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REPORT NUMBER 4

WATER DISINFECTION PRACTICE

ANNUAL SUMMARY REPORT

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October 18, 1968

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Washington, D. C. 20315

Contract No. DADA 17-67-C-7062

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Summary

The current review of canteen water disinfection has proceeded along three general lines.

I. Review of the Literature on Canteen Water Disinfection

A summary has been prepared of the information available from the literature on canteen water disinfection.

II. Discussions of Problems of Disinfection with Dr. J. Carrell Morris and Dr. Shih L. Chang

The current opinions of two outstanding investigators in the field of disinfection have been solicited in personal interviews and summarized.

III. Summary of the "Harvard Report"*

The "Harvard Report," possibly the most detailed research study of canteen water disinfection ever conducted, has hitherto been published only in fragments. A summary of the most salient features of this work has been completed.

*Harvard University, "Disinfection of Water and Related Substances," Final Report to the Committee on Medical Research, Cambridge, Mass. (Dec. 31, 1945).

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REVIEW OF THE LITERATURE ON THE FIELD DISINFECTION OF SMALL QUANTITIES OF WATER

1.1 There are many occasions when water disinfection must be practiced on a small scale and under adverse conditions. The need for a ready-to-use disinfectant is greatest during military operations or at times of natural disasters when small groups of people or even individuals have to depend upon sources of water which might be contaminated. Even during peace time, campers, sportsmen and adventurers have need for a packaged, instant-disinfectant such as a tablet. This need was first recognized more than fifty years ago (1). However, only a few preparations, usually consisting of iodine and chlorine, were in use at the beginning of the Second World War. At that time a team of scientists and engineers conducted an extensive investigation at Harvard University under a contract with the Committee on Medical Research of the Office of Scientific Research and Development. The Harvard researchers (2) listed the following desirable properties of chemical disinfecting agents which are intended for use under field conditions:

A. This should be made available as a tablet of such size as to permit use of a single or at most two tablets for a small quantity of water.

B. The technique of applying the disinfectant should be simple of management, substantially foolproof, and not unduly time consuming.

C. The agent should disintegrate or dissolve quickly and liberate its active ingredient or ingredients rapidly in order to free as much time as possible for the kill.

D. Dosages should preferably be such as to ensure disinfection of all kinds of natural waters to be treated without testing for residual concentrations of the disinfectant.

E. The treated water should be acceptable to the user. In other words, odor, taste and appearance of the water should not be objectionable and foods and beverage powders or concentrates placed in the water should not be changed in normal appearance or flavor.

F. The treated water should not be toxic or otherwise undesirably physiologically active during periods of reasonable use. The water, furthermore, must not interfere with essential prophylactic or therapeutic medication.

G. The treated water should not be corrosive to water containers.

H. The disinfecting agent should be stable under conditions of storage and actual use.

I. The ingredients required in compounding the disinfectant should be economically and strategically available.

J. Manufacture of the chemical agent should lend itself to large scale preparation with normally available chemical and pharmaceutical equipment.

1.2 Ingredients of a Tablet

Apart from disinfectant, a tablet must have substances which help either in the manufacture or its dissolution or promotion of disinfecting process. These ingredients could be classified as follows:

A. Filler

A filler or an excipient is always required in pharmaceutical practice to give the tablet adequate bulk. A number of fillers are available but a disinfecting tablet must employ one which is soluble (to preserve the clarity of the treated water), and at the same time should not be hygroscopic and should be inert to the disinfecting chemical. As shall be discussed later, the halazone tablet has sodium chloride as an excipient. A number of soluble nitrates, phosphates, acetates and sulfates could also be usefully employed.

B. Buffer

The selection of a buffer to promote the disinfecting action of the agent is very important. For example, for any chlorine compound to be an effective disinfectant, it is essential that the pH of the chlorinated water be less than 8. Above pH 8, the predominance of hypochlorite ion seriously reduces the disinfection capability. Similarly, where iodine is used, the pH of the solution should not be less than 7. Otherwise, the viricidal efficiency of hypoiodous acid will be sacrificed. Sometimes, the buffer also serves as a filler.

This is true of globaline tablets which employ disodium dihydrogen pyrophosphate as a buffer as well as an excipient.

C. Lubricant

The function of this ingredient is to lubricate the punches of tablet-making machines. Talc is a popular lubricant. Calcium or magnesium stearate are also sometimes added. The purpose of a lubricant may sometimes be performed by the filler itself.

D. Swelling Agent

Use of certain colloidal clays, such as bentonite, promotes the disintegration of tablets by quick swelling in water causing the tablet to burst. This clay is chemically inert but physically very active.

1.3 Test Organism

Emergency conditions demand that the disinfecting agent or tablet should be capable of killing the most resistant water-borne pathogen. The Harvard Report (2) states in this regard that "leaving out of consideration the virus of infectious hepatitis, the cysts of Entamoeba histolytica appear to be the most resistant water-borne pathogens that must be dealt with in the water disinfection and so appear to determine the pattern of accomplishment that must be established both in the laboratory and in the field." Much work has since been carried out on various human enteroviruses and the results confirm the earlier observations that cysts of Entamoeba histolytica offer greater resistance than any enteric virus, including infectious hepatitis, to the disinfecting action of chlorine (2). Morris (3), for instance,

quotes other investigators who state that the concentrations of HOCl needed to yield 99% germicidal effect in 10 minutes at 5°C for virus and cysts are 0.002-0.4 ppm and 10 ppm respectively. Chang (4) presents data for iodine which shows that for a contact period of 10 minutes at 18°C and 99.9% kill, the concentrations of I_2 and HOI needed for poliovirus Type I and E. histolytica are:

Species	Poliovirus Type I	E. histolytica
Iodine	20 mg/l	2.5 mg/l
Hypoiodous Acid	0.45 mg/l	4 mg/l

This data indicates that for effective disinfection of cysts and virus with reasonable doses of iodine, both molecular iodine and hypoiodous acid should be present in solution. It is interesting to note here that at pH 7, a dilute solution of iodine contains almost equal percentages of molecular iodine and hypoiodous acid (5). This fact underscores the role the buffer has in a disinfecting tablet containing iodine.

1.4 Tablets in Use

There are currently two tablets being used for water disinfection in the U. S. The halazone tablet has been in use prior to and during World War II. The disinfectant employed is a chlorine compound. The other tablet, globaline, which contains an iodine-based disinfectant, is used by the U. S. Armed Forces for the disinfection of

canteen waters. This tablet was developed by the Harvard researchers and has many advantages over the halazone tablet for this purpose.

A. Standard Halazone Tablet - Composition and Reactions

The composition of this tablet is as follows:

Halazone - - - - - - - - - - -	= 5.30 mg
Soda Ash, dried - - - - - - -	= 5.18 mg
Boric Acid - - - - - - - - -	= 11.92 mg
Sodium Chloride - - - - -	= 114.00 mg
Weight per Tablet - - - -	= 136.40 mg

The chemical name of halazone is p-dichlorosulfonamidobenzoic acid. It reacts with water to release hypochlorous acid up to 50% of the titrable chlorine present. One tablet dissolved in a quart of water produces a titrable chlorine* concentration of 2.3 ppm and a maximum concentration of HOCl (as Cl_2) of 1.1 ppm. The reaction of the halazone in water is as below:

$$Cl_2NO_2SC_6H_4COOH + H_2O \rightarrow Cl\ HNO_2SC_6H_4COOH + HOCl$$

In this tablet sodium chloride is the filler and the remaining two compounds form an alkaline buffer.

B. Globaline Tablet - Composition and Reactions

The Globaline tablet derived its name from a chemical compound which was developed by the Harvard researchers. The

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* The Harvard researchers (2) defined titrable chlorine as the total oxidizing power of the material or solution under consideration which is effective in oxidizing iodide ion to iodine in dilute acetic acid solution, expressed as ppm of elemental chlorine.

Harvard Report (2) refers to globaline as triglycine hydroperiodide, $(NH_2CH_2COOH)_3 \cdot HI \cdot I_2$. The formulation was later modified to tetraglycine hydroperiodide $(NH_2CH_2COOH)_4$ HI . $1.24I_2$. This compound provides 42.32% titrable iodine and 59.42% total iodine. The composition of the globaline tablet is as below:

tetraglycine hydroperiodide - - - - - - - - = 19.3 to 21 mg

disodium dihydrogen pyrophosphate - - - - = 82.5 to 92.3 mg
$(Na_2H_2P_2O_7)$

talc - = not more than 6 mg

weight per tablet - - - - - - - - - - - - = 110 to 120 mg

One tablet dissolves in a quart of water to give 8 ppm of titrable iodine.

The talc is employed as a lubricant and disodium dihydrogen pysophosphate works as an acid buffer as well as an excipient. This acid buffer serves to lower the pH of natural waters for it was then thought that elemental iodine was more germicidal in general than its main hydrolysis product, hypoiodous acid. As discussed earlier, Chang (4) has shown that while molecular iodine is an excellent cysticidal agent, it has poor viricidal properties. On the other hand, hypoiodous acid requires about double the dose of molecular iodine for killing cysts under the same conditions, but is about 40 times as viricidal as iodine. These results indicate the need for the presence of both I_2 and HOI in reasonable concentrations in water for effective disinfection of all organisms rapidly.

1.5 Comparison of the Two Tablets

The Harvard Report (2) provides sufficient data on almost all properties of the two tablets discussed. The following is a summary of some of this data:

1.5.1 Dissolution Time

Field studies employing soldiers in acceptability tests indicated that they considered rapid solubility of tablet as a primary criterion for acceptability. They were impatient with agents that required a waiting period of more than 10 minutes.

For field simulation, the tablet to be tested was placed in a liter volumetric flask containing tap water at 23°C. The stoppered flask was then inverted end-over-end continuously, causing the tablet to drop through water until it was dissolved. These tests showed that while globaline disintegrated and dissolved in less than one minute, standard halazone tablets required $7\frac{1}{2}$ minutes. Thus, in the case of halazone, the actual contact time between the disinfectant and the organism is $2\frac{1}{2}$ minutes, if 10 minutes is taken as the total time a soldier will wait.

It may be mentioned here that the disintegration of the tablets is not primarily a function of the disinfecting agent but rather of the filler and expanding agent used in the tablet. Since halazone contains sodium chloride which hardens or "sets up" with time, it suffers from a low rate of solution. As for the solubility of halazone itself, it was tested at different pH values. The results showed that the solubility was low and constant up to a pH of about 4.

Above this pH, the solubility increased quite rapidly, either because of hydrolysis of the dichlor group or through ionization of the carboxylic acid group. For example, some values were as follows:

pH	3.8	5.5	5.6
halazone solubility, grams/liter	0.09	0.83	1.200

These figures indicate that a change in the filler now employed in Halazone might improve the dissolution time of the tablet markedly. On the other hand, the use of disodium dihydrogen pyrophosphate as a buffer and free-flowing filler in the globaline tablet was a marked improvement even though the solubility of globaline compound is far greater than that of halazone. Globaline has a solubility of 380 grams per liter of distilled water.

A. Effect of Storage and Humidity on Dissolution Time

In general tests showed that storage at 140°F and room humidity did not affect the dissolving properties of the tablets tested.

B. Effect of Temperature on Dissolution Time

In general, lowering of the water temperature increased the time of dissolution for both the tablets substantially in accordance with the Van't Hoff-Arrhenius formulation. Some of the dissolution times obtained were:

	10°C	20°C	30°C
Globaline	1.9 min	1.2 min	0.8 min
Halazone	9.5 min	8 min	6.5 min

1.5.2 Cysticidal Dose

Cysticidal doses of globaline and halazone tablets were determined in Cambridge tap water alone or with the addition of interfering substances that might be present in natural polluted water. The cyst density was 60 per ml of water. This density is considered to be far higher than the highest conceivable concentration of cysts in sewage. This estimate is based on an area of high endemicity, say 50%, where the ratio of amoebic cysts to *E. coli* would be of the order of 1 to 100,000. (The number of coliform organisms discharged by an individual is estimated to be about 400 billion per day and an infected individual would discharge cysts in numbers varying from several hundred to some ten million per day.) This ratio would make the number of cysts in concentrated sewage about 10/ml.

The tests with globaline gave the following results:

Kind of Water	Temp °C	Contact Time, Minutes	pH		Cysticidal Dose Tablet/Quart	Cysticidal Residual I_2-ppm
			Initial	Final		
Tap	3	25	8.0 to 9.0	6.5	1	7.5
Tap	10	15	8.0 to 9.0	6.6	1	6.9
Tap	23	10	8.0 to 9.0	7.3	1	7.5
Tap	28	5	8.0 to 9.0	6.65	1	7.5
Tea Infusion	23	5	7.2	6.4	2	8.7

The above dat certifies that one tablet of globaline should be able to disinfect all cysts, pathogenic bacteria and spores. No conclusive tests were carried out against organisms of infectious hepatitis and other enteroviruses. Nevertheless, it is possible now to

estimate the viricidal capacity of waters disinfected with globaline. At 10°C, the initial pH of tap water was lowered to 6.6 with one globaline tablet thereby leaving a residual of 6.9 ppm of iodine. At pH 6.6, about 5% of the titrable iodine is in the form of HOI (6). As a result, the hypoiodous acid concentration is about 0.35 ppm. This amount of HOI may not be sufficient to be viricidal. The high concentration of titrable iodine and the use of an acidic buffer result, therefore, in a high cysticidal efficiency but lower viricidal capacity.

The tests with halazone tablets showed that at room temperature about 5 tablets per quart of water were required to destroy all cysts in 10 minutes, whereas $2\frac{1}{2}$ tablets would do so in 30 minutes. In moderately to heavily polluted water at the same temperature, 7 tablets were needed for 10 minutes contact time and about 5 to do so in 30 minutes. Larger dosages of these tablets are required for the following reasons:

A. This tablet can release a maximum concentration of titrable chlorine equal to 2.5 ppm and HOCl equal to 1.25 ppm. This is far less than the dose required under adverse conditions. Morris (3) reports that 10 ppm of HOCl are required for 99% kill of E. histolytica in 10 minutes at 5°C.

B. The halazone tablet has an alkaline buffer to aid in dissolving the compound. Unfortunately, at high pH the predominant species of chlorine is OCl^- which is about 100 times less cysticidal than HOCl.

C. The dissolution time of the halazone tablet is slow; $7\frac{1}{2}$ minutes at room temperature. Halazone has a great advantage in that HOCl reportedly is an excellent viricidal agent (3,10). It may be safe to

assume, therefore, that if a certain dose of HOCl is cysticidal, it is also sufficient for all types of enterovirus. In summary, a major improvement which appears to be possible in the preparation of tablets containing halazone is the inclusion of an acidifying agent which will not affect the solubility of the compound.

1.5.3 Acceptability of Tablets by Users

The acceptance of the disinfecting agent by the user is probably as important as its germicidal action. The user may hesitate to use the agent because of (a) unpleasant taste, odor or color, (b) adverse physiological reaction, or (c) excessive time for disinfection.

A. Unpleasant Taste, Odor or Color

Tastes and odors may be caused either by the tablet itself in water or by its combination with beverage powders.

For purposes of comparison, the Whipple Scale of intensity of odors and testes (7) was adopted as a yardstick to determine the relative palatability of the tablets. Investigators (2) used four tablets of halazone providing about 10 ppm of titrable chlorine and one tablet of globaline providing 8 ppm of titrable iodine per liter of boiled distilled water at 23°C. The pH was varied with citric acid, dihydrogen disodium pyrophosphate of sulfuric acid. The water was tested by seven to fourteen subjects. The results obtained indicate that in the "pH range commonly encountered," the globaline was more acceptable than halazone. In fact, in this range of pH, globaline produced "faint" to "distinct" intensity of odor and taste whereas halazone treated water had "decided" to "very strong" range on the Whipple scale.

The "objectionable thresholds" were also determined in boiled distilled water at 23°C and the results were as follows:

Compound	Percent of Normal Cysticidal Dose at which "Objectionable Threshold" is Reached					
pH	4	5	6	7	8	9
halazone	50	40	25	25	25	25
globaline	-	200	-	200	-	-

From this it is apparent that globaline would reach the "objectionable threshold" only if 2 tablets were used as is prescribed for heavily polluted waters.

As for the effect of pH upon tastes and odors, it was deduced, though not conclusively, that minimum tastes and odors were produced at the pH values attained when the tablets are added to neutral, unbuffered waters.

To study the effect of temperature on the tastes and odors, tests were made at temperatures of 15°C, 23°C, and 30°C. The results indicate that the intensity increased with temperature but did not become objectionable even at 30°C, although at that temperature no water is pleasant to drink. All observers agreed that the coldest drink was the most palatable.

With regard to the effect of disinfection on beverage powders, no specific tests were made with either of the two tablets.

B. Adverse Physiological Reaction

The physiological response of the use of iodinated water has long been a matter of concern. A number of laboratory as well as

field studies have been reported. Studies were conducted at;

1. Department of Pharmacology, Harvard University (Dr. Otto Krayer)
2. Division of Pharmacology, Food and Drug Administration
3. Armored Medical Research Laboratory, Fort Knox
4. Naval Installations, Marshall Islands

All of these investigations were performed using iodine in concentrations equivalent to or in excess of those used in the field purification process. The tablets themselves were not used in these tests. The first three studies or their conclusions have been described in the Harvard Report (2) whereas the fourth study has been reported by Morgan and Karpen (8). While the first three studies indicate in general that the ingestion of iodine-disinfected water by healthy male adults should have no injurious effect, the analysis of data in the fourth study revealed no evidence of weight loss, failure of vision, cardiovascular damage, altered thyroid activity, anemia, bone marrow depression, renal irritation, sensitization to iodine, predisposition to diseases of the skin, or impaired wound healing.

A more exhaustive study is now underway at Gainesville, Florida, under Dr. A. P. Black where far lower dosages of iodine are being used. Partially reported results indicate that there is no evidence that iodine, under the experimental conditions employed, has had any detrimental effect on general health or thyroid function (5,9).

C. Excessive Time of Disinfection

As reported earlier, the acceptability tests show that the soldiers in the field are impatient with disinfectants which take more than 10 minutes to complete their action. In other words, the

dissolution should take place in a matter of seconds to leave about 10 minutes contact time for sterilization. Obviously halazone tablets which require more than 7 minutes for solution, have to compensate for a shortened contact time by higher dosage. Globaline, on the other hand, is reported to dissolve in less than a minute, thus leaving most of the 10 minute time for disinfection.

1.5.4 Thermal Stability of Tablets

Water disinfecting tablets designed for global use must be capable of withstanding extremes in air temperature as well as heat developed in storage warehouses. To test the stability of globaline, accelerated storage tests at 140°F and room humidity were carried out to determine the rate at which tablets decompose and at what rate active ingredients are dissipated.

Tests on globaline powder indicate that it lost about 30% of its iodine after one month and about 60% after two months. On the other hand, results of experiments with halazone tablets indicated that no appreciable loss of available chlorine occurred after 20 days at 140°F. Therefore, the halazone tablet can be described as thermally stable.

1.5.5 Resistance to Humidity

To determine the relative stability of tablets in humid atmospheres, they were subjected to tests at humidities of 100%, 79% and 55% at room temperature. The gain in weight after certain time intervals at room temperature was measured.

At 100% humidity globaline appeared to be more stable than halazone as the former retained 37% of original iodine and the latter 24.7% of original chlorine after the same number of days.

At 79% humidity as well as 55% humidity, globaline appeared to be less hygroscopic. Over long periods of time at 32% humidity, globaline again proved to be a stable substance.

1.5.6 Simulated Field Test

In order to gauge resistance to humidity and thermal stability during actual use in the field, bottles of globaline and halazone tablets, with and without cotton plugs, were placed in a control room held at 80 to 90% humidity and approximately 80°F. Every two hours during the day each bottle was opened for a minute and a tablet was drawn. Over a three-week period, none of the compounds showed an appreciable loss of strength. and there was little variation between the bottles with or without cotton plugs.

1.6 Corrosion of Metals

To see the effect of halazone and globaline disinfected waters on the materials of canteens, a series of experiments was conducted on aluminum and steel canteens. To perform accelerated tests, the strength of solutions was quadrupled. Thus, the globaline solution contained 32 ppm of titrable iodine and the halazone solution had 20 ppm of titrable chlorine. Two types of tests were conducted, drip tests and immersion tests.

1.6.1 Drip Tests

In the drip tests, the solutions were allowed to drop upon the experimental metal and run down it for about 9 hours each day over a period of 36 to 50 days. The same solution was used over and over again, but it was freshly reconcentrated each day with the respective tablets. The loss in metal was assumed to be an indication of corrosion.

The results showed that the steel canteen metal was much more resistant to corrosion than the aluminum metal. Upon aluminum, globaline appears to be more corrosive than halazone, although upon steel, the action of globaline is less pronounced than that of halazone.

1.6.2 Immersion Tests

In normal immersion tests with the same solutions of globaline and halazone tablets, the former was less corrosive than the latter on steel canteen but the reverse was true in case of aluminum canteens.

1.7 Conclusions

The globaline tablet was developed as a result of a tremendous effort on the part of scientists and engineers at Harvard. It has satisfied most of the criteria set for a disinfecting tablet. The halazone tablet suffers from serious drawbacks which limit its efficiency. However, since the production of these tablets, much work has been done on the subject of disinfection and many misconceptions have been corrected. It may be possible, therefore, to re-evaluate the potency of these products and make further improvements.

Globaline was produced on the basic assumption that molecular iodine alone is germicidal (and not its hydrolysis products) and that cysts of *E. hystolytica* represent the test organism. Molecular iodine is still known to be an extremely good cysticidal agent but it has been proven by several researchers (4, 10) that it is much less viricidal. The Harvard Report (2) assumed that "the destruction

of virus by disinfectants appear to be of the same order of magnitude as that of most pathogenic nonsporulating bacteria." Since this assumption has been disproven (3,10), it would be useful to evaluate the viricidal power of globaline tablets. As discussed in paragraph 1.5.2, due to the effect of disodium dihydrogen pyrophosphate (acidic buffer) in lowering the pH of the water, the hypoiodous acid content produced of the water may be so low that it may be insufficient to kill any virus present. This situation points to an area of possible improvement in the globaline tablet. The substitution of an alkaline buffer (pH 8) would yield about 40% HOI and 60% molecular I_2.

At room temperature the globaline tablet was expected to dissolve in less than a minute. Studies at the University of Illinois (12) have indicated that it may take longer, perhaps from 3 to 4 minutes. However, this experimentation was done on tablets which had been manufactured a few years earlier. The discrepancy may be ascribed either to the adverse effect of storage on the solution properties of the tablet or the pressure exerted by tableting machines. Since these factors are difficult to control, further studies to find a more suitable swelling agent are indicated. An alternative would be an effort to make the tablet effervescent. This problem is one that involves the psychology of the thirsty soldier and improvements towards a more satisfactory solution should be constantly pursued.

Color, taste and odor problems are associated with the use of globaline tablets but not to an extent that it is alarming. In fact, these signs are significant as they indicate the presence of a fair amount of residual iodine.

The halazone tablet, at present, is not a suitable disinfecting agent for military use. No only because little titrable chlorine is released, but also because most of the chlorine released ionizes into OCl^- due to the presence of an alkaline buffer. Since OCl^- is about 100 times less cysticidal than HOCl, the efficiency of the chlorine is greatly reduced. The alkaline buffer was added to increase the rate of solution of halazone which is very low at low pH values but increases markedly above a pH of 6. It might be possible, therefore, to prepare a reasonably soluble tablet buffered at a pH of 6 rather than 8 or 9. The solubility might further be enhanced by the addition of a swelling agent or by making it an effervescent tablet.

Comparing iodine and chlorine based tablets as disinfectants for small water supplies, the former appears to have advantages over the latter for the following reasons:

1. On molar basis, iodine is more cysticidal than hypochlorous acid.
2. Iodine has very little organic demand as compared to chlorine.
3. Chlorine has a strong affinity for nitrogenous matter, whereas iodine has almost none.
4. Both predominant forms of iodine, molecular iodine and hypoiodous acid, are efficient germicides. They form an excellent combination for cysts and enterovirus. On the other hand, where chlorine is used, hypochlorous acid alone is a good germicide while OCl^- is a poor disinfectant.

Finally, the present practice of packaging 50 tablets of globaline in a single bottle may also be subject to improvement. Once opened for the use of first tablet, the remaining tablets may start to "set up" or harden. In addition, the disinfecting agent may be lost. With the tremendous improvements in packaging techniques and materials, it may not be difficult to devise a package which contains one or two tablets. Alternately, the use of a powder pillow may be a solution to the problems of stability and solubility.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Department of Civil Engineering University of Illinois Urbana, Illinois	2a. REPORT SECURITY CLASSIFICATION 2b. GROUP

3. REPORT TITLE

Water Disinfection Practice

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Annual Report

5. AUTHOR(S) (First name, middle initial, last name)

John T. O'Connor

6. REPORT DATE October 16, 1968	7a. TOTAL NO. OF PAGES 26	7b. NO. OF REFS 12
8a. CONTRACT OR GRANT NO. DADA 17-67-C-7062 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 4 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Medical Research and Development Command

13. ABSTRACT

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DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

Summary of Interviews with Dr. S. L. Chang and Dr. J. C. Morris

"Free Available Chlorine"

Both Dr. S. L. Chang and Dr. J. C. Morris agreed that the term, free available chlorine, is misleading as it does not reflect the effect of pH on the disinfecting capability of a chlorinated water. A solution to this problem would be to report HOCl in lieu of "free available chlorine" as is done now. HOCl would be a measure of intensity, whereas, "free available chlorine" is a measure of capacity. Unfortunately, there are numerous difficulties in developing a technique for the direct analytical determination of HOCl. Dr. Chang suggested the measurement of the redox potential of chlorinated water as a possible measure of HOCl. Dr. Morris suggested the development of a membrane which could be employed to pass HOCl and reject OCl^-. These ideas have not been pursued experimentally.

From these discussions, it appears that until a direct analytical method for HOCl can be developed, a "disinfecting intensity" should be calculated. This term should take into account the concentration and disinfecting efficiency of each species which is capable of disinfection. For example, at a certain pH, a solution may have the following composition:

$HOCl = n_1$ Mols/L

$OCl^- = n_2$ Mols/L

$NH_2Cl = n_3$ Mols/L

$NHCl_2 = n_4$ Mols/L

If each of these species is capable of a specified percentage of kill in a specified contact time, the relative efficiencies of kill may be expressed as f_1, f_2, f_3 and f_4, respectively. Finally, disinfecting intensity = $n_1 \times f_1 + n_2 f_2 + n_3 f_3 + n_4 f_4$.

This idea was suggested to Dr. Chang and Dr. Morris along with a proposal that for different "free available chlorine residuals", pH, NH_3 and temperatures, tables or nomograms might be prepared which would guide water plant operators in the determination of effective disinfecting intensity. Of course, new standards for this term will have to be developed. Both Dr. Morris and Dr. Chang endorsed this idea.

Test Organism

In recent years, low level transmission of viral infection has cast a doubt on the established bacteriological standards for drinking water. There appears to be, however, a divergence of opinion on the issue. Dr. Chang is for revision of the existing standards. He discussed this matter at length and explained that he does not advocate the changeover from E.Coli to virus as a test organism but that he feels a revision of E.Coli standards fixed by U.S.P.H.S. is in order. This revision should be based on establishing E.Coli/virus ratios in the laboratory. In big cities, however, where the availability of well-equipped laboratories for detection of virus should not be a problem, Dr. Chang felt that virus should be used as an additional test organism. Of course, this would require the establishment of

1) an enterovirus index; and,
2) a standard method for the detection of low levels of virus.

Dr. Morris, on the other hand, suggested that much more research on the "low level transmission" of viral infection be done before such a changeover is considered. He was, however, for the establishment of "dual" (or more comprehensive) set of standards.

Iodination

While chlorine has become, over many years, the predominant choice as a disinfectant for water, recently iodine is assuming more importance. It has been argued that iodine has many advantages over chlorine. It is less reactive with organic matter and persists for a longer time than chlorine.

Both Dr. Chang and Dr. Morris were not satisfied with the "short term" limited experimentation with iodine in that the physiological reactions of human beings are not fully determined. Dr. Chang felt that the effect of iodination on infants and pregnant women should be explored. Both felt that iodination is uneconomical for public water supplies. They were also not satisfied with the color, taste and ordor imparted by higher dosages of iodine.

Globaline Tablet

Since both Dr. Chang and Dr. Morris worked for the development of globaline tablets at Harvard in 1940-45, their views on the limitations of the globaline tablet are most valuable. Dr. Morris was of the view that the pill has all the properties required of a good disinfectant but the dissolution time needs to be substantially reduced. While it is true that the Harvard tests in the forties resulted in faster dissolution under ideal conditions, Dr. Morris felt that the manufacturing firm may not be sufficiently careful about the pressure exerted in preparing the tablet. As a result, the dissolution time may be increased. One possible improvement, therefore, could be made on the excipient or buffer. If the pill could have effervescent properties, its effectiveness would be greatly enhanced. The adverse effects of storage on the dissolution time are also felt to need attention.

Ozonation

While ozonation is very popular in European countries, it has hardly been tried in the U. S. A. High cost, no residuals and lack of viricidal power are cited as limitations usually associated with ozonation. Dr. Morris conceded that "no residual" is a big problem but high cost and viricidal efficiency are points which need future investigations in the U. S. A. He cited figures from Europe which showed that ozone has good viricidal efficiency. However, Dr. Morris called for research in this area in the U. S. A. He also questioned the argument that ozonation is costly when electric power is cheap in the U. S. A.

Dr. Chang recommends ozonation as a prelude to chlorination. Ozone would meet most of the organic demand and partially reduce the pathogenic load in water. He quoted numerous authors to show that ozone is more viricidal than free chlorine when a comparison is made on weight basis.

The consensus of opinion was that ozone should be accepted as a reliable disinfecting agent only after detailed studies have been made.