PURIFICATION OF WATER ON A SMALL SCALE

BY

Major H. J. ANDERSON

Royal Army Medical Corps

THIS rather brief title refers mainly to the purification of water by the individual for his own personal consumption. In these days of extensive public supplies, and national water policies, it is obvious that such a method of purification has certainly very limited uses, and that the problem is therefore confined almost entirely to the Services.

As large-scale purification plants have developed due to the increasing tendency of the population to gather together in large cities, so, as the speed of travel increases and the range and mobility of activity of our fighting forces becomes more extensive, must improvements at the individual level continue to be sought.

The realization that purification of water, for drinking purposes for any community, was essential, came towards the end of last century. It is interesting, at the commencement, to see how the supply of water has developed, to trace the knowledge so acquired from the consequent lessening of disease in large communities to its application to smaller groups of mobile forces, and thence to the individual thrown on his own resources, frequently in extremely difficult circumstances. For, as the fear of disease has in the past forced Governments into action, so a Commander in the Field, equally fearing disease as he realizes it can destroy his forces more effectively than any enemy, demands similar protection for his men.

HISTORICAL SUMMARY OF GROWTH OF WATER SUPPLIES

Water is our greatest necessity—water in plenty for drinking, cooking, washing and bathing. As the world developed, each house or cottage had its own water supply, or houses were sited in groups on rivers or lakes so that their demands might be satisfied. Later the need for a communal supply developed as towns grew, until today we find an organization like the London Metropolitan Water Board supplying one-sixth to one-fifth of the population of England and Wales.

The Romans were our first great water undertakers and their aqueducts were a triumph of engineering in many parts of the world. In 1447 we find Hull was granted a Royal Charter by King Henry VI to construct a public water undertaking. A century later in 1585 Sir Francis Drake was instrumental in obtaining Plymouth's first Water Act, and in 1590 he obtained the contract for the works from the Corporation. In 1613 Sir Hugh Myddleton completed London's New River project with the help of funds provided by King James I.

It was not until the nineteenth century that water supplies and disease

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became associated. In his surveys for his famous report in 1842 on the sanitary conditions of the Labouring Population of Great Britain, Edwin Chadwick not only noted how badly the greater part of the population were supplied with water, but that what water there was was grossly contaminated by lack of proper drainage and sewage, causing untold illness, debilitation and deaths. These facts were confirmed in the reports for the Health of Towns Commission. Smellie, in his History of Local Government, tells us that in 1850 taste was still the method used by inspectors to test the purity of a water supply. However the association of disease with faulty or contaminated water supplies was gaining ground and opinions expressed by doctors were beginning to receive attention.

Dr. William Budd, in 1849, stated that the cause of cholera was an organism of distinct species, passed in air, food and principally water. Again, in 1873, in his classical "Typhoid Fever," he maintained that typhoid was conveyed by water, that it was a contagious disease, and that the most virulent part of the disease was conveyed in the discharges of the patient ill with fever.

Dr. John Snow in his investigation of the cholera epidemic of 1854 in the city of London, proved that the disease was conveyed by water obtained from a pump in Broad Street, which had been contaminated by cholera cases in the neighbourhood. A third, Dr. Michael Taylor of Penrith, traced typhoid, scarlet fever and diphtheria to milk. It is astounding to realize that these conclusions were made in the days before the bacterial theory of disease was propounded.

Fear made the Government take action. Sir John Simon was appointed medical officer to the newly constituted Board of Health, and in panic the Sanitary Act of 1866 was passed. As Sir John Simon puts it, "the imperative mood" was adopted in legislation. From this date a duty was placed on Local Authorities to seek out and suppress nuisances.

Progress now became more rapid. The science of bacteriology was developing. Waters that previously had been regarded as eminently suitable were now no longer regarded as safe for human consumption as pathogenic organisms were discovered in them. Taste and appearance, while desirable in every way, could now no longer be regarded as sufficient criteria for the suitability of a water for domestic purposes. Other essentials became obvious. The source of a supply must be free from all contamination and the carriage and distribution must allow of no contamination. (This first point is still being stressed by Sir William Jameson in his annual reports.)

Position at the End of Last Century

We come now to our term purification. Human undertakings always have an element of error. A perfect source is not always obtainable. Rain and floods cause an increase of mud and other organic particles and, in spite of all precautions, dangerous organisms may gain access to our carefully protected water. An additional precaution was obviously required and so the process known as Purification was introduced at the close of the last century.

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Two main principles are the basis of this—clarification and sterilization. The first removes the larger particles of organic matter and the latter destroys harmful organisms. In practice a water is considered sterile if a sample of 100 millilitres is free from *B. coli*.

To develop the subject of this dissertation I must turn now from purification in general to a much more particular side, from purification for large groups under static conditions to purification for small mobile groups.

The problem of providing a safe water supply for men in the Field was realized at an early date by the Army. The provision of a pure supply for garrisons and static camps differs in no way from that of a town, but men on the march and under active service conditions present a very different problem. The difficulty of careful selection of a source is considerably increased due to both the shortage of time available, and the understandable desire of any enemy to attempt to deny an advancing column the most suitable sources in the vicinity.

Confusion was increased at this time by differences of opinion of two schools of thought. One held that all water in the Field must be considered dangerous to drink unless it was first purified and the other maintained that water was only dangerous after recent specific contamination.

Brigadier G. S. Parkinson, *C.B.E.*, *D.S.O.*, who served in the South African campaign, recounts comparative absence of facilities for the purification of water supplies.

From a study of the papers available one comes to the conclusion at the time of the South African campaign that purification for mobile Army units was considered rather from the point of view of units on the march. The smallest unit considered capable of purifying water was half a battalion.

The reason for this was the fact that the process of purification was only considered in terms of scaling down larger static plants. Clarification was produced by pumping water through compressed sponge filters and sterilization by passing this water through filter candles of Berkenfeldt and Pasteur Chamberlain patterns. These principles were combined in a water-cart holding 110 gallons. The tank held water after it was clarified by the sponges, and this was not pumped through the candles until the time of actual delivery. This 110 gallons would replenish the water bottles of 440 men if there was no wastage.

Men separated from their water-cart, a highly probable contingency under Service conditions, were thrown back on their water bottles, filled the previous night. The only step taken towards individual purification was a recommendation to boil all drinking water. Boiling requires fuel, dry matches, takes time, leaves the water too hot to drink and perhaps worst of all causes smoke and flame which give away the position to the enemy.

The large number of cases of enteric fever which occurred in this campaign—57,000 cases with 8,000 deaths and an incidence of 100 per 1,000 per annum—indicates the inadequacy of means of obtaining pure water under all conditions.

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South African Campaign to World War I

Many now realize that, in the South African campaign, our methods of supplying drinking water in the Field were inadequate and attention was being paid for the first time to individual methods.

Vaillard in 1902 published a method of purifying small quantities of water for drinking by means of iodine. In his method iodine was liberated in the free state by the interaction of sodium iodate with tartaric acid and then dissolved in an excess of potassium iodide. Vaillard claimed sterilization in ten minutes and the treated water was of normal appearance with no smell or taste. Nesfield, in India, evolved a similar process at about the same time. He had experimented during the South African War with peroxides, nascent hydrogen, sulphuric acid, hydrochloric acid, phosphoric acid, and finally with nascent chlorine. For small quantities of water he experimented with hypochlorite of lime compounded with bicarbonate of soda to form a tablet. This was found too unsatisfactory on account of the instability of the hypochlorite of lime. He then turned to iodine which has a very stable iodide and iodate which readily split into free iodine in the presence of weak acids.

Three tablets were employed, the first containing sodium iodate, and potassium iodide coloured with methylene-blue, the second tartaric acid with a red colouring matter, and the third sodium hyposulphite. Iodine is liberated from the sodium iodate by the tartaric acid and the water is exposed to its action for ten minutes, at the end of this time the sodium hyposulphite is added which exactly combines with the free iodine.

The results were good, but the procedure, simple as it may seem, is rather too complicated for Service conditions. It is obvious that if the tablets were to be used in the wrong order the only result would be a false sense of security which might prove disastrous.

The decade following the South African War was largely spent in trying to perfect physical methods such as heat exchange, and improving filtration methods. Chemical methods of purifying water were regarded by many as visionary, impracticable and incompatible with hostile activities.

Nesfield, however, proceeded with his investigations, and when he accompanied the Tibet expedition in 1904 iodine was used for the purification of the drinking water required. A cholera epidemic was raging in North Bengal at the time but the expedition took 760 Kashmir coolies through the Teesta Valley without the occurrence of a single case of cholera. Other batches of coolies during the same period had deaths from cholera ranging from 2 to 10 per cent of their number. The quantity of iodine used by Nesfield was ½ grain per gallon.

Investigations were also being carried out at the Royal Army Medical College, and at the Army School of Sanitation under Lt.-Col. R. H. Firth and it is interesting to record a demonstration of processes devised for sterilizing drinking water on Field Service given at Millbank Barracks, London on February 10, 1905. Chemical methods featured largely as well as those by filtration and heat.

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(1) *Chemical.*—(i) *Bromine:* Schumberg's process devised by Surgeon-General Schumberg of the United States Army. Bromine solution (contained in glass capsules, each holding 2 c.c. = 6 grammes of free bromine, sufficient for 1 litre of water) was added to the water to be sterilized. After standing seven to thirty minutes the bromine was neutralized by adding a mixture of sodium sulphate and sodium carbonate. In about two minutes the odour of the bromine disappeared but a slight stale taste remained.

(ii) *Iodine:* This has already been described. After treatment the water had no smell and was not altered in appearance, while it was difficult to distinguish any difference in taste between natural water and the water thus treated.

(iii) *Chlorine:* The water was treated with bleaching powder and bicarbonate of soda. At the end of ten minutes the free chlorine was neutralized by the addition of sodium sulphite. It was, however, difficult to get rid of the smell and taste of chlorine.

(iv) *Bisulphate of Soda:* First employed by Dr. Samuel Rideal who claimed that 15 grains of bisulphate of soda would sterilize 1 pint of water. An acid taste was imparted to the water, but all the acid could be neutralized by the addition of bicarbonate of soda. A further objection was that the treated water had been found to take up iron from the water bottles.

(v) *Permanganate of Potassium:* Recommended by Dr. Hankin in India. This was added to the water until a faint pink colour becomes permanent. This process was in extensive use in India, but was objected to by the men, partly on account of the colour, and partly because of the slight taste imparted to the water.

(vi) *Copper Sulphate:* This process was still in the experimental stage. The experiments of Dr. George Moore, of the Scientific Staff of the United States Government, appeared to indicate that a solution of copper sulphate, of a strength 1 : 100,000, killed both typhoid and cholera germs at laboratory temperature. From Rideal and Baines' experiments in this country it would appear, however, that 1 : 1,000 copper sulphate killed typhoid and coli in one hour; 1 : 10,000 killed typhoid but not coli; and 1 : 100,000 was ineffective. A solution of copper sulphate 1 : 100,000 was tasteless and colourless; and after it had been allowed to stand no trace of copper could be detected in the water. More interesting still were the experiments which go to show that water kept in a copper vessel was freed from *Bacillus coli* or *Bacillus typhosus* in twenty-four hours. It was thought that, should the experiments be confirmed, their practical application to the wants of the soldier was obvious, and that we had in view a comparatively simple solution of what had hitherto proved a most difficult problem.

(vii) *Alum:* In the proportion of 6 grains to the gallon, alum had long been employed for the purpose of clearing water containing much suspended matter, but, in addition to purifying water by expediting sedimentation, the alum is also germicidal in action.

The following opinion was also expressed. Chemical processes, generally

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speaking, are no doubt germicidally effective, but there are many difficulties in the way of their being universally practicable. The processes are largely such as could hardly be entrusted to the individual soldier to carry out; and the time required for sterilization would be a great bar, when a man is parched with thirst, however well disciplined he may be on other occasions; while there is also widespread objection among the men to drinking "doctored water."

(2) *Filtration.*—Various patterns of Field Service filters were on view, illustrating its evolution and showing recent improvements. The earliest pattern consisted of a single candle filter in a metal cylinder, mounted on a tripod, with a semi-rotary pump and air vessel. There was no means for preliminary clarification of the water to be filtered, and in consequence the candles became quickly clogged, and the filter soon became unusable. A special clarifying chamber was added, in which cloth straining bags were placed, so that the water was cleared of matter in suspension before it passed to the chamber containing the filter candle. The next important variation was to encase the filter candle in straining bags. This permitted a second candle being placed in the clarifying cylinder, thus doubling the filtering surface without increasing the weight of the filter.

The yield at trials had been 30 to 40 gallons per hour. The yield varied, of course, according to the amount of suspended matter in the water being dealt with.

In the Service water-cart, fitted with Slack and Brownlow filters, the tank of the cart was filled direct from stream or source of supply and no water could be drawn from the cart until it had been passed through the filters.

(3) *Sterilization by Heat.*—Four varieties of heat exchange apparatus were shown.

Dewar, in 1907, in a paper Sanitation of Armies, in the Field on Active Service, stated: "No reagent has been discovered which fulfils all the requirements, namely, rapid action as a disinfectant, moderate cost, convenience in use, portability, stability of composition and the leaving of the treated water in such a condition that it is neither unwholesome nor unpalatable." He gave a list of compounds, all of which except one, namely brandy and wine, have already been discussed. These, he said, were slow and unreliable. I find it hard to believe he thought the soldier would load himself with brandy or wine for the sole purpose of purifying suspicious drinking water.

About 1908 it began to be realized that any purification apparatus for Field Service use which depended for its efficiency on earthenware candle would not service the strain. Attention was again directed to the sterilization of water by chemicals, after preliminary clarification. After numerous experiments in the Royal Army Medical College on the sterilization of clarified water by means of active chlorine from chloride of lime, it was ascertained that most well-clarified waters could be rendered innocuous by 1 part of active chlorine per 1,000,000 acting for a minimum period of half an hour. Professor G. Sims Woodhead read a Paper in Cambridge on July 16, 1910, stating that

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even large numbers of *B. coli* were rendered inactive by 1 part of free chlorine in 2,000,000 parts of water.

At the same time Colonel Horrocks, later Sir William Horrocks, experimenting with water from Regent's Park Canal and Hampstead ponds came to the conclusion that the main reasons why chlorine had fallen into disfavour were:

(*a*) That attempts had been made to chlorinate imperfectly clarified water.

(*b*) In many experiments pathogenic and other bacteria were added in large quantities, and the time of contact had been too short (five to ten minutes), which necessitated large doses of the chemical followed by subsequent treatment to remove the taste.

The earliest work in chlorination had been by German and Austrian medical officers (Traube in 1893, Bassenge in 1895, and Lode in 1895). Lode had discovered the important fact that the amount of chlorine required varied directly with the amount of organic matter present.

Horrocks now turned his attention to the clarification as an essential preliminary to sterilization, as the standard sponge clarifiers were inefficient and failed to prevent rapid blocking of the filter candles. He devised the well-known clarifying cylinder which was used successfully through World War I and in some theatres in World War II.

The cylinder contained a cylindrical reel round which several layers of flannelette were wrapped. Alum was placed in the inlet box; the alum water passed to the outer side of the reel, and a layer of coagulated suspended material was gradually formed on the surface of the flannelette which then acted as an efficient clarifier.

For small detachments a portable "Box clarifier" was designed which consisted of a clarifying cylinder with hose and pumps packed in a special box for issue to small units and messes. Its total weight including the wooden case was 150 lb.

It was hoped to have a Field test in the summer of 1914 but this was prevented by the war.

World War—1914 to 1918

In August 1914 it was evident from a survey in Belgium and North-East France that the water in many cases would require clarification and in all cases sterilization. On Colonel Horrock's advice all M.O.s were instructed to use chloride of lime. Suspended matter was first to be removed by alum, 3 grains to the gallon was advised, and the clear water sterilized by the addition of 23 grains of chloride of lime. 4-ounce tins with a spoon holding 23 grains were issued to all units.

The fear that filter candles would not stand up to Service conditions was soon confirmed. In the first week in November 1914 the Army Sanitary Committee visited France and made a careful examination of water-carts in the front-line divisions. They found that all carts depending on filter candles for the sterilization of water had broken down.

By this time it was realized that organic matter in water which had managed

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to pass the filters took up the chlorine before it could kill any bacteria present. It was evident that some simple process by which M.O.s could determine the amount of chloride of lime required to render each water supply safe would be a great help. This help was soon given.

Professor G. Sims Woodhead of Cambridge, published a Paper on September 19, 1914, on the sterilization of water supplies for troops on Active Service. In this paper he stated: "I satisfied myself that if particulate matter could be removed from a water by means of any of the ordinary filters it was possible to render even a highly polluted water perfectly safe for drinking purposes by the addition of appropriate amounts of chlorine, and that these appropriate amounts could be determined by the starch and iodine test." He devised a simple test which when slightly modified by Colonel Horrocks was admirably suited for Field Service. The Horrocks Box, almost in its original form, is still in use in the British Army and has no rival for the purpose for which it was designed.

An analysis at the Royal Army Medical College of the contents of tins of chloride of lime showed that on an average the available chlorine in each tin was 33 per cent.

Horrocks and Woodhead showed when an emulsion of 2 grammes of this powder in 250 c.c. of water was made, that 1/15 c.c. of this emulsion when added to 187 c.c. of water liberated 1 part per million of free chlorine.

They also demonstrated that 2 grammes of this chloride of lime, when added to 110 gallons of water, the capacity of a water-cart, produced approximately the same amount of free chlorine.

Based on these facts the Field Test Case devised by Horrocks contained a standard scoop holding exactly 2 grammes of powder, one cup holding 250 c.c. for the emulsion and six cups each holding 187 c.c. for the estimation of the absorption of chlorine. Pipettes were included which, when held vertically, delivered exactly 1/15 c.c. of the emulsion. A bottle of starch iodine indicator solution comprised the complete box.

Small parties of men could now be guaranteed pure water from any source. Unfortunately the apparatus required was much too heavy unless some form of transport was available consisting as it did of a clarifier, a pump, two canvas tanks, a test box, a supply of alum and a stable chloride of lime. The total weight was about 200 lb.

It was decided also, in August 1914, to issue tablets of acid sodium sulphate (Rideal and Parkes, 1901) for small parties of cavalry, who it was thought might easily get separated from their units. Each tablet contained 16 grains of anhydrous sodium bisulphate and $\frac{1}{4}$ minim of oil of lemon. They were issued for emergency use only as they had several drawbacks. Being a powerful metal solvent they acted on water bottles made of enamelled iron if they were chipped forming ferrous sulphate which has a bad taste and colours the water. A very objectionable taste occurred on prolonged contact with aluminium, and if exposed to a moist atmosphere acid was liberated which burnt both clothing and skin.

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Soldiers were instructed to dissolve one tablet in each half-pint of water used and to allow the water to stand half an hour before drinking. Half an hour is too long to expect parched men in advanced positions to wait.

Just as things seemed to be nicely settled, Nesfield, this time in Mesopotamia, reported in June 1916 that chloride of lime was unreliable as it was completely unstable in hot climates. He maintained that the only possible chlorine compound was sodium hypochlorite which kept its potency for twelve months or more in India. This difficulty was not overcome until 1918 when Nettie, Smith and Richie discovered that the addition of quicklime to bleaching powder considerably improved its keeping qualities and, after further investigations by Aumonier and Elliott, a mixture of four-fifths bleaching powder and one-fifth quicklime was adopted by the British Army under the name of water sterilizing powder.

This mixture reduces the amount of available chlorine slightly but its keeping qualities are so improved that it should not fall below 22·5 per cent in one year.

Trouble also came from another quarter. The number of cases of schistosomiasis in Egypt and Palestine was causing great concern. Prevention was difficult as little was known of this most debilitating disease, so a mission was sent to Egypt in February 1915 under Dr. R. T. Leiper, assisted by Dr. R. P. Cockin and Dr. J. G. Thompson. They returned to England in July 1915, having established the definite life-history of the parasite and shown that storage of screened water—screening 16 meshes to the linear inch—for forty-eight hours was an effective precaution. This was very satisfactory but unfortunately their investigation showed that chlorination as ordinarily practised for drinking water did not suffice to destroy the cercariæ which might even pass through the filters. In a solution containing 1 part available chlorine in 100,000 they were alive and active after one and a half hours. Sodium bisulphate 1 : 1,000 killed them almost immediately.

In May 1917 a further advance came. W. H. D. Dakin and Major E. K. Dunham of the U.S. Army Medical Service after experimenting with several compounds came to the conclusion that p-sulphondichloramino benzoic acid, or Halazen, was the most suitable for individual use. A concentration of 1 : 300,000 was sufficient to sterilize heavily contaminated water in thirty minutes. It was more stable than chloramine T and when kept in amber bottles under ordinary conditions no decomposition was noted in two months. When exposed to bright sunlight in clear glass bottles decomposition occurred.

Toluene-sulphondichloramines were found to be unsuitable due to the fact that in the tablet form they were almost insoluble and that the rate of decomposition increased rapidly when mixed with sodium chloride to form tablets.

Halazen tablets were issued for the sterilization of small quantities of water such as are needed by cavalry. The reports as to the sterilizing action were on the whole favourable, but some doubts were expressed as to its maintaining its efficiency under Active Service conditions, especially in the tropics.

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1918 Onwards

No further advances were made until Harold began developing the process of chloramination. This, however, is suitable for large-scale purification and apart from mentioning the ingenious mobile water purifier devised by Elliott which is capable of filtering and purifying 3,000 gallons per hour using ammonium sulphate and chlorine generated by electrolysis from brine, further description does not come within the scope of this paper. The whole apparatus is mounted on a 30 cwt. chassis. It is, therefore, mobile but restricted by its weight to tracks negotiable by heavy transport.

In summing up the position in 1923 Lt.-Col. J. A. Anderson calls attention to the fact that apart from the tablets of sodium bisulphate of Rideal and Parkes which have many disadvantages, no standard arrangements for small detached parties existed. Lelean had devised a method of adding chlorine to water bottles and small water containers like pakhals. It was ingenious but, again, although it was adaptable for small parties, it required time and at least one member of the party skilled in using the Horrocks Test Box. The number of scoopfuls of W.S.P. required to leave one part per million of the free chlorine in 100 gallons must first be determined by using the Horrocks Box. This amount is added to the contents of one water bottle to form a strong solution; one scoopful of this solution when added to another water bottle will give a solution containing one part of free chlorine per million. It is an excellent method and I have had many an occasion to use it when out on a column, but it is not suitable for individual use.

One of the objections to chlorination is the taste remaining in the water after treatment. This may be chlorinous or one described as a "chemist's shop" taste due to the formation of iodoform if any phenols are present in the water. It was discovered in 1938 by Mackenzie that this taste could be got rid of by over-chlorinating followed by the removal of the excess chlorine by the addition of sodium thiosulphate. This is known as superchlorination.

Its advantages over simple chlorination are many. The contact time is lessened from thirty minutes to fifteen minutes. The deviation of chlorine by any organic matter is of the less importance. Underdosing is less liable to occur. All taste of chlorine is removed immediately on adding the thiosulphate and any phenol taste is removed.

To superchlorinate, W.S.P. is added in sufficient doses to give 2 parts of free chlorine per million after deviation by organic matter has taken place. The Horrocks Test indicates the amount necessary to give 1 part per million; consequently to give 2 parts per million one extra scoop will be required per 100 gallons.

This amount of free chlorine will kill all pathogenic organisms in fifteen minutes or less.

Dechlorination is carried out by the addition of sodium thiosulphate at the end of fifteen minutes—1 gramme per 100 gallons. The anhydrous salt which contains half of its water of crystallization is used as it is very stable. The

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crystalline salt melts at a temperature of 118° F. and would be useless in the tropics.

Using this method Colonel E. F. W. Mackenzie developed a modification of Lelean's water-bottle method where no Horrocks Box is available. He decided on a fixed dose of 4 parts per million and advocated a period of thirty minutes' contact followed by dechlorination. Using this massive dose there is no need to allow for compensation for loss of chlorine due either to excessive deviation or deterioration of the W.S.P. The long contact time of thirty minutes was designed to allow penetration of particulate matter where filtration had been impracticable. Colonel Mackenzie shows that his test was evolved from practical experience by adding that it is highly improbable that thirsty men will wait the full time. This heavy dose, he claims, will, in five minutes, purify a grossly polluted water under severe conditions of temperature and pH values.

Following these lines, the halazone method of individual purification introduced by Dakin and Dunham was developed. The underlying principle again being superchlorination to a high degree followed by dechlorination. Being an individual method no Horrocks Test would be available and therefore no estimate of the amount of chlorine necessary for sterilization could be made.

A compact outfit was made consisting of a tin box, 2 in. by 2 in. by $\frac{3}{4}$ in., containing two small bottles. The first holds the sterilizing tablets each containing 3 grains of a mixture of halazone 7·5 per cent, anhydrous sodium carbonate 10·5 per cent, and anhydrous sodium chloride 82 per cent. They are white in colour and stable under hot dry climates but deteriorate rapidly when exposed to a humid atmosphere. One tablet liberates 4 to 7 parts per million of free chlorine in a water bottle of water. The second contains the dechlorinating tablets each containing $1\frac{1}{2}$ grains of a mixture of sodium chloride 85 per cent, and anhydrous sodium thiosulphate 15 per cent. These tablets are blue in colour. Directions for use are printed inside the lid of the box. The bottles have cork stoppers, not composition corks which disintegrate, and they are sealed with plastic wax which sticks to glass and metal.

These individual outfits were issued freely during the last war. They are, however, not ideal. The chief fault is that the white or chlorinating tablet is extremely difficult to dissolve unless it is crushed against the neck of the water bottle first. This is much easier said than done, as the present water bottle has a very narrow neck and the tablet either slips into the bottle intact and refuses to dissolve, or shoots behind the now desperately thirsty individual into the jungle and is lost for ever. Having accomplished this tricky manœuvre and waited patiently for the prescribed time of fifteen minutes, another trial awaits our now dehydrated soldier. He uncorks his bottle of blue tablets, to detaste, and attempts to shake one into his hand. Nothing happens. He inserts a twig to loosen one, and a sticky mass of indeterminate amount emerges attached to its tip. Two things may now happen, one, the twig and blue mass are inserted into the water bottle and if the stick is contaminated

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so also is the resultant water, the other, twig and bottle containing the blue mass are thrown away and the strong chlorine solution consumed, with no ill-effects except that the soldier will probably never use the white tablets again. In a few days the tin and bottle of white pills will follow its blue companion into the jungle.

These comments may seem rather harsh, for on the whole the halazone method of individual purification gives good results under most conditions, but in battle for superiority, like many other excellent pieces of Service equipment, tropical jungle comes out the winner.

During the inter-war period experiments were carried out to improve the portable clarifying apparatus. The cloth reel filter designed by Horrocks was efficient provided it received careful maintenance. This included scrubbing and washing of the special cloth for the reel. Considering how sheets are returned from modern laundries, it was amazing how long clothes lasted, but sooner or later a hole would appear which might render the filter useless unless a spare cloth were available. A second point was at the joining of the spigot at the end of the reel which was made watertight by a rubber ring. Any leakage at this point and unclarified water passed directly into the tank. Lastly if the water concerned was very full of sediment the cloth might become so heavily coated that it would be impossible to force more water through it. This meant dismantling and cleaning the filter before it could be used again.

The result of much research was the design of compact pressure filters of two types, the Meta and Stellar, which differ in construction only slightly.

Each filter consists of a cylindrical metal chamber surmounted by a movable metal head to which is fixed a "core" composed of a number of flat non-corroding metal rings and washers, slightly embossed on one side, which are strung over a fluted rod and secured by pressure from the ends. The rings are of two sizes, every sixth ring being larger than its neighbours; these serve to support the filter bed and a wire gauze sleeve. The space between the rings is 1/3,000th inch.

The Stellar filter has a core of monel wire wound round a brass former. The space again between the spirals of the wire is 1/3,000th inch.

The filter medium consists of a charge of specially prepared Kieselguhr coated with silver and mixed with aluminium hydrate. This forms a bed over the whole surface of the core on pumping. Water passing through it is rendered free from suspended matter and substantially free from bacteria. Both cysts of *Entamœba hystolytica* and cercariæ are retained by the filter.

After use for some time the filter may clog. This can be freed immediately by back flushing and then reforming the bed in the usual way.

The filters are mounted in pairs on the water-cart so that one can be used to clean the other. Each filter head holds four cores or six to increase the speed of filtering. The candles have a filtering area of one square foot and, combined, have a capacity for dealing with 200 gallons of water per hour.

A portable filter for use with detached parties has also been designed. This has a capacity of 100 gallons per hour, which means it will fill 200 water

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bottles in half an hour. This filter complete with hand pump and tripod mounting can be packed into two panniers of approximately 90 lb. each, and can be carried in light transport or by mules.

A midget Meta filter with a capacity of 20 to 30 gallons per hour weighing 14 lb. for even smaller parties has also been produced.

If pumping is stopped for any reason, the bed may break off the candle, resulting in the first quart of water being turbid on repumping. Investigation is being carried out at present at the Army School of Hygiene by Major Carrick to overcome this difficulty.

Kieselguhr is a white gritty powder, pure silica ($Si O_2$), made up of the skeletons of diatoms. It is dug out of the earth, ignited to destroy organic matter and then air-blown to grade it into various sizes. The coarsest of the eight varieties gives a high rate of flow—1,000 gallons per square foot per hour, but will not filter clay out of water. The finest variety yields about 40 gallons per square foot per hour and gives a very good filtrate. The Service variety is intermediate yielding about 200 gallons and efficiently filtering clay, cysts and ova.

Kieselguhr is completely insoluble in, and does not alter the composition of, water. Powdered coal is a good substitute but only yields 100 gallons per square foot per hour.

A new type of candle for pressure filters has been produced by Sintered Products Ltd. This candle is made of porous gun metal. It is half the weight of the Stellar or Meta filters, takes half the amount of Kieselguhr and backwashes more easily.

It has not yet been accepted as a standard Army type.

With the advent of paratroops came the urgent necessity for making individual methods absolutely safe and reliable for general use and not merely as a temporary measure. In the Burma campaign there was no question of infantry and transport following up initial paratroop landings in a matter of twenty-four or forty-eight hours. It was also realized that conditions, in many cases, compel the soldier to make use of water so dirty that even if all the available chlorine liberated by a halazone tablet was not deviated before killing any bacteria present, the resulting fluid would be unpotable. Some type of suitable filter had to be devised. It was obvious that it would have to be light, small, compact and extremely simple to use. Clearly no adaptation of the pressure filter would be of any use, as its weight, bulk and supplies of Kieselguhr were out of the question for such type of fighting.

The answer was discovered by Major Stanley Elliott and Major Hall who produced the Millbank Filter Bag. This consists simply of a "chain weave" light canvas bag approximately 4 in. across and 12 in. deep, one side being slightly longer than the other. To use it the bag must be thoroughly wet first, then filled with water and hung up on a stick.

The first half to one pint is allowed to run to waste, after which the water is clear and water bottles can be filled. The bag must not be touched while it is filtering.

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Cleaning it is equally simple. It is turned inside-out and either back-flushed with clean water, or the mud is washed off and the bag is allowed to dry.

This chain-weave bag removes clay, cysts, ova and cercariæ from any water. Sterilization can then be carried out by halazone tablets giving a safe potable drinking water from any source.

The bag when not in use is rolled up and put in a little waterproof wallet a few inches square. The total weight is about one ounce.

It has always been felt that a two tablet or multiple system of purification has the disadvantage that, under the stress of battle, the tablets might easily be used in the wrong order, or that only one might be used and the other neglected resulting in either case in an unpurified water.

To overcome this, and also the disadvantage of chlorine, which is liable to be deviated, lacks persistence and penetrating power, produces an objectionable taste and whose action is delayed by highly alkaline water or waters containing ammonia, the use of iodine was again investigated. Two products were made in America in 1944. Bursoline (diglycine hydriodide phosphate) and Globaline (triglycine hydriodate phosphate).

These compounds are not yet available in this country, but it is claimed that one tablet of 0·112 gramme will yield 7 parts per million of iodine in one quart of water. All pathogenic bacteria are said to be killed in ten minutes. Cysts and cercariæ are also claimed to be killed.

If these claims are substantiated these will undoubtedly be valuable products for Service conditions.

The possibility of using Catadyn units of specially prepared silvered beads or sand in water bottles has not been considered on account of the expense and the time required for sterilization. Although contact of the water with the units for a few minutes only is necessary the water must then stand for two hours for the germicidal action to be completed.

Recent Advances in Chlorination

Atomic Age

Impure waters containing salts of calcium, sodium, sulphur, nitrates and iron may remain radio-active for long periods unless considerable dilution can take place. As water from a radio-active source is unfit for use, a form of easily portable detector will have to be relied on as a safeguard. For Service conditions it is obvious that such a detector will have to be compact, light and strong and of such a size that it can be easily carried and used by one man.

Major Booker has designed such an instrument, but it has not been accepted yet for Service use.

Recent work shows that there are five interdependent variables affecting the speed and efficiency of chlorination:

(1) Concentration of organisms—with a heavy contamination a large dose of chlorine is needed.

(2) Heavy dose of chlorine—much quicker and safer.

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(3) Concentration of ammonia—if much is present and the Cl/NH_3 ratio approaches 1/1 the process is slowed up—risk if heavy sewage contamination.

(4) pH values—the more acid the water the quicker the action.

(5) Temperature—the higher the temperature the quicker the action. At 2° C. 1 p.p.m. works in the normal way unless retarded by ammonia. This is important under Arctic and sub-Arctic conditions.

Cercariæ and E.H. cysts—recent work by Chang and Fair in America shows that all the above five factors are concerned. 1 part per million of free chlorine will kill 100 cysts per cubic centimetre in half an hour at 20° C. provided no ammonia is present and the pH value is 7·4. Any departure will cause failure.

Leptospira icterohæmorrhagiæ are less resistant than coli.

Poliomyelitis virus in water was inactivated in ten minutes at a pH of 6·8 to 7·4 with the temperature varying between 20 to 30° C. by 0·05 part per million of free chlorine. When the pH value was over 8·5 the virus was sometimes unaltered. $\frac{1}{2}$ to $\frac{3}{4}$ p.p.m. of chlorine was effective at all pH values in less than two hours. 0·2 p.p.m. of chloramine was not effective.

Methods Used by Other Armies

A short comparison of progress made by other countries is interesting. As mentioned earlier Vaillard introduced the iodine method of individual purification in 1902 in France about the same time as Nesfield but no attempt seems to have been made to follow it up and adopt it for Field Service. Professor Testi devised a modification of the American Schumberg's bromine method for the Italian Army in 1909 but this also died a natural death.

In 1910 Regimentsarzt Dr. Galser published a paper on the purification of drinking water for the individual soldier. He advised the use of calcium permanganate followed by magnesium sulphate. This method had a great disadvantage in that tablets of these compounds were insoluble and concentrated solutions were required. No more came of this method and in July 1912 the Berlin Neueste Nachrichten stated that the next German Army Budget would include a sum for the provision of sterilizers for drinking water for Medical Store Depots on Lines of Communication. The method of sterilization was by heat and no further particulars were given.

In the last war the Japanese used an apparatus containing filter candles. It was complicated and neither portable nor efficient. The water to be sterilized was pumped by a semi-rotary pump into a chamber containing six large candles, grouped round a central brush. The candles were about 3 inches in diameter and 2 feet long. In theory if the candles started to clog and the pressure on the pump increased, by turning a crank handle the candles not only revolved round the central brush, but also turned in their seating and so all the clogging matter was removed and washed into a sump drained by a tap.

The whole apparatus complete with hoses and floats was contained in a chest approximately 3 ft. by 2 ft. by 2 ft., fitted with telescoping handles and weighed about 3 cwt.

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In practice the rotary pumps were insufficient and could only lift water about 2 ft. This meant that the contraption had to be built into the river bank and if heavy rain occurred during the night and the river rose, it was almost suicidal struggling up a steep river bank in the dark with this appalling weight.

Sometimes with great care this rather temperamental object might yield water, but although we were assured many times a day that the resulting fluid was absolutely sterile, the "effluent" was always very carefully boiled by the Japanese before consumption in spite of the fact that if we were found following suit it was considered a deadly insult to the Emperor in doubting the efficiency of any of his Armies' equipment. However, even the Japanese, who carry more junk around with them than any other Army, abandoned these "gifts" of the Emperor in the jungle.

In Conclusion

An attempt has been made in this paper to show that in putting an Army in the Field, as much care and attention must be paid to providing the individual soldier with the means of protecting himself from drinking impure water, as is paid in training and equipping him to fight an enemy. A sick soldier cannot only not fight but is a heavy burden on his comrades.

The ideal method must be simple, and not a series of processes. Any material required must be light and compact as the burden of the fighting soldier must be reduced to a minimum. It must also be durable to withstand all conditions in all weathers and climates from Tropical to Arctic. Similarly any chemicals used must be stable under these conditions for considerable periods.

An improved water bottle with a wider mouth, screw stopper and detachable cap has been used on field trials. This embodies many improvements but has been found to have several disadvantages.

As detection of poisons in water is still the province of the chemist or the doctor no mention of it has been made. Advanced troops are still at the mercy of their own discretion.

The advent of the Atomic Era has presented new problems with added dangers which must be solved.

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