c., and

(3) B. Coli removed from the animal body and kept at 20°C either in sea water or tap water dies usually in from 3 to 9 days. The B. Coli is a decadent microbe when divorced from the animal body ; hence its presence in a water in any number probably points to fairly recent pollution.

The term B. Coli Communis does not denote a single definite organism but it includes a considerable group of distinct forms which may be split up into various sub-types by biochemical tests. No two bacteriologists therefore use the term in the same sense. Savage suggests that the expression " excretal B. Coli " should be used for organisms giving all the following characteristics :—

(*a*) A short rounded bacillus,

(*b*) Translucent non-corrugated growth on gelatin slope.

(*c*) Non-liquefaction of gelatin (two weeks).

(*d*) Acid production in litmus milk with coagulation (within two weeks).

(*e*) Fermentation of lactose with production of acid and gas.

(*f*) " " glucose " " " " "

(*g*) Neutral red reaction (in glucose media).

(*h*) Production of indol in peptone water.

It is difficult to say where the line shall be drawn. The different tests have not an equal value : some such as the fermentation of sugars, liquefaction of gelatin, and acid production in milk are permanent in character and are very important, and negative results would exclude the organism isolated from being Bacillus Coli at all, whereas the presence of motility, indol reaction, the characteristic, of gelatin surface colonies are subject to such great variations, that negative results under these heads would not lead to the significance of the organism being diminished on these grounds.

Hence it is that bacteriologists classify the Bacillus Coli into "typical" and "atypical" forms. Of late years there has been a growing feeling that such arbitrary definitions went either too far or not far enough. The whole group of lactose fermenters being characteristically of intestinal origin, it is clear that the whole class of such organisms should be absent from safe water supplies. The Colon group may therefore be for practical purposes described as including all aerobic non-sporing bacilli which produce acid and gas in dextrose and lactose media. As these organisms which ferment lactose, ferment dextrose as well, the tests may be still further curtailed to positive reaction in lactose fermenting medium. It is usual now in laboratory reports to indicate the presence of lactose fermenters in least dilution of water.

Clemesha has shown that most of the waters which have to be used in India are simply loaded with fæcal contamination and expresses the opinion that a great deal of the pollution of surface waters is caused by excrement of animals, mostly cattle and goats, whereas in England the pollution that is most common in rivers has its origin in sewage from large towns which we know to be derived from man, and he considers this a difficulty in the way of accepting standards applicable to England as being equally suitable for India.

The great rivers of India differ in many important respects from those in England, the self-purification of the rivers' water being the most important. In England the rivers which are the sources of supply of water are comparatively small streams, into which the sewage and effluents flow from the towns on the banks. The water therefore is largely polluted and has to be purified thoroughly before it is potable. The rapid current and the presence of very little sunlight make the natural self-purification of the water an impossibility. In India, on the other hand, the great rivers (the Ganges, the Mahanudi, etc.) are several miles long and the current is so extremely slow that the water takes several days to drift from the source to the sea. The towns on the banks not having regular drainage system, very little of the sewage of the town goes into the river, and even this is diluted by the large quantity of water, and it must be remembered that yet along the banks there is always evidence of dangerous and deadly pollution. The climatic conditions are such that the sun's rays cause great amount of evaporation from the surface and cause self-purification of the water.

MacConkey, not being satisfied with the classification adopted by most bacteriologists of Colon bacilli into "typical" and "atypical" forms, and believing that the so-called "typical" B. Coli are a complex group including a considerable number of definite individual types, outlined a new classification of the lactose fermenting bacteria based on fermentative reactions in the rarer sugars. Using saccharose and dulcite he first divided the lactose fermenters into four groups :—

(1) Ferments neither saccharose nor dulcite.
(2) ,, dulcite but not saccharose.
(3) ,, both dulcite and saccharose.
(4) ,, saccharose but not dulcite.

Col. Clemesha, however, recommends proceeding further and by the use of the fermentation of adonit, inulin, dulcit and saccharose, the Voges and Proskauers reaction, the indol reaction, the motility test and, when possible, the liquefaction of gelatin test, splitting up the group of fæcal bacilli and studying the individual species as far as possible; and thus in time he anticipates that one may be able to assign a relative value as an indicator of pollution to each of these organisms.

Col. Clemesha finds both in human fæces and in cow-dung the prevailing types to be B. Coli, B. Grunthal, and B. Coscoroba, the three together usually making up 75 per cent. of all the lactose fermenting organisms present. A very interesting fact revealed by his investigations was the occurrence of "epidemics" of particular types which at certain periods become suddenly frequent, usually prevailing in human fæces, cow fæces, and water supplies at the same time. Clemesha made a number of experiments on the relative resistance of various lactose fermenters by placing fæcal emulsions, with or without sand, in shallow dishes in the sunlight and at various intervals isolating colonies of predominant types and working out their fermentative reactions. The experiments showed that B. Coli was the principal type isolated in the beginning, it quickly disappeared however and in a few hours B. lactis Aerogenes, B. acidi Lactici, B. Cloacæ, and others appeared. At the end of the experiments B. Grunthal or B. Cloacæ were generally the only forms surviving.

The moral drawn from Col. Clemesha's investigations is that in India, in waters stored in warm sunned lakes and large rivers, as the sensitive fæcal bacilli have an opportunity to die out and the more resistant have an ample opportunity of multiplying and increasing, it is not proper to condemn any water merely from the presence of the colon group without finding out whether it contains the sensitive or more resistant types. In view therefore of the natural process of self-purification going on in Indian lakes and rivers, the utter futility of hard and fast numerical standards of purity of waters is evident. The more one studies the self-purification of waters, the more certain one is that it is necessary to study the *kind of organisms* rather than their *number* in order to come to a satisfactory conclusion.

As the result of a large series of experiments, Clemesha proposes tentative standards for the various kinds of waters, and in the course of his experiments he has compiled a list of organisms grouped in three classes according to their power to resist sunlight, but expresses the opinion that as evidence accumulates class II may have to be re-arranged.

In the classification adopted by him, the organisms high up in the list of each class are considered to be less resistant than those at the bottom, so far as present experience goes.

Class I (least resistant).	Class II.	Class III.
Oxytocus perniciosus No. 10 ,, 39 ,, 69 ,, 70 Nos. 97 and 98 Coli communis. No. 35 ,, 36	No. 33 ,, 38 Pneumonia. No. 9 Neapolitanus. Lactis Ærogenes Coscoroba Acidi Lactici No. 6 ,, 100 ,, 101	No. 73 ,, 75. Grunthal or 7 or 8 Cloacæ.

Clemesha very rightly insists on the fact that his proposed standards are only tentative ones, and adds that no analyst in any country would ever venture to give a definite opinion without knowing a few elementary facts concerning the source from which the sample has been taken. Such questions, as whether the samples are drawn from lake, river, well or spring—the quantity and date of recent rainfall—the condition in the case of a river, whether in heavy flood or nearly dry—are matters of great importance to the bacteriologist, who has to pronounce an opinion on the subject. Consequently in the application of the method proposed, the question the analyst should always bear in mind is—what chances has this sample had of being exposed to sunlight ? The more exposure it has had, the more will the arguments involved in this method apply to the water, and the less it has had, the more guarded must be any expression of opinion. To lakes, tanks, ponds, storage reservoirs, settling tanks, etc., the method is applicable. The extent to which it applies to rivers must depend on the condition of the river itself. The extent to which it is applicable to wells, springs and underground waters generally is uncertain, and this forms a serious limitation to the utility of the method.

PROPOSED STANDARDS.

LAKE WATERS.

Good Lake Water should contain—

(1) less than 100 colonies per c.c. (on agar at 37° C.);

(2) no lactose fermenters in 20 c.c.;

(3) no organisms of class I in 50 c.c.;

(4) the few fæcal organisms isolated should belong to class II and lactis ærogenes should be plentiful.

Fair or usable Lake Water—

(1) should not contain more than 200 organisms per c.c. (agar 37° C.);

(2) lactose fermenters should not be present in less than 5 c.c.;

(3) no organisms of class I should be present in less than 20 c.c.;

(4) lactis ærogenes should largely predominate.

A Lake Water is suspicious—

(1) if it contains more fæcal organisms than 1 in a c.c., even though these be confined to class III; as this indicates that the lake is very low and conditions are suitable for the spread of Cholera.

A Lake Water should be condemned—

(1) if it contains organisms of class I in a c.c. or less;

(2) if fæcal organisms are present in the characteristic proportions seen in fresh fæces;

(3) if lactis ærogenes are absent or scarce. It should be remembered that 48 hours will make an enormous difference in the purity of a lake-water.

WELL AND SPRING WATERS.

A good water should contain—

(1) no fæcal bacilli in 20 c.c.;

(2) no organisms of class I in 100 c.c.;

(3) total colonies under 50 per c.c.

RIVER WATERS.

Good River Water should contain—

(1) not more than 100 colonies (on agar at 37° C.);

(2) fæcal organisms not exceeding 1 in 10 c.c.;

(3) no organisms of class I in 50 c.c.

Any fæcal organisms present should belong to either class III or to the more resistant class II.

Fair or usable River Water should contain—

(1) not more than 300 colonies (on agar at 37° C.);

(2) not more than 1 in 1 c.c. of fæcal organisms and no organisms of class I in less than 20 c.c.

The fæcal organisms present should consist mainly of mixtures of class III and class II and there should be a tendency for one class of organisms to preponderate.

River Water should be condemned—

(1) if total colonies are more than 800 (on agar 37°C.);
(2) if lactose fermenters are present in number of 10 to 100 per c.c.;

(3) if organisms of class I exceed 1 in 5 c.c., or if the fæcal organisms isolated (class I being absent) are rich in varieties, such as occur in an emulsion of fæces.

The following table is taken from Clemesha's "Study of the Bacteriology of Drinking Water Supplies in Tropical Climates."

Number.	—	Lactose.	Saccharose.	Dulcit.	Adonit.	Inulin.	P. & V. reaction.	Indol.	Motility.	Grams stain.	Gelatin.	Litmus milk.	Acidity in litmus whey.	Reduction of nitrates.	Inosit.
													PER CENT.		
1		+	—	—	+	—	—	+	+	—	—	+	..	+	—
2	B. Acidi lactici (Huppe)	+	—	—	+	—	—	+	—	—	—	+	23	+	—
3	B. Levans	+	—	—	—	+	+	—	+	—	+	+	14	+	—
4	B. Grunthal	—	—	—	—	—	—	+	+	—	—	+	20	+	—
	B. Sulcatus gasiformans	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	B. Castellus	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5	B. Vesiculosus	+	—	—	—	—	—	+	—	—	—	+	25	+	—
6		+	—	—	—	—	+	+	—	—	—	+	..	..	..
7		+	—	—	—	—	—	—	+	—	—	+	..	—	—
8	B. Coli mutabilis (Massini)	+	—	—	—	—	—	—	—	—	—	+	..	..	..
9		+	—	—	+	—	+	+	—	..	..	..	..	..	..
10		+	—	—	—	+	—	..	..	..	..	..	..	..	..
33		+	—	+	+	—	—	+	+	+	—	—	..	..	—
34	B. Coli communis	+	—	+	—	—	—	+	+	—	—	+	28	+	—
	B. Cavicidæ	+	..	..	..	..	..	..	..	..	..	..	..	..	..
35	B. Schæfferi	+	—	+	—	—	—	+	—	—	—	+	22	+	—
36		+	—	+	—	—	—	—	+	—	+	+	..	+	—
37		+	—	+	—	—	+	..	—	..	..	..	..	..	..

38		+	—	+	+	—	+	..	..	..	..	..	..	..	..
39		+	—	+	—	+	—	..	+	..	..	..	..	..	..
65	B. Oxytocus perniciosus	+	+	+	+	+	+	+	—	—	+	+	26	+	+
66		+	+	+	+	—	—	+	—	—	—	+	..	+	—
67		+	+	+	+	—	+	—	—	—	—	+	..	+	+
68	B. Rhinoscleroma Pneumoniæ	+	+	+	+	—	—	—	—	—	—	+	14	+	+
69		+	+	+	—	+	+	—	+	—	+	+	..	..	—
70		+	+	+	—	+	—	—	+	—	+	+	..	..	—
71		+	+	+	—	—	—	+	+	—	—	+	..	+	—
72	B. Neapolitanus	+	+	+	—	—	—	+	—	—	—	+	22	+	—
73		+	+	+	—	—	+	—	+	—	+	+	..	+	—
74		+	+	+	—	—	—	—	+	—	—	+	..	..	..
75		+	+	+	—	—	+	—	—	—	—	+	..	..	+
97		+	+	—	+	+	+	+	—	—	+	+	..	+	—
98		+	+	—	+	+	+	—	—	—	—	+	..	+	+
99		+	+	—	+	+	—	—	—	—	—	+	..	+	+
100		+	+	—	+	—	—	+	+	—	—	+	..	..	..
101		+	+	—	+	—	—	+	—	—	—	+	..	+	+
102		+	+	—	+	—	+	—	+	—	+	+	..	..	..
103	B. Lactis ærogenes	+	+	—	+	—	+	—	—	—	—	+	30	+	+
	B. Dysentericæ Vitulorum	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	B. Capsulatus (Pfeiffer)	..	..	..	..	..	..	..	..	..	..	..	..	..	..
104	B. Gasiformans non-liquefaciens	+	+	—	+	—	+	—	—	—	—	+	12	+	—
105		+	+	—	—	+	+	—	+	—	+	+	..	..	—
106		+	+	—	—	—	—	+	+	—	—	+	..	..	—
107	B. Coscoroba	+	+	—	—	—	—	+	—	—	—	+	25	+	—
108	B. Cloacæ	+	+	—	—	—	+	—	+	—	+	+	20	+	—
109		+	+	—	—	—	—	—	+	—	—	+	..	..	—
110		+	+	—	[illegible]	+	—	..	..	..	..	..	..	..	..

Clemesha in his work (which should be consulted in original for all details) does not accept the definition applied by Houston, Savage and others to the term "Coli Bacillus"; but adopts that applied by MacConkey, Orr and others, who use the term "Bacillus Coli communis" in reference to Escherichs organism only, calling all bacilli that differ from it in any "permanent" test different species, to which different names or numbers are applied.

Discussing the value of the three groups of organisms used as "indicators," Savage (*The Bacteriological Examination of Food and Water, Cambridge Press*, 1914) states—

All three groups of organisms are abundant in crude sewage. The actual number found will of course vary greatly with the strength of the sewage, but the data given by Houston give average figures. These are :

B. Coli and allied forms	100,000	per c. c.
Streptococci	1,000 to 10,000	,,
Spores of B. E. Sporogenes	100 to 1,000	,,

Experiments go to show that members of the B. Coli group are only present when the soil has been contaminated with excrementitious matters and that virgin soil and soil not manured are free from these organisms further, that these organisms gradually die out in soil,

In quite pure water, pure air, etc., B. Coli group do not occur.

The organisms of this group do not multiply to any great extent under ordinary natural conditions outside the animal body.

As regards the saprophytic distribution of streptococci, there is no evidence that streptococci have any true home, under natural conditions, apart from the animal body.

Outside the animal body, they may survive for considerable periods but do not thrive. The evidence as to the duration of viability and vitality outside the animal body is somewhat conflicting, but in general, it would appear that the majority are delicate organisms and rapidly die out, but that a small number of hardy strains may persist for very long periods.

BAC. ENTERITIDIS SPOROGENES.

In considering the value of this organism as an excretal indicator, it must be remembered that it is a spore-bearing bacillus and that its spores are very resistant. Animal excretal pollution is so widespread that it is not a matter of surprise that such a highly resistant organism should be widely distributed in nature. The available evidence shows that it is absent or relatively absent, from sources which have never been contaminated, but that it is fairly prevalent in sources the pollution of which had taken place possibly at a long antecedent period. These considerations obviously place a considerable limit to its usefulness.

PROTECTION OF WATER SUPPLIES.

When discussing reservoirs, mention has already been made that one must protect the gathering ground of any reservoir, as far as possible. No cultivation of the land should be permitted, nor should any human habitations other than those necessary for the care-taker or workmen employed, and these must be constructed in such a situation and so drained as to make it impossible for the water supply to be contaminated from this source.

The area should be well wooded and, where possible, fenced off.

No mining or manufacturing operations should be permitted within the area.

In many countries, to control a gathering ground in this manner is a very difficult, if not impossible task, but in India this objection has not quite the same weight.

In regard to wells, the precautions to be adopted have been fully enumerated already.

When the water-supply of a town or village is taken from a river, certain precautions are necessary in addition to those mentioned; especially in India, where so many religious ceremonies are so closely associated with certain rivers, at which the village washing and personal ablutions also take place.

The river should be mapped out into three parts. The uppermost portion should be strictly reserved for drinking water and water for domestic purposes, *e.g.*, cooking, washing cooking utensils, etc. The portion immediately below this, in the direction of the flood of the stream, should be reserved for personal ablutions and the third and lowest portion for washing clothes.

In the presence of an epidemic of Cholera or Typhoid, it may be necessary to take more active measures.

Frequently, the bathing is carried out in pools along the river's edge and as the bathers use the water to cleanse their mouths,—and even drink it,—these pools should be disinfected with potassium permanganate, as should also the pools in which the clothes are washed. Efforts should be made to instruct the bathers in the risks they run by swallowing the water. This can best be done by addressing senior men and enlisting their aid. Provision should be made also to supply pure, boiled and ærated water to the bathers by establishing small depôts, due observance being paid to religious prejudices, etc.

It is of the utmost importance that water pipes should be laid well away from drains and closets and that the pipes be laid as far as possible in straight lines, and that they be well supported in their course so as to prevent sagging and consequent risk of the opening of joints.

All overflow pipes from cisterns must be made to discharge into the open air and not permitted to be connected to a drain.

No water-closet should be directly supplied by a tap, a cistern must always intervene, as otherwise foul air and filth may possibly be drawn into the pipe.

Provisions of Bombay Act No. III, 1888, *as modified to May* 31*st*, 1920, *relating to Water Supply*.

CONSTRUCTION AND MAINTENANCE OF MUNICIPAL WATER WORKS.

Section.

261. For the purpose of providing the city with a supply of water proper and sufficient for public and private purposes, the Commissioner when authorised by the Corporation in this behalf, may—

(*a*) construct and maintain water works, either within or without the city, and do any other necessary acts;

(b) purchase or take on lease any water-work or any water or right to store or to take and convey water, either within or without the city;

(c) enter into any arrangement with any person for a supply of water.

262. The Commissioner shall manage all water-works belonging to the Corporation, all of which water-works are in this Act referred to as "municipal water-works," and maintain the same in good repair and efficient condition, and shall cause all such alterations and extensions to be from time to time made in the said water-works as shall be necessary or expedient for improving the said works.

263. (1) The Commissioner, and any person appointed by Government under section 264 in this behalf, may, for the purpose of inspecting or repairing or executing any work in, upon or in connection with any municipal water-work at all reasonable times—

(a) enter upon and pass through any land within or without the city, adjacent to or in the vicinity of such water-work, in whomsoever such land may vest;

(b) convey into and through any such land all necessary materials, tools and implements.

(2) In the exercise of any power conferred by this section, as little damage as can shall be done, and compensation for any damage which, may be done in the exercise of any of the said powers shall be paid by the Commissioner, or, if any person appointed under section 264 by Government has caused the damage, by Government.

264. Any person appointed by Government in this behalf shall at all reasonable times have liberty to enter upon and inspect any municipal water-works.

265. The Commissioner shall have the same powers and be subject to the same restrictions for carrying, renewing and repairing water-mains, pipes and ducts within or without the city, as he has and is subject to under the provisions hereinbefore contained for carryng, renewing and repairing drains within the city.

266. The Commissioner shall cause fire-hydrants and all necessary works, machinery and assistance for supplying water in case of fire to be provided and maintained; and shall have painted or marked on the buildings and walls or in some other conspicuous manner, within the streets, words or marks near to such hydrants to denote the situation thereof and shall cause a hydrant-key to be deposited at each place within the city where a municipal fire-engine is kept, and to do such other things for the purpose aforesaid as he shall deem expedient.

Section.

267. (1) Except with the sanction of the Corporation and, in the case of the Vehar water-works, of Government, or for the purposes

Section.

of section 262, under the authority of the Commissioner, no person shall

(a) erect any building for any purpose whatever within the limits of the water-shed of any lake or reservoir, from which a supply of water is derived for any municipal water-work;

(b) extend, alter or apply to any purpose different to that to which the same has been heretofore applied, any building already existing within the said limits;

(c) carry on, within the said limits, any operation of manufacture, trade or agriculture in any manner, or do any act whatsoever, whereby injury may arise to any such lake or reservoir or to any portion thereof, or whereby the water of any such lake, tank or reservoir may be fouled or rendered less wholesome.

(2) The limits of the water-shed of the Vehar lake shall, for the purposes of this section, be deemed to be limits defined in a plan marked B authenticated by the signatures of the Governor and Members of Council, and deposited in the office of the Secretary to the Government of Bombay.

268. (1) Without the written permission of the Commissioner, no building, wall or other structure shall be newly erected, and no street or railway shall be constructed over any municipal water main.

(2) If any building, wall or other structure be so erected, or any street or railway be so constructed, the Commissioner may, with the approval of the Standing Cimmittee, cause the same to be removed or otherwise dealt with as to him shall appear fit, and the expenses thereby incurred shall be paid by the person offending.

PUBLIC GRATUITOUS WATER-SUPPLY.

269. (1) All existing public drinking-fountains, tanks, reservoirs, cisterns, pumps, wells, ducts and works for the supply of water for the gratuitous use of the inhabitants of the city shall vest in the Corporation and be under the control of the Commissioner.

(2) The Commissioner may maintain the said works and provide them with water, and, when authorised by the Corporation in this behalf, may construct any other such works for supplying water for the gratuitous use of the inhabitants of the city.

(3) Provided that the water carried away by any of the inhabitants from any such work shall be taken only for his private use and not for sale, and shall not, except with the written permission of the Commissioner, be carried away in a cask, cart, pakhal or masak.

(4) The Commissioner may temporarily, and with the approval of the Corporation permanently, close any of the said works, either entirely or partially.

Section.

(5) In case any such work is permanently closed, either entirely or partially, by the Commissioner, the site thereof, or of the portion thereof which is so closed, and the materials of the same may be disposed of as the property of the Corporation: provided that if any such work, which is permanently closed either entirely or partially, was a gift to the public by some private person, the said site and materials or the proceeds of the sale thereof shall, unless by reason of their value being insignificant or for any other sufficient reason the Corporation think fit to otherwise direct, be applied to or towards some local work of public utility bearing the name of such persons, or to or towards any such local work which shall be approved by the Corporation and by the heirs or any other representatives, if any, of the said person.

270 (1) The Commissioner may assign and set apart each of the said works and the water therein for use by the public for such purpose only as he shall think fit, and shall cause to be indicated, by a notice affixed on a conspicuous spot on or near each such work, the purpose for which the same is so assigned and set apart.

(2) No person shall make use of any such work or of any water therein for any purpose other than the purpose for which the same has been so assigned or set apart.

PRIVATE WATER-SUPPLY.

271 (1) Communication-pipes for conveying to any premises a private supply of water from a water-main or other municipal water-work shall not ordinarily be connected with the main or other water-work, except on the written application or with the written assent of the owner of the premises, or of the person primarily liable for the payment of property-taxes on the said premises.

(2) But if it shall appear to the Commissioner that any premises, situate within any portion of the city in which a public notice has been given by the Commissioner under clause (*b*) of section 141, are without a proper supply of pure water, the Commissioner shall, by written notice, require the owner of the said premises, or any person primarily liable for the payment of property-taxes thereon, to obtain a supply from a municipal water-work adequate to the requirements of the persons usually occupying or employed upon the said premises, and to provide communication-pipes and do all such works as may be necessary for that purpose.

Section.

[SECTION 141 (*b*) READS AS FOLLOWS :—

Subject to the provisions of section 169, the water-tax shall be levied only in respect of premises which are situated in a portion of the city in which the Commissioner has given public notice that sufficient water is available from municipal water-works for furnishing a reasonable supply to all the premises in the said portion.]

272. (1) No connection with any municipal water-work shall be made or renewed—

(*a*) except by a municipal officer or servant empowered in that behalf by the Commissioner and

(*b*) until the certificate specified in sub-section (4) has been given.

(2) In every case where a new connection with a municipal water-work is made or an existing connection requires renewal, all necessary communication pipes and fittings from and including the ferrule on the supply main up to and including the stop-cock nearest the supply main, shall be supplied by the Commissioner, and the work of laying and applying such communication-pipes and fittings shall be executed by municipal agency under the Commissioner's orders, but the cost of making or removing any such connection, and of all the communication-pipes and fittings so supplied, and of all the work so executed shall be paid by the person on whose application or for whose premises the connection is made or renewed.

(3) Every such new connection or renewed connection with its communication-pipes and fittings up to and including its stop-cock as aforesaid shall thereafter vest in the Corporation and be maintained at the charge of the Municipal Fund as a municipal water-work.

(4) All communication-pipes and fittings beyond the said stop-cock shall be laid and applied under the supervision of a municipal-officer appointed by the Commissioner in that behalf, who shall give and sign a certificate, free of charge, when such communication-pipes and all necessary fittings and work have been laid, applied and executed in a satisfactory manner and when proper and sufficient arrangements have been made for draining off waste water.

(5) Where any communication-pipe or fitting is laid, applied, added to or altered, or any connection is made in contravention of this section, the Commissioner may, with the previous approval of the Standing Committee, remove such communication-pipe, fitting or connection, and make good such water-work; and the expenses incurred by him in so doing shall be paid by the owner or occupier of the premises in which or for supply to which such communication-pipe or fitting

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has been laid, applied, added to or altered, or such connection has been made, or by the person offending.

273. The Commissioner may, if he thinks fit, take charge on behalf of the Corporation of all communication-pipes and fittings of any existing private service connected with any municipal water-work up to and including the stop-cock nearest the supply main for the said service, and the same shall thereafter vest in, and be maintained at the expense of, the Corporation as a municipal water-work.

273 A. The Commissioner may, if at any time he deems it expedient to alter the position of an existing connection with any municipal water-work, or of the communication-pipes or fittings thereof, and after giving to the owner of such communication-pipes or fittings not less than four days' previous notice of his intention so to do, cause the said connection to be moved to such other position as he thinks fit, and cause any or all of the said communication-pipes and fittings to be relaid and applied, or others to be laid and applied, in lieu thereof, in such position as he may direct; and in every such case such removal and alteration shall be carried out at the expense of the Municipal Fund, and the new connection, with its communication-pipes and fittings up to and including the stop-cock nearest the supply main, shall thereafter vest in the Corporation and be maintained at the charge of the Municipal Fund as a municipal water-work.

274. (1) The Commissioner may, whenever it shall appear to him to be necessary, by written notice require that any premises furnished with a private water-supply from any municipal water-work shall within a reasonable period which shall be prescribed in the said notice, be provided with a storage cistern of such size, material, quality and description, and with such fittings and placed in such position as he thinks fit.

(2) The Commissioner shall, also from time to time, prescribe the size, material, quality, description and position of the pipes, taps, cocks and other fittings to be employed for the purposes of any connection with, or of any communication from any municipal water-work and no such connection or communication shall be made by any person otherwise than so prescribed.

275. It shall be incumbent on the owner or occupier of any premises to which a private water-supply is furnished from any municipal water-work, to keep in efficient repair every pipe conveying water from the said water-work to such premises and every meter for measuring water, not being a municipal meter, and every tap, cock or other fitting and every storage cistern

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in or connected with any such pipe, so as effectually to prevent the water from running to waste.

276. (1) Where water is supplied by measurement, the Commissioner may either provide a meter and charge the consumer for the same such rent as shall from time to time be prescribed in this behalf by the Standing Committee, or may permit the consumer to provide a meter of his own of such size, material and description as the Commissioner shall approve for this purpose.

(2) The Commissioner shall at all times keep all meters and other instruments for measuring water, let by him for hire to any person, in proper order for correctly registering the supply of water, and in default of his so doing such person shall not be liable to pay rent for the same during such time as such default continues.

277. Where water is supplied by measurement, the register of the meter or other instrument for measuring water shall be *prima facie* evidence of the quantity consumed.

INSPECTION.

278. (1) The Commissioner may make an inspection of any premises to which a private water-supply is furnished by the Corporation, in order—

(*a*) to remove, test, examine and replace any meter for measuring water ; or

(*b*) to examine the communication-pipes and the taps, cocks and other fittings thereof, and the storage-cisterns connected therewith ; or

(*c*) to see if there be any waste or misuse of the water.

(2) The Commissioner may, by written notice, require the owner or occupier of the premises to remedy any defect which shall be found to exist in any such meter let to him for hire, or in any such communication-pipe, tap, cock or other fitting or cistern.

CUTTING OFF PRIVATE WATER-SUPPLY.

279. (1) The Commissioner may, with the sanction of the Standing Committee, cut off any connection between any municipal water-work and any premises, to which a private water-supply is furnished by the Corporation or turn off the water from such premises in any of the following cases, namely :—

(*a*) in default of payment of any instalment of water-tax or of any sum due for water within fifteen days after the bill for such tax or sum has been duly presented ;

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(b) if the owner or occupier of the premises neglects within the period prescribed in this behalf in any notice given under sub-section (1) of section 274, to comply with any requisition made to him by the Commissioner regarding the provision of a storage cistern ;

(c) if the owner or occupier of the premises fails, within the period prescribed in this behalf in any notice given under sub-section (2) of section 278 to put any such cistern or pipe conveying water from any municipal water-work or any tap, cock or other fitting thereof into good repair so as effectually to prevent the water from running to waste :

(d) if, after receipt of a written notice from the Commissioner requiring him to refrain from so doing, the owner or occupier of the premises continues—

(i) to use the water, or permit the same to be used, in contravention of any bye-law made under this Act or of any condition prescribed under sub-section (2) of section 169;

SUB-SECTION (2) OF SECTION 169 READS—

The Standing Committee may, for the cases in which the Commissioner charges for water by measurement under clause (a), from time to time prescribe such conditions as they shall think fit as to the use of the water and as to the charge to be paid for water consumed whilst a metre is out of order or under repair ; and in each case in which a composition is made under clause (b), the said Committee may prescribe such conditions as to the use of the water as they shall think fit ; provided that no condition prescribed under this sub-section shall be inconsistent with this Act or with any bye-law made under this Act.

CLAUSE (a) READS—

The Commissioner may, in such cases as the Standing Committee shall either generally or specially direct, instead of levying the water-tax in respect of any premises liable thereunto under section 141, charge for the water supplied to such premises by measurement at such rate as shall, from time to time, be prescribed by the said Committee in this behalf.

CLAUSE (b) READS—

The Commissioner may, with the approval of the Standing Committee, compound with any person for the supply of water to any premises for a renewable term of one or more years not exceeding five on payment of a fixed periodical sum in lieu of the water-tax or charge by measurement which would otherwise be leviable from such person in respect of the said premises.]

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(*ii*) when payment for the water is not made by measurement, to permit any person not residing on premises in respect of which water-tax is paid to carry away from such owner's or occupier's premises water derived from the municipal water-work,

(*e*) if the owner or occupier of the premises wilfully or negligently injures or damages his meter or any pipe conveying water from any municipal water-work.

(2) The expense of cutting off the connection or of turning off the water in any such case as aforesaid shall be paid by the owner or occupier of the premises.

280. No person, to whom water is supplied by measurement or on payment of a fixed periodical sum, shall contravene any condition prescribed under sub-section 2 of section 169 for the use of such water, or permit any such condition to be contravened.

281. No water-pipe shall be laid in a drain, or on the surface of an open channel or house-gully, or within 20 feet of a cesspool or in any position where the pipe is likely to be injured or the water therein polluted; and no well or tank, and except with the consent of the Commissioner, no cistern, shall be constructed within 20 feet of a privy, water-closet or cesspool.

282. (1) No person shall fraudulently dispose of any water supplied to him by the Corporation.

(2) No person to whom a private supply of water is furnished by the Corporation shall, except when the water supplied is charged for by measurement, permit any person who does not reside on the premises in respect of which water tax is paid to carry away water from the premises to which it is supplied.

(3) No person, who does not reside on premises in respect of which water-tax is paid, shall carry away water from any premises to which a private supply is furnished by the Corporation, unless, in any case in which such supply is charged for by measurement, he does so with the permission of the person to whom such supply is furnished.

283. (1) No person shall fraudulently—

(*a*) alter the index to any meter or prevent any meter from duly registering the quantity of water supplied;

(*b*) abstract or use water before it has been registered by a meter set up for the purpose of measuring the same.

(2) The existence of artificial means under the control of the consumer for causing any such alteration, prevention, abstraction or use shall be evidence that the consumer has fraudulently effected the same.

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GENERAL PROVISIONS.

284. No person shall wilfully or negligently—

(a) injure or suffer to be injured any meter belonging to the Corporation or any of the fittings of any such meter;

(b) break, injure or open any lock, cock, valve, pipe, work or engine appertaining to any municipal water-work;

(c) flush or draw off the water from any such water-work, thereby causing such water to be wasted;

(d) do any act whereby the water in or derived from any municipal water-work shall be wasted;

(e) obstruct, divert or in any way injure or alter any water-main or duct.

285. Compensation shall be paid by the offender for any damage which the Corporation sustains by reason of any contravention of section 283 or section 284.

286. If it shall be shown that an offence against some provision of this chapter or against some bye-law made under this Act at the time in force relating to water-supply has occurred on any premises to which a private supply of water is furnished by the Corporation, it shall be presumed, until the contrary is proved, that such offence has been committed by the occupier of the said premises.

287 (1) On the written request of any person who is required under any of the provisions of this chapter to supply any materials or fittings or to do any work, the Commissioner may, in such person's behalf, supply the necessary materials or fittings or cause the necessary work to be done; but he shall not do so in any case to which the provisions of section 493 or 495 will not apply, unless a deposit is first of all made by the said person of a sum which will, in the opinion of the Commissioner, suffice to cover the cost of the said materials, fittings and work.

[SECTIONS 493 AND 495 READ AS FOLLOWS:—

493. Instead of recovering any such expenses as aforesaid in any manner hereinbefore provided, the Commissioner may, if he thinks fit and with the approval of the Standing Committee, take an agreement from the person liable for the payment thereof, to pay the same in instalments of such amounts and at such intervals as will secure the payment of the whole amount due, with interest thereon at the rate of nine per centum, per annum, within a period of not more than five years.

495. (1) Improvement expenses shall be a charge on the premises in respect of which or for the benefit of which the same have

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been incurred and shall be recoverable in instalments of such amounts not being less for any premises than twelve rupees per annum, and at such intervals as will suffice to discharge such expenses, together with interest thereon at the rate of six per centum per annum, within such period not exceeding thirty years as the Commissioner, with the approval of the Corporation, may, in each case, determine.

(2) The said instalments shall be payable by the occupier of the premises on which the expenses are so charged or, in the event of the said premises becoming unoccupied at any time before the expiration of the period fixed for the payment of such expenses or before the same, with interest as aforesaid, are fully paid off, by the owner for the time being of the said premises, so long as the same continue to be unoccupied.

287. (2) No person shall permit any work, which he is required to do under any of the provisions of this chapter, to be done except through the agency of a licensed plumber, and any person who causes or allows communication-pipes, or any fittings or work necessary for conveying a private supply of water from a municipal water-work into any premises, to be laid, applied or executed by any person other than a licensed plumber, shall not be entitled to demand a connection with the municipal water-work.

287 A (1) The Commissioner may, if he thinks fit, cause any work described in this chapter to be executed by municipal or other agency under his own orders, without first of all giving the person by whom the same would otherwise have to be executed the option of doing the same.

(2) The expenses of the work so done shall be paid by the person aforesaid, unless the Corporation shall, by a general or special order or resolution, sanction, as they are hereby empowered to sanction, the execution of such work at the charge of the Municipal Fund.

288. The Commissioner may supply water from a municipal water-work to any local authority or person without the city on such terms as to payment and as to the period and conditions of supply as shall be, either generally or specially, approved by the Corporation.

BOMBAY WATER WORKS.

The City of Bombay is supplied from three different lakes situated at some distance from the City, *viz.*, Vehar, Tulsi and Tansa.

VEHAR LAKE.

Vehar lake has a gathering ground of 2,500 acres. Its full capacity is 9,120 million gallons. The mean rainfall for several years past is 84·70 inches. The water of this lake is conveyed to the City by means of two cast-iron pipes, one of 24 inches diameter and the other 48 inches reducing to 32 inches diameter. The 24-inch pipe discharges direct into the distributing mains and the latter pipe into the Bhandarwada Reservoir. The main evaporation comes to about 4½ feet per annum. The depth of the lowest outlet below overflow level is 34 feet. The greatest depth of water stored is 61 feet. The height of the lowest draw-off on the T. H. Datum is 232·5.

TULSI LAKE.

The second of these lakes is Tulsi. The area of its gathering ground is 1,385 acres. It has two dams ; the height of the lowest draw-off on the T. H. D. is 399·36 ; capacity available, when the lake is full, 2,294 million gallons ; mean rainfall comes to 103·82 inches ; mean evaporation is 4½ feet per annum ; depth of lowest outlet below overflow level is 57 feet ; greatest depth of water stored is 57 feet. It was constructed in 1879, and is 19 miles from the Town Hall of Bombay. The water is brought into the City by means of cast-iron pipes 24 inches in diameter laid generally above the level of the ground, and discharging into the Malabar Hill Reservoir.

TANSA LAKE.

Tansa is the largest lake. The area of gathering ground is 33,600 acres ; there is only one dam ; height of lowest draw-off on the T. H. D. 380 feet ; as originally constructed, the capacity available for supply when the lake was full was 18,600 million gallons ; by the raising of the dam in 1915 the capacity has been increased to 29,041 million gallons ;

evaporation is about 7 feet per annum; depth of the lowest outlet below overflow level was 25 feet and has now been increased to 34·50 feet; greatest depth of water stored was 110 feet, now increased to 119·5 feet; average rainfall comes to 106 inches; it is 58 miles from the Town Hall of Bombay. It was finished in 1891 and the dam subsequently raised in 1915. The water is brought into the City by means of a masonry conduit as far as practicable. The syphons across the valleys are of cast-iron pipes, 48 inches in diameter, laid generally above the surface of the ground; these syphons were duplicated in 1915 by 50-inch diameter steel pipes.

CALCUTTA WATER WORKS.

In Calcutta the river Hooghly gives the water-supply. The river is tidal at the intake and at high tide it is more or less salt. The raw river water is also very turbid varying from month to month, the total solids being sometimes as high as 1 in 1,000 in the early rains. The water is pumped from the river into settling tanks during the last hour of ebb and the first hour of flow of the tide. During the rains the water is treated in the settling tanks with alumina ferric (1 to 2 grs. per gallon). This leaves a comparatively clean water, which is drawn off from near the surface of the tanks and then passes to sand filters. The cost of this treatment is about 1 Rupee per 1,000,000 gallons. The use of alumina ferric has been found to reduce the turbidity by as much as 75 per cent. after 24 hours' settlement, whereas when untreated, the same water has shown only 30 per cent. reduction after 40 hours' settlement.

CHAPTER V.

Food and Milk.

Man is, in practice, omnivorous; he, however, adopts such food as is suitable to the environments and the climatic conditions he lives in, and to the daily pursuits of his life, whether active or otherwise. Thus the inhabitants of extremely cold climates take large quantities of animal food with fats, as it serves a double purpose, nutritive and heat-producing. In temperate climates, other conditions prevail and the people adopt a food suited to the physiological requirements of a temperate climate. The food is of a mixed nature, consisting both of animal and vegetable products. In tropical climates the conditions are entirely changed. The temperature is such as not to demand a continuous supply of a heat-producer; besides, the land produces an abundance of vegetables, fruits, etc., which are more agreeable to taste and more easy of digestion.

A brief review here of how inhabitants come to adopt a food, suitable to the environments and climatic conditions they live in, will be instructive.

From times immemorial, India has always been coveted on account of its fertile lands. The first invasion was that of the Aryans. They came down from the north of the Pamirs in Central Asia and occupied fertile lands in the Punjab along the Indus and its tributaries, whence at different periods further migrations were made down south.

In the Central Asian wilds their habits were nomadic, partly martial and partly agricultural. Their chief occupation and pleasure in life was hunting and hence they were essentially meat-eaters; but in the land of their adoption, in this very early period, "the Vedic" Aryans indulged in a variety of foods. R. C. Dutt, in his "History of Civilisation in Ancient India" (Vol. 1, page 5), says "there were no temples or idols. Each patriarch of a family lighted the Sacrificial Fire in his own hearth and offered milk and rice offerings or animals or libations of 'Soma' juice to the fire, and invoked the 'bright' Gods for the blessings of health and wealth for himself and his children"; and later, on page 41, says:—"It may be easily imagined that animal food was largely used by the early

Hindus of the Punjab. In the Rigveda there are frequent allusions to 'the cooking of cows, buffaloes and bulls' and there is also mention of a "slaughter house" where cows were killed. The fermented juice of the plant 'Soma' appears to be the only intoxicating drink used in the Vedic times. This drink was heavily indulged in by the Aryans and their cousins, the Iranians."

On account of the fertile nature of the soil, however, they took largely to agriculture. As a result, under the altered climatic conditions and with an abundance of agricultural products, they, to suit the existing conditions, adopted a diet of a mixed nature which by experience they found supplied the same quantity of physical energy as in days of old. In course of time the settlers, adapting themselves to the conditions of their land of adoption, led a life different from what they were wont to. Their customs, social habits and religious ideals changed (Epic period) with these new standards in life and concomitantly also in relation to food stuffs. This was the era of the evolution and development of the great religious caste system of Hindus.

Those who still kept to active pursuits in life consumed mixed diet, but those whose pursuits were mainly religious and literary became gradually purely vegetarian. Their needs were few, and the consequent waste in the human economy was easily made good by vegetable diet which *included* milk!

Other eyes, however, coveted the fertile plains of India, and the Greeks of Bactria and the Turanians invaded India. The former introduced Greek civilisation and culture into Western India. The latter established the kingdom of Kashmere and its dependencies. Later, the martial and marauding Tartars and Berbers began to make invasions and inroads into India. The "far-seeing" Manu promulgated the new code of castes, by means of which he secured the defence of the country and, at the same time, yielded to the high ideals of the religious and literati. He therefore divided the people into two great sects: the martial, the Kshatrias, and, the religious, the Brahmins. To the former he allowed mixed diet consisting both of meat and vegetable, which were necessary for the up-keep of the human physique, the supply of physical energy and the repair of waste tissue. On the latter (Brahmins) he enjoined purely vegetable diet, in which milk was included.

Guided by experience, and in conformity with both social and religious customs, the Aryan Hindus adopted the mixed diet as the best and most suited to the climatic conditions.

Mixed diet may be of two kinds :—(1) a mixture of animal meats consisting of albuminates, and vegetable food and sugar containing starches (wheat, rice, etc.), *i.e.*, carbohydrates. (2) Vegetable matter only, *i.e.*, cereals containing vegetable albuminates in addition to starches or sugars.

To both the above there is always a proportionate admixture either of animal fats or vegetable oils, butter or ghee.

In the human system provision is made for the digestion of animal and vegetable albuminates, starches or carbohydrates, and fats and oils. In the mouth, in the process of mastication and trituration, the food is intimately mixed with saliva which contains a ferment, "ptyalin," by the action of which starchy and farinaceous foods are dissolved and converted into soluble sugar compounds ready for assimilation and absorption. In the stomach, there is the gastric juice containing a ferment called "pepsin," which acts on albuminoid and protein compounds converting the same into soluble and easily absorbable forms called "peptones." The portions of food not absorbed in the stomach, being only partially digested, pass into the intestine which receives secretions from two large and important glands, the liver and the pancreas.

The secretion of the liver is bile. By its action the animal fats and vegetable oils are emulsified and saponified and rendered easy of digestion. The pancreas supplies the pancreatic juice possessing peculiar properties which enable it to perform the double function of both the gastric juice and saliva. This special action is due to the three ferments it contains, namely, (1) trypsin, (2) amylopsin and (3) steapsin. Trypsin further peptonises and splits the peptones up into leucin and tyrosin and asparmatic acid, crystalline nitrogenous substances very different from proteids. Trypsin is, in all respects, a more powerful ferment than pepsin: it reduces peptones into more easily absorbable products. Amylopsin or sugar-forming ferment changes starch into dextrin and maltose, just like ptyalin of saliva. Steapsin or fat-splitting ferment splits up fats into glycerine and corresponding fatty acids; the latter acids unite with the alkalies of the pancreatic juice and bile which emulsifies and saponifies fats and oils. As digestion proceeds, the food is reduced first to a sloppy condition and finally to a liquid state. This fluid is of a milky consistence and is called chyme ; as it passes downwards it is absorbed by hair-like processes called villi, which project from the walls of the intestine, and from these it soon passes into the blood vessels with which the intestine is abundantly provided.

Besides the albuminates, carbo-hydrates and fats and oils, there are other adjuncts which are necessary for the preservation of health. These are water, mineral salts, and acids chiefly vegetable.

Water.—In the human system the percentage of water to the body weight is about 62 and the body loses about 100 ounces daily. The necessity for water is therefore obvious ; it must compensate for the losses caused by the excretory organs and skin. Its presence is a necessary condition for the occurrence of chemical changes in other bodies in the human system. It is valuable for the dilution and solution of solid foods, whereby they are easily digested and assimilated. Moreover, it is a necessary constituent of all body tissues.

The quantity required by each individual varies according to the bodily labour and the temperature he lives in. The more the functional activity of the body organs, the more is the need of water.

Water, the principal beverage of man, should, therefore, be as pure as possible. It is liable to be rendered impure by inorganic or organic matters, or to be contaminated by sewage impurities and by active pathogenic germs. The inorganic impurities may be due to active poisonous mineral matters held in solution, such as lead, or due to alkaline or earthy salts derived from the soil, or similar salts derived from the decomposition of organic substances.

Vegetable acids of fruits and vegetables have a beneficial effect on the well-being of the individual. They occur as salts of citric, tartaric, malic, oxalic, lactic and acetic acids and are converted into carbonates which produce the alkalinity, which is a necessary character of the normal constitution of blood and other fluids of the body; when deficient or absent from the food, a state of malnutrition occurs which, if continued, finally developes into scurvy.

Salts are as essential to the body as nitrogenous principles. The chief are common salt, phosphates of lime, soda, potash, magnesium and iron. Common salt occurs in all tissues and fluids of the body and promotes the solution and diffusion of fluids through membranes. The phosphates help in the development of bone.

Dietaries of individuals differ according to the nature of their occupation, according to the body weight and physical labour or energy employed. The latter two include (1) internal mechanical work which is required for the maintenance of circulation, respiration, digestion, etc., and (2) external mechanical work expended in movements or locomotion, lifting and carrying weights, etc. There is also mental work or nervous energy spent to be considered. The internal mechanical work is performed automatically by the heart and the organs and is estimated at 260 foot-tons, *i.e.*, "it is equivalent to the work which a man does who raises 260 tons to the height of one foot." The average external work, also called productive mechanical work, is estimated at 300 foot-tons.

The average weight of a European is between 140 to 150 lbs. The average weight of an Indian is about 115 lbs.

The ordinary work of a European labourer is estimated at 300 foot-tons, and *pari passu* that of an Indian must be estimated at a lower figure—220 foot-tons. Dietaries, therefore, are calculated according as the diet is necessary for—

(1) subsistence, just sufficient for the internal mechanical work of the body;

(2) ordinary work (consumption of visible energy equivalent to 300 foot-tons); and

(3) laborious work: to compensate a work equivalent to 450 to 500 foot-tons.

It follows, therefore, that a large proportion of albuminoids to starch and oils is naturally required for those whose stress and amount of work are greater.

By means of chemical analysis, the relative proportions of proteids (albuminates), carbo-hydrates (starch), water and mineral matter in each of the various foods have been ascertained. On this basis estimates have been made and it is found that the "nutritive value" of vegetable (proteids) foods is almost equal to that of corresponding proteids of animal foods.

Prof. A. H. Church, in his hand-book on "Food Grains of India" (page 4) says: "the expression 'nutrient value' refers to the sum total of the albuminoids, starch and the starch-equivalent of oil, and the term 'nutrient ratio' designates the proportion of albuminoids to starch, including with the starch, the starch-equivalent of any oil or fat present in the food." A complete nutrient ratio will necessarily include, besides the above, water and saline and mineral salts. It has been found by experiments that one part of vegetable oil or fat is practically equal to 2·3 parts of starch, and for reckoning purposes the factor 2·3 is used as the "starch-equivalent" of one part of oil.

By practice, it has been ascertained that the 'nutrient ratio' in good standard diets of nitrogenous food to non-nitrogenous or, which is the same thing, of albuminates to carbo-hydrates, should not be less than 1 to 6, and this proportion has been fixed in the construction of a standard dietary for a European weighing 150 lbs. and doing moderate work.

For hard work more nitrogenous food is necessary for the repair of tissue and loss by heat of physical energy. Consequently, for hard work, in the calculation and construction of a diet for such individuals, a higher proportion in nutrient ratios must be aimed at to compensate the loss; hence more nitrogenous food and (equivalent) proportional rise in carbo-hydrates.

Prof. Church referring to Indians says (page 19):—"If then, we assume "an amount of daily work performed by an average European labourer "weighing 150 lbs. can be expressible in this form—that he lifts 300 tons "one foot—we shall find that the natives of India weighing 115 lbs. can "and do perform an amount of daily work equal to 230 foot-tons, and, if "their weight be 105 lbs., they can and do accomplish work equal to 215 "foot-tons." On the above basis, he gives the following standard dietaries for Indians weighing 105 lbs. expressed in ounces avoirdupois. If the Indian weighs 115 lbs., one-tenth must be added to the calculated quantities—

STANDARD TABLE FOR INDIANS WEIGHING 105 LBS.

——	Albuminates.	Oil.	Starch.	Starch-equivalent.	Nutrient ratio.
A. Bare sustenance ..	2·123	0·752	7·520	9·250	1 : 4·34
B. Moderate work ..	2·954	1·412	12·531	15·779	1 : 5·34
C. Hard work ..	3·635	2·506	18·190	26·954	1 : 4·66

For an average European weighing 150 *lbs. the following table gives approximately the dietaries under the same conditions. On comparing the two, the excess required by the European will be at once patent. These are also expressed in ounces avoirdupois.*

——	Proteids.	Fats.	Carbo-hydrates.
1. Subsistence diet	2·33	0·84	11·69
2. Moderate work	4·215	1·397	28·69
3. Active labour	5·41	2·41	27·92
4. Hard work	5·64	2·34	20·41

It will thus be observed that mixed diet is the most suitable diet for man. In nature there does not exist any complete food having the adequate proportions of nutrient ratio of a mixed diet. Even milk, the ideal food for infants and growing children, is not a complete food in the sense required by an adult, inasmuch as it contains no starch, for the digestion of which two specific ferments are provided in the human system, namely, saliva and pancreatic juice It contains a large proportion of water and relatively large proportion of fats in comparison to the proteids and carbo-hydrates. Eggs have all the necessary nutrients for an adult but are deficient in carbo-hydrates and hence cannot be a complete and perfect food.

To calculate and construct a suitable mixed diet, only experience can be our best guide. It should be small in quantity, easily digestible, agreeable to taste and of good quality. All these various attributes can readily be obtained in a mixture of animal and vegetable foods. Vegetables alone, cereals and pulses may contain all the necessary ingredients, but the quantity required must necessarily be larger so as to attain a proper nutrient ratio, and because of its bulk it is less easily digested and liable to undergo fermentation in the alimentary digestive tract. Therefore, if by custom and religion a mixed diet made up of ingredients of both animal and vegetable stuffs is prohibited, a selection of cereals, pulses and vegetable oils must be made and so adjusted as to obtain a complete food with the minimum of quantity and maximum of digestibility.

Regarding food grains of India, cereals and pulses, exhaustive analyses and researches have been made by Dr. Forbes Watson and later by Professor A. H. Church, and the exact ratios of each of the different varieties of grain and pulses ascertained. The nutrient values of these foods are tabulated and dietaries proposed and incorporated in the hand-book on "Food Grains of India," to which reference may be made in computing diets of a vegetable nature only.

The ailments due to excess of food, either too large or too frequent meals, require no special mention. Unwholesome food or food in a state of partial decomposition produces symptoms of severe gastric irritation due to ptomains and other toxins which such food contains.

All meats of animals suffering from infectious or acute inflammatory diseases must be entirely prohibited. Reference will be made here to such foods, animal or vegetable, used in these countries, as may be the carriers, or be the cause of the production, of particular diseases in man.

Animals in tropical climates suffer from the same kind of parasites as in colder climates ; the chief of these are Tenia Solium from the Cysticercus Cellulosæ of the pig, and Tenia Mediocanelata from the Cysticercus Bovis of the ox. These