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Government of Madras.

Public Works DEPARTMENT.

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*Proceedings of the Madras Government Public Works Department,
15th January 1869.*

No 231 Read the following Circular from the Government of India, Public Works Department, (Civil Works—Miscellaneous,) dated Simla, 30th October 1868, No 91 —

Best means of keeping water sweet in tanks

Read again —

Public Works Department Circular, No 39, of 1858
Despatch to Secretary of State, No 66 of 22nd April 1868

Read also the following Despatch from the Secretary of State for India, to the Government of India, dated 16th September 1868, No 80

1 With reference to the request contained in your Excellency's Despatch, dated April 22nd, (No. 66), 1868, that the opinions of the best authorities in England, on the subject of keeping water sweet when stored in reservoirs, may be obtained for the information of your Government, I have to inform you that the question was referred to Mr Edwin Chadwick, C B, Mr Robert Rawlinson, C B, Dr Letheby, and Dr Sutherland, the Secretary of the Army Sanitary Commission

2. I now transmit copies of the Reports, which, in compliance with my request, have been furnished by these gentlemen With reference to Mr Rawlinson's recommendation at the end of his Report, I have requested him to superintend the preparation of plans, sections, and estimates of the best forms of sand filters and pure water basins, which will illustrate general principles, although, of course, they cannot fit all places and circumstances These will be transmitted to India as soon as they are completed

From E CHADWICK, Esq, C B, to the Secretary of State for India, dated 20th August, 1868
The information which I have to submit in answer to the request I have had the honor to receive, that I would state for the Government of India my views on the best means of keeping water sweet when stored in artificial reservoirs has been derived from observation of the sanitary condition of the chief cities in England as a Sanitary Commissioner, and as Chief Executive Officer of the General Board of Health, where we had to conduct a special examination into the condition of the water-supply of the Metropolis

One common condition in which I found the water supplies, collected and distributed in the ordinary manner, was that water of a superior quality at its source was found to be deteriorated to an excessive degree at its delivery

The first stage of its deterioration was in its detention and exposure to light and air in open reservoirs

Our examination of the water-supply of the Metropolis extended to the changes the river water underwent in its course, and Dr Angus Smith, an eminent Chemist, who aided in that examination, was requested in his instructions for tracing the changes of the Thames water from adventitious pollutions, to aid his chemical analysis by microscopical examinations of the animalculæ contained in it

The view with which these instructions were given was to ascertain whether, on the point most important for sanitary purposes, not merely the quantity, but the nature and quality of organic matter contained in water, which chemical analysis leaves obscure, some light might not be gained by the observation of the animalculæ The eminent German Naturalist, Ehrenbarg, as one result of very extended observations, established the fact that the existence of visible animalculæ generally indicates the presence of a lower series of invisible animalculæ descending in magnitude, to the smallest monad of the most simple structure, so small, that there is probably no smaller organized creature on which it can feed, while, as is commonly conceived, by arresting matter on the very limit of the organic world, and converting it into its own nutriment, it furnishes in its turn sustenance to higher orders of animalcular life

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Be this as it may, it is very certain that the presence of animalculæ in large numbers indicates the existence of animal and vegetable matter usually in a state of decomposition, which invariably acts injuriously, if the water containing them is used largely for the purposes of food, and the effects may be more immediate and marked when the animalculæ are large and numerous.

In respect to vegetable matter, it is to be observed that, when water is kept stagnant and exposed to the sun in moderate temperatures, vegetable infusion of the class called algæ, and also fungoid vegetation appear rapidly. Many tribes of these vegetable productions appear to die with great rapidity, sometimes in one or two days, and then decompose. Immediately after these, animalcular life appears. Stagnant water is the most favorable to this order of vegetable productions, which, in giving rise to animalcular life, appears to keep pace with the animalized excreta discharged in the house drainage of towns. This insalubrious order of production is indicated by the smell in stagnant, or nearly stagnant ornamental waters, such as the stagnant portions of the Serpentine river, which have often excited so much declamation. Certain degrees of motion in water are unfavorable to the production of algæ, or other infusorial plants, the tissues of which are destroyed by brisk motion, but a large proportion of them are found in slow running waters, or open canals with little traffic, such as the Regent Canal. In summer time the extent of pollution here is perceptible to the smell over the bridges, and at some considerable distance. The same round of life and death also takes place in open and shallow reservoirs, and in open cisterns where the water is frequently changed. Light, however, seems to be necessary to the production of infusoria, and fungoid vegetation, and their formation is prevented by such covering as excludes the light and heat of the sun. Whilst exposure and stagnancy, or slow motion, thus increase the animal and vegetable impurities in water they likewise increase its mineral impurities by the increased evaporation, which leaves a larger proportion of mineral matter as residuum. Thus we have had examples of shallow spring water, or agricultural tile drainage-water, of only 4 degrees of hardness, taken from the tile drains as in Richmond Park, increased to 8 degrees of hardness in water from the same soil, after it has stood for a time in ponds. Water of only 2 or 3 degrees at its source is found to increase to 10 or 12 degrees of hardness in canals, a difference not to be accounted for from the qualities of any puddings of clay, or strata containing lime, over which the water may have passed.

Mr. Cooper gives an instance in the Surrey Canal, a canal of little traffic, which is fed from the Thames at Rotherhithe.

He examined it by taking specimens of the water at several points between its entrance at Rotherhithe, and its termination at Camberwell. The examination showed an increase of specific gravity, an increase of organic matters, and a corresponding increase of saline matters, and of hardness from its entrance to its termination. This progressive increase of impurity up to the termination he could not but ascribe to the process of evaporation combined with the smaller amount of traffic which there was towards the end of the line.

Further researches tended to sustain the inference that it is the Office of the lowest monads to convert the gaseous products of decomposition into organic tissue, which serves as food for all the upper series of animalculæ and animal life. Certain it is that, if the products of decomposition were left unabsorbed by this animal and vegetable life, deleterious miasma would be produced in much larger quantity. Of the sequence, there can be no doubt, but the sources, nature, and properties of these spores, with the laws of their diffusion, appear still to be examined and determined by the Naturalist.

One effect of exposure in stagnant reservoirs is, that the quantity of air held in solution in the water is diminished. The water so de-aerated on the intermittent system of supply is taken in the water butts, which are kept in the back-yards of lower class dwellings, commonly near cess-pits. Here it absorbs rapidly the noxious products of decomposition.

In the poorest class of houses the people carry up the water from the butts, and keep it in jugs in their crowded rooms. Surgeons, who have had to perform operations in such dwellings, have told me that the water given to them to wash their hands has imparted to them a disagreeable smell.

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Under these conditions of distribution of drinking water at the source at the foot of the mountain, you may be said to be drinking mountain air, sometimes, at the reservoirs where the matter of decomposition has not been kept down, you may be drinking marsh miasma, and in the close Court or Alley, you are drinking the air of the cess-pool. Taken at its source, the water is cool and refreshing, taken from stagnant butts in the town, it is mawkish and disagreeable.

The development of vegetable and animal life varied with the nature of the water and the conditions in which it is placed. With some water, as in those containing much phosphate, the vegetable development was of extraordinary rapidity in others they decayed quickly. When there was an adjustment of the animal and vegetable life, the water was not unwholesome, in the water butts of the town, even it could not be said to be unwholesome, or more than that it was of an inferior quality, and the great evil was that the people from its mawkishness pronounce it to be undrinkable, and do not drink it, but drink fermented liquors. In epidemic periods, however, these inferior qualities of water appeared to be powerfully affected in manners which we had no time or opportunities to investigate, but which led people to believe that the water was poisoned.

As between hard and soft water, there was less vegetation in the calcareous waters, but these waters had the disadvantage of being less solvent for culinary purposes, &c.

I was strongly impressed as to the proper treatment of water for household purposes by what I met with, in examining the practice of John Day, the Horse Trainer. I found that the greatest care was taken by him to collect rain-water from slate roofs, and convey it immediately to a deep slate tank, 20 or 30 feet deep, from which the light was shut out. This precious water was carried in barrels for the supply of the horses at distant race meetings. Some of the tanks of other Horse Trainers had a charcoal division, through which the water passed, to retain any vegetable or other impurities which it might have collected from the roof. From the observation of such instances, I was led to conclude that the right treatment of the water for the population was to collect it as soon as possible in covered reservoirs by covered channels. There are nearly 200 miles (square) of sandy surface, bearing little vegetation, in the vicinity of Allersholt (the Surrey Sands). I proposed to use these as gathering grounds for the supply of London. A convenient site was reported on of about 500 acres, which, at the available depth, would have sufficed for the storage of a supply for three months. I proposed that this should be covered with a roof of hollow brick as the best roof to maintain an even temperature. It was to be constructed in the form of a series of groined arches. By manufacturing the bricks, specially the cost of this tank, roofed with hollow brick, and floored with tiles, was estimated at three quarters of a million of money. The covering, we found, could be done at about 3 to 4 superficial yards. This reservoir would effect an enormous economy by doing away with the necessity for private tanks and cisterns.

In many situations great expenses have been incurred by having large filtering basins which are merely sieves that imperfectly remove the impurities that are collected by the open storage reservoirs, and the covering of a reservoir which would have prevented the introduction of these impurities would, perhaps, not have cost more than the expense incurred by the construction and working of the filtering basins erected for their removal.

In one part of the site chosen for this storage reservoir, there was a deep gorge with a sandy foundation. The covering would have been difficult and expensive, I proposed a floating cover. The first materials suggested was wood, which was liable to decay, at length it occurred to me to accomplish the object by constructing a floating cover of hexagonal pots, which I found could be constructed at a cheap rate if made in numbers. They might be tied together with wires. I have a strong impression that this expedient might be frequently used with advantage.

On examining closely the area of the 200 square miles of gathering ground, however, perennial springs were found in such quantities even in dry seasons as to dispense with the necessity of any such extensive storage reservoirs.

But the Water Companies were too strong for us in Parliament, and we failed to carry this measure for the supply of London. The Committee of the House of Commons, however, did adopt the principle of having the reservoirs covered, and the Companies were ordered to cover them, but I believe, the order has been carried out very imperfectly, and small covered reservoirs have been used only at the end of the storage and filtration basins. In a number of towns the principle has

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since been applied very completely, the water derived from springs, or from hill sides, is led in covered channels into covered reservoirs, and does not see the light until it is drawn from the tap in the house, and there it arrives in a beautifully filtered, clear, cool, and highly aerated condition, often as much so as soda-water.

When the deductions from the course of investigations I have cited were made known, it proclaimed that the plan was in truth that of the ancients. At Constantinople, there is a great underground reservoir.

The services of Captain Vitch, of the Royal Engineers in Spain, had made him acquainted with the Roman remains of covered reservoirs there, and the advantages of preserving water in deep covered cisterns, underground, according to the Roman practice. The covered reservoirs or cisterns at Rome were immense works, adorned with architectural decorations. Constantinople had covered reservoirs or cisterns holding at the least 400 millions of gallons. One of these reservoirs which still remains is described as constructed of brick and covered with cement, it has a vaulted roof, supported by 336 marble columns of the Corinthian order, 40 feet 9 inches high. Arches of brick rested upon the capitals, which are surmounted by a massive marble abacus. These columns are placed in rows, 12 feet apart, longitudinally there are 12 ranges, and latitudinally 28. The cistern is 336 feet in length, 180 to 200 broad, consequently its cubical contents to the top of the capitals of the columns would be 3,861,144 cubic feet, or it would hold 25,000,000 gallons of water. This edifice, with its ground vaulting, would be about as capacious as one of our Cathedrals.

In Spain, where the water collected and stored in covered tanks is valued according to the length of keeping as old wine. The Spaniards in Peru used a similar system, and as to leading water in open channels, they considered it, as it were leading it waste in the open air. Even in England there is considerable loss by evaporation which increases the proportion of solid impurity in the water.

On these several grounds, I conclude, that all water for the supply of cities should be received, led in covered conduits, and stored in covered reservoirs.

The chief question is the economical construction of the covering, whether of concrete or of hollow brick, which I prefer. I believe for India, as at Madras, where I am informed that the manufacture of bricks is half as costly as in London, the pot construction might be made very cheaply. A man and a boy in England at piece-work I found would mould ninety-two gallon pots in a day. These are of much superior quality to the machine-made bricks, and a machine may be constructed to give them strength and exactitude of form at a very low rate.

A valuable source of water might be distributed separately for household purposes only, leaving commoner water to be used for gardening, street washing, and manufacturing purposes.

For the softer water which act powerfully on metals, earthen-ware pipes would be best. These are used in France up to a pressure of 160 feet, and cost about one-half the price of metal.

From such information as I have collected, it appears to me that the conclusions deduced from the Home experience are *a fortiori* applicable to the question of the storage of water in a tropical climate, where from the heat the activity of animal and vegetable life is greater, decomposition more rapid and dangerous in its products, evaporation and consequent deterioration of the water is so much greater.

On looking over the papers transmitted I think it is confirmatory of the experience I have cited. A common opinion is expressed, that vegetation and fish conduce to the salubrity of water. I should rather say that they reduce its insalubrity by the absorption of the products of decomposition. Like the process of filtration they serve to diminish, what ought not to have been admitted. I agree with what is said by the Superintendent of the Government Central Museum, who says, "I have been engaged in microscopical enquiries for more than 16 years, in the course of which I have examined water from all kinds of reservoirs, and my experience has led me to the belief, that it is utterly impossible to prevent the introduction of infusoria (animalculæ) and minute plants, such as desmids and diatomacæ into water, unless both light and air be excluded, and I quite agree with those who consider growing plants as purifiers of water, and there is no doubt that the larger animalculæ such as the rotiferæ, both act as scavengers, and feed upon the smaller animals and

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plants, very few tanks I suppose are without a supply of the water-snail paludoums, which feed upon decaying vegetables, and which are kept in aquariums for that purpose in England. On two or three occasions at the latter end of last year, I was induced to examine the dew deposited on leaves of plants during the night, and I found in it both infusoria and fungi. If these are thus developed in the course of a few hours, it is plain they cannot be kept out of a tank or river, the truth is their germs are always floating in the atmosphere, and become developed as soon as they are surrounded by water."

I have a great prepossession in favor of the plan, I have submitted of a floating pot cover to water-tanks, as I think it would serve to diminish the quantity of the floating spores taken up by the water, though, I believe, it may almost be said to be impossible to exclude them absolutely, but the covering, exclusion from sun light, and diminution of heat, does certainly prevent their development, and the large sequence of animal and vegetable production, I would commend the plan for trial on a small scale in the first instance.

The Officer of the Hill Roads Division states that "he considers that tanks should be periodically cleaned if it is found that the balance of animal and vegetable life is not sufficiently equal to keep water sweet, and recommends covered tanks and deep reservoirs as being likely to be more free from the evils of heat in India."

Dr R Cole, Principal Inspector General, Medical Department, says, "as a general rule, that it is doubtful in this country whether water artificially stored will ever be so safe for drinking purposes as deep well water." Now deep well water is under the condition of that kept in a covered reservoir.

Captain Swetenham considers that the water should be covered, so as to prevent evaporation as much as possible, "because all evaporated water ascends perfectly pure, leaving its share of impurities to increase the percentage of that left behind."

These other facts support the like general conclusion.

Where the water is derived from river sources, it is chiefly derived from the surface washings of lands in England, often from cultivated and manured lands, and it carries with it much soil, and much of the manure from the surface of the land which, in some cases, is more than is contained in the sewerage from towns.

To get rid of the matters in suspension, "settling reservoirs" are necessary, previously to filtration and to storage in covered reservoirs. It is now admitted, as a rule, by Water Companies that the water, after being filtered, should not see the light again, or the work of filtration would be soon undone. But we have made efforts to obtain water not from the surface of the land, but that which has passed through the soil, and is there collected by sub-soil drains. Sand mixed with loam occupied with vegetation, but not highly manured, constitutes a filter of the highest order. Most filters (all filters of the common sort) are merely strainers and remove little but the matter in suspension, but the drainage through such cultivate, not only remove the matter in suspension, but takes away to the greatest extent, matter in solution. This land filter, if it may be so-called, takes out much of what may have been brought down by the rain in passing through the atmosphere.

The waters derived from sub-soil drainage were of the highest order of purity and quality, clear, cool, and well aerated, and in the best condition for storage in covered reservoirs direct, and without any subsiding tanks.

Where water cannot be got direct from naked primitive rock, than sub-soil drainage waters are the best of all. As an immediate expedient, I would recommend the formation of covered reservoirs at the head of the great tanks, and that the water so preserved should be led off for domestic supplies.

The chief practical point in the cheapness of the covering, whether of hollow brick, or of concrete, Mr Austin, who prepared the projects for the water-supply of London, is dead, and the plans are lost. Some of the covered reservoirs made on the principle recommended, cost about £1,000 for each million of gallons stored, this was, however, for reservoirs of comparative small scale.

A tank, such as that at Constantinople, might have been constructed probably for £60,000 £70,000, constructed of concrete, it may be done at 3d. or 4d. per foot of space. There are points

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in the construction of some of Mr Rawlinson's covered reservoirs which would commend his plan for study and consideration

I have already submitted as topics for distinct examination and consideration the subject of water distribution in France by earthen-ware pipes, and also the subject of the chief preparations of concrete, to determine the best available for large covered reservoir constructions

I may now add, as another topic, the manufacture of machine-made hollow bricks, together with the manufacture of earthen-ware pipes

From H LLLHEBY, Esq., M.B., M.A., and Professor of Chemistry in the London Hospital, and Medical Officer of Health for the City of London, to the Under Secretary of State for India, dated 23rd July 1868

I have to acknowledge the receipt of your letter of the 3rd inst., with a collection of printed papers on the subject of the best means of keeping water sweet when stored in artificial reservoirs, and having read them, I submit the following observations for the information of Sir Stafford Northcote, and for the use of the Government of India.

The experience of water-supply in this country has long since decided that, if we are to secure sweet and wholesome water for domestic use we must pay the strictest attention to the several details of the three following points, namely, the character of the gathering ground, the condition of the storage reservoir, and the purification of the water immediately before distribution. Judging, however, from the papers you have sent to me, I am led to think that these important points are not sufficiently considered in the water-supply of India, notwithstanding that the necessity for their observance is even greater in that warm climate than with us

1st As regards the collection of water—It is manifestly of the greatest importance that the district or gathering ground should be selected as free from polluting influence as possible and that it should be strictly guarded from all preventible sources of impurity, as from sewage deposits, from agricultural operations, and from the too luxuriant growth of rank vegetation. I am not precisely acquainted with the general character of the Districts from which the water-supply of the large cities of India is derived, but it appears to me from the evidence afforded by the papers sent to me, that very insufficient attention is bestowed on this part of the subject, and that therefore the water is permitted at the very first to become fouled to a very serious extent with organic impurities. The obvious remedy for this is, the periodical clearing of the ground from decaying vegetable matter, by burning them, before the rainy season arrives. It is also necessary that the natural channels for the flow of the water to the storage reservoirs or tanks, should be kept clean and orderly, and that if any notoriously bad water occurs upon the ground, it should be conveyed by special channels to another outfall, and so directed from the storage reservoir.

2nd With respect to the tanks or reservoirs of India—It is abundantly evident that they are rarely constructed or maintained in a proper manner, and in the case of the Vchar Lake, degree, for the banks of the lake are so shallow that when the water retires the aquatic plants die and become putrid, and the natural ground of the lake appears to be a soil unusually charged with organic matter, besides which there is manifestly a large accumulation of decomposing mud, which gives offensive quality to the deep water, and in addition to all this, it is very probable that the water is fouled by the cattle, and by the filthy habits of the Natives. To remedy this, it will be necessary to give a steeper slope to the sides of the lake and to construct them, if possible, of stone-work, to remove the dead aquatic plants before the rainy season occurs, and to take measures for the removal of mud, and for the periodical cleansing of the lake, as by dividing the lake into two or more parts, and above all, it is necessary that the water should be strictly guarded from all such preventible and unjustifiable pollution, as from bathing, from washing of clothes, watering cattle, &c., &c., and as to the question of the presence of aquatic plants and animals, there can be no doubt that within reasonable limits, they are useful in purifying the water, and keeping down the proportion of soluble organic matters, but if permitted to thrive to such an extent as to communicate a perceptible taint to the water, they are a cause of injury to it, and in every case provision should be made for the quick removal of dead and decaying substances

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3rd Concerning the purification of water immediately before its distribution—I may state that it is a very general practice in this country to filter all lake and river water directly before it is delivered to the public, and considering the quality of the waters of India, I have no doubt that such a practice is very desirable there also. Filtration with us is effected through shingle or gravel, coarse sand, and fine sand. The order of the materials is usually as follows—

At the bottom of the filter there is a layer of shingle or coarse gravel to the depth of 12 inches or thereabout, upon this is laid about 9 or 10 inches of fine gravel with sometimes an upper layer of broken shells to the depth of 3 or 4 inches, then comes a layer 9 inches deep of coarse sand, and finally upon the top of all a layer, 24 inches deep, of fine siliceous sand. The water flows downwards through such a filter at the rate of from 70 to 80 gallons per day for each square foot of surface, and it flows into a covered service reservoir, which is placed at a lower-level

When the filters become foul, and cease to deliver the water, they are cleansed by taking off a thin layer of sand from the upper surface. This sand is washed and returned to the filter. In conducting this operation it is necessary to have two or even three filters, so that one or two may be in use when the other is undergoing the process of cleansing, and the storage, or rather the service reservoir for this filtered water, should be covered to prevent the access of light, and the growth of plants or infusorial animals

It should have a capacity of not less than one day supply

Taking all the circumstances into consideration, as detailed in the printed papers submitted to me, and applying the knowledge which I have derived from a professional examination of most of the large water-works of England, I am of opinion that the means which are necessary for securing a supply of sweet and wholesome water in India, are—

- 1st—A proper selection and proper treatment of the gathering grounds.
- 2nd—A better construction and preservation of the tanks or storage reservoirs, and
- 3rd—The filtration of the water into a covered service reservoir immediately before its distribution to the public

From R RAWLINSON, Esq., To the Secretary of State for India

Herewith, I beg to forward my report on the "best method of keeping water sweet when stored in tanks" in India

If in furtherance of the recommendation I can render additional assistance, it will give me pleasure

Any young Royal Engineers about to be sent out to India may have a short but special training in water-filtering and covered reservoir (tank) work

I think they may with advantage visit special works, make plans, sections, details, estimates, and reports of the same, as in my experience I have ever found that actual work at any subject of this sort, alone gives full practical knowledge.

Report by R RAWLINSON, Esq., C.E., Civil Engineer, Chief Inspector, Local Government Act Office, Whitehall, on best method of keeping water sweet when stored in tanks, dated 24th July 1869

As instructed by your letter dated the 3rd July 1868, I have examined the several papers sent from India relative to water-supply, and have given special consideration to the question as to the best method of keeping water sweet when stored in tanks

In India the word "Tank" appears to be used generally to designate artificial constructions for storing water, as for instance the Vchar Lake, and other similar artificial constructions, are called tanks. In England the word "Reservoir" would be used, excepting for small constructions of stone, timber, or iron. In this Report the word "Tank" and "Reservoir" had better be considered as synonymous

In England, a work similar to the Vchar Lake, for the supply of Bombay with water, would be an "Impounding Reservoir". The area from which the water is collected would be designated "The Gathering Ground," and the outlet pipe would be the "Conduit"

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Artificial constructions near a town, and in which water brought by the conduit is stored, and from which it is distributed, would, if open, be called "Open Service Reservoirs," and if closed "Covered Service Reservoirs."

Before considering how to preserve water pure, some few facts connected with it and with water-works may be considered.

There is only one source in nature from which water is obtained, namely, the ocean, there is only one process by which salt-water becomes fresh, evaporation. All fresh water found on the surface of the land in lakes, in rivers, and in rivulets, or beneath the surface in the substrata, or issuing in springs, has been evaporated and condensed in the form of rain, or of dew. Distilled water is pure water, rain-water is therefore pure water. A Chemist may object to the term "pure," but for the purposes of this report, the statement that rain is pure water, may be accepted.

Lakes, rivers, springs, and wells, never furnish water as pure as it falls from clouds, or is condensed from the atmosphere.

The solvent power of pure water is very active, and on its coming into contact with earthy, mineral, or organic matter, combination takes place between the rain-water, and these substances in proportion as they be more or less soluble, or a greater or less time in contact.

In geology, formations of granite, of clay slate, of mill-stone grit, and some others, yield water in a comparatively pure state. All formations in which there is lime in a soluble state, as (chiefly in the form of bicarbonate or sulphate) has been dissolved. Chalybeate waters contain lime, iron, or sulphur, with other minerals as the case may be.

Hot springs rise through fissures from depths of several thousand feet, such springs, being, however, in all cases fed from the surface. The warm springs both of Bath and of Buxton, are effected in volume by the seasons. The dry weather volume of water in ordinary rivers is spring alternations of the seasons accumulating and melting these deposits. A spring of water is simply an outpour of water from porous strata, the spring being a fissure or conduit at a lower point than the general level of the sub-soil basin. Water drawn from wells must necessarily be impregnated with some of the mineral ingredients of the strata, this is so much the case, that a Chemist who has studied water analysis from the several formations will pronounce, from testing a sample of water, the formation it has been drawn from. A Geologist in like manner, who has studied Chalybeate gathering grounds, from drift-ways, from well-sinking, or from artesian borings, when he knows which of the great geological formations has to be dealt with.

The operations of nature are constant, and though simple in detail, the effect is stupendous. The power of evaporation is in the heat from the sun, pure water is raised from the ocean, and floated in the atmosphere over the land.

The solvent power of water from rain and dew removes lime and other matters in chemical combination, and the mechanical power of water in floods, disintegrates, drifts and floats solids, in proportion to the areas acted upon the gradients, the violence of the rain, and the volume of the rivers when in flood.

The solvent and chemical action of water is, however, probably the greatest, as it is unceasing. Water flowing from chalk, for instance, contains about 16 grains of bicarbonate of lime in each gallon, and this in one million gallons amounts to one ton.

The drainage area of the River Thames is about 5,000 square miles, and the average flow of water is about 1,000 million gallons per day, and 365,000 million gallons per annum, so that not less than 365,000 tons of bicarbonate of lime is annually dissolved from the chalk of the London Basin, and is imperceptibly removed to the sea.

About $\frac{1}{4}$ th of the land surface of the earth are composed of lime strata, and yield hard water, at or exceeding this proportion (16 grains in each gallon), so that an increasing and silent geological change on a vast scale in the aggregate is taking place.

Pure water is said to have a chemical affinity for certain things, and for some this affinity is stronger than for others. Pure water will for instance dissolve the colouring matter from plants,

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and therefore a lake or river having its sources on granite, or on clay slate, which yield comparatively pure (soft) water may be dark or coffee-coloured looking, from vegetable tinge, whilst a river or lake having its sources in mountain lime-stone, the oolites or chalk which yield hard water would be transparent and sparkling.

Again, if the soft and dark coloured water from granite or clay slate flows into and over a lime-stone District, combination with lime will take place, and the vegetable colouring matter will be precipitated, hard waters are therefore usually bright and sparkling, soft water, excepting naturally or artificially filtered, is frequently dark looking.

Water enters certain strata as sand-stones, sands and gravel chalk, &c, and fills the pores and cavities of the rock, just as water fills sponge. The proportion varies from $\frac{1}{16}$ th to $\frac{1}{4}$ th, this water is not evenly distributed, but accumulates along lines, and in basins according to the contour, dip, and character of the rocks.

A well sunk in certain known water bearing strata, may or may not yield water in abundance, well-sinking at random may therefore be disappointing. In some cases water may be abundant at depths of from 300 to 600 feet, and yet at 900 or 1,200 feet, the strata may be dry. Deep sinking or boring may therefore be disappointing. Sinking deeper will not in all cases increase the volume yielded by a well.

The cube of strata drawn from by a well, may be considered an inverted cone, with the well in its deepest part forming the apex of such cone, capillary attraction preventing water separating from the surrounding strata in any other manner; as the apex of such cone is deepened, the cube of the cone is increased, and if the whole strata at this part is water-bearing, the volume at command will have been enlarged.

The form of a cone is of course merely given to indicate a principle, there may be fissures and other conditions in the strata, which would bring in water from beyond any lines arbitrarily sketched, the great facts to be accepted are that sub-soil or underground waters are uncertain in their area and volume, and limited in their depth.

Water obtained either from springs or from wells, as previously explained, must necessarily be impregnated with some of the mineral ingredients of the strata, and it is only reasonable to suppose that the deeper the well, and the greater the amount of mineral impregnation, this is not, however, general, as water combines with some salts up to a certain standard, and is satisfied. Chalybeate and other waters of analogous character are special, local, and usually confined to small areas.

The question as to admitting the growth of aquatic plants, or otherwise, may be settled by the answer, that in open and shallow water, under the sunshine and temperature of India, whether in small tanks, or on the margins of large tanks like the Vchar Lake, they will grow, and the only practical good to be accomplished is in some cases to embank of flat areas which have not more than 6 feet in depth, and in other cases substitute wholesome and permanent aquatic plants, where practicable, that is if there are water plants which will do less injury than others, substitute the best for the more worthless and pernicious weed.

Vast areas, hundreds of acres in extent cannot practically be manipulated by human labor in weed cleansing.

The Metropolis of England (London) with its three millions of inhabitants, is supplied with about 100 millions of gallons of water per day, drawn from the River Thames and River Lea, which is a tributary of the Thames. Weeds (aquatic plant.) grow most prolific in these waters, and both rivers abound in fish. During dry weather, the waters are comparatively bright, in wet weather and during floods the waters are turbid.

Some of the Water Companies have large settling tanks, into which muddy water is drawn to clear itself by subsidence before filtration, but all the water is now sand filtered at a rate of about one-half gallon per minute, through each square yard of sand surface, that is 720 gallons of water from each square yard or thereabouts per day. After filtration the water is passed into covered pure water tanks, and flows direct through the mains for use. See Appendix as to the legal Clause relative to filtering and storing water in covered pure water tanks for London (1852).

Weeds in England abound most in shallow and comparatively still water, and are most prolific in hot summers. No practicable cleansing would prevent the growth of weeds and aquatic plants in

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such rivers as the Thames, or on the margins of large impounding reservoirs, and I anticipate that any attempted "uprooting of all aquatic plants from every part of the basin of the Vehar Tank" would be a failure, as other weeds *would* grow immediately. The sand of the London water-works filter beds, although scraped and cleansed at short intervals, produces weeds all through the summer, and it is impossible to prevent such growth, the only remedy is to scrape the sand at short intervals, wash it, and renew it upon the filtering beds. To attempt uprooting weeds on a large scale in India, would necessarily disturb the mud, and render the water turbid, and there may be salts in such mud, comparatively harmless in a quiescent state, but which disturbed and mixed in larger doses with the diminished volume of water, may increase any injurious effects upon health.

Water in the shallow parts of the reservoirs or tanks becomes offensive when exposed in a stagnant condition to the sun, and water in the deeper part of such tanks, may even be affected, but deep tanks are nevertheless more desirable. As water is lowered from the surface of a large tank, the shore mud becomes putrid, aquatic plants left dry, decay causing the reduced body of water to become noxious, which before was comparatively sweet. The only practical remedy will be filtration and storage in covered tanks.

With respect to the storage of water in India, I have come to the following conclusions —

CONCLUSIONS

That before works of water-supply are commenced in India, the surface or the substrata shall be most carefully examined, and that the site which will yield the best water shall be chosen.

That store tanks should not have shallow margins, but that such shoals should be deepened by excavation, or be banked out as may be most practicable, a depth not less than 6 feet in the shallowest part should be secured when a tank is full.

That the shores of tanks may be covered with broken stones, where such protection against washing and wasting of the surface of the land is desirable.

That the main collecting channels of gathering grounds should be cleansed and scavenged from time to time.

That the water surface of tanks should regularly be cleansed from all floating refuse of every sort.

That aquatic plants and fish do not necessarily injure water, but that both should be kept within certain limits, dictated by local experience.

That artificial agitation of large volumes of water cannot practically be accomplished, neither is it necessary.

That all water from open tanks should be drawn through fine wire screens, to prevent floating and suspended solids flowing on to and over the filters.

That all open tank waters without any exception, should be sand filtered, and be stored in covered tanks, or passed direct into the supply mains for use.

RECOMMENDATION.

I beg to recommend that plans, sections, details, and estimates of the most recent and approved forms of screening chambers, sand filters, and pure water basins may be supplied to the Water-Works Departments of India.

APPENDIX

Previous to the year 1852, the several Metropolitan Water Companies took water for domestic uses from tidal and impure portions of the river Thames, simply straining it through the wire screens on its way to open settling tanks, from which it was pumped for use. There were from time to time great complaints as to the impurity of such water, and medical men attributed excess of disease (cholera especially when this disease prevailed) to the use of it. Full and searching inquiry was made into the truth or otherwise of these allegations, and Parliament was so convinced that foul and unfiltered water was liable to be injurious for drinking, that it passed the Metropolitan Water-supply Act of 1852.

The following extract shows the purport of this new Water-works Act, which was to compel the London Water Companies to abstract water free from the polluting sewage influences of the Metropolis to sand-filter, and then store the water so purified in covered reservoirs —

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15 AND 16 VICT CAP 84

An Act to make better provision respecting the supply of water to the Metropolis, July 1852.

1 From and after the 31st day of August 1855, it shall not be lawful for any Company supplying the Metropolis or any part thereof with water for domestic uses

to take any water for such purposes from any part of the river Thames, below Teddington Lock, or from any part of the tributary river, or streams of the river Thames below the highest point where the tide flows in such tributary rivers and streams respectively

2 From and after the 31st day of August 1855, every reservoir within a distance in a straight line from St Paul's Cathedral in the City of London, of not more than five miles in which water for the supply for domestic use of the Metropolis, or any part thereof is stored or kept by any Company shall be roofed in, or otherwise covered over, provided always, that this provision shall not extend to any reservoir, the water from which is subjected by the Company to efficient filtration after it is discharged from such reservoir, and before it is passed into the mains or pipes of the Company for distribution, or to any reservoir, the whole of the water from which is distributed through distinct mains or pipes for other than domestic purposes, nor to any reservoir whatever, the water stored in which shall be used exclusively for other than domestic purposes

3 From and after the 31st day of December 1855, no water shall be brought or conducted within the Metropolis by any Company for the purposes of domestic use, otherwise than through pipes or through covered aqueducts, unless the same shall be afterwards filtered before distribution

4 From and after the 31st day of December 1855, every Company shall effectually filter all water supplied by them within the Metropolis for domestic use, before the same shall pass into the pipes for distribution, excepting any water which may be pumped from wells into a covered reservoir or aqueduct, without exposure to the atmosphere, and which shall not be afterwards mixed with unfiltered water

N B — The practical effect of these Clauses has been to induce sand-filtration, and supply of water from covered pure water tanks to the entire Metropolis

From J SUTHERLAND, Esq., to the Under Secretary of State for India, dated 7th August 1868

I beg to acknowledge the receipt of your letter of the 3rd ultimo, enclosing a copy of a Circular No 39, Public Works, Government of India, respecting the "best method of keeping water sweet when stored in tanks," and requesting the communication of my views on the subject for the information of Sir Stafford Northcote

Having already concurred in a Minute of the Army Sanitary Commission, in which this subject has been discussed, I shall confine my reply to a brief statement of principles involved in the question, which have been established by experience

1st — It may be stated as a general reply to the question propounded in the papers, that there is no known method by which in such a climate as that of India it would be possible to preserve water in open tanks and impounded reservoirs in such a condition of purity as is desirable for health

It follows that, as a general rule, water should not be drawn direct for domestic use from open impounded reservoirs and tanks, unless the water has been shown to be sufficiently pure by chemical analysis. The reason why this precaution is necessary is perfectly well known

In a country where vegetation is so active, there must always be a large surplus of decaying organized matter, which is more or less carried into reservoirs and tanks by rains and winds. In populous Districts again, surface filth and animal debris are washed by rains into surface tanks. In either case the water becomes charged more or less with suspended and dissolved organic matter, animal or vegetable, the amount of which can be determined by Chemical analysis. The water becomes disagreeable to sight, taste, and smell, and such water without previous warning other than this altered physical state may act as a poison when epidemics, especially of cholera, are in the country

* Note — Teddington Lock is above tidal influence and Metropolitan sewage contamination

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It is not the absolute amount of decaying matter in water that is injurious, it is the state or condition the organic matter is passing through at the time, which is the source of danger.

Good soap which contains a large amount of dead organized matter in a fixed condition, is as every one knows highly nutritious and wholesome, but if a small portion of this soap were to be swallowed while undergoing certain putrefactive changes, it would be dangerous to health, especially during epidemic seasons.

Unfortunately this poisonous condition of organic matter in water has only hitherto been known by its influence on the health of men and animals, and when it has once shown its presence by its effects, the mischief is done.

In some cases matter in a poisonous condition exists in water, whose physical qualities do not lead to suspicion of its presence.

2nd—These general statements regarding the condition of stagnant waters in warm climates are not of universal application. Impounded waters vary indefinitely in constitution. Whether or not they apply in any given case, can be ascertained only from the physical qualities of the water, and from careful chemical analysis.

It may be taken for granted that wherever water supplied for domestic use has perceptible color, taste, or smell, or wherever chemical analysis shows the presence of organic matter, the points stated above in regard to the effects of decaying organic matter on health and life require to be kept carefully in view in providing water for the wants of a population.

3rd—There are compensatory processes by which the amount of organic matter in water is constantly being diminished, otherwise stagnant water would soon cease to be fit for use. The most potent of these agencies is atmospheric oxygen acting on the surface of water in such a way as to change or destroy the dissolved organic matter to a certain depth below the surface. This active, purifying agent, does its work most effectually when water dashes over a clean stony bed in its way to or from the reservoir.

This is one cause of the purity of mountain streams. The principle involved in it is not unfrequently made use of in conveying water from gathering surfaces to tanks. In such cases the water enters the channel with perhaps a brownish tint, and arrives pellucid at its destination.

All Alpine countries afford abundant illustrations of this great natural purifying power.

Another well known agency by which water containing organic matter is purified, is the action of living vegetation, whose office is to convert decaying noxious organized matter into innocuous living forms. The agency of water plants is hence directly beneficial to water. It is possible to suppose a case in which the action of the atmosphere, and the influence of vegetation, would be so balanced against the sources of organic impurity, that one set of agencies would neutralize the other, so that the water would be always pure, but obviously in practice this could not be trusted to, unless the results were checked by chemical examination.

Notwithstanding the action of the atmosphere and living vegetation, it must practically be assumed in a country like India, that stagnant water will, in the great majority of cases, contain a greater or less amount of organic matter, ready to pass into a condition injurious to the physical conditions of the water, and under certain circumstances dangerous to the public health.

At the best, vegetation and atmospheric oxygen act only at the surface, so that while the upper strata of water are kept comparatively pure, the lower strata may be accumulating organic matter. This appears to have been the case with the deeper parts of the Vihar Lake, and no doubt the same law operates in all similar instances.

4th—In dealing practically with this part of the subject, it is obviously necessary to adopt means for excluding as large an amount of organic matter as possible from all impounded reservoirs and tanks. This is done by organized Water-police, which involves the cleansing of ground near all tanks, prevention of nuisances and of bathing, removal of dead vegetation from the vicinity, margins, and surfaces of lake or tank, periodical cleaning out of tanks where practicable, paving and cleaning of all water-courses, conveying water, and similar measures.

It is evident that by adopting such precautions in addition to the natural agency of the atmosphere and of water-plants, existing water-sources might be improved in purity, and that there are

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cases where probably no other measures would be requisite to insure that water for domestic use was good and wholesome. But here again there would be no security unless such water were proved to be good by chemical enquiry.

5th—After what has been stated above, it would be obviously inadvisable to remove water-plants from the surface of open tanks and reservoirs. Dead water-plants should be cleared away, and care should be taken that the vegetation does not become so great as to interfere with water supply works connected with the reservoir. Fish, if there are any, should be left in the water, they have their own office to perform, in diminishing the amount of dead matter.

6th—The state of the Vihar Lake, of which the deeper parts contain impure water, shows that in this, and all similar cases, the natural agencies of air and vegetation are not sufficient to preserve the purity of the whole body of water. In this, as in other cases, improved Water-police would diminish extraneous sources of impurity, but there will probably always be a considerable balance of decaying and dead matter at a certain depth below the surface. Water for use would hence have to be drawn only from the surface strata, (as has sometimes been done in small water-works in this country, where simple *subsidence* was all that was required to purify the water), or what would be far better and safer in practice, artificial methods should be adopted for removing as much of the organic matter, suspended and dissolved as possible. Subsidence and filtration are, as every one knows, the methods which experience has shewn to be effectual for these purposes.

Filtration removes suspended matter by straining, but what is perhaps of greater importance, it acts as a destroying agent, on the dissolved organic matter, a greater or less proportion of which is oxydised by the oxygen in the filtering medium, so that, not only are the sensible qualities of the water improved, but chemical analysis shews a decided diminution in the amount of dissolved organic matter. All experience has proved that water, less disagreeable or unwholesome before filtration becomes potable and wholesome after filtration. Filtration is the only known method of improving water in the condition of that of the Vihar Lake. It is nature's own method, of which we see the results in water-springs.

It may be impossible to cleanse water for the supply of a large population of all organic matter, by filtration, but practically that most important form or class of organic matter, alluded to above, which is at the same time the most dangerous and the most easily oxydised, would be removed, so that filtered water, if passed directly into the water mains, and used shortly after, would be to all intents and purposes pure water. But it does not follow that water once purified by filtration, will never become impure, even if kept from extraneous sources of impurity. It is well known that filtered water, which always contains a remnant of organic and saline matter, undergoes important changes, under the influence of ordinary temperatures, and becomes, in a short time, disagreeable, if not, injurious to health. Filtered water should not, therefore, be again impounded with the view of keeping it, the sooner it is used the better.

If it is run into open tanks it will become rapidly covered with vegetation and will return more or less to its original condition.

In practice it is, I believe, necessary to provide a day's supply of filtered water for the population.

The filter is a spring always acting whether the people are drawing water or not, and the service tank is thus in practice a necessary part of the filter. This service tank or cistern should always be covered so as to exclude light, heat, and impurities.

7th—The general principle stated above may be briefly summed up as follows—

1.—That all water sources, their adjuncts and neighbourhood, should be placed under Police regulation, to prevent fouling, and to insure the immediate removal of decaying organic matter.

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- 2—That atmospheric agency, living vegetation and fish, are all conducive to the purity of water in open impounded reservoirs and tanks
- 3—That practically, (unless the contrary were shown by chemical analysis), all water in open reservoirs and tanks must be assumed in India as containing more organic matter in uncertain conditions than would be safe for the public health, especially during epidemic seasons, if the water were drawn direct from the open tank for use.
- 4—That filtration is a necessary part of water-supply from impounded reservoirs and tanks in India as elsewhere
- 5—That filtered water should be used as soon as possible after filtration, and that practically a covered filtered water-cistern or tank capable of containing a day's supply of filtered water for the population would be a necessary adjunct to all works of water-supply

Memorandum by the Army Sanitary Commission on the impure state of water supplied from the Vihar Lake to Bombay, and the best means of keeping water sweet when stored in tanks in India

The questions in the papers, although primarily raised, in regard to water supplied from the Vihar Lake to Bombay, involve principles of great importance in regard to Indian water-supplies generally

Bombay derives its water from a large impounded reservoir supplied by the surface drainage of the surrounding hilly districts. The country is covered with vegetation, and large quantities of different species of water-plants have grown in the lake, which also contains a multitude of fishes

In this, as in every case where there is much living vegetation, and a superabundance of animal life, there is decaying and dead organized matter, and all lakes, with shelving margins, are liable to have the space between high and low-water fouled by various sources of impurity. This has happened in the case of the Vihar Lake in a tropical climate.

The result has been that the water, especially that drawn from the deeper part of the lake, has become impure, and the practical question is, how this state of things is to be remedied, and its recurrence prevented. There is nothing in the case different from what might have happened in England under similar circumstances, only in India all the sources of impurity are rendered of more importance by the nature of the climate

In dealing with the subject, we shall, in the first instance, re-state the principles of water-supply bearing on this and similar cases already laid down in our suggestions for the Sanitary improvement of Indian Stations

In these suggestions we have pointed out that the most common source of organic impurity in mountain districts is superabundance of decaying vegetable matter from trees and jungle, and that waters of this class are unfit for use unless they are purified by filtration. We have further stated that the most common source of animal organic matter in Indian tanks is surface filth.

We have shewn the necessity for removing all extraneous impurities from the sources of water-supply, and that the channels, stream courses in valley lines, and conduits, connected with impounded tanks and reservoirs, should be cleansed and paved, so as to present a clean surface, and that care should be taken to prevent all gathering surfaces becoming fouled. We have further stated that storage reservoirs must be fenced in, and that conduits, open or covered, must be regularly looked to, and scavenged so as to prevent fouling.

Precautions of this nature are necessary in Great Britain, in order to secure that at the fountain head, every probable source of impurity is constantly removed, and there are usually clauses inserted in Water Company's Acts for punishing all persons wilfully injuring the purity of sources of supply. These precautions are an indispensable part of the Sanitary Police of Water-works, the

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main functions of which are to keep a constant and unremitting watch over all gathering surfaces, reservoir, banks, brooks, and channels, through which any part of the water flows

The very same principles are applicable to the Bombay case, and to all similar cases. Every means must be adopted to remove decaying vegetation from conduits and channels conveying water to or from impounding reservoirs. The amount of living vegetation to be left on gathering surfaces will depend on local circumstances, but there can be no doubt that dead vegetation, such as dead leaves, branches, decaying timber, and the like, near the lake, should be removed, and the gathering surfaces kept as clear as possible of all such sources of impurity.

In planning new works, the nature of the gathering surface, and the amount and character of its vegetation, requires to be considered as one of the elements in selecting a source of supply. Another source of impurity in impounding reservoirs, with sloping banks, is the growth and decay of vegetation, or the deposit of foul matters on the exposed bank between high and low-water mark

An immediate remedy for this is cleansing and removal of vegetation and impurities from the exposed surface

Wherever the extent of exposed surface between high and low-water can be lessened by banking out shallow areas, this should be done

A further diminution of risk of impurity from the exposed bank can be obtained by paving it with stones, as is done in the large filtering establishments in this country. Paved surfaces of this class can readily be cleansed, and one great cause of impurity of water in reservoirs cut off

But after every precaution is taken to ensure that the source of supply is kept as free as possible from extraneous impurity, there will always be more organic matter in impounded water than is desirable for health. Hence, in our suggestions already referred to, we have in every case advised that waters of this class, whether contained in large reservoirs, or in ordinary tanks, should be filtered before use, for the double purpose of removing suspended impurities, and of oxydizing dissolved organic matter. This precaution is absolutely necessary. No water-supply can be considered safe without sand-filtration. We have given in our suggestions, plans and sections of filtering arrangements suitable for water-supplies of both large and small amounts.

Most of the water supplied to large cities and towns in Great Britain undergoes sand-filtration before passing into the mains, as is to be done with the water-supply of Calcutta.

The whole of the water-supply of London is sand filtered. The East London Company filters 20 millions of gallons per day, through 12 statute acres of sand-filter. The new River Company uses 11½ acres of sand-filter for filtering 18 millions of gallons a day. The Lambeth and Vauxhall Water Company, the Chelsea Company, and the West Middlesex Company, taking about 48 millions of gallons of water per day from the River Thames, sand filters the whole. When the water is turbid on account of floods, it is first run into depositing reservoirs to be purified by subsidence before it is passed into the sand filter. The rate of filtering is about 700 gallons every 24 hours, for every square yard of sand surface. The filters are run dry, and surface scraped about once every five weeks, less in cold weather, more in hot weather, less when the water to be filtered is clear, more when it is turbid.

In some filters the depth of sand at the surface is 2 feet 6 inches, in others 4 feet. The filtration and oxygenation of the water is chiefly accomplished by the upper 6 inches of sand. The thicker the layer of sand the slower the process, and the more perfect is the deposit of sediment by gravity. Under certain circumstances, a layer of wood or animal-charcoal may be placed in the filter. The London Companies use clean sand only. After filtration the water is received into covered service reservoirs, whence it passes directly into the mains and so to the houses. Water once filtered is never again allowed to become foul on the works of the London Water Companies, as it is passed directly into covered reservoirs, and then into the supply mains, without any further exposure to extraneous sources of impurity.

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These principles, which have been arrived at by experience in this country, indicate what ought to be done in the case of the Vchar Water-works, and in all similar cases in India.
We recommend therefore—

- (1).—That means, such as those stated above, be taken to preserve the water in the Vchar Lake as free as possible from decaying organic matter proceeding from the gathering ground, and from the margins of the lake or from conduits
- (2).—That all water supplied to Bombay from the lake be drawn from the lake through fine wire-screens, so as to prevent floating matters and fish entering any conduit, and that such water in all cases be sand filtered, and passed into a covered pure water-tank or reservoir in immediate connection with the filters previous to distribution through the mains
- (3).—That the filters and covered pure water reservoir should be at the Bombay end of the pipe conduit if practicable. The contents of the covered reservoir should be equal to a day's supply of the population
- (4).—That similar measures be adopted for preserving the purity of sources of supply of all open water-tanks in which water is stored for domestic use, and that all open tank water be sand-filtered and stored in covered expense tanks or cisterns, from which it can be drawn pure for consumption *

If these precautions be diligently carried out, the other questions raised in the papers, regarding the propriety, or not of permitting the growth of water-plants and fish in impounded reservoirs and tanks, will become of little importance

Living vegetation if not allowed to exist to such an extent as to interfere with the supply-works and if care be taken to remove all dead vegetation from the surface and banks, and if possible from the bottom of the lake, is rather an advantage than otherwise, unless the plants be poisonous. The vegetation exists for a specific purpose, and that is the conversion of dead organized matter into living forms

This is one of nature's processes for purifying water. The flow of impure water over clear rocky channels is another. Both agencies are useful in their place and degree

In the same way, the existence of fish in impounded reservoirs or tanks is not necessarily injurious. On the contrary their tendency is to preserve that balance in vital forces throughout the body of water which tends to reduction of dead organized matter. Certain kinds of water-plants and fish are perhaps better adapted for these ends than others, and this question may very well be studied in India

As regards the depth from the surface at which water should be drawn from the Vchar Lake, it should be taken as near the surface as possible,† but this is a matter of secondary importance if the water is filtered, but there would be no difficulty in arranging the out-lets, so that water might be drawn from any depth, or always close to the surface, if considered desirable

WAP OFFICE,
7th August 1868

J. HOPE GRANT
DOUGLAS GALTON.
JOHN SUTHERLAND
H. H. MASSY
B. H. MARTINDALE
PROBY T. CAUTLEY
J. R. MARTIN
ROBERT RAWLINSON
COLONEL MURRAY, on leave

* Note.—It is not of course intended that the open tanks or reservoirs should be covered, but only the tanks or cisterns into which a day's supply of filtered water is received for use

† Note.—The water towers in the Vchar Lake contain water at different elevations, so that water can be drawn at any one of these levels

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15th January 1869.*

Order.—Ordered, that copies of this Despatch, and of its enclosures, be forwarded to all Local Governments and Administrations, in continuation of Public Works Department Circular No. 39 of 1868.

Ordered also, that a copy of this Despatch, and of the earlier papers, be forwarded to the Sanitary Commissioner with the Government of India, for information

(Signed) C. H. DICKENS, Colonel, R. A.
Secy. to the Govt. of India.

To the Secretary to the Government of Madras, Public Works Department

No. 232.

ORDER THEREON, 15th January 1869, No. 113.

Ordered to be recorded.

CIVIL WORKS, No. 30.

(True Extract.)
(Signed) CHARLES A. ORR, Colonel, R. E.,
Secretary to Government.

To the Chief Engineer for Irrigation.

- .. Superintending Engineers
- .. Sanitary Commissioner
- .. Public Department.
- .. Revenue do.
- .. Military do.

Exd. G. A. Turton

Cont. of 1869 Orders.

PUBLIC WORKS.

To

THE CHIEF ENGINEER FOR IRRIGATION

&c, &c, &c

Dated January, 15th.

Recd

For

G. O., 15th Jan. 1869, No 113

JANUARY.

Nos. 231-232

Keeping water sweet in tanks—Circular from the Government of India regarding the best means of keeping water sweet in tanks, recorded.

CIRCULAR No. 91 PUBLIC WORKS.
GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.

CIVIL WORKS
Miscellaneous

SIMLA, OCTOBER 30, 1868.

Best means of keeping water sweet in tanks.

Read again:—

Public Works Department Circular No 39 of 1868
Despatch to Secretary of State, No 66 of 22nd April 1868

Read also the following Despatch:—

No 80, dated 16th September, 1868
From—The Secretary of State for India,
To—The Government of India.

With reference to the request contained in your Excellency's Despatch, dated April 22nd (No. 66), 1868, that the opinions of the best authorities in England, on the subject of keeping water sweet when stored in reservoirs, may be obtained for the information of your Government, I have to inform you that the question was referred to Mr. Edwin Chadwick, C. B., Mr. Robert Rawlinson, C. B., Dr. Letheby, and Dr. Sutherland, the Secretary of the Army Sanitary Commission.

2. I now transmit copies of the Reports, which, in compliance with my request, have been furnished by these gentlemen. With reference to Mr. Rawlinson's recommendation at the end of his Report, I have requested him to superintend the preparation of plans, sections, and estimates of the best forms of sand filters and pure water basins, which will illustrate general principles, although, of course, they cannot fit all places and circumstances. These will be transmitted to India as soon as they are completed.

Dated 20th August, 1868
From—E. CHADWICK, Esq, C B,
To—The Secretary of State for India

The information which I have to submit in answer to the request I have had the honour to receive, that I would state for the Government of India my views on the best means of keeping water sweet when stored in artificial reservoirs has been derived from observation of the sanitary condition of the chief cities in England as a Sanitary Commissioner, and as chief Executive Officer of the General Board of Health, where we had to conduct a special examination into the condition of the water-supply of the Metropolis.

One common condition in which I found the water supplies, collected and distributed in the ordinary manner, was that water of a superior quality at its source was found to be deteriorated to an excessive degree at its delivery.

The first stage of its deterioration was in its detention and exposure to light and air in open reservoirs.

Our examination of the water-supply of the Metropolis extended to the changes the river water underwent in its course, and Dr Angus Smith, an eminent Chemist, who aided in that examination, was requested in his instructions for tracing the changes of the Thames water from adventitious pollutions, to aid his chemical analysis by microscopical examinations of the animalculæ contained in it.

The view with which these instructions were given was to ascertain whether, on the point most important for sanitary purposes, not merely the quantity, but the nature and quality of organic matter contained in water, which chemical analysis leaves obscure, some

light might not be gained by the observation of the animalculæ. The eminent German Naturalist, Ehrenberg, as one result of very extended observations, established the fact that the existence of visible animalculæ generally indicates the presence of a lower series of invisible animalculæ descending in magnitude, to the smallest monad of the most simple structure, so small that there is probably no smaller organised creature on which it can feed, while, as is commonly conceived, by arresting matter on the very limit of the organic world, and converting it into its own nutriment, it furnishes in its turn sustenance to higher orders of animalcular life.

Be this as it may, it is very certain that the presence of animalculæ in large numbers indicates the existence of animal and vegetable matter usually in a state of decomposition, which invariably acts injuriously, if the water containing them is used largely for the purposes of food, and the effects may be more immediate and marked when the animalculæ are large and numerous.

In respect to vegetable matter, it is to be observed that, when water is kept stagnant and exposed to the sun in moderate temperatures, vegetable infusion of the class called algæ, and also fungoid vegetation appear rapidly. Many tribes of these vegetable productions appear to die with great rapidity, sometimes in one or two days, and then decompose. Immediately after these animalcular life appears. Stagnant water is the most favourable to this order of vegetable productions, which, in giving rise to animalcular life, appears to keep pace with the animalized excreta discharged in the house drainage of towns. This insalubrious order of production is indicated by the smell in stagnant, or nearly stagnant ornamental waters, such as the stagnant portions of the Serpentine River, which have often excited so much declamation. Certain degrees of motion in water are unfavourable to the production of algæ, or other infusorial plants, the tissues of which are destroyed by brisk motion, but a large portion of them are found in slow running waters, or open canals with little traffic, such as the Regent Canal. In summer time the extent of pollution here is perceptible to the smell over the bridges, and at some considerable distance. The same round of life and death also takes place in open and shallow reservoirs, and in open cisterns where the water is frequently changed. Light, however, seems to be necessary to the production of infusoria, and fungoid vegetation, and their formation is prevented by such covering as excludes the light and heat of the sun. Whilst exposure and stagnancy, or slow motion, thus increase the animal and vegetable impurities in water, they likewise increase its mineral impurities by the increased evaporation, which leaves a larger proportion of mineral matter as residuum. Thus we have had examples of shallow spring water, or agricultural tile drainage-water, of only 4 degrees of hardness, taken from the tile drains as in Richmond Park, increased to 8 degrees of hardness in water from the same soil, after it has stood for a time in ponds. Water of only 2 or 3 degrees at its source is found to increase to 10 or 12 degrees of hardness in canals, a difference not to be accounted for from the qualities of any puddings of clay, or strata containing lime, over which the water may have passed.

Mr Cooper gives an instance in the Surrey Canal, a canal of little traffic, which is fed from the Thames at Rotherhithe.

He examined it by taking specimens of the water at several points between its entrance at Rotherhithe, and its termination at Camberwell. The examination showed an increase of specific gravity, an increase of organic matters, and a corresponding increase of saline matters, and of hardness from its entrance to its termination. This progressive increase of impurity up to the termination he could not but ascribe to the process of evaporation combined with the smaller amount of traffic which there was towards the end of the line.

Further researches tended to sustain the inference that it is the Office of the lowest monads to convert the gaseous products of decomposition into organic tissue, which serves as food for all the upper series of animalculæ and animal life. Certain it is that, if the products of decomposition were left unabsorbed by this animal and vegetable life, deleterious miasma would be produced in much larger quantity. Of the sequence, there can be no doubt but the sources, nature, and properties of these spores, with the laws of their diffusion, appear still to be examined and determined by the Naturalist.

One effect of exposure in stagnant reservoirs is, that the quantity of air held in solution in the water is diminished. The water so deteriorated on the intermittent system of supply taken in water butts, which are kept in the back yards of lower class dwellings, commonly near cess-pits. Here it absorbs rapidly the noxious products of decomposition.

In the poorest class of houses the people carry up the water from the butts, and keep it in jugs in their crowded rooms. Surgeons, who have had to perform operations in such dwellings, have told me that the water given to them to wash their hands has imparted to them a disagreeable smell.

Under these conditions of distribution of drinking water at the source at the foot of the mountain, you may be said to be drinking mountain air, sometimes at the reservoirs where the matter of decomposition has not been kept down, you may be drinking marsh miasma, and in the close Court or Alley, you are drinking the air of the cess-pool. Taken at its source, the water is cool and refreshing, taken from stagnant butts in the town, it is mawkish and disagreeable.

The development of vegetable and animal life varied with the nature of the water and the conditions in which it is placed. With some water, as in those containing much phosphate, the vegetable development was of extraordinary rapidity, in others they decayed quickly.

When there was an adjustment of the animal and vegetable life, the water was not unwholesome, in the water butts of the town, even it could not be said to be unwholesome, or more than that it was of an inferior quality, and the great evil was that the people from its mawkishness pronounce it to be undrinkable, and do not drink it, but drink fermented liquors. In epidemic periods, however, these inferior qualities of water appeared to be powerfully affected in manners which we had no time or opportunities to investigate, but which led people to believe that the water was poisoned.

As between hard and soft water, there was less vegetation in the calcareous waters, but these waters had the disadvantage of being less solvent for culinary purposes, &c.

I was strongly impressed as to the proper treatment of water for household purposes by what I met with in examining the practice of John Day, the Horse Trainer. I found that the greatest care was taken by him to collect rain-water from slate-roofs, and convey it immediately to a deep slate tank, 20 or 30 feet deep, from which the light was shut out. This precious water was carried in barrels for the supply of the horses at distant race meetings. Some of the tanks of other Horse Trainers had a charcoal division, through which the water passed, to retain any vegetable or other impurities which it might have collected from the roof. From the observation of such instances, I was led to conclude that the right treatment of the water for the population was to collect it as soon as possible in covered reservoirs by covered channels. There are nearly 200 miles (square) of sandy surface, bearing little vegetation in the vicinity of Alderholt (the Surrey Sands). I proposed to use these as gathering grounds for the supply of London. A convenient site was reported on of about 500 acres, which, at the available depth, would have sufficed for the storage of a supply for three months. I proposed that this should be covered with a roof of hollow brick as the best roof to maintain an even temperature. It was to be constructed in the form of a series of groined arches. By manufacturing the bricks, specially the cost of this tank, roofed with hollow brick, and floored with tiles, was estimated at three quarters of a million of money. The covering, we found, could be done at about 3 to 4 superficial yard. This reservoir would effect an enormous economy by doing away with the necessity for private tanks and cisterns.

In many situations great expenses have been incurred by having large filtering basins which are merely screens that imperfectly remove the impurities that are collected by the open storage reservoirs, and the covering of a reservoir which would have prevented the introduction of these impurities would, perhaps, not have cost more than the expense incurred by the construction and working of the filtering basins erected for their removal.

In one part of the site chosen for this storage reservoir, there was a deep gorge with a sandy foundation. The covering would have been difficult and expensive, I proposed a floating cover. The first materials suggested was wood, which was liable to decay, at length it occurred to me to accomplish the object by constructing a floating cover of hexagonal pots, which I found could be constructed at a cheap rate if made in numbers. They might be tied together with wires. I have a strong impression that this expedient might be frequently used with advantage.

On examining closely the area of the 200 square miles of gathering ground, however, perennial springs were found in such quantities even in dry seasons as to dispense with the necessity of any such extensive storage reservoirs.

But the Water Companies were too strong for us in Parliament, and we failed to carry this measure for the supply of London. The Committee of the House of Commons, however, did adopt the principle of having the reservoirs covered, and the Companies were ordered to cover them, but, I believe, the order has been carried out very imperfectly, and small covered reservoirs have been used only at the end of the storage and filtration basins. In a number of towns the principle has since been applied very completely, the water derived from springs, or from hill sides, is led in covered channels into covered reservoirs, and does not see the light until it is drawn from the tap in the house, and there it arrives in a beautifully filtered, clear, cool, and highly aerated condition, often as much so as soda-water.

When the deductions from the course of investigations I have cited were made known, it proclaimed that the plan was in truth that of the ancients. At Constantinople, there is a great underground reservoir.

The services of Cyprian Vitch, of the Royal Engineers in Spain, had made him acquainted with the Roman remains of covered reservoirs there, and the advantages of preserving water in deep covered cisterns underground according to the Roman practice. The covered reservoirs or cisterns at Rome were immense works, adorned with architectural decorations, of gallons. One of these reservoirs which still remains is described as constructed of brick and covered with cement, it has a vaulted roof, supported by 336 marble columns of the Corinthian order, 40 feet 9 inches high. Arches of brick rested upon the capitals, which are surmounted by a massive marble abacus. These columns are placed in rows, 12 feet apart, longitudinally there are 12 ranges, and latitudinally 23. The cistern is 336 feet in length, 150 to 200 broad, consequently its cubical contents to the top of the capitals of the columns would be 3,861,114 cubic feet, or it would hold 25,000,000 gallons of water. This edifice, with its ground vaulting, would be about as capacious as one of our Cathedrals.

In Spain, where the water collected and stored in covered tanks is valued according to the length of keeping as old wine. The Spaniards in Peru used a similar system, and as to leading water in open channels, they considered it, as it were leading it waste in the open air. Even in England there is considerable loss by evaporation which increases the proportion of solid impurity in the water.

On these several grounds I conclude that *all* water for the supply of cities should be received, led in covered conduits, and stored in covered reservoirs.

The chief question is the economical construction of the covering, whether of concrete or of hollow brick, which I prefer. I believe for India, as at Madras, where I am informed that the manufacture of bricks is half as costly as in London, the pot construction might be made very cheaply. A man and a boy in England at piece-work I found would mould ninety-two gallon pots in a day. These are of much superior quality to the machine-made bricks, and a machine may be constructed to give them strength and exactitude of form at a very low rate.

A valuable source of water might be distributed separately for household purposes only, leaving commoner water to be used for gardening, street washing, and manufacturing purposes.

For the softer water which act powerfully on metals, earthen-ware pipes would be best of metal. These are used in France up to a pressure of 160 feet, and cost about one-half the price of metal.

From such information as I have collected, it appears to me that the conclusions deduced from the Home experience are *a fortiori* applicable to the question of the storage of water in a tropical climate, where from the heat the activity of animal and vegetable life is greater, decomposition more rapid and dangerous in its products, evaporation and consequent deterioration of the water is so much greater.

On looking over the papers transmitted, I think it is confirmatory of the experience I have cited. A common opinion is expressed, that vegetation and fish conduce to the salubrity of decomposition. Like the process of filtration they serve to diminish, what ought not to have been admitted. I agree with what is said by the Superintendent of the Government Central Museum, who says, "I have been engaged in microscopical enquiries reservoirs, and my experience has led me to the belief that it is utterly impossible to prevent the introduction of infusoria (animalculæ) and minute plants, such as desmids and diatomacæ into water, unless both light and air be excluded, and I quite agree with those who consider growing plants as purifiers of water, and there is no doubt that the larger animalculæ such as the rotifers, both act as scavengers, and feed upon the smaller animals and plants, very few tanks I suppose are without a supply of the water-snail paludoums, which feed upon decaying vegetables, and which are kept in aquariums for that purpose in England. On two or three occasions at the latter end of last year, I was induced to examine the dew deposited on leaves of plants during the night, and I found in it both infusoria and fungi. If these are thus developed in the course of a few hours, it is plain they cannot be kept out of a tank or river, the truth is their germs are always floating in the atmosphere, and become developed as soon as they are surrounded by water."

I have a great prepossession in favour of the plan, I have submitted of a floating pot cover to water-tanks, as I think it would serve to diminish the quantity of the floating spores taken up by the water, though, I believe, it may almost be said to be impossible to exclude them absolutely, but the covering, exclusion from sun light, and diminution of heat, does certainly prevent their development, and the large sequence of animal and vegetable production, I would commend the plan for trial on a small scale in the first instance.

The Officer of the Hill Roads Division states that "he considers that tanks should be periodically cleaned if it is found that the balance of animal and vegetable life is not as being likely to be more free from the evils of heat in India."

Dr. R. Cole, Principal Inspector General, Medical Department, says, "as a general rule, that it is doubtful in this country whether water artificially stored will ever be so safe for drinking purposes as deep well water." Now deep well water is under the condition of that kept in a covered reservoir.

Captain Swetenham considers that the water should be covered, so as to prevent evaporation as much as possible, "because all evaporated water ascends perfectly pure, leaving its share of impurities to increase the percentage of that left behind."

These other facts support the like general conclusion.

Where the water is derived from river sources, it is chiefly derived from the surface washings of lands in England, often from cultivated and manured lands, and it carries with it much soil, and much of the manure from the surface of the land which, in some cases, is more than is contained in the sewerage from towns.

To get rid of the matters in suspension, "settling reservoirs" are necessary, previously to filtration, and to storage in covered reservoirs. It is now admitted, as a rule, by Water Companies that the water, after being filtered, should not see the light again, or the work of filtration would be soon undone. But we have made efforts to obtain water not from the surface of the land, but that which has passed through the soil, and is there collected by

sub-soil drains. Sand mixed with loam occupied with vegetation, but not highly manured, constitutes a filter of the highest order. Most filters (all filters of the common sort) are merely strainers and remove little but the matter in suspension, but the drainage through such cultivate, not only remove the matter in suspension, but takes away to the greatest extent, matter in solution. This land filter, if it may be so-called, takes out much of what may have been brought down by the rain in passing through the atmosphere.

The waters derived from sub-soil drainage were of the highest order of purity and quality, clear, cool, and well aerated, and in the best condition for storage in covered reservoirs direct, and without any subsiding tanks.

Where water cannot be got direct from naked primitive rock, than sub-soil drainage waters are the best of all. As an immediate expedient, I would recommend the formation of covered reservoirs at the head of the great tanks, and that the water so preserved should be led off for domestic supplies.

The chief practical point in the cheapness of the covering, whether of hollow brick, or of concrete, Mr. Austin, who prepared the projects for the water-supply of London, is dead, and the plans are lost. Some of the covered reservoirs made on the principle recommended, cost about £1,000 for each million of gallons stored, this was, however, for reservoirs of comparative small scale.

A tank, such as that at Constantinople, might have been constructed probably for £60,000 or £70,000, constructed of concrete, it may be done at 3d or 4d. per foot of space. There are points in the construction of some of Mr. Rawlinson's covered reservoirs which would commend his plan for study and consideration.

I have already submitted as topics for distinct examination and consideration the subject of water distribution in France by earthen-ware pipes, and also the subject of the chief preparations of concrete, to determine the best available for large covered reservoir constructions.

I may now add, as another topic, the manufacture of machine-made hollow bricks, together with the manufacture of earthen-ware pipes.

Dated 23rd July, 1868

From—H. LETHBRIDGE, Esq., M. B. A., and Professor of Chemistry in the London Hospital, and Medical Officer of Health for the City of London,

To—Under Secretary of State for India.

I have to acknowledge the receipt of your letter of the 3rd instant, with a collection of printed papers on the subject of the best means of keeping water sweet when stored in artificial reservoirs, and having read them, I submit the following observations for the information of Sir Stafford Northcote, and for the use of the Government of India.

The experience of water-supply in this country has long since decided that, if we are to secure sweet and wholesome water for domestic use, we must pay the strictest attention to the several details of the three following points, namely, the character of the gathering ground, the condition of the storage reservoir, and the purification of the water immediately before distribution. Judging, however, from the papers you have sent to me, I am led to think that these important points are not sufficiently considered in the water-supply of India, notwithstanding that the necessity for their observance is even greater in that warm climate than with us.

1st As regards the collection of water.—It is manifestly of the greatest importance that the district or gathering ground should be selected as free from polluting influence as possible, and that it should be strictly guarded from all preventable sources of impurity, as from sewage deposits from agricultural operations, and from the too luxuriant growth of rank vegetation. I am not precisely acquainted with the general character of the Districts from which the water-supply of the large cities of India is derived, but it appears to me from the evidence afforded by the papers sent to me, that very insufficient attention is bestowed on this part of the subject, and that therefore the water is permitted at the very first to become fouled to a very serious extent with organic impurities. The obvious remedy for this is the periodical cleaning of the ground from decaying vegetable matter, by burning them, before the rainy season arrives. It is also necessary that the natural channels for the flow of the water to the storage reservoirs or tanks, should be kept clean and orderly, and that if any notoriously bad water occurs upon the ground, it should be conveyed by special channels to another outfall, and so diverted from the storage reservoir.

2nd With respect to the tanks or reservoirs of India.—It is abundantly evident that they are rarely constructed or maintained in a proper manner, and in the case of the Vehar Lake, it is so faulty in every respect, that it is not surprising the water is foul and repulsive in the highest degree, for the banks of the lake are so shallow that when the water retires the aquatic plants die and become putrid, and the natural ground of the lake appears to be a soil unusually charged with organic matter, besides which there is manifestly a large accumulation of decomposing mud, which gives offensive quality to the deep water, and in addition to all this, it is very probable that the water is fouled by the cattle, and by the filthy habits of the Natives. To remedy this, it will be necessary to give a steeper slope to the sides of the lake.

and to construct them, if possible, of stone-work, to remove the dead aquatic plants before the rainy season occurs, and to take measures for the removal of mud, and for the periodical cleansing of the lake, as by dividing the lake into two or more parts, and above all it is necessary that the water should be strictly guarded from all such preventable and unjustifiable pollution, as from bathing, from washing of clothes, watering cattle, &c, &c, and as to the question of the presence of aquatic plants and animals, there can be no doubt that within reasonable limits, they are useful in purifying the water, and keeping down the proportion of soluble organic matters, but if permitted to thrive to such an extent as to communicate a perceptible taint to the water, they are a cause of injury to it, and in every case provision should be made for the quick removal of dead and decaying substances

3rd Concerning the purification of water immediately before its distribution.—I may state that it is a very general practice in this country to filter all lake and river water directly before it is delivered to the public, and considering the quality of the waters of India, I have no doubt that such a practice is very desirable there also. Filtration with us is effected through shingle or gravel, coarse sand, and fine sand. The order of the materials is usually as follows —

At the bottom of the filter there is a layer of shingle or coarse gravel to the depth of 12 inches or thereabout, upon this is laid about 9 or 10 inches of fine gravel with sometimes an upper layer of broken shells to the depth of 3 or 4 inches, then comes a layer 9 inches deep of coarse sand, and finally upon the top of all a layer, 24 inches deep, of fine siliceous sand. The water flows downwards through such a filter at the rate of from 70 to 80 gallons per day for each square foot of surface, and it flows into a covered service reservoir, which is placed at a lower-level

When the filters become foul, and cease to deliver the water, they are cleansed by taking off a thin layer of sand from the upper surface. This sand is washed and returned to the filter. In conducting this operation it is necessary to have two or even three filters, so that one or two may be in use when the other is undergoing the process of cleansing, and the storage, or rather the service reservoir for this filtered water, should be covered to prevent the access of light, and the growth of plants or infusorial animals

It should have a capacity of not less than one day supply

Taking all the circumstances into consideration, as detailed in the printed papers submitted to me, and applying the knowledge which I have derived from a professional examination of most of the large water-works of England, I am of opinion that the means which are necessary for securing a supply of sweet and wholesome water in India, are—

- 1st —A proper selection and proper treatment of the gathering grounds.
- 2nd —A better construction and preservation of the tanks on storage reservoirs, and
- 3rd —The filtration of the water into a covered service reservoir immediately before its distribution to the public

From—R. RAWLINSON, Esq.,

To—The Secretary of State for India.

Herewith I beg to forward my Report on the "best method of keeping water sweet when stored in tanks" in India.

If in furtherance of the recommendation I can render additional assistance, it will give me pleasure

Any young Royal Engineers about to be sent out to India may have a short but special training in water-filtering and covered reservoir (tank) work

I think they may with advantage visit special works, make plans, sections, details, estimates, and reports of the same, as in my experience I have ever found that actual work at any subject of this sort, alone gives full practical knowledge

Dated 24th July, 1868

Report by R. RAWLINSON, Esq., C. B., Civil Engineer, Chief Inspector, Local Government
Act Office, Whitehall, on best method of keeping water sweet when stored in tanks

As instructed by your letter dated the 31d July 1868, I have examined the several papers sent from India relative to water-supply, and have given special consideration to the question as to the "best method of keeping water sweet when stored in tanks"

In India the word "Tank" appears to be used generally to designate artificial constructions for storing water as for instance the Vihar Lake, and other similar artificial constructions, are called tanks. In England the word "Reservoir" would be used, excepting for small constructions of stone, timber, or iron. In this Report the word "Tank" and "Reservoir" had better be considered as synonymous

In England, a work similar to the Vihar Lake, for the supply of Bombay with water, would be an "Impounding Reservoir". The area from which the water is collected would be designated "The Gathering Ground," and the outlet pipe would be the "Conduit"

Artificial constructions near a town, and in which water brought by the conduit is stored, and from which it is distributed, would, if open, be called "Open Service Reservoirs," and if closed "Covered Service Reservoirs"

Before considering how to preserve water pure, some few facts connected with it and with water-works may be considered

There is only one source in nature from which water is obtained, namely, the ocean, there is only one process by which salt-water becomes fresh, evaporation. All fresh water found on the surface of the land in lakes, in rivers, and in rivulets, or beneath the surface in the substrata, or issuing in springs, has been evaporated and condensed in the form of rain, or of dew. Distilled water is pure water, rain water is therefore pure water. A Chemist may object to the term "pure," but for the purposes of this report, the statement that rain is pure water, may be accepted.

Lakes, rivers, springs, and wells, never furnish water as pure as it falls from clouds, or is condensed from the atmosphere.

The solvent power of pure water is very active, and on its coming into contact with earthy mineral, or organic matter, combination takes place betwixt the rain-water, and these substances in proportion as they be more or less soluble, or a greater or less time in contact

In geology, formations of granite, of clay slate, of mill-stone grit, and some others, yield water in a comparatively pure state. All formations in which there is lime in a soluble state, as mountain lime-stone, new red sand-stone, the oolites and chalk give hard water, because lime (chiefly in the form of bicarbonate or sulphate) has been dissolved. Chalybeate waters contain lime, iron, or sulphur, with other minerals as the case may be

Hot springs rise through fissures from depths of several thousand feet, such springs, being, however, in all cases fed from the surface. The worm springs both of Bath and of Buxton, are effected in volume by the seasons. The dry weather volume of water in ordinary rivers is spring water, large rivers rising in mountain ranges, where ice and snow (glaciers) exist, are fed by the alternations of the seasons accumulating and melting these deposits. A spring of water is simply an outpour of water from porous strata, the spring being a fissure or conduit at a lower point than the general level of the sub-soil basin. Water drawn from wells must necessarily be impregnated with some of the mineral ingredients of the strata, this is so much the case, that a Chemist who has studied water analysis from the several formations will pronounce, from testing a sample of water, the formation it has been drawn from. A Geologist in like manner, who has studied chemistry, and water analysis, will also predict as to the quality of water to be expected, either from surface gathering grounds, from drift-ways, from well-sinking, or from artesian borings, when he knows which of the great geological formations has to be dealt with

The operations of nature are constant, and though simple in detail, the effect is stupendous. The power of evaporation is in the heat from the sun, pure water is raised from the ocean, and floated in the atmosphere over the land

The solvent power of water from rain and dew removes lime and other matters in chemical combination, and the mechanical power of water in floods, disintegrates drifts and floats solids, in proportion to the areas acted upon the gradients, the violence of the rain, and the volume of the rivers when in flood.

The solvent and chemical action of water is, however, probably the greatest, as it is unceasing. Water flowing from chalk, for instance, contains about 16 grains of bicarbonate of lime in each gallon, and this in one million gallons amounts to one ton.

The drainage area of the River Thames is about 5,000 square miles, and the average flow of water is about 1,000 million gallons per day, and 365,000 million gallons per annum, so that not less than 365,000 tons of bicarbonate of lime is annually dissolved from the chalk of the London Basin, and is imperceptibly removed to the sea

About 3ths of the land surface of the earth are composed of lime strata, and yield hard water, at or exceeding this proportion (16 grains in each gallon), so that an increasing and silent geological change on a vast scale in the aggregate is taking place

Pure water is said to have a chemical affinity for certain things, and for some this affinity is stronger than for others. Pure water will for instance dissolve the colouring matter from plants, and therefore a lake or river having its sources on granite, or on clay slate, which yield comparatively pure (soft) water may be dark or coffee-coloured looking, from vegetable tinge, whilst a river or lake having its sources in mountain lime-stone, the oolites or chalk which yield hard water would be transparent and sparkling

Again, if the soft and dark coloured water from granite or clay slate flows into and over a lime-stone District, combination with lime will take place, and the vegetable colouring matter will be precipitated, hard waters are therefore usually bright and sparkling, soft water, excepting naturally or artificially filtered, is frequently dark looking

Water enters certain strata as sand-stones, sands, and gravel chalk, &c, and fills the pores and cavities of the rock, just as water fills sponge. The proportion varies from 1/10th to 1/4th, this water is not evenly distributed, but accumulates along lines, and in basins according to the contour, dip, and character of the rocks

A well sunk in certain known water bearing strata, may or may not yield water in abundance, well-sinking at random may therefore be disappointing. In some cases water may be abundant at depths of from 300 to 600 feet, and yet at 900 or 1,200 feet, the strata may be dry. Deep sinking or boring may therefore be disappointing. Sinking deeper will not in all cases increase the volume yielded by a well.

The cube of strata drawn from by a well, may be considered an inverted cone, with the well in its deepest part forming the apex of such cone, capillary attraction preventing water separating from the surrounding strata in any other manner, as the apex of such cone is deepened, the cube of the cone is increased, and if the whole strata at this part is water-bearing, the volume at command will have been enlarged.

The form of a cone is of course merely given to indicate a principle, there may be fissures and other conditions in the strata, which would bring in water from beyond any lines arbitrarily sketched, the great facts to be accepted are that sub-soil or underground waters are uncertain in their area and volume, and limited in their depth.

Water obtained either from springs or from wells, as previously explained, must necessarily be impregnated with some of the mineral ingredients of the strata, and it is only reasonable to suppose that the deeper the well, and the greater the amount of mineral impregnation, this is not, however, general, as water combines with some salts up to a certain standard, and is satisfied. Chalybeate and other waters of analogous character are special, local, and usually confined to small areas.

The question as to admitting the growth of aquatic plants, or otherwise, may be settled by the answer, that in open and shallow water, under the sunshine and temperature of India, whether in small tanks, or on the margins of large tanks like the Vihar Lake, they will grow, and the only practical good to be accomplished is in some cases to embank of flat areas which have not more than 6 feet in depth, and in other cases substitute wholesome and permanent aquatic plants, where practicable, that is if there are water plants which will do less injury than others, substitute the best for the more worthless and pernicious weed.

Vast areas, hundreds of acres in extent cannot practically be manipulated by human labour in weed cleansing.

The Metropolis of England (London) with its three millions of inhabitants, is supplied with about 100 millions of gallons of water per day, drawn from the River Thames and River Lea, which is a tributary of the Thames. Weeds (aquatic plants) grow most prolific in these waters, and both rivers abound in fish. During dry weather, the waters are comparatively bright, in wet weather and during floods the waters are turbid.

Some of the Water Companies have large settling tanks, into which muddy water is drawn to clear itself by subsidence before filtration, but all the water is now sand filtered at a rate of about one-half gallon per minute, through each square yard of sand surface, that is 720 gallons of water from each square yard or thereabouts per day. After filtration the water is passed into covered pure water tanks, and flows direct through the mains for use. See Appendix as to the legal Clause relative to filtering and storing water in covered pure water tanks for London (1852).

Weeds in England abound most in shallow and comparatively still water, and are most prolific in hot summers. No practicable cleansing would prevent the growth of weeds and aquatic plants in such Rivers as the Thames, or on the margins of large impounding reservoirs, and I anticipate that any attempted "uprooting of all aquatic plants from every part of the basin of the Vihar Tank" would be a failure, as other weeds would grow immediately. The sand of the London water-works filter beds, although scraped and cleansed at short intervals, produces weeds all through the summer, and it is impossible to prevent such growth, the only remedy is to scrape the sand at short intervals, wash it, and renew it upon the filtering beds. To attempt uprooting weeds on a large scale in India, would necessarily disturb the mud, and render the water turbid, and there may be salts in such mud, comparatively harmless in a quiescent state, but which disturbed and mixed in larger doses with the diminished volume of water, may increase any injurious effects upon health.

Water in the shallow parts of the reservoirs or tanks becomes offensive when exposed in a stagnant condition to the sun, and water in the deeper part of such tanks, may even be affected, but deep tanks are nevertheless more desirable. As water is lowered from the surface of a large tank, the shore mud becomes putrid, aquatic plants left dry, decay, causing the reduced body of water to become noxious, which before was comparatively sweet. The only practical remedy will be filtration and storage in covered tanks.

With respect to the storage of water in India, I have come to the following conclusions —

CONCLUSIONS

That before works of water-supply are commenced in India, the surface or the substrata shall be most carefully examined, and that the site which will yield the best water shall be chosen.

That store tanks should not have shallow margins, but that such shoals should be deepened by excavation, or be banked out as may be most practicable, a depth not less than 6 feet in the shallowest part should be secured when a tank is full.

That the shores of tanks may be covered with broken stones, where such protection against washing and wasting of the surface of the land is desirable.

That the main collecting channels of gathering grounds should be cleansed and scavenged from time to time.

That the water surface of tanks should regularly be cleansed from all floating refuse of every sort.

That aquatic plants and fish do not necessarily injure water, but that both should be kept within certain limits, dictated by local experience.

That artificial agitation of large volumes of water cannot practically be accomplished, neither is it necessary.

That all water from open tanks should be drawn through fine wire screens, to prevent floating and suspended solids flowing on to and over the filters.

That all open tank waters without any exception, should be sand filtered, and be stored in covered tanks, or passed direct into the supply mains for use.

RECOMMENDATION

I beg to recommend that plans, sections, details, and estimates of the most recent and approved forms of screening chambers, sand filters, and pure water basins may be supplied to the Water-Works Departments of India.

APPENDIX.

Previous to the year 1852, the several Metropolitan Water Companies took water for domestic uses from tidal and impure portions of the River Thames, simply straining it through the wire screens on its way to open settling tanks, from which it was pumped for use. There were from time to time great complaints as to the impurity of such water, and medical men attributed excess of disease (cholera especially when this disease prevailed) to the use of it. Full and searching inquiry was made into the truth or otherwise of these allegations, and Parliament was so convinced that foul and unfiltered water was liable to be injurious for drinking, that it passed the Metropolitan Water-supply Act of 1852.

The following extract show the purport of this new Water-works Act, which was to compel the London Water Companies to abstract water free from the polluting sewage influences of the Metropolis to sand-filter, and then store the water so purified in covered reservoirs —

15 AND 16 VICT CAP 84

An Act to make better provision respecting the supply of water to the Metropolis, July 1852

1. From and after the 31st day of August 1855, it shall not be lawful for any Company supplying the Metropolis or any part thereof with water for domestic uses * *

* * * * *
to take any water for such purposes from any part of the River Thames, below Teddington Lock,* or from any part of the tributary river, or streams of the River Thames below the highest point where the tide flows in such tributary rivers and streams respectively * *

* * * * *
2. From and after the 31st day of August 1855, every reservoir within a distance in a straight line from St Paul's Cathedral in the City of London, of not more than five miles in which water for the supply for domestic use of the Metropolis, or any part thereof is stored or kept by any Company shall be roofed in, or otherwise covered over, provided always, that this provision shall not extend to any reservoir, the water from which is subjected by the Company to efficient filtration after it is discharged from such reservoir, and before it is passed into the mains or pipes of the Company for distribution, or to any reservoir, the whole of the water from which is distributed through distinct mains or pipes for other than domestic purposes, nor to any reservoir whatever, the water stored in which shall be used exclusively for other than domestic purposes.

3. From and after the 31st day of December 1855, no water shall be brought or conducted within the Metropolis by any Company for the purposes of domestic use, otherwise than through pipes or through covered aqueducts, unless the same shall be afterwards filtered before distribution.

4. From and after the 31st day of December 1855, every Company shall effectually filter all water supplied by them within the Metropolis for domestic use, before the same shall pass into the pipes for distribution, excepting any water which may be pumped from wells into a covered reservoir or aqueduct, without exposure to the atmosphere, and which shall not be afterwards mixed with unfiltered water.

N.B.—The practical effect of these Clauses has been to induce sand-filtration, and supply of water from covered pure water tanks to the entire Metropolis.

* NOTE — Teddington Lock is above tidal influence and Metropolitan sewage contamination.

(10)

Dated 7th August, 1868.

From—J. SUTHERLAND, Esq.,

To—Under Secretary of State for India

I beg to acknowledge the receipt of your letter of the 3rd ultimo, enclosing a copy of a Circular No 39, Public Works, Government of India, respecting the "best method of keeping water sweet when stored in tanks," and requesting the communication of my views on the subject for the information of Sir Stafford Northcote

Having already concurred in a Minute of the Army Sanitary Commission, in which this subject has been discussed, I shall confine my reply to a brief statement of principles involved in the question, which have been established by experience

1st—It may be stated as a general reply to the question propounded in the papers, that there is no known method by which in such a climate as that of India it would be possible to preserve water in open tanks and impounded reservoirs in such a condition of purity as is desirable for health

It follows that, as a general rule, water should not be drawn direct for domestic use from open impounded reservoirs and tanks, unless the water has been shown to be sufficiently pure by chemical analysis. The reason why this precaution is necessary is perfectly well known

In a country where vegetation is so active, there must always be a large surplus of decaying organized matter, which is more or less carried into reservoirs and tanks by rains and winds. In populous Districts again surface filth and animal debris are washed by rains into surface tanks. In either case the water becomes charged more or less with suspended and dissolved organic matter, animal or vegetable, the amount of which can be determined by chemical analysis. The water becomes disagreeable to sight, taste, and smell, and such when epidemics, especially of cholera, are in the country

It is not the absolute amount of decaying matter in water that is injurious, it is the state or condition the organic matter is passing through at the time, which is the source of danger

Good soap which contains a large amount of dead organized matter in a fixed condition, is as every one knows highly nutritious and wholesome, but if a small portion of this soap were to be swallowed while undergoing certain putrefactive changes, it would be dangerous to health, especially during epidemic seasons

Unfortunately this poisonous condition of organic matter in water has only hitherto been known by its influence on the health of men and animals, and when it has once shown its presence by its effects, the mischief is done

In some cases matter in a poisonous condition exists in water, whose physical qualities do not lead to suspicion of its presence

2nd—These general statements regarding the condition of stagnant waters in warm climates are not of universal application. Impounded waters vary indefinitely in constitution. Whether or not they apply in any given case, can be ascertained only from the physical qualities of the water, and from careful chemical analysis

It may be taken for granted that wherever water supplied for domestic use has perceptible colour, taste, or smell, or wherever chemical analysis shows the presence of organic matter, the points stated above in regard to the effects of decaying organic matter on health and life require to be kept carefully in view in providing water for the wants of a population

3rd—There are compensatory processes by which the amount of organic matter in water is constantly being diminished, otherwise stagnant water would soon cease to be fit for use. The most potent of these agencies is atmospheric oxygen acting on the surface of water in such a way as to change or destroy the dissolved organic matter to a certain depth below the surface. This active purifying agent does its work most effectually when water dashes over a clean stony bed in its way to or from the reservoir

This is one cause of the purity of mountain streams. The principle involved in it is not unfrequently made use of in conveying water from gathering surfaces to tanks. In such cases the water enters the channel with perhaps a brownish tint, and arrives pellucid at its destination

All Alpine countries afford abundant illustrations of this great natural purifying power

Another well known agency by which water containing organic matter is purified, is the action of living vegetation, whose office is to convert decaying noxious organized matter into innocuous living forms. The agency of water plants is hence directly beneficial to water. It is possible to suppose a case in which the action of the atmosphere, and the influence of vegetation, would be so balanced against the sources of organic impurity, that one set of agencies would neutralize the other, so that the water would be always pure, but obviously in practice, this could not be trusted to, unless the results were checked by chemical examination

(11)

Notwithstanding the action of the atmosphere and of living vegetation, it must practically be assumed in a country like India, that stagnant water will, in the great majority of cases, contain a greater or less amount of organic matter, ready to pass into a condition injurious to the physical conditions of the water, and under certain circumstances dangerous to the public health

At the best, vegetation and atmospheric oxygen act only at the surface, so that while the upper strata of water are kept comparatively pure, the lower strata may be accumulating organic matter. This appears to have been the case with the deeper parts of the Vehar Lake, and no doubt the same law operates in all similar instances

4th—In dealing practically with this part of the subject, it is obviously necessary to adopt means for excluding as large an amount of organic matter as possible from all impounded reservoirs and tanks. This is done by organized Water-police, which involves the cleansing of ground near all tanks, prevention of nuisances and of bathing, removal of dead vegetation from the vicinity, margins, and surfaces of lake or tank, periodical cleansing out of tanks where practicable, paving and cleansing of all water-courses, conveying water, and similar measures

It is evident that by adopting such precautions in addition to the natural agency of the atmosphere and of water-plants, existing water-sources might be improved in purity, and that there are cases where probably no other measures would be requisite to insure that water for domestic use, was good and wholesome. But here again there would be no security unless such water were proved to be good by chemical enquiry

5th—After what has been stated above, it would be obviously inadvisable to remove water-plants from the surface of open tanks and reservoirs. Dead water-plants should be cleared away, and care should be taken that the vegetation does not become so great as to interfere with water-supply works connected with the reservoir. Fish, if there are any, should be left in the water, they have their own office to perform, in diminishing the amount of dead matter

6th—The state of the Vehar Lake, of which the deeper parts contain impure water, shows that in this, and all similar cases, the natural agencies of air and vegetation are not sufficient to preserve the purity of the whole body of water. In this, as in other cases, improved Water-police would diminish extraneous sources of impurity, but there will probably always be a considerable balance of decaying and dead matter at a certain depth below the surface. Water for use would hence have to be drawn only from the surface strata, (as has sometimes been done in small water-works in this country, where simple subsidence was all that was required to purify the water), or what would be far better and safer in practice, artificial methods should be adopted for removing as much of the organic matter, suspended and dissolved as possible. Subsidence and filtration are, as every one knows, the methods which experience has shown to be effectual for these purposes

Filtration removes suspended matter by straining, but what is perhaps of greater importance, it acts as a destroying agent, on the dissolved organic matter, a greater or less proportion of which is oxydised by the oxygen in the filtering medium, so that, not only are the sensible qualities of the water improved, but chemical analysis shows a decided diminution in the amount of dissolved organic matter. All experience has proved that water more or less disagreeable or unwholesome before filtration becomes potable and wholesome after filtration. Filtration is the only known method of improving water in the condition of that of the Vehar Lake. It is nature's own method, of which we see the results in water-springs

It may be impossible to cleanse water for the supply of a large population of all organic matter by filtration, but practically that most important form or class of organic matter, alluded to above, which is at the same time the most dangerous and the most easily oxydised, would be removed, so that filtered water, if passed directly into the water mains, and used shortly after, would be to all intents and purposes pure water. But it does not follow that water once purified by filtration, will never become impure, even if kept from extraneous sources of impurity. It is well known that filtered water, which always contains a remnant of organic and saline matter, undergoes important changes, under the influence of ordinary temperatures, and becomes, in a short time, disagreeable, if not, injurious to health. Filtered water should not, therefore, be again impounded with the view of keeping it, the sooner it is used the better

If it is run into open tanks it will become rapidly covered with vegetation, and will return more or less to its original condition

In practice it is, I believe, necessary to provide a day's supply of filtered water for the population

The filter is a spring always acting whether the people are drawing water or not, and the service tank is thus in practice a necessary part of the filter. This service tank or cistern should always be covered so as to exclude light, heat, and impurities

7th—The general principle stated above may be briefly summed up as follows—

- 1—That all water sources, their adjuncts and neighbourhood, should be placed under Police regulation, to prevent fouling, and to insure the immediate removal of decaying organic matter
- 2—That atmospheric agency, living vegetation and fish, are all conducive to the purity of water in open impounded reservoirs and tanks
- 3—That practically (unless the contrary were shown by chemical analysis), all water in open reservoirs and tanks must be assumed in India as containing more organic matter in uncertain conditions than would be safe for the public health, especially during epidemic seasons, if the water were drawn direct from the open tank for use
- 4—That filtration is a necessary part of water-supply from impounded reservoirs and tanks in India as elsewhere
- 5—That filtered water should be used as soon as possible after filtration, and that practically a covered filtered water-cistern or tank capable of containing a day's supply of filtered water for the population would be a necessary adjunct to all works of water-supply

Memorandum by the Army Sanitary Commission on the impure state of water supplied from the Vihar Lake to Bombay, and the best means of keeping water sweet when stored in tanks in India

The questions in the papers, although primarily raised, in regard to water supplied from the Vihar Lake to Bombay, involve principles of great importance in regard to Indian water-supplies generally

Bombay derives its water from a large impounded reservoir supplied by the surface drainage of the surrounding hilly Districts. The country is covered with vegetation, and large quantities of different species of water-plants have grown in the lake, which also contains a multitude of fishes

In this, as in every case where there is much living vegetation, and a superabundance of animal life, there is decaying and dead organized matter, and all lakes, with shelving margins, are liable to have the space between high and low-water fouled by various sources of impurity. This has happened in the case of the Vihar Lake in a tropical climate

The result has been that the water, especially that drawn from the deeper part of the lake, has become impure, and the practical question is, how this state of things is to be remedied, and its recurrence prevented. There is nothing in the case different from what might have happened in England under similar circumstances, only in India all the sources of impurity are rendered of more importance by the nature of the climate

In dealing with the subject, we shall, in the first instance, re-state the principles of water-supply bearing on this and similar cases already laid down in our suggestions for the sanitary improvement of Indian Stations

In these suggestions we have pointed out that the most common source of organic impurity in mountain Districts is superabundance of decaying vegetable matter from trees and jungle, and that waters of this class are unfit for use unless they are purified by filtration. We have further stated that the most common source of animal organic matter in Indian tanks is surface filth

We have shown the necessity for removing all extraneous impurities from the sources of water-supply, and that the channels, stream courses in valley lines, and conduits, connected with impounded tanks and reservoirs, should be cleansed and paved, so as to present a clean surface, and that care should be taken to prevent all gathering surfaces becoming fouled. We have further stated that storage reservoirs must be fenced in, and that conduits, open or covered, must be regularly looked to, and scavenged so as to prevent fouling

Precautions of this nature are necessary in Great Britain, in order to secure that at the fountain head, every probable source of impurity is constantly removed, and there are usually clauses inserted in Water Company's Acts for punishing all persons wilfully injuring the purity of sources of supply. These precautions are an indispensable part of the Sanitary Police of Water-works, the main functions of which are to keep a constant and unremitting watch over all gathering surfaces, reservoir, banks, brooks, and channels, through which any part of the water flows

The very same principles are applicable to the Bombay case, and to all similar cases. Every means must be adopted to remove decaying vegetation from conduits and channels conveying water to or from impounding reservoirs. The amount of living vegetation to be left on gathering surfaces will depend on local circumstances, but there can be no doubt that dead vegetation, such as dead leaves, branches, decaying timber, and the like, near the lake, should be removed, and the gatherings surfaces kept as clear as possible of all such sources of impurity.

In planning new works, the nature of the gathering surface, and the amount and character of its vegetation, requires to be considered as one of the elements in selecting a source of supply. Another source of impurity in impounding reservoirs, with sloping banks, is the growth and decay of vegetation, or the deposit of foul matters on the exposed bank between high and low-water mark.

An immediate remedy for this is cleansing and removal of vegetation and impurities from the exposed surface

Wherever the extent of exposed surface between high and low-water can be lessened by banking out shallow areas, this should be done

A further diminution of risk of impurity from the exposed bank can be obtained by paving it with stones as is done in the large filtering establishments in this country. Paved surfaces of this class can readily be cleansed, and one great cause of impurity of water in reservoirs cut off

But after every precaution is taken to ensure that the source of supply is kept as free as possible from extraneous impurity, there will always be more organic matter in impounded water than is desirable for health. Hence, in our suggestions already referred to, we have in every case advised that waters of this class, whether contained in large reservoirs, or in ordinary tanks, should be filtered before use, for the double purpose of removing suspended impurities, and of oxidizing dissolved organic matter. This precaution is absolutely necessary. No water-supply can be considered safe without sand-filtration. We have given in our suggestions plans and sections of filtering arrangements suitable for water-supplies of both large and small amounts

Most of the water supplied to large cities and towns in Great Britain undergoes sand-filtration before passing into the mains, as is to be done with the water-supply of Calcutta

The whole of the water-supply of London is sand-filtered. The East London Company filters 20 millions of gallons per day, through 12 statute acres of sand filter. The new River Company uses 11½ acres of sand-filter for filtering 18 millions of gallons a day. The Lambeth and Vauxhall Water Company, the Chelsea Company, and the West Middlesex Company, taking about 48 millions of gallons of water per day from the River Thames, sand filter the whole. When the water is turbid on account of floods, it is first run into depositing reservoirs to be purified by subsidence before it is passed into the sand filter. The rate of filtering is about 700 gallons every 24 hours, for every square yard of sand surface. The filters are run dry, and surface scraped about once every five weeks, less in cold weather, more in hot weather, less when the water to be filtered is clear, more when it is turbid

In some filters the depth of sand at the surface is 2 feet 6 inches, in others 4 feet. The filtration and oxygenation of the water is chiefly accomplished by the upper 6 inches of sand. The thicker the layer of sand the slower the process, and the more perfect is the deposit of sediment by gravity. Under certain circumstances, a layer of wood or animal-charcoal may be placed in the filter. The London Companies use clean sand only. After filtration the water is received into covered service reservoirs, whence it passes directly into the mains and so to the houses. Water once filtered is never again allowed to become foul on the works of the London Water Companies, as it is passed directly into covered reservoirs, and thence into the supply mains, without any further exposure to extraneous sources of impurity

These principles, which have been arrived at by experience in this country, indicate what ought to be done in the case of the Vihar Water-works, and in all similar cases in India

We recommend therefore—

- (1)—That means, such as those stated above, be taken to preserve the water in the Vihar Lake as free as possible from decaying organic matter proceeding from the gathering ground, and from the margins of the lake or from conduits
- (2)—That all water supplied to Bombay from the lake be drawn from the lake through fine wire-screens, so as to prevent floating matters and fish entering any conduit, and that such water in all cases be sand-filtered, and passed into a covered pure water-tank or reservoir in immediate connexion with the filters previous to distribution through the mains
- (3)—That the filters and covered pure water reservoir should be at the Bombay end of the pipe conduit if practicable. The contents of the covered reservoir should be equal to a day's supply of the population
- (4)—That similar measures be adopted for preserving the purity of sources of supply of all open water-tanks in which water is stored for domestic use, and that all open tank water be sand-filtered and stored in covered expense tanks or cisterns, from which it can be drawn pure for consumption *

If these precautions be diligently carried out, the other questions raised in the papers, regarding the propriety, or not of permitting the growth of water-plants and fish in impounded reservoirs and tanks, will become of little importance.

* Note—It is not of course intended that the open storage tanks or reservoirs should be covered, but only the tanks or cisterns into which a day's supply of filtered water is received for use

Living vegetation if not allowed to exist to such an extent as to interfere with the supply-works, and if care be taken to remove all dead vegetation from the surface and banks, and if possible from the bottom of the lake, is rather an advantage than otherwise, unless the plants be poisonous. The vegetation exists for a specific purpose, and that is the conversion of dead organized matter into living forms.

This is one of nature's processes for purifying water. The flow of impure water over clear rocky channels is another. Both agencies are useful in their place and degree.

In the same way, the existence of fish in impounded reservoirs or tanks is not necessarily injurious. On the contrary their tendency is to preserve that balance in vital forces throughout the body of water which tends to reduction of dead organized matter. Certain kinds of water-plants and fishes are perhaps better adapted for these ends than others, and this question may very well be studied in India.

As regards the depth from the surface at which water should be drawn from the Vechar Lake, it should be taken as near the surface as possible,* but this is a matter of secondary importance if the water is filtered, but there would be no difficulty in arranging the out-lets, so that water might be drawn from any depth, or always close to the surface, if considered desirable.

WAR OFFICE,

7th August, 1868 }

J HOPE GRANT
DOUGLAS GALTON
JOHN SUTHERLAND
H H MASSY
B H MARTINDALE
PROBY T. CAUTLEY.
J R MARTIN
ROBERT RAWLINSON
COLONEL MURRAY, on leave

* Note—The water tower in the Vechar Lake contains valves at different elevations, so that water can be drawn at any one of these levels.

ORDER—Ordered, that copies of this Despatch, and of its enclosures, be forwarded to all Local Governments and Administrations, in continuation of Public Works Department Circular No. 39 of 1868.

Ordered also, that a copy of this Despatch, and of the earlier papers, be forwarded to the Sanitary Commissioner with the Government of India, for information.

(Signed) C H. DICKENS, Colonel, R A,
Secy to the Govt of India.

W. H. Alexander, C E.,
Offg. Asstt Secy. to the Govt of India.

To
The Secretary to the Government of Madras
Public Works Department

12/11. 1868 & 12/21

GOVERNMENT OF INDIA
PUBLIC WORKS DEPARTMENT.
CIVIL WORKS
Miscellaneous

To *No 4518*

CIRCULAR No. 91 PUBLIC WORKS.

Dated SIMLA, October 30, 1868

Received *26 Nov -*

12/11. 1868 & 12/21

12/11. 1868

12/11. 1868

No 113 - 15th January 1869

Best means of keeping water sweet in tanks

12/11. 1868 & 12/21
To the Secretary to Government
Public Works Department
Simla
15th January 1869

Ordered the record -

No 113

15th January 1869
Sanat & Co.

Cue 4518

Court. of 1868 Madras.

PUBLIC WORKS.

To
The Chief Engineer for
Irrigation

do, do, &c.

Dated

Recd

Encl.

G O. 15th Jan'y 1868 No. 113

Nos. 231 & 232

Keeping water sweet in tanks.
Circular from the Govt of India
regarding the best means of
keeping water sweet in
tanks. recorded

With our orders