Water supplies in the field : notes for medical officers

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MEDICAL OFFICERS

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By Authority: Wilke and Co. Pty. Ltd., 19-47 Jeffcott Street, Melbourne.

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APPENDICES.

WATER SUPPLIES IN THE FIELD.

The provision of an adequate and safe water supply is of the first importance in the maintenance of the fighting efficiency and health of an Army.

In many instances, especially in tropical campaigns, the need for water may become so urgent that it outweighs all other considerations. It is the responsibility of every Army Commander to ensure that this provision is made.

The Medical Service must satisfy itself that the troops receive a ration of water sufficient for their physiological requirements, that its distribution is satisfactory from a hygienic point of view, and that it is safe to drink.

The duties of this service are, however, almost entirely advisory, except as regards unit supplies, in which case the regimental medical officer, with the aid of his water duty personnel and apparatus, is responsible for producing an ample supply of pure water sufficient for the needs of his unit.

Executive responsibility of this nature with higher formations, *i.e.*, where bulk supplies are dealt with, lies with the Royal Engineers. NB

It will be realised, therefore, that the Regimental Medical Officer should have a good working knowledge of the subject of water supplies, and that his water duty men should be specially selected, intelligent, trustworthy, and properly trained. This training is normally carried out at the Army School of Hygiene, but on service, when casualties have to be replaced, it often falls to the lot of the medical officer to train the men himself. A wise officer should, therefore, have a surplus number trained in peace time.

In addition, these water duty personnel should not have a history of typhoid or dysentery.

All unit water vehicles and water equipment are in the Medical Officer's charge, and he is responsible to the O.C. unit for their cleanliness and readiness for use, and for ensuring that there are ample supplies of the necessary chemicals, etc.

If he is in need of advice or assistance, he may consult with the Deputy Assistant Director of Medical Services at the headquarters of the division to which his unit belongs, or with the O.C. the Field Hygiene Section, should a unit of this nature be operating in the area.

The Regimental Medical Officer should know also that he is responsible for selecting a suitable water source and for ensuring that it is properly policed.

Finally, if the men of his unit are poisoned or become ill as a result of drinking water of which he has authorised the use, he will be held solely responsible, as he has the means of detecting the one, and can prevent the other, by carrying out the instructions which are provided with his water vehicle. One point that should never be lost sight of, and that is that on Active Service all water supplies, whether piped or not, must be considered unsafe, and be treated.

AMOUNTS.

A soldier marching in battle kit on a warm day in a temperate climate loses roughly 1 pint of sweat per hour. This amount may be greatly exceeded in a tropical country.

Loss of water from the body in sweating must be replaced by an equal intake.

The recognised minimum allowance on service is:—

For drinking and cooking only—1 gallon per man.
For all purposes—3 to 5 gallons.
For horse or camel—10 gallons.
For mule or ox—6 gallons.

The amounts for drinking may have to be increased three-fold in hot climates when troops are doing hard work.

SOURCES OF WATER.

(A) **Rain water** may contain impurities which it has picked up in the air or after falling on the receiving surface.

It is essentially a soft water, with comparatively large amounts of ammonia present.

It is not very palatable, but, being soft, is excellent for laundries, boilers and for cooking.

It is plumbo-solvent.

The catchment area, whether it be a roof or a prepared surface of land, should be kept as clean as possible. The land area should be fenced in, all vegetation removed, and the surface cemented over.

The first washings after a period of drought should be run to waste.

Runnels, rain-gutters and storage tanks must be regularly inspected and cleaned.

Storage tanks should preferably be placed under-ground if the gradient permits of delivery by gravity.

If rain water is collected solely for washing purposes a notice to the effect that it is unfit for drinking should be placed beside the taps.

A constant watch should be kept on mosquito breeding in barrels and tanks.

The high ammonia present (since it unites with the chlorine to form chloramine) may upset the Horrocks' Test. See page 54.

(B) **Surface Waters** include:—

Any water which lies on or flows over the surface of the ground.

Moorland collections, lakes, reservoirs, ponds, rivers, streams, canals and irrigation channels can all be classed as surface waters.

(1) Moorland or upland water is variable in its yield depending on the amount of evaporation that takes place and the permeability of the ground. The water is usually soft and is liable to be discoloured with peat, in which case it will be acid and plumbo-solvent. The peaty discoloration is removed by alum, when this chemical is used in the process of filtration or sedimentation. The acidity must be reduced by the addition of lime or soda if sedimentation with alum is to be effective.

(2) The character of the water of lakes and reservoirs will depend on the source of their feeders. If the water is from a moorland source it will be soft, and possibly peaty; if from a spring or from streams which flow over limestone it may be hard and clear. The water may, therefore, be plumbo-solvent or non plumbo-solvent, depending on which of these two sources it is derived from. The first flow after drought should be run to waste.

Storage Reservoirs should be deep rather than broad, to reduce the amount of evaporation, and water should be taken as far away from the inlet as possible, so that advantage can be taken of sedimentation.

Algal growths are liable to occur on prolonged storage if the water is exposed to sunlight. Enclosure and policing of the catchment area and of open leats is necessary.

Reservoirs and lakes so protected and free from flood contamination contain remarkably pure water. Not only does sedimentation of suspended matter occur, but the organisms are reduced enormously by the action of sun and wind.

Service Reservoirs should not normally have a capacity of more than one or two days' supply, owing to the deterioration that takes place on storage.

(3) Ponds near villages are usually heavily contaminated with vegetable and animal organic matter. In the summer months ponds may be green with algal growths, the decomposition of which may impart a disagreeable taste to the water.

There is usually a heavy sediment which is easily disturbed. The water is generally soft, with a high ammonia content. The large amount of organic matter may deviate considerable amounts of chlorine.

$CuSO_4$ 10 lbs/1,000,000 = 1 : 1,000,000.

Algal growths can be prevented by covering an area of the water with some form of screening, for example, a tarpaulin to exclude sunlight; or by adding copper sulphate in the proportion of 10 lbs. per million gallons (1 p.p.m.) and thoroughly mixing it with the water.

Once the growth has established itself unsatisfactory results are obtained with copper treatment, owing to the objectionable taste the decomposed vegetable matter gives to the water.

N.B. Collections of water in shell holes are usually dangerously contaminated with human excrement, and may contain amounts of arsenic sufficient to cause symptoms of poisoning. The water should never be used, except as a last resort.

(4) Rivers and canals, etc., are common sources of water supply in war time. Most rivers are contaminated, while all canal waters are dangerously so.

The hardness of the water will depend on its source, *i.e.*, spring or moorland water. Heavy rains after drought very considerably increase the pollution of rivers by washing into them the contaminations of the land. The amount of inorganic material is also increased. Heavy suspensions of clay are common in some rivers when in flood; for example, the Nile; also fine particles of mica have been noted in rivers in the North-West Frontier of India. In some rivers and canals decomposing organic matter is present to such an extent that the water will not support animal and vegetable life. Trade wastes also cause heavy pollution, and may render the water unfit to drink, even after the normal treatment. Chemicals may be intentionally added by the enemy to a part of the river higher up in its course.

Rivers have considerable powers of self purification, due to such agencies as sedimentation, aeration, and the ingestion of matter by fish, worms and infusoria. In most cases, self purification is hardly ever completed before the river receives further contamination.

To safeguard a river supply, the banks should, if possible, be patrolled for 2 or 3 miles above the intake.

Three distinct and flagged zones should be defined in the following order upstream.

(1) Drinking and radiator water zone marked by *white* flag.

(2) Animal watering zone marked by *blue* flag.

(3) Ablution zone marked by *red* flag.

- (*a*) Personal.
- (*b*) Laundering of clothes.
- (*c*) Washing of vehicles.

Water should be pumped in each case to tanks or troughs sited well back from the river bank, the intervening area being wired off.

A trench should be dug between tanks and river and parallel to it to collect seepage, which would otherwise find its way back into the water supply. On no account will water be drawn direct from the river, animals watered, or men bathe in the river at the zoned area.

As regards streams, much of what has just been said applies to them also.

The approximate yield of a stream can be calculated as follows:—

Select a straight length of 15 to 20 yards where the channel is fairly uniform, and where there are no eddies.

Measure the breadth and depth at three or four places, and from these obtain the average sectional area (A) of the channel.

Drop in a chip of wood and find the time it takes to travel in seconds a known distance in feet (say 30 feet). This gives the surface velocity (V) of the stream in feet per second.

Then $\frac{4}{5}V \times A =$ Yield in cubic feet per second.

or $\frac{4}{5}V \times A \times 6.25 \times 60 =$ galls. per minute.

(c) Subsoil water is water that has percolated through the soil and is retained by an impermeable stratum. This water may come to the surface in the form of a spring, or is reached by digging a pit or well. There are two kinds of springs and wells.

(1) Land springs and shallow wells.

(2) Main springs and deep wells.

(1) Land springs and shallow wells tap water above the highest impermeable stratum. The yield is variable, depending on the rainfall. The water is apt to be polluted, as surface washings may drain into it. The hardness of the water will depend on the nature of the water bearing stratum. and if the latter is of chalk or limestone the water will be hard.

(2) Main springs and deep wells tap water beneath one or more impermeable strata. The yield is constant, and only remotely increased by rain. It can be increased in the case of wells by driving adits or galleries in the water bearing stratum at right angles to the shaft of the well. The water is usually cool and pure. The best sources are from chalk, oolite, sandstone and limestone strata. The water contains much mineral matter, and may be very hard. Deep wells, however, may be just as liable as shallow wells to pollution if there are faults or fissures in the impermeable stratum leading down to the water bearing area, or the steining shows faulty construction.

"Artesian Wells" are deep wells which tap water confined, under pressure, between two impermeable strata. These wells may be many thousand feet deep. The water is pure and generally very hard.

Norton Tube Wells are useful for prospecting purposes and for small camp supplies. The well consists of an iron tube with perforations at the lower end, driven from the surface to the water bearing stratum. A pump can be fixed to the top of the tube. The tube, being small, is in itself capable of containing only a very small supply of water, which would be exhausted by a few strokes of the pump.

It is therefore essential, if the well is to be of any use, that there shall be a free flow of water from the outside through the apertures into the lower end of the tube. The tube can be driven through sand, gravel, chalk and very hard beds of flint and gravel, breaking the larger flints after a few blows.

Measures to protect wells from contamination.—The protection of a well is most important. The following points should be attended to:—

(1) A well should be sited in relation to any source of pollution, cesspit, midden, etc., so that the flow of ground water is from the well towards the source of pollution, and not *vice versa*, and at least 100 feet away.

(2) It should be fenced or walled in so that a circular area having a radius of 100 feet is enclosed. This area should be kept scrupulously clean.

(3) Surface drainage so arranged that spilled water is led away from the mouth of the well.

(4) Steining or lining of the shaft to an adequate depth with bricks set in cement or steel tubing. For shallow wells the steining should extend down 20 feet, and for deep wells to the first impermeable layer, to which it should be embodied. This assures adequate filtration through the soil of possibly polluted surface water.

(5) The lining should be prolonged above ground in the form of a coping one foot high. This coping should be provided with a properly fitting cover, and the ground immediately surrounding it should be concreted for at least six feet from the coping outwards with a slope away from the well.

(6) Water should be raised from the well by a pump which should discharge its water through a closed pipe leading to a storage tank or reservoir outside the fenced area.

If a windlass and bucket are the only available means of raising water, the cover of the well should be hinged. Wells that have been used by the enemy may have been filled in with debris. If this has occurred the water must invariably be tested at once, both by means of the Case, Water Testing, Sterilisation, and Case, Water Testing, Poisons.

A notice board should then be put up stating whether it is fit or unfit to drink. If the water is unfit access to the well should be made physically impossible by means of barbed wire.

Detection of a source of Pollution.—If there is any suspicion that well water is being contaminated by sewage from cesspools, manure dumps, etc., the following methods may be used. Pour over the suspected area

(*a*) An alkaline solution of fluorescin made up of:

Fluorescin	1 lb.
Caustic soda	1 lb.
Water	10 gallons.

1 part fluorescin causes fluorescence in 10,000,000 parts of water. The presence of green fluorescence is watched for in the well water for a period of a week.

(*b*) A strong solution of ordinary salt.

The well water is examined for an increase in chlorides.

In both these cases the well should be pumped thoroughly for some days before and after the test.

Cleansing of a Well.—The following procedure will be carried out if a well is found polluted with manure, etc. It should be:—

(1) Cleaned of debris as far as possible.

(2) Disinfected by having about half a barrel of freshly burned lime thrown into it; and the water being thoroughly stirred up. When the well is so deep that stirring is impracticable the lime must be added in solution. The lining of the well above water level must be scrubbed with the same solution.

(3) Pumped out and allowed to refill and treated with a second supply of lime.

(4) Allowed to stand for 24 hours.

(5) Pumped out again after a thorough stirring and allowed to refill. No more lime is to be added, and the well should be pumped out until none remains in the water.

When lime is unobtainable, chlorinated lime (bleaching powder) should be substituted. The number of pounds of chlorinated lime required for this purpose is

$$\frac{D^2 \times d \times 23}{100}$$

Where D = the diameter of the well in feet.
Where d = depth of water in the well in feet.

Yield of a Well.—The most practical way of gauging the yield of a well is to pump the water down to a definite level, and to take the time of refilling for each foot up to the former level. The yield can then be determined by calculation. Generally, the greater the distance the water is lowered, the greater the hourly yield.

METAL SOLVENCY IN WATER.

Iron, in the ferrous state, is frequently present in water, but generally in very small amounts. It is advisable to remove it, as it gives trouble by producing brown coloration or precipitates on oxidation to the ferric state, and imparts an unpleasant odour, taste and colour to the water. It may lead to blocking of service pipes owing to Crenothrix, a vegetable filamentous growth, which can multiply rapidly in water containing only very small quantities of iron salts. The only certain method of getting rid of such organisms is to free the water from iron compounds. Iron can be removed by:—

(1) Oxidation, by means of aeration, by cascade or passage through a perforated plate, or by the action of an oxidising agent, such as water sterilising powder, the iron being precipitated as the ferric hydroxide.

(2) Filtration through activated carbon or certain proprietary materials, such as manganese permutit.

Aluminium is very seldom present in natural waters.

Although alum is used as a coagulant in water clarification, no aluminium has been found in the water so treated. There is no danger from storing water in aluminium containers unless the water is rendered acid, for example, by the addition of sterilisant tablets of acid sodium sulphate.

Zinc does not occur in natural waters, but may be absorbed from galvanised pipes and tanks. Cases of zinc poisoning are very rare.

Lead may occur naturally in waters from mountain limestone containing lead veins. It is present as the oxycarbonate which sinks to the bottom of pools in rivers, and may be stirred up, enter the water supply and cause poison symptoms. The oxycarbonate which is insoluble in alkaline waters may also occur on the surface of lead pipes and cisterns. In both these cases, if the water is plumbo-solvent, that is, soft and acid, the oxycarbonate goes into solution, and danger of lead poisoning is greatly increased.

The permissible limit of lead in water is 0.05 part per 100,000. 0.07 part is likely to cause plumbism sooner or later.

The amounts of lead in a piped moorland water supply may vary considerably throughout the day.

The Prevention of Plumbo-Solvency can be Effected by:—

(1) Cutting out the more acid feeders to a catchment area of a reservoir.

(2) Allowing the first flow from a catchment area after a drought to run to waste.

(3) Filtration through coarsely ground limestone or chalk.

(4) Neutralisation by the addition of lime followed by alum and filtration.

(5) The addition of a solution of sodium silicate (1 to 2 grains of sodium silicate per gallon) and filtration.

(6) The avoidance of lead pipes and cisterns.

HARDNESS OF WATER.

Hardness is objectionable for three reasons:—

(1) It is wasteful of soap. Hard water is therefore unsuitable for laundries. Sullage from washhouses will contain large amounts of soap, which is difficult to dispose of in camps.

(2) It causes a fur in pipes and boilers, resulting in wastage of fuel and a danger of bursts. The fur is usually composed of the salts, causing temporary hardness, but when the water is under pressure and of a high temperature the sulphates which give rise to permanent hardness form a very hard and obstinate deposit.

(3) Vegetables cooked in hard water are less digestible.

Hardness may be either temporary or permanent.

(1) **Temporary Hardness** is due to the presence of calcium and magnesium carbonates held in solution in water by CO_2 It may be removed by:—

(*a*) Boiling—the CO_2 is driven off and the insoluble carbonate is precipitated.

(*b*) The addition of quicklime (Clark's process).

(*c*) The Permutit or Base exchange process.

Clark's process consists of:—

(i) The addition of lime—1 ounce of CaO in the form of a 10 per cent. milk of lime for 700 gallons for every grain of temporary hardness to be removed per gallon. If the hardness is due to magnesium carbonate double this dose is necessary.

(ii) Thorough mixing.

(iii) Sedimentation or filtration. Sedimentation is not complete for 10-12 hours. Any form of rough filtration will do.

(2) **Permanent Hardness** is due to sulphates, nitrates, or chlorides of calcium and magnesium. Magnesium chloride has a marked corrosive effect on boilers owing to the liberation of hydrochloric acid, and it must be eliminated if the water is to be used for this purpose.

Permanent hardness is removed by the addition of:—

(1) Washing soda, or sometimes by caustic soda. In the case of a water which contains temporary as well as permanent hardness, the use of lime and soda will remove both. This is also done in certain cases by a caustic soda-sodium carbonate process. The addition of these chemicals is followed by sedimentation and filtration, as in Clark's process.

(2) Permutit or Base exchange process. This method depends on the presence of sodium aluminium silicate, which has the property of exchanging its sodium for the bases calcium and magnesium. The water after the process contains sodium carbonate and sodium sulphate, which are innocuous, and do not cause hardness. All hardness, both temporary and permanent, is removed. Gradually the permutit becomes exhausted by the sodium being replaced by calcium and magnesium, but the plant can be regenerated by the addition of a strong solution of common salt.

There are many water softening plants, both for large-scale and domestic purposes, on the market.

BRACKISH WATERS.

Many waters in the desert and elsewhere contain "salt," making the water undrinkable. Below 100 parts per 100,000, the taste of salt is not appreciated.

Sodium chloride can be removed from water by condensation and by the Permutit Hydrogen Ion Demineralisation Process.

The brackish water should be blended with the condensed water in such proportions that the salt content of the mixture does not rise above 100 parts per 100,000.

A certain amount of salt in the drinking water in hot climates is an advantage as a prevention against heat disorders.

BITTER APERIENT WATERS.

Some waters, notably those in the rivers of the North-West Frontier of India, may contain large amounts of magnesium sulphate sufficient to cause an aperient action on the consumer. If possible, such waters, the reputation of which is known to the local inhabitants, should be avoided.

The removal of magnesium sulphate can be carried out by the Lime Method. Calcium sulphate is formed, which has no aperient action. The method is described in Appendix XVII. The use of Permutit or soda is contra-indicated, as both result in the formation of sodium sulphate (Glaubers salt), which has the same aperient action as magnesium sulphate.

EXAMINATION OF WATER SUPPLIES.

It is usual to carry out three investigations:—

(1) A chemical analysis.

(2) A bacteriological analysis.

(3) A local inspection of the water source and its environs.

The chemical analysis gives an indication of the organic and inorganic impurities of the water. It measures the amount of hardness and the quantity of common salt in the water.

It gives information as to the extent of organic matter and whether it is animal or vegetable, but it cannot prove that the pollution is human sewage. The bacteriological test goes a step further. By it the presence of B coli is identified, and the numbers present in certain measurements of water specified. It is possible to say whether the pollution present is, or is not, from the bowel of an animal, but we cannot state that the animal is man. It is only by an inspection of the supply at its source and distribution that we can include or exclude man as the polluting agency.

Inspection is of much greater value than the other methods, as it gives first-hand and immediate information of the condition of the supply. A complete chemical analysis takes the better part of a day—a bacteriological, 48 hours.

No examination of water, however, is complete which does not embrace all three. The best results are obtained by regarding laboratory examinations as adjuncts to **careful personal inspection.**

Personal Inspection must include the source, the purification plant and the means of distribution to the consumer.

Attention has already been drawn to the kinds of pollution that can occur in rivers, lakes, reservoirs and wells. It is only necessary to add that in regard to catchment areas which are carefully fenced in and free from human trespass the presence of B. coli in the water is probably due to droppings of animals or birds, and may be ignored.

Chemical and Physical Examination.

The physical examination includes the reaction, turbidity, colour and odour. The reaction of most waters is neutral (pH 7). Water with a pH of 5.5 or less is definitely acid, and almost certainly plumbo-solvent.

Highly alkaline waters with pH over 8 retard the bactericidal action of chlorine and chloramine. A sparkling clear water is not necessarily a safe water. It may have a high bacterial content. Turbidity is tested by looking at printed matter through a 2-ft. column of water in a glass cylinder. If it cannot be read the water requires clarification. A rough test is to observe the shadow in water running from a hose; if black and white the water is clear, if grey and white the water is turbid. An experienced eye can quickly detect the difference.

There are many causes of turbidity in water, the most common being: —

(1) Organic debris—either vegetable, *e.g.,* peat, or animal, *e.g.,* sewage.

(2) Inorganic matter—usually clay in various physical states.

The colour of water may be faint blue-green (chalk), yellow (peat), brown (organic matter). Pure water should not have an odour. Some waters have a musty smell from prolonged storage.

A chemical analysis of water for organic pollution has a very limited application in the field. Certain supplies at the base and L. of C. may be chemically examined in this manner, but in the front areas tests are impracticable, and a water is judged solely by its physical appearance and on the results of the Horrocks' Test. Even bacteriological tests are mostly out of the question, full trust being placed in the sterilising action of chlorine after clarification. As it is a routine measure to chlorinate all water supplies, the bacteriological test becomes a criterion of the efficacy of the purification methods rather than of the purity of the raw supply.

The chemical analysis of water for inorganic substances is commonly carried out, especially for the determination of hardness, and may be required as a confirmatory test to that made by the M.O., using the Poison Test case for the detection of poisons.

Samples of water are collected, as described in Appendix 1, and sent to the O.C., Mobile Hygiene Laboratory.

Interpretation of the Chemical Analysis.—When organic matter decomposes it breaks up into the simple compounds Water (H_2O), Carbonic Acid (CO_2) and Ammonia (NH_3). Ammonia is oxidised by organisms, first to nitrites and then to nitrates. The greater the amount of ammonia and nitrites the more recent the pollution, the less these two substances and the greater the amounts of nitrates the more remote it is.

In the chemical examination the amounts of the substances present are expressed as parts per hundred thousand.

Ammonia may be (1) free saline, which most commonly results from the decomposition of urine, occurs in rain water, and may be high in waters containing reducing iron salts from greensand strata; (2) albuminoid, which is typically a product of vegetable organic matter.

If both ammonias low (F. & S. 0.005 part per 100,000 or less; Alb. 0.01 part per 100,000 or less) water is probably good.

If both ammonias high (higher than above figures) water is bad.

If F. & S. is high and Alb. low, the water is probably:—

(1) Rain water, when the other constituents will probably be small.

(2) Deep well water with reducing iron salts (greensand strata), when other figures point to a pure deep source.

(3) Sewage, when all other figures will be high.

If F. & S. is low and Alb. is high this indicates vegetable contamination, especially if the Oxygen Absorbed figure is high.

The Oxygen Absorbed figure is next examined. So long as there is oxidisable matter in the water oxygen will be absorbed from the water. As regards sewage, the more recent it is the more oxidisable it will be, and the more oxygen it will absorb. Some streams are so heavily polluted with crude sewage that all oxygen is removed from the water, and the life of fish, etc., cannot be maintained.

In determining the oxygen absorbed figure, two separate tests are normally carried out:—

(1) The O_2 absorbed figure after 15 minutes. This indicates the amount of reducing inorganic substances, such as nitrites and ferrous salts, but, at the same time, it may indicate the presence of certain rapidly oxidisable elements in sewage. An examination of other figures in the analysis and the absence of Iron will assist in forming an opinion.

(2) The O_2 absorbed figure after 2 or 4 hours. This gives the total oxidisable material present in the water, *i.e.,* that under (1) above and organic material, mainly vegetable (co-related with albuminoid ammonia), and, to some small extent, sewage.

If the difference between the two Oxygen absorbed figures is high (0.08 or more) probably vegetable pollution is present; but this must be confirmed by noting if the albuminoid ammonia is also high and Free and Saline low, and whether the water is acid and soft (peaty).

Chlorides are the next to be studied. An increase occurs in pollution with sea water, sewage (urine) and water from certain deep strata. If above 1, in the case of surface waters, sewage should be suspected. In case of deep wells the figure may run from 1 to 50 or more, and a comparison must be made with the "Chloride figure" for the district before deciding if pollution is present.

Nitrites, being the first stage in the oxidation of ammonia, are indicative of recent pollution, but they can also be present in waters from a greensand strata, owing to the reducing action of the latter on Nitrates. If Nitrites are present the water should be condemned, unless from such a stratum.

Nitrates represent remote pollution, and if found in amounts above 0.1 in a surface water, or above 0.5 in a deep well, the water should be regarded with suspicion.

Hardness.—If the water is for domestic use, the amount of hardness should not be more than 30 parts, of which not more than 10 should be permanent. For laundries and boilers the softer the water the better.

Total Solids.—The amount is of small importance if other figures are satisfactory. As a rough guide, in clean surface water it is rarely above 20, and in pure deep water rarely above 60.

The above standards are not hard and fast dividing lines above which a water is to be immediately condemned or below which it is safe to drink. They merely indicate figures above which a good water rarely rises and below which a bad water rarely falls.

Examinations should be made at regular intervals and graphs plotted. It is never wise to draw a conclusion from one examination only.

Bacteriological Examination.

The usual examination is to estimate the number of indicator organisms present. These are normal inhabitants of the intestine, and comprise B. coli, streptococcus fæcalis and Clostridium welchii. Of these, B. coli is the most important and numerous, and the presence of the others merely confirms the suspicion of fæcal pollution raised by the finding of the former in excessive amounts, and for routine and practical purposes the test for B. coli is normally alone employed. The isolation and identification of true Bacterium coli are somewhat complicated, and to simplify matters presumptive B. coli (coli-aerogenes group) are looked for, as the test for these is a simple one, *i.e.*, the production of acid and gas in MacConkey's broth in 24-48 hours at 37° C.

As this group includes certain atypical B. coli, the presence of which indicates more or less remote pollution, and others of the aerogenes type, which are often present in soil, the test is clearly a more severe one than that for the true Bacterium coli (type I).

If a more exact test is required to identify the Bacterium coli type I, then the Voges Proskauer (V.P.), the Methyl Red (M.R.), the Indol and Koser Citrate tests are carried out. If further proof is required, the Eijkman test may be added.

The Mobile Hygiene Laboratory is not equipped to carry out the above more exact tests, which will have to be done by the Bacteriological Laboratory.

The Mobile Hygiene Laboratory.

The Mobile Hygiene Laboratory is mounted on a 5-ton lorry, and is equipped to carry out the chemical and bacteriological examinations of water, for each of which 6 carriers are held, the detection of poisons and the analysis of the various chemicals used in the treatment of water.

It draws the media for the bacteriological test from the Media Making Centre.

The personnel consists of an Officer Commanding (a chemist), and two laboratory assistants. It will be located near army headquarters.

PURIFICATION OF WATER.

The method and apparatus by means of which water is rendered safe for human consumption are among the most important considerations in connection with water supply in the field.

The following are the essential requirements for a potable water supply:—

(1) It must be free from pathogenic organisms of all kinds.

(2) It must be free from poisonous substances, either organic or inorganic.

In addition, there are certain desirable requirements:—

(3) It should, as far as possible, be free from colour, taste and odour.

(4) It should not contain any appreciable amount of mineral or organic suspended matter.

(5) It should not contain large quantities of common salt or of alkaline carbonates.

(6) For drinking purposes it should be aerated and cool.

The standard method of purification of water in the field is clarification, which removes suspended matter, followed by sterilisation with chlorine, which kills pathogenic organisms.

In the case of the Mobile Purifier, the process is reversed, and sterilisation precedes clarification, the sterilisant used being chloramine.

Clarification.

This will often be necessary owing to the presence of turbidity in the water supplies, which may be due to organic matter or to clay and other inorganic substances in suspension.

There are two methods of clarification available:—

(1) Filtration, which is carried out in the army either by passage through cloth filters, using water clarifying powder (alum 2 parts, anhydrous sodium carbonate 1 part; or Filter earth 50, alum 33, anhydrous sodium carbonate 17 parts), or through metal filters, in which case filter earth is employed.

(2) Sedimentation, using aluminium sulphate or alumino-ferric.

Filtration is superior to sedimentation if the suspended matter is not too dense and if the apparatus is available, and ensures the rapid clarification of large quantities of water.

Sedimentation requires much time (several hours), and the amount of water that can be dealt with is limited by the size of tanks available, which, moreover, require some time for erection. Filtration, also, in contradistinction to sedimentation, is effective in eliminating the great proportion of bacteria, all ova and cysts. The metal filters probably also hold back the schistosome cercariæ. In both clarification methods, whenever alum or aluminoferric is used, discoloration of the water, if present, is removed. Sometimes difficulty in filtration is experienced owing to the presence in the water of silt in colloidal suspension. This may be obviated by preliminary sedimentation in the ordinary way, but this involves the expenditure of much time, and it should be noted that, provided flocculation, as distinct from sedimentation, is allowed to occur, filtration may be effected without blockage. This is due to the fact that when "floc" forms the clay particles are separated and the clay silt becomes porous. The metal filter supplied with the Army Water Vehicles is designed to overcome these difficulties in filtration.

Filtration.

Filtration in the Army is normally carried out by means of the standard cloth or metal filters attached to the various water vehicles, a detailed description of which is given in Appendices X and XIA, but, in their absence, rough filtration can be effected with a blanket tied by its corners to four stakes. Alum may be added to the first 2 or 3 pailfuls of water to be filtered, and a clearer filtrate will ultimately be obtained.

The Standard Cloth Filters (Appendix XIA) have stood the test of time, and are admirably suited to a hand-worked plant.

The cloth filters do not stand up to a pressure above that produced by hand pumping (a relief valve, which blows off at a pressure of 15 lbs., is fitted to each pump), and are not constructed to allow of self-cleansing.

The removal of the cloth when clogging has occurred is a laborious business, which, with very turbid waters, may occupy a man's whole time.

When indenting for new cloths, pattern O.O. should be specially asked for, as many varieties of material have proved unsatisfactory.

The Mollinite Filter, a full description of which is given in Appendix X, consists of an inner heavy galvanised flat wire mesh strip, which acts as a waterway and support to the fine bronze or monel mesh with which both sides of it are covered.

Before operation, a dose of filter earth is added, which impacts against the metal mesh, blocking the spaces and forming the filter bed. When the filtration is completed the filter earth is washed off the metal mesh, and is re-formed on recommencing filtration.

The filter earth used must be of a suitable grade. If either too coarse or too fine a grade is used, the filter will not function efficiently and impurities may be forced through.

The Mollinite filter stands up to much higher pressures than the cloth filters before dirt is forced through, but, with the correct grade of filter earth, filtration will be performed at relatively low pressures.

Filter earths are marketed under various trade names, for example, Mollicel, Cellite, Hyflo. Only an approved grade must be used.

The Mollinite filter used with the water trailer is the same in every respect as that used on the water truck and water lorry. The two filters are completely interchangeable.

Two filters are fitted to each water truck or lorry, and one to each water trailer. Each filter has a capacity of 100 gallons in 20 minutes, with the hand pump used.

Portable Filtration Plant.

There are occasions when mechanical vehicles are unable to follow a column, or when small units or detachments are sent to isolated places, where local arrangements must be made for filtration of water. A small portable plant becomes necessary under these circumstances, capable of being carried on ordinary transport vehicles or on a pack animal, or by hand.

Such a plant, mounted on a tripod stand, has been constructed. It is fitted with a suitable type of Mollinite filter.

Sedimentation.

The method is described fully in Appendix XV. When alum or aluminoferric is added to water a flocculant gelatinous precipitate of aluminium hydroxide forms, which settles, bringing down matter in suspension with it.

There are two very important points to remember if the process is to be successful.

(1) That alum, or aluminoferric, is used and not clarifying powder or filter earth.

(2) That the correct pH is obtained. In 99 cases out of 100 no adjustment is necessary, and a dose of about 4 grains of alum or aluminoferric per gallon is effective.

It is a slow (4 to 6 hours) and rather complicated method, and is not employed unless there are no filters available, or where the nature of the suspended matter makes it necessary as a preliminary to filtration.

When sedimenting, it is an advantage to leave the "floc" of the previous sedimentation in the tank, as, after dosing the next supply of water with alum and mixing it with the "floc" already present, settlement is considerably accelerated.

In using the process as a preliminary to filtration, it should be remembered, as previously stated, that filtration may be proceeded with as soon as flocculation has occurred, and it is not necessary to wait for the completion of sedimentation.

Sterilisation by Chlorine.

Chlorine, in one form or other, is the chemical agent most universally employed in the sterilisation of water.

It is germicidal in very small concentrations, and its action is quick and reliable.

There is an increasing consensus of opinion that it kills not by oxidation, as formerly thought, but by the direct toxic effect of chlorine on the organisms. It is important to remember that chlorine has a less affinity for organisms than for other forms of organic matter, and sufficient must therefore be added to saturate the organic matter and to leave a balance of free chlorine in the water to kill the germs. This does not, however, apply in the case of chloramine.

In view of the above, the dose of chlorine will depend on the amounts of organic matter in the water, and is determined by the Horrocks' Test, described in detail in Appendix IV. This test shows the number of scoopfuls (standard size scoops are provided) of water sterilising powder required per 100 gallons of the water to be treated, each scoopful representing 1 part per million of chlorine. When chloramine is employed there is no difference in the amounts of the ammonium salt and water sterilising powder used to produce it, whatever the state of the water being treated. There are many forms in which chlorine may be used, for example:—

(1) Chlorine gas. This is not advocated in the Army owing to the danger of leakage from the cylinders in which it is contained.

(2) A hypochlorite is liberated from Bleaching Powder, Water Sterilising Powder, Para-sulphon-dichlor-amino-benzole acid tablets, or produced by the electrolysis of a salt solution.

(3) Chloramine formed by the interaction of ammonia and chlorine (usually in the form of tablets of ammonium chloride followed by water sterilising powder).

The method of employing chlorine in the Army may be one of the following:—

(1) Superchlorination followed by dechlorination. This is preferred for unit supplies, as it is quicker in its action, and the water treated is tasteless.

(2) Chlorination. This has largely been superseded, except in India, where it is the standard method. It takes a longer period for sterilisation to be effective, and is an unpopular method with the troops because of the liability to taste troubles.

(3) Chloramination (ammonia-chlorine). This has one disadvantage, in that it takes a much longer period to sterilise the water than the previously mentioned methods. It has a continued action, and is eminently suited for bulk supplies.

The following table shows the special characteristics of the three methods.

	Superchlorination with dechlorination.	Chlorination.	Chloramination.
Dose	2 p.p.m. for Chlorine controlled by Horrocks' Test.	1 p.p.m. for Chlorine controlled by Horrocks' Test.	1·5 to 2 p.p.m. Standard dose uncontrolled.
Toxicity ..	Bactericidal action complete in 15 minutes.	Bactericidal action complete in 30 minutes.	Ammonia enhances toxicity but delays bactericidal action, which is complete in 60 minutes.
	Delayed by high alkalinity and low temperatures.	Delayed by high alkalinity and low temperatures.	Delayed by high alkalinity and low temperatures.
Presence of large quantities of natural ammonia in the water.	Will only slightly reduce bactericidal action.	May definitely reduce bactericidal action.	Will definitely reduce bactericidal action.
Deviation by organic matter.	Yes. Requires prefiltration.	Yes. Requires prefiltration.	Filtration can follow chloramination.
Penetration ..	Does not penetrate particulate matter.	Does not penetrate particulate matter.	Does not penetrate particulate matter.
Persistence ..	Having double the dose of chlorination disappears half as slowly.	Disappears rapidly from water exposed to air.	Persists for one or two days. Rusting pipes or containers are liable to remove chloramine.
Taste	Removes all taste of chlorine, also tastes present in raw water. No taste with phenols. Precipitates iron in water.	Over 1 p.p.m. free Cl. gives a chlorinous taste to the water. May accentuate taste present in raw water. Gives taste with phenols.	Tasteless up to 2 p.p.m. No taste with phenols.

Before proceeding to describe in greater detail the three methods of purification of water supplies used in the Army, we should give brief consideration to the question of the chlorinating compound, namely, water sterilising powder, which is used in the greater majority of instances for water purification.

Water sterilising powder (W.S.P.) contains 25 per cent. available chlorine, consists of 4 parts ordinary bleaching powder and 1 part quicklime (CaO), introduced to absorb moisture and so preserve the bleach from deterioration. The powder is stable in dry, hot climates, but loses chlorine when it becomes damp. It is contained in 4-oz. hermetically-sealed tins, each of which is supplied with a metal scoop to hold 2 grammes when the powder in it is level.

Tins should be stored in a dry place, and should be examined from time to time for rust and erosion. It is very important that the W.S.P. is up to full strength, as, with superchlorination, the extra dose over and above that indicated by the Horrocks' test may only be a fraction of 1 p.p.m., and sterilisation may not be completed in 15 minutes.

Every care, therefore, should be taken when chlorinating water to protect the contents of the tin from rain or dampness, which would cause deterioration.

The lid should be invariably tightly replaced immediately the dose has been extracted. If this is attended to little or no loss will occur during use. Where the Horrocks' Test is not available, a standard dose of 4 p.p.m. is added, and contact allowed for 15 minutes. If the water is unfiltered the period of contact should be extended to 30 minutes.

This is sufficient to destroy pathogenic organisms in all acceptable waters.

Estimation of Available Chlorine in Water Sterilising Powder.

The chlorine content of the powder should also be periodically tested.

(1) Roughly, by adding one part per million, as described under the Horrocks' Test in Appendix IV, to a white cup filled with distilled water. Varying depths of blue, to the experienced eye, will indicate the proportion of chlorine present.

(2) Or, more accurately, by the method described in Appendix VI.

We will now turn to a detailed consideration of the three methods by which chlorine is used in the Army for water purification.

Superchlorination.

This is the standard method of treatment adopted in the apparatus supplied to units for the purification of their water supply. Such apparatus will normally comprise either the Water Truck or Lorry, or Water Trailer, both of which are described in Appendices X and XI, though in the absence of these it may be necessary for units to carry out the treatment in tanks, as described later.

The method involves:—

(1) **Superchlorination** by means of Water Sterilising Powder in doses sufficient to give 2 parts of free chlorine per million after deviation by organic matter present has taken place.

The carrying out of Horrocks' Test indicates the amount of this powder necessary to give 1 part per million of free chlorine in standard scoops per 100 gallons; consequently, to give 2 parts per million of free chlorine after deviation one extra scoop will be required per 100 gallons.

This amount of free chlorine will kill all pathogenic organisms in a minimum of 15 minutes, and the schistosome cercariæ in half an hour.

A word of warning is however necessary in regard to water with a high natural ammonia content, as is sometimes found in the case of rain water, or water recently and heavily polluted with organic matter. In such a case a certain amount of chloramine will be formed. This has two effects —firstly, it may upset the Horrocks' Test, as a blue colour will show itself even though there is oxidisable organic matter present, since chloramine is not deviated, and gives the same reaction with starch and iodine as chlorine.

Secondly, if the proportion of chloramine is appreciable there will be a lag in sterilisation owing to the slower bactericidal action of chloramine.

Consequently, dealing with waters of the nature mentioned, it is advisable to extend the contact time to a minimum of 30 minutes.

It should be borne in mind that it is essential in adding water sterilising powder to a water, it should first be made into a strong solution in water in a bucket or similar receptacle, and that this solution should be added gradually to the bulk of the water to be dealt with and mixed thoroughly with it.

(2) After the lapse of the necessary contact time (normally 15 minutes), the colour test described in Appendix V is carried out. With superchlorination a deep blue colour should be given in the white cup.

Having proved the presence of an adequate amount of free chlorine in this way, we proceed to:—

(3) **Dechlorination,** by means of tablets of anhydrous sodium thiosulphate (0.5 gramme)—two per 100 gallons.

This effectually takes away any taste of chlorine in the water.

The use of the crystalline salt (Hypo) is not recommended, as it commences to melt at a temperature of 118° F., and would not be suitable for the tropics. The anhydrous salt is very stable, and has been selected for this reason.

Just as in the case of W.S.P., the necessary number of tablets, according to the volume of water being treated, should be made into a strong solution and mixed thoroughly with the bulk of the water.

One dechlorinating tablet is sufficient to remove 1 part per million of chlorine in 100 gallons of water, and not only is all taste due to chlorine removed immediately, but the combined process of superchlorination and dechlorination destroys any unpleasant taste or odour the water may have had previous to treatment.

It is of the greatest importance that water duty personnel fully appreciate the danger to the consumers of adding the dechlorinating tablets before the full period of contact with chlorine has elapsed.

Chlorination.

If dechlorinating tablets are not available, ordinary chlorination must be resorted to.

The technique (see Appendix XIII) of its use is identical to that of superchlorination, with the exception that the dose of water sterilising powder is that indicated by the Horrocks' Test, *i.e.,* 1 part per million after deviation, half that of superchlorination, and the period of contact is a full 30 minutes as a minimum.

It is very important that the dose is not exceeded, otherwise complaints of taste will be made.

Water duty orderlies are inclined to be over-zealous, and often add an extra portion for safety.

In all cases, the water should be tested for the presence of chlorine at the end of the period of contact, but, as distinct from superchlorination, a light blue colour only in the white cup when the colour test is carried out will be an adequate indication of the effectiveness of the sterilisation.

Chloramination.

There are two methods in the Army of chloraminating water.

(1) The Harold McKibbin (Ammonia-Chlorine) process is fully described in Appendix XII. With this method two tablets of ammonium chloride (ammonia) are added to and mixed with every 100 gallons of water, followed by two scoopfuls of water sterilising powder (chlorine).

When dealing with large supplies, powdered ammonium chloride, contained in half-pound tins supplied with a 50-grain scoop, is generally preferred. It is very important that thorough mixing of the chemicals is carried out. The ammonium chloride solution must be mixed in with the bulk of the water being treated before addition of the "bleach" solution.

In the case of the baffled tanks, not only should the plunger be used vigorously, but the chemicals should be distributed equally in each of the compartments.

(2) The method employed in the Mobile Water Purifier (see page 30 and Appendix XVI), where chloramine is formed by first adding to the water, as it is pumped to the filters, a measured quantity of ammonium sulphate solution, followed by the requisite dose of chlorine, which is in the form of sodium hypochlorite, and is produced by the electrolysis of a 5-10 per cent. salt solution.

The advantages and disadvantages of chloramination, compared with the other methods, are given in detail in the table on page 24, and its chief demerit is that its lethal action takes twice as long as ordinary chlorination and four times as long as superchlorination.

Its essential value as a water sterilisant is its persistence. It is therefore to be preferred to chlorination at bulk-supply water points, where there is no urgency in the provision of water and where the distribution is by pipes, water vehicles or small containers, which are liable to become contaminated, the sterilising action continuing for a long period of time. If rust, however, is present, destruction of chloramine rapidly occurs.

The starch iodide indicator is used to indicate the presence of chloramine by means of the colour test, in just the same way as with ordinary chlorination. It is very essential to remember that the W.S.P. employed should be up to full strength, as otherwise the correct proportion of chlorine to ammonia (4 : 1) is not obtained. This necessitates a constant check on the available chlorine present in the W.S.P. by carrying out the test described in Appendix VI.

WATER VEHICLES, WATER POINTS AND DISTRIBUTION.

Bulk Supplies.

All bulk supplies are organised and administered by the Engineers, the medical authorities being responsible for the selection of water points and advice as to the method of treatment and for the carrying out of certain tests. Water points should be numerous and the sites carefully drained and policed.

Certain points in regard to the selection of the site are of importance.

The clearest water available should be chosen, and if the source is a river the water point should be above any pollution entering from houses, factories, etc.

If the water is shallow a sump should be dug at the point chosen, otherwise the bed of the river should not be disturbed unnecessarily.

The intake should be away from the banks and supported above the bed to prevent scouring.

Polluted tributaries and feeders should be diverted where possible from the source, and it is important that rivers and other water supplies which are liable to intentional poisoning should be regularly tested for the presence of poisons.

In connection with each there should be a covered reservoir or tank holding one day's supply.

Water points should not be on the main roads; if this is unavoidable a by-pass should be constructed.

Plenty of accommodation must be provided for trucks waiting their turn to fill, and the number of stand pipes should be proportionate to the number of carts which will draw from the point.

At each water point there should be arrangements for filling dixies and water bottles.

Troops must not be allowed to dip utensils into the tanks.

Pumps may be reciprocating, lift and force (pulsating flow) or centrifugal (steady flow).

The maximum lift at sea level with a reciprocating pump is about 20 feet, and 15 feet for a centrifugal pump. The efficiency of a pump falls as the temperature of the water rises and as the altitude increases above sea level. At an altitude of 10,000 feet the lifting power of a pump falls by about a third.

Direction Boards indicating the position of water points should be erected in such a manner and on such a scale as to ensure the troops having no difficulty in finding the correct water supply.

All sources of supply should be distinctly marked with a notice board showing whether the water is fit for drinking or not.

If fit, the number of measures of W.S.P. per 100 gallons should be stated.

The dose is fixed by the Officer Commanding Field Hygiene Section or Deputy Assistant Director of Hygiene of the area after repeated daily tests, until a constant figure is obtained.

DRINKING WATER.

REQUIRES SCOOPFULS OF W.S.P. PER 100 GALLS.

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or

UNFIT FOR DRINKING.

A stock of these notices should be kept by the Field Hygiene Section.

Distribution in L. of C. and Base Areas should be by pipes and taps, while nearer the front line units would draw from the water point with whatever means they possess.

The Mobile Water Purifier.

This will be the normal unit for producing bulk supplies of drinking water. It consists of four components:—

(1) A sterilising unit.
(2) A pump and generator unit.
(3) A filtering unit.
(4) A petrol engine.

A full description of these is given in Appendix XVI. The water is sterilised by ammonia-chlorine (chloramine), which is formed by primarily ammoniating the water with a solution of ammonium sulphate, and then adding a solution of sodium hypochlorite prepared by the electrolysis of a 5 to 10 per cent. common salt solution. Should, however, it be decided to chlorinate, instead of chloraminating the water, the ammonia feed can be disconnected.

It should be remembered, however, that in this plant filtration follows sterilisation, and, unless the water is obviously clear or has been presedimented, chlorine will be deviated by the dirt, and may not be present in the water after filtration. At any rate, the Horrocks' Test must be carried out on the raw water.

The petrol engine is removed from the lorry when the plant is working, and drives the pump by a flexible cable. Its removal allows greater space on the vehicle for the operator, and does away with a great deal of vibration and noise.

The plant, which is mounted on a 30-cwt. lorry, can be worked detached from the vehicle.

With ordinary raw waters it has a production capacity of 3000 gallons an hour.

The pump has a lifting power of 20 feet. To pump water from levels lower than this an auxiliary pump, which can be placed beside the source and driven by the engine by means of a flexible cable, is provided. The Mobile Water Purifier is a R.E. unit, and is attached to an Engineer Field Park Company.

Four men, including one from the R.A.M.C., are required to operate the plant, and, although every man has a fixed duty, each should be able to perform the work of any of the others.

The main duty of the R.A.M.C. orderly is to prepare the two chemical solutions, and check the quantities of chloramine present in the treated water from time to time.

Should precoagulation be necessary, he will calculate the amounts of alum required.

He will also carry out the Horrocks' Test and test for the presence of poisons. Two mobile purifiers are provided in each A.T. Coy. and Fd. Park Coy., R.E.

Water Supply System with Water Tanks.

In the absence of mobile water purifiers at water points dealing with bulk supplies, or sometimes in the case of unit supplies when water trucks or trailers are not available, it may be necessary to treat the water in tanks.

These may be used for storage, apart from treatment, and may be:—

(1) **Galvanised Iron.**—There is no standard size, and tanks are built with sections of pressed steel bolted together, according to requirements.

The commonest size is 4 ft. × 4 ft. × 4 ft., holding 400 gallons.

The caulking between joints often causes an unpleasant taste in the water, which can be obviated by the application of bituminous or aluminium paint along the joints.

(2) **Canvas.**—The standard canvas tank, holding 1500 gallons (working capacity 1200 galls.) is circular in shape, and is self-supporting. It is fitted with two flexible hoses, which serve for filling and emptying.

A 4-inch Kapok rim keeps the tank erect and in shape. It weighs 83 lbs., but this is doubled when wet.

(3) Ground level tanks can be improvised by using a waterproof cover with which to line a sunk pit, the edges being pegged down to the earth mound formed by the excavation.

Requirements for Treatment and Storage.

A minimum of 3 canvas or galvanised iron tanks.

One or more pumps, depending on whether gravity flow is possible or not.

Lengths of hosing.

Float and strainer.

$\left.\begin{array}{l}\text{Alum Feed}\\ \text{Chlorine drip}\end{array}\right\}$ Oil Drums.

Method.

The tanks are arranged in series, the first for sedimentation, the second for chlorination, and the third for delivery.

Naturally, in large water points duplicate, triplicate, or more tanks may be required.

Sedimentation.

To each sedimentation tank is attached a drum containing a solution of alum, sufficient, when added to the volume of water in the tank, to give a proportion equal to 4 grains of alum per gallon. The rate of flow of the alum solution should be regulated to permit of the whole dose being added during filling.

When the tank is full, sedimentation is allowed to continue for 4 to 6 hours.

A detailed description of sedimentation is given in Appendix XV.

Superchlorination.

To each chlorination tank a system of chlorine feed similar to that described for alum is installed. The dose of chlorine is calculated on the results of the Horrocks' Test, and on the capacity of the tanks, remembering that with superchlorination 1 part per million is added over and above that indicated by the test.

A minimum period of 15 minutes is allowed for sterilisation to be effected, after which dechlorination is carried out by the addition of a solution of Taste remover tablets in the required amounts.

The dose of the latter solution is calculated on the fact that one Taste remover tablet neutralises 1 part of free chlorine per million in every 100 gallons of water to be treated.

Thorough stirring, by means of an oar or plunger, may be necessary, although in the majority of cases, efficient mixing will occur as the water is being pumped into the supply tank.

The Supply Tanks.

These should be raised, so that the draw off is at a height suitable for the particular method of distribution employed, *i.e.*, wheeled tanks, pakhals or water bottles.

A site should be selected so that a flow of water from one tank to another can occur by gravity, otherwise pumps are required between each series of tanks. A distribution pipe, with taps, should link up and be fed by the supply tanks.

Unit Supplies.

The normal method of water treatment in the front area will be by means of the Unit Water Lorry, Water Truck or Water Trailer (Appendices X and XI).

The responsibility for providing a safe supply falls on the Medical Officer attached to the Unit.

The Water Lorry (Appendix X) is a mechanically-propelled vehicle carrying a 200-gallon (working capacity 180 galls.) tank on a 30-cwt. chassis.

The Water Truck (Appendix X) is a mechanically-propelled vehicle carrying a 400-gallon (working capacity 375 galls.) tank on a three-ton W.D. chassis.

Each lorry or truck has two water-duty orderlies (including the driver).

The Water Trailer is designed for use with mechanised units, and is towed behind a lorry. There are two patterns: (a) With tank capacity 80 gallons; (b) with tank capacity 150 gallons.

Each trailer has 2 (two) water-duty orderlies attached.

The trailer is not suitable for use in sandy deserts, as, owing to its having only two wheels, it sinks deeply into the sand. The vehicle must have four wheels if this is to be avoided.

The tanks of both these water vehicles are baffled to prevent "surge" and strain on the chassis or axle.

Little or no surge occurs when the tank is full, and it is in this state the vehicle should, if possible, travel.

If the tank is partially full the greatest strain occurs in turning corners or in stopping suddenly.

Drivers should be instructed to proceed slowly in both these circumstances. There is a risk when going up very steep gradients of the vehicle tilting over. This can only occur if the tank is half full and the weight of water is thrown to the back of the tank.

It is advisable here to remind readers of the importance of

The Responsibility of the Unit Medical Officer in connection with Water Supplies.

He must ensure that:—

(1) The unit water duty personnel is properly trained and carries out its duties satisfactorily. Also that reserves are similarly trained so that casualties can be quickly replaced.

(2) The Pump and Filtering apparatus of the vehicle under his charge is in working order.

(3) The tanks are cleaned and disinfected with a strong solution of bleaching powder at least twice a week.

(4) He has adequate amounts of full strength water sterilising powder and of clarifying powder or filter earth and other necessary chemicals. These are obtainable from the nearest unit quartermaster.

(5) The Case Water Testing Sterilisation and Poison Test Case are in serviceable order.

It is imperative that every unit medical officer should give the points mentioned full attention.

Small Portable Containers for Unit Water Supplies.

Under certain circumstances, vehicles for the transport of water of the nature described may not be available, and resort must be had to small portable containers of other descriptions.

Those usually employed are either petrol tins or pakhals.

Petrol Tins.

The standard containers for transporting water in lorries or on pack animals. Each holds 2 gallons, and is a convenient size for one man to handle or carry, and, by a simple contrivance in the shape of a screwed-on funnel, water bottles can be easily filled. It is estimated that to supply a division with water in petrol tins, as was done in the trenches in France, 3100 tins are required. Arrangements have to be made for replacements. The only disadvantage of the petrol tin its its liability to rust, which is particularly noticeable in desert countries.

Pakhals.

In the East the 7-gallon Mule and 14-gallon Camel Pakhals are favoured.

The outsides of the pakhals are liable to gross pollution by being handled by mule and camel drivers, and by being laid on the ground or covered with dust during carriage in a column.

All pakhal lids should be fitted with a lock, for which responsible persons have the key. The lid should invariably be on when the pakhal is not in use.

Some pakhals have handles to hold while delivering the water, others have not, and the tendency is for the person to introduce a hand inside the opening for this purpose. This must never be allowed.

Whether during transport or in dumps, containers should be protected, if possible, from the sun—otherwise in a tropical country the water becomes hot and unrefreshing.

Pakhals are sometimes covered with a canvas cover, which though not a hygienic addition, nevertheless can be kept wet, and by evaporation the contents remain cool.

At any rate, a shelter should be erected at filling and distribution sites, and a cover spread over the loads while on transport.

All water containers should be thoroughly cleaned and sterilised with water containing 10 parts of chlorine per million and left for 15 minutes.

Individual Supplies.

On active service every soldier carries in his haversack a water bottle containing roughly 2 pints of water. When on the march he should not normally be allowed to drink from it until he has completed seven and a half miles.

By the end of the 15th mile he should have emptied the bottle, which should be refilled from the water vehicle. If the march is continued further, emptying and refilling should take place every 7½ miles.

There should be the strictest water discipline on the march, not only as regards conservation of water but also with regard to men filling their bottles from unauthorised sources.

Water bottles should be regularly inspected and sterilised with chlorine solution of a strength of 10 parts per million, made up by adding 5 scoops of W.S.P. to a water bottle full of water and adding one scoop of this strong solution to the bottles to be dealt with, which are half-filled with water. The bottle should then be vigorously shaken and allowed to stand for 15 minutes, when the contents can be poured out.

The Sterilisation of Water in Bottles.

An individual Water Sterilising Outfit is supplied for this purpose, and consists of:—

(1) Sterilising tablets containing a mixture of Water Sterilising Powder and Sodium Chloride.

These tablets are white in color.

(2) Taste Remover Tablets (Thio tablets), containing a mixture of Anhydrous Sodium Thiosulphate and Sodium Chloride.

These tablets are blue in colour.

The outfit is packed in a small tin, the white and blue tablets in separate bottles. Directions for use are printed on the inside surface of the lid of the tin.

Each sterilising tablet, when added to a bottle full of water (1 qrt.) liberates six parts per million of chlorine. A minimum period of half an hour's contact is necessary to ensure sterilisation before adding one Taste Remover tablet, as in all probability the water will not have been filtered.

The longer the period of contact the better.

Care should be taken that the bottles containing the tablets are kept tightly corked when not in use, and that only the number of tablets required are taken out at one time. IT IS ESSENTIAL THAT THE STERILISING AND TASTE REMOVER TABLETS ARE PUT INTO THE WATER IN THE RIGHT ORDER—THE WHITE FIRST AND THE BLUE LAST.

It will sometimes happen that the individual sterilising outfit is not available, and recourse must be had to other methods.

If the Horrocks' Box is available, which, with small detachments is unlikely, sterilisation may be carried out by superchlorination, provided the usual water sterilising powder and dechlorinating tablets are available.

In the absence of the latter tablets, ordinary chlorination may be practised.

If the Horrocks' Box is not available then recourse must be had to chloramination, or a special form of super-chlorination, in which 4 parts per million of chlorine (*i.e.*, 4 scoops of W.S.P. per 100 gallons) are added, and then, after a minimum of 30 minutes' contact, the equivalent of 4 dechlorinating tablets per 100 gallons.

This latter method will deal effectively with all acceptable waters, and should be employed, provided the dechlorinating tablets are available. If this is not the case, chloramination will be necessary.

Superchlorination in the ordinary or special form, and chloramination, are carried out by what is known as the **three bottle method**, and ordinary chlorination by the **two bottle method.**

These are described in detail in Appendix XIV, the procedure, briefly, being to make up strong solutions of the various sterilising agents employed and from these stock solutions to dose the water in the men's bottles.

With these methods, the strong solutions referred to will often be made up in the water bottles, but extra numbers of these will be required, and it may be found necessary instead to carry ordinary bottles of the solutions. For example, pint bottles (beer) could be employed—half the dose of chemicals required for the ordinary service water bottle being used.

In the employment of these methods certain important points require special attention.

(1) One man should be responsible for carrying out the treatment.

He should preferably be a junior N.C.O.

(2) He should see that men fill their bottles from the cleanest source.

(3) He should be careful to see that his strong solutions are marked, and that they are added in the right order.

(4) He should make sure that the men understand that the water is unsafe to drink until half an hour has elapsed in the case of superchlorination and chlorination, or one hour in the case of chloramination.

(5) In the case of superchlorination, if the men complain of taste, he should add more taste remover solution.

POISONING OF WATER SUPPLIES BY THE ENEMY.

Metallic Poisons.—There was not a solitary instance of water being poisoned by the enemy in any area in the late war, nevertheless, the possibility of its use cannot be entirely ruled out. The number of poisonous substances that could be used with effect and not be obvious to the senses is not great. It is likely that wells alone would be attacked, as other supplies, such as rivers and lakes, would require large quantities to ensure a lethal effect.

Obvious poisons, such as cresol, paraffin, dead bodies, farmyard manure, excreta, etc., and substances such as common salt, and other non-poisonous bodies present in great excess cannot be removed by any practicable process. A well contaminated with such substances can be rendered usable in a few days by cleaning and continuous pumping (*vide* Wells, page 10).

Arsenic (sheep dip), Mercury (perchloride), Antimony (Tartrate), Cyanide (Sodium), Lead (Subacetate), and Mustard Gas are substances which can be removed by treatment. Every Officer in Medical Charge of a Unit has, as well as the Case, Water Testing Sterilisation, a Case, Water Testing Poisons, by means of which most of the common poisons can be identified.

See Appendix IX.

Immediately a well or other source is taken from the enemy the Medical Officer should test for the presence of poisons.

If the test is positive, or he is suspicious, he must take measures to ensure that the soldiers cannot get at the water, a sample of which should be forwarded to the Mobile Hygiene Laboratory attached to Army Headquarters, by the most rapid means available. At the same time, an urgent telegram stating the circumstances should be sent to the D.M.S. Army Headquarters.

The officer i/c Mobile Hygiene Laboratory, or a chemist specially detailed by the D.M.S., would probably undertake the work of removal of the poisons.

In any case, it would be some time before arrangements could be made and the work completed.

It is therefore essential that another supply should be made available, and the poisoned well be put completely out of action.

Water Contaminated with Mustard Gas and Lewisite.

Introductory Remarks.

Mustard gas is a heavy, oily liquid, which, when dropped into water, sinks to the bottom, and is slowly decomposed into harmless products, one of which reacts to the iodoplatinate test in the same way as the gas itself. A thin, oily film may remain on the surface of the water for some time after contamination.

Lewisite is also a heavy, oily liquid, but differs from mustard gas in being comparatively rapidly decomposed by water to give arsenical products, which are somewhat soluble and very toxic. Sources contaminated with lewisite must, therefore, on no account be used until the necessary chemical treatment has been carried out to free the water from arsenic. A possible exception to this is a large reservoir, in which much dilution of the arsenical salts has occurred. In the majority of cases areas which have been contaminated will be known to the military authorities, and water supplies in these areas, unless under the most exceptional circumstances, where no other supply is available, will on no account be used for any purpose whatsoever.

Neither the cloth nor metal filters using alum or filter-earth keep back oily globules of mustard gas, if these are present in the water in considerable quantities, and should such globules enter the pipe, they will contaminate the whole system of pumps, filters and tanks, and this will necessitate the condemnation of the water in the vehicle and the complete dismantling and decontamination of every part of the system by a skilled decontamination squad, which will result in the apparatus being rendered unserviceable for a considerable period of time.

It is, therefore, essential that known or suspected contaminated supplies should be avoided.

Measures for the Detection of Mustard Gas and Action to be Taken if it is Found to be Present.

(1) Suspected sources and those taken over from the enemy should be tested for the presence of mustard gas and arsenic, as well as for other poisons, using the poison test case.

The sample of water should be taken from the sources by means of a tin, bucket or dipper, care being taken that, in the case of surface supplies, the person taking the sample does not wade into the water for the purpose.

A positive result indicates either the presence of mustard gas or its decomposition products.

It should be noted, however, that he deviation of large quantities of chlorine, as evidenced by the Horrocks' Test, is also suggestive of the presence of these chemicals, and the warning is one which should be heeded.

As regards mustard gas globules lying at the bottom of a water source, a sample may be obtained by the employment of the following method:—

A suitable length of metal piping or glass or rubber tubing is selected, and, with one end kept closed by the finger, the other end is carefully lowered to reach the bottom of the water.

On releasing the finger, water will flow into the tube, and can be held there by closing or pinching the upper end as before while the tube is withdrawn.

It is realised that it is only in special circumstances that this test is a practicable one.

A sample should never be taken by using a pump, as the latter may at once be rendered unserviceable.

(2) If a source is found to be contaminated with mustard gas or lewisite an alternative uncontaminated source must be looked for and, if found, used.

The contaminated source should be suitably marked with warning signs, and fenced in so that it is impossible for men to draw water from it.

(3) It is only in the most urgent circumstances that water contaminated with mustard gas would be utilised.

Under **no** circumstances, except possibly in the case of very large reservoirs, with consequent great dilution of the poison, would water contaminated with lewisite be utilised, until special chemical treatment to deal with the arsenic had been carried out.

In the very remote event of supplies contaminated with mustard gas having to be used, the following instructions must be carefully adhered to:—

(*a*) **Where the source is deep (i.e., over 4 ft.)**, in which case the water lorry, truck or trailer may be used.

(1) The intake point should be selected where the water is deepest.

(2) The bottom of the source should not be disturbed in any way.

(3) The inlet pipe should be introduced gently into the water, so that its opening lies at least 9 in. below the surface.

(4) Provided the water has been at rest for 2 hours, Horrocks' Test, followed by superchlorination, should be carried out.

(*b*) **Where the source is a shallow one (i.e., less than 4 ft.)**, in which case the water lorry, truck or trailer must never be used.

The circumstances must be extremely grave to warrant the use of such water, and if it is utilised, it should be carefully removed with a bucket, care being taken not to disturb the bottom.

Subsequent boiling for 30 minutes is essential, and will render it safe for consumption.

If boiling is not practicable, an alternative method is to filter the water by digging a trench or hole near to the edge of the source if it is a surface supply, and allowing it to seep through into the cavity.

The water filtered in this way must then be super-chlorinated as in (*a*) (4) above.

A pump should not be used if it can possibly be avoided, but if it is employed then a double fold of blanket should be wrapped round the end of the inlet pipe. Subsequent boiling for 30 minutes will be required.

In conclusion, it should be realised that in all cases of doubt or difficulty an expert on gas should be called in to advise.

WATER SUPPLIES CONTAMINATED WITH SCHISTOSOME CERCARIÆ.

Water in some districts of the world, especially in the Valley of the Nile, Mesopotamia, and the Far East, may be infested with the cercariæ of Schistosome worms, which are present in persons suffering from the disease Bilharziasis, or Schistosomiasis.

The ova of the worms are passed in the urine or fæces of such people, and if the ova gain access to water they hatch out into free swimming miracidia.

The duration of life of these miracidia is but 24 hours, unless they can find entrance to a special fresh water snail, which acts as the intermediate host. Development takes place in the snail with the production of myriads of cercariæ, which may penetrate the skin or mucous membrane of a person bathing or drinking the water in which they are present, and give rise to the disease in question.

It is generally possible to learn from inhabitants which waters in a locality are infested, and these should be avoided.

To ensure a safe water supply the following measures should be adopted:—

(1) Clean away the supply of weed on which the snails feed.

(2) If practicable, drain dry the channel in which the water lies. If sun-baked the snails rapidly die.

(3) Snails can be destroyed by adding copper sulphate in amounts equal to 1 lb. for every 100,000 gallons (1 p.p.m.).

(4) Snails can be eliminated from the water supply by means of a screen, 16 meshes to the linear inch, placed between the source and the intake.

(5) Unless cercariæ find a human host they die in 36 hours—storage of water free from snails for 48 hours is alone sufficient to make it safe.

(6) Methods of clarification, either by sedimentation with alum or filtration through sand or cloth filters, do not hold back cercariæ—which are known to penetrate 3 feet of sand.

The metal filters, *e.g.*, the Mollinite filter, may however, possibly remove these infective agents.

(7) Superchlorination kills cercariæ in 30 minutes.

(8) Chloramine in doses of 3 p.p.m. will kill in one hour.

(9) Where the water is not used for drinking, cresol, 1½ ozs. to 100 gallons, will render it safe.

(10) Men, *e.g.*, engineers, who may have to work in water, should have their legs and arms protected with rubber thigh boots and gloves—as cercariæ pass easily through clothing.

APPENDIX I.

INSTRUCTIONS FOR SENDING SAMPLES OF WATER FOR CHEMICAL AND BACTERIOLOGICAL EXAMINATION.

All samples of water for Chemical and Bacteriological examination will be forwarded to the O.C., Mobile Hygiene Laboratory, and will be accompanied with separate details of the water sample on A.F.I. 1223.

The results of the examination will be communicated by the O.C., Mobile Hygiene Laboratory on the same form, and in urgent circumstances will be telegraphed.

Receptacles and carriers for the transmission of water samples are held on charge at the Mobile Hygiene Laboratory.

(*a*) Samples for chemical examination should measure at least half a gallon, and should be forwarded in Winchester quart bottles, which contain that amount when full.

(*b*) Samples for bacteriological examination must be forwarded in the sterile bottles and carrier specially provided for the purpose. The officer in charge of the mobile laboratory is responsible for seeing that the bottles are sterilised before being placed in the containers. A certificate, with data stating that this has been done should accompany the carrier. If a chlorinated water is being tested, a crystal of hypo should be sterilised with the bottle, so that the bacteriological picture at the time of sampling can be obtained, otherwise if chlorine is present, sterilisation will continue during dispatch. If circumstances allow of the media being inoculated with water on the spot this should be carried out, and if this is done a delay of 24 hours in incubation in no way affects the results.

The taking of samples will be carried out under the direct supervision of a M.O. detailed for the purpose, who will be responsible for the observance of the following directions.

Great care must be taken that a fair average sample of the supply is collected and submitted. In the case of piped supplies, samples should be taken direct from the mains, as well as from delivery taps in houses.

Samples for chemical and bacteriological examination from any individual source must be taken at the same point and at the same time.

(*a*) **Chemical Samples.**—If possible, without disturbing any sediment that may be present, bottles should be filled while fully submerged—thus avoiding scum. Piped water should be allowed to run to waste freely, so that impurities in the pipe's lumen may be washed out before a sample is taken.

(*b*) **Bacteriological Samples.**—The following additional precautions are necessary:—

(i) If sampling from a tap, flame the tap for a minute, and then let the water run to waste for three minutes before taking the sample. (Note the importance of ensuring against leakage from the washer from the top of the tap into the sample.)

(ii) Before opening the sterilised bottle, flame its neck and stopper for half a minute by means of a spirit lamp. With a similarly sterilised pair of forceps, remove the stopper, and hold it thus until, after a final passage through the flame, it is replaced in the bottle, which should meanwhile have been completely filled so that no bubble of air is finally retained.

(iii) Replace the cap on the bottle before inserting the latter in the inner cylinder of the carrier, which should then be closed by its cover.

(iv) Fill the outer cylinder of the carrier with ice and sawdust, or with dry sawdust if no ice is obtainable.

3. **Transmission of Samples and Particulars.**—To enable it to be identified, each sample should be securely labelled, the label giving full particulars of its source. Samples will always be forwarded by the most expeditious route. Those for bacteriological examination should reach the laboratory within 48 hours of collection (preferably 24 hours).

Full information on the following points must be dispatched at the same time as, but separately from, the samples:—

(*a*) The reason for, and the exact nature of, the examination required.

(*b*) The date and hour of sampling.

(*c*) The nature and location of the source of the water; and the site of sampling.

(*d*) The nature and distance of any source from which an inflow of pollution appears probable.

(*e*) Geological strata (as far as readily ascertainable) likely to affect the water constituents.

(*f*) If the source is a well—the depth to water, depth of water, steining, coping, covering, strata penetrated, method of raising water.

(*g*) If a stored surface-water—the nature of the collecting surface and conditions of storage.

(*h*) Meteorological conditions, with reference to recent drought or heavy rainfall.

(*i*) Any treatment that the water has received that may alter its constituents, *e.g.*, clarification, chlorination, softening or boiling.

APPENDIX II.

EXAMPLES OF WATER ANALYSES AND THEIR INTERPRETATION.

	A.	B.	C.	D.	E.	F.
PHYSICAL CHARACTERS						
Reaction, *p*H. Value ..	6·0	5·3	Alk.	Alk.	Alk.	Alk.
Turbidity	Nil	Nil	Nil	slight	turbid	Nil
Colour	Nil	sl. brown	green-blue	brownish	brown	Nil
Odour	Nil	Nil	Nil	—	Unpleasant	Nil
CHEMICAL CHARACTERS	(In p	arts per	100,000)			
Ammonia F. & S. ..	0·049	0·0008	0·0014	0·0122	0·45	0·006
Ammonia Alb. ..	Nil	0·0160	0·0020	0·0098	0·07	0·11
O_2 absorbed ¼ hr. ..	0·003	0·103	0·005	0·042	0·69	0·50
O_2 absorbed 4 hrs. ..	0·005	0·180	0·052	0·146	·29	0·84
NITRITES	Nil	Nil	Nil	+ +	+ +	Nil
Nitrates	Nil	Nil	0·31	0·36	0·80	0·6
Chlorides	0·15	1·1	1·6	1·9	6·25	4·5
Hardness, Temporary	0·2	0·8	22·8	19·6	2·0	15·0
Hardness, Permanent	Nil	0·8	1·4	1·8	5·0	10·0
Total Solids	2·3	4·0	28·4	29·6	46·7	40·0
Metals	Nil	Iron	Nil	Nil	Nil	Nil

(A) **Rain Water.**—F. and S. ammonia very high (from air), alb. ammonia absent and O_2 absorbed very low. No nitrites or nitrates. Very low chlorides, hardness and total solids. A pure rain water.

(B) **Peat Surface Water.**—Acid. Brown colour. F. and S. ammonia very low, alb. ammonia and O_2 absorbed very high. Nitrites and nitrates absent. Chlorides about normal for surface water. Very low hardness and total solids. Iron present. A soft water, presumably plumbo-solvent, not showing signs of animal pollution, either recent or remote.

(C) **River—Derived from Chalk Springs.**—F. and S. ammonia, low alb. ammonia, and O_2 absorbed very low. Nitrites absent, nitrates and chlorides higher than normal for clean surface water. Temporary hardness high, permanent low. A good river water, but showing some evidence of past animal pollution (nitrates and chlorides).

(D) **Water from River in (C) After Receiving Sewage.**—Note turbidity, and colour changed from blue to brown. F.

and S. ammonia very high, alb. ammonia low, O_2 absorbed high. Nitrites present. Nitrates and chlorides rather high (note increase in chlorides). Increase in permanent hardness probably due to sulphates in sewage. A very impure water, showing evidence of recent animal pollution.

(E) **Water from Pond Receiving Sewage.**—A turbid brown, unpleasant-smelling water. F. and S. alb. ammonias and O_2 absorbed all very high. Nitrites present, nitrates and chlorides very high. Permanent hardness probably due to sulphates from sewage. A very bad water, showing marked evidence of recent animal and vegetable pollution.

(F) **Water from Well with Bad Surface Protection.**—F. and S. ammonia high, alb. ammonia and O_2 absorbed very high. Nitrites nil, but nitrates rather high. Chlorides high (figure for this district = 2.0). Temporary and permanent hardness high. A poor well water, almost certainly contaminated by surface washings.

APPENDIX III.

BACTERIOLOGICAL EXAMINATION OF WATER.

Methods of Estimation of the Coli-aerogenes Group (Presumptive B. coli.)

(A) **Ordinary Method (Ministry of Health).**—Sample should be collected in sterilised bottles of at least 6 ozs. capacity, and all necessary precautions in collecting must be taken.

They should be packed in ice, and reach an incubator as soon as possible, though incubation of the bottles of medium on the spot is preferable.

One of the two following series of tests is employed, the quantities of the medium and of the sample with which it is inoculated being indicated. 6-oz., 2-oz. or 1-oz. bottles, depending on circumstances, are used with screw tops, and containing a small inverted tube closed at the upper end, in which gas formed can be seen.

SERIES I.

ONE bottle containing 50 mls. of double-strength MacConkey's broth and 50 mls. of sample.

FIVE bottles containing 10 mls. of double-strength MacConkey's broth and 10 mls. of sample.

FIVE bottles containing 10 mls. of single-strength MacConkey's broth and 1 ml. of sample.

SERIES II.

FIVE bottles containing 10 mls. of double-strength MacConkey's broth and 10 mls. of sample.

FIVE bottles containing 10 mls. of single-strength MacConkey's broth and 1 ml. of sample.

FIVE bottles containing 10 mls. of single-strength MacConkey's broth and 0.1 ml. of sample (1 ml. of a 1-in-10 dilution).

Series I should be used for a water that is likely to be satisfactory, and Series II for the more unsatisfactory waters (*i.e.,* these showing presumptive coli in one or more of the bottles containing 0.1 ml.).

Incubation at 37° C. for 24-48 hours is carried out, and from the number of bottles in which acid and gas appears, and by the use of a table (pages 47-50, the probable number of organisms of the coli-aerogenes group per 100 ml. of the original sample is easily ascertained.

(B) A Modification of the Ordinary Method Suitable for Use in the Field.—This is a rapid method, and likely to be of special value in the field in regard to the determination of the efficiency of a purification system, and, in certain cases, for aiding a decision as to the respective merits or demerits of two or more water sources from which a choice has to be made.

Five small bottles only are used (about 2 ozs. capacity), with inverted tube in each as before. Each is calibrated at 10 mls. and 20 mls., and in each are placed 10 mls. of the sample, with 10 mls. of medium (double-strength MacConkey's broth).

Inoculation is carried out on the spot, and, if no incubator is available locally, the specimens suffer little even if they do not arrive at an incubator for 24 hours after inoculation.

Standards.

(A) Ministry of Health Method.—Two organisms per 100 mls.—Good. 2-10 organisms per 100 mls.—Intermediate. 10 or more organisms per 100 mls.—Bad.

Efficient chlorination should result in freedom from these organisms in 100 mls., though to allow for experimental error 2 per 100 mls. may be allowed in 10 per cent. of chlorinated samples.

From a Service point of view, if a water shows more than 2 per 100 mls., chlorination should be practised.

(B) Modified Method.—No bottle should show presence of these organisms if the water is to be accepted.

INTERPRETATION OF RESULTS.

On pages 47-50, tables, computed by McGrady, are given. These indicate the probable number of bacteria of the coli-aerogenes group present in 100 ml. of water, as shown by the various combinations of positive and negative results in the quantities used for test.

APPENDIX III—contd. TABLE I.

Quantity of water put up in each tube.	50 ml.	10 ml.	1 ml.	Probable number of coli-aerogenes organisms in 100 ml. of the original water.
No. of tubes used..	1	5	5	
Number of tubes giving positive reaction.	0	0	0	0
	0	0	1	1
	0	0	2	2
	0	1	0	1
	0	1	1	2
	0	1	2	3
	0	2	0	2
	0	2	1	3
	0	2	2	4
	0	3	0	3
	0	3	1	5
	0	4	0	5
	1	0	0	1
	1	0	1	3
	1	0	2	4
	1	0	3	6
	1	1	0	3
	1	1	1	5
	1	1	2	7
	1	1	3	9
	1	2	0	5
	1	2	1	7
	1	2	2	10
	1	2	3	12
	1	3	0	8
	1	3	1	11
	1	3	2	14
	1	3	3	18
	1	3	4	20
	1	4	0	13
	1	4	1	17
	1	4	2	20
	1	4	3	30
	1	4	4	35
	1	4	5	40
	1	5	0	25
	1	5	1	35
	1	5	2	50
	1	5	3	90
	1	5	4	160
	1	5	5	180

NOTE.—The above most probable numbers, from 0 to 20, are correct to the nearest unit; above 20 are correct to the nearest 5.

APPENDIX III—contd. TABLE II.

Quantity of water put up in each tube.	10 ml.	1 ml.	0·1 ml.	
No. of tubes used..	5	5	5	
Number of tubes giving positive reaction.	0	0	0	0
	0	0	1	2
	0	0	2	4
	0	1	0	2
	0	1	1	4
	0	1	2	6
	0	2	0	4
	0	2	1	6
	0	3	0	6
	1	0	0	2
	1	0	1	4
	1	0	2	6
	1	0	3	8
	1	1	0	4
	1	1	1	6
	1	1	2	8
	1	2	0	6
	1	2	1	8
	1	2	2	10
	1	3	0	8
	1	3	1	10
	1	4	0	11
	2	0	0	5
	2	0	1	7
	2	0	2	9
	2	0	3	12
	2	1	0	7
	2	1	1	9
	2	1	2	12
	2	2	0	9
	2	2	1	12
	2	2	2	14
	2	3	0	12
	2	3	1	14
	2	4	0	14
	3	0	0	8
	3	0	1	11
	3	0	2	14
	3	1	0	11
	3	1	1	14

Probable number of coli-aerogenes organisms in 100 ml. of the original water.

APPENDIX III—contd. TABLE II—contd.

Quantity of water put up in each tube.	10 ml.	1 ml.	0·1 ml.	Probable number of coli-aerogenes organisms in 100 ml. of the original water.
No. of tubes used..	5	5	5	
Number of tubes giving positive reaction.	3	1	2	17
	3	1	3	20
	3	2	0	14
	3	2	1	17
	3	2	2	20
	3	3	0	17
	3	3	1	20
	3	4	0	20
	3	4	1	25
	3	5	0	25
	4	0	0	13
	4	0	1	17
	4	0	2	20
	4	0	3	25
	4	1	0	17
	4	1	1	20
	4	1	2	25
	4	2	0	20
	4	2	1	25
	4	2	2	30
	4	3	0	25
	4	3	1	30
	4	3	2	40
	4	4	0	35
	4	4	1	40
	4	5	0	40
	4	5	1	50
	5	0	0	25
	5	0	1	30
	5	0	2	40
	5	0	3	60
	5	0	4	75
	5	1	0	35

Quantity of water put up in each tube.	10 ml.	1 ml.	0·1 ml.	
No. of tubes used..	5	5	5	
Number of tubes giving positive reaction.				Probable number of coli-aerogenes organisms in 100 ml. of the original water.
	5	1	1	45
	5	1	2	60
	5	1	3	85
	5	2	0	50
	5	2	1	70
	5	2	2	95
	5	2	3	120
	5	2	4	150
	5	2	5	175
	5	3	0	80
	5	3	1	110
	5	3	2	140
	5	3	3	175
	5	3	4	200
	5	3	5	250
	5	4	0	130
	5	4	1	170
	5	4	2	250
	5	4	3	300
	5	4	4	350
	5	4	5	450
	5	5	0	250
	5	5	1	350
	5	5	2	600
	5	5	3	900
	5	5	4	1,600
	5	5	5	1,800

NOTE.—The above most probable numbers from 0 to 20 are correct to the nearest unit. From 20 to 200 are correct to nearest 5. Above 200 are correct to the nearest 50.

SUGGESTED FORM FOR THE REPORT ON A SAMPLE OF WATER.

Sample of water collected from:—

....

1. The reason for and exact nature of the examination required ....
2. Date and hour of sampling ....
3. Nature and location of source of water, the site of sampling ....
4. Nature and distance of any source from which an inflow of pollution appears probable ....
5. Geological strata likely to affect the water constituents ....
6. If the source be a well:—

   Depth of water ....

   Steining ....

   Coping ....

   Covering ....

   Strata penetrated ....

   Method of raising water ....
7. If stored surface water, nature of collecting surface and conditions of storage ....
8. Meteorological conditions, heavy rainfall or drought

   ....
9. Any treatment the water has received:—

   Clarification ....

   Chlorination ....

   Softening ....

   Boiling ....

....

Officer requesting analysis.

Station ....

Date ....

Received from ....

on ....

The sample was labelled:—

....

....

The results of the chemical analysis in parts per 100,000 were as follows:—

Colour in two foot tube ....

Odour ....

Insoluble matter ....

Reaction, *p*H value ....

Ammonia, free and saline ....

Ammonia, albuminoid ....

Oxygen absorbed from permanganate ¼ hour..............

4 hours ....

Nitrites ....

Nitrogen present as nitrates ....

Chlorine present as chlorides ....

Hardness, total ....

temporary ....

permanent ....

Total solids ....

Poisonous metals ....

The results of the bacteriological examination were as follows:—

....

....

Conclusions:—

....

....

....

....

O. I/C Laboratory.

APPENDIX IV.

THE HORROCKS' TEST.

Case, Water Testing, Sterilisation (Horrocks' Box).

The object of the test is to find out how much Water Sterilising Power is required to sterilise 100 gallons of water.

Description of Contents.

The contents of the case are as follows:—

Six white enamelled cups, holding 1/3 pint of water when filled nearly to the brim.

One black enamelled cup, with mark on the inside.

Two metal scoops, each holding two grammes when filled with water sterilising powder level with the brim. They are similar to the measure contained in the ¼-lb. tin of water sterilising powder.

One stock bottle of cadmium iodide and starch Indicator Solution, and one dropping bottle. Three drops of the Indicator Solution give a definite blue colour with water containing one part per 1,000,000 of free chlorine.

One bottle (3-oz.) containing Acetic Acid (50 per cent.).

Six glass tubes, or pipettes, each of such dimensions that a drop of standard water sterilising powder solution delivered by it, when held in a vertical position, into a white cup filled with water gives a dilution of chlorine of one part in a million.

Four glass stirring rods.

Tablets, Sodium Thiosulphate, gr. 1½.

Twelve pipe cleaners.

Two copies of instructions.

Method.—When clarification is performed, clarified water should be used. The test should be carried out while the tank is being filled.

1. Prepare a standard solution of water sterilising powder in the black cup, as follows:—

Put into the black cup one level scoopful of water sterilising powder, and make it into a thin paste with a little clarified water by stirring it with a glass stirring rod and carefully breaking up all lumps.

Add more water to the paste, and fill the black cup with water to the mark on the inside. Stir vigorously and leave the glass rod in the black cup. This solution is never clear, as it contains lime in suspension, which, however, gradually settles. Put into this solution one of the glass pipettes.

2. Fill the six white cups with clarified water to within a quarter of an inch from the top.

3. Add drops of the standard water sterilising powder solution, prepared as in (1) above, from the pipette to the water in the white cups, as follows:—

1st cup, 1 drop; 2nd cup, 2 drops; 3rd cup, 3 drops; 4th cup, 4 drops; 5th cup, 5 drops; 6th cup, 6 drops.

Stir the contents of each thoroughly with a clean stirring rod, starting at the first cup, and then place this stirring rod in the black cup. Allow the cups to stand for half an hour, shading them from the sunlight.

Note.—In order to add even drops of the standard water sterilising powder solution to the cups, it is necessary that the top of the pipette and also the finger should be quite dry. Pressure of the finger on the pipette keeps the liquid from running out. By gradually releasing the pressure a continuous series of drops can be made to fall from the pipette. The pipette must be held vertically, and a novice can soon learn the method of dropping by practising a few times with the solution in the black cup.

4. After half an hour add three drops of the indicator solution from the dropping bottle to each of the white cups, and stir each with a clean stirring rod.

5. Some of the six white cups will soon show no colour; some will show a blue colour. Note the first of the cups showing a definite blue colour. Say cups 1 and 2 show no colour, or only a faint blue, but cups 3, 4, 5 and 6 show a definite blue colour, then cup No. 3 is the one to be noted.

The number of this cup indicates the number of scoopfuls of the water sterilising powder required to give one part of free chlorine per 100 gallons of the water, the dose for chlorination. As double this dose is necessary for superchlorination, one more scoopful of water sterilising powder is added, that is, a total of 4 scoopfuls for every 100 gallons.

NOTE 1.—The water sterilising powder used for adding to the water to be treated must be taken from the same tin as that used for the Horrocks' Test.

NOTE 2.—A modification of the Horrocks' Test for use in the superchlorination method is described in the pamphlet "Instructions for use with the Water Tank Truck and Water Tank Trailer." Paras. 3, 4 and 5, as described above, are replaced in the modified test by the following paras.:—

3. Add drops of the standard water sterilising powder solution, prepared as in (1) above, from the pipette to the water in the white cups, as follows:—

1st cup, none; 2nd cup, 1 drop; 3rd cup, 2 drops; 4th cup, 3 drops; 5th cup, 4 drops; 6th cup, 5 drops.

Stir the contents of each thoroughly with a clean stirring rod, and then place this stirring rod in the black cup. Allow the cups to stand for half an hour, shading them from the sunlight.

4. After half an hour add three drops of the indicator solution from the dropping bottle to each of the white cups, and stir each with a clean stirring rod.

5. Some of the six white cups will show no colour; some will show a blue colour. Note the first of the cups showing a definite blue colour. Say cups 1, 2 and 3 show no colour or only a faint blue, but cups 4, 5 and 6 show a definite blue colour; then cup No. 4 is the one to be noted. The number of this cup indicates the number of scoopfuls of the water sterilising powder required to sterilise 100 gallons of the water. In the above case 4 scoopfuls should therefore be added to each 100 gallons of water to be treated.

APPENDIX V.

THE COLOUR TEST.

Method.—Not less than 15 minutes after the indicated quantity of water sterilising powder has been mixed with the water, and *before* the Taste Remover has been added, draw off from one of the delivery taps a sample of the water in a white cup. Add to this 3 drops of the indicator solution by means of the dropping bottle provided in the Horrocks' box. If a deep blue colour appears, the Taste Remover may then be added to the water. If no colour, or only a faint blue appears, the amount of water sterilising powder is insufficient.

In this case, another two scoopfuls of water sterilising powder must be added to each 100 gallons, thoroughly mixed, and the colour test carried out again at the end of a further period of 15 minutes.

NOTE.—In the case of vehicles, the draw-off pipe must be emptied of unsterilised water by turning on the delivery taps before taking the sample.

APPENDIX VI.

ESTIMATION OF AVAILABLE CHLORINE IN WATER STERILISING POWDER BY SODIUM THIOSULPHATE (HYPO).

Method.—(*a*) To make the standard hypo solution:—Dissolve one tablet of hypo, 1.5 grains, in the cleanest water available in one of the white cups in the Horrocks' box. Dilute until the cup is full to the brim, and mix thoroughly by stirring gently. (Strength 0.05 per cent.)

(*b*) To make the standard water sterilising solution:—Measure out a level scoopful of water sterilising powder into the black cup from the Horrocks' box. Mix into a thin paste with water. and dilute to the white line in the usual way. After it has been standing a few minutes, during which time the two scoops should be cleaned and rubbed over with a greasy rag, stir the solution of water sterilising powder thoroughly, and transfer a level scoopful to a clean white cup about a quarter full of clean water.

(*c*) **Titration.**—Pour into the white cup containing the diluted water sterilising powder solution about a scoopful of the cadmium iodide and starch indicator solution, and add half a scoopful of acetic acid (50 per cent.). Stir thoroughly.

The contents of the cup turn blue-black. Add now level scoopfuls of the standard hypo solution stirring between each addition and counting carefully the number added. When the colour just disappears the number of scoopfuls of hypo added represents the percentage of available chlorine.

Example.—15 scoopfuls of hypo are required in order to discharge the blue-black colour; the powder contains therefore only about 15 per cent. available chlorine.

NOTE.—Chlorinated water must not be used in carrying out this test.

APPENDIX VII.

DETERMINATION OF FREE CHLORINE IN WATER.

Requisites.—Case, Water Testing Sterilisation.

Method.—(1) Dissolve three hypo (sodium thiosulphate) tablets (1½ grains) in water in a white cup, fill to the brim and mix by pouring into another white cup.

(2) Fill another white cup with the water to be tested, to within ⅛ (one-eighth) of an inch of the brim.

(3) Stir into the cup containing the sample water about 10 (ten) drops of the cadmium iodide and starch indicator solution.

If there is any chlorine present in the water a blue colour will appear.

(4) If the water is blue add, drop by drop, the hypo solution, using the glass tubes or pipettes until the colour just disappears. The water must be continually stirred during the procedure.

(5) The number of drops of hypo solution required to remove the colour divided by 10 is equal to the amount of free chlorine in parts per million.

APPENDIX VIII.

METHOD OF PREPARATION OF INDICATOR SOLUTION.
(CADMIUM IODIDE AND STARCH SOLUTION.)

Method of Preparation.

Cadmium iodide (A.R.)	1½ ozs. (7.5%).
Starch, soluble (A.R.)	⅛ „ (1.5%).
Water	1 pint.

To the starch, add 2 or 3 ozs. of the water and stir well.

Take a clean vessel, place in it the remainder of the water and bring it to the boil.

To this, slowly add the starch and cold water mixture, stirring continuously.

Continue to boil gently for 15 minutes.

Cool, add the cadmium iodide, and dissolve by shaking.

The solution should be tightly corked and kept in best quality brown bottles and stored in the dark.

NOTE.—When available, freshly distilled water should be used in making the solution.

Keeping properties are enhanced by adjusting the *p*H to approximately 6.5, or by the addition of 1 per cent. formalin.

In an emergency potassium iodide may be used instead of cadmium iodide (A.R.), and white flour (R.A.S.C. quality) instead of starch, soluble (A.R.).

APPENDIX IX.

CASE, WATER TESTING: POISONS.

The Detection of Chemical Poisons in Water.

Description of Contents.

The contents of the case are as follows:—

	oz.
Acid, acetic (50 per cent. B.P. glacial)	4
Acid, hydrochloric, arsenic free	4
Caustic soda solution (0.5 per cent.)	2
Ferrous sulphate solution (25 per cent.)	2
Platinum chloride solution (0.083 per cent.)	8
Sodium sulphide solution (20 per cent.)	2
Spirit methylatis	4

	oz.
Starch (1 per cent.) and salt (16 per cent.) solution	2
Zinc, granulated, arsenic-free	4
	tubes
Tablets sodium iodide, 1 gr. (10)	6
	No.
Arsenic tubes	20
Bottle dropping, 10 c.c. ..	1
Corks, perforated	20
Porcelain tile on metal standard	1
Lamp, spirit, copper, complete	1
Stand, test tube	1
Tubes, test, 6-in. by ¾-in.	8

BIOLOGICAL TEST.

Whenever possible note the effects of the water on fish.

CHEMICAL TESTS.

Test 1.—Half fill a test tube with the water to be examined. Add half an inch of acetic acid. Then add a few drops of sodium sulphide solution, which should not be milky in appearance. A brown colour indicates the presence of LEAD, COPPER or MERCURY COMPOUNDS. A yellowish haze indicates gross amounts of ARSENIC or ANTIMONY COMPOUNDS. A white haze is due to sulphur deposited from old solutions of sodium sulphide, and is of no significance.

NOTE.—Iron compounds give a brown colour with waters to which no acid has been added.

Test 2.—Arsenic and antimony in small yet poisonous amounts will not be detected by Test 1, as it is not sufficiently sensitive.

(*a*) To ascertain whether the reagents and apparatus are free from arsenic and antimony.—Fit one of the fine glass tubes into a clean cork. Place five or six pellets of granulated zinc and an inch of hydrochloric acid in the test tube and fit in the cork and fine glass tube. After the lapse of about half a minute light the gas issuing from the tip of the tube and place the whole in the clip on the lid of the box, as in the illustration. Fix the white tile and push the tube towards it, until the top of the tube is almost touching it and the flame is spread over the surface of the tile. Care should be taken not to extinguish the flame.

If a black stain insoluble in hydrochloric acid diluted with two volumes of water appears, then there is contamination by arsenic and antimony, and the test must be repeated with fresh apparatus and reagents.

If there is no stain, then the water can be tested as follows:

(*b*) To ascertain if there is arsenic or antimony in the water.—Take out the cork of the tube and add two inches of the water to be tested, and more hydrochloric acid and zinc, if gas ceases to be evolved readily. Replace the cork and fine glass tube, and, after the lapse of half a minute, light the issuing gas and proceed as above.

If a dark stain appears on the tile, and it is insoluble in the diluted hydrochloric acid, ARSENIC or ANTIMONY IS PRESENT. A fresh cork and fine glass tube must be used for each sample of water to be tested.

Test 3.—Separate test for the detection of CYANIDE.—Half fill the test tube with the sample. Add half an inch depth of caustic soda solution and five drops of ferrous sulphate solution. Boil very thoroughly. Add hydrochloric acid until the contents of the test tube are clear. A BLUE colour indicates the presence of CYANIDE. This colour is more pronounced if the test tube is allowed to stand for 30 minutes.

Test 4.—Separate test for the detection of MUSTARD GAS.—Place one sodium iodide tablet in the clean, empty dropping bottle. Fill with the platinum solution to the neck.

Insert the stopper, and shake until the tablet is dissolved.

Half fill a test tube with the water to be examined. Add five drops of acetic acid, shake gently. Then add five drops of the sodium iodide and platinum chloride solution; shake again. Add five drops of the starch and salt solution.

Blue colour shows the presence of mustard gas, either old or new, or also chlorine in sterilised water. To distinguish between mustard gas and chlorine: Half fill a second test tube with the water to be examined, and dissolve a sodium iodide tablet in it, add starch and salt solution. A blue colour shows chlorine, and if the water has no smell or acid taste then it is safe to drink.

N.B.—Sodium iodide solution will not keep more than two days.

Test 5.—Separate test for the detection of *Lewisite*.

The presence of Lewisite in water will be indicated by a positive result to the Arsenic test, but, as the arsenic may be present in organic form, it will be necessary to convert this into inorganic form before carrying out the test for arsenic.

To do this, mix half a test tube of the water with half an inch of the caustic soda solution—Heat to boiling and cool. Then proceed to test for arsenic as above (Test 2).

NOTE.—The water cannot be certainly regarded as free from poisons until the above tests have been repeated, with negative results, in two consecutive examinations.

All test tubes used must be most carefully WASHED AND RINSED IN CLEAN WATER before being returned to the case.

APPENDIX X.

THE WATER LORRY AND WATER TRUCK.

PART A.—DESCRIPTION.

The Water Lorry. The vehicle consists of a standard chassis on which is mounted a 200-gallon water tank complete with pumps, filters, suction hoses and accessories.

1. **The Chassis.** A standard four-wheel 30-cwt. Chevrolet or Ford chassis.

2. **The Tank.** A di-metallised steel tank is mounted longitudinally on the chassis and provided with a central baffle

plate. Two manholes in the top of the tank provide access for cleaning and the addition of chemicals to the water.

Two rubber delivery hoses, one from each filter, open into the tank through a common delivery piece.

The tank, when filled, contains 200 gallons of water, which is sufficient to fill the water bottles of 800 men. A dip-stick, graduated in 10-gallon divisions, is provided so that the quantity of water in the tank may be determined.

When the required amount of water has been pumped into the tank, the sterilising agents are added, and are as evenly distributed as possible; adequate mixing is then secured by stirring.

A drain-hole plug is provided in the well, situated at the bottom of the tank, and is removed to empty the tank after cleaning.

The draw-off pipe is fitted with a branch pipe, to which are fitted four small delivery taps suitable for water bottles, and two large taps which can be used to fill camp kettles. A stopcock is fitted to the main draw-off pipe underneath the tank. By closing the stopcock, water can be prevented from entering the branch pipe.

3. **The Pumps.** Two manually operated pumps of the semi-rotary type are placed one on each side of the vehicle, and connected by means of suitable piping to the filter units.

A pressure gauge and pressure relief valve to blow off at 60 lbs. per sq. inch are included in the pipeline between the pump and the filter.

4. **The Suction Hoses.** Two 20-ft. lengths of armoured rubber suction hose are provided. When not in use they are coiled and carried in stores boxes on each side of the tank platform.

One end of the hose carries a union for attachment to the pipeline leading to the pump. At the other end of the hose a float, foot-valve and strainer are fitted. The foot-valve is situated at the end of a short pipe connecting to the suction hose, and is housed within the perforated metal strainer. The float is secured in position by passing this pipe through the centre of the float, and locking the assembly in position by means of a pipe flange and nut.

The Water Truck. The vehicle consists of a three-ton W.D. chassis on which is mounted a 400-gallon water tank, complete with pumps, filters, suction hoses and accessories, as in the case of the Water Lorry described above. A power-driven pump may be installed.

WATER VEHICLES FITTED WITH MOLLINITE FILTERS MARK M.F.4.

5. **The Filters.** Two Mollinite Filter Units, each complete with a semi-rotary manually operated pump, pressure gauge, pressure relief valve, and the necessary valves and piping, are mounted vertically, one on each side of the tank.

These filter units (complete) are assembled as a self-contained unit on a mounting plate. The mounting plates are interchangeable, and may be fitted on either the right or left-hand side of the tank.

Each filter consists of a cylindrical pressure vessel with a quick-release cap or lid on top, and a bronze manifold or collector at the bottom. This bronze manifold acts as a collector from the three filter elements or packs, which are connected thereto by detachable tapered spigot joints.

Each filter element consists of an inner heavy galvanised flat wire mesh strip, which acts as a waterway and support to the fine bronze or monel mesh with which both sides of it are covered. These three layers of wire mesh are confined in a watertight framework of channel iron, which extends completely around the edges of the element. A hole in the bottom section of the framework, leading through an attached spigot, serves as an exit for the water flowing through the filter element.

The manifold is a bronzed casting with three tapered vertical holes in line, which serve to make a watertight but detachable joint with the spigots on the element.

A plate (spacing plate), with three slots which fit over the handles on top of each element, ensures the elements remaining parallel and correctly spaced. A cadmium-plated spring affixed to the inside of the lid presses against this spacer plate, and further ensures that the elements will be pressed tightly into the spigot joints.

A plate on the bottom of the cylinder acts as a dissipator to the incoming water, and serves to maintain an even flow throughout the filter.

Air release cock is provided in top of lid.

Two suction inlet valves are provided on the lower side of the pump. One is for the main suction. The other (graduated) serves to admit the alum and filter-earth from a bucket, and controls the quantities required.

Pressure gauge and safety valve (set at 60 lbs. per sq. inch), between pump and filter, are provided, together with a sludge valve at bottom of cylinder. A valve to discharge first runnings during pre-coating, and a valve to admit filtered water to the tank, are provided on the outlet side of the filter.

Before use, each filter must be prepared, as shown in the operating instructions (Part B 1(a)).

This preparation, or precoating operation as it is called, is necessary so that a porous filter bed is formed over the whole area of the filter elements.

The porous bed is formed by mixing a quantity (8 ozs.) of filter-earth and alum, as indicated in the preliminary test, with 5 gallons of water, and passing the mixture through the filter and returning it to the bucket until the returning water is clear. The precoating operation being completed, the filtering operation may be commenced and continued according to the operating instructions until the required quantity of water is obtained.

6. **Stores Lockers.** On each side of the tank platform is situated a stores box in which is stored—

1 No. Suction hose complete with fittings (20-ft. length).
1 No. Bleeder hose.
1 No. Chemical suction hose.
1 No. Foot-valve, strainer and float (complete).
1 No. Agitator plate, rod and chain.

Situated at the rear of the tank is a large stores locker in which is stored—

24 No. 1½-lb. cartons filter-earth.
2 No. 4-lb. boxes alum.
6 No. ¼-lb. tins water sterilising powder (each tin containing a small scoop of the same size as those provided in the Horrocks' box).
2 No. ½-lb. packets lime, slaked.
2 No. Indicator test kits in case (complete).
1 No. Medical testing kit in case (Horrocks').
2 No. Brushes, filter pack.
2 No. Brushes, tank cleaning.
2 No. Filter packs (spare).
2 No. Boxes taste remover tablets.

Provision is also made for suitably housing the pump operating handles.

PART B.—WORKING INSTRUCTIONS.*

I.—Clarification.

(a) The water is clarified with the aid of alum and filter-earth as it is pumped through the Mollinite filters into the tank, where chemicals are then added in order to sterilise the water.

EACH FILTER UNIT is operated in accordance with the following instruction, including the actual testing operation of the water to be filtered.

1. Turn on the delivery taps and allow any water left in the tank to run to waste.

2. Throw the suction hose strainer into the source of water supply as far from the bank as possible.

3. Make sure that the leather washers are in position in the hose unions, and then attach the hose to the pump suction valve No. 1.

* **Note.**—These instructions refer to the operation of the Mollinite filter unit in filling the 200-gallon tank of the Water Lorry. In filling the 400-gallon tank of the Water Truck some variation in the working instructions will be required, since the larger amount of water to be filtered will involve variation in the amount of filter-earth, and of alum, etc., required. Working instructions for the Water Truck will be issued as soon as the trucks become available.

4. Attach handle to pump and then attach agitator chain to link of handle extension arm. The bucket is then placed in position, and agitator chain adjusted so that, at the beginning of pump stroke, agitator plate almost immediately commences to lift off bottom of bucket.

5. Attach chemical suction hose tightly to No. 2 feed valve inlet (see Note 6), and then place the free end in BOTTOM of bucket through two holding loops provided.

6. Attach bleeder hose to bleeder pipe (outlet end from Valve No. 3), and place free end so that discharge will go into bucket.

7. See that filter elements are tightly in position, and lid properly screwed down.

8. See that all valves, except the following, are closed: No. 1, Main Suction Valve; No. 3, Bleeder Valve; and Air Release Cock.

9. Commence pumping, using throughout long, steady strokes of between 30 and 40 per minute. Do not overstroke, as pump may jam. Close air release cock immediately air is displaced, and then water will automatically commence to discharge through bleeder hose into bucket. Fill bucket to the 5-gallon ring and stop.

10. Test water for coagulant dose as follows: Take the small end of measure scoop and fill level to top with alum without tamping. Add alum to bucket and plunge vigorously with agitator rod for about ½ minute. Half fill a test bottle with water from bucket, and add 2 to 3 drops of indicator solution. If a greenish yellow or yellow colour develops sufficient alum has been added to complete test. If the correct coloration is not obtained, continue test, keeping a careful count of the number of small scoops of alum added. The number of small scoops of alum necessary to give the correct coloration indicates the number of large scoops of alum required to coagulate the remaining 85 gallons of water to be treated by the filter. These should now be added to the water in the bucket. (See also Note (1)).

11. Add also about one-third of the charge of filter-earth from the carton, e.g., approximately 8 ozs. to the bucket.

12. Open Feed Valve No. 2 (see Note 6) approximately two or three turns, and close Main Suction Valve No. 1.

13. Commence pumping from the bucket, and at the same time release any air that may have become entrapped in cylinder. Cloudy water will discharge through the bleeder hose into bucket. This circulation of the water in bucket, known as the precoating operation, is continued until the water from bleeder hose is perfectly clear.

14. Stop pump, open Valves Nos. 1 and 4 full open, and Feed Valve No. 2 (see Note 6) approximately one to two turns. Nearly close Bleeder Valve No. 3 so that just a trickle of water will run from hose to waste (not into the

bucket) when pumping is recommenced, and then add the rest of the filter-earth (16 ozs.) to the bucket.

15. When this procedure has been repeated for both units, recommence pumping and continue until tank is filled, watching carefully the clarity of the water trickling through each bleeder pipe, and also from time to time releasing air through the air release valves.

16. When the required quantity of water is obtained, pumping is stopped, and the filter elements immediately cleaned. Unscrew Bridge Screw and remove cap and spacer plate, and then carefully lift out each element. A vigorous shake will remove most of the mud and filter-earth, after which the packs are finally cleaned in water with the pack cleaning brush.

Now open Drain Valve No. 5, and then, by stirring the water in the cylinder by hand, make sure that the mud which might otherwise rest and cake on the bottom is drained out.

17. Replace packs carefully and firmly. Fix spacer plate in position and close Valve No. 5, and pump cylinder full of water. Then place lid in position and tighten with bridge screw.

NOTE 1—TESTING OF WATER. The addition of alum is for the purpose of coagulating the mud particles, thus causing them to coalesce and consequently become sufficiently enlarged to prevent their passing through the filtering medium. A variation in the natural pH (see below) of the raw water necessitates varying additions of alum to bring this condition about.

The measuring scoop is designed for the twofold purpose of ascertaining the correct dosage necessary (small end of measure scoop), and then adding the total amount of alum necessary to clarify the 90 gallons (large end). The small end of the measure scoop holds sufficient alum when placed in 5 gallons of water to give a concentration of 2 grains per gallon. The large end of the measure scoop holds sufficient alum when placed in the bucket to give a concentration in the incoming water, e.g., the additional 85 gallons, of 2 grains to the gallon also. It should be noted that more alum than the 2 grains per gallon may be necessary to give the required result.

The pH range for satisfactory filtration is between 5½ and 6½, although satisfactory results will be produced with a pH as high as 6.8. It is at this point that the indicator solution will first commence to show a yellowish tint to the neutral green. Taking the range of pH 6.8 down to pH 5, the following series of colorations take place:

pH 6.8—Green, slightly yellowish.
pH 6.5—Yellowish-green.
pH 6.0—Yellow.
pH 5.5—Orange-yellow.
pH 5.0—Orange.

Orange-yellow, therefore, denotes the highest concentration recommended. After this, the colour would change to a deeper orange, then to red, indicating that the water was approaching an over-dosed condition.

Should this occur, bucket should be emptied, and procedure repeated till correct test coloration is obtained.

The most palatable waters are between the range of 6.5 and 6.8, therefore the ideal coloration to aim at is midway between yellow and green.

The pH of raw water is an international symbol denoting the degree of alkalinity or acidity. The addition of alum, which is in itself acid, will increase the acidity of a water—a condition necessary to obtain coagulation and the effect of this addition is measured by the colour changes mentioned under "Testing."

The full pH scale is shown under:

pH 14 down to pH 7.1 denote decreasing alkalinity.
pH 7—exactly neutral.
pH 6.9 down to pH 1 denote increasing acidity.

Most waters are slightly alkaline, and would, therefore, have a pH range of more than 7. **The addition of alum would decrease the alkalinity** and **ultimately produce an acidity.** As the acidity **increases** so the figure denoting the degree of acidity decreases.

NOTE 2—EMERGENCY WATER TEST.—If, through some accident, no indicator is available, testing may be carried out in the following manner, although this will take longer than the regulation test.

Add the first small scoopful of alum to the bucket. Mix well and wait two or three minutes, carefully noting the appearance of the water. If sufficient alum has been added, the water will appear to curdle, and soon a clear, thin layer of water, gradually deepening, will appear on top. If this has not happened, add another small scoopful and repeat procedure of mixing. When the water has assumed the correct appearance, add the same number of large scoops and carry on as outlined in paragraph 11.

Patience and careful observation are necessary to carry out this test correctly, otherwise overdosing can occur, and though a clear water will be produced, it will be unpalatable. Therefore, under all circumstances, once the filtering operation is well on the way, the water from the bleeder pipe should be tasted.

NOTE 3—SETTING CHEMICAL FEED VALVE. — This operation is the key to the success of the performance. If it is opened too far, overdosing will occur, with the result that the supply of alum and M.F.A. will be used up before the required quantity of water is obtained.

If it is not opened far enough, an insufficient supply of alum and filter-earth will be introduced into the filter, with the result that the filter bed will break down and dirty water will go into the tank. The actual setting will depend on experience, each filter requiring a somewhat different setting, due to the fact that the feed valve openings vary in the feed valves. Likewise, the height of the water lorry above the source of raw water will affect the suction on the chemical feed inlet.

NOTE 4—FILTER NOT IN USE.—Packs should not be allowed to become dry, as small particles of earth will adhere to the wire and gradually cement up the openings in the mesh. If this does happen, the packs may be cleaned by a bath in dilute hydrochloric or battery acid solution of 1 part acid, 20 parts water, for five to ten minutes, or until clean. They must then be well washed two or three times in a large volume of clean water. Vinegar can be used as a substitute for the dilute acid.

NOTE 5—TO FILL THE TANK WITHOUT PASSING WATER THROUGH FILTER.—Should a PURE supply of CLEAR WATER be available, and it is desired to fill tank without passing the water through the MOLLINITE FILTER, the unit should be operated as follows:

See that all valves except No. 1 MAIN SUCTION VALVE are closed.

Remove AIR BELL by loosening (not removing) the securing clamps and unscrewing the hose coupling situated beneath the Air Bell.

Remove DELIVERY HOSE from VALVE No. 4 and attach to NIPPLE from which Air Bell was removed.

The pump may now be operated in the usual manner until the required amount of water is lifted.

NOTE 6.—The flow meter is a recent attachment which has been added to some filter units in order to simplify the setting of the Chemical Feed Valve No. 2. In order to set the feed valve in conjunction with this apparatus, a steady pumping rate of approximately 34 strokes per minute is desired. Pumping at this rate, open Feed Valve No. 2 until the telltale in the glass tube commences to rise and fall with the stroking of the pump. When the maximum lift of the telltale reaches the mark on sight glass cover, the valve is correctly opened for the filtering operation. When the precoating operation is taking place, with Valve No. 2 open two or three turns, the float will rise practically to the top of the glass. No notice need be taken of this, as sufficient area has been provided to allow the maximum flow through the suction line for this operation.

The flow meter has other uses, and a careful observation of it will provide information on the operation of the filter, 2 taste tablets / 100 gallons.

e.g., if there is a partial blockage in the chemical suction line, this will be immediately shown by the telltale failing to reach the mark, and if complete blockage does occur, the telltale will remain at the bottom of the sight glass. Likewise, if the pump is not being stroked evenly, the telltale will rise more on one stroke than on the other. Exactly the same effect will occur if the valve on one side of the pump is operating at a different efficiency to the other.

As the flow meter is in a higher position than the original chemical suction feed inlet, a longer feed hose is necessary to reach the bucket. This longer feed hose will be supplied under the same part number as the original, viz., M.F.54.

N.B.—Filter-earth for use with the Mollinite Filter must be of correct grade. It is sold under various trade names—Mollicel, Cellite, Hyflo. Only an approved grade must be used.

How to Sterilise the Clarified Water in the Tank.

II.—Sterilisation.

Method of superchlorination followed by dechlorination:—

1. As soon as clarified water is available during the filling of the tank, take samples in the white cups and perform the Horrocks' Test, as laid down in Appendix IV.
2. Take the required number of scoopfuls of water sterilising powder, as indicated by the test, plus one extra for each 100 gallons, and make into a thin paste in the black cup, with a little clarified water, taking care to ensure that all lumps are broken up. Fill to the mark with clarified water, stir and pour into the tank, distributing as equally as possible. Mix thoroughly with the plunger. Allow to stand 15 minutes, and then
3. Perform the colour test (see Appendix V.).
4. The taste remover tablets should not be added until the water is required for issue. Immediately before issuing, dissolve two (2) tablets of taste remover for each 100 gallons in some chlorinated water in a white cup, add to the water in the tank, and mix well with the plunger. A sample should then be tasted, and if this is satisfactory, the water is ready for issue. If the water, however, still tastes of chlorine, an additional tablet of taste remover per 100 gallons should be added.

NOTE.—If for any reason it is impossible to perform the Horrocks' Test, then, for each 100 gallons, a fixed dose of 4 scoopfuls of water sterilising powder, followed, after the appropriate interval, by 4 tablets of taste remover, may be substituted for the above method.

III.—Method of Cleansing the Tank.

1. Fill the tank about half full with clarified water.

2. Mix half a ¼-lb. tin of water sterilising powder with some clarified water and add it to the tank.

3. Scrub the inside of the tank with the brush provided for this purpose, and, if possible, have the trailer or truck taken some distance along the road, in order to keep the water in the tank moving.

Take out the screw plugs at each end of the draw-off pipe, turn on the delivery taps, and allow the water to flow.

4. When about half the volume of water has run to waste, unscrew the drain-hole plug at the bottom of the tank and allow the remainder of the water to escape.

5. Repeat the process without the powder, using clarified water only.

NOTE.—When in constant use, the tank should be cleaned once a week.

IV.—Practical Hints.

1. Sometimes a pump fails to draw water. If this occurs, make sure that suction valve No. 1 is open. If so, unscrew the suction hose, close chemical suction valve No. 2, place the palm of the hand flat against the inlet at the pump, and test the suction by pumping with the other hand. If no suction is felt, the valves situated inside the pump may not be seating due to some foreign matter under their seats. This can usually be remedied by priming the pump through the discharge outlet. This outlet becomes accessible when the air bell is removed.

2. If suction is found to be satisfactory, and the pump still fails to draw water when the suction hose is again connected and valve No. 1 opened, then air is entering the pump either through a leak due to a defective washer in one of the hose connections or through a hole in the suction hose. This necessitates replacing the defective washer with a new one, or fitting a new suction hose.

3. During the pre-coating operation, when suction valve No. 1 is closed and chemical suction valve No. 2 is open, it sometimes happens that the bottom of the chemical suction hose becomes seated on the bottom of the bucket. This prevents the flow of chemicals from the bucket through the pump to the filter, and tends to make the pump handle fly back during stroking. The chemical suction hose should be lifted clear of the bottom of the bucket and pumping recommenced.

4. It is important, during the preliminary filling of the bucket for water testing purposes, that the air release cock on top of the filter remain open until all the air is discharged from the filter chamber. The bucket is then filled with water as required and pre-coating continued, as shown in the working instructions.

5. Remember that the pumps will not lift water to a height greater than 20 feet above water level.

6. Don't pump too quickly. Use long, steady strokes. Do not overstroke or the pump may jam.

7. Don't forget, in frosty weather, to close the stop-cock and drain off the water from the draw-off pipe by emptying the delivery taps. The stop-cock may also be closed at any other time, if so desired, in order to prevent the unauthorised drawing of water from the delivery taps. A removable key is provided for operating the stop-cock.

8. Don't forget, in frosty weather, to drain all lengths of hose and wrap up the pumps with sacking, etc.

9. It may also be necessary in frosty weather to release the ball valve at the bottom of the filter chamber in order to drain all water away from the valve.

10. Don't forget to place a leather washer in the hose union before attaching the suction hose.

11. Always clean the interior of the filter after pumping has ceased. Packs must be removed from the filter for cleaning, and particular care taken to ensure that the packs or the spigot seats are not damaged due to careless handling. The filter body should be drained clean of any earth deposits. Packs should be replaced and filter filled with water from the pump.

APPENDIX XI.

THE WATER TRAILER.

PART A—DESCRIPTION.

The Water Trailer consists of a sprung channel iron frame on which is mounted either: (a) An 80-gallon steel tank, or (b) a 150-gallon steel tank.

A suitable towing eye for connecting the trailer to the towing vehicle is provided; also three telescopic, adjustable legs to support the trailer when in location.

1. **The Chassis.** The chassis consists of a built-up channel iron frame of welded construction, mounted on a suitably

sprung axle, to which is fitted two standard wheels complete with pneumatic tyres.

2. **The Tank.** A semi-elliptical mild steel tank of welded construction is mounted, by means of suitable supports, to the chassis frame. A central baffle plate is fitted inside the tank. The inside of the tank is di-metallised. A manhole in the top of the tank provides access for cleaning and the addition of chemicals to the water. A rubber delivery hose from the filter unit opens into the top of the tank through a screwed delivery piece. When pumping is finished, the sterilising agents are added and are distributed as evenly as possible. Adequate mixing should then be secured by stirring. A drainhole plug is provided for emptying the tank after cleaning.

A draw-off pipe connects the tank with a branch pipe, to which is fitted four small taps for filling water bottles, and 1 large tap which can be used to fill camp kettles, etc. A stopcock is fitted in the draw-off pipe underneath the tank. By closing this stopcock, water can be prevented from entering the branch pipe.

3. **The Pump.** A manually operated pump of the semi-rotary type is mounted on a platform at the rear of the tank. The pump is connected by suitable piping to the filter unit.

A pressure gauge and pressure relief valve, set to blow off at 60 lbs. per sq. inch, are included in the pipeline between the pump and the filter.

4. **The Suction Hose.** A 20-ft. length of armoured rubber suction hose is provided, complete with all fittings. When not in use, the hose is coiled and secured on the top of the tank by means of straps.

One end of the hose carries a union for attachment to the pipeline leading to the pump. At the other end of the hose a float, foot-valve and strainer are fitted. The foot-valve is situated at the end of a short pipe connecting to the suction hose, and is housed within the perforated metal strainer. The float is secured in position by passing this pipe through the centre of the float and locking the assembly in position by means of a pipe flange and nut.

5. **The Filters.** One Mollinite Filter Unit, complete with S.R. manually operated pump, pressure gauge, pressure relief valve, and the necessary valves and piping, is mounted vertically at the rear of the tank.

The Filter Unit, as used with the Water Trailer, is identical with those in use on the Water Lorry. For description, see Appendix X No. 5. The Units are completely interchangeable, one type only being required for both vehicles.

6. **The Stores Locker.** Situated at the front of the tank is a stores locker for carrying the following medical stores and accessories, viz.:

12 No. 1½-lb. cartons filter-earth.
1 No. 4-lb. Box alum.
1 No. ½-lb. Packet lime, slaked.
1 No. Indicator test kit, in case (complete).
1 No. Medical testing kit, in case (Horrocks').
1 No. Brush filter pack.
1 No. Brush tank cleaning.
1 No. Filter pack (spare).
3 No. ¼-lb. Tins water sterilising powder (each tin containing a small scoop of the same size as those provided in the Horrocks' box).
1 No. Box taste remover tablets.

In addition to the Medical Stores, the stores locker contains:

1 No. Pump handle.
1 No. Chemical suction hose.
1 No. Bleeder hose.
1 No. Agitator plate, rod and chain.

A 6-gallon galvanised steel bucket is also mounted, by means of suitable clips, to the front of the chassis frame.

Working Instructions.

The Filter Unit in use on the Water Trailer is identical with the units in use on the Water Lorry. For complete Working Instructions of Filter Mark M.F.4 see Appendix X, Part B.

APPENDIX XI A.

WATER CLARIFICATION BY MEANS OF THE CLOTH FILTER.

In the cart, water tank (horse-drawn), the water is clarified by passing through a cloth filter before entering the tank.

It may be necessary to make use of this method of clarification, and a description follows of the CLARIFYING CYLINDERS used in the cloth filtration method, together with working instructions.

A.—DESCRIPTION.

The Clarifying Cylinders. — Two metal clarifying cylinders, each connected with one of the pumps, are fitted transversely on the body frame in front of the tank; although usually worked at the same time, each cylinder is independent of the other.

The clarifying cylinder consists of a body closed at one end (inlet) by a structure called the cylinder head, and at the other end (outlet) by a screw plug.

Contained within the cylinder is a reel, which consists of a metal framework blocked at one end; the other end is provided with an outlet through a spigot, around which is placed a rubber ring. It is around this reel that the clarifying cloth is wrapped.

The cylinder head has on the inside a chamber with four large apertures at the side for the entrance of the water.

Contained within the chamber are two circular wire gauze mesh plates, between which the clarifying powder is placed.

The outer wall of the chamber is perforated, and the inner wall consists of a movable cover, also perforated, and held in position by a bayonet catch.

The perforations in the outer wall ensure an even distribution over the mesh plates of the stream of water in its passage through the chamber.

The cylinder head is secured to the cylinder by six winged-nuts, a leather washer making the joint water-tight.

B.—WORKING INSTRUCTIONS.

The water is clarified as it is pumped through the clarifying cloths into the tank; chemicals are then added in order to sterilise the water.

(*a*) How to Clarify the Water and Fill the Tank.

1. Turn on the delivery taps and allow any water in the tank to run to waste.

2. Throw the strainer into the source of water supply, as far from the bank as possible. If the course is a swiftly flowing stream, the suction hose should be thrown over the bough of a tree or other support in order to prevent the strainer from being washed to the side.

See that the leather washer is in position in the hose union, and then attach the hose to the pump.

3. Remove the cylinder head by unscrewing the winged-nuts.

Take out the reel, and wrap around it the clarifying cloth. As efficient clarification depends to a great extent upon the proper wrapping of the cloth, the following precautions should be carefully observed:—

(*a*) The cloth should extend to each end of the reel, and must be wrapped smoothly, with as few creases as possible. If the cloth is too wide, it should be turned back at one end.

If the cloth shrinks after repeated washing, it should be gently stretched. If it is still not wide enough, put on two cloths and allow them to overlap in the middle of the reel.

(*b*) The clarifying cloth (which should go around the reel about three and a half times) is tied by five tapes sewn along one edge.

First tie the two outer tapes around the grooves at each end of the reel; then tie the three inner tapes. It is advisable to tie the tapes in bows, as in cold weather knots are difficult to undo.

4. Place in the clarifying cylinder the wrapped reel, and push it well home, so that the rubber ring around the spigot comes into contact with the end of the cylinder.

5. Open the cylinder head by undoing the bayonet catch of the perforated cover, and take out the wire gauze mesh plates.

Place four scoopfuls of clarifying powder (see page 20) between the mesh plates, using the scoop contained in a tin of clarifying powder.

Then replace the mesh plates in the cylinder head, put on the perforated cover, and fasten it down by means of the bayonet catch.

6. See that the leather washer is in place on the cylinder head, and then secure the cylinder head to the cylinder by screwing up the winged-nuts.

In putting on the cylinder head, screw up opposite pairs of winged-nuts together, and take care that the brass washers are on the outside of the flanges of the cylinder head.

The pressure of the cylinder head forces the reel against the end of the cylinder, forming, with the rubber ring on the spigot, a water-tight joint.

If the rubber ring becomes flattened by repeated use, replace it by a new one.

7. Unscrew the plug at the outlet of the cylinder.

8. Start pumping slowly, and increase gradually up to 30-40 double strokes (up and down) per minute.

The water now enters the clarifying cylinder, passes into the cylinder head and through the mesh plates, dissolving the clarifying powder contained therein. The water then travels along the cylinder around the outside of the clarifying cloth, through which it is forced to the inside of the reel.

In its passage through the reel the water deposits a film of aluminium hydroxide on the surface of the clarifying cloth.

The formation of this film on the clarifying cloth is necessary in order to clarify the water.

From the inside of the reel the water runs to waste at the outlet of the cylinder.

9. Clarification is imperfect until the film of aluminium hydroxide is deposited on the clarifying cloth.

As this usually takes a little time, the water should be allowed to run to waste until efficient clarification takes place, as shown by the issue of clear water.

The degree of clarification can be judged by taking samples of water from the outlet of the cylinder in one of the white cups provided in the Horrocks' Box.

When the water is clear, screw in the plug at the outlet of the cylinder; the water now stops running to waste and enters the tank through the delivery pipe.

10. If the water does not become clarified in a short time (say, 10 minutes), unscrew the cylinder head, take out the reel and examine it. Imperfect clarification may be due to any of the following causes:—

(1) Damage, with consequent leaking, at one or other end of the reel.

(2) Careless wrapping of the cloth around the reel, which allows unfiltered water to enter the reel.

(3) A flattened or badly-worn rubber ring around the spigot.

(4) Insufficient Clarifying Powder between the mesh plates.

The first defect is remedied by replacing the damaged reels by a sound one; the second, by re-wrapping the cloth correctly; the third, by replacing the defective rubber ring by a new one; and the fourth, by placing four more scoopfuls of Clarifying Powder between the mesh plates.

NOTE.—Four scoopfuls of Clarifying Powder should be added when the cylinder head is removed for any of the above purposes.

11. The escape of water from the relief valve of the pump is caused either by pumping too quickly or by clogging of the clarifying cloth with dirt when clarifying a very turbid water.

The remedy is to pump more slowly, or to replace the dirty cloth by a clean one.

12. The water which first enters the tank should be allowed to run to waste through the delivery taps at the back of the cart in order to flush out the bottom of the tank.

13. At this stage take samples of water in the six white cups, from one of the delivery taps, for carrying out the Horrocks' Test, which is described in Appendix IV.

Then close the delivery taps and pump water into the tank until water has risen to the top of the baffle plates. Then sterilise the water.

(*b*) **How to Sterilise the Clarified Water in the Tank.**

Method of Superchlorination followed by Dechlorination.

This is fully described in Appendix X (page 67).

(*c*) **Method of Cleansing the Cloths.**

Unscrew the cylinder heads, take out the reels; unwrap the cloths and scrub lightly and rinse them in water until free from dirt; then boil them for half an hour in the rectangular kettle.

(*d*) **Method of Cleansing the Tank.**

See the water truck (Appendix X (B), III.

(*e*) **Practical Hints.**

1. See also the water truck (Appendix X (B), IV.

2. If the large leather washers on the cylinder heads are dry, and cause a leak, they should be soaked in water.

3. Don't forget to take off the clarifying cloths from the reels and clean them as soon as possible after the tank has been filled.

4. Don't forget to put on clean clarifying cloths and recharge the cylinder head with clarifying powder for every 150 gallons of water pumped into the tank.

APPENDIX XII.

STERILISATION OF WATER BY THE AMMONIA-CHLORINE METHOD.

1. Water may be sterilised by means of ammonia-chlorine made from ammonium chloride tablets and water sterilising powder (chlorine). The standard dose of ammonia-chlorine for 100 gallons of water is obtained by adding two tablets (grs. v. each) of ammonium chloride followed by 2 scoopfuls of water sterilising powder (chlorine).

2. The following quantities will be required:—

Water Lorry (200 gallons)—

4 tablets ammonium chloride.

4 scoopfuls of water sterilising powder.

3. The tablets of ammonium chloride are dissolved in a little clarified water in a clean Horrocks' black cup, which is then filled to the mark with clarified water. The solution is distributed between the compartments of the tank and thoroughly mixed with the water by means of a plunger.

4. The black cup is washed with clarified water. The scoopfuls of water sterilising powder are made into a paste with

a little clarified water in the black cup, which is then filled to the mark with clarified water and well stirred.

The solution thus formed is similarly distributed in the tank, and is thoroughly mixed by means of a plunger.

NOTE.—As it is difficult to make an even paste with the number of scoopfuls, it may be necessary, after pouring most of the solution into the tank, to add more clarified water to the sediment in the black cup and to stir again before pouring in the remainder.

5. Leave the water in the tank for one hour to allow the necessary contact with the ammonia-chlorine.

6. When circumstances permit, water should be sterilised overnight, and not drawn for drinking until the following morning.

NOTE.—Estimation of the available chlorine in water sterilising powder, which is used for the production of ammonia-chlorine, must be carried out periodically. This is done by means of reagents contained in the Horrocks' box. See Appendix VI.

APPENDIX XIII.

STERILISATION OF WATER BY THE CHLORINATION METHOD.

This method is only carried out when, for any reason, taste remover tablets are not available.

The method provides a safe drinking water, but has the disadvantages of not being so speedy as superchlorination, and of being liable to cause taste troubles.

1. Carry out the Horrocks' Test, as described in Appendix IV.

2. Add to the water the number of scoopfuls of water sterilising powder per 100 gallons shown as necessary by the test.

3. The water must now be allowed to stand at least 30 minutes after the water sterilising powder has been added and mixed with the water in the tank.

4. Carry out the colour test at the end of the 30 minutes; if a blue colour is obtained, the water is fit to drink. If no blue colour is obtained, then 1 more scoopful of water sterilising powder per 100 gallons must be mixed in the black cup and added to the water in the tank. After mixing, again allow to stand for 30 minutes, and repeat colour test.

APPENDIX XIV.

PURIFICATION OF WATER IN WATER BOTTLES AND SMALL CONTAINERS.

WATER BOTTLES.

On occasions when the individual sterilising outfit is not available, the following methods may be carried out, depending on whether the Horrocks' Test is practicable or not, or whether superchlorination, chlorination or chloramination is the manner of sterilisation.

If Horrocks' Test is Available.

Superchlorination or chlorination is indicated.

Superchlorination.

Carry out the Horrocks' Test, and add to the black cup one scoopful of W.S.P. more than the number indicated by the test.

Mix into a paste, and wash into a water bottle marked with a distinctive sign, fill to the top with water and shake.

To the water in every water bottle to be treated add one scoopful of the above solution, shake, and allow to stand for at least 30 minutes (this period is necessary, as water is unfiltered).

In water in a white cup dissolve two tablets of taste remover and pour into a second water bottle, with a different mark, filling up to the neck with water.

When the sterilising action of chlorine has continued for 30 minutes or longer, add one scoopful of the taste remover solution to every water bottle and shake. The water is then fit and safe to drink. It is very necessary that the bottles containing strong solutions have their own mark, as water would not be sterilised if the order in which they were added was reversed.

Chlorination.

Only indicated when taste remover tablets not available. Carry out the Horrocks' Test, and add the number of scoopfuls of W.S.P. as indicated by the test, making up a solution in a cup and adding to a water bottle in the same manner as superchlorination.

Add one scoopful of this solution to every water bottle, and allow sterilisation to continue for 30 minutes or longer before taking the bottle into use.

If Horrocks' Test is not Available.

Superchlorination or Chloramination is Indicated.

Add four (4) scoopfuls of W.S.P. to a water bottle, mix with a little water, shake and complete the filling with water to the top.

Crush to a powder 4 taste remover tablets, add to another water bottle and shake thoroughly for a minute or two.

Add to every man's water bottle one scoopful of the chlorine solution, allow at least 30 minutes' contact, and then add one scoopful of taste remover solution.

Chloramination (Ammonia-chlorine).

Dissolve two ammonium chloride tablets in a water bottle full of water. Add two level scoopfuls of W.S.P. to another water bottle marked with a distinguishing sign. Add one scoopful of the ammonia solution to the water in the bottles to be sterilised, shake, and then add one scoopful of the chlorine solution. Allow at least one hour to sterilise.

NOTE.—On every occasion chlorine solution should be made up fresh.

SMALL CONTAINERS, I.E., PETROL TINS, PAKHALS, ETC.

When the Horrocks' Test is Available.

The Black Cup Method: Superchlorination.

Perform the Horrocks' Test. The second of the cups (one over the number indicated by the test), showing a definite blue colour, indicates the number of scoopfuls of W.S.P. to be added to the black cup to give a solution, one scoopful of which will be the required dose for every gallon of water to be treated.

Method.—Add one scoopful from the strong solution in the black cup for each gallon of water, and allow to stand for 30 minutes. After 30 minutes' contact or longer, dissolve two (2) taste remover tablets in a black cup filled to the white line. Add one scoopful of this solution for every gallon of water. The water is then ready for issue.

When Horrocks' Test is not Available.

Measure sixteen (16) level scoopfuls of W.S.P. into a water bottle, add a little water, and shake. Fill the bottle to the shoulder with water and again shake.

Add one scoopful to every gallon required to be treated. Dissolve sixteen (16) taste remover tablets in a water bottle full of water.

One scoopful of this is added to every gallon of water after it has had 30 minutes' contact with the chlorine.

¾ lb alum / 1200 galls.

APPENDIX XV.

CLARIFICATION OF WATER BY SEDIMENTATION.

Clarification by sedimentation becomes necessary when:—

(1) Filtration apparatus is not available.

(2) The raw water is heavily loaded with suspended matter, which would rapidly choke the filters. In this latter case preliminary coagulation may be followed by filtration.

Note. — The Army Water Vehicles fitted with Mollinite Filter Units Mark M.F.4 are able to deal with water containing large amounts of suspended matter without preliminary coagulation. (See Appendix X.)

Requisites.—(1) One or more 1500-gallon canvas tanks, holding actually 1200 gallons.

(2) A pail or other container.

(3) The case, water testing, sterilisation (Horrocks' Box).

(4) Alum or alumino-ferric. (*Not Clarifying Powder or Filter Earth.*)

(5) Lime.

(6) Brom-Thymol Blue indicator powder or Polychrome indicator.

Method.—(1) Dissolve a heaped black cupful (¾ of a pound) of alum completely in a pail of water. (This amount, added to the 1200 gallons of water, is equal to 4 to 4½ grains a gallon.)

(2) Pour the alum solution into the canvas tank.

(3) Fill the tank with the water that requires treatment.

(4) After standing for ½ (half) an hour "flocs" appear suspended in the water.

If flocculation has been carried out as a preliminary to filtration, and the water is required as soon as possible, the water can now be filtered without undue blockage of the filter.

If filters are not available the water must stand for a further 2 hours or more, until it has settled sufficiently to allow a good depth of clear water to be drawn off.

Failure to Obtain a Floc.—Is quite exceptional, and may be due to the water being too acid or too alkaline.

(*a*) *Acid Waters.*—These are usually from a moorland or peaty source, and are normally coloured brown.

The addition of alum increases the acidity of the water and prevents sedimentation.

To correct the reaction of the water, lime must be added, the amount being determined by an indicator—Brom-Thymol Blue.

Method of correcting the reaction of water:—

(1) To the water in the canvas tank, which has failed to "floc" on the addition of alum, add a W.S.P. tinful of lime (2¾ ozs.) mixed with a little water into a cream, and stir thoroughly.

(2) Then take a sample of this water in a white cup (Horrocks' Box), and stir in a knife-point of Brom-Thymol Blue powder.

(3) Allow the sample to stand one or two minutes and note the colour.

If green, the reaction is correct and a "floc" will occur.

If yellow, the water is still acid, and a further tinful of lime and water mixture is necessary. Continue adding lime and stirring until a green colour is obtained.

Normally most peaty waters require 4 (four) grains of alum and 2 (two) of lime per gallon of water.

(*b*) *Alkaline Waters.*—Such waters give a blue colour with Brom-Thymol Blue.

Method of correcting the reaction of water:—

(1) Into a black cup of the Case, water testing, sterilsation, measure one *level* scoopful (the scoop from a tin of water sterilising powder) of powdered sample of the alum being used for sedimentation.

(2) Dissolve as completely as possible in water and fill to the white mark, thus making a 1 per cent. solution.

(3) Arrange the six white cups in a row, and, with a glass tube or pipette add 16, 20, 24, 28, 32 and 36 drops of the 1 per cent. alum solution into the cups in succession. The cups, when filled with water to be clarified, will contain proportions of alum equal to 4, 5, 6, 7, 8 and 9 grains per gallon.

(4) Mix a knife-point of Brom-Thymol Blue indicator with a teaspoonful or so of water, and add sufficient of this mixture to each cup to give a distinct colour, and stir.

(5) Allow to stand for a minute, and then note the cup which shows a green colour.

Usually three cups are green, in which case choose the middle one.

(6) The dose of alum in grains per gallon is thus determined.

For example, if the 4th cup is the middle of three cups showing green, the dose would be 7 grains per gallon.

The following table shows the measure of alum required for 1200 gallons of water according to the dose determined by the above test:—

1 grain per gall.	= 2¾	ozs. to	1200	galls. or 2¾ scoopfuls per 100 galls.
2 grains per gall.	= 5½	„	1200	„ 5½ scoopfuls per 100 galls.
3 „ „	= 8¼	„	1200	„ 8¼ scoopfuls per 100 galls.
4 „ „	= 11	„	1200	„ 11 scoopfuls per 100 galls.
5 „ „	= 13¾	„	1200	„ 13¾ scoopfuls per 100 galls.
6 „ „	= 16½	„	1200	„ 16½ scoopfuls per 100 galls.
7 „ „	= 19¼	„	1200	„ 19¼ scoopfuls per 100 galls.
8 „ „	= 22	„	1200	„ 22 scoopfuls per 100 galls.
9 „ „	= 24¾	„	1200	„ 24¾ scoopfuls per 100 galls.

N.B.—The scoop referred to is that supplied with a tin of Water Sterilising Powder.

One ounce of powdered alum is equivalent to 12 (twelve) level scoopfuls.

Note.—For determination of the pH value of water in relation to the dose of alum and lime, or of alum, required to produce a "floc," the Polychrome Indicator, described in Appendix X, may be used as an alternative to the Brom-Thymol Blue Indicator.

APPENDIX XVI.

THE WATER PURIFICATION SET—MOBILE.

Description.

The water purification set, mobile, provides a standard unit for drawing water from any polluted source, filtering it and sterilising it, and pumping it to a delivery point for distribution and use. The set does not store or transport potable water.

It consists of:—

(*a*) A chloramine dosing unit.

(*b*) A pump and generator unit, which supplies electrical power for the chloramine unit. The pump is of the mono type, and acts as the main pump of the set.

(*c*) A filter unit, consisting of two 10 sq. ft. (pressure) "Stellar" filters.

(*d*) An 8 h.p. petrol engine (1800 revs. per min.) acting as the prime mover of the set.

(*e*) A flex-driven auxiliary pump, to be used when the source cannot be reached direct by the mono pump.

(*f*) A water flow meter, fitted on the outlet piping from the filters.

(*g*) Suction and delivery hose.

(*h*) Canvas water tanks—
   (1) 1200-gallon S type for sedimentation.
   (2) 30-gallon, supported on a tripod, for general purposes.

(*i*) Flexible drives. One for main drive between engine and mono pump. The second for auxiliary drive to pump, feed, driver.

(*j*) Interconnections between the pump and generator unit and the dosing unit.

(*k*) Interconnection between the pump and generator unit and the filter unit.

(*l*) Boxes and lockers to hold equipment, tools, clothing, etc.

The whole of the set is carried on a 30-cwt. lorry. The plant is normally operated within the vehicle, after certain parts are taken out, but if necessary the whole plant can be set up and operated on any level and firm site.

1. **The Chloramine Dosing Unit** consists of a steel cabinet with double doors fitted on a framework above the ammonia sulphate and salt dosing tanks.

On the dosing panel inside the cabinet are fitted the injectors, which force the two solutions into the suction of the pump through the rubber interconnection pipes, the amount being regulated by a valve up to a maximum of three parts per million of chlorine and three-quarters parts per million of ammonia. The amount of the dose can be measured by the timing vessels provided on the panel.

On the panel are also mounted the electrolytic cell (30 amperes), which converts the salt into sodium hypochlorite before it enters the suction pipe, and also the control panel of the generator.

2. **The Pump and Generator Unit** consists essentially of the main pump and the generator mounted on a bed plate. The pump shaft terminates in a socket flexible drive terminal, and is driven directly by the engine through 16 ft. of drive flexible.

A counter shaft chain, driven by the pump shaft at the same speed, drives the generator mounted above it by a belt. This counter shaft is fitted at the other end with a flexible drive spigot terminal, to which a flexible drive can be fitted to drive the auxiliary pump when it is needed.

(*a*) The pump is a mono-pump, with a capacity of 3000 gallons per hour at 1800 revs. per min. It comprises a fixed stator, in which a single rotor revolves, and gives a uniform continuous and positive pumping effect.

A pressure relief valve is therefore fitted, and also a by-pass valve, so that the output can be varied without altering the engine speed.

The suction pipe, to which the inlet hose is connected, is fitted with a valve and a draw-off connection pipe for the injectors on the dosing panel.

(*b*) The generator is a D.C. shunt machine, 4 to 7½ volts, 45 amperes. Power and control leads are taken to the switch panel on the dosing panel by means of a flexible cable.

The generator provides the electrical power required for the electrolytic cell mounted on the dosing panel.

3. The filter unit consists of two Stellar (pressure) filters mounted on a bed plate, each giving 1500 gallons per hour, and water from the pump enters the bottom of the filters, which are made up of candles, similar in construction to those described in the instructions for the water truck.

Arrangements are made whereby the filters can be cleaned, if necessary, one at a time. The filter is connected to the pump by a length of hose, and a delivery hose is connected to the common delivery pipe.

A flow meter, actuated by the water flow through a venturi tube, registers the output in gallons per hour.

Medical and Chemical Considerations.

1. *Equipment.*—The equipment necessary for measuring solutions and testing the water consists of:—

- (*a*) A case, water testing, sterilisation, for measuring the ammonium sulphate solutions, and for the determination of the proportion of chlorine present in the water, and of the percentage of chlorine in the water sterilising powder.
- (*b*) A case, water testing, poisons, for the identification of metal and other poisons.

The details of the tests are given in Appendix IX.

2. *Turbidity.*—Normally there is little difficulty in clarifying the water by filtration, but when clay is present in a fine

colloidal suspension rapid clogging of the filter occurs, and presedimentation with alum becomes necessary.

To carry this out. Mix three-quarters of a pound of alum (not filter powder) with water in a bucket, and stir it into the raw water contained in the 1200-gallon tank.

Leave for half an hour, in which time a "floc" will have formed.

If the water is now filtered no clogging will occur.

In acid, peaty waters no "floc" forms, and it becomes necessary to add 5 to 6 ounces of lime, made into a cream with a little water, before dosing with alum.

3. *Sterilisation.*—Chloramine, which is produced by the sterilising unit, is not weakened by the presence of organic matter in the water. It is possible, therefore, to filter after chloramination. Germs which have passed through the filters are killed by chloramine after one hour's contact.

The normal dose is 2 parts of chlorine and about one-half of a part of ammonia per million.

This gives a ratio of four of chlorine to one of ammonia.

If the proportion of ammonia is increased, the sterilising action is reduced, and a longer period than one hour is necessary for sterilisation to be complete.

The raw materials, sulphate of ammonia and common salt, are both corrosive if damp, and are therefore stored in earthenware jars.

One quarter the weight of sulphate of ammonia consists of ammonia. A saturated solution contains 54 per cent. of the sulphate, *i.e.,* 100 mls. contain 54 grammes of the sulphate.

A saturated solution of common salt contains 33 per cent. of salt.

A gallon of the saturated solution holds about three and a third pounds of salt (one gallon of water weighs 10 lbs.).

By using saturated solutions and these data there is no need for scales. Saturated solutions are made in the following manner:—

Lumps of the two chemicals are put into separate buckets of water, and stirred until no more can be dissolved.

Both pails will contain saturated solutions of their respective chemicals.

Requisite amounts of each are added to the tanks under the sterilising cabinet, and when the tanks are filled with water the correct working dilution is obtained.

The ammonium sulphate used is a 0.186 per cent. solution, the salt a 5 to 10 per cent. solution.

Working Instructions.

POWER AND PUMP UNIT.

(*See* Layout Diagram.)

To be mounted on inside of right-hand door of steriliser cabinet below Layout Diagram.

BEFORE STARTING INSTRUCTIONS.

(*a*) (i) Place engine on ground on near side about 12 feet from lorry, opposite hole in side of truck.

(ii) Check petrol and oil, and immediately run up light to warm.

(*b*)—(i) Uncoil section of 22 mm. (larger size) flexible drive, keeping ends clean, and adjust position so that, when connected to engine and pump, drive is straight, or has, at most, only easy curves.

(ii) Check drive for free rotation of shaft inside cover.

(iii) Pass spigot terminal end through hole and couple tightly to pump socket, with coupling removed from coiled section.

(*c*)—(i) Connect short length of armoured hose to filter by-pass union (beyond (8)).

(ii) Set up small canvas tank on tripod stand to receive water from this hose.

(*d*) Check valve and cock positions (which, unless stated otherwise, close clockwise) as under:—

(2) (suction).—OPEN.

(3c) (hypochlorite stop).—CLOSED.

(3M) (Amm. sulph. stop).—CLOSED.

(4) (pump by-pass).—FULLY SCREWED OUT ANTI-CLOCKWISE.

(5) (sterilising supply stop).—CLOSED.

(6) (pump priming).—CLOSED.

(8) (filter by-pass).—CLOSED.

(9) (flow indicator).—At "AIR RELEASE."

(10) (filter inlet).—CLOSED to A and B filters.

NOTE.—7u and 7d (upstream and downstream isolating cocks to rate of flow indicator) to be FULL OPEN at all times while plant is assembled in vehicle.

(*e*) Prime pump through (6) till water reaches funnel level, RECLOSE (6).

Then—

(*f*) (i) Connect (1)—(footvalve and strainer) to necessary armoured suction hose.

(ii) Fill suction hose with water to test tightness of valve and joints.

(iii) Connect suction hose to union outside stop valve (2) and place (1) in water.

NOTE.—(1) *Footvalve and strainer must not rest on the bottom of a muddy or gravelly source of supply.*

(2) All suction joints must be absolutely tight.

Finally—

(*g*)—(i) Stop engine and connect up drive to it.

(ii) Swing several times by hand to test freedom. The unit is then ready to start up.

Starting and Stopping Instructions.

(i) Check over valves as in (*d*) above and START engine to run on governor.

(ii) OPEN (8) (filter by-pass), then SCREW DOWN HALF WAY (4) (pump by-pass).

(iii) When water issues behind (9) (flow indicator), TURN wheel CLOCKWISE through "EQUALISE" to "INDICATING."

(iv) Regulate delivery as required by use of (4) (pump by-pass) only—(screw down to increase, screw out to decrease).

(v) SCREW OUT (4) (pump by-pass), then close (8) (filter by-pass).

(vi) Leave engine running if required soon, otherwise shut down.

NOTES.—(1) Starting of pump will be required to get water to change filters if no clean water is available. See Instructions for Filters outside left-hand door of steriliser cabinet.

(2) Never close (4) (pump by-pass) unless some other delivery path is open.

(3) On first starting, and at least daily, check indicator by time to fill small canvas tank, whose capacity, when bottom is fully supported and tank is filled to mark on side, is indicated on tank.

(4) Never pump with suction line disconnected or (1) (footvalve) out of water.

FILTER-UNIT.

(See Layout Diagram.)

To be mounted on outside of left-hand door of steriliser cabinet.

BEFORE STARTING INSTRUCTIONS.

(*a*) Filters should be CLEAN and EMPTY if these instructions have always been carried out in previous working. New plant should be received clean, dry and empty.

(*b*) (i) Check that ALL filter valves and cocks are CLOSED.

(ii) SET (11) (filter outlet) to A and B OPEN; OPEN (12A) and (12B) (air releases).

(*c*) (OPERATION 1):—TO CHARGE FILTER A.

(i) Mix in bucket 1½ lb. filter powder (kieselguhr) to cream without lumps. Use clean water if available. For alternative treatment, using 1200-gallon tank, see Handbook, Section 4.

(ii) Add slowly 1 gallon water, stirring thoroughly.

(iii) OPEN (13A) (charging cock), pour in mixture, wash in with 2 gallons water; CLOSE (13A).

(*d*) Charge filter B similarly through charging cock (13B).

(*e*) (i) Connect single short length of armoured hose to filter outlet (11).

(ii) Connect (16) (delivery two-way cock) to outer end of hose and SET to WASTE.

(iii) Connect necessary canvas hose to delivery point from SERVICE union of (16).

Starting, Running, Stopping.

NOTE.—(1) FULL FLOW in these instructions is 3000 g.p.h. for both filters and 1500 g.p.h. for one filter, unless a lower figure is ordered.

(2) Instructions are given below for operating two filters together. Filter can be operated alone by appropriate valve movements, leaving other valves closed.

(*a*) (OPERATION 2):—**To form filter bed.**—(i) Check valve and cock positions as at end of **Charging** (Op. 1).

(ii) START pump in accordance with INSTRUCTIONS FOR STARTING (ETC.) PUMP (on inside of right-hand door).

(iii) MOVE (10) (inlet) to "A and B OPEN."

(iv) SCREW DOWN (4) (pump by-pass) until (9) (indicator) reads 1500 g.p.h. (approximately).

(v) When water discharges from air release pipes CLOSE (12A) and (12B) (air releases).

(*b*) **To charge head tank.**—(i) When delivery water is satisfactory OPEN (14A) and (14B) (head tank cocks).

(ii) SET (11) (outlet) to A and B CLOSED till head tank overflows.

(iii) SET (11) to A and B OPEN, and **immediately** CLOSE (14A) and (14B).

(iv) SLOWLY SCREW DOWN (4) pump by-pass till (9) indicator reads full flow ordered.

(*c*) (OPERATION 3):—**To reactive filter beds when gauge (GA) or (GB) reads 60 lbs./sq. in.**—(i) SCREW OUT FULLY (4) (pump by-pass).

(ii) SET (10) (inlet) to A and B CLOSED.

(iii) OPEN FOR ONE MINUTE (12A) and (12B) (air releases).

(iv) During this minute SET (16) (two-way cock) to WASTE.

(v) CLOSE (12A) and (12B) and SET (10) to A and B OPEN.

(vi) SCREW DOWN (4) till (9) indicates 1500 g.p.h.

(vii) When delivery is satisfactory, SET (16) to SERVICE and SCREW DOWN (4) to full flow.

Notes.—Repeat operation when pressure reaches 60 lb. till it is no longer effective.

(*d*) (OPERATION 4).—**To deal with an interruption in pumping.**

2. If for any reason pump stops, IMMEDIATELY SCREW OUT (4) and SET (10) to A and B CLOSED. *After re-starting*, complete Operation 3 (iii to vi).

(*e*) (OPERATION 5).—**To clean either filter with clean water from the other.**

NOTE.—Movements refer to the particular valves, doors, etc., of filter under treatment. Unless particularly instructed, do not move (10) (common inlet) and (11) (common outlet) to or *through* A and B CLOSED positions.

(i) SET (16) (two-way cock) to WASTE.

(ii) SCREW OUT (4) (filter by-pass) till (9) (indicator) reads 750 g.p.h.

(iii) SET (10) (inlet) to position CLOSED for filter under treatment (*i.e.*, OPEN to other filter).

(iv) SET (11) (outlet) as for (10) (inlet).

(v) SLIGHTLY OPEN sludge door (at bottom of shell).

(vi) OPEN (12) (air release), then FULLY OPEN sludge door and secure this.

(vii) SET (11) to A and B CLOSED position until discharge from door is clear of dirt and old filter bed.

(viii) SET (11) to position CLOSED for filter under treatment.

(ix) CLOSE (12) and OPEN (15) (flush).

(x) CLOSE (15) after 1 minute if nothing is being brought down.

(xi) CLOSE sludge door and then OPEN (12).

(*f*)—(OPERATION 6). —

To carry on for further work.

(i) Charge filter just cleaned exactly as in Operation 1 (BEFORE STARTING INSTRUCTIONS).

(ii) SET (10) (inlet) to A and B OPEN position.

(iii) SCREW DOWN (4) (pump by-pass) until (9) indicator reads 1500 g.p.h.

(iv) When water issues from air release pipe, close (12) (air release).

(v) SET (11) (outlet) to A and B OPEN position.

(vi) When delivery is satisfactory repeat whole of Operations 5 and 6 on filter not yet cleaned.

(vii) When delivery from this is satisfactory SCREW DOWN (4) to FULL FLOW.

(viii) If delivery still satisfactory, SET (16) (two-way cock) to SERVICE.

OR (*g*) (OPERATION 7).—

To clean preparatory to shut down.

(i) Carry out cleaning of first filter exactly as in Operation 5.

(ii) SCREW OUT FULLY (4) (pump by-pass) then STOP pump.

(iii) SET (10) (inlet) and (11) (outlet) to position CLOSED to filter still uncleaned.

NOTE. — Remaining instructions refer to valves, etc., connected to this filter.

(iv) OPEN sludge door, and then (14) (head tank cock) till head tank is empty.

(v) CLOSE sludge door, and (14) then OPEN (12) (air release).

STERILISER UNIT.

(*See* LAYOUT DIAGRAM.)

To be mounted on inside of left-hand door of steriliser cabinet.

NOTE.—These and operating instructions are to be carried out first on starting up, *after* filters are in action.

(*a*) Fill up dosing tanks. They each hold 15 gallons (1 gallon per $\frac{5}{8}$ths. inch of height). Use graduated dipstick, white cup from *Case Water Testing Sterilisation: canvas water buckets*, each holding 2 gallons (1 pint per in. of height when resting on level ground). Small canvas tank capacity when resting on level ground, fully extended by tripod and filled to mark on wall, is indicated on tank.

(i) To fill brine (right-hand) tank. Dissolve 12 level cupfuls crushed salt to one full bucket of filtered water; pour this saturated solution into tank through strainer and dilute with three further bucketfuls of water; repeat as necessary. At same time, dissolve 6 level cupfuls in stone jar (1 gallon) to give reserve of the saturated solution.

(ii) To fill ammonium sulphate tank. This is required comparatively infrequently. Make up at any convenient time beforehand a saturated solution for storage in 1-gallon stone jar provided, using 10 level cupfuls of crushed crystals to 1 gallon of filtered water. To replenish tank, use one cupful of this saturated solution to 15 gallons of filtered water. To estimate smaller quantity, remember that white cup holds 200 c.c. brimful, and the black cup holds 250 c.c. when filled to white mark.

Starting, Adjustment and Stopping Instructions.

NOTES.—(1) Pump must be running to waste at full flow, as ordered, and as indicated by (9) (flow indicator), until these instructions have been carried out completely.

(2) (3M), (3C) and (5) (Stop valves) are assumed to be CLOSED (clockwise). (17M and MC) (regulators) should be HALF OPEN or as left at end of last run, 18U and 18C (air vents) should OPEN; (S) (switch) at *either* OFF position.

(3) The stop clock should be to hand.

(*a*) **Start Flow.**

	Ammon. Sulph.	Brine.
(i) OPEN (6) (supply stop valve)	—	—
(ii) CLOSE air vents	18M	18C
(iii) OPEN stop valves	3M	3C
When solutions should be seen to flow through (Timing Vessels)	TM	TC

(*b*) **Make Preliminary Solution Flow Adjustments.**

NOTE.—(1) The quantities on which these adjustments are based are explained in Section 4 of Handbook.

(2) Check rate of flow of each solution in turn.

	Ammon. Sulph.	Brine.		Ammon. Sulph.	Brine.
(i) CLOSE stop valve	(3 M)	(3 C)	(iv) Repeat (i) to (iii) adjusting regulator till correct time in sec. is read, for varying flows, *see* Note below.	(17 M)	(17 C)
(ii) OPEN air vents till timing vessel empties then CLOSE	(18 M) (T M)	(18 C) (T C)			
(iii) QUICKLY OPEN FULL stop valve.	(3 M)	(3 C)	(v) LOCK regulator. (Ammon. sulph.)	(17 M)	

Note.—Correct timings for various flows are as under :—

G.P.H.	Time		G.P.H.	Time		G.P.H.	Time		G.P.H.	Time		G.P.H.	Time	
	TM	TC		TH	TC		TM	TC		TM	TC		TM	TC

(*c*) *Start electrolyser.*

Note.—If no orders have been received set to give *dosage* of 2 P.P.M.

(i) Switch (S) to either " ON " position and adjust (R) rheostat to correct value for water flow indicated and hypochlorite dosage required :—

G.P.H.	P.P.M.	AMPS.	G.P.H.	P.P.M.	AMPS.	G.P.H.	P.P.M.	AMPS.	G.P.H.	P.P.M.	AMPS.	G.P.H.	P.P.M.	AMPS.

(ii) LOCK (17 C) (brine regulator).

(*d*) **Test Delivery for Chlorine Content.**—(i) Dissolve 3 tablets of hypo (thio-sulphate) from Case Water Testing Sterlisation in a white cup. Fill with water taken from WASTE delivery of (16) (two-way cock). Diffuse by pouring solution into a second white cup.

(ii) Fill a third white cup from delivery of (16), and add indicator solution till distinct blue colour appears.

(iii) Add hypo solution, made as in (i) above, from pipette (glass tube) drop by drop, until blue colour disappears on stirring. Then number of drops added divided by ten equal parts per million (P.P.M.) of free chlorine.

(*e*) **Adjust Dosage in Accordance with Result of Test.**

NOTE.—If no orders to contrary have been received, now assume that correct figure for *free* chlorine is 2 P.P.M.

(i) ADJUST R (to increase amps. if test result is less than correct figure, to decrease amps. if more).

(ii) Retest as in (*d*) and when test is satisfactory

(iii) Set (16) (two-way cock) to SERVICE.

(*f*) **Carry out Running Adjustments.**—If water delivery is altered *for any reason*—

(i) RESET solution flows as in (*b*) above.

(ii) Adjust electrolysers as in (*c*) above for same dose for new flow.

(iii) RETEST as in (*d*) above.

(iv) ADJUST dosage as in (*e*) above.

NOTE.—(1) If flow has been temporarily reduced, *e.g.*, to clean filters, etc., steriliser controls may be left unaltered.

(2) If flow is greatly increased, first SET (16) (two-way cock) to WASTE, adjust flow as (i) to (iv) above, then RESET (16) to SERVICE.

(3) If suction lift is greatly altered, check Timings, as in (*b*) above at one end, and adjust, if necessary, to correct figure.

(*g*) Shut down, as under:—

NOTE.—If pump has stopped suddenly, immediately close stop valves (3C, 3M, c), then switch off.

Normally shut down as under:—

	Ammon. Sulph.	Brine.
(i) Switch OFF	—	—
(ii) CLOSE stop valves (6) and ..	3M	3C
OPEN air vents till timing vessels drain	18M	18C
Leave regulators locked in last position of use	17M	17C

RUNNING INSTRUCTIONS.

To be mounted on outside of right-hand door of steriliser cabinet.

(*a*) Check these points in order every 15 minutes:—

Engine Drive and Pump.—(i) Overheating of engine or drive (particularly at each end of drive sections).

(ii) Main pump gland leakage.

(iii) Correct value of flow as ordered, also its steadiness.

(iv) Leaking joints.

Filter Units.—(i) Pressure in each filter—turn cocks of GA and GB (gauges) off and on to ensure that these have not stuck.

(ii) Head tank full.

Sterilizer.—(i) Solution rates.

(ii) Current.

(iii) Change polarity.

Delivery.—Clarity.

Chlorine content.

(*b*) Check the following additional points hourly:—

Engine Drive and Pump.—Petrol, oil; lubrication of pump, drive and generator.

Filter.—New charge ready.

Sterilizer.—Solution levels in tanks.

Delivery.—Small tank full of filtered water.

(*c*) Continually keep an eye on—

flow indicator	(G)
filter gauge	GA and GB
warning light	(L)

APPENDIX XVII.

METHOD OF REMOVING MAGNESIUM SULPHATE FROM BITTER APERIENT WATERS.

1. Stir in 2 or 3 pounds of lime to 100 gallons of the water.

2. Half fill a second 100 gallon tank with water and add to this portions of 10 gallons of the limed water and stir.

3. After each addition of lime take a Horrocks' cupful of the mixture and filter through a piece of filter paper.

4. Add a few drops of silver nitrate solution to the filtrate and when the filtrate shows a brown colour stop the addition of lime and add 10 gallons of the raw water (to precipitate the excess lime).

5. Allow the precipitate formed to settle (roughly 2 to 3 hours) and syphon off the clear supernatant fluid which will contain calcium sulphate which is not aperient.

APPENDIX XVIII.

HOW TO OBTAIN REQUIREMENTS FOR WATER PURIFICATION.

Articles.	How obtained.	Endorsed by	Issued by
(a) FOR CLARIFICATION.			
Lime .. .. Clarifying Powder .. .. .. Filter-earth .. .. Copper sulphate	Indent on A.B.55	C.O.	Supply Officer
Aluminium sulphate .. .. Ferrous sulphate .. .. .. Alumino-ferric .. .. Filter-cloth (cover, clarifying reel for Cart, Water Tank)	Indent on F.20	C.O.	D.A.D.O.S.
(b) FOR STERILIZATION.			
Water, Sterilizing Powder . Halazone Outfit .. .. Hypo. (Sod. Thiosulph.) .. Detasting tablets .. .. .. Tabs. Acid Sod. Sulph. .. .. Tabs. Ammon. chloride . ..	Indent on A.B.55	C.O.	Supply Officer
Horrocks' Box and replenishments of its contents ..	Indent on A.A.F.D.50 by M.O.	M.O.	Depot of Med. and Vet. Supplies
Water Purification Set Mobile	Auth. scale	—	Ordnance (R.E. Unit)
Sulphate of ammonia and common salt replenishments for above	A.B.55	C.O.	Supply Officer
(c) STORAGE AND ISSUE.			
Cart, Water .. .. Water Lorry .. .. Water Truck and Water Trailer	Authorized Scale.	—	A.A.O.C. Through Q.M. Unit
(d) DETECTION OF POISONS.			
Case, Water Testing, Poisons, and replenishments of its contents	Indent on A.A.F.D.50 by M.O.	—	Depot of Med. and Vet. Supplies
(e) FOR COLLECTION OF SAMPLES.			
Case, Water, Sampling, Chemical, and Case, Water, Sampling, Bacteriological	Requisitioned by M.O. as required	—	O. i.c. Mobile Hygiene Laboratory Through A.D.M.S.

Useful Data. APPENDIX XIX.

Conversion Factors.

1 ml. of pure water at 4° C.		weighs 1 gramme.
1 gramme	=	15.43 grains.
1 gramme	=	0.035 oz.
1 kilogramme	=	2 lbs. 3¼ oz.
1 ounce (avoirdupois)	=	28.35 grammes.
1 grain	=	0.065 grammes.
1 ounce (Troy)	=	31.1 grammes.
1 ml.	=	0.035 fluid ozs.
1 ml.	=	16.23 minims.
1 litre (1,000 ml.)	=	35.196 fluid ozs. = 1¾ pints.
1 fluid ounce	=	28.42 mls.
1 pint	=	568.18 ml. = 0.57 litre.
1 gallon	=	4.54 litres = 10 lbs. = 0.16 cu. ft.
1 cubic foot of water	=	6¼ gallons.
1 pound (avoirdupois)	=	7,000 grains, 453.59 grammes.
1 gallon of water	=	70,000 grains.
1 fathom	=	6 feet.
1° Salinity	=	5 ozs. of salt per gallon.

Measure in Cube.

Area of a—

Rectangle = Length × Breadth.
Triangle = ½ base × height.
Circle = the square of the radius × 3.1416.

Volume of a—

Rectangular space = Length × Breadth × Height.
Pyramid = Area of base × 1/3 height.
Cylinder = Area of base × height.

Capacity of Various Containers.

Water Cart holds 110 gallons—working capacity 100 gls.
Water Tank Trailer, 180 galls.—working capacity 150 gls.
Water Tank Truck, 230 galls.—working capacity 200 gls.
Canvas Tanks hold 1,500 working capacity 1,200 gallons.

Canvas Tanks (with mobile purifier)	50 gallons
Camel Pakhal	14 ,,
Mule Pakhal	7 ,,
Biscuit tin	6¼ ,,
Petrol tin	2 ,,
Pail	3 ,,
Horrocks' Test White Cup	⅓ pint
Horrocks' Test White Cup	½ lb. of salt
Mess tin (larger pan)	2 pts. 4 oz.
(Smaller pan)	2 pints
1 scoop W.S.P. .. .. =	2 grammes W.S.P.
1 scoop Clarifying powder ..	83 grains of powder

Doses.

Chemical (Chlorination)—1 p.p.m. of free Cl_2.
Chemical (Superchlorination)—2 p.p.m. of free Cl_2.
(Free Chlorine = Chlorine left after deviation.)
Chloramination (Harold-McKibbin) = 1.5 to 1.8 p.p.m.
(Two 5 grain tablets of ammonium chloride and two scoopfuls of W.S.P.)
Chloramination (water purifier mobile) = 2 p.p.m.
(½ p.p.m. of ammonia and Chlorine 2 p.p.m.)
Alum = 3 to 5 grains per gallon.
Clarifying powder = 4 scoopfuls per filter cloth.

(Filter Powder Kieselguhr) = 3 oz. per square foot of filtering surface of Stellar filter.
= 3 oz. per 4 candle Stellar Filter on Water Tank Truck.
= 1½ lb. per 10 square feet Stellar Filter on Water purification set, mobile.

By Authority: Wilke & Co. Pty. Ltd., 19-47 Jeffcott Street, Melbourne.