STERILIZATION OF WATER BY CHLORINE.

BY

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AN article entitled "Sterilization of Infected Water in Camp and on the Line of March in India," published in the *Journal of the Royal Army Medical Corps* for October, 1913, under the names of Colonel F. H. Treherne and myself, described a method of generating chlorine, and of using it for sterilizing water. The article was not written for publication, and as some alterations were made in regard to the method of preparing the chlorine without my knowledge, and in consequence some confusion has arisen regarding the technique, it seems now advisable to publish fuller details, both with reference to the method and the results obtained by me.

EVOLUTION OF THE METHOD.

In September, 1912, Colonel F. H. Treherne, A.M.S., suggested to me, whilst I was in charge of the Brigade Laboratory, Bangalore, the advisability of carrying out some experiments to ascertain the value of chlorine as a water-purifying agent. As bleaching powder is unstable, and not easily obtained in India, he suggested the use of potassium chlorate and concentrated hydrochloric acid to produce chlorine, on the same lines as are used in the preparation of Burney Yeo's chlorine mixture.

Into a bottle capable of holding 30 oz. 14 grains of potassium chlorate were placed. One drachm of concentrated hydrochloric acid was then added and the bottle stoppered. When all the potassium chlorate had been decomposed by the acid the stopper of the bottle was removed and 20 oz. of water added by degrees, shaking between each addition to take the liberated chlorine into solution. A solution of chlorine of such a strength should have thus been obtained that 1 oz. added to 5 gallons of water gave 1 in 500,000 of free chlorine. But fallacies were soon found in this procedure. The potassium chlorate got scattered about the large bottle, and in consequence by no means all of it was decomposed by the acid; and when as much chlorine as possible had been liberated, a considerable amount of gas was lost at each unstopping of the large bottle when adding the water to it. In consequence the actual strength of chlorine solution finally obtained must have been considerably below that calculated.

A number of experiments were carried out with chlorine prepared in this way, and though the results were uncertain they were sufficiently encouraging for continuance of the investigation.

The obvious defects of the method having impressed me, I devised other means of producing chlorine so as to get the full value of the gas from the potassium chlorate used, and I finally settled on the method described in the *Journal of the Royal Army Medical Corps* already referred to, and have had every reason to be satisfied with it.

THE APPARATUS AND METHOD OF PREPARING CHLORINE SOLUTION.

Instead of having a large bottle full of chlorine solution and adding water, I have reversed the process by having a bottle holding 20 oz. of water and adding the chlorine in the following manner:—Two bottles are required—one, A, with a capacity of 24 oz., and another, B, with a capacity of 1 oz. The large bottle has a mark on the side indicating 20 oz.; the smaller has a mark indicating 2 drachms. The stopper of A is perforated, and two pieces of glass tubing about 0.5 cm. in diameter are passed through. One passes down almost to the bottom of the large bottle A, the other just passes through the stopper. The stopper of small bottle B has one piece of tubing let through which projects inwards for $\frac{1}{2}$ in. This small bottle is connected to the long tube in bottle A by rubber tubing.

A complete apparatus, of which this is the model, is being made for me. It consists of an unbreakable apparatus as described, an unbreakable bottle holding 24 oz. of concentrated hydrochloric acid, a small box holding 350 5-grain potassium chlorate tablets, measure

glass, and spare parts. It weighs only 12 lb., and contains sufficient material to sterilize 9,600 gallons of water without replenishing—that is, sufficient water for a battalion 1,000 strong for nine days.

Preparation of the Chlorine Solution.

Fill the large bottle A up to the 20 oz. mark with water and insert the stopper, closing the stopcock on the short tube.

Place 2 drachms of concentrated hydrochloric acid in the small bottle B, powder three 5-grain tablets of potassium chlorate (grains 15), and add the powder to the hydrochloric acid in the small bottle. At once insert the stopper. The potassium chlorate is decomposed by the HCl and Cl_2 and ClO_2 are liberated.

These gases pass along the rubber tubing, down through the long tube in bottle A, and bubbling up through the water in the large bottle, being readily soluble, go into solution. The evolution of these gases is accelerated by shaking the small bottle and warming it gently.

From time to time the stopcock on the short tube of bottle A is opened to lower the pressure. When the whole of the potassium chlorate in bottle B has been decomposed by the hydrochloric acid, its contents are poured into bottle A by unstopping both bottles. This makes certain of getting all the Cl_2 and ClO_2 liberated from the original potassium chlorate. The large bottle then contains a solution of Cl_2 and ClO_2 of such a strength that 1 oz. added to 5 gallons of water gives a dilution of 1 in 440,000.

The preparation of chlorine solution as described takes only fifteen minutes.

Chemistry of Process.

The reaction I rely on requires an excess of concentrated hydrochloric acid, and is as follows:

ClO_2 itself is a very powerful oxidizing agent and some of it is probably acted upon by the HCl, chlorine being liberated.

In all equations such as this the resulting products are seldom truly quantitative, the products coming off in somewhat different proportions according to the conditions under which the substances react, such as concentration, excess of either, temperature, etc. But the variation cannot be great.

The atomic weight of potassium chlorate is 122.56 (K = 39.1, Cl = 35.46, and O = 16).

Therefore, taking my formula as given:

$4 \text{KClO}_3 + 12 \text{HCl}$ liberates $9 \text{Cl} + 3 \text{ClO}_2$;
or $4 \times 122.56 (\text{KClO}_3) + 12 \text{HCl} = 9 \times 35.46 (\text{Cl}) + 3 \times 67.46 (\text{ClO}_2)$;
i.e., 490.24 parts of KClO_3 yield 319.14 of Cl + 202.38 of ClO_2 ;
or 490.24 parts of KClO_3 yield 521.52 parts of gas ($\text{Cl}_2 + \text{ClO}_2$).

Therefore 1 part of KClO_3 will yield $\frac{521.52}{490.24}$ parts of gas.
= 1.06 parts of gas.

1 grain of KClO_3 acted on by HCl therefore yields 1.06 grains of gas; 15 grains of KClO_3 will therefore yield 15.9 grains of gas.

In almost all of my experiments I have taken 15 grains of potassium chlorate plus 2 drachms of HCl. From the above calculations these quantities yield 15.9 grains of gas ($\text{Cl}_2 + \text{ClO}_2$), which pass into solution in 20 oz. of water in the large bottle A. As 20 oz. of water contain 8,750 grains by weight, it means that my stock solution of chlorine is 1 in 550 ($8,750 \div 15.9$). One ounce of this is added to 5 gallons of water. This equals 1 oz. to 800 oz., and as the stock solution is of a strength of 1 in 550, it follows that there is 1 of gas in 800×550 , or 1 in 440,000 of water.

In nearly all my experiments I worked with this strength of chlorine (roughly 1 in 500,000). My reason for doing so was that I found this concentration to be efficient in destroying organisms of water-borne diseases without rendering the water unpalatable, and also because I wished to standardize the whole process, so that no matter what water was being dealt with the technique would always be the same. By having a fixed strength of chlorine and a fixed period of contact, unskilled persons

can be trained to carry out the whole process, and mistakes will not be made.

The reason potassium chlorate and hydrochloric acid have been selected as the source of chlorine is that these substances are cheap, universally obtainable and not dangerous to handle.

EXPERIMENTAL RESULTS.

In all experiments recorded in this paper the technique described above has invariably been adhered to. A strength of 1 in 440,000 of chlorine has been used, and half an hour's contact allowed before making observations on the efficacy of the method. Further, I have always worked with large bulks of water, never less than 2½ gallons. From a practical point of view this seemed sounder than using small quantities.

My experiments fall roughly into two main groups: I, Observations on Bangalore tap water artificially contaminated with *B. typhosus*, *B. paratyphosus* A, and *B. cholerae*. II, Observations on "natural waters" such as would be used on service, that is, waters from open tanks, wells, etc.

A few isolated experiments regarding the reliability of the process in domestic water supplies, camps, and the preparation of mineral waters, are also given.

I. Artificially Contaminated Waters.

In all of these experiments Bangalore tap water was used. This water is of exceptionally good quality. It is pumped up from a well-protected catchment area 18 miles distant, sedimented with alum and purified by filtration through Jewell filters. It is very clear, and contains very little organic matter.

Experiment 1.

October 15th, 1912.—Five gallons of tap water were taken and contaminated by adding 10 c.cm. of 24-hours fresh broth culture of *B. typhosus*.

(a) A colony count on Drigalski-Conradi medium, after 48 hours' incubation, was made, and five tubes of MacConkey's bile salt lactose broth were inoculated with 10 c.cm. each of the contaminated water.

(b) As a control 10 oz. of the contaminated water were set aside. Half an hour later a colony count on Drigalski-Conradi, after 48 hours' incubation at 37° C. was made, and each of five tubes of MacConkey's bile salt lactose broth were inoculated with 10 c.cm. of this specimen.

(c) To the 5 gallons of contaminated water 1 oz. of chlorine solution was added and allowed half an hour's contact. At the end of half an hour Drigalski-Conradi was inoculated with 1 c.cm. of chlorinated water for purposes of making a colony count, and each of five tubes of MacConkey's bile salt lactose broth was inoculated with 10 c.cm. of specimen.

Result.

Sample.	Colony Count on Drigalski-Conradi after 48 hours at 37° C.	5 Tubes Bile Salt Lactose Broth after 48 hours at 37° C.
(a) Tap water + <i>B. typhosus</i> before adding chlorine	500 per c.cm.	+5
(b) Same, control, half-hour later	380 per c.cm.	+5
(c) Tap water + <i>B. typhosus</i> + Cl ₂ (1 in 440,000)	Sterile	-5

From this experiment it is seen that a water, highly contaminated with *B. typhosus*, after half an hour's contact with chlorine in the strength recommended, is rendered free from all typhoid organisms.

Experiment 2.

October 17th, 1912.—The above experiment was repeated in every detail except that a twenty-four hours' culture of *B. paratyphosus* A was used instead of *B. typhosus*.

Result.

Sample.	Colony Count on Drigalski-Conradi after 48 hours at 37° C.	5 Tubes Bile Salt Lactose Broth after 48 hours at 37° C.
(a) Tap water + <i>B. paratyphosus</i> A before addition of chlorine	200 per c.cm.	+5
(b) As above half-hour later ...	240 per c.cm.	+5
(c) Tap water + <i>B. paratyphosus</i> A + Cl ₂ (1 in 440,000)	Sterile	-5

This experiment shows that chlorine completely destroys the *B. paratyphosus* A in half an hour.

Experiment 3.

November 11th, 1912.—Five gallons of tap water were contaminated by adding 10 c.cm. of a twenty-four hours' growth of *B. cholerae* in peptone broth. Two pints were kept as a control. To the remainder 1 oz. of chlorine water was added and allowed half an hour's contact. At the end of this period five Durham's tubes containing peptone broth were inoculated with chlorinated water, and five others with untreated water and incubated for twenty-four hours at 37° C.

Result.

Sample.	5 Durham's Tubes containing Peptone Broth.
(a) Five gallons tap water + <i>B. cholerae</i> + Cl ₂ (after half an hour's contact)	-5
(b) Control. Tap water + <i>B. cholerae</i> ...	+5

This shows that chlorine, in the strength recommended, completely destroys *B. cholerae* in half an hour.

These are a few examples of a large series of experiments using other organisms, such as *B. coli* of Escherich, *B. dysenteriae* (Shiga), and *B. coscoroba*. The invariable result of half an hour's contact with chlorine in the strength recommended was to render the contaminated waters absolutely safe, and in most cases sterile.

II. Observations on "Natural Waters."

The waters of this series of observations were collected from wells, open tanks, and streams. They were very good samples of the kind of water that would be used by troops on service, and, as a matter of fact, many of the specimens of this series were actually collected by me for examination with a view to their being used on camps and manœuvres. There is therefore great practical value to be attached to the results of these experiments, far more than to those of the artificially-contaminated waters.

Experiment 1.

December 9th, 1912.—Water from a surface tank at the twelfth milestone, Dodballapur Road. This tank is about half a mile long by a quarter of a mile broad. It is within 200 yards of a village and surrounded by cultivation. The tank is well sunned and the water fairly clear. It had been used two days previously by the 7th Queen's Own Hussars to water their horses during a night's bivouac in its vicinity.

Result of Examination.

Before Treatment with Chlorine.			After Half an Hour's Contact with Chlorine.		
Medium.	Total Colonies per c.cm. after 48 hours at 37° C.	<i>B. coli</i> Present in c.cm.	Medium.	Total Colonies per c.cm. after 48 hours at 37° C.	<i>B. coli</i> Present in c.cm.
Agar	900	1 c.cm.	Agar	Nil	None in 50 c.cm.

This sample of water was examined in fuller detail according to Clemensha's method to determine the varieties of organisms present and classify them according to their powers of resistance to sunlight, etc., and the following interesting results were obtained by picking off ten colonies from the agar and passing them through sugars as given below.

CLASSIFICATION OF TEN COLONIES.

Source as above.

Colony Number.	Motility.	Gram Stain.	Spores.	Gelatin Liquefaction.	Indol.	Lactose.	Saccharose.	Adonit.	Dulcit.	Inulin.	Voges-Proskauer.	Organism and Group.
1.	+	-	-	+	-	+	+	-	-	-	+	<i>B. cloacae</i> IV.
2.	+	-	-	+	-	+	+	-	-	-	+	<i>B. cloacae</i> IV.
3.	+	+	-	-	+	-	-	-	-	-	-	<i>B. Grunthal</i> I.
4.	-	-	-	-	+	+	+	-	-	-	-	<i>B. coscoroba</i> IV.
5.	+	+	-	-	+	-	-	-	-	-	-	<i>B. Grunthal</i> I.
6.	+	-	-	-	+	+	-	-	+	-	-	<i>B. coli communis</i> I.
7.	-	-	-	-	-	+	+	+	-	-	+	<i>B. lactis aerogenes</i> IV.
8.	+	-	-	-	+	+	-	-	+	-	-	<i>B. coli communis</i> I.
9.	+	-	-	+	-	+	+	-	-	-	+	<i>B. cloacae</i> IV.
10.	+	-	-	+	-	+	+	-	-	-	+	<i>B. cloacae</i> IV.

There were therefore present four organisms of Group I, the least resistant type, and therefore indicating recent contamination, and six organisms of Group IV, the most resistant type. Yet after half an hour's contact with chlorine (1 in 440,000) all, including the highly resistant Group IV, of the organisms had been destroyed—an excellent testimony to the efficiency of the method I advocate for purifying infected waters.

Experiment 2.

October 28th, 1912.—Water from a well at tenth milestone, Yelahanka Road, near Bangalore. The well is a deep one, protected all round by a wall and stone lined to level of water in it. Situated on outskirts of a village and used by the villagers as their water supply. The water is clear.

EXAMINATION BEFORE CHLORINATION.

Source as above. Collected, 28-10-12. Examined, 29-10-12. Total Colonies on Agar after 48 Hours at 37° C., 700 per c.cm. Faecal Organisms present in 5 c.cm.

Colony Number.	Motility.	Gram.	Spores.	Gelatin Liquefaction.	Indol.	Lactose.	Saccharose.	Adonit.	Dulcit.	Inulin.	Voges-Proskauer.	Organism and Group.
1.	+	+	-	-	-	+	+	+	-	-	+	B. lactis aerogenes IV.
2.	+	+	-	-	-	+	+	+	-	-	+	B. lactis aerogenes IV.
3.	+	-	-	+	-	+	+	-	-	-	-	B. cloacae IV.
4.	+	+	-	-	+	+	+	-	-	-	-	B. coscoroba IV.
5.	+	+	-	-	-	+	+	+	-	-	+	B. lactis aerogenes IV.
6.	+	+	-	-	-	+	+	+	-	-	+	B. lactis aerogenes IV.
7.	+	-	-	+	-	+	+	-	-	-	-	B. cloacae IV.
8.	+	-	-	-	+	+	-	-	+	-	-	B. coli communis I.
9.	+	-	-	+	-	+	+	-	-	-	-	B. cloacae IV.
10.	+	-	-	-	+	+	-	-	+	-	-	B. coli communis I.

Group I, two colonies; Group IV, eight colonies. A fairly good water supply of its kind, but showing recent contamination. It was treated with chlorine, and examined on the same lines after half an hour's contact, with the following result:

EXAMINATION AFTER CHLORINATION.

Source, as above. Total Colonies on Agar after 48 Hours at 37° C., 4 per c.cm. Faecal Organisms, None in 50 c.cm.

Colony Number.	Motility.	Gram.	Spores.	Gelatin Liquefaction.	Indol.	Lactose.	Saccharose.	Adonit.	Dulcit.	Inulin.	Voges-Proskauer.	Organism and Group.
1.	+	-	-	+	-	+	+	-	-	-	+	B. cloacae IV.
2.	+	-	-	+	-	+	+	-	-	-	+	B. cloacae IV.
3.	+	-	-	+	-	+	+	-	-	-	+	B. cloacae IV.
4.	+	+	-	-	-	+	+	+	-	-	+	B. lactis aerogenes IV.

This experiment again shows the value of chlorine. The colony count was reduced from 700 to 4 per c.cm. Faecal organisms present in 5 c.cm. and upwards before were not found in 50 c.cm. after chlorination.

Experiment 3.

October 14th, 1914. — Source of water, the Jewell filters, Bangalore, before filtration, but after sedimentation with alum. Two pakhals, A and B, were taken, and five gallons of this water placed in each. (A pakhal is a metal receptacle for carrying water, capable of holding six gallons, which can be loaded on a mule. Each mule carries two, one on each side. Every regiment has one pair per company for camps, etc.) Pakhal A was kept as a control. To pakhal B was added 1 ounce of chlorine water. The water in both pakhals was identical except that to B chlorine had been added.

The mule was sent for a walk at 9 a.m., immediately after adding the chlorine. At 9.30 specimens were taken from both pakhals and examined.

Result of Examination.

Specimen.	Colonies on Agar.	B. coli Present.	Comments.
(a) From pakhal A (control)	660 per c.cm.	Present in 10 c.cm.	Twelve colonies examined showed Group II-9, Group IV-3.
(b) From pakhal B. Same as (a) plus chlorine	2 per c.cm.	None in 50 c.cm.	Both B. cloacae. Clemesha's Group IV.

This observation I consider of great importance, as it shows that water can be dealt with efficiently whilst troops are actually on the move. In this case the colony count was reduced from 660 per c.cm. to 2 colonies per c.cm., and though faecal organisms were found in 10 c.cm. of the control (pakhal A), none were present in 50 c.cm. of the chlorinated water after half an hour's contact.

These are a few examples of a large series of experiments which were performed to test thoroughly the efficiency of the method of sterilizing water which I have described, and they show clearly how very simple and effectual it is. In no instance did I fail to get satisfactory results.

I wish now to produce negative evidence in favour of the method advocated. Major R. Hime, R.A.M.C., writes as follows:

I am sorry the chlorine method does not seem popular in your part of the country, as I am a firm believer in the method of purifying water. I used it entirely, continuously, and solely at Camp Rajankunti for three weeks at the end of November and beginning of December last. No other method was employed; in fact, no boilers were taken out, nor was firewood issued for boiling water. The method employed for making the chlorine water was that recommended by Colonel Treherne and yourself in the *Corps Journal* some months ago.

I or my assistant surgeon made a couple of Winchester quarts of chlorine water each evening, so as to have it ready for use early the following morning.

One of the sanitary orderlies was instructed as to the quantity of chlorine water to be added to the water-carts or pakhals, and he did this at the well where they were filled up before the cart started back for camp.

Only drinking water was treated, and all carts, etc., which were used for drinking water were specially marked, and whenever they came to the wells had chlorine added.

The well was a "shallow one," within about eighty yards of a native village, and surrounded by stacks of manure, etc.

The water, after treatment, by the time it had been poured into the drinking-water receptacles had practically no smell or taste. Water used for making mineral waters was treated in the same way, and though the mineral water was very largely used in camp, I never had a single complaint from either the officers' mess (fifty officers) or men.

I had five batteries in camp for rather over three weeks and during the whole of that period I never sent one sick man to hospital, nor did any man report sick with the ordinary bowel complaints (diarrhoea, constipation, gastritis, etc.). The only people I had to deal with were those suffering from accidents. The weather was cold, raw, and damp, and one would have expected bowel complaints, but none came. I am a firm believer in the process. Simplicity, combined with efficiency and cheapness. Make what use you like of my remarks.

Colonel D. Macewen, commanding the 2nd Queen's Own Cameron Highlanders, writes as follows:

Many thanks for your letter in connexion with chlorine. We used it from Belgaum to Poona with satisfactory results, as there were only 3 cases which one could attribute to water, namely, 1 dysentery, 1 diarrhoea, and 1 stomach-ache. We drank some pretty foul-looking water too. During medical and inter-brigade manoeuvres the battalion again had it in use. There were no intestinal cases. The advantages of a sterilizer such as chlorine were most marked. . . . There is no question that the boiling of water on active service and even at manoeuvres is impracticable.

There have been no complaints as to taste. I have taken the trouble to ask repeatedly. The minerals are made with chlorinated water and are in every way satisfactory.

These two testimonies regarding the ease with which the whole process can be carried out and the very satisfactory results obtained under service conditions from an experienced medical officer and observant commanding officer should be received with the greatest respect and confidence. It seems to me that little can be added to substantiate the claim that this method of purifying water by chlorine is an advance on all previous efforts in this direction, and that it is worthy of extended trial.

No claim is advanced to regard sterilization by chlorine as a new discovery. The work of Sims Woodhead has

established chlorine as pre-eminently the best chemical means of attaining this end. He has shown that as weak a solution as 1 in 7 million of chlorine will destroy the *coli* and typhoid group of organisms.

Nasmith of Toronto has also demonstrated the very powerful germicidal powers of this gas. Dr. F. Adams of the Toronto Health Department has kindly written to me regarding the use of chlorine in water purification. He states:

Here in Toronto we use a chlorine dose up to 0.3 parts per million. To get efficiency and still avoid taste we find it necessary to vary the dose according to the season, the direction of the wind, etc. A dose from 0.15 to 0.3 is, we believe, suitable for great lakes water, such as we have here in Toronto. In Ottawa we understand they find it necessary to use a dose of chlorine more than five times as great as we use in Toronto. The Ottawa water supply is from the Ottawa River, which has its origin in swampy water. Bleaching powder is commonly used as the source of chlorine in this country.

Dr. Adams kindly enclosed a pamphlet by Dr. Nasmith describing his method of preparing and using chlorine. The following facts are there recorded:

This will give 0.4 to 0.5 part of free chlorine to a million parts of water, and in ten minutes will destroy all typhoid and colon bacilli or other dysentery-producing organisms in the water. Moreover, all traces of chlorine will rapidly disappear. This method of purification has been used with Toronto Bay water inoculated with millions of bacteria. Every dangerous germ has been destroyed, and it has been found quite unnecessary to boil the water. This method has been in use for several years, and has proved of great value to those living in summer places where water supplies are apt to be impure.

I advocate the use of chlorine in a strength of, roughly, one in half a million. This is four times as strong as Nasmith, and fourteen times as strong as Sims Woodhead recommends. I also recommend thirty minutes' contact, as against ten minutes recommended by Nasmith and twenty minutes by Woodhead. I have done this because Indian waters contain often a large excess of organic matter which absorbs a good deal of free chlorine. Experiment has shown me, however, that any water that would be selected for drinking purposes can be rendered absolutely safe by 1 part in 500,000 of chlorine with thirty minutes' contact, and so, as already pointed out, in order to standardize the whole process, no alteration is made regarding these factors to obviate errors which might otherwise arise.

Chlorine used in this strength does not give the water any objectionable taste. This has been referred to in the letters of Colonel Macewen and Major Hime, and in my own regiment I have been using this method for months, and the men, though very particular about their drinking water, have not once made any complaints on this score.

PRACTICAL APPLICATION OF THE METHOD.

The method was originally devised for use on service with troops, but it has a much wider sphere of usefulness. It can be used by troops on the march, on manoeuvres, etc., by troops in barracks, by smaller parties, such as men out shooting, by households where there is no filtered supply available, and so on. In fact there is no limit to its use.

When used by troops each battalion or independent unit should have one apparatus for every 200 men—roughly one for each double company, squadron of cavalry, or battery of artillery—with perhaps an extra outfit for head quarters.

During peace men should be trained in the method of preparing and using the chlorine, and on service trained men would thus be at once available for duties in the water section of his unit. Each water orderly would carry a complete outfit—weighing only 12 lb.—and he would then have sufficient material to give each of 200 men one gallon of drinking water a day for seven weeks without replenishing.

If the water used as the source of supply is clear, the plan adopted by Major Hime, of adding the requisite amount of chlorine at the place of filling the pakhsals or water tank, is excellent. The shaking of the water in the receptacles during transit to camp ensures thorough mixing of the chlorine with the water, and also time is saved by the period of contact being partly taken up by the time of transit. In this way the water is ready for drinking in much less than thirty minutes after it reaches the receptacles in camp.

If the water is turbid, clarifying by alum is necessary. This must be done in camp to allow sedimentation to take place, and then the requisite amount of chlorine is added to the water.

I have frequently examined samples of water treated in this way with most satisfactory results. The experiment already given of pakhsals on a mule is one of such. Another observation of a similar nature, kindly carried out by Major W. W. Browne, R.A.M.C., is as follows:

June 30th, 1914.—Source of sample, Ahmednagar water supply. This water was very turbid, being an unfiltered supply, not even clarified with alum, distributed through pipes. It is often quite muddy. My regimental "diggies" (Willesden canvas receptacles supported by a collapsible wooden framework, and for use on manoeuvres, etc., capable of holding 60 gallons each) were filled at 7 a.m. The requisite quantities of chlorine were added by a sanitary orderly, and specimens collected by him.

Report on Results.

Specimen.	Colonies on Agar per c.cm. after 48 Hours at 37° C.	Colonies on Drigalski-Conradi after 48 Hours at 37° C.
1. Tap water from "diggie" unclarified and before adding chlorine	Profuse growth	Profuse growth.
2. Tap water from "diggie" after being clarified with alum, but before adding chlorine	Profuse growth	Profuse growth.
3. Tap water from "diggie" not clarified with alum, but treated with chlorine and allowed 30 minutes' contact	Profuse growth	Sterile.
4. Tap water from "diggie" after clarification with alum, and then treated with chlorine and allowed 30 minutes' contact	Sterile	Sterile.

The chlorine used in these experiments was prepared the previous evening by my subassistant-surgeon, and used in the strength recommended, 1 in 440,000. From this experiment it is seen that by sedimenting and chlorinating the water complete sterilization resulted.

Domestic Supplies.

The method of purification is eminently suited for domestic water supplies where filtered water is not available. I have used it for many months in my own bungalow in Ahmednagar in the following way:

I had two tanks made of tin capable of holding five gallons each. One is placed on a shelf on the wall, and the second on a table immediately below (see diagram). Each tank has a tap 2 in. from the bottom. Both have closely fitting removable lids.

The upper tank is filled the last thing at night and alum added as required. During the night sedimentation takes place, all the sediment falling below the level of the tap. In the morning the lid of the lower tank is taken off, and the clarified water from the upper tank is run into it. The requisite amount of chlorine is then added to the lower tank, the lid replaced, and in half an hour the water is ready for use.

The water from the lower tank is beautifully clear and sparkling, and, though frequently examined, it has always been bacteriologically above reproach.

Mineral water factories can similarly be supplied with a safe water. Boiling, the almost universal practice in India, is extremely difficult to carry out on a large scale, and as it is not uncommon for factories to require 200 gallons of water daily, even though the water be boiled it is almost as difficult to cool it again rapidly enough for use. If the water is not cool the gases cannot be forced into solution in sufficient quantities, and the mineral, therefore, is very flat. By using chlorine, in place of boiling, all these difficulties are solved. In my own regimental factory the chlorine method has been in use for many months with complete success.

Fig. 2.—A, Lid; B, sedimentary tank; C, shelf; D, chlorinating tank; E, table.

The following is the report of Major Browne, R.A.M.C. kindly made for me on one occasion:

MAY 8TH, 1914.

Specimen.	Colonies per c.cm. on Agar after 48 Hours at 37° C.	Colonies per c.cm. on Drigalski-Conradi after 48 Hours at 37° C.
1. Ahmednagar tap water ...	Profuse	Profuse
2. Tap water + alum + chlorine	Scanty	Sterile
3. Soda water made from (2) ...	Scanty	Sterile

This shows how reliable the method is, and it is perfectly simply carried out. In this case the whole process was left to a sepoy trained to carry it out.

Cost of Process.

To be generally used the method must not only be reliable, but also cheap. This requirement is fulfilled by my method.

To supply a battalion of 1,000 men with one gallon a head a day for a month of thirty days will require 900 (say 1,000) 5-grain tablets of potassium chlorate and 5 pounds of concentrated hydrochloric acid. The tablets can be purchased at Rs.1.8 (2s.) a 1,000 and acid at 8 annas (8d.) a pound. The total cost per month, therefore, for 1,000 men at a gallon a head is only Rs.4 (5s. 4d.).

The cost of boiling water is infinitely more. Soldiers are allowed four-fifths of a pound of wood a head a day for boiling drinking water. For 1,000 men this comes to 800 lb. (equals 10 maunds) a day, or 300 maunds a month. The cost of wood is 10 annas (10d.) a maund, so that the cost of boiling water comes to Rs.187.8 (£12 10s.) as against Rs.4 (5s. 4d.) for chlorine. Comment is unnecessary.

Conclusions.

Much more could be written regarding the process, its efficiency, and the ease with which it can be carried out. And there are many side questions I have not touched on. But I think I have produced sufficient evidence to warrant the method receiving a fair trial. And I am sanguine enough to believe that it will not be found wanting. I advance it as a substitute for boiling of water, being quicker, more easily carried out, and as reliable. The apparatus is small, and its adoption, especially for use by troops, should diminish the long-standing difficulty of getting safe water for men to drink without keeping them waiting unnecessarily long for it.

NOTE.

Since writing this article I have had the method in constant use by my own regiment on service for over four months. The waters used have been very bad in every way. Storage difficulties have been very great, yet out of a strength of 800 men and followers I have during this period only had to send eight men to hospital with intestinal complaints, only one of whom has had to be invalided to India. I have no figures regarding other regiments of our force, but understand they are not so good as mine. The method, with improvised outfits, is now being extended by use by all other units.

AMONG the French medical periodicals which have come to life again after temporary suspension mention should have been made of the *Archives des Maladies du Cœur, des Vaisseaux et du Sang*, published under the direction of Dr. H. Vaquez, *professeur agrégé* at the Paris Medical Faculty, and physician to the Saint-Antoine Hospital. This valuable journal began to appear again in January, and we regret the oversight which led to its omission from the list of resuscitated periodicals.

DR. FLAISSIÈRES, Senator for the Bouches-du-Rhône, although he is 64 years of age, is on active service with the French army as *médecin-major* of the first class. He has recently been mentioned in the Order of the day by the general commanding the 96th Division for having continued to give his professional services to the wounded in his regiment on the occasion of the bombardment of a village. Dr. Flaissières, though himself suffering from illness, superintended their transfer to the ambulance, and did not leave his station till every man had been dressed and he had made his report.

A Clinical Lecture ON BIRTH PALSY.*

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BIRTH palsy or obstetrical palsy is by no means a rare condition. It has been said to occur once in every two thousand births (Frauenthal¹), an estimate of frequency which is in all probability rather too low. It will be the fate of a goodly proportion of practitioners to encounter this condition at least once during their professional careers. From the point of view of the general practitioner birth palsy is of special importance, as in the majority of instances the parents of the child are prone to bestow undeserved blame on the doctor who conducted the labour.

For some time it has been held by most authorities that the lesion present in birth palsy is an injury to the brachial plexus in the neck; this occurs during delivery as a result of traction applied to the head with the shoulder fixed, or vice versa. The German school of orthopaedic surgeons, most notably Lange² and Vulpinus,³ consider that a primary shoulder-joint or bone lesion is present, paralysis being either absent or of secondary importance. This view was originally propounded by Küster in 1889, who described the condition as a rotatory displacement of the upper humeral epiphysis.

Last year Turner Thomas,⁴ of Philadelphia, brought forward new evidence in favour of the shoulder-joint lesion theory.

Certain etiological factors are well established and accepted by all. In the vast majority of cases birth palsy is seen in an infant born after a prolonged and difficult labour in which there was a disproportion between the size of the child and the maternal pelvis.

Statistics available show that the injury occurs more frequently in vertex than in breech presentations, but the exact relative proportions remain to be settled in the future from a large series of cases.

There are, then, two opposing theories to explain the etiology of birth palsy:

1. Primary paralysis, due to stretching or tearing of the brachial plexus.
2. Primary joint or bone lesion, with or without secondary paralytic phenomena.

SYMPTOMS AND SIGNS.

Following a difficult labour in which instruments may or may not have been employed, it is noticed that one arm of the infant hangs limp and motionless. The position of the affected limb is characteristic, the arm hanging close by the side in full internal rotation at the shoulder, with the elbow extended, the forearm pronated, the fingers flexed, and in some cases obvious wrist-drop. For a few days the neck and shoulder may be tender, the infant resisting all efforts of examination and manipulation of the limb; usually no actual bruising or other superficial local signs of trauma are seen. If untreated, the subsequent progress of the case may be along one of three lines:

1. Rapid and complete spontaneous recovery may ensue, leaving the limb in a practically normal state.
2. There may be complete absence of recovery with persistence of a flail limb. This is a rare sequel.
3. Considerable recovery may take place, but in an incomplete manner, leaving a residual paralysis.

This latter event is the one usually seen, so that after some weeks the arm is no longer limp but is used by the child with fair power. As time goes on in all moderate and severe cases there is an evident lack of growth in the whole limb and shoulder girdle.

Invariably in this type of case with incomplete recovery,

* The substance of a post-graduate lecture delivered at the Ancoats Hospital, January 26th, 1915.