WATER SUPPLIES IN THE FIELD

Notes for

MEDICAL OFFICERS

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[1941?]

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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.

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 threefold 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 60.

(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.

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.

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 miça 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 $\frac{4}{5}V \times A \times 6{\cdot}25 \times 60 =$ 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, Sterilization, 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 a brown coloration or precipitate 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 sterilizing 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 sterilizant 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) Neutralization 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 Demineralization 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 I and sent to the O.C., Mobile Hygiene Laboratory.

Interpretation of the Chemical Analyses.—When organic matter decomposes it breaks up into the simple compounds Water (HO) 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 and 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 bette.

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 (Kieselguhr 50, Alum 33, Sodium Carbonate 17 parts) or through metal filters in which case filter powder (Kieselguhr) 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, especially with such waters as from the Nile and Tigris, difficulty in filtration is experienced owing to the presence in the water of silt in colloidal suspension and rapid blocking of the filters occurs. 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 time saved by adopting this procedure is considerable.

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 XI, 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 XI) have stood the test of time and are admirably suited to a hand-worked plant, but with the introduction of mechanisation it was natural to seek a method of utilising the mechanical power provided.

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 Stellar Filter, a full description of which is given in Appendix X, consists of a metal candle composed of a brass former carrying a spiral thread round which a monel metal wire is wound.

The gauge of the thread allows a space of 1/3,000 of an inch to exist between the coils of wire.

Before operation a dose of filter powder (Kieselguhr) is added which impacts against the candle, blocking the spaces and forming the filter bed. When the pressure is released the whole filter bed falls off to be re-formed on recommencing filtration.

Over 90 per cent. of germs, the ova of worms and the cysts of Amœba histolytica are withheld by filtration through the Stellar filters.

If, however, the filters are worked at a pressure exceeding 100 lbs., dirt and germs may be forced through.

The Stellar filter stands up to very much higher pressure than the cloth filter before dirt is forced through and it can be easily and automatically cleaned by back-flushing.

Back-flushing is assisted by the configuration of the surface of the filter on which the deposit forms.

The interval between each spiral wire is roughly V-shaped and into this space the filter aid impacts in the form of a wedge. When the flow of water is reversed the pressure is on the apex of the wedge and the whole deposit is easily dislodged and washed off.

The Stellar Filter has an output of 50-100 gallons per square foot of filtering area per hour.

There are three types, two of which are standard patterns.

(1) A four-candle filter. Two of these are fitted to the water-tank truck. Each filter has a capacity of 100 gallons per hour if a hand pump is used; if a mechanical pump is used the two filters will deal with 400 gallons an hour.

(2) A ten-square foot twin filter (Total 20 sq. ft.) as fitted to the Mobile Water Purifier and capable of delivering 3,000 gallons an hour.

(3) A non-official small domestic filter.

The first two types are fully described in Appendices.

The Domestic Type weighs and delivers 30-40 gallons of clarified water an hour. It is very suitable for use with small groups of mechanised units separated from their normal supply. One such filter would give a supply per hour sufficient to fill the bottles of over 100 men.

To complete the water purification outfit a hand pump and stand, a canvas bucket, filter aid and a " water sterilising outfit " are required.

Portable Filtration Plant.—There may be occasions when mechanical vehicles are unable to follow a column and a portable plant capable of being carried on pack animals or by man becomes very necessary.

The Plant consists of:—

(1) One four-candle filter constructed of aluminium.

(2) Hand pump and stand.

(3) Two canvas tanks.

(4) The necessary chemicals, *i.e.* filter aid and W.S.P.

The set weighs roughly 54 lbs. and can with ease be carried by two men, or on one mule.

Two such sets would supply 200 gallons an hour, *i.e.* sufficient to fill the water bottles of an infantry unit.

The Meta-Filter. (*See* Appendix X.)

A certain number of water tank trucks are fitted with the Meta-filter; the principles are much the same as the Stellar Filter.

The filter consists of a hollow candle composed of monel metal discs kept separate by bosses on their surfaces, allowing a space of one three-thousandth of an inch to exist between the discs.

Some of the discs are larger than others to give stability to the filter bed when formed.

The candle is covered with a gauze sleeve.

When in operation a charge of Metasil (Kieselguhr powder) is added to the chamber in which the candle is fitted and when the water pressure rises inside the chamber the powder surrounds the filter candle both inside and outside the wire gauze, forming a complete filter bed. When the pressure is released that part of the bed which lies outside the gauze falls off to be again implanted on the candle when the flow of water is resumed. The Filter bed which lies between the gauze and discs is not dislodged and so keeps a clean surface in contact with the candle.

Sooner or later the deposit of dirt becomes too dense for easy filtration and back-flushing is necessary. A new charge of metasil is added when the filter is again put into use.

Owing to the construction of the filter candle there is a tendency for the spaces between the discs to become clogged with deposit, the removal of which can only be effected by dismantling the whole candle and brushing the discs, a somewhat laborious procedure.

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 powder (Kieselguhr).

(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 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.

Sterilization 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.

(2) 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 naturalammonia 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 Sterilizing 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 Tank Truck, or Water Tank 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 35 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 28, 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) are 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.

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 3,000 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 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 1,500 gallons (working capacity 1,200 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 sèries 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 Tank Truck or Water Tank Trailer (Appendices X and XI).

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

The Water Tank Truck (Appendix X) is a mechanically-propelled vehicle carrying a 230-gallon (working capacity 200 galls.) tank on a 15-cwt chassis.

The scale is 2 (two) trucks per Infantry unit and the personnel two water-duty orderlies (including the driver) per truck.

The Water Tank Trailer is designed for use with mechanised units and is towed behind a lorry. It has a capacity of 180 gallons (working capacity 150 galls.).

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 metasil or filter powder, whichever is in use. These are obtainable from the nearest unit quarter-master.

(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, 3,100 tins are required. Arrangements have to be made for replacements. The only disadvantage of the petrol tin is 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 the purpose and consists of:—

(1) Sterlising tablets containing 3 grains of a mixture (0·2 gramme) of Para-sulphon-dichloramino-benzoic acid 5·3 per cent.

Sodium carbonate, 10·5 per cent.
Salt, 84·2 per cent.
These are white in colour.

(2) Taste remover tablets (thio tablets) tinted a blue colour and containing 1½ grains (0·1 gramme) of the following mixture—

Sodium chloride, 100 parts.
Anhydrous sodium thiosulphate, 10 parts.

Each sterilising tablet when added to a bottle full of water liberates 4 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; in fact it would be preferable to add the taste remover tablets just prior to the bottle being put into use.

The sterilising tablet is stable under dry hot conditions of the atmosphere, but deteriorates rapidly when exposed to moisture. Care should be taken that the container is kept closed when not in use, and that only the number of tablets required are taken out at one time.

ALSO THAT THE STERILISING AND DETASTING 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 superchlorination 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 Kieselguhr 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 the 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 cart, 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 cart, 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 superchlorinated 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 CERCARIAE.

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, *i.e.*, the Stellar or Meta 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 sterilized 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 sterilized with the bottle, so that the bacteriological picture at the time of sampling can be obtained, otherwise if chlorine is present sterilization 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 sterilized bottle, flame its neck and stopper for half a minute by means of a spirit lamp. With a similarly sterilized 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 despatched 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 dought 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 54–57), 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.**—2 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 54–57, 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.	
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

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

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.	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.	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

APPENDIX III—*contd.*

TABLE II—*contd.*

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.	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

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.	
No. of tubes used..	5	5	5	Probable number of coli-aerogenes organisms in 100 ml. of the original water.
Number of tubes giving positive reaction.	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, pH 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.

6 copies

APPENDIX IV.

THE HORROCKS' TEST.

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

The object of the test is to find out how much Water Sterilizing Power is required to sterilize 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 sterilizing powder level with the brim. They are similar to the measure contained in the ¼-lb. tin of water sterilizing 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 Glacial Acetic Acid (50 per cent.).

Six glass tubes, or pipettes, each of such dimensions that a drop of standard water sterilizing 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, No. 25.

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 sterilizing powder in the black cup, as follows:—

250cc

Put into the black cup one level scoopful of water sterilizing 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.

2.5cc

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 sterilizing 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 sterilizing 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 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 sterilizing 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 sterilizing powder is added, that is, a total of 4 scoopfuls for every 100 gallons.

Note 1.—The water sterilizing 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 sterilizing 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 sterilizing powder required to sterilize 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 sterilizing 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 sterilizing powder is insufficient.

In this case another two scoopfuls of water sterilizing 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 unsterilized water by turning on the delivery taps before taking the sample.

APPENDIX VI.

ESTIMATION OF AVAILABLE CHLORINE IN WATER STERILIZING 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 sterilizing solution:—Measure out a level scoopful of water sterilizing 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 sterilizing 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 sterilizing powder solution about a scoopful of the cadmium iodide and starch indicator solution, and add half a scoopful of glacial 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 Sterilization.

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.) ..	$1\frac{1}{2}$ ozs. (7·5%).
Starch, soluble (A.R.)	$\frac{1}{3}$,, (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 one 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 $\frac{3}{4}$-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 sterilized 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 tests tubes used must be most carefully WASHED AND RINSED IN CLEAN WATER before being returned to the case.

APPENDIX X.

THE WATER TANK TRUCK.

Part A.—Description.

A standard motor truck provided with a 230-gallon water tank, pumps, suction hoses and filters.

1. **The Chassis.**—A standard 4-wheeled, 15-cwt. Morris Commerçial C.S. 8 truck.

2. **The Tank.**—A galvanized steel tank mounted longitudinally, and provided with baffle plates. A manhole in the top provides access for cleansing and the addition of chemicals to the water.

One common delivery pipe from both filters opens into the top of the tank.

The tank, when filled to a level of 2 in. above the top of the baffle plates in the centre, contains 200 gallons, which is sufficient to fill the water bottles of about 800 men. A vertical metal strip which is attached to one of the side baffles indicates the quantity of water in the tank.

When pumping is finished the sterilizing agents are added, and are distributed as evenly as possible; adequate mixing is then secured by use of a metal plunger which is kept in the locker.

One large drain-hole plug is provided for emptying the tank after cleaning.

The draw-off pipe is fitted with six small delivery taps suitable for water bottles, and one large tap which can be used to fill camp kettles.

A stop-cock is fitted to the elbow connection underneath the tank. By closing the stop-cock by means of a key provided, water can be prevented from entering the draw-off pipe.

3. **The Pumps.**—Two hand pumps of the differential type are placed one on each side of the truck. Each pump is fitted with a relief valve adjusted to blow off when the water inside reaches an undesirable pressure. When a mechanical pump is provided, it is driven by means of a pin and forked coupling from the front end of the crank shaft.

4. **The Suction Hoses.**—Two 20-ft. lengths of suction hose are provided. When not in use they are coiled and carried in the locker at the rear of the truck.

One end of each hose carries a union for attachment to the pipe line leading to the pump.

At the other end are a float, strainer and perforated galvanized iron outside casing.

The strainer consists of two parts :—

(i) An iron case; and
(ii) A brass perforated tube.

The outside casing encloses the strainer and is fastened by a split pin.

The float is wired to the hose.

5. **The Filters.** (*a*) **Water tank trucks fitted with Metafilters.**—Two Meta filters, each connected with a hand pump, are fitted vertically, one on each side of the tank.

Each filter consists of a cylindrical metal chamber surmounted by a filter head, into the under surface of which are screwed six metal-ring filter candles.

Each filter candle consists of a number of metal rings separated from each other by minute bosses, and stacked around a grooved metal core. Some of the rings are larger than the others in order to give stability to the filter bed when formed.

Each filter candle is surrounded by a metal gauze sleeve which serves to divide the filter bed into an outer and an inner portion.

The free ends of the filter candles are protected by means of a metal frame, which is clamped into position by a thumb screw.

Before use, each filter must be prepared as shown in Part B.I. (*a*).

The filtrate pipes, which carry clarified water from the filters, join by means of a " 3-way cock " situated at the top of the front end of the tank.

The 3-way cock enables the filters to be worked both together or one at a time while, in addition, either filter is capable of being back-flushed by means of the filtrate, *i.e.*, the clarified water from the other.

When the arm of the 3-way cock is pointing downwards, both filters are connected to the tank.

When the arm is pointing in the direction of one of the filters, that filter only is connected to the tank, the other being completely shut off ; in this way it is possible to prepare each filter in turn and get its filter bed established without interfering with the working of the other filter.

When the arm of the 3-way cock is pointing upwards, the filtrate pipes are directly connected with each other and no water can pass into the tank ; in this position it is possible to back-flush either filter.

A filtrate first-runnings tap is situated above the filter head.

A filler cap is placed half-way up the side of the filter chamber.

A drain cap is placed at the lower part of the chamber.

A pressure release cock is placed high up in the wall of the chamber.

(*b*) **Water Tank Trucks fitted with Stellar-Filters. The Filters (Stellar).**—Two Stellar Filters, each connected with a hand pump, are fitted vertically one on each side of the tank. Each filter consists of a cylindrical metal chamber surmounted by a filter head, into the under surface of which are screwed four monel wire filter candles. Each filter candle consists of a brass former, comprising a tube having a number of projections on the outer surface similar to those on a gear wheel, running the whole length of the former.

These projections are threaded, and monel wire is wound spirally into the threads, thereby forming a rigid foundation for the filter bed when deposited on the external surface of the wire.

Before use, each filter must be prepared as shown in the working instructions given later (Part B, Ib). The filtrate pipes, which carry clarified water from the filters, join by means of a 3-way cock situated at the top of the front of the tank.

The 3-way cock enables the filters to be worked both together or one at a time while, in addition, either filter is capable of being back-flushed by means of the filtrate, *i.e.*, the clarified water, from the other.

When the arm of the 3-way cock is pointing downwards, both filters are connected to the tank.

When the arm is pointing in the direction of one of the filters, that filter only is connected to the tank, the other being completely shut off ; in this way it is possible to prepare each filter in turn and get its filter bed established without interfering with the working of the other filter.

When the arm of the 3-way cock is pointing upwards the filtrate pipes are directly connected with each other, and no water can pass into the tank ; in this position it is possible to back-flush either filter.

A filtrate first-runnings tap is situated above the filter head.

A filler cap is placed half-way up the side of the filter chamber.

A drain plug, by means of which all water is drained away, is fitted in the centre of the conical base of the chamber.

A pressure release cock is fitted in the centre of the drain plug at the base of the filter.

6. **Stores Locker**.—Behind the tank is a locker for carrying :—

Two suction hoses with strainers and floats.
Plunger, water, stirring.
Two pump handles.
Filter aid (Metasil A) in 11-oz. tins, for use with Meta-filter.

Or Filter Powder (Kieselguhr) in bulk tins.
(Note.—3-oz. charge per filter, for use with Stellar Filter.)

Water Sterilizing Powder (W.S.P.) in ¼-lb. tins (each tin containing a small scoop of the same size as those provided in the Horrocks' Box).
Taste remover tablets.
Case, water testing, sterilization (Horrocks' Box).
Case, leather, small stores.
Small spare parts.

Measure, water, ½-gallon, Mk. I (in compartment beneath platform).

Two small brushes for cleaning filter candles.

To trucks fitted with Stellar Filters is added a one-ounce measure for filter powder (Kieselguhr).

Part B.—Working Instructions.

I.—Clarification.

(*a*) **By means of** META-FILTERS.—The water is clarified as it is pumped through the Meta-filters into the tank; chemicals are then added in order to sterilize the water.

How to Clarify the Water and Fill the Tank.

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

2. Throw the strainers into the source of water supply as far from the bank as possible.

3. Make sure that the leather washer is in position in the hose union and then attach the hose to the pump.

4. Prepare the near side filter first. To do this turn the arm of the 3-way cock away from this filter, which is thereby completely disconnected.

5. Unscrew the filler cap and pour into the filter chamber the contents of a tin of filter aid (Metasil A), mixed with about half a gallon of water in the galvanized iron jug provided. Replace the filler cap.

6. Open the filtrate first runnings tap.

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

Water now enters the filter chamber, which it gradually fills, and is then forced through the filter candles, from the inside of which it passes up to the filter head and runs to waste.

In its passage through the filter candles the water rapidly deposits a film of filter aid on their outer surfaces forming the filter bed, and clarification takes place in a very short time.

The degree of clarification can be judged by inspecting samples of the water as it runs to waste in one of the white cups provided in the Horrocks' Box.

8. As soon as the water becomes clear, turn the arm of the 3-way cock towards the nearside filter which is now ready for use and close the filtrate first runnings tap.

The clarified water now enters the tank and should be allowed to run to waste for a short period through the delivery taps in order to flush out the bottom of the tank.

Note.—It will normally be necessary to complete the back-flushing of the offside filter at this stage.

9. Samples of water are taken in the six white cups from one of the delivery taps, for carrying out the Horrocks' Test, which is described in Appendix IV. The delivery taps are then closed.

10. The offside filter is prepared in a similar way, and the arm of the 3-way cock is then turned downwards so that both filters are connected with the tank.

11. Continue pumping through both Meta-filters until 200 gallons have passed into the tank.

12. When 200 gallons have been passed into the tank the appropriate quantities of water sterilizing agents are added, and mixing is carried out by means of the plunger.

13. Occasionally one or other of the Meta-filters may begin to clog before this quantity of water has been clarified. The increase in pressure is shown by increasing stiffness in working the pump and by the escape of water from the pressure relief valve on the pump. The condition may be relieved by dropping the outer filter bed.

In order to do this, stop pumping and turn the arm of the 3-way cock away from the filter, which is then completely disconnected. Then open the pressure release cock, open the filtrate first runnings tap, and wait for one or two minutes.

At the end of this period the pressure release cock and filtrate first runnings tap are closed. When the arm of the 3-way cock has been returned to its downward position and after pumping has been resumed, the pressure will be found to have fallen to normal.

Should a Meta-filter continue to clog at short intervals after dropping the outer filter bed, it will be necessary to back-flush it.

14. Back-flushing is carried out in the following way:—

Turn the arm of the 3-way cock upwards and unscrew the drain cap of the filter. Begin pumping with the opposite pump; this back-flushes the filter with clarified water. Continue pumping until clear water emerges from the drain of the filter; during this time dirty water escapes from the filter chamber. Replace drain cap. The filter is now ready to receive a fresh charge if pumping is to be continued.

15. Unless there is some special reason for economy in the use of filter aid, the following routine procedure is to be carried out at the end of each working day.

Back-flush the nearside filter. Then open the pressure release cock and the drain cap of the offside filter and allow to remain open a few minutes during which most of the muddy filter aid and water will drain from the filter chamber. Next morning or before filling the tank again, prepare the nearside filter. Then complete the back-flushing of the offside filter and prepare it as described in paras. 4-10.

Note I.—If filter aid is allowed to remain overnight in the filter chambers it may settle to the bottom and form a hard mass. This may produce difficulty by (*a*) blocking the ball valve at the bottom of the chamber, or (*b*) forming an uneven filter bed when pumping is resumed the following morning.

The procedure in para. 15 ensures that both filter chambers remain empty of filter aid overnight.

Note II.—When the truck is in regular use it is desirable, once a month or more often, when muddy water has been pumped, to remove the filter head with the candles attached and to wash them thoroughly in water.

The metal gauze sleeves should be removed. The diameter of a sleeve is slightly increased by pressing one end towards the other with the fingers of both hands; in this way it may be more easily worked off the metal rings. It must not be forcibly pulled off, or damage to the gauze will result. The candles should be scrubbed carefully with a brush, but should not be unscrewed from the filter head.

Note III.—In no circumstances must water be pumped through a filter unless filter aid is present in the filter chamber.

Should this be inadvertently done, it may result in blocking of the filter candles which will necessitate complete dismantling with removal and cleaning of all the metal rings.

Filter candles are to be dismantled only by skilled personnel.

(*b*) **By Means of** STELLAR FILTERS.—The water is clarified as it is pumped through the Stellar Filters into the tank; chemicals are then added in order to sterilize the water.

How to clarify Water and Fill the Tank.

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

2. Throw the strainers into the source of water supply as far from the bank as possible.

3. Make sure that the leather washer is in position in the hose union and then attach the hose.

4. Prepare the nearside filter first. To do this turn the arm of the 3-way cock away from the filter, which is thereby completely disconnected.

5. Unscrew the filler cap and pour into the filter chamber a filter charge prepared as follows:—

Measure a 3-oz. charge or take a tablet of Filter Powder (Kieselguhr); mix with sufficient water to give it a creamy consistency to break up lumps, and then add about half a gallon of water. This procedure is carried out in the galvanised-iron jug provided.

Having poured the charge into the filter chamber replace the filler cap.

6. Open the filtrate first-runnings tap.

7. Start pumping slowly with hand pump and increase gradually up to 30-40 double strokes (up and down) per minute. When a mechanical pump is used, the rate should be gradually increased in a similar manner.

Water now enters the filter chamber which it gradually fills, and is then forced through the filter candles, from the inside of which it passes up to the filter head and runs to waste.

In its passage through the filter candles the water rapidly deposits a film of filter powder on their outer surface forming the filter bed, and clarification takes place in a very short time.

The degree of clarification can be judged by inspecting samples of water, as it runs to waste, in one of the white cups provided in the Horrocks' Box.

8. As soon as the water becomes clear, turn the arm of the 3-way cock towards the nearside filter which is now ready for use, and close the filtrate first-runnings tap.

The clarified water now enters the tank and should be allowed to run to waste for a short period through the delivery taps in order to flush out the bottom of the tank.

NOTE.—It will normally be necessary to complete the back-flushing of the offside filter at this stage (see para 15).

9. Samples of water are taken in the six white cups from one of the delivery taps, for carrying out the Horrocks' Test, which is described in Appendix IV.

The delivery taps are then closed.

10. The offside filter is prepared in a similar way, and the arm of the 3-way cock is then turned downwards so that both filters are connected with the tank.

11. Continue pumping through both filters until 200 gallons have passed into the tank.

NOTE.—When it is necessary for any reason to stop pumping, it is desirable that the filtrate first-runnings tap should be opened when pumping is resumed; a sample of the water running to waste may then be inspected as to its clarity before closing the tap and allowing the water to pass into the tank.

12. When 200 gallons have passed into the tank, the appropriate quantities of water sterilizing agents are added and mixing is carried out by means of the plunger.

13. Occasionally one or both of the filters may begin to clog before this quantity of water has been clarified. The resulting increase in pressure is shown by increasing stiffness in working the pump, and eventually by the escape of water from the pressure relief valve. The condition can be relieved by dropping the filter bed. In order to do this, stop pumping and turn the arm of the 3-way cock away from the filter, which is then completely disconnected. Open the filtrate first-runnings tap. Open the pressure cock for a few seconds and then close it. Wait for one to two minutes.

At the end of this period pumping is recommenced until clear water is obtained. The arm of the 3-way cock is then returned to its downward position, the first-runnings tap closed and pressure will be found to have returned to normal.

Should the filter continue to clog at short intervals after dropping the filter bed, it will be necessary to back-flush it.

14. Back-flushing is carried out in the following way :—

Turn the arm of the 3-way cock upwards and unscrew the drain plug of the filter. Begin pumping with the opposite pump ; this back-flushes the filter with clarified water. Continue pumping until clear water emerges from the drain of the filter ; during this time dirty water escapes from the filter chamber. Replace drain plug. The filter is now ready to receive a fresh charge if pumping is to be continued.

15. At the end of each working day back-flushing of the nearside filter should be carried out according to the above instructions.

When there is no danger of freezing, the offside filter chamber may be left filled with water ; in frosty weather, however, all water must be drained from it.

When it is intended to fill the tank again, the nearside filter is prepared and back-flushing of the offside filter is completed. The offside filter is then prepared and both filters are ready for use.

Note I.—It may be desirable at times to remove the filter head together with the candles and brush the monel wire with a bristle brush.

The necessity for this is indicated by clogging of the filter which is not relieved by dropping of the filter bed or back-flushing.

In any case, when the truck is in regular use, this procedure should be carried out monthly.

Note II.—Should the filter candles be damaged, resulting in dented wire, the filter bed and dirty water may pass through. Temporary repair can be effected by covering the defective portion with adhesive tape, fabric or string. Permanent repair can be effected by soldering over the spot.

Note III.—In circumstances where no filter powder is available, water may be pumped through the filters without the use of a filter bed—thereby removing a large percentage of coarse suspended matter. Cleansing should then be effected by brushing as previously described.

How to Sterilize the Clarified Water in the Tank.

II.—Sterilization.

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 sterilizing 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 sterilizing 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 $\frac{1}{4}$-lb. tin of water sterilizing 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, unscrew the suction hose, place the palm of the hand flat against the inlet of the pump and test the suction by pumping with the other hand. If no suction is felt, a little dubbin on the washers inside or priming the pump with a little water will remedy the defect.

2. If suction is found to be satisfactory and the pump still fails to draw water, then air is entering the pump, either through a leak due to a defective washer in the hose union or through a hole in the suction hose. This necessitates replacing the defective washer by a new one, or putting on a new suction hose.

3. It occasionally happens, when pumping, that the pump handle tends to fly back. This is due to the detachment of the inner lining of the hose, which collapses and so blocks the hose on each suction stroke of the pump.

4. Remember that the pumps will not lift water to a height exceeding 20 ft.

5. Don't pump too quickly.

6. 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 unauthorized drawing of water from the delivery taps. A removable key is provided for operating the stop-cock.

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

8. 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.

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

10. Don't fill the tank by pouring buckets of water through the opening on the top.

APPENDIX XI.

THE WATER TANK TRAILER.

Note.—There are two water tank trailers, one of 15 cwt. (150 gallons) and the other of 10 cwt. (80 gallons); the method of purification is similar in both, and a description of the larger trailer only is given.

A.—DESCRIPTION.

1. **The Chassis.**—This is a 15-cwt. two-wheeled G.S. trailer with pneumatic tyres.

2. **The Tank.**—This is of mild steel, and has a total capacity of 180 gallons, with a "travelling" capacity of 150 gallons when filled to the top of the baffle plates. This is sufficient to fill the water bottles of about 600 men. The baffle plates divide the tank into four equal compartments.

A manhole in the top provides access for cleansing and the addition of chemicals to the water.

Two delivery pipes from the clarifying cylinders open into the top of the tank.

When pumping is finished the sterilizing agents are added and are distributed as evenly as possible; adequate mixing should then be secured by use of a metal plunger.

One drain hole plug is provided for emptying the tank after cleaning.

The draw-off pipe is fitted with four small delivery taps.

By closing a stop-cock by means of a key provided, water can be prevented from entering the draw-off pipe.

3. **The Pumps.**—Two hand pumps of the differential type are placed one on each side, towards the rear of the trailer. Each pump is fitted with a relief valve adjusted to blow off when the water inside reaches a pressure of approximately 15 lbs. to the square inch.

4. **The Suction Hoses.**—Two 20-ft. lengths of suction hose are provided; when not in use they are coiled and strapped on the front of the tank.

One end of the hose carries a union for attachment to the pump; at the other end are a float, strainer and perforated galvanized iron outside casing.

The strainer consists of two parts :—

(i) an iron cage; and

(ii) a brass perforated tube.

The outside casing encloses the strainer and is fastened by a split pin.

The float is wired to the hose

5. **The Clarifying Cylinders.**—Two metal clarifying cylinders, each connected with one of the pumps described above, 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.

6. **The Store Box, etc.**—Behind the tank is a wooden box for carrying :—

Spare reels and clarifying cloths.

Water clarifying powder in ½-lb. tins (each containing a large scoop).

Water sterilizing powder (W.S.P.) in ½-lb. tins (each containing a small scoop of the same size as those provided in the Horrocks' Box).

Taste remover tablets.

Case, water testing, sterilization (Horrocks' Box).

Case, leather, small stores.

Small spare parts.

Metal plunger.

Fastened by straps to the top of the store box is a rectangular-shaped kettle in which the clarifying cloths can be boiled.

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 sterilize 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 source 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 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 sterilize the water.

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

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 Sterilizing Powder for each 100 gallons, as indicated by the test, 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 sterilizing powder, followed after the appropriate interval by 4 tablets of taste remover, may be substituted for the above method.

(*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 tank truck (Appendix X (*b*), III.

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

1. See also the water tank 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.

STERILIZATION OF WATER BY THE AMMONIA-CHLORINE METHOD.

1. Water may be sterilized by means of ammonia-chlorine made from ammonium chloride tablets and water sterilizing 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 sterilizing powder (chlorine).

2. The following quantities will be required :—

Water tank truck (200 gallons)—

4 tablets ammonium chloride.
4 scoopfuls of water sterilizing 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 sterilizing 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 sterilized overnight and not drawn for drinking until the following morning.

NOTE.—Estimation of the available chlorine in water sterilizing 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.

STERILIZATION 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 sterilizing 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 sterilizing powder has been added and mixed with the water in the tank.

4. Carry out the colour test at the end of the 30 mimutes; if a blue colour is obtained, the water is fit to drink. If no blue colour is obtained, then 1 more scoopful of water sterilizing 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 sterilizing 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 sterilization.

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 sterilizing 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 sterilized 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 sterilization 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. water bottle = 1/4 gal.

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 sterilized, shake and then add one scoopful of the chlorine solution. Allow at least one hour to sterilize.

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.

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.

Requisites.—(1) One or more 1,500-gallon canvas tanks, holding actually 1,200 gallons.

(2) A pail or other container.

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

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

(5) Lime.

(6) Brom-Thymol Blue indicator powder.

Method.—(1) Dissolve a heaped black cupful (¾ of a pound) of alum completely in a pail of water. (This amount, added to the 1,200 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, sterilization, measure one *level* scoopful (the scoop from a tin of water sterilizing 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 1,200 gallons of water according to the dose determined by the above test :—

1 grain per gall.	= $2\frac{3}{4}$ ozs.	to	1,200	galls. or	$2\frac{3}{4}$ scoopfuls per 100 galls.
2 grains per gall.	= $5\frac{1}{2}$	,,	1,200	,,	$5\frac{1}{2}$ scoopfuls per 100 galls.
3 ,, ,,	= $8\frac{1}{4}$	,,	1,200	,,	$8\frac{1}{4}$ scoopfuls per 100 galls.
4 ,, ,,	= 11	,,	1,200	,,	11 scoopfuls per 100 galls.
5 ,, ,,	= $13\frac{3}{4}$	,,	1,200	,,	$13\frac{3}{4}$ scoopfuls per 100 galls.
6 ,, ,,	= $16\frac{1}{2}$	,,	1,200	,,	$16\frac{1}{2}$ scoopfuls per 100 galls.
7 ,, ,,	= $19\frac{1}{4}$	,,	1,200	,,	$19\frac{1}{4}$ scoopfuls per 100 galls.
8 ,, ,,	= 22	,,	1,200	,,	22 scoopfuls per 100 galls.
9 ,, ,,	= $24\frac{3}{4}$	,,	1,200	,,	$24\frac{3}{4}$ scoopfuls per 100 galls.

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

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

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 sterilizing 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 (1,800 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) 1,200 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 3,000 gallons per hour at 1,800 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 1,500 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 (*vide* page 69, Appendix X, Part B. I (*b*)).

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 register 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, sterilization, 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 sterilizing 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 1,200 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. *Sterilization.*—Chloramine which is produced by the sterilizing 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 sterilizing action is reduced and a longer period than one hour is necessary for sterilization 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 sterilizing 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 sterilizer 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 values as in (*d*) above and START engine to run on governor.

(ii) OPEN (8) (filter by-pass), THEN SCREW DOWN HALFWAY (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 charge filters if no clean water is available. See Instructions for Filters outside left-hand door of sterilizer 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) (foot-valve) out of water.

FILTER UNIT.

(See Layout Diagram.)

To be mounted on outside of left-hand door of sterilizer 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 1,200 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 3,000 g.p.h. for both filters and 1,500 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 1,500 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 1,500 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 restarting, 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). — OR (*g*) (OPERATION 7).—

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 1,500 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.

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).

STERILIZER UNIT.

(*See* LAYOUT DIAGRAM.)

To be mounted on inside of left-hand door of sterilizer 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 ⅝ths. inch of height). Use graduated dipstick, white cup from *Case Water Testing Sterilization : 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)	(v) LOCK regulator. (Ammon. sulph.)	(17 M)	
(iii) QUICKLY OPEN FULL stop valve.	(3 M)	(3 C)			

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 Sterilization 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., sterilizer 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 sterilizer 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	References in Regulations.
(a) FOR CLARIFICATION.				
Lime .. .. Clarifying Powder .. Metasil .. .. Filter Powder (Kieselguhr) Copper sulphate .. .. Aluminium sulphate .. Ferrous sulphate .. Alumino-ferric	Indent on A.B. 30 by Q.M. of Unit	M.O.	O. i/c. Supplies, R.A.S.C. Through Q.M. Unit.	Regs. M.S.A. and S.T. and B. Regs.
Filter-cloth (cover, clarifying reel for Cart, Water Tank)	Indent on A.F. G.997 in triplicate to:— D.A.D.O.S.	M.O.	R.A.O.C. Through Q.M. Unit.	Equipt. Regs.
(b) FOR STERILIZATION.				
Water, Sterilizing Powder Halazone Outfit .. .. Hypo. (Sod. Thiosulph.) Detasting tablets .. Tabs. Acid Sod. Sulph. .. Tabs. Ammon. chloride ..	Indent on A.B. 30	M.O.	O. i/c. Supplies, R.A.S.C. Through Q.M. Unit.	Regs. M.S.A.
Horrocks' Box and replenishments of its contents	Indent on A.F. I.1209 by M.O.	M.O.	O.C. Hospital	Regs. M.S.A.
Water Purification Set Mobile	Auth. scale.	—	Ordnance (R.E. Unit).	—
Sulphate of ammonia and common salt replenishments for above.	As required.	—	O. i c. Supplies, R.A.S.C.	S.T. and B. Regs.
(c) STORAGE AND ISSUE.				
Cart, Water, Tank .. Water Tank Truck and Water Tank Trailer ..	Authorized Scale.	—	R.A.O.C. Through Q.M. Unit.	Equipt. Regs.
(d) DETECTION OF POISONS				
Case, Water Testing, Poisons, and replenishments of its contents	Indent on A.F.I. 1209 by M.O. to A.D.M.S.	—	O.C. Hospital.	—
(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.	Regs. M.S.A. 1938. (Appendix 15A.

Purif[illegible] of small amts of Water

Black cup – standard meal.

modified – Horrocks test.

(chlorinated tablet – to 1 white cup water
2 scoops of this soln to each gallon.)

4 gal to be purified.
Test gives 3 scoop per 100 gal
3 × 4 = 12 scoops. Standard W.S.P. soln:
Black cup 250 cc – [illegible] scoop to [illegible] 2.5 cc
300 of scoop W.S.P. per 100 gal
= no of scoops of standard soln per 1 gal.

White cup = 180 cc. (1/4 in of top)
brim 200 cc
bore of pipette 2.6 mm.

Chlramme T . dh C T.

1:250,000

4.6 my

hall 86.4 ? tablet Jaddwai.

Chmeae. 9.0