BIOLOGICAL WARFARE AGAINST PUBLIC WATER SUPPLIES[1]

This bulletin provides information on the vulnerability of drinking water systems to biological warfare and on the evaluation of measures to prevent or control this type of enemy attack.

Among the potential biological warfare agents are micro-organisms (e.g., pathogenic bacteria, fungi, viruses, and protozoa) and toxins produced by micro-organisms (e.g., botulinum toxin, diphtheria toxin, and staphylococcus enterotoxin).

DRINKING WATER AS BW AGENT VEHICLE

Enemy plans for the deliberate contamination of our drinking water supplies probably would depend on their ability to produce disease in a large number of persons in a target area. To be effective the enemy would place enough BW agent in the water to produce disease in at least 50 percent of the persons who consumed the water. Owing to differences in personal drinking habits, this might result in a casualty rate of about 20 percent. The practicability of this method of attack would depend on a solution of the logistical problems involved and the ability to overcome barriers to the prevention or control of naturally occurring waterborne disease. Therefore, the following questions are of importance to public health agencies:

(*a*) If BW agents that are normally waterborne are used, would epidemiologists recognize that they were deliberately introduced into the water?

(*b*) If BW agents that are not normally waterborne are used, would epidemiologists recognize drinking water as the method of disease transmission?

If the answer to both questions is "yes," the defense against this type of operation is less difficult. Defense measures might include boiling of drinking water as a permanent practice, or the use of auxiliary drinking water sources of unquestionably safe quality. An enemy probably would consider this operation a one-shot affair to be directed against a number of highly important areas simultaneously, or as a solely psychological warfare operation.

If the answer to either or both of these questions is "no," our defense problems are more difficult.

Epidemiological opinion on these questions is as follows:

(*a*) If the outbreak is sudden and well-defined geographically, and involves 20 percent or more of the population of an area, an act of sabotage would be suspected. This is based on the fact that such an outbreak would be unique in waterworks experience. If only a small area and relatively few persons were affected, the sabotage might be undetected. Even this is doubtful however, since this latter plan would probably be aimed at key persons whose simultaneous illness would certainly be cause for suspicion.

(*b*) If the disease agent were not normally spread by drinking water, it is unlikely that the outbreak would be attributed immediately to the water supply in spite of the knowledge that a common source of infection was involved. If a disease normally spread by arthropods broke out, epidemiologists would probably first investigate the presence of this particular arthropod rather than the water supply. However, any disease outbreak recognized as caused by enemy action, regardless of the vehicle of transmission, would lead to extraordinary precautions being taken for water, food, and milk supplies.

To be effective, an enemy attack would have to create serious disruption in the target area population. To accomplish this, the drinking water system would be considered a vehicle for disseminating BW agents to cause this disruption. With a given point of attack, BW agents could be directed at an area

of specific importance, and the time it would take to reach the target could be roughly predicted. Every advantage this method provides could be exploited to cause illness among important segments of our population or to cause panic as part of a psychological warfare operation.

BW AGENTS

Some diseases an enemy might produce with the BW agents which could be used against a civilian population are listed in table 1. Many of these agents are stable in ordinary dechlorinated tap water. Others may be made so, although it is generally considered unlikely that protozoan agents would be used. A BW agent would probably be selected for the specific effect it would produce. Among the factors for consideration are:

(*a*) *Degree of immobilization of target population desired.*—Enemy strategy might be to produce death, protracted debilitating disease, or other degree of disability.

(*b*) *Immune status of population.*—A BW agent to which a large portion of the target population is highly resistant would probably not be used.

(*c*) *Availability of effective prophylaxis and therapy.*—BW agents for which adequate control and treatment do not exist might be of particular interest.

(*d*) *Incubation period desired.*—BW agents might be used that will in time create maximum disruption to a specific production or defense effort.

Characteristics to be considered in selecting a BW agent are:

(*a*) Stability of the agent in the drinking water system to be attacked.

(*b*) Virulence.

(*c*) Ability to obtain cultures and produce the agent in the quantity required.

(*d*) Resistance of the agent to water purification processes, including disinfection, which it will encounter.

(*e*) Resistance of the agent to detection and identification procedures.

Disease-producing agents not normally found in drinking water may be stable and virulent or toxic in water suspension. Therefore, our public health personnel should be particularly alert to outbreaks of nonintestinal illnesses that show case distribution characteristics normally associated with waterborne disease.

TABLE 1.—*Potential diseases an enemy might use in BW*

Bacterial diseases	Viral diseases	Rickettsial diseases
Anthrax _____	Dengue _____	Endemic typhus.
Bacillary dysentery.	Encephalitides ___	Epidemic typhus.
Brucellosis _____	Infectious hepatitis	Rocky Mountain spotted fever.
Cholera _____	Influenza _____	
Glanders _____	Psittacosis _____	Q fever.
Leptospiroses ____	Rift Valley fever__	Scrub typhus.
Plague _____	Smallpox _____	
Treponematoses __	----------------	
Typhoid _____	----------------	
Tularemia _____	----------------	

Fungal diseases	Protozoan diseases	Toxins
Blastomycosis ____	Amoebic dysentery	Botulinum toxin.
Coccidioidomycosis.	Malaria _____	Diphtheria toxin.
Histoplasmosis ___	Toxoplasmosis ___	Staphylococcus enterotoxin.
Nocardiosis _____	----------------	

VULNERABILITY OF WATER SOURCES AND DISTRIBUTION SYSTEMS

Surface water sources are vulnerable to enemy action and could easily be contaminated. Water utility patrols in watersheds reduce the threat, but cannot eliminate it. However, the raw water source may not be an attractive target since it involves the entire water system and may create logistics difficulties. Moreover, much of the BW material may be wasted by flow past water intakes, or by biological decay in impoundments and lakes. The opportunities for finding unobserved sites for sabotage are few as compared with the distribution system. Finally, there is the obstacle of the purification plant where BW material would be reduced in concentration and where abnormal physical, chemical, and biological aspects of the water would be most readily noted. The application of BW agent to the system after the water had passed through the water treatment plant would probably be preferred.

Current water treatment practice is designed to produce water of acceptable bacterial quality in terms of the coliform group of bacteria. This effectiveness may also apply to fungi if breakpoint chlorination and a prolonged contact period are provided. Although much work has been done in improving the effectiveness of sedimentation, coagulation, settling, sand filtration, and chlorination in removing or destroying bacteria, information on the ability of standard water treatment processes in removing certain BW agents is not available.

Viruses represent a significant unknown in the water purification field. Few studies have been made on these organisms due to difficulty in growth and titration with the facilities available in laboratories

engaged in water quality examinations. The importance of including free residual chlorination as one of the water treatment processes for the removal or destruction of viruses is suggested in recent studies on infectious hepatitis and poliomyelitis.

Peacetime waterworks practice as well as protection against BW require that additional intensive research be undertaken to evaluate and improve the effectiveness of water purification methods in destroying viruses. The problem presented by toxins and poisons also requires investigation. Studies on water containing algae-produced toxin have indicated that standard water purification and disinfection processes will not remove this material.

Standard water treatment methods including chlorination will not under all conditions effectively purify water contaminated with any type of BW agent. However, some reduction in the material will be accomplished.

To introduce BW agents into the distribution system would not be difficult, since substantial amounts of an agent could be pumped directly into the system, using portable commercial equipment. Selection of critical points in a distribution system would not be difficult. In the past, little attempt was made to safeguard layout drawings of the water distribution systems of many of our large cities. The National Board of Fire Underwriters' plans, and material put out by many water utilities, have been given to persons showing an interest in this information.

LOGISTICS

The feasibility of a BW attack through the distribution system depends on whether BW material that is stable in water and virulent or toxic when ingested could be unobtrusively obtained or produced. Any person experienced in waterworks could put this material into the water in the main. However, the quantity of material needed to produce widespread disease in the population would be a factor. An estimate of the quantity of BW agent must be based on the human oral infective dose. Data of this nature are very scanty, as there is little demand for this information in peacetime. However, with existing literature on human oral infective dosages for several pathogenic materials, an estimate can be made of the size of the logistical problem that would be met in attempting to contaminate a drinking-water supply.

The quantities of contaminant needed to produce one human infective dose in every drink of water contained in a million gallons of water is given in the following examples of micro-organisms and toxins that are infective by the oral route. For this purpose a drink of water is assumed to be 100 milliliter.

(*a*) Less than 1 pound of a preparation of *Salmonella anatum* in 1,000,000 gallons of water would be required to produce salmonellosis in 50 percent of the exposed population. This is based on a determination that 3 of 6 human volunteers succumbed to an oral dose of 860,000 cells of this organism. These bacteria can readily be prepared in a concentration of 10^{11} organisms per milliliter. It is generally believed that *Salmonella anatum* is less infective than *Salmonella typhosa* and that fewer of the latter pathogen would be required to produce the same incidence of illness.

(*b*) Less than 15 pounds of dried, partially purified staphylococcus enterotoxin in 1,000,000 gallons of water would produce poisoning in a majority of the exposed population. Accordingly, the vomiting dose for man is 0.16 milligram dry weight of the partially purified enterotoxin.

(*c*) Less than 10 pounds of partially purified botulinum toxin in 1,000,000 gallons of water would produce botulism in more than 90 percent of the exposed population.

The quantity of BW agent required to produce infection or poisoning is considerably less than that of readily available poisonous chemicals. Using the same frame of reference, that is, one estimated human lethal oral dose in each 100 milliliter of a million gallons of water, 20,000 pounds of potassium cyanide and 10,000 pounds of sodium fluoroacetate (a highly toxic rodenticide) respectively, would be required. Most pathogens could be obtained without great difficulty. Highly concentrated suspensions could be produced from bacterial stock cultures with improvised equipment. The production of viral and rickettsial agents in eggs or by tissue culture would involve little risk or difficulty for a skilled enemy technician when the basic technique is available. The production of bacterial toxin in quantity may be more difficult, but could be improvised. This material could also be surreptitiously imported and stockpiled for a covert attack.

Some risk and technical difficulty would be involved in the production and application of sufficient BW material to contaminate a major portion of a large city's water supply. However, application of the relatively small quantities of BW agent which could produce significant illness in concentrated populations of up to 10,000 persons would not involve logistical problems.

WATER QUALITY SAFEGUARDS

The common chemical, physical, and bacteriological water quality safeguards may not be relied on to detect or destroy a BW agent added to the water flowing through a main. Chlorine residuals may be overcome or may otherwise be made ineffective; physical appearance, taste, and odor may give no clues to the presence of abnormal materials; and the standard coliform test is unsuited to BW agent detection.

Chlorination

In spite of some shortcomings chlorination is the best single protective practice, both as a BW agent destructive measure and as a device for detecting the presence of an abnormal, chlorine demanding material. However, complete dependence on current chlorination practices may not be possible for the following reasons:

(*a*) Chlorine residuals are frequently absent or very low at many locations in a water distribution system.

(*b*) In the distribution system, chlorine residuals are measured too infrequently to represent a useful detection device for the presence of unusually high chlorine-demanding substances.

(*c*) Chlorine residuals may be simply destroyed by chlorine-reducing substances, such as sodium thiosulfate. The application of this material would not be difficult since it is readily purchased and applied. It has no known deleterious effect on pathogens, and its stoichiometric relationship with chlorine introduces no logistical difficulty.

(*d*) Levels of chlorine residuals even when high by normal standards may be inadequate to cope with applied concentrations of BW material. The spores of *Bacillus anthracis* may be inactivated only when exposed to a free chlorine residual of 2 parts per million for 30 minutes. Pathogenic viruses also require greater chlorine residuals for their inactivation than do the common vegetative bacteria of intestinal origin. The viruses of infectious hepatitis, and poliomyelitis, and the Coxsackie virus, will not be destroyed unless free chlorine residuals are present. An appreciable free chlorine residual and contact period may also be required for fungi. It has been found that a free chlorine residual of 0.35 parts per million and a contact period of 4 hours were necessary to destroy spores of *Histoplasma capsulatum* suspended in water. However, chlorination as customarily practiced is probably ineffective in destroying toxins.

(*e*) Certain materials may exert their chlorine de-

mand so slowly in the relatively low concentrations of chlorine residual usually encountered in water mains that no significant reduction in BW agent concentration or in chlorine residual is produced in the contact period available. For example, *Bacillus globigii* (a nonpathogenic spore former) requires a contact period ten thousand times greater than *Escherichia coli* for inactivation by the same chlorine residual. Chlorination may be similarly ineffective even for certain vegetative pathogens. The tubercle bacillus, a vegetative cell encased in a waxy capsule, is almost completely resistant to chlorination.

Despite these apparent shortcomings, proper chlorination will limit the number of BW agents that might be used against us, and the threat of deliberate contamination of water distribution systems can be lessened by strengthening our chlorination procedures. Breakpoint chlorination at the treatment plant and booster chlorination in the distribution system should be practiced to provide free chlorine residuals in all important segments of the distribution system. This is clearly essential to water quality protection. Current schedules for chlorine residual readings at selected representative points in the distribution system should be intensified. The frequency of these readings should be increased at locations which might be particularly important.

Automatic, continuous chlorine residual measuring devices will be useful at key points in the system. Equipment of this type is commercially available. These devices may be connected to alarms and automatic sample collectors which would operate in the event that significantly low residuals occur. The alarm would signify that something untoward had happened; that there had been a change in treatment at the source; that inadvertent pollution was entering a localized section of the distribution system; or that a BW agent had been introduced into the distribution system. Samples should be forwarded immediately to an appropriate laboratory for determination of the chlorine demand in the water and for identification of the chlorine-demanding material. Waterworks and public health officials should warn water consumers to boil drinking water if the low chlorine residual recorded represents an improbable occurrence under normal conditions. An analysis of locations where significantly low chlorine residuals have been recorded may show the point of contamination.

At particularly critical points, such as key industrial plants, research laboratories, civil defense, and police headquarters, additional measures might be instituted. Inexpensive devices which would signal

when a significant drop in chlorine residual occurred could be readily developed and installed for continuous operation. As an alternative, frequent manual chlorine residual observations could be made by available staff on a "round the clock" schedule. Alarms could be given and samples collected as has already been described.

Bacteriological Examination

The ineffectiveness of the coliform test as a detection device for BW agents is indicated by the fact that not one of the pathogens listed in table 1 will ferment lactose with production of gas. Moreover, the relative infrequency of routine sampling in the distribution system and the lag between sample collection and recording of results makes the normal sampling procedure completely unsuited to the protection of drinking water against BW attack. The membrane filter technique for coliform determination will not change this situation in any fundamental way. (See TM-13-2, *Operation and Repair of Water Facilities in Civil Defense Emergencies*.)

Although the membrane filter holds great promise as an inexpensive and rapid BW agent detection device, at present its use for this purpose has the defects inherent in classical bacteriological procedures. The membrane filter may not be applicable to BW agents other than bacteria and perhaps fungi, and it does not provide for an automatic and immediate warning of the presence of BW material. It is possible that no single procedure can be developed that will do these things. Further research will define the usefulness of the membrane filter in the early detection and identification of BW agents.

Physical Quality Tests

The deliberate contamination of drinking water with BW material may not affect the physical quality of the water in any significant respect. Tests were made by the Physical Defense Division at Camp Detrick, Md., to determine:

(*a*) The lowest concentration of a vegetative cell that can be detected in water suspension by direct visual inspection, by taste, by odor, and by a sensitive device for measurement of light scattering.

(*b*) The concentration of vegetative bacteria equivalent to a turbidity of 10 parts per million. Table 2 shows the results of these tests.

TABLE 2.—*Detection of Escherichia coli in drinking water*

Test	Bacterial population per 100 ml.	
	Detected	Undetected
Visual (unaided eye)	10^7	10^6
Taste	10^{11}	10^{10}
Odor	10^{11}	10^{10}
Light scattering (microphotometer)	10^7	10^6

As the results show, these tests cannot be depended on to detect vegetative bacteria suspended in a concentration of approximately 10^6 organisms per 100 milliliter. (In the discussion on logistics it was indicated that less than this amount of *Salmonella anatum* was required to produce illness in 50 percent of the exposed population.) This study showed further that a suspicious turbidity (exceeding 10 parts per million) was not imparted to the water until the *Escherichia coli* concentration reached approximately 10^9 per 100 milliliter.

Although the physical changes in the water resulting from BW contamination may appear too slight to warrant consideration as dependable indications of BW contamination, they should not be dismissed as having no value in defense. The rate of water flow in a main varies appreciably within short periods of time. Deliberate contamination of the water could not be done without frequent overdosing, particularly since an attempt would probably be made to maintain a BW agent concentration greater than a minimum human infecting dose. Equipment that would permit frequent observation of water from the main could be simple and cheap. The small investment required for such a device should justify its use.

SUMMARY

To prevent, recognize, and ward off a BW attack through public drinking-water supplies, the following should be considered:

(*a*) Public drinking-water supplies can be an attractive target.

(*b*) A wide variety of potential BW agents is available to the enemy, including those not normally associated with drinking water.

(*c*) It is likely that a BW attack through the water supply system would be either a one-shot effort to produce widespread illness in a number of target areas, or a more localized attempt directed at key persons, with the expectation that the sabotage might not be recognized. The recognition of a single act of sabotage involving water supplies would

automatically lead to the application of extraordinary precautions in all target areas.

(*d*) The distribution system would be a more attractive target than the source of supply.

(*e*) Logistics would present no great difficulty.

(*f*) Substantial free chlorine residuals in important segments of the distribution system represent our best current protection. However, this protection may not be complete under all circumstances.

(*g*) Current routine bacteriological water quality examinations are not useful in detecting the presence of BW material.

(*h*) A BW attack may not be accompanied by readily detectable changes in physical characteristics of the water.

RECOMMENDATIONS

Recommended measures for the protection of public drinking water supplies against enemy action with BW agents are as follows:

(*a*) Reinforcement of security measures at the source of supply, at the treatment plant, and at all critical structures of the distribution system.

(*b*) Establishment of liaison between water quality laboratories and specialized bacteriological, viral, and toxicological laboratory services through government agencies.

(*c*) Evaluation of currently used water purification processes in removing or destroying pathogenic viruses and rickettsiae, fungi, and toxins, and initiation of research for the development of new materials, procedures, and equipment to supplement present methods.

(*d*) Strengthening of chlorination measures and continuous observation of chlorine residuals in the distribution system, as suggested.

(*e*) Installation of simple, uncovered, transparent, flow-through chambers at important locations to permit convenient observation by competent persons on physical characteristics of the water.

(*f*) Acceleration of research for prevention of sabotage, development of warning devices, rapid detection and identification of BW materials, and development of completely dependable methods of water decontamination. Although much of the research must be conducted in laboratories having specialized facilities, there are opportunities for the ingenious waterworks engineer, chemist, or biologist to do original work on the problem.

(*g*) Location of dependable, safe, and easily protected auxiliary sources of drinking water for use if sabotage of the public supply is suspected and if decontamination may not be applied with confidence to water from mains.

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The following OCDM publications can be obtained through your local civil defense director or at nominal cost from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.:

Civil Defense Against Biological Warfare, TM-11-10.

Emergency Measurement of Radioactivity in Food and Water, TB-11-9.

Operation and Repair of Water Facilities in Civil Defense Emergencies, TM-13-2.

Permissible Emergency Levels of Radioactivity in Water and Food, TB-11-8.

Responsibilities for Production and Distribution of Potable Water During Emergencies, TB-11-10.