fluid, and so arrests osmosis and diffusion in the case of the parietal peritoneal vessels. This arrest of osmosis occurs at a certain stage in each animal, depending entirely upon the rate of output of lymph.

The protein thus originates in the lymph which is being rapidly produced by the viscera, and for this reason the fluid becomes of the same composition as the original ascites.

When salt solution is introduced into the peritoneum of the normal animal protein appears in it for the same reason—namely, that there is normally a very slow output of lymph into the peritoneum, which is being as rapidly absorbed, so that this structure is kept slightly moist, and there is no accumulation of fluid in it. It is this normal lymph production which accounts for the appearance of protein in the peritoneal saline solution. In support of this hypothesis may be mentioned the fact, noted by Gray and myself, that sometimes in the normal hutch-fed rabbit, and commonly when it is pregnant and the muscles are flabby and the abdomen is full, ascitic fluid is present. We showed that there were no pressure changes in the circulation of these ascitic animals. The ascitic fluid of these rabbits appears to be normal tissue fluid, the rate of production of which is probably normal, but absorption by the lymphatics is impeded owing to the respiratory movements and action of the abdominal muscles being less effective in this direction than are those of a wild animal, in which the abdomen is taut and the movements active and vigorous.

Finally, we arrive at the question whether absorption entirely ceases by the blood vessels of the peritoneum when osmotic equilibrium is established between the ascitic fluid and the blood. This entirely depends upon whether protein is absorbed by the capillary wall or not.

An increased absorption of fluid may be occurring by the capillaries of the abdominal wall, although they do not take up the ascitic fluid from the peritoneum. The explanation of this is that the protein concentration of tissue fluid is kept low by the tissue cells using up the protein during their metabolic activities, whilst the ascitic fluid remains of the same protein concentration. Until proof is forthcoming that absorption of protein may occur by the capillary wall, we must assume that when the ascitic fluid attains osmotic equilibrium with the blood plasma the ascites is entirely absorbed by the lymphatics.

SUMMARY.

1. The accumulation of fluid in the peritoneal cavity following an incomplete obstruction of the inferior vena cava in the chest, or in uncompensated heart disease, is due to an increased output of lymph from the viscera, more especially the liver. This increased output is constantly occurring at all stages of the disease; an increase in the amount of fluid is due to an increase in the rate of output, and the disappearance of the fluid is due to a gradual falling off of the rate of output.

2. Absorption from the peritoneal cavity by the lymphatics is occurring at all stages at the normal rate, a check being thus placed to an excessive accumulation of the ascitic fluid. The fluid is therefore being continuously renewed, and there is a constant circulation of lymph from the blood into the peritoneal cavity and back again to the blood by the thoracic duct.

3. Increased absorption of tissue fluid is taking place in the abdominal wall and hind legs, as in the fore part of the body, but it has not been proved that the ascitic fluid is absorbed as such by the capillaries of the parietal peritoneum. There is no evidence to show that the endothelial cells of the peritoneum actively absorb the fluid.

4. The increased lymph flow from the thoracic duct observed at a certain stage in the course of the dropsy is an index of increased lymph production in the abdominal organs owing to the plethora.

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THE DISINFECTION OF DRINKING WATER

WITH A DESCRIPTION OF A NEW SUBSTANCE FOR THE
PREPARATION OF STABLE TABLETS FOR THE
STERILIZATION OF POLLUTED WATER.

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THE sterilization of contaminated drinking water is a problem of special importance in war time. The use of bleaching powder, or similar hypochlorite or chlorine preparation, has been used with the greatest success for the sterilization of relatively large volumes of water. The use of water-carts containing water treated with a carefully regulated quantity of bleaching powder has given every satisfaction when the method could be satisfactorily carried out—as, for example, when troops are practically stationary. The problem of sterilizing small individual quantities of water, such as are needed by cavalry or rapidly moving troops, is much more difficult, and, up to the present, it has not been perfectly solved. The use of hypochlorites for such purposes is difficult, owing to the instability of small tablets containing the minute quantity of active disinfectant. In their place acid sulphates of the alkali metals have been extensively used in tablet form, but the superior potency of many chlorine compounds would indicate that a stable potable chlorine disinfectant suitable for the sterilization of small quantities of water is desirable. With this end in view, we have made a number of experiments with various types of substances, one of which we believe to be worth practical application.

Our first experiments were made with chloramine-T,* but it was found that when this substance was added to heavily contaminated waters it required a relatively high concentration to sterilize the water promptly, particularly in the case of hard alkaline waters. For example, 1 part of chloramine-T to 25,000 parts of water may be necessary, and such an amount is decidedly unpalatable. Subsequently it was found that much lower concentrations of chloramine-T were effective if the contaminated water was slightly acidified with any acid—for example, citric, tartaric, acetic, etc. Under these conditions 1 : 250,000 or less of chloramine-T was effective (see Table I), and the resulting water was not unpleasant to the taste. But

TABLE I.

Experiments with Chloramine-T, with and without Addition of Tartaric or Citric Acid.

No.	Water Treated.	Concentration of Disinfectant.	Acid Added. Grams per Litre.	Time of Action in Minutes.	Surviving Organisms per c.cm.
1	Hard water + B. coli ...	1 : 25,000 1 : 25,000	None None	10 30	2,508,800 35,200 14,880
2	Hard water + B. coli ...	1 : 300,000 1 : 300,000	— 0.4 0.4	— 10 30	1,120,000 180 0
3	Hard water + B. coli + 0.1 % faeces	1 : 200,000	0.8 0.8	— 10	3,232,000 0
4	Hard water + B. coli ...	1 : 250,000 1 : 250,000 1 : 250,000 1 : 250,000	— 0.2 0.2 0.8 0.8	— 10 30 10 30	520,000 27,200 7,200 130 50
5	Hard water + V. cholerae	1 : 250,000 1 : 500,000	— 0.8 0.8	— 10 10	744,000 0 0
6	Hard water + B. typhosus	1 : 250,000 1 : 500,000 1 : 500,000	— 0.8 0.8 0.8	— 10 10 30	345,000 0 1,760 0

* The abbreviated name for sodium toluene-p-sulphochloramide, (Cp. *BRITISH MEDICAL JOURNAL*, January 29th, 1916; *Proc. Roy. Soc.*, B, 89, p. 232, 1916.

chloramine-T could not be made up in a tablet with the addition of an acid without decomposition, and the two tablet system was regarded as impracticable.

Subsequently we experimented with preformed toluenesulphondichloramines, since a substance of this type is formed on adding acid to chloramine-T. The early results were most encouraging (see Table II), and it was

TABLE II.

Experiments with *o*- and *p*-Toluenesulphondichloramine in Powder and Tablet Form.

No.	Water Treated.	Concentration of Disinfectant.	Time of Action in Minutes.	Surviving Organisms per c.cm.	Form of Disinfectant.
1	Tap water + <i>B. coli</i> ...	—	—	11,520	<i>o</i> -powder
		1: 250,000	7	680	
		1: 250,000	15	0	
2	Tap water + <i>B. coli</i> ...	—	—	40,980	<i>o</i> -powder <i>o</i> -powder <i>o</i> -powder
		1: 250,000	7	20	
		1: 250,000	15	4	
		1: 250,000	30	0	
3	Hard water + faeces suspension	—	—	22,080	<i>o</i> -powder <i>o</i> -powder
		1: 250,000	7	200	
		1: 250,000	15	0	
4	Hard water + 10% city sewage	—	—	64,000	<i>o</i> -powder
		1: 250,000	7	448	
		—	15	210	
		—	30	74	
		—	60	2	
5	Tap water + 2.5% city sewage	—	—	6,420	<i>o</i> -powder
		1: 250,000	7	0	
6	Tap water + 5% sewage	—	—	18,300	<i>p</i> -powder
		1: 250,000	7	1,644	
		1: 250,000	15	455	
		1: 250,000	30	0	
7	Tap water + 5% sewage	—	—	18,300	<i>p</i> -powder
		1: 500,000	7	11,928	
		—	15	2,600	
		—	30	930	
		—	60	0	
8	Tap water + 5% sewage	—	—	18,300	<i>p</i> -powder
		1: 1,000,000	7	19,405	
		1: 1,000,000	15	18,920	
		1: 1,000,000	30	7,024	
		1: 1,000,000	60	630	
9	Hard water + <i>B. coli</i>	—	—	161,000	<i>p</i> -tablet
		1: 200,000	10	166,400	
		1: 200,000	40	108,288	
		1: 200,000	60	56,160	

not until we had the product put up in tablet form that we found it to be unsuitable. The difficulties were twofold. When the small necessary quantity of dichloramine—for example, 0.002 gram for 0.5 litre of water—was mixed with what were assumed to be inert salts, such as, for example, sodium chloride, for making into small tablets, the very slow normal rate of decomposition of the dichloramine was greatly accelerated. Secondly, the dichloramine, in tablet form, became too insoluble to effect prompt sterilization. The substance had therefore to be abandoned, and we turned our attention to a search for similarly active compounds which would show greater stability and solubility.

The substance which is the most suitable that we have yet found is *p*-sulphondichloraminobenzoic acid— $\text{Cl}_2\text{N.O}_2\text{S.C}_6\text{H}_4\text{COOH}$. It is easily prepared from cheap, readily available materials, and appears to be effective and reasonably stable. The presence of the COOH group confers a slight but definite degree of solubility in water, which is increased by dispensing it with alkaline salts such as sodium carbonate or bicarbonate, borax or sodium phosphate. Formulae for the tablets are appended, together with details of the preparation of the substance and an estimate of its cost. Since the synthetic name of the disinfectant is inconveniently long for ordinary use, we propose to apply the name "halazone" to the tablets containing it. The abbreviated name gives some indication of the character of the compound.

In Table III (p. 684) are given some of our bacteriological results. The technique employed was that in general use and requires no special description. Five or ten standard drops of the treated water were generally used for plating on agar for counting the surviving organisms. Suitable controls were invariably carried out.

From the results in Table III it appears that a concentration of 1: 300,000 is sufficient to sterilize an ordinarily heavily contaminated water in about thirty minutes. Such a concentration could be relied upon to remove *coli*, typhoid, or cholera organisms. Special experiments showed that the substance in tablet form was efficacious when acting on water contained in aluminium bottles, although a very trifling action on the metal may be observed if tablets are allowed to remain undisturbed in long contact with the metal. We believe such action to be of no practical moment. The concentration of disinfectant given above is just perceptible to the taste, especially in warm water containing little organic matter, but the water is perfectly palatable. One point of advantage possessed by the present disinfectant over most hypochlorite preparations is the fact that the active chlorine is less rapidly used up, so that the process of disinfection continues for a longer period.

Preparation and Properties of the Disinfectant.

The starting-point in the preparation of the substance is *p*-toluenesulphonamide, a product which is readily obtained by the action of ammonia on *p*-toluenesulphonic chloride. The latter substance is a very cheap waste product in the manufacture of saccharine, and is available in relatively large quantities. It is now used for the manufacture of chloramine-T.

Toluenesulphonamide is oxidized to *p*-sulphonamidobenzoic acid, and the latter substance on treatment with chlorine under suitable conditions gives the desired dichloramino acid. The reactions may be expressed as follows:

The experimental details are as follows:

Preparation of *p*-Sulphonamidobenzoic Acid.

Add 250 grams commercial sodium dichromate to a mixture of 200 c.cm. concentrated sulphuric acid and 600 c.cm. water contained in 2-litre round flask. Then add 100 grams crude toluene-*p*-sulphonamide, and heat on a sand bath with reflux condenser for one hour, using a small flame at first as the reaction is vigorous. On cooling, wash the separated crystals well with cold water, and then dissolve them in hot dilute sodium hydroxide in slight excess. Filter hot, and add excess of hydrochloric acid, and when cold filter off the precipitated acid and wash well with water and dry. The yield is about 80 per cent. of theory.¹

Preparation of *p*-Sulphondichloraminobenzoic Acid.

Twenty grams of *p*-sulphonamidobenzoic acid are dissolved in 200 c.cm. approximately normal sodium hydroxide (2 mols.), warming if necessary. About 200 grams of crushed ice is then added, and the mixture saturated with a rapid current of chlorine. The reaction is most conveniently carried out in a fairly wide-mouthed flask, which may be shaken while the gas is being introduced. If the temperature should rise more ice can be added. A white, rather chalky precipitate of the dichloramino acid is at once precipitated. The acid is filtered off, using suction, well washed with cold water, and dried *in vacuo* on a porous plate. The dry substance is practically pure, and may be powdered and preserved apparently indefinitely. Prepared by this method, the yield of the dichloramino acid is practically the theoretical amount.

The substance is sparingly soluble in water and in chloroform and insoluble in petroleum. It readily dissolves in glacial acetic acid, crystallizing in stout prisms, which melt at 213° C. The substance explodes feebly when rapidly heated on platinum foil, but, compared with most members of the group, is remarkably stable.

The purity of the compound may be checked by titration as follows: 0.1 gram is weighed out, dissolved in glacial acetic acid and potassium iodide added. The liberated iodine is titrated with decinormal sodium thiosulphate, of which 14.8 to 14.9 c.cm. will be required.

The dichloramino acid dissolves, apparently without change, in excess of cold sodium hydrate solution, and may be reprecipitated on addition of acids. With smaller quantities of sodium hydroxide or with feebly alkaline

salts, such as phosphates or borates, hydrolysis occurs, with liberation of disagreeably smelling compounds of nitrogen and chlorine.* (See footnote at end.)

Preparation of Tablets.

We have observed no very marked differences in the behaviour of the sulphonichloraminobenzoic acid when made into a tablet with salt and either sodium carbonate or bicarbonate, dry or crystallized borax, or sodium phosphate, although the crystallized salts are undesirable if the tablets are exposed to high temperatures. The sodium carbonate tablets seem as satisfactory as any, and a convenient formula for tablets weighing 100 to 105 mg. is to use sulphonichloraminobenzoic acid 4 per cent., sodium carbonate 4 per cent. (or dried borax 8 per cent.), sodium chloride (pure) 92 per cent. The acid should be ground up with the dry salt and the sodium carbonate added subsequently. The mixture may be passed through a 40-mesh sieve. No lubricant or other addition is necessary and should be avoided. The strength of the tablets should be tested by dissolving in acetic acid and potassium iodide solution, and titrating with sodium thiosulphate as already described (1 c.cm. of N/10 thiosulphate = 0.00675 gram of the dichloramino acid). They must not be allowed to dissolve in water and subsequently titrated, as then decomposition occurs. The tablets should be stored in small amber glass bottles.

Tablets so prepared of the weight mentioned contain about 4 mg. of the disinfectant, and are suitable for the sterilization of a litre or quart of reasonably heavily contaminated water. In the case of extreme contamination a second tablet may be necessary.

Stability of Tablets.

The practical success of the disinfectant we propose will depend very largely on the stability of the tablet. At present sufficient time has not elapsed for entirely convincing experiments, but it appears, as judged by a very few months' observation, that the tablets are stable enough for practical use. They are certainly more stable than other similar compounds with which we are acquainted. When kept in amber bottles under ordinary conditions no

TABLE III.
Experiments with *p*-Sulphonichloraminobenzoic Acid in Tablet Form.
BACILLUS COLI.

No.	Water Treated.	Concentration of Disinfectant.	Time of Action in Minutes.	Surviving Organisms per c.cm.	Tablet Dissolved, in Minutes.
1	Tap water + B. coli ...	1: 200,000	30	63,800 0	4
2	Tap water + B. coli ...	1: 200,000	30	38,629 0	9
3	Tap water + B. coli ...	1: 200,000	15	112,525 0	9
4	Tap water + B. coli ...	1: 250,000	15	112,525 0	9
5	Tap water + B. coli ...	1: 400,000	15	112,525 0	10
6	Tap water + B. coli ...	1: 500,000 1: 500,000	15 30	178,528 987 0	10 10
7	Tap water + B. coli ...	1: 500,000 1: 500,000	15 30	125,420 406 0	12 12
8	Tap water + 5% sewage + B. coli	1: 175,000	15 30 60	1,119,003 6,000 0 0	9 9 9
9	Tap water + 5% sewage + B. coli	1: 330,000 1: 330,000 1: 330,000	15 30 60	1,158,500 120,064 9,146 0	7 7 7
10	Tap water + 5% sewage + B. coli	1: 500,000 1: 500,000 1: 500,000	15 30 60	1,120,000 284,800 49,318 70	5 5 5
11	Deep yellow polluted river water + B. coli	0 1: 250,000 1: 250,000 1: 250,000	— 20 40 60	33,152 10,940 852 0	13

TABLE III (continued).
PATHOGENIC ORGANISMS.

No.	Water Treated.	Concentration of Disinfectant.	Time of Action in Minutes.	Surviving Organisms per c.cm.	Tablet Dissolved, in Minutes.
12	Tap water + B. typhosus	0 1: 225,000	— 20	1,155,400 0	17
13	Hard water + B. typhosus	0 1: 333,333	— 20	85,400 0	14
14	Tap water + 5% sewage + B. typhosus	0 1: 333,333 1: 333,333	— 20 40	66,017 242 0	14
15	Tap water + 5% sewage + B. typhosus	0 1: 225,000 1: 225,000	— 20 40	240,000 13 0	14
16	Tap water + B. paratyphosus A	0 1: 225,000	— 20	112,000 0	17
17	Tap water + 5% sewage + B. paratyphosus A	0 1: 225,000	— 20	138,880 0	13
18	Tap water + 5% sewage + B. paratyphosus A	0 1: 333,333 1: 333,333	— 20 40	29,400 15 0	12
19	Tap water + B. paratyphosus B	0 1: 225,000 1: 225,000	— 20 40	322,500 10 0	17
20	Tap water + 5% sewage + B. paratyphosus B	0 1: 225,000 1: 225,000	— 20 40	309,120 305 0	13½
21	Tap water + 5% sewage + B. paratyphosus B	0 1: 333,333 1: 333,333	— 20 40	139,776 290 0	12
22	Tap water + V. cholerae	0 1: 450,000	— 20	13,706 0	13½
23	Tap water + 5% sewage + V. cholerae	0 1: 333,333	— 20	11,170 0	13
24	Tap water + B. dysenteriae (Flexner)	0 1: 450,000 1: 450,000	— 15 30	66,998 25 0	13
25	Tap water + B. dysenteriae (Flexner)	0 1: 333,333 1: 333,333	— 20 40	98,990 17,363 58	7
26	Tap water + 5% sewage + B. dysenteriae (Flexner)	0 1: 333,333 1: 333,333	— 20 40	164,864 38 0	13
27	Tap water + B. dysenteriae (Shiga)	0 1: 450,000 1: 450,000	— 15 30	33,852 12,227 1,060	6
28	Tap water + B. dysenteriae (Shiga)	0 1: 333,333 1: 333,333	— 20 40	31,200 10,934 0	11
29	Tap water + 5% sewage + B. dysenteriae (Shiga)	0 1: 333,333	— 20	2,108 0	13

Tap water = New York City water (Croton Reservoir).

decomposition was noted in two months. When exposed to bright sunlight in clear glass tubes decomposition was more marked, and the same was true of the crystallized borax tablets at a temperature of 38° C. The dried borax and sodium carbonate preparations were stable under these conditions, the bicarbonate ones less so. On the whole, dry borax or dry sodium carbonate appear preferable to the other salts.

Cost.

It is rather difficult to give precise estimates of the cost of the finished product, but it is safe to say that the tablets could be sold at such a price that 100 gallons of water could be sterilized at a cost of one penny.

REFERENCE.

¹ Cf. Remsen, *Ann.*, 178, p. 298, 1875.

* If the ethyl ester of sulphonamidobenzoic acid is chlorinated in chloroform solution in the presence of aqueous sodium acetate, ethyl sulphonichloraminobenzoate is readily obtained on evaporating the chloroform solution. It crystallizes from acetic acid or carbon tetrachloride in stout prisms, which melt at about 80° C. One tenth of a gram on titration with thiosulphate, after adding potassium iodide, required 14.0 c.cm. The theoretical amount for Cl₂N.SO₂.C₆H₄.COOC₂H₅ is 14.1 c.cm. The substance was not found to present any advantages over the free acid as an antiseptic or disinfectant.