THE ROSS INSTITUTE

INFORMATION AND ADVISORY SERVICE

BULLETIN No. 10 *APRIL, 1975*

SMALL WATER SUPPLIES

Published by THE ROSS INSTITUTE
THE LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE
Keppel Street (Gower Street), London, WC1E 7HT

INFORMATION AND ADVISORY SERVICE

THE primary object of the Ross Institute is the prevention of disease in the tropics. In the course of working towards this end it has become apparent that the co-operation of industry is essential if rapid progress is to be made. Fortunately, this co-operation has never been lacking, for those responsible for directing tropical industry were quick to appreciate the immense value to them of healthy labour and have therefore been among the strongest supporters of the Ross Institute since its inception.

For this reason the Ross Institute has made it an important matter of policy to keep tropical industry informed of the progress of medical knowledge, and of the practical methods by which the greatest benefit may be obtained from its application. This series of bulletins, which have been specially written for non-medical people, is one of the means by which this information is made available; other publications are issued from time to time and a list of those now current will be found on page 62.

The Ross Institute invites all those whose work is connected with the tropics to refer to it on any matter concerned with health or welfare in tropical countries. The Director and his staff will answer as promptly and as fully as possible all inquiries and requests for advice.

SMALL WATER SUPPLIES

CONTENTS

APPENDICES :

THE ROSS INSTITUTE INFORMATION AND ADVISORY SERVICE

Bulletin No. 10 *Reprinted* **April, 1975**

(*Originally issued June* 1955, *revised June* 1957, *re-written July* 1961, *revised June* 1964, *revised June* 1967, *revised November* 1971, *reprinted May* 1974)

Small Water Supplies

Water is essential to life and it is also required for the maintenance of personal and domestic cleanliness. Water, however, plays a predominant part in the transmission of certain diseases of which man himself is almost the only source. Thus, water may be beneficial or malignant, depending on how it is treated. Those who provide others with water for household purposes have a responsibility to see that the water supplied is safe for human use. The following notes are intended to help them in their task.

SOURCES OF WATER

Fresh water is derived from rain, hail, snow and dew. When rain falls on the ground some of it evaporates; part of it—varying with the amount and intensity of the precipitation—runs over the surface into streams, rivers, lakes and ponds; and part of it soaks into the soil. Thus, there are three principal sources from which water for domestic purposes may be obtained, namely rainwater, surface water, and ground-water.

Rainwater is really distilled water and is, therefore, pure but as it falls it may pick up impurities from the atmosphere, e.g. soot, ammonia, etc. near cities, salt near the sea and dust in dry regions. In most rural areas this risk is remote and there rainwater is generally the safest of all natural waters, provided it is properly collected and correctly stored. In a few places, notably from the rock faces in Gibraltar, it is gathered and supplied to communities, but in the great majority of cases it is obtained by individual families from the roofs of their houses for their own use. Rainwater is soft and particularly suitable for laundry purposes.

Surface Waters are those of streams, rivers, ponds, lakes etc. and their quality depends largely on their location. Water from hills and valleys situated upland from human habitations and coming from catchment areas where good sanitary control is maintained is usually suitable for domestic use with little or no prior treatment. Rivers and lakes in populated areas collect from villages and towns human and animal wastes, and are invariably heavily polluted. Self-purification processes cannot be depended upon to render their waters bacteriologically safe, nor is clear water necessarily free from danger. Surface waters are usually soft and, though they often contain organic matter of vegetable origin, their inorganic content is usually low.

Ground-Water soaks into the ground and seeps downward till it meets the first impermeable layer (see Fig. No. 1). It then travels along the incline of the layer to: (i) the point where the layer outcrops on the surface and there the water appears as seepages, or springs: or (ii) it reaches an area where water accumulates in the spaces of the soil, above the first impermeable layer. This water is referred to as "shallow ground-water" and is the water that is tapped by the great majority of wells for rural water supplies: or (iii) it infiltrates below an impermeable layer, either where that layer appears on the surface, or through faults in that layer. Such water accumulates above a deeper impermeable layer and is then known as "deep ground-water." In some places this deep ground-water is under such pressure that it is forced up a well and discharges without pumping. Wells of this type are known as "flowing" or "artesian" wells.

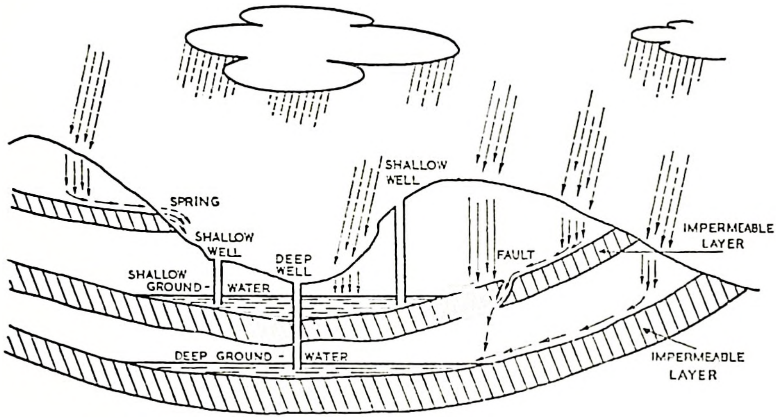


Fig. No. 1 :—A diagram illustrating the subsurface layers and the location of shallow and deep ground-water

Ground-water is seldom stationary but moves slowly downward along the impermeable layers at a rate determined by the permeability of the water-bearing layer (i.e. the "aquifer") and the slope of the underlying impermeable layer. The direction of the slope of these layers, frequently, but not invariably, follows the contours of the surface of the ground. As sanitary security requires that all sources of possible contamination should be situated at a safe distance (100 ft. at least), preferably down the underground stream, from shallow wells, the direction of flow of the underground water is important. Special care is needed in limestone areas as part of the formation is likely to be dissolved by the water as it percolates through the layer causing open "solution channels" to appear. Along such channels water, pure or impure, may flow considerable distances.

As the result of the filtration which occurs as it seeps through the soil ground-water is likely to be free of pathogenic bacteria and often it may be used without further treatment. Frequently it can be found near the houses and it is usually practical and economical to obtain. The aquifer provides natural storage for the water at the point of intake, but like a surface reservoir, it can be depleted if more water is taken from it than enters it. In rural areas this is seldom a concern as the demands are generally small but it is advisable to check this point before installing an expensive supply system. Gravels and sands are the best water-bearing formations as they can hold large quantities of water which they yield readily. Sandstone (especially if confined between two impermeable layers) is another formation which may be tapped to provide quantities of water. The chief disadvantages of ground-water are that it may have a high mineral content; it is sometimes hard; and it usually requires pumping.

THE BASIC REQUIREMENTS OF A WATER SUPPLY

The objectives of any water supply, big or small, are to provide the consumers with safe and wholesome water in adequate amounts and to make that water readily available to users.

Safe and Wholesome Water has been defined as water that may be consumed without risk from its chemical and bacterial content. Its colour and odour should be unobjectionable and it should be free of visible suspended matter.

Conditions vary so greatly in different parts of the world that it is impossible to lay down rigid standards of chemical quality. Those suggested by WHO are to be found in Appendix A and the method of collecting a sample of the water for chemical examination is detailed in Appendix B. The bacteriological standards of drinking water recommended by WHO are quoted in Appendix C, and the method of collecting samples for bacteriological examination are outlined in Appendix D.

Much valuable information concerning its sanitary quality may be obtained by chemical examination of a water but it is impossible to say that a water is free of sewage pollution by chemical analysis alone. Where the presence of pollution is being investigated bacteriological examination is essential. The results of the chemical and bacteriological analysis should be co-related, but these examinations can refer only to samples examined. A water which the tests have shown to be safe may be polluted after the samples have been taken and the only way of ensuring the early detection of intermittent pollution is through frequent routine bacteriological examinations. In rural areas it is often difficult enough to have one such examination done but to insist on weekly repetitions would be quite unrealistic. *Escherichia coli* which normally lives in the bowels of warm-blooded animals and which is present in human faeces in enormous numbers is used as the bacterial indicator of pollution. Unfortunately there is no ready method of differentiating strains of *E. coli* of animal origin from those of human origin.

In view of the foregoing it is of the utmost importance that the supply system be correctly located and constructed so as to provide natural protection against outside contamination. A careful inspection of the pertinent area must, therefore, be carried out, and it should be repeated at regular intervals to ensure that this area is maintained in the necessary sanitary state.

The demand per head will materially depend upon the method of distribution to the consumers. Individual supplies to each family in their respective homes should be the aim from a hygienic point of view, but it is rarely that in a small African or Asian community this can be achieved at the outset, and street fountains or standpipes will, as an interim measure, be the source of water for a large proportion of the population. Only experience within the particular country concerned will show what actual demands are likely to be, but something like this pattern will emerge:

Water carried from a standpipe ...	25 litres per person per day
Water from a single tap in the home	50 litres per person per day
House with bath, wc, etc.	75–100 litres per person per day

Taking, as an example, a village community of 2,000 inhabitants, it might be reasonable to assume an initial demand of 50 cubic metres per day, rising to 75 cubic metres per day in five years' time, and to 100 in the future. Design would be based on the middle figure of 75, and allowance made in the layout for this to be extended by one-third in the future.

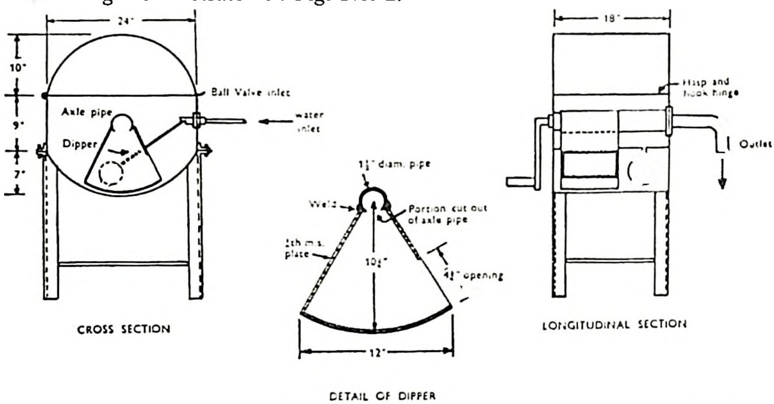
Readily Available : "From the purely public health view-point there is no question but that the aim should be to supply safe and wholesome water in adequate quantity to every family in its home". Experience on estates in Ceylon and elsewhere has shown that, when the workers are provided with taps in their own houses they look after the taps and the wastage of water is minimal. On the other hand, where the distribution of water to workers is by public stand-pipes, the taps are generally left running and many of them are repeatedly broken so that they cannot be turned off. Unfortunately the capital cost of a waterpoint in each house is often too great and it is then necessary to compromise between economic realities and public health principles.

Until they actually experience the benefits of safe water tropical people rarely understand or appreciate its advantages and they will continue to use their old polluted sources unless the new supply is superior in some respects obvious to them, such as greater convenience, or greater reliability. They may bathe themselves and wash their clothes at the new waterpoints but the general standard of household cleanliness will vary inversely with the distance the water has to be carried. If the new waterpoints are not as handy or as dependable as the old ones the people will continue to use unprotected shallow wells near their homes or persist in going to the river for polluted water. Such practices defeat the real object for which the new supply is being installed, namely, to improve the public health. As many stand-pipes and household connections as possible should, therefore, be supplied and the layout of the whole pipe system should be such as to facilitate the future provision of a tap in each house. The following are suggested as minimum standards :—one stand-pipe should not serve much more than 40 people ; and in the case of wells to which the people must go for their water there should be at least one well for every 250 people.

Even where water is in short supply people all too commonly leave the public standpipe taps running and this, if unchecked, could soon lead to an acute shortage of water. To deal with this problem various types of press taps, e.g. the "Totem Tap"* (invented by T. N.

*Obtainable from the Colombo Commercial Company Ltd. Slave Island, Colombo.

H. Marquis, a planter in Ceylon) have been tried. In many cases, however, the users find a way of tying the press-cap back so that the water continues to run without manual pressure on the tap. Many managers deal with this by shutting off the water to the lines (or camps) for certain suitable hours daily. One method of coping with the problem was used on an estate in Ceylon. The manager constructed, at ground level, one concrete tank to serve each 3 family quarters. The tank held an adequate amount of water for one day for the people concerned and it was filled from the pipe supply during the night. The workers obtained their water from it by means of a pitcher-spout suction pump fixed to the top of the tank (similar to the arrangement shown in Fig. No. 4). Damages to the pump were not unreasonable. Another way of dealing with water wastage was invented by the Engineers of Dunlop Malayan Estates Ltd. They designed an ingenious cistern-pump which takes the place of the usual stand pipe. This appliance, and the method of its working are illustrated in Fig. No. 2.



Reproduced by kind permission of the Dunlop Malayan Estates Ltd.

Fig. No. 2 :—A cistern/standpipe. The water level in the cistern is maintained by a ball valve on the inlet. The dipper is rotated by the handle and on its passage through the water it scoops up some. As the dipper continues on upwards it tips this water into the open side of the axle pipe and water flows along this pipe to the outlet.

SELECTION OF THE SOURCE OF SUPPLY

The choice of source of supply for development depends on a number of factors: the quantity and quality of the water available; the possibilities of sanitary control of the catchment area; whether the water can be supplied to the consumers by gravity or has to be pumped; and the distance from the source to the houses. In order to obtain full information on these points it is necessary to carry out a very careful preliminary survey.

Sources of Supply

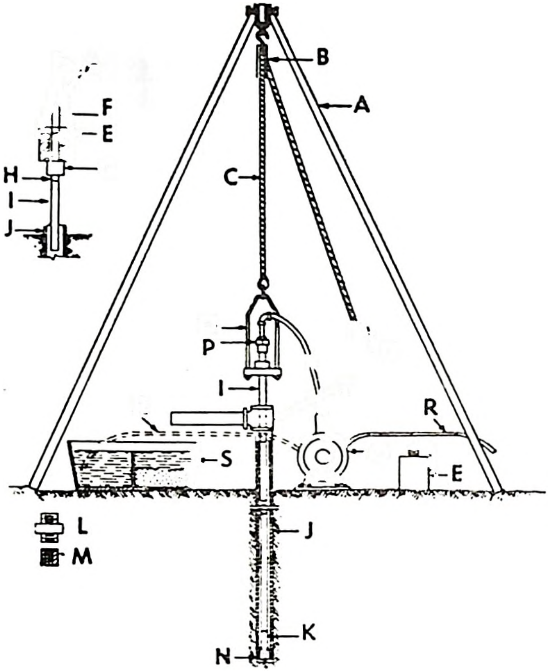
The first step in starting any water scheme is to ascertain what sources of supply are available. Frequently a good source is not difficult to find but it is usually advisable to check all alternatives as some, though less evident, may be more economical and safer to develop. Sometimes suitable sources are not obvious and a search should then be made in the valleys, along the foot of the hills, where the vegetation is greener, and such places. In this reconnaissance the inhabitants are generally very willing to assist with their local knowledge.

If the quest fails to reveal a satisfactory source an investigation of the ground-water becomes necessary, and for this a knowledge of the local geological formations is most helpful but usually there are no records available. A study of any existing well will provide some information about the layers it penetrates, and the location, quantity and quality of the water. Unless a good deal is already known about the aquifer it is expedient to sink test holes at various likely spots. (See Fig. No. 3.) These holes may be made with a pipe, about 2 inches in diameter, tipped with a point, and driven into the ground by a hammer, or a pipe sunk by an earth auger or by boring. A reasonably practical man can generally cope with this, provided the water is not more than 30 feet or so from the surface. If it is necessary to probe the potentialities of the deep ground-water, however, it is wise to obtain the services of an engineer possessing the experience and the equipment for this type of work. Deep well exploration and construction are expensive and are not jobs for amateurs.

The next step is to ascertain the quantity of water available, by the methods described in Appendix E. The rainfall figures may be obtained and the history of springs and existing wells may often be secured from the local residents. An estimate of the capacity of the aquifer may be made by pumping a well and noting the rate at which the well refills but the approximate yield in the dry season must be determined as that is often a decisive factor.

The Sanitary Survey

The sanitary conditions prevailing in the immediate environs and catchment areas of possible sources should be thoroughly investigated. This is most important because the methods of purification of water, under rural conditions, are limited, and the process is too often neglected. Animal contamination of the water is very undesirable, and in some places may be dangerous, but the greatest hazard lies in pollution from human sources. It may be possible to find a spring, or stream, coming from a safe catchment area situated uphill from human habitation, or it may be practicable to render a source safe by moving potential origins of contamination or to protect the source by suitable intercepting drainage etc. Though the water from a stream may be liable to pollution it is often feasible to obtain wholesome water through wells and infiltration channels sunk in sand and gravel layers near the stream.



A = Tripod
B = Sheave wheel
C = Rope
D = To motor winch
E = Drive hammer
F = Jar length
G = Drive head
H = Rod coupling
I = Drill rod
J = Casing
K = Chopping bit (This may be replaced with a sampler if desired. The water swivel is then replaced by a rod drive head.)

L = Casing drive head
M = Rod drive head
N = Casing drive shoe
O = Lifting bail
P = Water swivel
Q = Pump
R = Suction hose
S = Tank
T = Tee, replaced by drive head when driving casing

(Reproduced from WHO Monograph Series No. 42)

Fig. No. 3 :—Shows simple equipment for making exploratory holes. Casing is driven into water-bearing formation, and cuttings are washed out. Undisturbed samples can be taken at necessary intervals. Well screens may be set in holes for test pumping when desirable.

Wherever possible the water should be examined chemically and bacteriologically and results considered in the light of the sanitary survey.

In the final selection, the water which needs no purification to bring it up to the recommended physical, chemical and bacteriological standards is to be chosen before water that requires some treatment, and water that can be supplied by gravity is commonly to be favoured over water that entails pumping. Of these two qualities the water that requires no treatment but needs pumping is generally preferable to the water which needs treatment but no pumping. The first choice, namely water that demands neither purification nor pumping, is ordinarily restricted to springs and streams in protected drainage areas situated uphill from human habitations.

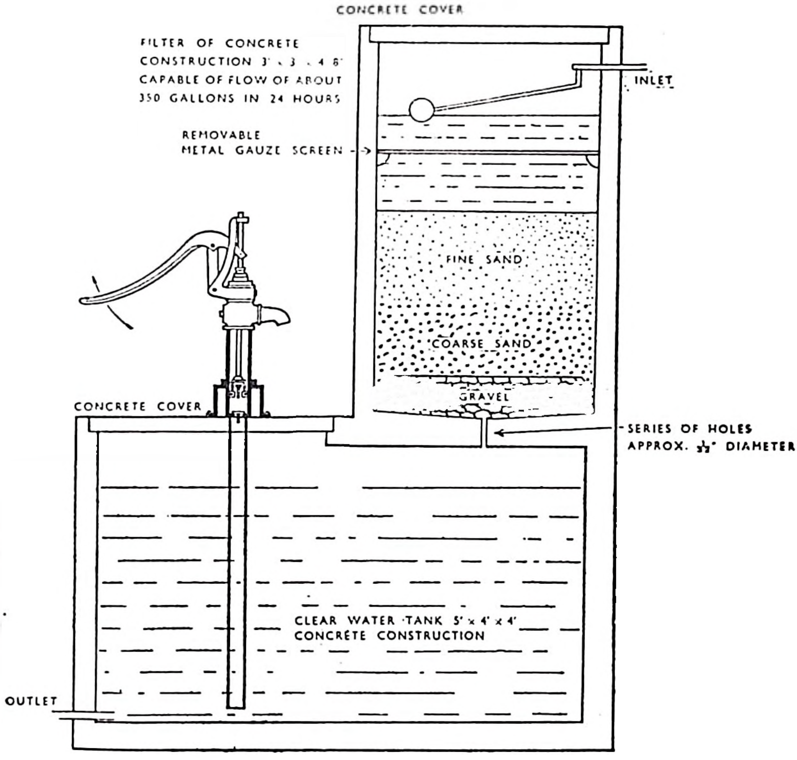


Fig. No. 4 :—A domestic sand filter and water cistern

THE SANITARY COLLECTION OF WATER

The methods of collecting water so as to protect it against pollution vary with the source and the circumstances. The general principles of the methods needed are described below.

Rainwater: The collection of rainwater requires that roofs and roof gutterings are as clean as practicable. The roofs should be of tiles, slates or sheeting (G.I., aluminium or asbestos) and not of thatch or lead. The guttering should be well graded and free of sagging (this also avoids the occurrence of pools which would form suitable breeding places for mosquitoes). Dust, dead leaves, bird-droppings etc. are liable to accumulate on the roof and in the gutters during dry periods and it is advisable to run to waste the first water of each shower. This may be done by means of a manually, or automatically, operated separator installed in the down-pipe from the roof. Both types of separator are available. It is also advisable to extract from the water any suspended matter which it may contain. A metal strainer or sand-filter (see Fig. No. 4) located at the inlet to the storage tank or cistern will do this, but they cannot be relied upon to remove bacteria. The cistern and the sand-filter should be cleaned regularly, and they must be situated and constructed so that the entry of surface water and possible pollution by sewage, are prevented.

Water storage tanks and cisterns should have covers that are dust-proof and prevent the entry of light and animals. Overflow pipes should be screened against the access of mosquitoes and other insects. The outlet pipes should be about 2 inches above the bottom of the tanks and the clean-out pipes flush with the bottom. There should be no connection between cistern drains and sewage drains. Metal tanks are commonly used for storage above ground, where, if possible, they should be shaded from the sun. As rainwater is soft and has a markedly corrosive effect on iron, tanks of that metal should be well galvanised. For convenience and economy masonry tanks are frequently built underground and that helps to keep the stored water cool in the hot weather. Reinforced concrete is the best material for underground tanks since it provides water-tight walls as well as the necessary structural strength. Masonry walls must be carefully built, with strong cement mortar joints, and plastered inside with two $\frac{1}{2}$ inch coats of mortar (1 Portland cement: 3 sand) to make them water-proof.

Surface Waters:—

Streams: In rural areas water from small streams draining isolated, or uninhabited valleys (e.g. ravines in the jungle) may be of sufficiently good chemical and bacteriological quality for human consumption in its natural state. The intake may consist of submerged pipe protected by a cage or a screen at the open end. It should be placed some distance from the bank towards the centre of the flow and not too close to the bottom of the stream. A small diversion dam may be required. In suitable circumstances, the water may be gathered behind dams (see page 27) into ponds and reservoirs but the area used for this purpose must have a reasonably impermeable soil (e.g. various types of clay). At the time of construction the area to be submerged should be cleared of vegetation and decaying matter. Steps should also be taken to protect (by intercepting ditches, fences, hedges etc.) the environs of the reservoir and the areas drained by its inflowing streams against surface washings, human and animal pollution. The ponds so formed may become breeding places for mosquitoes and fresh-water snails (vectors of bilharzia), so such schemes should not be undertaken without previously consulting the local medical authorities.

Though safe brooks of the type described above may be found in sparsely populated areas, the waters of streams, rivers, ponds, etc., in inhabited places are so liable to pollution that they should be regarded as dangerous for human consumption unless they are subjected to purification. The kind of treatment necessary to render such waters continually safe for domestic purposes is often impracticable for small communities because of the expense involved and the standard of supervision required.

Ground-water

Infiltration Galleries are really horizontal wells which collect water over their entire length. In the case of large supplies they may be tunnels which run into aquifer for varying distances from the main shaft of the well. In rural areas they generally consist of open-jointed, 4-inch (or larger) diameter pipes, surrounded by 6 inches or so of gravel, and laid on the bottom of trenches which are deep enough to enter the water-bearing layer. After the pipes and gravel have been installed the trenches are infilled. The latter type may also be used to collect water from a series of seepages or small springs. For this purpose the trenches should be excavated a suitable distance uphill from the seepages and springs and should follow the contours as the contours normally lie across the flow of the water. By these means the water is gathered before it appears on the surface. The pipes should slope to selected points from which the water may be pumped.

In areas where the streams are too liable to pollution for their water to be used for domestic purposes without prior treatment it may be possible to collect water from sand and gravel layers situated near the streams. In these instances wells and/or infiltration galleries, are constructed in the water-bearing layer, about 30 feet or more from the banks of the stream. (See Fig. No. 5.) The water so obtained has usually been adequately filtered through the sand before it enters the collecting pipes but its purity should be checked by the necessary tests.

Springs: Provided the spring water has been filtered through at least 10 feet of soil (though it may have acquired some chemical substances on the way) it has usually been freed of harmful bacteria. (Care must be taken not to mistake for a spring, the reappearance on the surface, of a stream that has gone underground for a short distance.) The risk of contamination arises if the spring water is allowed to flow over the ground before collection but the hazard may be eliminated by gathering the water before it reaches the surface. This means digging back into the hillside and placing a collecting tank on the impermeable layer as illustrated in Fig. No. 5. Be careful not to dig through the underlying impermeable layer as that is likely to let the water seep downward and cause the loss of the spring. A diversion ditch should be dug some 25 feet or more uphill and around the sides of the collecting point in order to intercept surface water before it can flow into, and contaminate the spring. The soil from the ditch should be thrown up on the downhill side so as to form a "bund" which increases the effectiveness of the ditch. Putting a fence or thick prickly hedge on the bund tends to prevent human trespassers.

The water from a number of small springs may be collected by the method illustrated in Fig. No. 6, or by means of open-jointed agricultural pipes in a subsoil drain which follows the contour—a drain similar to

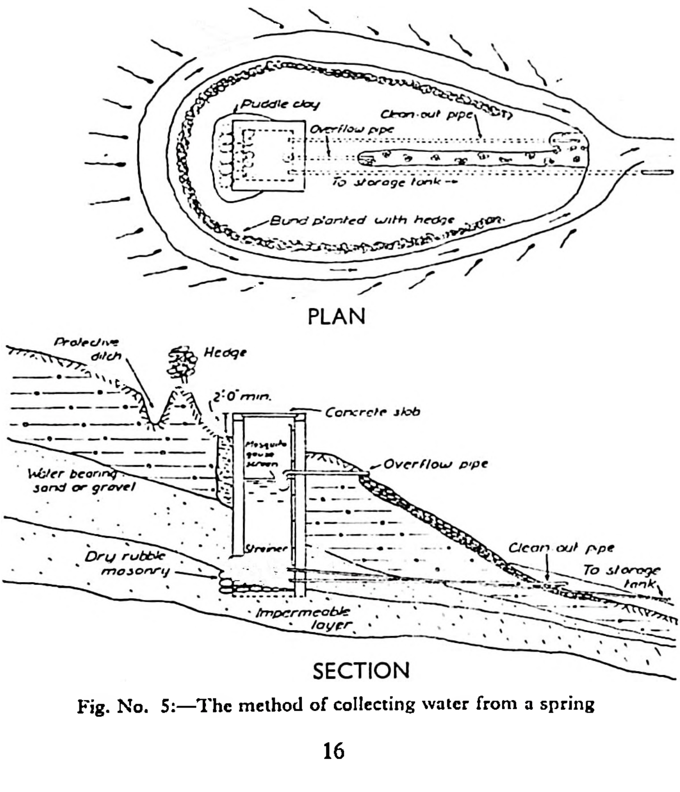


Fig. No. 5:—The method of collecting water from a spring a small infiltration gallery. The pipes should slope towards one or more points from which the water is conveyed to a collecting tank. The area concerned should be protected against surface washings by an intercepting ditch and bund, and against human and animal trespass by a suitable hedge or fence.

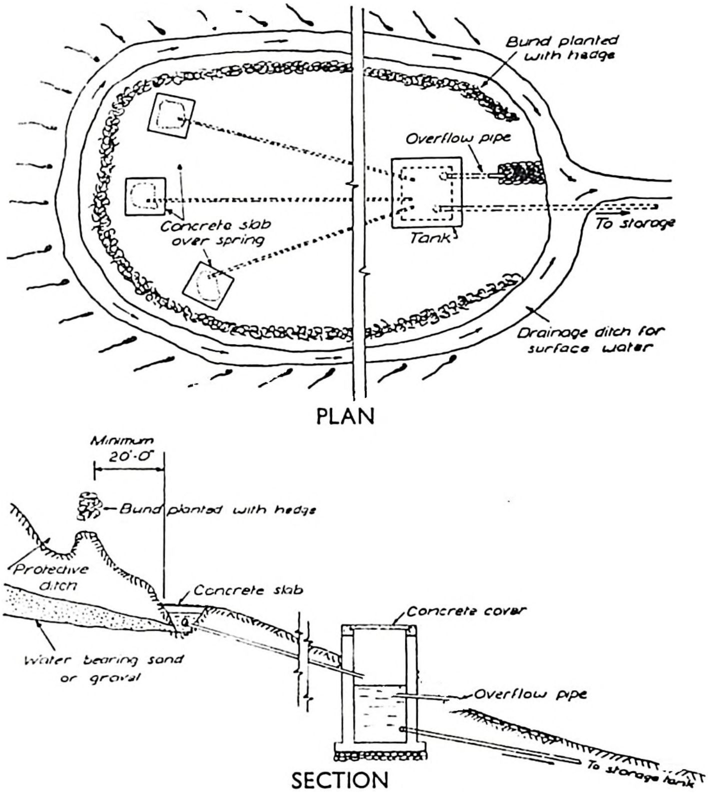


Fig. No. 6 :—One method of collecting water from a number of small springs

Wells : The common method of collecting ground-water is by means of wells of which the main types are the hand-dug, the driven, the jetted, the bore hole and the drilled. Irrespective of its type of construction, a well which obtains its supply from the shallow ground-water (i.e. the water above the first impermeable layer) is called a *shallow* *well* and one which draws from the deep ground-water (i.e. water below the first impermeable layer) is referred to as a *deep well.* The terms "shallow" and "deep", as used in this connection, do not refer to the actual depth of the well, and the shallow ground-water may be further below the surface in some places than the deep ground-water is in other parts. Most shallow wells are hand-dug, but some are jetted or driven. Deep wells are generally drilled.

The Hand-dug Well: this is the commonest type of well in rural areas throughout the world and it is usually the most suitable for small communities. The equipment required for its construction is simple and in most areas men accustomed to the work are to be found. The majority of hand-dug wells are about 25 feet (7 metres) deep but depths of 50 feet (15 metres) are not unusual, and occasional wells descend to 100 (30 metres) and more feet. The maximum depth for a hand-dug well is considered to be 200 feet (60 metres), but the construction of such wells is not free from danger to the workmen and it is advisable to employ a trained supervisor, particularly for the deeper ones. Hand-dug wells are almost invariably circular in shape as that has great advantages in economy and strength. The cost of lining a well varies directly with its diameter but the diameter must be large enough to allow room in which the men can do the excavating. The standard diameter is between 3 and 4 feet and the latter allows sufficient space for two sinkers to work together. Hand-dug wells act as reservoirs for the water.

The usual way of constructing a shallow well is to excavate a hole of the required diameter and depth and then to line it with masonry, brickwork or concrete rings making sure that all the joints between the stones, bricks or rings, for a depth of at least 10 feet below ground level are watertight. If the ground appears at all unstable the excavation should proceed for 3 feet or so and the walls of the hole should then be revetted with timber so to protect the workmen against caving of the sides. The process of alternate digging and revetting the excavation should then proceed to the required depth. Sometimes the permanent lining is installed in similar stages, each section being held in position by pins and curbs, or the lining is built in sections above its final level and each section is sunk as a completed unit towards its final position, as the excavation proceeds. Generally a combination of these methods is employed.

Sanitary Precautions: It is most important that the location and the design of the well are such as to afford to its water the greatest possible protection against contamination. For this purpose the well should possess the following features (see Fig. 7):— (i) It should be situated on adequately drained ground which is above flood level and at least 100 feet, preferably uphill, from all potential sources of pollution.

(ii) The well should have a watertight lining (e.g. concrete, or

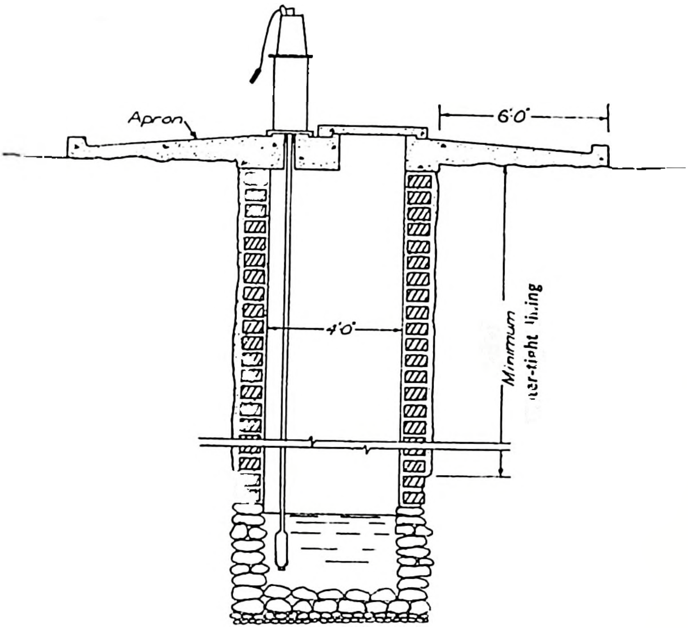


Fig. No. 7 :—The features of a hand-dug well

tight-jointed bricks or stones), which may be improved by filling in the space between the lining and the surrounding earth with puddled clay, or concrete. In the case of shallow wells this lining should reach downwards into the water-bearing layer, or to at least 10 feet (3 metres) below the surface of the ground. The lining should be continued above the ground (1 foot (30 cms) or more) and be surrounded at ground level by a 6 foot (2 metres) wide watertight apron which is sloped to a perimeter drain that carries the waste water away from the well. The lining and the apron ensure that surface water can enter the well only after it has been filtered through at least 12 feet (2 metres) of soil. In the case of deep wells the lining should continue into the first impermeable layer so that water cannot enter the well above that layer.

(iii) The well cover should be watertight and dustproof and its upper surface should slope downwards and outwards from the centre.

(iv) The water should be drawn, preferably by a pump that is self-priming, as that avoids the risk of the well being polluted by extraneous water used for priming. Pumps which have their cylinders above ground are cheaper to buy and easier to maintain than those with their cylinders in the well.

(v) A well on sloping ground should be protected by an intercepting contour ditch situated about 50 feet (15 metres) uphill from the well.

Before putting a well into use the water, the pump and the suction pipe should be disinfected by super-chlorination. (For method see page 37.)

N.B. Though pumps are capable of forcing water up pipes for variable distances (depending on their power, and other factors) they are incapable of sucking water upwards for much more than 20 feet (6 metres). Pumps must, therefore, be located less than 20 feet (6 metres) above the water. Where the water does not reach to within that distance of the surface the pump must be lowered into the well for requisite depth.

Driven Wells

In areas where ground-water is available about 15 feet (4·5 metres) or 30 feet (9 metres) below the surface and the intervening soil is neither rocky nor unduly hard, driven wells have proved both efficient and popular. Such wells are constructed by driving into the water-bearing stratum, by means of a hammer or driving monkey, a screened well-point to the upper end of which, as it descends, suitable lengths of pipe are attached. The pipes are commonly 1½ to 2 inches in diameter and it is only rarely that the depth of such a well is as much as 50 feet. A small hole, about 2 feet deep, is dug with a crowbar to start the well-point on its downward path and it is essential to see that the pipe is maintained in a vertical position during driving. The plumb line used for checking this should also be lowered frequently into the pipe to ascertain when water has been reached. After the water-bearing layer has been entered it is advisable to continue driving as the deeper this layer is penetrated the less likely is the well to dry up. The pump should then be attached to the upper end of the pipe, the pipe should be filled with clean water and pumping should be started. At first the water obtained will be muddy but it will usually clear after an hour or so of vigorous pumping. Such pumping will remove the sand and fine earth from the vicinity of the well-point and so "open" the aquifer—a procedure necessary to ensure a steady supply of water. The process may be assisted by stopping the pump for a moment thus causing the water in the pipe to fall suddenly and to pour out through the well-point disturbing the fine particles surrounding the pipe. Pumping should be recommenced immediately, and the process repeated several times till the water is clear.

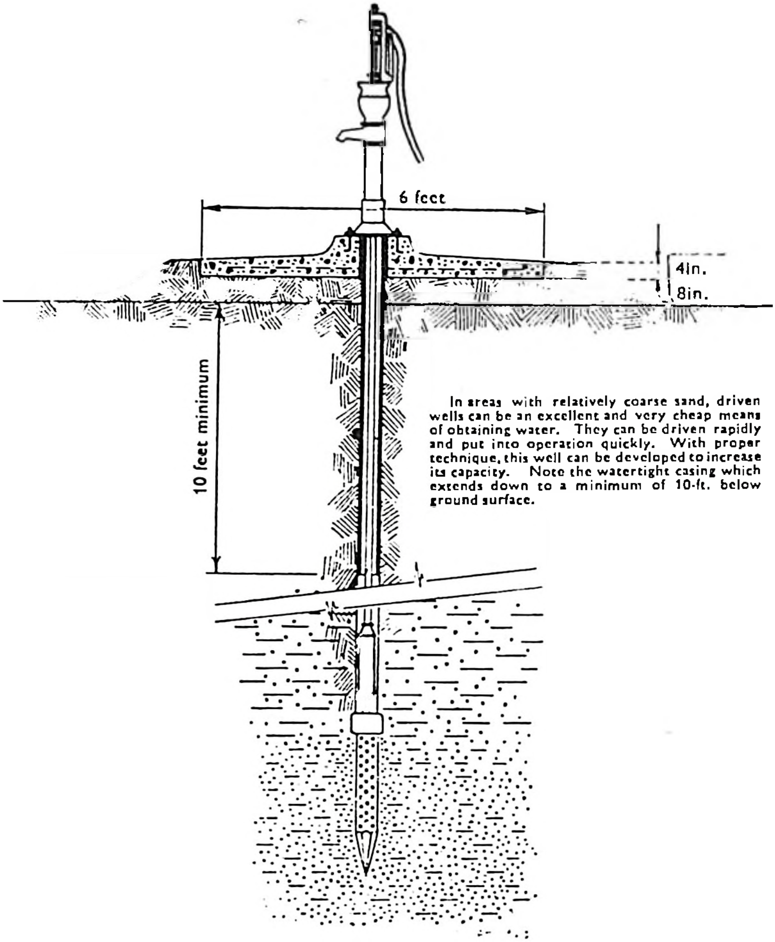
The pipe should be withdrawn if, by mistake, it has been driven beyond the water-bearing stratum. If driving is obstructed by boulders, or no water obtained at a suitable depth, the pipe should be lifted out of the ground and put down in another place. This may be done by using a crowbar, or wooden beam placed across a log or trestle, as a lever.

Once the water from the well becomes clear, a concrete platform with a 6 foot radius sloping to a surrounding drain, should be built around the pipe at ground level. The junction of the platform with the pipe should be sealed so that surface water cannot trickle down alongside the pipe. This is best done by employing a pump with a base that is wide enough to cover the hole completely. (See Fig. No. 8.) The pump should be firmly fixed so that it does not move the pipe during pumping. It is a common practice to withdraw the pipe and point used in driving the well once the flow of water is established, and to replace it with new piping and new screened well-point before sealing the top of the well.

Most of these wells are fitted with suction pumps, usually of the pitcher-spout type. The risk of contamination by priming may be avoided by installing a well-casing of sufficient diameter to permit the pump cylinder being immersed in the water. The plunger is attached by a long rod to the pump handle. Before putting it into use the well and its fittings should be disinfected. This is done by pouring down the well a solution of chloride of lime (prepared as follows: — Mix 3 ozs of chloride of lime containing 25% available chlorine into a watery paste and then add sufficient water to make the mixture up to 5 gallons: stir thoroughly and allow to stand: use the clear liquid and discard the inert material that has settled to the bottom of the container). Operate the pump till the water discharged to waste smells distinctly of chlorine. Repeat this procedure a few times at intervals of one hour and then allow the chlorine solution to remain in the well for 12 hours. At the end of that time pump water to waste till it is free of the odour of chlorine.

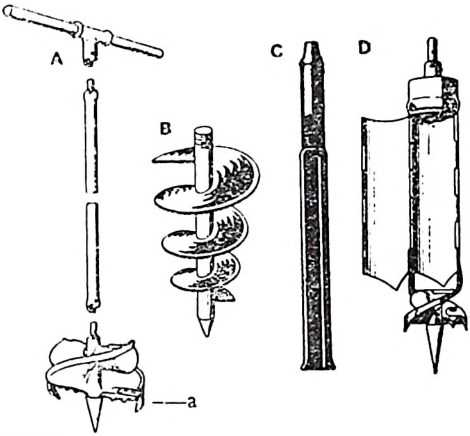
The purpose of the screened well-point is to allow ground-water to enter the pipe freely but to exclude sand. A suitable size of opening for the screen may be determined by passing sand from the water-bearing stratum through sieves of known size. Once the screen deteriorates the well-point must be withdrawn and replaced by a new one. It is, therefore, advisable to select a screen of good quality metal that will last as long as possible.

Jetted Wells: where plenty of water is available a good method of sinking a well is by jetting. This process consists of inserting into the ground a pipe tipped with a steel cutter and rotating this pipe while water is pumped into its upper end. Under these conditions the pipe descends into the soil and the water washes out of the hole the earth loosened by the cutter. Wells with a diameter of about 1½ inches are easily made by this method. Where the soil is suitable, and the necessary amount of water is available, wells with diameters of 10 to 15 inches may be sunk to a depth of 300 feet, by jetting, but for the construction of these bigger wells it is advisable to employ an engineer trained in the work.



(Reproduced from WHO Monograph Series No. 42)

Fig. No. 8 :—A driven well.



A — Tool for boring in top soil, clay, sandy clay, or formations that are not too hard or caving. Cutter (a) may be added to permit boring up to 3-in. wider than standard size.
B — Spiral auger
C — Regular club bit for breaking through hard formations, loosening rock, and breaking soft rock.
D — Tool for boring in soft, wet, sandy soils.

(Reproduced from WHO Monograph Series No. 42)

Fig. No. 9 :—Various types of earth augers

The system of jetting small diameter wells as used in India has been described by P. C. Bose. It has given excellent results and a summary of the method (quoted from WHO'S Monograph Series No. 42: "Water Supply for Rural Areas and Small Communities") is given in Appendix F.

Bore-hole Wells: A simple method of sinking a small diameter well of shallow depth is by means of an auger. The auger (see Fig. No. 9) which is usually about 4 inches across is rotated by hand. It is advisable to give it a start by digging the first 12 or so inches of the hole with a crow-bar. The shape of the spiral allows the earth loosened by the boring to rise upwards, but from time to time the borer should be raised out of the hole together with the loose soil. If rocks or other hard layers are encountered the auger has to be removed and a new hole started elsewhere.

Once the water-bearing layer has been penetrated sufficiently the necessary length of piping, tipped with a screened well-point or strainer, is lowered into the hole; the pump is attached to its upper end; and the well is "cleared" by pumping. The space between the pipe and the sides of the hole is then packed with concrete or puddled clay to a minimum depth of 10 feet, and the usual concrete platform constructed around the well at ground level.

Drilled Well: A drilled well is made by one or another type of special drilling machine and the hole is then lined with a suitable (usually steel) casing. This method has the advantage that it can reach water-bearing strata farther below the surface than could be attained by any other kind of well. As a rule the yields are high, and unaffected by droughts. The deep water is almost invariably free of pathogenic bacteria but it often contains inorganic substances dissolved as it percolated downwards.

The construction of a drilled well is a specialised task and should be restricted to those experienced in the work. In the absence of local geological data or previous drilling history in the area an attempt to obtain water by this method is apt to be a gamble. It is expensive and is generally beyond the means of small communities.

Cleaning of Wells: Open wells are very liable to become contaminated by dust. In dry, windy climates the dust entering a well may amount to several inches in a year. Cleaning is therefore necessary, not only to maintain the quality of the supply, but to ensure that the quantity is not seriously reduced by dust or other foreign matter preventing water gaining access to the well. In addition, small animals, e.g. frogs, rats, are prone to commit suicide in wells in their anxiety to reach water. Dug wells should be cleaned at least once a year and in dry areas with much dust every six months.

The concrete or brick lining at the top of the well should first be carefully examined, since if it has become loose it will make the cleaning a dangerous operation for the cleaners. The inside of the well may often be inspected by a shaft of light reflected from a mirror. A lighted candle should be lowered into the well to test for harmful gases. Old wells, particularly if over 15 metres in depth, often contain a high concentration of carbon dioxide. If the candle flickers or goes out, it should be assumed that gas is present in a dangerous concentration and the well must be ventilated. Any method of circulating air will achieve this purpose, e.g. a bundle of leaves or grasses is lowered into the well and quickly withdrawn, and repeated until the well is clear of gas. A hand-operated centrifugal fan forcing air through flexible canvas tubes is also effective.

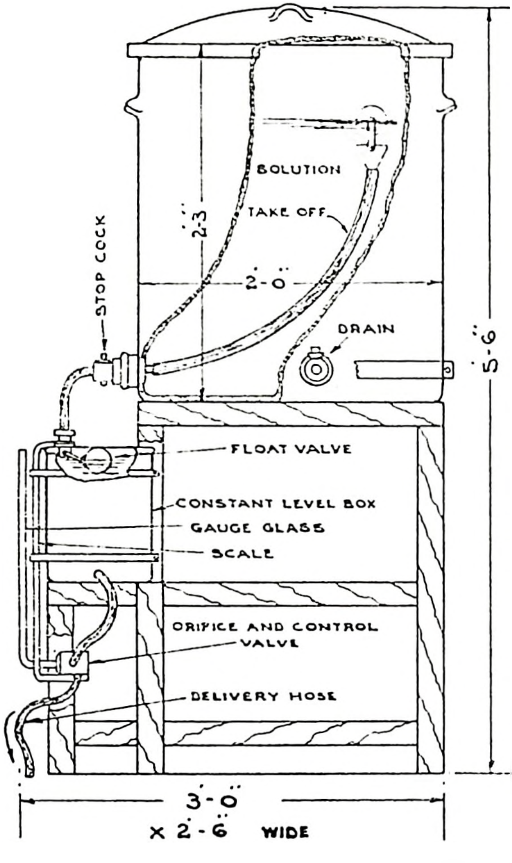
PURIFICATION OF WATER UNDER RURAL CONDITIONS

The purification of unsafe water requires some trained supervision if it is to be done effectively. Such supervision is rarely available in the villages and even on well-managed estates the procedure tends to be neglected sooner or later. Under these circumstances *every effort must be made to obtain a source that provides a naturally wholesome water and then to collect that water and protect it against pollution* by the methods already described. Thus, the necessity for treatment of the water may be avoided, and the practical importance of managing this can hardly be over-emphasised.

If the water needs treatment this should, if at all possible, be done for the whole community and certainly before, or on entry to the dwelling so that the water from all the taps in the house is safe. The practice, common in the tropics, of disinfecting (by filtration and boiling) only the water to be used for drinking, teeth-cleaning, etc., though efficient in itself (when carefully done) is frequently nullified by the servants who, the moment the householder's back is turned, are liable to fill the carafes from the nearest tap rather than go some distance to collect the safe water. Children are also likely to use the water from any tap. Contrary to an all too common opinion, ordinary freezing of water, though it may retard the multiplication of bacteria does not kill them, and ice from a household refrigerator is no safer than the water from which it was made.

Where some purification is required it should be confined to one or more of such processes, as plain sedimentation, aeration, filtration and sterilisation.

Sedimentation. To accomplish sedimentation it is necessary to retain the water for a time but the tank or reservoir used for this purpose also provides storage and that assists in the maintenance of a continuous supply. Dangerous intestinal bacteria in water are gradually reduced in numbers during storage, as conditions are not favourable to their multiplication. Holding of the water allows suspended solids to settle to the bottom and in doing so the solids carry many of the bacteria with them. It requires 6 or more days (depending on the degree of the initial contamination) to produce a marked reduction in the numbers of bacteria and the cysts of amoebic dysentery may persist in water for 10 to 30 days. The solids settle at a rate which is largely related to their particulate sizes ; e.g. coarse sand will settle quickly but fine clays and silts need several hours. The time necessary for sedimentation may be reduced to hours by adding a coagulant (e.g. alum or alumina ferric—$2\frac{1}{2}$ grains per gallon of water=1 lb. to 2,800 galls.) manually or automatically, to still or slowly moving water by means of special apparatus (see Fig. No. 10). This process requires supervision.



(By kind permission of Jewell Filter Co. Ltd.)

Fig. No. 10 :—One type of micro-feed apparatus for adding chemicals (e.g. alumina ferric, chlorine, etc.) to water

The type of settling basin most practicable for rural conditions is that formed by constructing a simple earth dam across a suitable and protected ravine. Such a basin also serves as storage for the water. The velocity of the water should be reduced on entry to the tank and it should be uniformally distributed across it. Earthen or wooden baffles may assist in this. Cleaning and repairing of the basin is facilitated if it can be divided into two sections each of which can operate independently of the other.

The construction of a dam is not the simple matter it often appears to be and if the proposed structure is to be other than small it is advisable to obtain the services of an engineer experienced in the particular work. Even for the smaller dams some knowledge of the basic principles of siting and design are required. It is necessary beforehand to make sure that the soil of the selected basin is sufficiently impermeable to prevent the water soaking away; that the catchment area is large enough to provide the required amount of water; and that the strength of the dam is more than adequate to support the weight of water behind it. A badly built concrete dam may collapse suddenly, and an earthen bank often goes rapidly once it is breached.

The commonest cause of breakdown of an earth dam is the flowing of water over the top of the dam (unless this is sufficiently protected by concrete) due to inadequate provision for the diversion of excess water, more particularly the flow that follows heavy rain. This occurrence is to be prevented by the construction of proper spillways clear of the dam itself (see Fig. No. 11). Spillways should be cut out of solid ground and their inverts should be well below the level of the top of the dam. It is sometimes safer to make two spillways, one at each end of the dam. Another common cause of failure is faulty construction and undermining of the embankment. The dam must have a base wide enough to provide a slope of not less than 1 in 3 on the upstream side of the embankment and 1 in 2 on the downstream side. In building up an earth dam three fundamental rules must be observed:—(1) The material (best is clayey containing some sand) must be spread in continuous shallow layers (4 ins. to 6 ins. deep) over the whole area; (2) it must be kept damp (enough to retain a foot-print) but not too wet; and (3) each layer must be well compacted before the next layer is added. (For fuller details the reader is referred to standard books on this subject, and to Annex 7 of WHO Monograph Series No. 42.)

Aeration. Aeration can be accomplished by allowing the water to cascade over some rough concrete steps. Alternately, where the necessary head is available, the water may be sprayed into the air from nozzles and drained back into a tank in thin sheets over a rough concrete apron.

Aeration is commonly employed to eliminate odours (more particularly those due to hydrogen sulphide) and to oxidise iron and manganese salts. Aeration is also used for ridding the water of excessive amounts of carbon dioxide which, when present, cause water to attack any iron exposed in the distribution system.

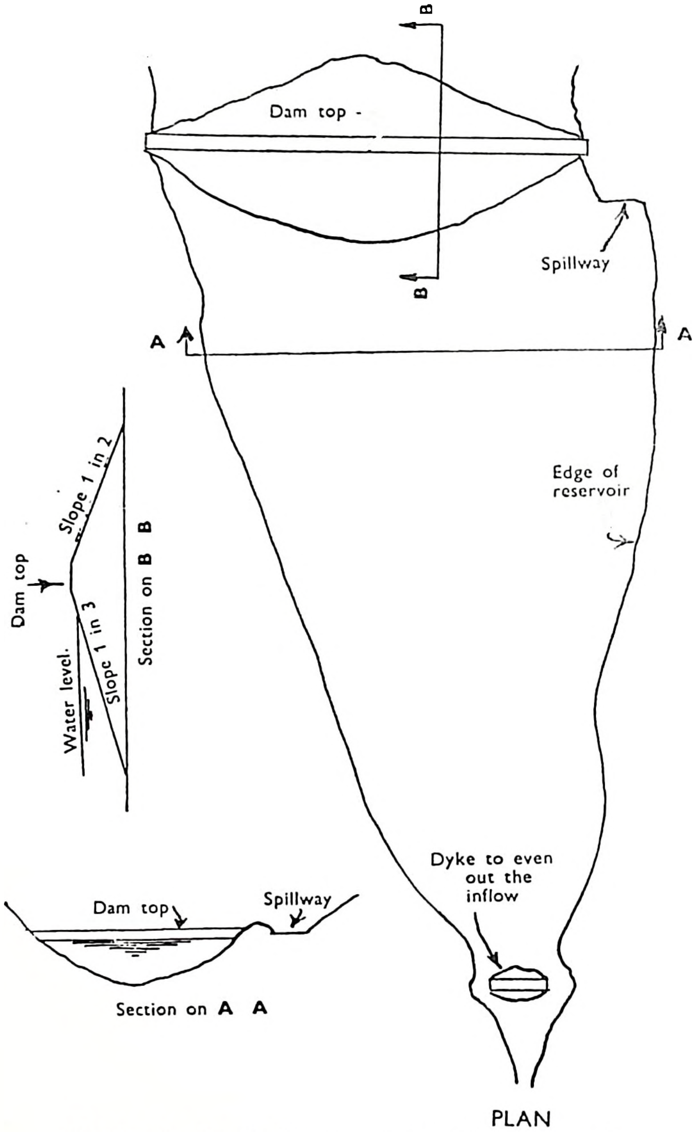


Fig. No. 11 :—The details of an earth dam built across a ravine to form a reservoir.

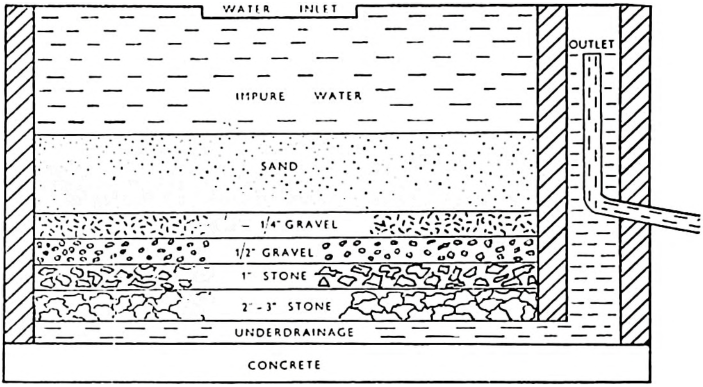


Fig. No. 12 :—Section of a slow sand filter. Note that the outlet is situated above the level of the filter bed.

Filtration. Filtration through sand as a method of purification of water has stood the test of time. It may reduce the bacterial content of the water by 85% to 99%. The two types of filter in common use in community water supplies are the slow sand filter and the rapid (or pressure) filter. Household filters are described on pages 43 and 44.

The slow sand filter requires little operational and maintenance skill but it does need a certain amount of attention regularly. If it is neglected it is liable to become a breeding ground for bacteria and a source of contamination of the water. In urban supplies the filters are under constant skilled supervision but experience has shown that in rural areas the filters are far too often overlooked, especially if they are any distance from the houses. This difficulty may be overcome in the case of villages by appointing a particular resident to be responsible for the filter and arranging for the local sanitary officer to inspect it at stated intervals.

A slow filter consists of a masonry tank containing 30 to 40 inches (75 cm. to 1 metre) of fine sand, resting on a layer of shingle about 12 inches (30 cm.) deep. Below the shingle (on the floor of the tank), are underdrains (open-jointed pipes or tiles) which collect the filtered water and lead it to the outlet. (See Fig. No. 12.) Filters of this type usually work with about 4 to 5 feet (1 to 1·5 metres) depth of water on top of the sand and the water should percolate through at approximately 2 gallons per square foot of filter surface per hour: i.e. a filter bed of 10 ft. × 10 ft. (3 m. × 3 m.) could deal with some 5,000 gallons of water during 24 hours.

In the upper 1 to 3 inches of the sand an organic material (known as "zoogloea") collects and this greatly improves the efficiency of the filtration. The sand of the filter should be kept covered with water so as to help maintain this biological layer. To prevent the water falling too low the outlet of the filter is usually located 2 feet or so above the level of the top of the sand (see Fig. No. 12). This matter needs attention especially when the filter is being used intermittently. As time goes on the zoogloea increases in quantity till it is sufficient to retard the flow of the water unduly. When that happens the top 1 to 3 inches of sand should be scraped off. After it has been washed this sand may be used again or fresh sand may be employed.

The raw water going on to the filter should be sufficiently clear to permit seeing a silver coin held on edge between the fingers at least 10 inches below the surface (i.e. with a turbidity less than 40 parts per million, approximately). If the coin cannot be seen at that depth the turbidity must be reduced by passing the water through a settlement basin before it enters the filter. Failure to do this will result in the filter becoming clogged and useless after too short a period (which varies with the degree of turbidity). It has then to be cleaned and restored before being put into service again.

Rapid Sand Filters:—For effective rapid filtration pretreatment of the raw water is generally necessary. This treatment consists of adding to the water, before it passes on to the filter bed, a coagulant, such as alum or alumino-ferric, which forms a gelatinous precipitate, or "floc", that enmeshes the suspended solids and bacteria. This preliminary "chemical filtration" assists the rapid passage and improves the standard of the filtrate.

There are two types of rapid sand filter, namely the open gravity filter and the closed pressure filter. In the former the filtering material is contained in an open concrete box and the water passes through it by gravity. Such filters often form part of urban purification plants but they require more competent supervision than the ordinary small community can afford.

In the *pressure filter* the filtering medium is enclosed in a sealed metal drum to which the water is introduced under pressure. If the turbidity of the raw water is less than 40 parts per million (see above) the pretreatment may be carried out in the drum, but where the turbidity is greater than this the filter alone is not sufficient to ensure complete removal of suspended solids, and in such cases the water must be clarified before entering the filter. These filters also require competent supervision, but of a standard that is available on most plantations. The usual rate at which pressure filters work is 80 to 100 gallons of water per square foot of filtering surface per hour, but they may cope with more than that if the character of the raw water permits.

These pressure filters can work under a maximum pressure of 100 lbs. per square inch, but it is usual to employ a much lower pressure. The minimum pressure recommended is about 12 to 17 lbs. per square inch (i.e. with a head of 30 to 40 feet). If the supply system has a fall of less than this minimum it is necessary to provide the required head by means of a pump. These filters are cleaned by first blowing air through the dirty sand and then "back-washing", i.e. passing water in the reverse direction (from bottom to top) through the filtering medium, and so washing away the impurities that were held up by the upper part of the sand, and leaving the medium clean and ready for use. For this purpose the water used should be filtered water (so as not to contaminate the lower part of the filter) and it should be under a pressure head of 25 to 30ft. Back-washing may be required daily (or at longer intervals depending on the conditions of the new raw water) and the wash water with its load of impurities must be run to waste. Allowance for this must be made in calculating the total amount of water required. A typical layout of a pressure filter system is illustrated in Fig. No. 14.

In *filtration* the filter consists of a "candle" constructed of metal washers, kept separate by small bosses on their surfaces (e.g. the Metafilter (see Fig. No. 15), or of spirally wound wire on a hollow core (e.g. the Stellar filter, see Fig. No. 16). One or more of these

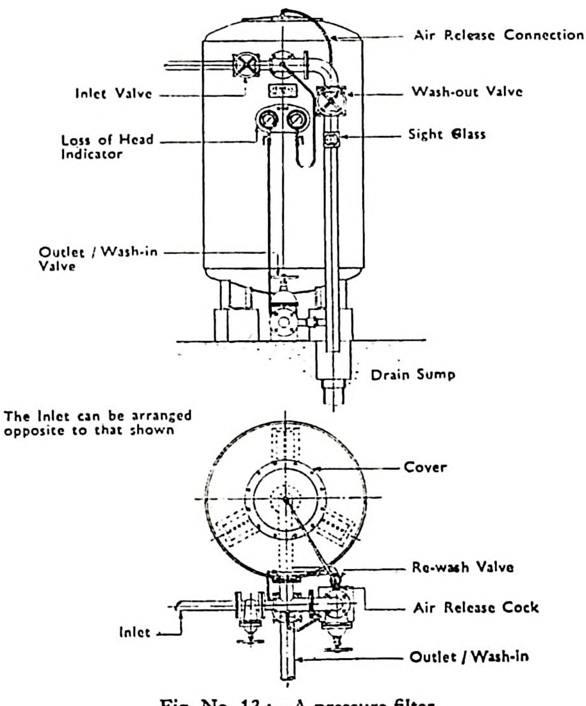
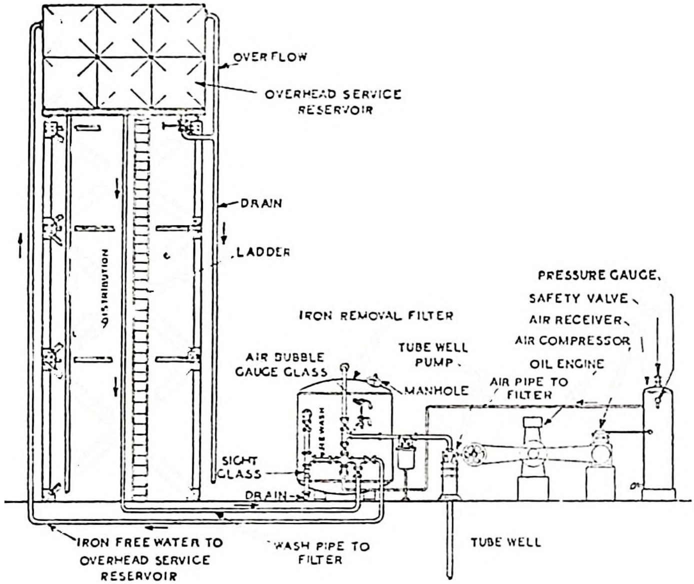


Fig. No. 13 :—A pressure filter.



(By kind permission of Jewell Filter Co. Ltd.)

Fig. No. 14 :—A typical layout of a pressure filter and overhead storage tank from which the water for back-washing the filter is obtained

candles are contained in a glass or metal cylinder, into which certain amounts of diatomaceous earth (Kieselguhr) are introduced. The raw water is then run into the cylinder under pressure and as it escapes into the candle it carries the diatomaceous earth and deposits it as a coating on the outer surface of the washers or wire. So long as the necessary pressure of water is maintained the diatomaceous earth forms a highly effective filtering layer on the candle. The first water discharged from the filter should be run to waste till it comes clear.

As filtration proceeds the slime and dirt extracted from the water are retained on the surface of the diatomite till eventually the pressure required to force the water through becomes excessive and the flow diminishes to a uselessly low rate. When this occurs filtered water should be sent the reverse way through the candles. This causes the diatomite layer to fall off the candle to the bottom of the cylinder. The filtering may then be resumed (running the first water to waste as before). It is possible to repeat this procedure a number of times, but sooner or later the re-used diatomite must be discarded by back-washing it out of the filter unit through the sludge valve in the bottom of the cylinder. When the waste runs clear the valve is closed; a fresh quantity of diatomite is introduced and the filter restarted.

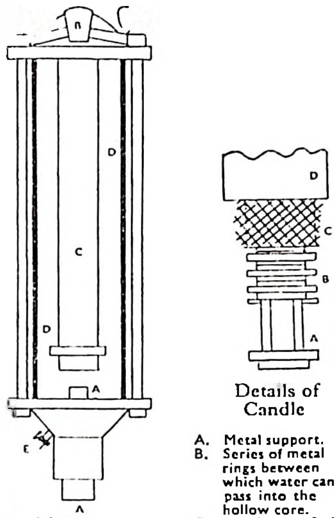


Fig. No. 15:—
Section of a Metafilter*

The candles are mounted in batteries in the cylinders and their number depends on the amount of water and rate of filtration required. Filters of this type are used by the Services (especially on the standard water carts) and they are made in various sizes capable of filtering from 25 (i.e. for domestic filter) to 16,000 gallons per hour. Larger sizes may be made or units can be worked in parallel.

The makers claim that Metafilters, without the help of their Kieselguhr filter beds, will filter out particles down to 0·0001 inches. They supply Kieselguhrs with textures of three different sizes which they call Metasil A, B and C. Metasil A is relatively open and will pass liquid through rapidly. It is a fine filtering medium but not quite fine enough to remove bacteria completely. Metasil B has smaller particles and when a filter bed of this grade is used a filtrate free of bacteria, but not viruses, is produced. Metasil C is finer still and slower filtering. The company also produces "Metasil ALAG" in which a silver coating has been given to the Kieselguhr particles (somewhat similar to the Sterasyl and Katadyn filters—see below). The silver disinfects the water and prevents the growth of bacteria in the filter bed. There are several other varieties of Metasil.

The Katadyn Filter† : consists of one or more ceramic filter candles (see Fig. No. 17), the hollow cores of which have been filled with sand that has been impregnated with activated silver (known as "Katadyn"). The water is filtered through the candles and the sand and in the process takes up minute quantities of the silver. This silver has bactericidal properties in clear water and the disinfecting power remains on storage, provided the water contains, as suspended or colloidal matter, no sulphides, no iodine in excess of 0·05 ppm, no chlorides in excess of 25 to 40 ppm and is not hard. The water is thus filtered and disinfected in one process. Katadyn filters are made in different sizes that contain from one to thirty candles and, depending upon the water pressure,

*Obtainable from Paterson Candy International Ltd.
†Obtainable from Messrs. C. M. Wales, Ltd.

are capable of dealing with 15 to 1,000 gallons per hour. With normal usage Katadyn filter candles will last for 2 years.

The Sterasyl (made by Berkefeld) and the Katadyn domestic filters contain activated silver which makes them self-sterilising so they do not require boiling.

All the impurities that are filtered from the water are deposited on the outside of the candles. Regular cleaning of the candles with a soft brush or cloth is, therefore, required, and care must be taken when removing the cylinder to see that the candles are not bumped and cracked. The makers claim that "for all normal purposes the effective life of a candle is from two to five years".

Disinfection

There are a number of methods used for disinfection of water supplies, e.g. chlorination, silver treatment, ultra-violet radiation, etc. Whatever method is employed it should be the last stage, or the finishing process, in the purification, before the water is distributed.

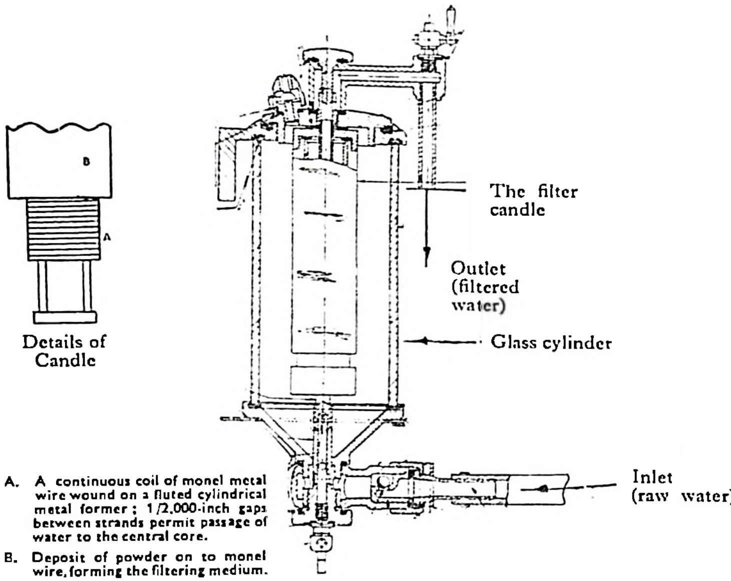


Fig. No. 16:—Section of a Stellar Filter.*

*Obtainable from Paterson Candy International Ltd.

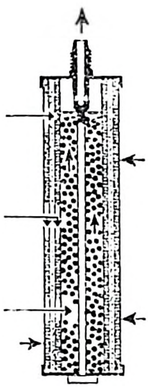


Fig. No. 17 :—
Section of a Katadyn filter candle.
(by kind permission of Messrs. C. M. Wales)

Chlorination: The most commonly used method of disinfecting communal water supplies is chlorination. It is most effective when the water is reasonably bright and clear. There are a number of ways of applying chlorine to water and various types of equipment for this purpose may be purchased from any of the better known water engineering firms. One type is illustrated in Fig. No. 10.

For small supplies the method should be simple and any apparatus which has tiny openings (that are liable to blockage), should be avoided. In rural areas chlorine is generally applied as a solution of calcium hypochlorite (bleaching powder). The amount of chlorine available from ordinary bleaching powder is 25% to 30% (this point should be carefully checked at the time of purchase) but the powder is liable to lose some of its chlorine during storage and on exposure to air. Stabilised forms of bleaching powder (i.e. chlorinated lime with an excess of unslaked lime), however, are available (e.g. "Tropical Chloride of Lime" made by I.C.I.: "Stabo-Chlor": "Caporit": etc.) and only such a type should be employed.

When chlorine is added to water it immediately combines with any organic matter present in the water and the chlorine so deviated is not available as a bactericide. It is, therefore, necessary to add sufficient chlorine so that, after this combination has occurred, there will be adequate chlorine left (i.e. "residual chlorine") to destroy the micro-organisms. Chlorine must be in contact with bacteria for some time if it is to kill them and the amount of chlorine required for this has an inverse relationship with the contact time. Thus the dosage of chlorine that should be applied to a particular water depends on the organic content of that water and the time during which the chlorine will be in contact with the germs.

A simple method of ascertaining the correct dosage of chlorine is to make up a quantity of solution of bleaching powder of known strength and to test it against the water to be treated. For example—10 grammes (150 grains) of bleaching powder of 25% strength is dissolved in 5 litres (8.79 pints) of water to give a stock solution containing available chlorine 500 parts per million (ppm) parts of water. One part of this stock solution should be added to 100 parts of the water to be treated. This would give a dosage of chlorine of ͻ ppm. If the chlorine residual after 30 minutes contact were found (by means of the DPD test—see below) to be greater than 0.5 ppm, the dosage should be reduced, and if less than

0.5 ppm the dosage should be increased. Once the dosage is determined the required amount may be added to a known volume of water to be retained in a tank for 30 minutes or it may be applied by a drip feed adjusted to supply a certain amount of the chlorine solution, within a certain time to a volume of moving water known to pass a particular point in the same time.

Estimation of Free and Combined Residual Chlorine in Water.

Now that the Ortho-Tolidine test has had to be discontinued, a suitable alternative is provided by the DPD method (Diethyl-p-phenylene-diamine sulphate), also known as p-amino-diethyl-aniline sulphate, first developed by Dr. Palin, and known as the Palin-DPD method.

The reagent can be bought in a pure form, and in conjunction with potassium iodide, can be used to estimate the concentration of "free" chlorine (i.e. hypochlorus acid and hyposulphite ion), monochloramine (NH_2Cl) and dichloramine ($NHCl_2$) in successive stages. The reagent produces a red colour with "free" chlorine (and also with chlorine dioxide), but gives no colour with chloramines until potassium iodide is added. The monochloramine releases free iodine from potassium iodide and the iodine gives the same colour as the equivalent concentration of chlorine combined with chloramine. (Both intensity and colour are identical.) An excess of KI is required to release iodine from dichloramine, but otherwise the reaction is the same. For a small user of the test, it is convenient to buy the compressed tablets sold for for the test by BDH, and for measuring the colour developed, standard discs are also available for use in both the Lovibond Nessleriser and the Lovibond Comparator.

Tablets

No. 1 tablet contains DPD and complexing agent, etc. This tablet gives a colour with free chlorine only.

No. 2 is a small tablet containing a *limited* quantity of KI. Iodine is released from monochloramine only. Thus tablets 1 and 2 together give Free and monochloramine or separately Free followed by monochloramine.

No. 3 tablet is a larger KI tablet which releases iodine from dichloramine (also nitrogen trichloride).

Thus tablets 1 and 3 give a total chlorine content. Tablet 1 followed by 2 followed by 3 give separately the quantities of free chlorine; free chlorine and monochloramine; free chlorine and monochloramine and dichloramine.

Discs for measuring the intensity of colour produced are:—

For Comparator (10 ml samples):

Disc 3/40 A Range 0–1.0 in 9 steps
Discs 3/40 B Range 0–4.0 in 9 steps

For *Nessleriser* 50 ml samples:

NDP 0.05 to 0.50.

Residual chlorine present in the strength of 0.5 parts per million parts of water after thirty minutes contact, though a somewhat high dose, is usually advisable to ensure adequate disinfection under rural conditions. The cercariae of schistosoma are killed during thirty minutes contact with 0.5 to 0.6 ppm residual chlorine but 2.0 ppm for the same contact time may be required to destroy the cysts of amoebic dysentery. Chlorine in such a dosage would give the water a chlorinous taste and make dechlorination (see below) necessary. Filtration is a much better and safer method of preventing the waterborne infection with these cysts.

Super-chlorination consists in the application of a dose of chlorine which considerably exceeds that required to disinfect the water. After a suitable contact time the water is dechlorinated. It is the process to use for single applications, e.g. in an emergency; after completing or repairing a well and before putting it into use, etc.

The method is as follows :—To super-chlorinate use ½ oz. of 25% stabilised bleaching powder to every 100 gallons of water to be treated (i.e. an application of chlorine at 10 ppm). Weigh out the required amount of powder, mix to a cream with some water and then dilute with more water to one bucketful. Add the bucketful of solution to the water, preferably while the tank etc. is filling; stirring during the addition: allow 5 to 10 minutes contact period and then dechlorinate by adding sodium thiosulphate crystals (dissolved in a bucket of water) at the rate of ⅓ oz. of crystals to every 100 gallons of water. Stir the treated water thoroughly.

(Note: To ascertain the amount of water to be treated in a well etc. see Appendix E)

For removing green growth and slime from the walls of the tanks apply a solution containing ½ lb. of 25% stabilised bleaching powder in 3 gallons of water. After a few minutes contact scrub the surface thoroughly and finally swill with water.

Disinfection by Silver

The purifying effect of silver on water has been known for centuries and it imparts no unpleasant taste to the water. The water to be treated must be clear (if necessary by prior sedimentation and filtration) and aeration helps the disinfection. Deviation of a portion of the silver occurs in the presence of chlorides, iron, hydrogen sulphide, or organic matter. The bactericidal properties of activated silver (Katadyn) were demonstrated by Krause in 1929 and are used in the Katadyn filters (see Fig. No. 17) and in the Electro-Katadyn Water Sterilizing Units.* The Unit consists of a cylindrical chamber holding a number of silver electrodes. The water goes through the chamber while a feeble direct current passes between the electrodes carrying silver ions into the

*Obtainable from the Katadyn Filter Co., Zurich ; and from C. M. Wales Ltd., Piltdown Lodge, Piltdown, Uckfield, Sussex.

water. The water is then retained in a storage tank for the required contact time (about 1 to 12 hours). The action continues so that the treated water is bactericidal and capable of disinfecting a further quantity of water (up to three-quarters of the original amount which may be added to it). Used in this way these Units will disinfect between 14,000 gallons and 1,440,000 gallons a day.

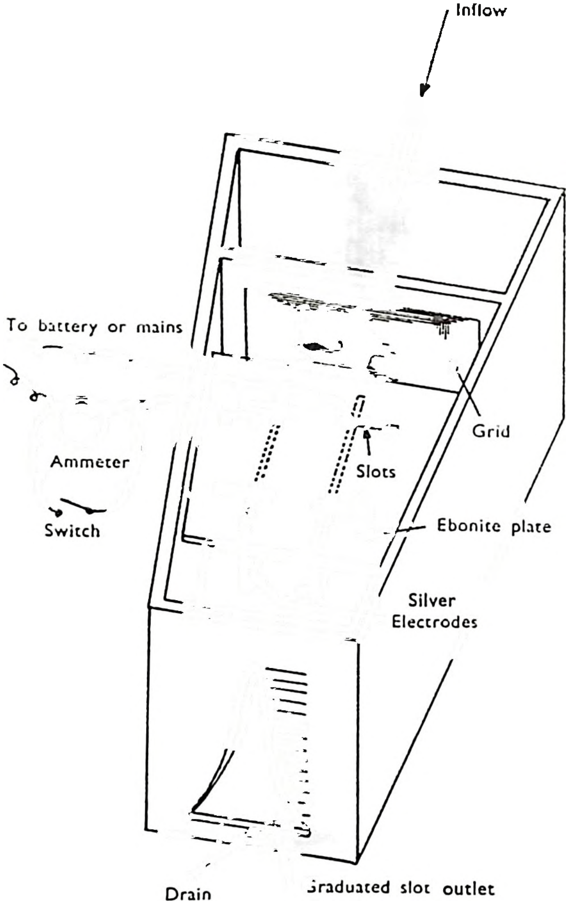


Fig. No. 18 :—An electro-silver water steriliser designed at the Tea Research Institute, Assam. The graduated slot and the rate of flow determine the depth that the silver electrodes are immersed in the water.

The bacteriologists of the Tea Research Institute, Tocklai, Assam as the result of their experience during the construction of the Assam/ China Road in 1942-45 devised a purification plant suitable for use on Tea Estates (see I.T.A. Memorandum No. 18 "Purification of Tea Estates' Water Supplies": May 1947). In this plant the water is sprayed (aerated) into a series of three settling tanks. (Alumino-ferric, approximately 1 lb. to 5,000 gallons may be added if necessary.) From the settling tanks the water passes through a slow sand filter, then through a home-made electro-silver sterilisation unit. (See Fig. No. 18).

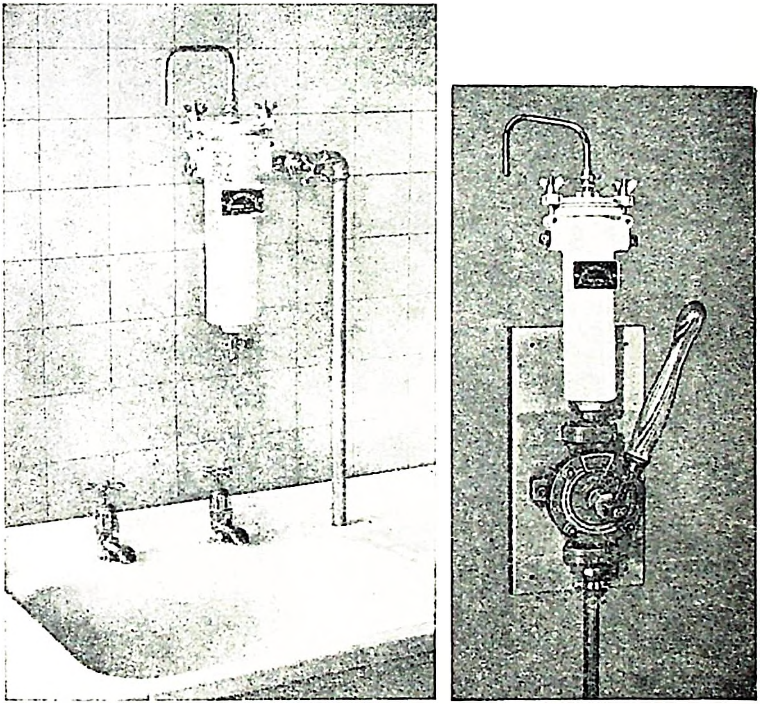


Fig. No. 19 :—Domestic pressure filters containing single Sterasyl filter candles. The pressure may be supplied by the mains, by a pump, or by gravity, but should not be less than 10lbs. per square inch (i.e. 23 feet head of water, approx), preferably 40 lbs. per sq. in. Filters with a number of candles for larger supplies are available.

(By kind permission of British Berkefeld Filters Ltd.)

This plant has proved effective and is usually adjusted to deal with 300 to 350 gallons of water an hour, or approximately 8,000 gallons in 24 hours.

Removal of Iron and Manganese.

Iron is present in most soils, and nearly all ground-waters, as they percolate through the earth, acquire some iron, though it may be only a minute quantity. Surface waters may also be affected. Manganese usually accompanies the iron but in smaller amounts. Waters that contain more than a trace of iron (0.3 parts per million is permissible but 1 part, or more, per million is excessive), have a flat metallic taste, and are undesirable for laundry or culinary uses (e.g. the iron combines with the tannin in tea to give the infusion an inky colour). When present even in traces the iron tends to accumulate in the pipes of a distribution system. That generally leads to the growth of "iron bacteria" which accentuate the undesirable taste and colour of the water and increase the tendency to blockage of the pipes. Ferruginous waters are unsuitable for boilers and for many industrial processes.

Iron is usually present in water in solution as ferrous bicarbonate (occasionally as higher oxides or in complex organic combinations). The exposure of such water to the air changes the soluble ferrous bicarbonate into the insoluble ferric hydroxide, which appears as an opalescence and then as a brown deposit. This reaction is utilised to free water of iron and the usual processes of open storage and filtration will remove the traces of iron present in most waters. Where this is inadequate the water should be aerated (see page 27), and the insoluble iron allowed to settle to the bottom of a storage tank, helped, if necessary, by the addition of a coagulant such as alumino-ferric (2½ grains per gallon of water). The water may then be filtered, but if most of the iron is not removed before filtration it is apt to cause blockage of the filters.

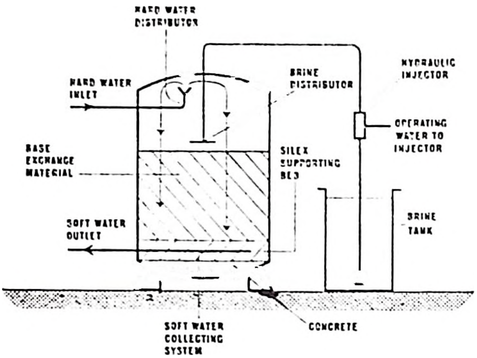
In some cases these methods are not sufficient and more complicated treatment, including the use of chemicals, may be required. Chlorination assists in precipitating iron from the water, and the 'lime' process of softening water is also effective in extracting iron. Before embarking on such processes, however, it is wise to obtain the advice of water engineers or chemists.

Special pressure filters designed to remove iron and manganese from water are obtainable from the leading water engineering companies. In these filters there is a layer of hard, dark, granular, sand-like substance on top of the sand-bed, and as the water passes through this layer the desired chemical change occurs. The insoluble iron is then extracted as the water continues through the ordinary filtering medium, and is discharged from the filter during back washing. Filters of this type have proved efficient on certain tea estates in Assam.

Hardness. Hardness, or the soap-destroying property, of certain waters is most undesirable for such waters not only form an insoluble curd with soap but deposit lime-scale ("fur") in boilers and hot water systems. Hardness has little or no effect on synthetic detergents so the need for household water-softeners has been reduced. If the hardness is removed by boiling it is known as "temporary hardness" and it is due to the presence in solution in the water of the bicarbonates of calcium and magnesium. These substances are reduced by heat (160°F, or more) to the insoluble carbonates and precipitated out of the water. If the hardness does not disappear with boiling it is known as "permanent hardness" and is caused by the presence of sulphates, chlorides or nitrates of calcium and magnesium which remain in solution in spite of heat.

Of the methods of softening hard water the base-exchange process is the most suitable for small supplies. In it the water is passed through synthetic resins which have the power of absorbing calcium and magnesium and replacing them with their equivalents of sodium. This exchange takes place practically instantaneously but after a time the supply of sodium becomes exhausted and the resins have to be regenerated by passing a solution of sodium chloride (i.e. brine) through them. A typical water-softening plant consists of an enamelled cylinder almost filled with resins. The raw water enters at one point, passes through the resins, and is drawn off at another point entirely free of hardening salts. Once the quantity of water with which the apparatus can deal (this is usually marked on an attached meter) has passed through, the required amount of common salt (or brine may be used) is added through the top of the cylinder. The water on entry dissolves the salt, carries it through the resins, depositing sodium and acquiring calcium and magnesium on the way, and is then discarded. Though this interchange takes only a few minutes it is necessary to continue running the water to waste till all the salt has been removed from the plant before putting it into use again. Plants which are automatically regenerated by brine from an adjacent cistern are also obtainable. (See Fig. No. 20.)

Removal of Salts. Sodium chloride and other salts may be removed from water by "distillation" (i.e. by boiling the water and condensing the steam in a still) or by "artificial distillation" (an ion-exchange process), but both methods are so expensive as to be practicable only in special cases and/or for limited amounts of water (e.g. drinking water only; water for boilers; etc.) It is usually better to obtain another, salt-free source of supply, where that is possible. Small ion-exchange plants, capable of providing a few gallons of fresh water from salt water daily and suitable for individual dwellings are obtainable and bigger sets are made by most of the water-engineering firms (e.g. Paterson Candy International Ltd.).



(By kind permission of Permutit & Co. Ltd.)

Fig. No. 20 :—A domestic water softener

PURIFICATION OF WATER ON A DOMESTIC OR INDIVIDUAL SCALE

The principal methods of purifying water on a small scale are, boiling, chemical disinfection and filtration. These methods may be used singly or in combination but if more than filtration is needed the boiling or chemical disinfection should be done last.

Disinfection.

Boiling is the most satisfactory way of destroying pathogenic organisms in water, and it is equally effective whether the water is clear or cloudy, whether it is relatively pure or heavily contaminated with organic matter. Boiling destroys all forms of disease-producing organisms usually encountered in water, whether they be bacteria, viruses, spores, cysts or ova. To be safe the water must be brought to a good "rolling" boil (not just simmering) and kept there for some minutes. Boiling drives out the gases dissolved in the water and gives it a flat taste, but if the water is left for a few hours in a partly filled container, even though the mouth of the container is covered, it will absorb air and lose its flat, boiled taste. It is wise to store the water in the vessel in which it was boiled. Avoid pouring the water from one receptacle to another with the object of aerating or cooling it as that introduces a risk of re-contamination.

Chlorine is a good disinfectant for drinking water as it is effective against the bacteria associated with water-borne disease. In its usual doses, however, it is ineffective against the cysts of amoebic dysentery, ova of worms, cercariae and organisms embedded in solid particles.

Chlorine is easiest to apply in the form of a solution and a useful solution is one which contains 1% available chlorine, e.g. Milton Antiseptic; (Dakin's solution contains 0.5% available chlorine, and bleaching powder holds 25% to 30% available chlorine). About 2½ tablespoonfuls of bleaching powder dissolved in one quart of water will give a 1% (approx.) chlorine solution. To chlorinate the water add 3 drops of 1% solution to each quart of water to be treated (2 tablespoonfuls to 32 Imperial gallons), mix thoroughly and allow it to stand for 20 minutes or longer before using the water.

Chlorine may be obtained in tablet form as "Sterotabs" (formerly known as "Halazone") and obtainable from Boots the Chemists, Ltd. in the U.K.); the directions for use are on the packages.

Iodine is a first-class disinfecting agent and 2 drops of the ordinary tincture of iodine are sufficient to treat 1 quart of water. Water that is cloudy or muddy, or water that has a noticeable colour even when clear is not suitable for disinfection by iodine. Filtering may render the water fit for treatment with iodine. If the water is heavily polluted the dose should be doubled. Though the higher dosage is harmless it will give the water a medicinal taste. To remove any medicinal taste add 7% solution of sodium thiosulphate in a quantity equal to the amount of iodine added.

Iodine compounds for the disinfection of water have been put into tablet form, e.g. "Potable Aqua Tablets" (obtainable from Frost Laboratories, 430 Lexington St., Auburndale, Boston 66, Massachusetts); full directions for use are given on the packages. These tablets are among the most useful disinfection devices developed to date and they are effective against amoeba cysts, cercariae, leptospira and some of the viruses.

Domestic Filters

There are two types of domestic filter in common use, viz. the sand filter and the candle filter. In the tropics the supervision of all domestic filters should not be left to the servants. It is a task for the householder himself or his wife.

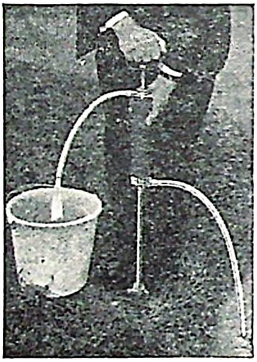
A Household Sand Filter (see Fig. No. 4) is easily made with a steel drum, sand and gravel, and though they cannot be relied upon (unless operated with skill) to remove bacteria, they are generally effective against the larger organisms such as amoebic cysts, eggs of worms, etc. The upper layer of the sand has to be removed periodically, and the filter, if neglected, is liable to become a breeding place for bacteria. Sand filters are, therefore, not recommended for ordinary domestic use. *Household Pressure Filters* dealing with 1,800 gallons or more in the day are made by he leading water-engineering firms. They are reliable, but like all filters, require some attention, e.g. back-washing etc.

There are several types of *candle filters* but only those with fine-grained candles are suitable for household purposes unless the water is boiled or disinfected after filtration. *Ceramic Filters* with fine-grained candles (e.g. Chamberland 1.2 and Selas 015) will remove pathogenic bacteria but they must be carefully examined at frequent intervals to ensure that there are no cracks in the candles or leaks that would let the water through without filtration. At least once a week the candles should be scrubbed with a grease-free brush and then boiled for 20 minutes. This should also be done if the candle becomes coated or clogged.

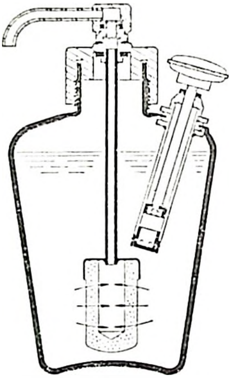
Provided this care is taken the filtered water may be used without boiling, or disinfection.

Another kind of candle filter employs Kieselguhr (diatomaceous earth) as the filtering medium. Only the fine-grained type should be obtained. The Metafilter and Stellar filter (which have already been described) are of this type and are available in sizes suitable for household purposes. The Berkefeld* (see Fig. No. 22) is another well-known domestic filter using Kieselguhr candles.

Most leading manufacturers of water appliances make an apparatus consisting of a filter candle housed in a casing to which a hand pump and inlet and outlet lengths of hose are attached (see Fig. No. 21). With such a unit a traveller may pump water from a stream or lake through the filter into a suitable vessel. The apparatus, which is some 14 inches long and weighs about 7 pounds when packed for transport, will filter approximately 15 to 25 gallons of water per hour. A smaller and very much lighter type called "The New Traveller" is also available (Fig. No. 21)*. If "silver" is incorporated in the candle (e.g. Katadyn, Sterasyl, Metafilter, etc.) the water will not only be cleared of such things as cysts, ova, cercariae and suspended matter but will also be



A



B

Fig. No. 21:—Two types of portable filters suitable for travellers, campers etc. They each use silver-impregnated candles. The method of operating (a) is illustrated. To operate (b) remove the cap, fill the container with the water, screw the cap down tightly and pump for about 30 seconds.

(By kind permission of British Berkefeld Filters Ltd.)

*Obtainable from British Berkefeld Filters Ltd.

freed (after 20 minutes retention in a non-metal container) of pathogenic bacteria (*see also page* 33). These silver-impregnated candles are self-serilising and do not need to be boiled.

In tests carried out at the London School of Hygiene and Tropical Medicine, Professor Fulton added live Coxsackie virus to a quantity of distilled water, and passed the water through a Sterasyl filter candle. The filtrate was allowed to stand in a test tube at room temperature for five minutes, when it was injected into mice, and found to be non-infective. This result was most probably due to the sterilising effect of the silver as the pores in the filter were too big to hold back organisms as minute as viruses.

Household Water Containers : Where water has to be carried from a well or standpipe it is the common practice to keep some water in the house. Water that has been treated with chlorine, iodine or silver retains some residual protection for a short time but water that has been purified by boiling or filtering may be recontaminated immediately. It is therefore, essential that the stored water be shielded against pollution. The containers used for storage must be kept clean and regularly rinsed with boiling water or washed out with a strong chloride of lime solution (e.g. 1½ ozs. to 5 gallons water) which is later removed by swilling with wholesome water. The containers should have a cover which fits closely enough to prevent the entry of insects, dust and other impurities, and cups and other utensils should not be dipped in the water. A container with a narrow neck is an advantage as it prevents this. The water should be poured from the container or drawn off through a built-in tap or spigot.

Aerated Waters : There is a common belief that soda and other aerated waters are safe, but this is true only if they have been made with wholesome water and the necessary care against contamination has been exercised during manufacture. In bottled water bacteria gradually decrease in numbers but the cysts of amoebic dysentery and ova of certain parasites harmful to man may survive long storage. Carbon dioxide acts on some bacteria only, so carbonated beverages are not necessarily safe.

Swimming Pools: Many estate and mine bungalows now have bathing pools located in their compounds. The pools are generally small and intended solely for the use of the family and a few friends. Though many allegations of infections acquired from swimming pools are ill-founded, there are undoubted risks where pools are inadequately supervised. The main dangers are from human sources, but in countries like Malaya there are also risks from animals, e.g. leptospirosis from pollution of the water by rats etc.

Pools having a good natural flow of water through them can be satisfactory but they are only as safe as the water in them, and its safety depends (as described in the preceding pages) upon its source and its liability to pollution. The precautions already mentioned should be carefully followed.

It is the general practice for the bungalow pool to be filled with clean water and then to be emptied, cleansed and refilled at intervals of a few days or even a few weeks. This method of "fill and empty" is not by itself satisfactory as the sanitary standard of the water deteriorates after a brief period of use. It should be reinforced by the periodical addition to the pool water of a disinfectant. Disinfection by the electro-silver method (see pp. 37–40) is suitable, or chlorine may be used. In the latter case 1 oz. of stabilised bleaching powder is required for every 1,000 gallons of water in the pool. The required amount of bleaching powder is dissolved in cold water in a bucket. After stirring thoroughly, allow it to settle and then apply the solution as evenly as possible over the whole surface of the water in the pool. This may be done by means of a watering can or a stirrup pump. The disinfectant should be added to the fresh water and then applied each evening when bathing for the day is finished. It is a good thing to check the chlorination by taking samples of the water from a few places in the pool half an hour after the application of the bleaching powder. The amount of residual chlorine present in the water can then be tested with the DPD reagent as described on page 36. There should be a residual chlorine of at least 1 ppm and the amount of bleaching powder added should be sufficient to ensure this concentration.

The "fill and empty" method, augmented by disinfection, is suitable only for pools holding less than 20,000 gallons of water. For pools with a capacity in excess of this it is preferable to install a continuous circulation system with a filtration aeration and chlorination plant as is done at all modern public swimming baths.

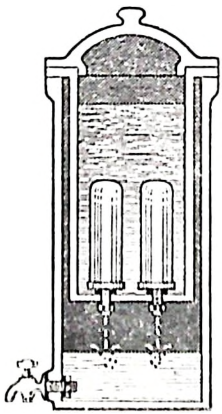


Fig. No. 22:—A domestic filter using Kieselguhr candles.

APPENDIX A

Chemical Standards for Drinking Water.

(*a*) (suggested by WHO Study Group). The following substances may be present in the quantities designated "permissible" and the water would be generally acceptable by consumers. Values greater than those marked excessive would markedly impair the potability of the water.

Substance	*Concentrations in parts per million (i.e. mg per litre).*	
	Permissible	*Excessive*
Total solids	500	1,500
Colour	5 units*	50 units*
Turbidity	5 units†	25 units†
Taste — unobjectionable ...		
Odour — unobjectionable		
Iron (Fe)	0.3	1.0
Manganese (Mn)	0.1	0.5
Copper (Cu)	1.0	1.5
Zinc (Zn)	5.0	15.0
Calcium (Ca)	75	200
Magnesium (Mg)	50	150
Sulphate (SO_4)	200	400
Chloride (Cl)	200	600
Magnesium + Sodium Sulphate	500	1,000
Phenolic Substances (such as Phenol)	0.001	0.002

*Platinum Cobalt Scale. †Turbidity Units.

for further details consult the standard works, e.g.
"Water Treatment and Examination". Ed. W. S. Holden. Churchill: London, 1970.
"Standard Methods" by U.S. Public Health Association; etc.)

The water should be neutral or slightly alkaline (pH 7.0 to 8.5) with a pH never less than pH 6.5 or more than pH 9.2.

Fluorides in concentrations of one part per million are quite safe and markedly reduce the incidence of dental caries in the community. Public Health Authorities recommend that waters with a lower content than that should have sufficient sodium fluoride added to make the concentration up to 1 ppm. Public supplies should not ordinarily contain more than 1.5 ppm fluorides as effects, varying from slight mottling of the teeth to more serious consequences, depending upon the degree of excess, may occur.

Nitrates in excess of 50 parts per million (as NO_3) may adversely affect the red colouring matter of the blood (haemoglobin) in infants.

(*b*) There are a number of substances which are not harmful in themselves but which are used as indicators of contamination. They are all increased in the case of pollution of animal origin.

The usual upper limits are :—

Oxygen absorbed from permanganate	2 parts per million
Albuminoid ammonia	0.1 ppm.
Free and saline ammonia ...	0.05 ppm.
Nitrites	a trace

A rough guide is—if the albuminoid ammonia is as much as 0.08 parts per million the free and saline ammonia should not exceed 0.05 parts per million. In all sewage, and most sewage effluents, the free ammonia exceeds the albuminoid ammonia. If pollution from human sources can definitely be excluded higher values than those mentioned may be allowed.

(*c*) (suggested by WHO Group). The following substances, if present in drinking water in excess of the concentrations mentioned would give rise to actual danger to health and would constitute grounds for the rejection of the water for domestic purposes :—

Substance	*Maximum allowable concentration*
Lead (as Pb)	0.1 parts per million
Selenium (as Se)	0.05 parts per million
Arsenic (as As)	0.2 parts per million
Chromium (as Cr hexavalent) ...	0.05 parts per million
Cyanide (as CN)	0.01 parts per million

APPENDIX B

Methods of Collecting Water Samples for Chemical Examination

If the sample is taken from a standpipe, the water should be allowed to run for a few minutes before drawing the sample. The mouth of the pipe should be washed with running water. Allow the water to flow slowly into the bottle, down the side, to avoid aeration.

A sample is obtained from a well by lowering a clean bucket into the water and filling the bucket so as not to disturb the sediment at the bottom of the well. The bottle is filled from the bucket by means of a clean cup. New wells should be allowed to settle before taking samples.

Samples should be collected in a thoroughly clean Winchester Quart bottle (about ½ gallon) but if that is not available use one or more ordinary bottles capable of holding ½ gallon between them. The corks and bottles should be clean. The bottle or bottles should be rinsed in the water to be sampled and then filled up to the top, stopper inserted and securely tied down.

If the water passes through cisterns, storage tanks or a system of distributing pipes, it is better to take samples from the pipe as it is used for consumption.

Fill the bottle under normal weather conditions, label clearly with brief description of the water whether Well, Stream, Tank etc. and its uses. Date and Time of collection of the samples should be stated. A covering letter should give as much information as possible as to source of supply, liability to pollution etc.

APPENDIX C

Bacteriological Standards for Drinking Water recommended by the WHO Study Group

"Some public drinking-water supplies are chlorinated or otherwise disinfected before being distributed; others are not. Effective chlorination yields a water which is virtually free from coliform organisms i.e. these organisms are absent in 100-ml portions; if communal supplies which are distributed without treatment or disinfection cannot be maintained to the bacteriological standard established for treated and disinfected water, steps should be taken to institute chlorination or disinfection, or other treatment, of these supplies.

"A standard demanding that coliform organisms be absent from each 100-ml sample of water entering the distribution system—whether the water be disinfected or naturally pure—and from at least 90% of the samples taken from the distribution system can be applied in many parts of the world. Although there is no doubt that this is a standard that should be aimed at everywhere, there are many areas in which the attainment of such a standard is not economically or technically practicable.

"In these circumstances there would appear to be economic and technical reasons for establishing different bacteriological standards for public water-supplies which are treated or disinfected and for those which are not treated. The following bacteriological standards are recommended for treated and untreated supplies for present use throughout the world, with the hope that improvements in economic and technical resources will permit stricter standards to be adopted in the future.

"The standards described below are based on the assumption that frequent samples of water will be taken...For each individual sample, coliform density is estimated in terms of the 'most probable number (M.P.N.)' in 100-ml of water, or 'MPN' index... The use of the MPN index is recommended as the basis of quantitative estimation of coliform density after full recognition of its limitations. However, the value of the index is sufficiently enhanced by the use of data from a series of samples to warrant its use in the recommended standards.

"*Treated water*

" In 90% of the samples examined throughout any year, coliform bacteria shall not be detected or the MPN index of coliform micro-organisms shall be less than 1.0 None of the samples shall have an MPN index of coliform bacteria in excess of 10.

"An MPN index of 8-10 should not occur in consecutive samples. With the examination of five 10-ml portions of a sample, this would preclude three of the five 10-ml portions (an MPN index of 9.2) being positive in consecutive samples.

"In any instance in which two consecutive samples show an MPN index of coliform bacteria in excess of 8, an additional sample or samples from the same sampling point should be examined without delay. This is the minimum action that should be taken. It may also be desirable to examine samples from several points in the distribution system and to supplement these with samples collected from sources, reservoirs, pumping stations and treatment points. In addition, the operation of all treatment processes should be investigated immediately.

"*Untreated water*

"In 90% of the samples examined throughout any year, the MPN index of coliform micro-organisms should be less than 10. None of the samples should show an MPN index greater than 20.

"An MPN index of 15 or more should not be permitted in consecutive samples. With the examination of five 10-ml portions of a sample, this would preclude four of the five 10-ml portions (an MPN index of 16) being positive in consecutive samples. If the MPN index is consistently 20 or greater, application of treatment to the water-supply should be considered.

"In any instance in which two consecutive samples show an MPN index of coliform organisms greater than 10, an additional sample or samples from the same sampling point should be examined immediately. It may also be desirable to examine samples from several points in the distribution system and to supplement these with samples collected from sources, reservoirs and pumping stations.

"When accurate and complete data concerning the sanitary conditions at the sources of an untreated water-supply, covering all possible points of pollution, are available and indicate that indices higher than the established maximum may bear little relation to potential health hazards, the local health and water-supply authorities should be responsible for ruling that such higher indices do not constitute need for treatment of the water."

APPENDIX D

Collection of Water Samples for Bacteriological Examination

Samples of water should be collected and sent for examination in sterilised glass stoppered bottles of approximately 280 ml. (about ½ pint) capacity.

If the sample of water to be examined is likely to contain traces of chlorine this fact should be stated when applying to the laboratory for the bottles, as bottles specially prepared for collecting such samples have to be supplied.

If the sample will necessarily take more than three hours to reach the laboratory it should be dispatched packed in ice (in an insulated box if possible).

The best time to collect a sample of water is about 7.30 a.m.

The sterile bottle should be opened only at the moment it is required for filling with the sample of water.

Carefully remove the paper cap covering the mouth of the bottle. Hold the bottle at the bottom, cautiously remove the stopper with the other hand and hold it in the fingers until the bottle is filled. The stopper should not be laid down or allowed to touch anything. When the bottle is full replace the stopper, tie the paper cap round, label and despatch.

Collection of Water from a Tap: Remove any external fittings such as anti-splash nozzle, rubber tubing, etc. Turn the tap on full and allow the water to run to waste for two or three minutes. Then turn the tap off, clean the outside with a clean dry cloth, flame the tap with a blow lamp or a piece of cotton wool soaked in methylated spirits for two or three minutes. Cool the tap by opening it and allowing the water to run to waste for a few seconds, then fill the bottle with the water running gently, so as to avoid splashing. Replace the stopper and paper cap, label and despatch.

Collection from a Stream, Lake, Reservoir, Spring, or Shallow Well: Remove the paper cap and the stopper as described above. Hold the bottle from the bottom and plunge it neck downwards to a depth of about one foot below the surface of the water. The bottle should then be rotated till the neck points slightly upwards, the mouth being directed towards the current. If no current exists as in the case of a shallow well, an artificial current should be created by moving the bottle horizontally.

When the bottle is completely full bring it up rapidly to the surface and immediately re-stopper it. Care should be taken that no water entering the bottle has previously come in contact with the hand. From a stream, lake, etc., water should not be collected too near the bank or too far away from the point of draw-off.

From a Deep Well fitted with a Hand Pump : The pump should be operated for about five minutes before collecting the sample. The mouth of the pump is sterilised by means of a blow lamp or cotton wool soaked in spirits as in the case of a tap. After sterilising the pump should be worked again until seven or eight gallons of water run to waste. Collect the sample by allowing the water to flow directly into the bottle from the pump.

From a Well without a Pump : Where the water has to be lifted up by means of a pail. Sterilise the pail by means of a blow lamp or by filling it up with boiling water and leaving it there for about ten minutes and then emptying it completely. After sterilising the pail it should not be allowed to touch the ground. Allow it to cool and lower it into the well without touching the sides. Fill the pail with water at a depth of about one foot from the surface, quickly withdraw it and fill the bottle. Care should be taken not to contaminate the stopper with the fingers. Replace the stopper and paper cap, label and despatch.

APPENDIX E

Estimation of Quantity of Water Available

The amount of water in a well may be ascertained by the use of the following formula :—

$$D^2 \times W \times 5 = \text{Gallons of water}$$

Where : D = Diameter of the well in feet
W = Depth of the water in feet

The amount of water in a full pipe may be ascertained by the following formula :—

$$G = D^2 \div 30$$

Where : G = number of gallons per foot length of pipe
and D = the internal diameter of the pipe in inches

The approximate amount of water that can be raised by means of a pump may be determined by the following formula :—

$$G = d^2 \times L \times 0.034 \times S$$

in which G = gallons discharged per minute
d = diameter of the pump in inches
L = length of stroke in feet
0.034 = gallons contained in 1 foot of 1-inch pipe
S = strokes per minute

An allowance of at least 10% must be made for inefficiency of the pump.

The approximate amount of water which can be raised by a hydraulic ram may be determined by the following formula :—

$$g = \frac{G \times H \times e}{h}$$

in which G = gallons per hour passing through the ram
H = head of water on the drive pipe
h = height in feet to which water is to be raised
e = efficiency of the ram
g = gallons per hour raised

The value of "e" varies considerably with different factors for "H" and "h", but averages about 60%

Head of Water and Pressure

1 foot head of water = 0.4331 lbs. per sq. inch pressure

1 pound per square inch pressure of water = 2.31 feet head

APPENDIX F

A Method of Jetting Small Diameter Wells (as used in India, described by P. C. Bose)

(Copied from WHO Manuscript Series No. 42)

"*Equipment :*

(1) tripod bamboo with 25ft. of clearance
(2) hand-operated lift and force pump (double-acting, with plunger 4 in. in diameter)
(3) 4 chain-type wrenches for gripping pipes
(4) 40 ft. of high quality hose, 1½ in. diameter.
(5) casing pipe, boring pipe, a swivel joint, steel cutter, pulley ropes, small hand tools.

The Jetting process :

(1) Dig a hole 5 ft. deep over which the tripod is mounted; this gives a reasonable starting depth.
(2) Attach the cutter to one end of a 1½ in. boring pipe, usually about 20 ft. in length; swivel to other end and place cutter end of pipe into the hole; suspend the pipe and swivel with pulleys from the tripod. The swivel joint allows water to enter the boring pipe from the hose while, at the same time, permitting the boring pipe to revolve without leaking.
(3) The hose is attached to the force pump which pumps water from a sump excavated in the ground near the well. (The pump suction pipe must be held clear of the bottom and sides to avoid sucking up mud and sand.)
(4) Jet-boring starts as the pumpers begin to force water into the boring pipe, at which point the men with the chain wrenches begin to turn the pipe.
(5) With the pressure of the water and the twisting action, the bore pipe begins to descend, and the jetted water begins to boil up around the sides of the bore pipe. This water is full of suspended matter and is really light mud. (*The more water that can be pumped through the pipe, the faster it will descend and the more and larger will be the suspended matter being washed out of the hole.*) In a short time the first 20 ft. of pipe will be at ground level. The swivel is removed; a second length of bore pipe is screwed on; the swivel is attached to this new length of pipe; and the pumping, jet-boring process begins again.
(6) One after another, the bore pipes are sunk until the desired depth is reached. This can be ascertained by examining the borings that are coming out of the well. (In West Bengal the water-bearing stratum is fairly fine sand with an effective size of from 0.16 mm to 0.02 mm.) When this stratum is reached boring is stopped; but pumping continues at that level for some time to clean the whole well.

(7) Jetting water is re-used by letting the dirt and sand settle out in the sump.

Placing the Screen

(1) The entire column of jet-boring pipe is now removed and the cutter is taken from the end of the bottom pipe.

(2) The well screen is now attached to the first length of well pipe, and the process of lowering the pipe is repeated with pumping, but through the screen. (Naturally there is little resistance in the recently jetted hole.) The screen is open at the bottom; and, when it is in the position desired, a pre-seated plug is dropped into the pipe and closes the hole at the bottom of the well screen, sealing the bottom of the well. A well-point with a closed end may also be used, although sometimes a few feet of hole may be lost while raising the the jet and lowering the well-point.

At this stage of the process, when water is being pumped down through the well pipe and screen, washed pebbles can be dropped into the hole around the out-side of the well pipe. These are heavy enough to settle against the upward stream of water, and the stream can be regulated to allow settlement. These pebbles of round, washed gravel, about 1/25th in. to 1/5th in. in size help form a gravel pack around the well, thus reducing the possibility that fine sand may get packed up around the screen and enter the well, with a consequent cutting-down of capacity. It should be added that, where sufficient sand-free water is being obtained without the attempt at gravel packing, the methods that have proved successful should be followed. Where trouble is encountered in getting water from fine-sand strata, it will be worth while to experiment with gravel packing. It is highly important that round, selected, washed material be used.

(3) A $\frac{3}{4}$ in. pipe is now lowered into the well pipe to the bottom, and a strong jet is pumped. This is done to clean the inside of the well pipe and screen off any possible sediment, sand or dirt.

Finishing the Well

(1) The space between the well pipe and the earth hole should be back-filled with compacted clay or concrete to prevent contamination from reaching the water table through this space.

(2) The well is now complete, and the hand-pump is installed and operated continuously for (at least) eight hours per day for three days to clean out the jetting water.

(3) A little hypochlorite of lime solution should be introduced into the well, allowed to stand for 24 hours, and then pumped out again.

(4) A watertight platform should be constructed to complete the well.

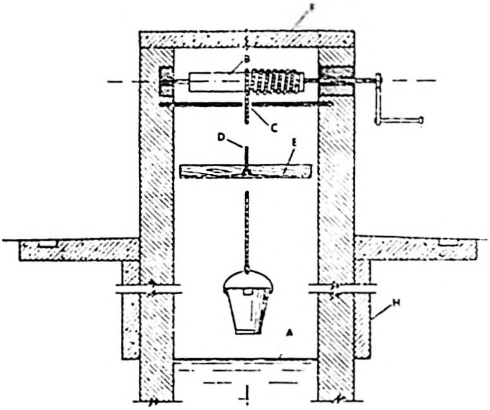
APPENDIX G

Relative Merits of Pumps for use in Small Water-Supply Systems

(Reproduced from WHO Monograph Series No. 42)

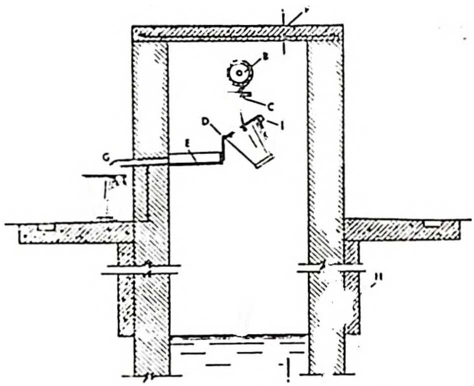
	POSITIVE DISPLACEMENT			VELOCITY			
Types of pumps	hand pumps, plunger type	motor, wind driven, plunger type	chain or continuous bucket	centrifugal	deep-well turbine	jet	air-lift
Efficiency range (%)	Low ; can be improved with double-acting cylinders : 25%-60%	Low ; can be improved with double-acting cylinders : 25%-60%	Low	good : 50%-85%	good : 65%-80%	Low : 40%-60%	Low : 25%-60%
Operation	Very simple	Simple	Very simple	Simple	More difficult ; needs attention	Simple ; air-locks can cause trouble	More difficult compressor needs attention
Maintenance	Simple, but valves and plunger require attention ; more difficult when pump cylinder is in the well	Same as hand pump ; maintenance of motors sometimes difficult in rural areas	Simple	Simple but attention necessary	More difficult and constant skilled attention is necessary	Simple but attention is necessary	Compressor needs constant attention

Capacity gallons/ minute	2-10	9-22	3-15	Very wide range : to unlimited	Very wide range ; 22-4,500	5-110	5-2,500
Head (feet)	Low	High	Low	16-1,650	75-1,650	Low	Low
Cost	Low, but higher when cylinder is in the well	Low, but higher when cylinder is in the well	Reasonable	Reasonable	Higher especially in deep wells	Reasonable	Reasonable
Advantages	Low speed ; easily understood by unskilled people ; low cost	Low cost ; simple ; low speed	Simple ; easy to operate and maintain	Efficient ; wide range of capacity and head	Good for small diameter bore-holes ; ease of operation	Moving parts on surface ; ease of operation	Moving parts on surface ; can pump turbid and sandy water
Dis-advantages	Low efficiency limited use ; maintenance more difficult when cylinder is in the well	Low efficiency ; limited use ; maintenance more difficult when cylinder is in the well	Low efficiency ; limited use	Moving parts and packing require attention	Moving parts in well : rather expensive ; requires good maintenance and operation	Limited application ; low efficiency ; moving parts require attention	Limited application low efficiency ; compressor requires constant attention
Power	Hand or animal	Wind, motor	Hand, animal wind, motor	Motor	Motor	Motor	Motor



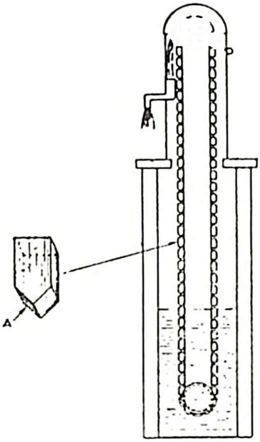
A — Water level in well
B — Windlass
C — Guide hole for rope
D — Stop hook
E — Trough
F — Tight cover, removable
H — Compacted clay, or concrete grout

A — Water level in well
B — Windlass
C — Guide hole for rope
D — Stop hook
E — Trough
F — Tight cover, removable
G — Discharge opening
H — Compacted clay, or concrete grout
I — Weight attached to top side of bucket to make it tilt when bucket is lowered onto water surface



(Reproduced from WHO Monograph Series No. 42)

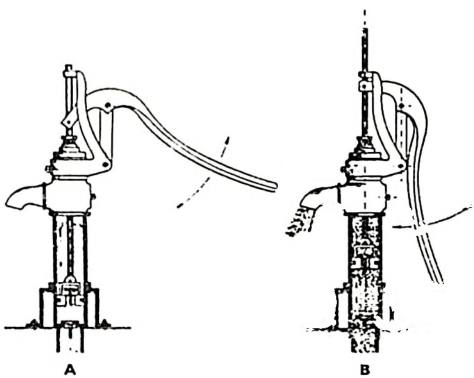
Fig. No. 23 :—A sanitary rope and bucket well.



Water is elevated in small buckets attached to a belt which continuously carries it to the surface. This is a fairly foolproof system, with little maintenance required. The original cost is considerable, but the pump could be made locally from local materials. Note the location of openings (A) of buckets.

(Reproduced from WHO Monograph Series No. 42)

Fig. No. 24 :—A continuous belt bucket pump



(Taken from WHO Monograph Series No. 42)

A – Down-stroke: Cylinder above plunger fills while valve at base of cylinder closes, and valve in plunger opens.
B – Upstroke: Cylinder full of water above plunger is expelled while, at the same time, valve at base of pump opens, filling cylinder below plunger. As plunger rises, a vacuum is formed below, pulling water into the cylinder.
When the cylinder is above ground, a foot valve is necessary to avoid pumping.

Fig. No. 25 :—A hand-operated Displacement Pump.

A self-priming lift-and-force pump which can be fitted to deliver water from wells to ground level, or to an overhead tank.

(By kind permission of Lee, Howl & Co. Ltd., Tipton, Staffs.)

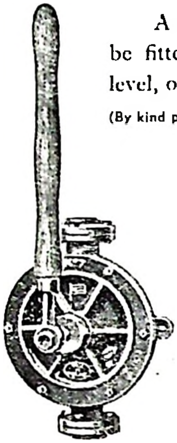
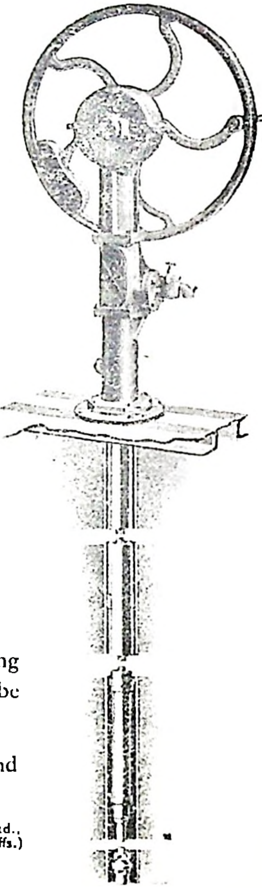


Fig. No. 26



Another type of self-priming lift-and-force pump which may be driven by hand or by power.

Suitable for use in villages and rural supplies.

(By kind permission of Lee, Howl & Co. Ltd., Tipton, Staffs.)

Fig. No. 27

SUPPLIERS OF WATER EQUIPMENT

THE PERMUTIT CO. LTD.,
Pemberton House, 632/652 London Road, Isleworth, Middlesex.

PATERSON CANDY INTERNATIONAL LTD.,
21 The Mall, Ealing, London, W.5.

UNITED FILTERS & ENGINEERING LTD.,
25 Raleigh Gardens, London Road, Mitcham CR4 3UP, Surrey.

BELL BROS. (MANCHESTER) LTD.,
Ashton Road, Denton, Manchester M34 3LS.

WILLIAM BOBY & CO. LTD.
23 High Street, Rickmansworth, Herts. WD3 1HP.

C. M. WALES LTD.,
Piltdown Lodge, Piltdown, Uckfield, Sussex.

PUBLICATIONS OF THE ROSS INSTITUTE

The Preservation of Personal Health in Warm Climates.
(*7th Edition, March,* 1971; *Revised and Reprinted, July* 1974)
(A handbook for those going to the tropics for the first time)

Ross Institute Bulletins:—

(1) Insecticides. (*Reprinted*) *October*, 1973.

(2) Anti-Malarial Drugs. (*Revised*) *April*, 1975.

(3) (*Out of Print.*)

(4) Tropical Ulcer. (*Revised*) *August*, 1973.

(5) The Housefly and its Control. (*Reprinted*) *July*, 1973.

(6) Schistosomiasis. (*Reprinted*) *May*, 1974.

(7) Malaria and its Control. (*Reprinted*) *May*, 1974.

(8) Rural Sanitation in the Tropics. (*Reprinted*) *May*, 1974.

(9) The Inflammatory Diseases of the Bowel. (*Revised*) *August*, 1970.

(10) Small Water Supplies. (*Reprinted*) *April*, 1975.

(11) Anaemia in the Tropics. (*Reprinted*) *June*, 1974.

(12) Protein Calorie Malnutrition in Children. (*Reprinted*) *June*, 1974.

These publications are revised from time to time and new and revised editions are issued as occasion warrants. They are available at printing cost plus postage on application to:—

The Publications Secretary,
The Ross Institute,
London School of Hygiene & Tropical Medicine,
Keppel Street (Gower Street),
London, WC1E 7HT
Tel: 01-636 8636.