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Purification of Water on a Small Scale
Technical Paper No. 3

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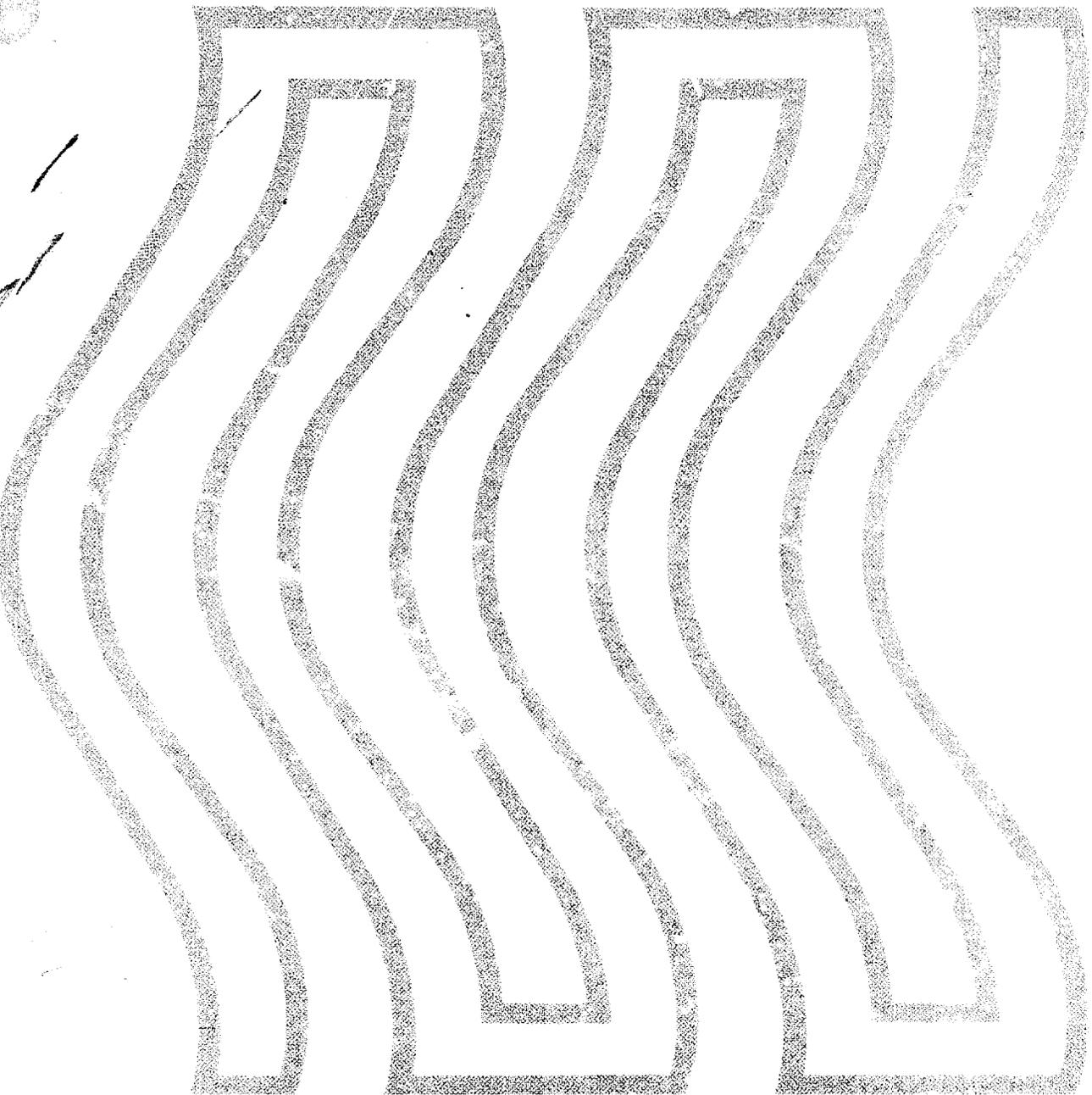
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Who International's formula
for community water supply

the purification of water on a small scale



technical paper no. 3

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WORLD HEALTH ORGANIZATION
INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY

TECHNICAL PAPER NO. 3

The Purification of Water on a Small Scale

MARCH 1973

THE HAGUE - THE NETHERLANDS

Introduction

In 1956 Mr. R.N. Clark of The Division of Environmental Sanitation of the World Health Organisation in Geneva prepared a note on the Purification of Water on a small scale which was published in the Bull. Wld. Hlth. Org. 1956, 14, 820-826.

There is a great need for these practical instructions, especially for rural areas, where health conditions leave much to be desired and no sanitary drinking water supply exists.

In connection herewith W.H.O. suggested to the I.R.C. for Community Water Supply to republish this paper, including new data available.

This I.R.C. technical paper no. 3 resulted from collaborative efforts between I.R.C. and W.H.O. and it is intended to be used by the latter organisation in its briefing of new consultants. It is hoped that the paper will be of use to them and also to many others working in the field of water supply.

I.R.C. will highly appreciate receiving any contribution, which may further improve this paper..

THE PURIFICATION OF WATER ON A SMALL SCALE

There are three general methods for the purification of water on an individual or domestic scale:

1. Boiling
2. Chemical disinfection, and
3. Filtration

These methods can be used singly or in combination.

1. Boiling

Boiling is a satisfactory method for destroying disease organisms in water and it is equally effective whether the water is clear or cloudy, whether it is relatively pure or highly contaminated with organic matter. Boiling destroys all forms of disease organisms usually encountered in water, whether they be bacteria, spores, cercariae, cysts or ova.

The amount of fuel required to boil water varies with the type of fire, stove, and vessel. Under the conditions usually associated with the boiling of drinking water, it requires about 1 kg of wood to boil one litre (approx. 2 lb per quart).

To be safe, water must be brought to a "rolling boil". The appearance of bubbles (simmering) is sometimes confused with boiling, as is the appearance of mist or steam over the water. None of these signs is sufficient indication that water has reached a boiling temperature. Having reached boiling point the water should continue to boil for at least five minutes. Five minutes will be the minimum suitable to low level locations, say, below 1000 metre elevation and, as a rule, one minute further boiling should be given for locations at intervals of height above sea-level of 1000 metres, the reason being that water will boil at lower temperatures at higher altitudes.

It is also recommended that turbid or cloudy water be boiled somewhat longer than clear water. It is good practice to boil water in the same container in which it is to be cooled and stored and to use this container for no other purpose.

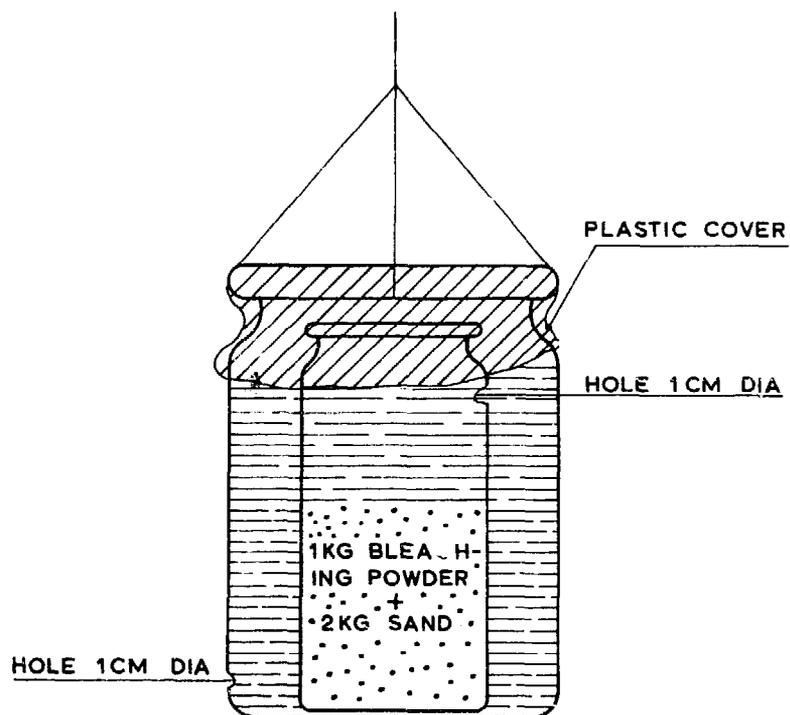


FIG.1 CHLORINATION POT FOR HOUSEHOLD WELLS
CAP. 400 LITRES PER DAY (100 GPD) OF DRINKING WATER ;
CHEMICAL RECHARGE EVERY 3 WEEKS
(SOURCE : C PHERI , NAGPUR , INDIA)

Boiling alters the taste of water because it drives out dissolved gases, particularly carbon dioxide. The practice of aerating water by stirring or by pouring from one container to another is not recommended as this makes for a serious risk of recontamination. Water left for a period of several hours, up to a day, in a partially filled container, where there is a good air surface exposed, even though the mouth of the container is covered, will lose most of the boiled taste in particular if stored in a refrigerator. In any case, it is preferable to be reconciled to the inoffensive taste of boiled water than to run the risk of drinking polluted water

2. Chemical disinfection

Where a house has its own private well as its source of drinking water, the water can be disinfected in the well. Research into simple but efficient methods of disinfection has resulted in several successful designs using chlorine. Fig. 1. illustrates a double jar chlorinator developed at the Central Public Health Engineering Research Institute, Nagpur, India. An alternative method of disinfection by means of iodine is still in development with the W.H.O. International Reference Centre for Community Water Supply.

For water brought into the house from outside sources, simple chemical treatment can be given to ensure its safety. The two chemicals recommended on the grounds of efficiency and easy availability are chlorine and iodine.

Chlorine

Chlorine is a useful disinfectant for drinking water and is effective against the bacteria commonly associated with water-borne diseases. In the usual doses, it is not effective against certain cysts and ova, nor against organisms embedded in solid particles. Chlorine enters almost instantaneously into chemical combination with organic matter in water and in such "combined" form, is only of limited use for disinfection.

Sufficient chlorine must therefore be added to satisfy the "chlorine demand" of water in addition to the amount required for bacterial action.

This combination with other substances may give rise to a chlorine taste, but the presence of such a taste gives some indication that a "free chlorine" residual exists. In general, a cloudy water, or highly polluted water, containing large quantities of organic matter, is not suitable for chlorination. Turbid water can be filtered, and when clear, it can be successfully chlorinated.

Experience indicates that a contact period of about 20-30 minutes is necessary for the chlorine to destroy harmful bacteria.

Chlorine is easiest to apply in the form of a solution. A good stock solution to use in treating water contains about 1% available chlorine. This is about the strength of proprietary disinfectants such as "Milton", "Zonite" or "Javel water".

Other easily available sources of chlorine are the commercial laundry bleaches sold under a variety of trade names (see Annex 1). These will usually contain about 3% to 5% available chlorine and can be easily diluted to a 1% solution by addition of appropriate quantities of pure water.

It is also possible to purchase bleaching powder or chlorinated lime. This is a white powder which contains about 30% available chlorine when freshly made. However, the strength of this powder rapidly diminishes after the container is opened. Storage over a long period, even without opening, can also result in a loss of strength. In using chlorinated lime, it is best to use the whole container at once, immediately after opening, to make up a stock solution. The inert lime will settle in a few hours leaving the active chlorine in the clear solution which can then be poured off and kept in a tightly stoppered bottle for future use. This stock solution is still subject to chemical degradation which complicates the reliability of dosing.

Another type of powder is high-test hypochlorite, which contains about 70% available chlorine. Containers of this powder should be kept as cool as possible, there having been instances of cans bursting when left in the hot sun or in hot storage places. The powder can be used to make a stock solution in the same way as chlorinated lime. High-test hypochlorite is more stable than chlorinated lime, and will keep its strength better after the container is opened, so it is not necessary to use the whole container at once. However, even this material will lose most of its strength in a month or two after the container is opened.

Chlorine solutions are unstable in warm climates. They should be kept in brown or green bottles, well stoppered and stored in dark, cool, places.

To make a litre (one quart) of about 1% stock solution, add the requisite amount of water to any of the following:

- either 250 ml (1 cup) of liquid laundry bleach,
- or 40 g (2½ tablespoons) of chlorinated lime,
- or 15 g (1 tablespoon) of high-test hypochlorite.

Smaller quantities of stock solution can be made by using proportionate amounts.

The proprietary disinfectants, of which examples have been given, generally have a 1% solution strength and can be used without dilution.

To chlorinate water, add three drops of 1% solution to each litre (quart) of water or one fluid ounce to 32 imperial gallons. If the water is clear but highly coloured, like very weak tea, or if it has a noticeable sulphur odour, the dosage should be doubled. It is repeated that a contact period of about 30 minutes should be allowed before use to ensure complete disinfection.

Chlorine is also available in tablet form, of which the following are examples of commercial brands which may be available: "Halazone" and "Chlor-dechlor"; other brand names are given in Annex 1. Directions for use as given on the package should be followed carefully. For example, Chlor-dechlor has a double action. This tablet first disinfects the water with a special chlorine compound. Then, after the outer portion of the tablet dissolves, the inner core neutralizes the remaining chlorine to reduce the taste. If more than one tablet is to be used, the whole amount must be put in at the same time. Tablets added after the dechlorinating core of even one of these tablets is dissolved are completely ineffective.

The foregoing practices are all related to water within the house. Fig. 1. illustrates a practice suitable for well chlorination.

Iodine

Iodine is an excellent disinfecting agent and, as tincture of iodine, is normally available from any chemist. In addition, water disinfectants based on iodine are commercially available, an example of which is "Globaline". Each tablet contains sufficient iodine to disinfect one litre (one quart) of clear water by liberating 8 mg of iodine; for turbid or

highly polluted water, two tablets are recommended. Contact period prior to use should be not less than 20 minutes and in very cold climates this should be increased to 25 minutes. Other makes are shown in Annex 1.

If tincture of iodine is used to disinfect water, normally two drops of 2% strength will suffice for one litre of water. However, water which is cloudy or muddy, or water having noticeable colour, even when clear, is not well suited for disinfection with iodine solution. Turbid water can be filtered and the clear filtrate can then be treated. If the water is known or suspected to be heavily polluted, the dose should be doubled. There is no harm in using the higher dosage, but it will produce a medicinal taste.

The commercially produced tablets are normally iodine compounds, such as tetraglycine potassium tri-iodine, and are effective against amoebic cysts, cercariae, leptospira, and some viruses as well.

When iodine is the disinfectant a similar contact period to that recommended for chlorine should be followed, i.e. 20-30 minutes. When using proprietary tablets the manufacturer's instructions should be carefully read and followed.

Potassium Permanganate

Potassium permanganate has frequently been used for the disinfection of water. It is a powerful oxidizing agent, on which account its action is rapidly spent in waters containing organic material. The commonly used dosage is one part in 2000 or 0.5 g/l. Potassium permanganate may possibly be effective against the cholera vibrio, but it is of little use against other disease organisms. Water treated with potassium permanganate in time produces a dark brown precipitate, which is difficult to remove without scouring. The opinion is expressed that potassium permanganate is not a satisfactory disinfectant and its use is not recommended.

3. Filtration

There are two types of filters commonly used for the treatment of household water supplies: the sand filter, which is relatively coarse; and the ceramic filter, which is of a finer texture. There is also the carbon filter (Fig. 2.) the prime purpose of which is removal of excess chlorine.

Sand filter

The household sand filter, unless skillfully operated, is relatively ineffective against bacteria. It will, however, remove cysts, ova, cercariae, and similarly large organisms, and will strain out most of the coarse and visible matter in suspension, although it may pass some fine turbidity or cloudiness. Sand filtration may be made more effective by first carefully treating the water with alum, as a result of which a clear water can be obtained. Some household filters contain charcoal. This has almost no purifying effect, its function being to absorb certain taste-producing compounds, but even this effect is lost unless the charcoal is frequently renewed. Charcoal filters have the property to absorb organic matter, which can serve as nutrients causing an undesirable bacterial growth in the filter. There are instances of filtered water having a higher bacterial count than the unfiltered water. To a lesser extent this can also happen with sandfilters. From a hygienic point of view these filters should not be used as a single step of treatment. Subsequent to filtration the water should be boiled or disinfected.

With this reservation in mind, the household sand filter finds a definite place in water treatment. It can easily be made for household use wherever fine sand is found. The essential points in making a filter are, firstly, that the depth of sand through which water passes should be at least 60 cm (2 ft) - an additional 15 cm (6 inch) is, in fact, desirable - and, secondly, that the rate of flow through the filter should not be greater than $200 \text{ l/m}^2/\text{hr}$ (4 Imp. gall./ft²/hr or 4.8 US gall./ft²/hr).

A simple filter can be constructed from a steel drum 60 cm (24 inch) in diameter and 75 cm (30 inch) high, with the head cut off. Place the drum on a stand, with a container underneath, and drill a hole 2 mm (3/32 inch) in diameter at the bottom of the drum to serve as the filter outlet.

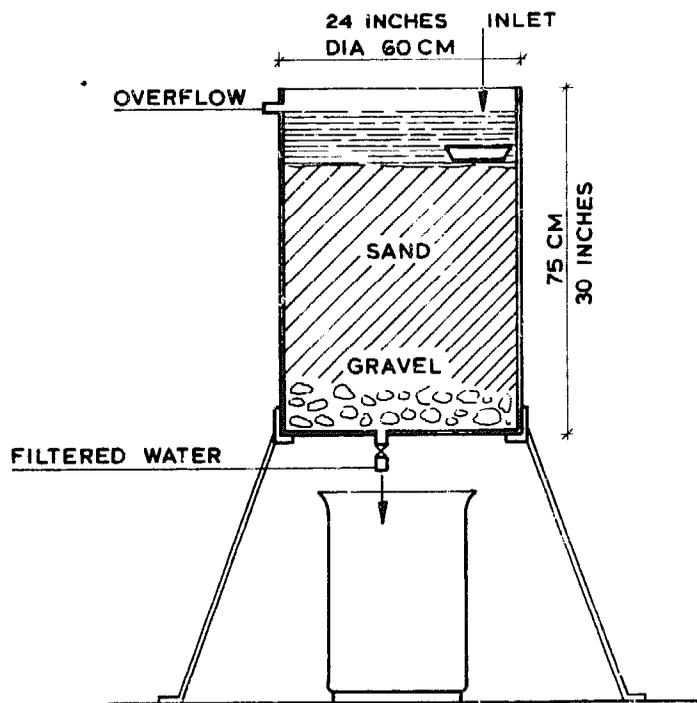


FIG. 3 SAND FILTER
CAPACITY 1 LITRE / MIN (12 GPH)

Place a few centimetres of small stones, about pea-size, in the bottom of the drum and fill to within 10 cm (4 inch) of the top with rather fine sand. Make a hole in the side of the drum just below the top rim for an overflow and insert a short length of pipe for an overflow line. A general layout of such a filter is illustrated in Fig. 3. Drums initially used for oil or chemicals should not normally be used as they may be heavily contaminated. The drum used should be thoroughly cleaned out and disinfected prior to use.

The sand and stones are also likely to be contaminated and have to be carefully cleaned before the filter is assembled. The filter should then be filled with highly chlorinated water and allowed to stand for 2 hours before draining to waste.

To operate the filter keep a continuous flow of water running into the top, just sufficient to keep the filter filled, with a slight overflow. It may be necessary to place a small disc on the surface of the sand under the inlet to prevent a hollow forming in the sand. A filter of these dimensions should deliver one litre per minute (12 gallons per hour) of clear water, which should nevertheless be chlorinated prior to drinking.

In operating such a filter, it is desirable to keep a continuous flow through the filter at all times. The rate of filtration is likely to fall off in time, but the filter should be cleaned only at long intervals possibly of several weeks or even months, since its efficiency depends highly on the biological growth on the surface of the sand. A slow sand filter as described, is a reliable barrier to disease organisms, (even when the after chlorination is failing because of chemical degradation of the chlorine solution).

Passage of organisms, however, will occur in the first week after the start of a newly constructed filter and after cleaning of the filter as described below. Trouble with green growths (algae) can be eliminated by covering the filter to keep it perfectly dark, since this green algae depends on light for growth. When it becomes necessary to clean the filter, a very thin layer, about $\frac{1}{2}$ cm ($\frac{1}{4}$ inch) can be carefully scraped off and discarded, following which the sand surface should be lightly raked or scratched to leave it loose. After several such cleanings, the sand should be restored to its initial level with clean sand after scraping the filter surface down to a clean level.

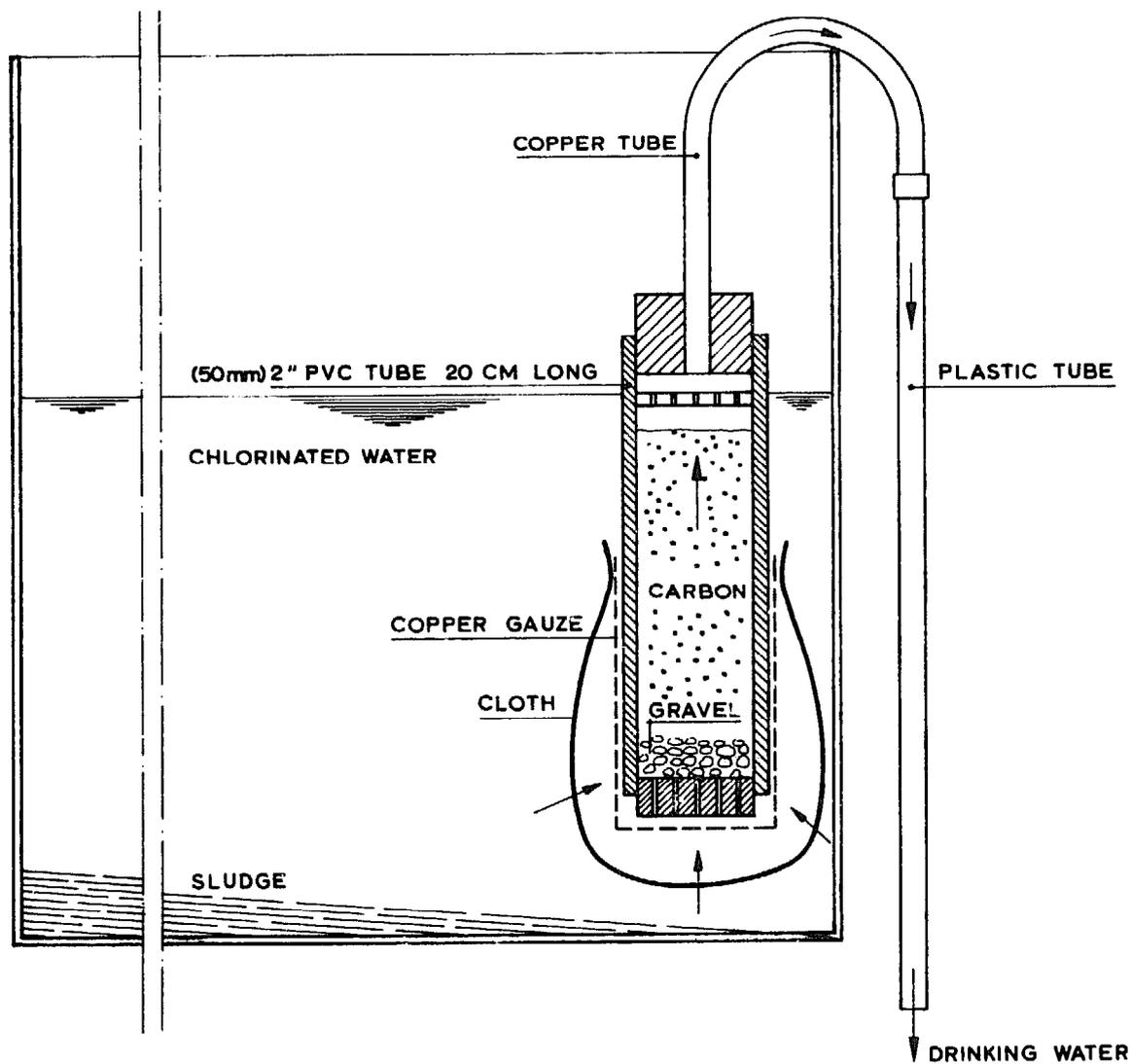


FIG.2 CARBON FILTER
FOR REMOVING EXCESS CHLORINE
(SOURCE: MIN. OF HEALTH, INDONESIA)

For more turbid waters, settling or coagulating and settling prior to filtration may be necessary. The latter may be carried out in a separate steel drum by stirring a solution of one tablespoon (10 g) of alum into 100 litres of the water to be treated for about three minutes until a floc starts to form, followed by adding 10 g (one tablespoon) of calcium carbonate under continuous stirring. A period of about half an hour should be allowed for the floc to settle; the settled water is then ready for filtering.

Ceramic filters

There are several types of ceramic filters, such as pressure filters, non-pressure filters, and filter pumps, and there is a wide range of ceramic media having different pore sizes. The heart of any of these is the filter candle, and the method of getting water through the candle is only a matter of convenience. Only clean water should be used with ceramic filters, otherwise, with cloudy or turbid water, the candles clog very quickly.

Coarse-grained filter candles are useful in removing suspended matter, helminth ova, cercariae, and cysts. They may only partially be effective in removing the smaller disease organisms, and consequently water should always be chlorinated or otherwise disinfected after passage through a coarse-grained or industrial-type filter.

Porcelain filters are made with pore sizes from a radius of 50μ or larger down to 0.30μ . To be satisfactory for water purification, the maximum pore radius should be about 1.5μ . Examples of such filters are the Chamberland L₂ and the Selas O15. These and similar fine-grained porcelain filters will remove all disease organisms usually found in drinking water during a limited period of time, and it is quite safe to use water after passage through such a filter without further treatment. After a prolonged use, however, the bacterial growth will penetrate and pass the filter. This breakthrough can generally be prevented by cleaning and boiling the filter at least once a week, even if the filter does not clog. If a filter gets coated or clogged, it should be scrubbed under running water with a stiff brush free from soap, grease, or oil, and then boiled for 15 or 20 minutes.

Another type of filter candle is known as the Kieselguhr, or infusorial or diatomaceous earth filter. Like the porcelain, this also is made with various pore sizes. The finer-grained types are efficient in removing all types of bacteria commonly found in water. Among the well-known Kieselguhr filters are the Berkefeld and Mandler filters. Their porosity is graded as V ("viel", or coarse), N (normal, or intermediate), and W ("wenig", or fine). The V filters are suitable only for the removal of suspended material, and following filtration with this type of candle, the water should be further treated to destroy bacteria. The N filters remove the smallest bacteria, and it is safe to use water filtered through this grade without further treatment. The same care should be taken of Kieselguhr candles as of porcelain candles, except that they should be cleaned more frequently, at intervals of not longer than four or five days at the most.

There is a special type of filter candle, known as the "Katadyn" filter, in which the surface of the filter wall is impregnated with a silver catalyst in such a way that the porosity is not impaired, but the bacteria coming in contact with the surface are killed by oligodynamic action. Such a filter needs cleaning only when it becomes clogged.

Above filters and their attachments should be carefully examined at frequent intervals to guard against cracks or leaks which might possibly permit unfiltered water to get by. For this reason and from a hygienic point of view, the filtered water should also be disinfected with chlorine.

Filter candles can be mounted in a gravity-type filter, which consists of two reservoirs with the candle or candles attached to the upper one. Water is simply poured in at the top, trickles through the ceramic candles, and is stored for use in the lower compartment. Another mounting is made where piped water is available under pressure. The candle is mounted in a pressure case which is attached directly to the water system, filtered water being drawn from the filter as needed. A third type is fitted with a hand pump. The suction tube is put into a vessel of water, and the pump is operated like a bicycle pump, the filter candle being inside. The filtered water is discharged through another tube. Any of these systems is satisfactory if suitable filter candles are selected.

Water storage

No matter how much care is taken in producing safe water, this will be nullified if the water is contaminated after treatment. If boiled or filtered water is "unprotected" it may be subjected to immediate recontamination. Water treated with chlorine or iodine has "residual protection" which will successfully deal with light recontamination for a considerable period of time. However, this residual effect eventually disappears unless additions of chemicals are made. It is very important to keep the treated water free from the hazards of recontamination.

The principles are simple. Use clean vessels to store water; do not dip anything into the water; and keep the vessels covered to prevent the entry of insects, dust, or other foreign substances.

Cleanliness of the storage vessels involves periodic emptying, washing, and rinsing with heavily chlorinated water, to prevent the accumulation of slime growths.

Wherever practicable, small-mouthed vessels should be used with a neck narrow enough to prevent the entry of a dipper, cup or hand. When large vessels are used, arrangements should be made for easy pouring, either by tipping or by rolling the vessel. The best scheme with large vessels is to use, if possible, a spigot.

To prevent the entry of dirt, dust and other foreign matter, some form of cover is necessary, preferably of impervious washable material. The form and type of cover depends primarily on the vessel. It should be tight enough to keep out flies, wasps, roaches, and other insects, and substantial enough not to be easily lost or broken.

Another precaution relates to the use of commercially produced bottled water and carbonated beverages. The fact that such products are put into bottles and capped does not ensure their purity. When water is bottled, its bacterial content decreases with time, but cysts and ova may survive long periods of storage. The amount of sugar in sweetened drinks determines their bactericidal properties, but complete safety depends on initial purity and long storage.

In the case of carbonated beverages, the carbon dioxide does inhibit bacteria, but its action is selective, since some organisms are more resistant than others. Carbonation alone cannot be counted on to make a beverage safe. The best policy would seem to be to use only beverages

bottled in establishments reliably known to use pure ingredients and which maintain a suitably high standard of plant hygiene and standards of operation.

It is also relevant to mention that ice, too, can harbour contamination. Ice cubes should be made from properly treated water; that means, from chlorinated drinking water or piped water from a public water supply. Unless the ice is reliably known to be pure, it should never be put directly into the beverage itself, but only packed round the beverage containers to effect cooling.

Conclusion

In conclusion, when dealing with drinking water it is safest not to take anything for granted. It is frequently, and often wrongly, assumed that all large cities have safe water supplies. Unless the validity of this assumption is established, it would be safer to leave nothing to chance. The transient traveller in particular, would be well advised to do his own unobtrusive job of water purification.

Summary of treatment

Type of water.	Recommended processes for rendering water suitable for drinking.
1. All types	boiling
2. Clear water	chlorination (disinfection)
3. Slightly turbid	filtration and disinfection
4. Turbid	settling, coagulation, filtration and disinfection
5. Special types, e.g. excessive hardness, corrosive, high content of minerals such as iron or manganese	seek professional advice for special treatment

PROPRIETARY NAMES OF SOLUTIONS OR TABLETS SUITABLE FOR WATER PURIFICATION
FOR INDIVIDUAL USAGE.

The following proprietary names are given for information only. The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by WHO or the WHO International Reference Centre, in preference to others of a similar nature which are not mentioned.

1. Sources of chlorine

a. Solid form

"Halazone" - tablets	(Use as directed)
"Chlor-dechlor" - tablets	(" " ")
"Hydro-chlorazone" - tablets	(" " ")
"Halamid" - tablets	(" " ")
"Chloramin-T Heyden" - tablets	(" " ")

b. Liquid form

"Zonite" - liquid	(approx. 1% chlorine solution - can be used as supplied)
"Milton antiseptic" - liquid	(" " " ")
"Javel water" - liquid	(" " " ")
"Dankin's solution" - liquid	(approx. 0.5% chlorine solution)
and other commercial laundry bleaches, e.g. "Clorox", "Dazzle" and "Regina"	(usually 3-5% chlorine solution - dilute to 1%)

2. Sources of iodine

a. Solid form

"Individual Water Purification Tablets" - tablets	(use as directed)
"Portable Aqua" - tablets	(" " ")
"Globaline" - tablets	(" " ")

B. Liquid form

"Lugol's solution" - liquid	(approx. 5% iodine solution)
"Tincture of iodine" - liquid	(approx. 2% iodine solution)