In dealing with the subject of the provision of pure or innocuous water to troops in the field it is necessary to repeat facts which are well known as well as those less known, so that the proper position of new principles and inventions may be made clear. Numbers of officers are instructed, every year, in this College, still it is not uncommon to find that though an officer may have a good knowledge of the principles which deal with the subject, he is not familiar with the limitations of the various methods which have been suggested for carrying out the principles. I hope I may therefore be excused if I seem to remind any of you present of facts with which you are already familiar, since my aim is to mention the particular circumstances in which each method should be adopted.

The search for simple and yet effective methods of providing innocuous water is still going on, and the evolution of a method of clarification as opposed to filtration has brought us a great deal nearer our goal. This method I hope to demonstrate in the Square after reading this paper.

Though many authorities are of opinion that the period of existence of Bacillus typhosus in water is very short under natural conditions, and that 99 out of a 100 waters, in the country districts, unless obviously polluted with sewage, could be used by troops without bad effect, still it is the 100th water which, by starting an epidemic of enteric fever, diminishes, to a large extent, military efficiency. Some method of water sterilization is therefore essential, whether for large bodies of troops or for single individuals.

The provision of pure water for troops in stationary camps and posts, such as the Base, Advanced Base, Rest Camps, General Hospitals, etc., is comparatively simple, since civilian appliances, capable of supplying harmless water to all, can be, more or less, used. Permanent sterilizing plants can be fitted up, and supervised by men trained for the purpose.

No arrangements which have fixed apparatus are of any use with troops in the field. Any such must be mobile and capable of following the units to which they are attached over practically any
sort of country. In determining what form of apparatus shall be adopted we have to consider what method of sterilization will give us the best results and at the same time allow of easy transport.

The size of the apparatus is of first importance. The larger the apparatus the more efficient and economical it is likely to be and the fewer men will be required to look after it. If possible, such an apparatus should be self-propelling and should sterilize water by self-contained power. It would, however, necessitate the provision of water-carts to carry the water to the units, since it would not itself be able to distribute it. If large bodies of men always acted together, this method would possess many advantages, since the unit could establish itself at some central stream and there supply the water-carts with sterile water. Such water would be protected from contamination, as there would be no handling necessary in distribution, the staff would be highly trained, and the water-carts, never taking in dirty water, would not require cleaning, and could be kept locked. It has been ruled, and I think rightly, that such units are inadvisable. Even if the troops supplied by the unit kept together there is a very good chance that, with the roads blocked by the transport supplying the army, either the unit would not reach the position or the carts would not find the unit. The half-battalion water-sterilizing cart has therefore been decided on as the maximum and minimum apparatus advisable. It is as small as is compatible with efficiency, forms a load for two horses on the road, and is reasonably mobile. If further subdivisions of troops are to be provided for, some means allowing for individual sterilization of water must be used.

The desiderata for a small sterilizing unit are as follows:—

(a) It must be able to follow the unit to which it belongs anywhere within reason.

(b) It must perform the duty of sterilization in such a manner as to remove from the water any matters which are likely to be deleterious to the health of the troops.

(c) It must be sufficiently simple in action to enable it to be handled by partially trained men.

(d) It must not contain fragile parts which, if broken and not immediately replaceable, will render the machine useless.

(e) It must be able to deliver innocuous water at a moment’s notice.

These conditions are severe, but represent the ideal of efficiency, and it is owing to the failure of each of the methods of sterilization which we possess, up to the present, in one or other of these
particulars that it is impossible to decide on any one method to the exclusion of the others.

The sterilization methods which are available are four, i.e., mechanical filtration, heat sterilization, chemical methods, and the use of the ultra-violet rays.

Commencing with the last it may be said at once that, at present, the method is quite unsuitable for units which would be supplied by the present water-cart. The necessary current cannot be generated in an economical manner, while, taking it from the telegraph battalions is hardly likely to be welcomed by the latter. The apparatus is fragile, requires very skilled supervision, and will not work with muddy water. A cart to which this apparatus is fixed has been designed in Germany and is described in the Corps Journal of May last. The weight of the installation, without the water in the cart and without a generating plant, is, I believe, two tons. This alone removes this form of cart from the region of practical politics.

The use of chemicals might seem to promise a way out of the difficulty, but, though they are efficient in small bulks of water, they fail when used with large quantities. The reason for this is that with appliances suitable for work in the field thorough mixture is impossible, and one cannot ensure that every portion of the water comes in contact with the disinfectant for the requisite period of time.

It must also be remembered that the water served out to the troops will contain a quantity of a salt which, though harmless if only taken for a short time, might produce unpleasant effects after prolonged use.

Sterilization by heat has many advantages and disadvantages which I have tried to set out in the following table, in which the various methods are contrasted.

Each of the four methods of water sterilization has its particular applicability, and under certain circumstances would be preferred. Thus, for example, for a hospital on the lines of communication which would almost certainly have electric light installed and which received, at any rate, clarified water, the ultra-violet rays would probably be the most suitable, since they are able to work automatically with very little attention. When they do require attention, however, it must be that of an expert electrician.

For such camps as rest camps, through which troops are constantly passing, and which never have a sufficient permanent staff to keep the camp in proper order and to provide water for the
### Mechanical sterilization

(a) The official cart can follow wherever wheeled transport is at all possible. Where wheeled transport cannot go there are patterns of the clarifier filters for carriage by mules or coolies.

(b) The old pattern filter water cart does not sterilize the water; at best, it removes a percentage of organisms only. The candles require periodic boiling, since it is possible for organisms to grow through the medium. The candles are thus put out of action, the joints cracking owing to the different expansion of the metal and porcelain.

(c) The filter cart is very simple in action and is easily worked. Very little training is required to deliver the water, though considerable knowledge and care is necessary to prevent it being contaminated after filtration.

(d) The candles are very fragile and easily broken. Without them the cart, as a filtering unit, is useless.

(e) The filter cart is ready to deliver water as soon as the pumps are worked. As long as the raw water is clear the delivery is reasonably good, but the presence of suspended matter in the water very soon puts the filters out of action.

**General.**—Both forms are cumbersome and add greatly to the weight of the water carts. If the idea of the Brigade Sterilizer could be carried out, this would undoubtedly be useful, as the water carts would carry water only and would want no other attendants than the driver, while the skilled personnel could be concentrated at the sterilizing point.

### Heat sterilization

(a) A cart has been devised which could follow the troops; but it is still in the experimental stage. To be efficient the apparatus must be on a much larger scale than the exigencies of military service will allow. (See Notter and Firth, p. 930)

(b) There is no doubt about the sterilizing powers of the heat exchangers. When in good order they sterilize the water without fail.

(c) The heat exchangers are automatic in action so long as they are in order, but are very easily damaged in transport.

(d) The whole apparatus is very fragile and the heat exchanger is frequently found broken. The capsule is delicate, and the burners, if lamps are used, also soon wear out.

(e) The heat exchanger can deliver water at about the same rate as the cart, but requires half an hour before delivery commences. This time is required to fill the exchanger. Mud rapidly blocks the apparatus and puts it out of action.

### Chemical sterilization

(a) Chemicals are, on account of their small bulk and weight, easily portable.

(b) Chemicals are fairly certain in their action in small bulks of water, but not in large, without bulky mechanical contrivances. (Water thus treated cannot be used continually.)

(c) Chemicals need only to be added and well mixed.

(d) Chemicals are only destroyed by exposure to water, and by age.

(e) Chemicals require an appreciable time to act. The longer the time available the less the amount of the reagent required. If the reagent has to be used in large quantities, the water being required for immediate consumption, the taste is apt to be nauseous.
incoming troops, the heat exchange installations might be the best. They will work as long as the supply of fuel, which can be of a simple character, is kept up, and require little attention. After a very slight training in mechanics, with a few tools, the man in charge could repair any ordinary defects.

The principle of mechanical filtration has been adopted for troops in the field, but till lately the mud in the water has always been the drawback. I remember the filters being returned into store or merely carried about in Egypt and in South Africa, because it was impossible to filter the water on account of excess of mud. Used with water such as is supplied at one's own house the filters give a fairly good output, but the presence of the smallest amount of mud blocks them in a short time. Again, too, the degree of efficiency of a filtering material in preventing the passage of micro-organisms depends on the opposition offered to the passage of the water. In other words the finer the pores of the medium the more organisms are kept back but the smaller is the delivery of water, while if we have a medium which gives a satisfactory water delivery, we cannot expect more than a partial removal of organisms.

With this we have to be content since a sufficient flow of water is an absolute necessity for military purposes. Compromise is therefore the order of the day. There has, however, been worked out at the School of Military Sanitation, Aldershot, and the Royal Army Medical College, a method which, while removing the mud from the water, utilizes it to remove the micro-organisms as well. In fact the sand filter is imitated, the so-called zooglea layer being supported on flannelette instead of sand. By this means, with Thames water, it has been found that from 60 to 80 per cent. of the organisms present in the water can be removed, while the delivery of perfectly clear water is very rapid. If absolute sterility is desired, it is only necessary to pass this clarified water through the existing candles to obtain it. It has been found possible to clarify water from a village duck pond by this method, though it must be remembered that coloration of water cannot be removed, since the colouring matter is in solution and not in suspension.

Were it not that it is impossible to deal with a specifically polluted clear water, which must be of very rare occurrence, by the clarifiers owing to the absence of mud, goodbye might be said to the filter candles as being expensive, heavy, fragile and generally unsatisfactory. Using the official water-cart it has been possible to sterilize both clear and Thames water with the clarifiers alone in combination with small quantities of bleaching powder. This method, however, is still in the experimental stage.
Coming now to the water supply of a number of troops smaller than half a battalion which are not in possession of a water-cart. These are the very people to whom we want to give the greatest attention, since they are more likely to come across streams of which the Medical Officer has no knowledge, and hence to run more chance of getting bad water. It is, therefore, very necessary for them to thoroughly understand what measures they should take under these circumstances. Below the half battalion there is no arrangement made for any system of collective water sterilization, so that the methods adopted must be applicable to single persons as well as to a number. The methods which are to hand are boiling, chemical sterilization and individual filtration.

The latter is impossible, since not only are the small filters unsatisfactory, but they add to the weight the soldier has to carry and to the work he has to perform.

The boiling of water can be carried out by individuals in their canteens, the water being either left to cool all night with the lid on or poured straight into the water-bottles as water or as tea. It is not generally known that such a bottle on a cold wet night acts as a hot-water bottle and considerably increases the comfort of the possessor, besides providing him with pure water for the day following. In small units it is possible for the cooks to put a kettle of water on the fire which remains when their work is done and to leave it there all night. This will either boil the water or will raise it to a sufficient temperature to destroy disease-producing organisms, while in the morning it will be cool enough to put into the water-bottles.

If fuel is not available, as in South Africa, or when, for tactical reasons, it is inadvisable to light a fire, then chemical methods might be of use. Of these there are several which are efficient, the two best being the iodine method of Vaillard, several times reborn under other names, and the acid sulphate of soda tablets of Parkes and Rideal. The latter, as modified by Colonel Firth, are the most practical. To sterilize the water in the water-bottle one tablet is dropped in, and after half an hour the water will be found to contain no organisms of the colon-typhoid group, even if they have been previously added. The addition of saccharine and oil of lemon to the tablets makes the water taste like weak lemonade, and the men usually like it.

The iodine process requires the use of three tablets, and is hence not advisable.

In preparation for the prolonged fights of the present day it
would be possible to issue to each man say seven tablets. One of these he would drop into his water bottle every time he filled it, which should not be oftener than once a day, and he would thus be able to sterilize his drinking water for seven days. Longer than this he should not require to go, for the battle would have been decided one way or the other before that, or the water carts would have reached him. What the result of such prolonged use of this acid water would be it is difficult to say, but I personally would sooner risk the effects of a dose of weak sulphuric acid than of *B. typhosus*. If issued in glass bottles there is a danger of the clothes being burnt as the bottles may be smashed, and any water getting to the tablets liberates the acid. This might be got over by using vulcanite or aluminium containers holding say seven tablets, the latter to be removed as required.

Whatever method we may decide to adopt, there is a necessity for strict water discipline to ensure that, after the water has been sterilized, it is not again contaminated by careless persons. Where collective schemes are adopted, such as, for instance, boiling in camp kettles, careful organization is required to see that the water is not fouled when the bottles are filled. The dipping of bottles with a dirty felt covering in the kettle will undo any good done by boiling. It is not sufficient to merely say boil and leave it there, the whole position must be thought out and strict rules issued. Actions which have very little significance in themselves have a very serious one from a sanitary point of view. Thus the giving of a drink to a comrade, to the lay mind a praiseworthy piece of generosity, to us is an indication of horrible danger should that comrade’s bill of health not be clean. The contamination of water after sterilization is far more fraught with danger than when raw water is used, since the contamination is likely to be with some of the parasitic organisms of disease harboured by man placed in water from which all competing organisms, which in the raw water would have soon got rid of the parasites, have been removed, and which is intended to be drunk in a short time.

The training of each individual in the proper care of water therefore ranks with, if not before, that of the purification of water since, if the former were properly carried out there would be little need of the latter. One must be taken with the other, and the sterilization of water should only be regarded as an absolute necessity in the few cases where water discipline has failed to protect the water supply.
DISCUSSION.

Major W. S. Harrison, R.A.M.C., asked whether the designers of the new cart had finally abandoned the position that it was possible to provide germ-free water for troops in the field, and whether they contented themselves with straining it. He noticed that with the best results there were still 20 per cent to 40 per cent of the original germs present after passing through the clarifier, and with specifically contaminated water it appeared that the water passing over would still be potentially infective. The author had said that one could remove the remainder of the germs by passing through candles, but then in another part of the paper he had condemned candles for field service work.

Colonel Ryan, Australian Medical Corps, said it was new to him that it was possible to provide water sterilized by mechanical means to troops in the field. In Australia, where troops would have to depend largely on the dirty water in dams, such an arrangement as Major Wanhill had described ought to be very useful.

Colonel Sir David Bruce said that our knowledge of water was constantly changing; we knew now that typhoid bacilli had a very short life in water, and he would fancy that the water in the dams of Australia would very rarely contain typhoid bacilli. At one time we thought that we had solved the problem of water supply in the field by the use of candle filters, but they were very fragile and their yield was very poor if they were really effective as sterilizers. In Ladysmith they managed to get water through candles by clarifying it beforehand, passing it through sand or ashes. Selous had told him that he personally always carried a "billy," and when he wanted a drink he made tea.

Major Wanhill, in reply, said there were two schools; one thought that all water was dangerous without sterilization, the other thought that water was only dangerous when it had been recently specifically contaminated. It was necessary to compromise in the matter; it was impossible to provide troops in the field with sufficient sterile water for their use, and it was doubtful if it was, except under special circumstances, necessary that one should do so, but no one questioned the desirability of providing troops with clean water; the clarifier would do that, and if it was necessary one could further pass the water through candles. Candle filters working with Thames water were choked in five minutes, and the purification of what water did pass through only amounted, with the porous candles they used, to 30 per cent reduction in germs. But if the water was first passed through the clarifier there was no choking, and clarified water passed through the filters came out sterile. The yield of the clarifiers was 130 gallons in twenty minutes, if the water passed through the filters also the yield was 120 gallons in an hour.