SOME SANITARY ENGINEERING DEVELOPMENTS DURING THE WAR

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War intensifies activities on all fronts. In spite of the destructive objectives generally dominating these efforts, valuable constructive collateral results come to light. Scientific studies in war fortunately include in their purposes the saving of life. World War II was no exception to this rule, except perhaps that the total research effort far exceeded that expended in any previous war.

The control of the sanitation of the environment was one of the disciplines of major concern to the military. It profited, therefore, materially in the broad attack on problems, solutions to which were essential for the protection and rehabilitation of military forces.

Space limitations alone prevent a detailed rehearsal of all of the advances in sanitary engineering practices and tools derived from war studies. A few important categories of international significance are briefly described, however, to illustrate advances in the science and in the art.

These developments are the result of multiple attacks by many investigators on the many facets of each problem. It is impossible therefore to list exhaustively the names of all investigators responsible for the significant contributions. Because the author has borrowed so extensively, both in subject matter and in language, from official and unofficial documents he has added to this brief commentary sufficient bibliographical reference to enable the interested reader to track truth as well as responsibility down to their originators.

1—Disinfection of Water[a]

In spite of the fact that, in municipal practice and large military installations chlorine and chlorine compounds have been the major chemical means for disinfecting water, the exact mechanism of the actions of these compounds has not been well understood. The work done by Gordon Fair and his group at the Harvard University laboratories, has contributed much to the clarification of the chemical action of these compounds.

It is now generally accepted that by and large the disinfecting power of these compounds is essentially proportional to the amount of un-ionized hypochlorous acid released when any one of these chlorine compounds is dissolved in water. Ionization is slight in acid solution and complete only in very basic solutions.

Current tests also make it clear that the cysticidal effectiveness of OCl^- relative to that of $HOCl$ is of the order of 3×10^{-3} for 30 minutes exposure. Since the methods for estimating chlorine give equal weight to $HOCl$ and OCl^-, the influence of pH on the amounts of chlorine requisite for disinfection is very marked. This pH effect may be particularly noticeable with the use of calcium hypochlorite since these commercial compounds may substantially increase the pH of natural waters. The buffer character of the water will, of course, dominate this effect.

Of the water-borne pathogens the cysts of *E. histolytica* appear to be the most resistant to disinfection. Within the range of expected numbers of pathogenic

[a] Excellent summaries on this subject are available in J. C. Geyer's paper on "Chlorination of Drinking Water" in U. S. Naval Medical Bulletin, September 1945, 45:3, pp. 579–602; and Shih Lu Chang on "Destruction of Micro-organisms," Jour. A. W. W. A., November 1944, 36:11, pp. 1192–1207.

bacteria, schistosome cercariae, and amoebic cysts, destruction of the cysts insures destruction of the other pathogens as well. Experimentally determined titratable chlorine residuals that will destroy 30 cysts of *E. histolytica* per ml. are, in general, substantially higher than the residuals that have commonly been employed in practice in the past, except where superchlorination to breakpoint chlorination have been in use.

"Formation of chloramines, while leaving the concentrations of titratable chlorine unchanged, nevertheless reduces its disinfecting power very substantially. Investigations by the U. S. Public Health Service indicate (1) that for equal titratable residuals, chloramines require 20 to 100 times as long as chlorine to produce complete kills, or (2) that for equal contact periods the titratable chloramine residuals must be 20 to 40 times as great as the chlorine residuals."

In military field operations problems of disinfection were further aggravated by high amounts of organic matter in field waters. In these instances, particularly for canteen water disinfection, it was essential to have a material available which would ensure disinfection under emergency conditions. In general Halazone tablets[(b)] were used. The number required to disinfect a canteen full of warm water in 36 minutes would have to be at least 6. When used in such amounts the water frequently was not palatable.

In the search for canteen disinfectants more satisfactory than Halazone, after preliminary review of cationic detergents (quaternary ammonium compounds) and triiodides, the triiodides proved to be effective. When suitable triiodides are added to the water, equilibrium is set up between iodine, iodide and triiodide ion. It was found that disinfection was proportional to the amount of elemental iodine present. All of the titratable iodine was directly useful.

"Experimental cysticidal times for 7.5 mg. per liter of elemental iodine are: 5 minutes at 23°C, 10 minutes at 10°C, and 20 minutes at 5°C. At this dosage and with these contact periods, Esch. coli, Eber. typhosa, Sh. dysenteries, Sal. schottmulleri, and Vibrio comma are reduced from about 100 million to 5 or less per 100 ml. of water."

It will be recalled, of course, that such disinfection results had been obtained with tincture of iodine in the past. The particular merit of the triiodides rested in the fact that they produce a better tasting water while avoiding the field use of a liquid reagent. Of the various triiodides that have been developed and tested, triglycine hydrotriiodide, TGHI, so far possesses the most desirable properties. It was developed from an earlier product, a mixture of diglycine hydriodide and iodine, called Bursoline. Stable, quickly dissolving tablets of TGHI, liberating 7.5 ppm. of elemental iodine in a quart of water, have been prepared.

The Naval Medical Research Laboratory and the National Institute of Health have cooperated in the evaluation of the disinfecting power of the triiodides. Field tests by the Army and Marine Corps have shown that the taste and odor of triiodide-treated water are acceptable at requisite iodine levels. Possible toxic effects are expected to be sufficiently rare in a military population to permit the use of triiodide disinfection under emergency field conditions.

2—Schistosomiasis[(c)]

Prevention of schistosomiasis in military forces depended primarily on avoidance of contact with fresh water infested with cercariae. Swimming, bathing, and

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[(b)] Standard Halazone tablets give about 2.5 ppm. of titratable chlorine, about half of which is hydrolyzed to HOCl.

[(c)] The Bulletin of the U. S. Medical Department, Vol. IV, No. 3, September, 945, pp. 275–276.

laundering of clothes and the washing of vehicles in fresh-water ponds, streams, and canals were prohibited in endemic areas. Educational lectures and propaganda posters were utilized to indoctrinate troops in the necessity for avoiding contact with infested water. When personnel were required to work in unsafe water, effort was made to have them wear rubber hip boots, waders, rubber gloves, or other waterproofed clothing.

Usual methods of filtration and chlorination were found to be unreliable in removing or destroying cercariae. The newly standardized diatomaceous earth filter, however, is effective. Application of chlorine sufficient to provide one part per million residual at the end of thirty minutes' contact is sufficient to kill cercariae.

Copper sulfate or copper carbonate (3 pounds per 1,000 square feet of water surface to be treated) may be used to kill the small intermediate hosts. These measures have their greatest usefulness where the infested bodies of water are small. Prevention of pollution of water by proper disposal of human feces from infected individuals is a control measure which reduces the number of infected snails. However, domestic animals such as dogs, cats, cattle, and water buffalo, often harbor S. japonicum and may serve to spread the infection.

3—Mechanism of Disinfection[d]

One of the important results of war time research in the field of bacterial disinfection was a clarification of the exact mechanism whereby the life of the organism is interrupted and retarded. This problem has been a matter of much discussion but little clarification prior to the war. In the effort to develop more effective agents for bacterial disinfection it was essential to determine, if possible, the exact mode of action of chemical agents on bacteria.

The assignment of this task to Dr. David E. Green of Columbia University, and his associates, bore valuable fruit. He disclosed that chlorinating agents are bactericidal primarily by virtue of their paralyzing action on the glucose oxidation system of the organism. He further found that "all the vegetative forms of bacteria which have been tested thus far fail to grow after being treated with low concentrations of chlorinating agents, and show the parallelism between degree of inhibition of glucose oxidation and degree of inhibition of growth. The spore forms of bacteria fall into an entirely different category insofar as their viability bears no relation to their ability to oxidize glucose. Spore cells of B. subtilis grow luxuriantly in broth after exposure to concentrations of chlorine which completely inhibit oxidation of glucose. Spore cells of B. subtilis heated to 30°C. for thirty minutes are viable, although the glucose oxidation system is destroyed by this treatment. Clearly glucose oxidation system in spores is not vital to growth as is the case for vegetative cells.

"The spore is not less sensitive to chlorinating agents because it is less permeable to these agents. Where present, the glucose oxidation system of spores is knocked out at the same level of chlorine as the same system in the vegetative cells. The problems of killing spores cannot be solved by varying the principle of chlorination. All the organic compounds containing active chlorine act precisely the same way as HOCl, although the effective concentration levels are different. In other words, if one chlorine compound will not act at all at the usual concentration level, all the other compounds will be found to be inadequate. At very high levels all chlorinating agents are sporicidal, but at these levels the action of chlorine is unspecific. The key system or systems in spores which are

[d] David E. Green, personal communication.

essential to growth are insensitive to the action of chlorinating agents. The problem is to find agents which selectively go for these essential systems of spore cells.

"Remarkably few compounds have been found to be sporicidal, e.g., iodosobenzoic acid, 2,4-dinitrobenzoic acid, periodate, malonate, sulfathiazole, copper sulfate, fluoride, gramicidin, carboxymethoxyamine, etc. Thus far, two substances have been found with marked sporicidal action, viz., merthiolate (sodium ethyl mercurothiosalicylate) and p-chloromercurobenzoic acid."

4—Control of Mosquitoes[e]

One of the most important developments is in the wide and successful application of the remarkable compound dichloro diphenyl trichlorethane, or DDT. The compound was known for years, but its almost uncanny effectiveness for the destruction of the insect enemies of man was almost unknown until the war intensified the search for improved weapons against insect borne diseases.

The results summarized below are necessarily preliminary in character, but should be helpful to workers in the laboratory and in the field in their further exploration of the potentialities of the so-called "miracle compound."

The average tenant house can be treated with a DDT residual spray at a cost of about $1.50 to $1.75, including labor, materials, and overhead, but exclusive of initial outlay for heavy equipment. The spray can be applied either with a hand pressure sprayer or with a power machine, and at a dosage of 200 mg. of DDT per square foot of surface area has effected a 60 to 90 percent mortality of wild mosquitoes in unoccupied houses 20 weeks subsequent to treatment. A residual toxicity of this duration suggests that one treatment per year might be sufficient in the more northern malaria zones of this country, but two treatments will probably be required in the southern zones.

Residual sprays do not give as effective a kill in occupied houses, not because of lack of toxicity, but due to the large proportion of untreated resting places such as furniture, bedding, and exposed wearing apparel. Treatment of household effects is advised where practical.

Treated wood surfaces exposed to 14 inches of rainfall over a period of four weeks effected a 25 percent kill compared with a 75 percent kill obtained from control panels. Sunlight alone caused a reduction of toxicity of 10 percent over the same period.

When applied as a spray at the rate of one-tenth pound of DDT per acre essentially 100 percent larva kills were obtained. According to the solvent and spreading or emulsifying agent employed, applications may be made as a surface film treatment, a stable emulsion, or as a suspension. No appreciable residual toxicity to larvae has been noted, and laboratory tests have shown that bottom mud inactivates the DDT. Distribution of the DDT-laden mud throughout the water has failed to restore toxicity, which suggests that the DDT actually combines with or adheres to compounds of the mud.

Materials for effective larviciding with DDT cost less than one-fifth as much as a comparable effective application of fuel oil. Solutions of 2.5 percent DDT in kerosene gave effective control of anopheline larvae when applied by boat oiling units at rates of approximately 0.1 pound DDT per acre, thereby making possible a reduction of about 90 per cent in the amount of kerosene normally used.

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[e] Tests of the effectiveness of DDT in Anopheline Control, S. W. Simmons, and staff, U. S. Public Health Service, Public Health Reports, August 10, 1945, Vol. 60, No. 32, pp. 917–927.

5—Airplane Dusting with DDT[f]

Field experience with the application of DDT by airplane has been extensive both in this country, in the Middle East and in the Far East. Full details of the results have not yet been made available in current literature. The results obtained, however, in the United States particularly in the Tennessee Valley area and other parts of southern United States are sufficiently in accord with those obtained elsewhere to warrant drawing important preliminary conclusions as to the successful use of this material distributed from the air. The findings listed below are those primarily summarized by workers in the continental North American areas. The data presented have their origin in the Public Health reports noted below.

DDT had to be diluted with 85 percent soapstone before a satisfactory airplane dusting mixture was obtained. With this mixture 90 percent control of *A. quadrimaculatus* larvae was obtained over 200-foot swaths at actual treatment rates as low as 0.005 pound per acre.

Certain polymethylnapthalenes (Velsicols) having a high solubility for DDT and a high boiling point were found to be ideal solvents for making liquid solutions of DDT to be applied by airplane.

Stearman airplanes proved to be more satisfactory for applying DDT larvicidal sprays than Cub airplanes because of their greater pay load and increased swath width. Fifteen to twenty percent solutions of DDT in Velsicol applied with the Stearman unit at actual treatment rates as low as 0.03 pound DDT per acre gave at least a 90 percent kill of *A. quadrimaculatus* larvae over swath widths of 200 to 300 feet.

A Stearman airplane was equipped with various types of exhaust generators for producing thermal aerosols from concentrated solutions of DDT in Velsicol. The most satisfactory was one having a terminal venturi section with a 2⅝ inch throat. Thermal aerosols distributed with this unit at actual treatment rates as low as 0.04 pound DDT per acre gave at least 90 percent kills of anopheline larvae over swaths as wide as 300 feet. Excellent control of *A. quadrimaculatus* adults in their diurnal places was also obtained with this unit at application rates of about 0.5 pound DDT per acre.

DDT dusts and thermal aerosols gave no evidence of injury to fish or other aquatic organisms when applied by airplane at rates of 0.1 pound DDT per acre. Five percent solutions of DDT in kerosene applied at rates of about 0.25 pound DDT per acre were quite destructive to aquatic insects living in close contact with the water surface, particularly Hemiptera and Coleoptera.

The opportunities for world wide application of DDT, with fair promise of results corresponding to those reported by the workers above, are now being explored in many countries of the world. If the methods are adjusted to the local requirements, with the kind of entomological control essential for any other form of mosquito control, the procedures should result in important reductions in mosquito-borne diseases throughout the world.

6—Rodenticides[g]

The world has been concerned with rodents for centuries because they are reservoirs of some diseases affecting man. Plague is first in importance among

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(f) Observations on the Use of DDT for the Control of Anopheles Quadrimaculatus, R. L. Metcalf, A. D. Hess, G. E. Smith, G. M. Jeffery, and G. W. Ludwig, Public Health Reports, July 6, 1945, Vol. 60, No. 27, pp. 753–774.

(g) The Bulletin of the U. S. Army Medical Department, Vol. IV, No. 3, September, 1945, pp. 321–322.

rodent-borne diseases. Endemic or murine typhus, also of importance, is transmitted to man by the bite of the rat flea. The causative organisms of various types of bacterial food poisoning infect rats and mice and may be transmitted to man by the contamination of his food with their feces and urine. Other diseases associated with rodents are infectious jaundice (Weil's disease), ratbite fever, tularemia, Rocky Mountain spotted fever, and scrub typhus. Field rodents are an increasing problem where they are reservoirs for bubonic plague and scrub typhus or where they cause damage.

Control work should be continuous rather than intermittent. After the removal of their food supply and elimination of shelters, the rodents should be destroyed by poisoning preceded by prebaiting. Before the war zinc phosphide, thallium sulfate, red Squill, barium carbonate, strychnine, and others were the rodenticides for general use. Rat infestations in ships or buildings which can be made gastight were eliminated by fumigation, using HCN gas. For rats in burrows, a fumigant dust giving off hydrocyanic gas when acted on by moisture in the air was recommended.

When war-created shortages of chemicals familiar as rodenticides occurred, energies directed toward the development of substitute or improved chemical compounds were remarkably successful. Out of these efforts came two effective materials, which may supersede more conventional materials of the past. The new compounds or at least new in their application, are "1080," or sodium fluoracetate, and "antu," or alpha-napthyl-thio-urea. Both compounds are highly toxic, stable, dependable and acceptable to rats and perhaps to most other rodents. They add to the economical armamentarium now available to the sanitarian for a renewed vigorous campaign against one of the most destructive and wily of the enemies of man.

Since the control of plague and other rodent-borne diseases involved not only destruction of rodents but preventing their parasites from attacking man, in some cases it has been possible to protect against parasites by the use of DDT. This procedure is being practiced extensively experimentally.

7—Cross Connections[h]

During the war the problems connected with cross connections and back-siphonage connections were aggravated beyond those normally encountered in peace time. These conditions are likely to continue, however, for many years following the war, because of the very large number of structural changes which took place during the war and which left a series of potential difficulties to be closely scrutinized for many years in the future.

It is well to point out the continuing significance, therefore, of this problem so that administrative and physical controls may be exercised without cessation.

In spite of the fact that great progress has been made in eliminating cross connections in the past two or more decades, many new ones have been created during the war. Even in peace time enforcement of excellent regulations prohibiting cross connections has lagged behind the establishment of controlled procedures.

The same comments may be made with equal force on back-siphonage connections between potable supply lines and plumbing systems, which may and do at times admit sewage to water lines under certain hydraulic conditions.

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[h] Report on Cross Connections and Back-Siphonage Connections under War Conditions, Report of the Committee on Sanitary Engineering, National Research Council, Journal of the New England Water Works Association, March, 1945, Vol. 59, No. 1, pp. 42–59.

The renewed emphasis on this problem during the war makes it desirable to re-emphasize to administrators and general practitioners in the field of water supply control that these potential hazards are not likely to disappear of their own accord. It is essential, therefore, that their importance should be recognized and the proper administrative and legal procedures be established to avoid accident and resultant infections.

The reader is therefore referred to the report of the Committee listed on the preceding page for complete review of the essential features of the hazards and of the progress made in correction.

CONTRIBUTIONS OF VETERINARY MEDICINE TO MEDICAL SCIENCES

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Research investigations in veterinary science have contributed richly and importantly to scientific medical knowledge. A number of epoch-making findings and discoveries in the field of medical sciences have resulted from observations and studies of diseases of lower animals.

Modern medicine, surgery, and sanitation owe much of their remarkable development to the revelations of bacteriology. Bacteriology, in turn, owes considerable of its foundation and development to research in the veterinary field. It may be recalled that the first definite proof of the ability of bacteria to produce disease resulted from studies of anthrax in cattle. Likewise, the first evidence that the higher bacteria (fungi) were capable of causing disease came with the discovery in 1878 of *Actinomyces bovis* as the etiological factor in actinomycosis of cattle. Griffith Evans, working in India in 1880, discovered that surra, a disease of horses, is caused by a trypanosome. This was the first knowledge of the ability of trypanosomes to produce disease.

The first proof that those elusive disease-producing agents which we have come to know as filtrable viruses could cause disease in lower animals and man, resulted from studies with aphthous fever or so-called "foot-and-mouth disease" of cattle. Since that particular discovery, filtrable viruses have become a highly important group of disease-producing agents both as regards man and the lower animals.

The great importance of insects as vectors of various diseases is universal, common knowledge. Prior to the acquisition of such knowledge it was impossible to develop means for the control and prevention of diseases like yellow fever and malaria. It was the classical and epoch-making research investigations of Smith and Kilbourne in 1893, wherein they proved that "Texas fever" or piroplasmosis of cattle is transmitted by ticks that gave rise to modern medical entomology.

With the development, over the years, of veterinary science important advances and contributions have continued to be made. While space will not permit of a review of all important accomplishments of recent years which might be mentioned, a few outstanding examples will be discussed.

Tuberculosis which has been so important from the standpoint of human medicine has likewise been of great importance among the diseases of lower animals, particularly in cattle, hogs, and fowl. While in early days the relationship of tuberculosis in man and lower animals was not well understood, research studies and investigations in the fields of both human and veterinary medicine finally eluci-